GEK-36383C

INSTRUCTIONS

THYRISTOR EXCITATION SYSTEM
FOR
HYDROELECTRIC AC GENERATORS

3S7931SA100 SERIES

Drive Systems Product Department • General Electric Company,
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GENERAL ELECTRIC

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THYRISTOR EXCITATION SYSTEM EQUIPMENT

INTRODUCTION

The 3S7931SA100 Thyristor Excitation System statically controls the voltage (or reactive volt-amperes) of an AC generator by controlling its excitation.

The generator excitation is controlled by varying the field current of the generator. This generator field current is controlled by a static voltage regulator. The regulator is a thyristor type using Silicon Controlled Rectifiers (SCR's) in the output circuit that drives the generator field. The system includes both an "Automatic" voltage regulator and a "Manual" voltage regulator to control generator terminal voltage.

This 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. If equipment is to be stored for more than three months, it should be kept heated to at least 5°C above ambient temperature to keep out moisture.

DESCRIPTION (COMPONENTS)

The 3S7931SA100 is a Thyristor Excitation System consisting of the following equipment:

3S7932JA118	Maximum Excitation Limit Panel
3S7932MA309	Auto Regulator Panel
3S7932MD170	Meter Panel (2)
3S7932CD162	Manual Regulator Panel
3S7932HA126	Motor Operated Voltage Adjusting Rheostat Panel (2)
3S7932MD169	Field Flashing Panel
3S7932CS105	Transfer Panel
3S7932RA123	Power Rectifier Panel
3S7932YA119	Transformer Protection Panel
3S7932YA118	Master Firing Circuit Panel
3S7932BA102	Compensation Panel
3S7932MD172	Relay Panel
3S7932YA120	Voltage Surge Supressor Panel
3S7932MD125	Shaft Voltage Suppressor Panel
3S7932RA124	SCR Bridge Assembly (2)
3S7932MA310	Current Transformer Panel
3S7932MD173	Shunt and Fuse Panel
44A334206-001	AC Circuit Breaker
44A315910-001	DC Circuit Breaker
IC914319281l6G4	Field Discharge Resistor
9RV6A159	Field Thyrite (2)

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). Make all wiring connections to control as specified on diagrams furnished for the particular installation.

CONNECTIONS

1. Wire check all external connections to excitation control cubicle.

2. Check phase connections of anode transformer, CT's and PT's.

3. Check generator phase sequence.

4. Check all large rectifiers with ohmmeter (in exciter field circuit).

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. DO NOT HI-POT OR MEGGER ANY CIRCUITS IN CONTROL OR RECTIFIER CUBICLE. EXCITATION CUBICLE WAS HI-POTTED AT FACTORY. (SEE TEST REPORTS.)

INITIAL OPERATION

BEFORE RUNNING GENERATOR CHECKS

The following steps must be performed before the initial startup:

1. Check polarity and energize DC for relay power.

2. Check operation of Generator Field circuit breaker (41) and AC Line breaker (52E).

3. Check operation of Manual Voltage adjuster (70MR) and Automatic Voltage adjuster (70MV).

4. Check operation of Off/Manual/Test/Regulate transfer switch (43R) and all associated relays. (See Principles of Operation -- Relaying and Control.)

5. Check operation of field flashing.

Off Line Tests, Generator Running

1. With turbine and generator stopped, remove 125 VDC from exciter cubicle.

2. Install a jumper between terminals R87 and R88 located in the rear compartment of the Regulator Section of the exciter cubicle. The generator breaker (52) appears closed in the relay logic. DO NOT CLOSE GENERATOR BREAKER (52) WITH THIS JUMPER INSTALLED.

3. Locate terminals HM13 and HM16 on the lower terminal board on the Manual Voltage Adjust Panel (the lower panel in the front compartment of the Regulator Section). Remove the grey #14 wire marked HM13 that leaves the panel from the terminal board. Remove the grey #14 wire marked HM16 that leaves the panel from the terminal board. Connect the two wires, which were removed from the terminal board, together to give a good electrical connection. The removal of these wires prevents the Manual Voltage adjuster (70MR) from being positioned by limit switches 70LS-6 and 70LS-7 when transferring from the Manual regulator to the Automatic regulator, but they must be connected together to allow the transfer to take place.

4. Connect a single pole, single throw switch between terminals A13 and A14 on the Automatic regulator panel located in the front compartment of the Regulator Section. This switch will simulate opening and closing the generator breaker (52) and will be used to provide a 10% generator terminal voltage step change required in the Automatic regulator stabilization procedure. Place the switch in the OPEN position for startup.

5. Apply 125 VDC to the exciter cubicle.

6. Place the Manual Voltage Control switch (1MR) in LOWER until the Manual regulator Lower Limit light is energized.

7. Place Off/Manual/Test/Regulate transfer switch (43R) in OFF.

8. Place Supply and Excitation Breaker Control switch (IXE) in CLOSE.

9. Check Generator Field circuit breaker (41) and AC Line breaker (52E) closed.

10. Increase generator speed to normal.

11. Place Off/Manual/Test/Regulate transfer switch in MANUAL and check generator terminal voltage increasing as field flashing occurs. The generator terminal voltage should settle out at about 25% of normal. If not, refer to Adjustments and Tests - Manual Regulator.

12. Place Manual Voltage Control switch (1MR) in RAISE until generator terminal voltage increases to normal.

13. Place Off/Manual/Test/Regulate transfer switch in TEST.

14. Check to see that the output of the Automatic regulator can be adjusted equal to the output of the Manual regulator by using Voltage Adjust Control switch (1V) to vary the position of Automatic Voltage adjuster (70MV). If the Automatic regulator is calling for more excitation than the Manual regulator, the Null Voltmeter (VR) will indicate to the right of zero. VR will indicate to the left of zero when the Automatic regulator is calling for less excitation than the Manual regulator and VR will be at zero when the two regulator outputs are equal. Terminate this check with VR at zero.

15. Place Off/Manual/Test/Regulate transfer switch (43R) in REGULATE.

16. Ten seconds after placing 43R in Regulate, check that the transfer from the Manual regulator to the Automatic regulator occurs as indicated by the Regulator Position lights.

17. Stabilize the Automatic regulator. Refer to Adjustments and Tests - Automatic Regulator.

18. Place Off/Manual/Test/Regulate transfer switch (43R) in Manual. Check that the Regulator Position lights change to Manual regulator.

19. Check generator terminal voltage at normal.

20. Place Off/Manual/Test/Regulate transfer switch (43R) in TEST.

21. Use Voltage Control switch (1V) to adjust the Automatic regulator output lower than the Manual regulator output. (VR to the left of zero.)

22. Place Off/Manual/Test/Regulate transfer switch (43R) in REGULATE.

23. Check VR moving to zero.

24. Ten seconds after VR reaches zero, check that transfer from Manual regulator to Automatic regulator occurs as indicated by the Regulator Position lights.

25. Repeat steps 18 through 24 except in step 21 adjust Automatic regulator output higher than Manual regulator output. (VR to right of zero.)

26. Place Off/Manual/Test/Regulate transfer switch (43R) in MANUAL. Check that Regulator Position lights change to Manual regulator.

27. Place Manual Voltage control switch (1MR) in LOWER until Manual regulator Lower Limit light is energized.

28. Place Supply and Excitation Control switch (IXE) in TRIP. Check that Generator Field circuit breaker (41) and AC Line breaker (52E) are open. Check generator terminal voltage at zero.

29. Stop generator and turbine.

30. Remove 125 VDC from exciter cubicle.

31. Remove jumper between terminals R87 and R88 installed in Step 2 above.

32. Re-connect wires removed from HM13 and HM16 in Step 3 above.

33. Remove switch connected between terminals A13 and A14 in Step 4 above.

On Line Tests, Generator Running

If Reactive Current Compensation and Active-Reactive Current Compensation is supplied, the following tests must be completed before transferring control of the generator excitation to the Automatic regulator.

1. Complete steps 1 through 9 of Operation -- Manual.

2. Pick up 10% rated load if possible.

3. Using the Manual Voltage Control switch (1MR), raise the Manual Voltage adjuster (70MR) to cause the generator to supply 5 or 10 per cent of its rating as VARS (overexcited).

4. Set the Reactive Current Compensator (RCC) and Active-Reactive Current Compensator (ARCC) switches G1SW and G2SW to zero. The RCC and ARCC panel is located in the front compartment of the Regulator Section.

5. Place Off/Manual/Test/Regulate transfer switch (43R) in TEST.

6. Use Voltage Adjust Control switch (1V) to match the output of the Automatic Regulator to the output of the Manual Regulator. A zero reading on the Null Voltmeter (VR) is indication of the two regulator outputs being matched.

7. Turn the G2SW COARSE knob on RCC thru 5, 10, 15, to 20. The A1VM voltage reading should increase. If reading decreases, short R31B and R32B by opening CT switch at those terminals, and reverse wires on R31A and R32A.

CAUTION

MAKE SURE THE PROPER TYPE OF SWITCH HAS BEEN SUPPLIED BEFORE OPENING IT. IT SHOULD SHORT THE INCOMING TERMINALS BEFORE OPENING THE OUTGOING (INTERIOR) TERMINALS.

Final adjustment of the compensator can be made only after considerable experience with the generator operating under control of the regulator. It is desirable to keep the amount of compensation to the minimum required for proper division of VARs between generators to avoid excessive voltage regulation. As an initial adjustment, it is advisable to turn the coarse adjustment knob to position 5 with the fine knob at 2.

Adjustments may be made with the compensator transformer energized (CT switch closed).

8. Turn the G2SW COARSE knob on ARCC thru 5, 1(and 15, to 20. The A1VM voltage reading should decrease. If reading increases, short R31B and R32B by opening CT switch and reverse the leads to terminals GxR and GxX. Close the CT switch.

Return the reactance-adjusting knob to zero, and turn the resistance-adjusting knob, G1RH, to the right to increase resistance; this should also decrease the A1VM voltage.

Final adjustment of the compensator must be made on the basis of experience. Preliminary adjustment may be made in accordance with the known values of resistance and reactance for that portion of the system over which compensation is desired. If the voltage at the point which is to be compensated decreases as the power factor becomes more lagging and increases as the power factor becomes less lagging, more reactance and possibly less resistance may be required.

9. Proceed to step 3 of Operation -- Test Mode.

10. Complete steps 1 through 5 of Operation -- Automatic (Transfer from Manual).

OPERATION

MANUAL

1. Apply 125 VDC to exciter cubicle.

2. Place Manual Voltage Control switch (1MR) in LOWER until Manual regulator Lower Limit light is energized.

3. Place Off/Manual/Test/Regulate transfer switch (43R) in MANUAL.

4. Place Supply and Excitation Breaker Control switch (IXE) in CLOSE.

5. Check that Generator Field circuit breaker (41) and AC Line breaker (52E) are closed.

6. Increase generator speed to normal.

7. At the set point of Speed Permissive switch (13) field flashing commences; observe generator terminal voltage increase to approximately 25% of normal.

8. Place Manual Voltage Control switch (1MR) in RAISE until generator terminal voltage increases to normal.

9. Synchronize generator frequency to system frequency and close Generator breaker (52).

10. Use Turbine Speed Control switch and Manual Voltage Control switch (1MR) to adjust watts and voltamperes to desired level.

TEST MODE

The Test mode of operation is a continuation of a Manual regulator startup before transferring the control of the generator excitation to the Automatic regulator.

1. Complete steps 1 through 10 of Manual Operation.

2. Place Off/Manual/Test/Regulate transfer switch (43R) in TEST.

3. Use Voltage Adjust Control switch (1V) to match the output of the Automatic regulator to the output of the Manual Regulator. A zero reading on the Null Voltmeter (VR) is indication of the two regulator outputs being matched.

AUTOMATIC (TRANSFER FROM MANUAL)

After completing the Test mode above, the generator excitation control may be transferred to the Automatic regulator.

1. Place Off/Manual/Test/Regulate transfer switch (43R) in REGULATE.

2. Regulator Voltage Matching adjusts the output of the Automatic regulator equal to the output of the Manual regulator and the Null Voltmeter (VR) returns to zero.

3. Ten seconds after the outputs of the regulators are matched, generator excitation control transfers to the Automatic regulator and the Regulator Position indicator lights change from Manual Regulator to Automatic Regulator.

4. Use Turbine Speed Control switch and Voltage Adjust Control switch (1V) to adjust watts and voltamperes to desired level.

PROGRAMMED STARTUP

The programmed startup is incorporated in the exciter to reduce the time spent by the operator on generator excitation control during plant startup. Requirements by the operator and components not contained within the exciter cubicle are marked with an asterisk (*).

*1. Apply 125 VDC to exciter cubicle.

*2. Place Off/Manual/Test/Regulate transfer switch (43R) in REGULATE.

*3. Unit Start relay (4) must be energized.

4. Generator Field Circuit breaker (41) closes.

5. AC Line breaker (52E closes).

*6. Turbine speed passes setpoint of Speed Permissive switch (13).

7. Field flashing commences.

8. Generator terminal voltages increases and settles out at approximately 85% of normal rated value.

*9. Place Auto Voltage Control switch (1MR) in RAISE until generator terminal voltage increases to normal.

*10. Synchronize generator frequency to system frequency and close Generator breaker (52).

*11. Use Turbine Speed Control switch and Voltage Adjust Control switch (1V) to adjust watts and voltamperes to desired level.

REMOTE STATION CONTROL

The remote station control provision has been added to allow for startup and control of the Automatic Regulator from an operating station remote from the equipment location. The current limit, maximum excitation limit and transfer to the Manual Regulator protection features are retained.

1. Apply 125 VDC to exciter cubicle.

2. Close Remote Station Control Breaker 96 SW.

3. Place Off/Manual/Test/Regulate transfer switch (43R) in REGULATE.

4. Unit Start Relay (4) must be energized.

5. Generator Field Circuit breaker (41) closes.

6. AC Line Breaker (52E) closes.

7. Turbine speed passes setpoint of Speed Permissive switch (13).

8. Field flashing commences.

9. Generator terminal voltage rises to 85% normal.

10. Adjust generator terminal voltage to normal.

11. Synchronize generator frequency to system frequency and close Generator breaker (52).

12. Adjust watts and volt-amperes to desired level.

LINE CHARGING

The line charging mode of operation is used when the generator is to be connected to a transmission line which is not energized. With the excitation system set for remote station control, the line charging mode is initiated by command. The Manual regulator is selected and the exciter output is such as to cause the system voltage to be normal when the generator is placed on the transmission line. After the line is charged to normal voltage, the control of the exciter output is automatically transferred to the Automatic regulator and the line charging circuitry is disabled.

The sequence of events for line charging is as follows:

1. Excitation system set for remote station control.

2. Government line charging contact closes.

3. Relay LC picks up and seals in.

4. Unit start command energizes Relay 1.

   a. Exciter field breaker and line breaker close.
   b. Field flashing operates.
   c. Generator builds up to approximately 6KV (115 amps field) in manual control.
   d. Regulator matching and auto-transfer circuit is energized.

5. After generator line breaker closes (52) and terminal voltage builds up to within 95% of rated (or desired), relay TV energizes.

6. Contact TV starts time delay relay TVTD to permit terminal voltage to stabilize. (Adjustment 1 to 300 seconds.)

7. Voltage balance relay 59 matches the AC regulator to the DC regulator.

8. After the regulators remain nulled for 10 seconds, relay 4CR energizes.

9. Contact 4CR energizes 43A, B, and B/X to transfer control to the AC regulator at rated voltage.

10. Operator assumes control.

11. Contact 43B/X deenergizes relay LC and regulator auto-transfer circuit.

PRINCIPLES OF OPERATION

GENERAL

The 3S7931SA100 Thyristor Excitation System controls the voltage of an AC generator by controlling the generator field current directly. The power for excitation is taken from the generator terminals and fed back to the generator field at a controlled rate for regulation and stability. The excitation system is illustrated by the block diagram in Figure 1.

The field current is varied by controlling the firing angle of two full wave Silicon Controlled Rectifier (SCR) bridges operating in parallel. The SCR phase control signal is generated by the Automatic Regulator or the Manual Regulator.

When operating in the Manual mode, the generator field current is held at a constant level as determined by the position of 70MR. When operating in the Automatic mode, the generator terminal voltage is held at a constant level as determined by the position of 70MV.

GENERATOR FIELD RECTIFIERS

Direct current for the generator field is furnished by two parallel 3-phase full wave SCR bridges.

SCR Circuit

The SCR circuit operates as a phase-controlled variable DC voltage source to control generator field current as required by the Automatic or Manual regulator. (Refer to Figure 2.)

Power Circuit

The input voltage to the SCR circuit is taken from the generator output through an anode transformer, which provides a source voltage that will allow the SCR's to supply a wide range of generator excitation. This typical operating condition is illustrated by Figure 2.

The top waveforms illustrate the source voltage and SCR firing sequence. The center waveforms indicate line current and current flow in the various SCR's.

The SCR's act as switches to connect the two output buses (positive and negative) to the three source lines sequentially as shown. The voltage subscripts indicate the voltage of the first line, with respect to the second line. Thus, in the graph of $e_{A'C'}$, line A' is higher in potential than line C' wherever this graph is positive.

The phase sequence and choice of subscripts are consistent, and show that line A' takes over conduction from line C', line B' takes over from line A', and line C' takes over conduction from line B'. The "anode" voltage reference for R4CD then is $e_{C'A'}$, which is minus $e_{A'C'}$. The anode voltage reference for R1CD is $e_{A'C'}$. The "anode" voltage reference for R5CD is $e_{A'B'}$ ($-e_{B'A'}$). The anode voltage reference for R2CD is $e_{B'A'}$. The "anode" voltage reference for R6CD is $e_{B'C'}$ ($-e_{C'B'}$). The anode voltage reference for R3CD is $e_{C'B'}$. The word "anode" is in quotation marks above in reference to R4CD, R5CD, and R6CD because these are the negative bus SCR's and their AC supply voltage connects to the cathode instead of the anode. Therefore, technically, it would be just as correct to call the supply voltage the cathode voltage and the supply voltage transformer the cathode transformer instead of anode voltage and anode transformer.

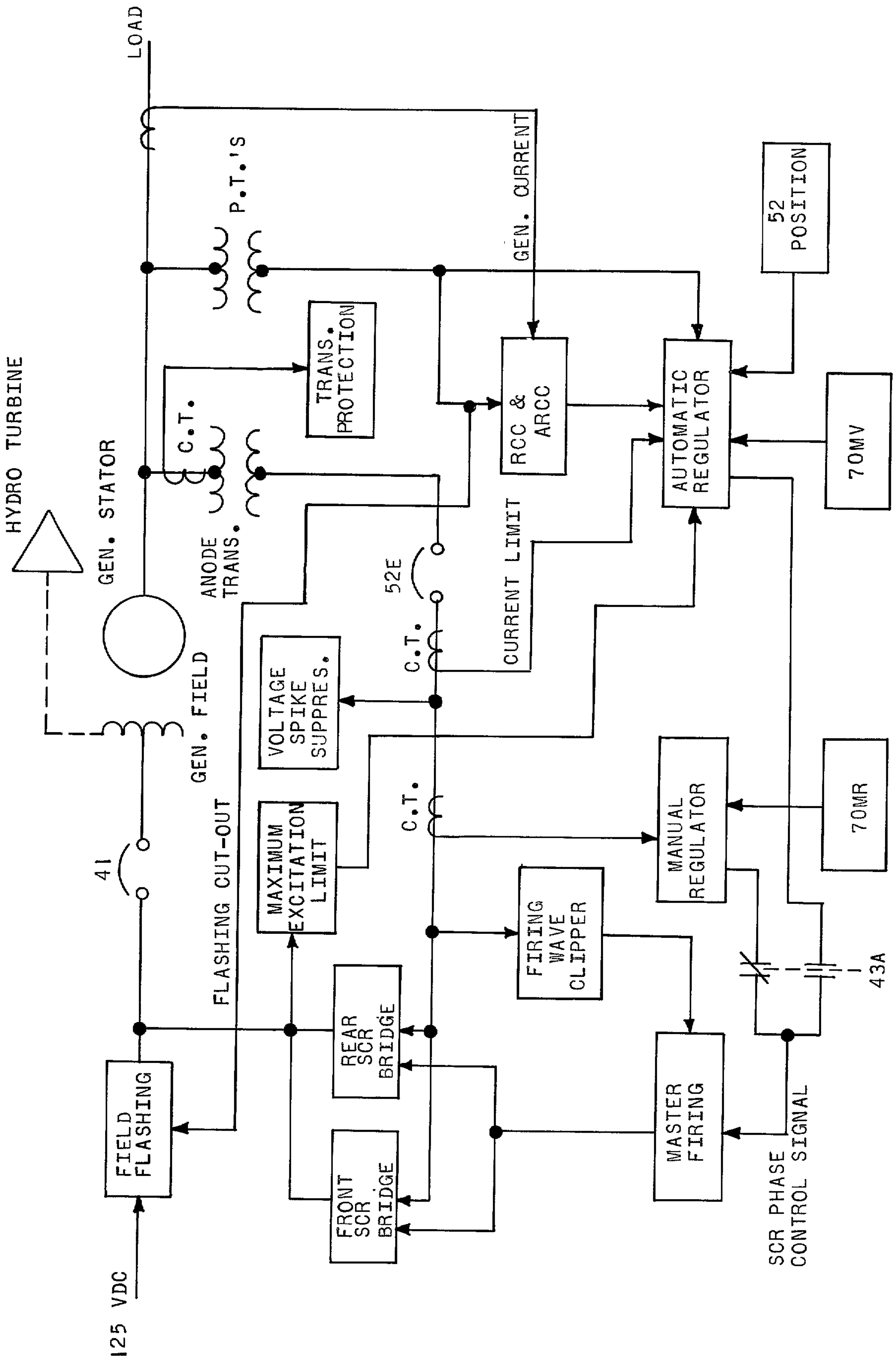
The net DC output voltage is then a plot of the difference in voltage between the positive and negative bus, as indicated by the bottom waveforms. This is the voltage that would be seen on an oscilloscope connected "standing on" the negative bus and "looking at" the positive bus. The center waveforms indicate instantaneous current as it flows from an AC line, through a positive-bus SCR through the load (DC), back through a negative-bus SCR, to another AC line. The current is constant between commutation intervals because the inductance of the load (the generator field winding) will not allow current to change appreciably during an SCR's conducting interval.

Current does not transfer instantly from one SCR to another but builds up in one SCR while it decays in the previous conducting SCR. This is due to the commutating reactance in the source preventing instantaneous changes in current. This same commutating reactance causes the notch in the output DC voltage, following SCR firing.

The result is that while current is decaying in the SCR being TURNED OFF and current is building up (to the constant load current value) in the SCR which has just been FIRED, the voltage at this commutating bus is the average of the two SCR voltages.

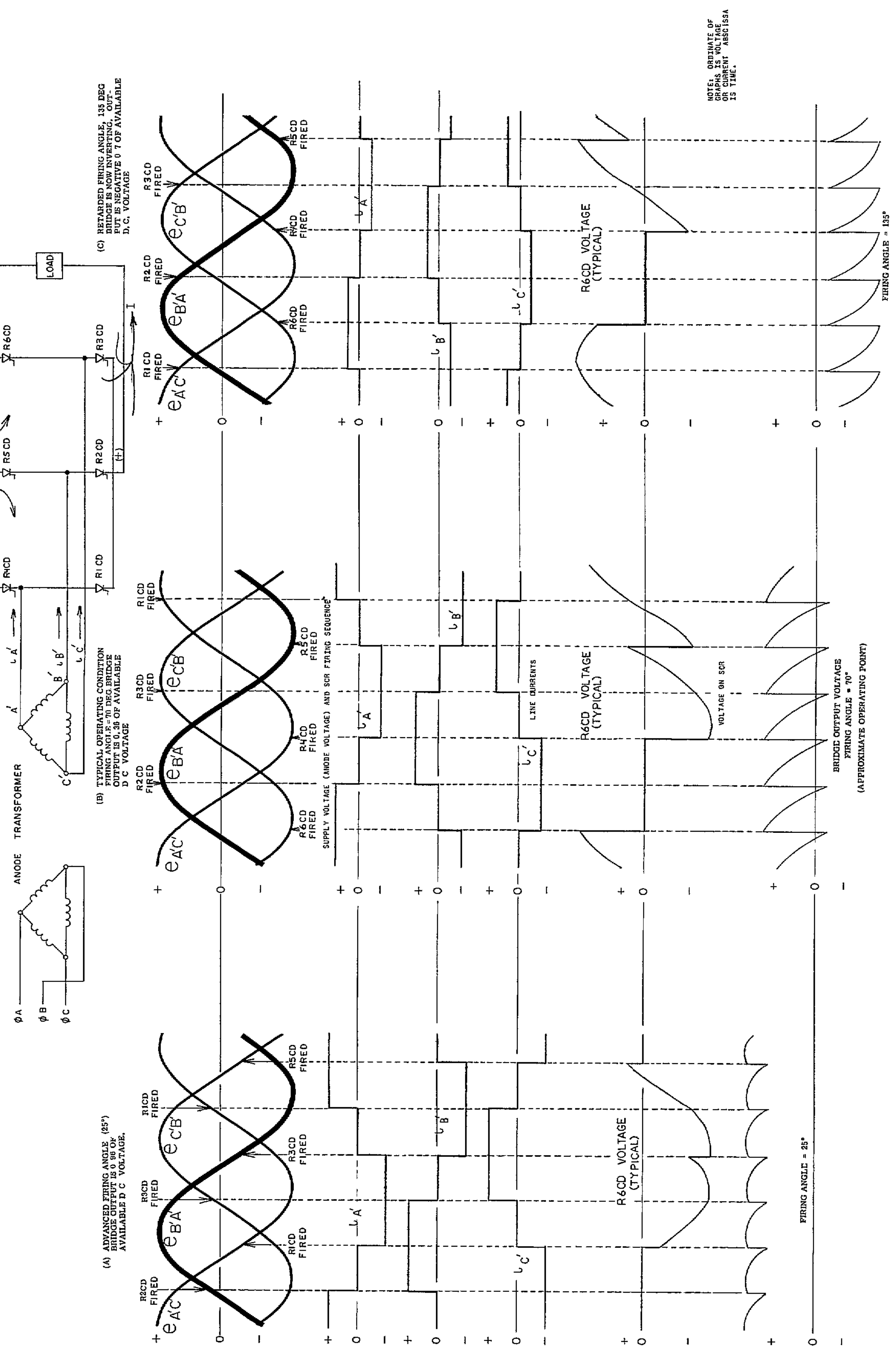
The firing angle of the SCR's can be measured from the fully phased-on condition (α) or from the fully phased-off condition (β). In this discussion, the firing angle is measured from the fully phased-on condition (α). For $\alpha = 0°$, the SCR's are turned full-on and the output corresponds to that obtained from a diode rectifier bridge. This angle may also be referred to as the ANGLE OF DELAY in firing.

If the regulator error signal calls for more excitation, the SCR's will be phased-on (α decreases) to furnish more positive DC output voltage. See Figure 2(a). If the regulator error signal calls for less excitation, the SCR's will be phased-off (α increases) to furnish less positive DC output voltage, or even negative DC output voltage. See Figure 2(c) and (d).



BLOCK DIAGRAM 3S7931SA100A1 SCR BUS-FED STATIC EXCITER

Figure 1



3-PHASE FULL-WAVE SCR INVERTING BRIDGE CIRCUIT

Figure 2

When the SCR's are phased off, the inductance of the load (exciter field winding) will force the instantaneous output voltage to follow the connected source voltage negative until the next SCR fires to connect a more positive phase source.

This "inverting" action causes the output DC voltage to swing negative transiently (as long as positive current is flowing in the inductive load). This inverting action provides both positive and negative voltage output from the SCR circuit for forcing generator field current both up and down. During normal operation (Figure 2(b)), power is flowing from the source to the generator field. During inverting operation (Figure 2(c)), power is flowing from the generator field back into the source.

The waveforms in Figure 2 illustrate variable DC voltage output by phase control.

Phase-Control Circuit

Parallel SCR bridges require a master and slave arrangement for phase control. The use of a master firing circuit and two slave firing circuits, one for each bridge, insures isolation of the gate firing pulses transmitted to two SCR's simultaneously.

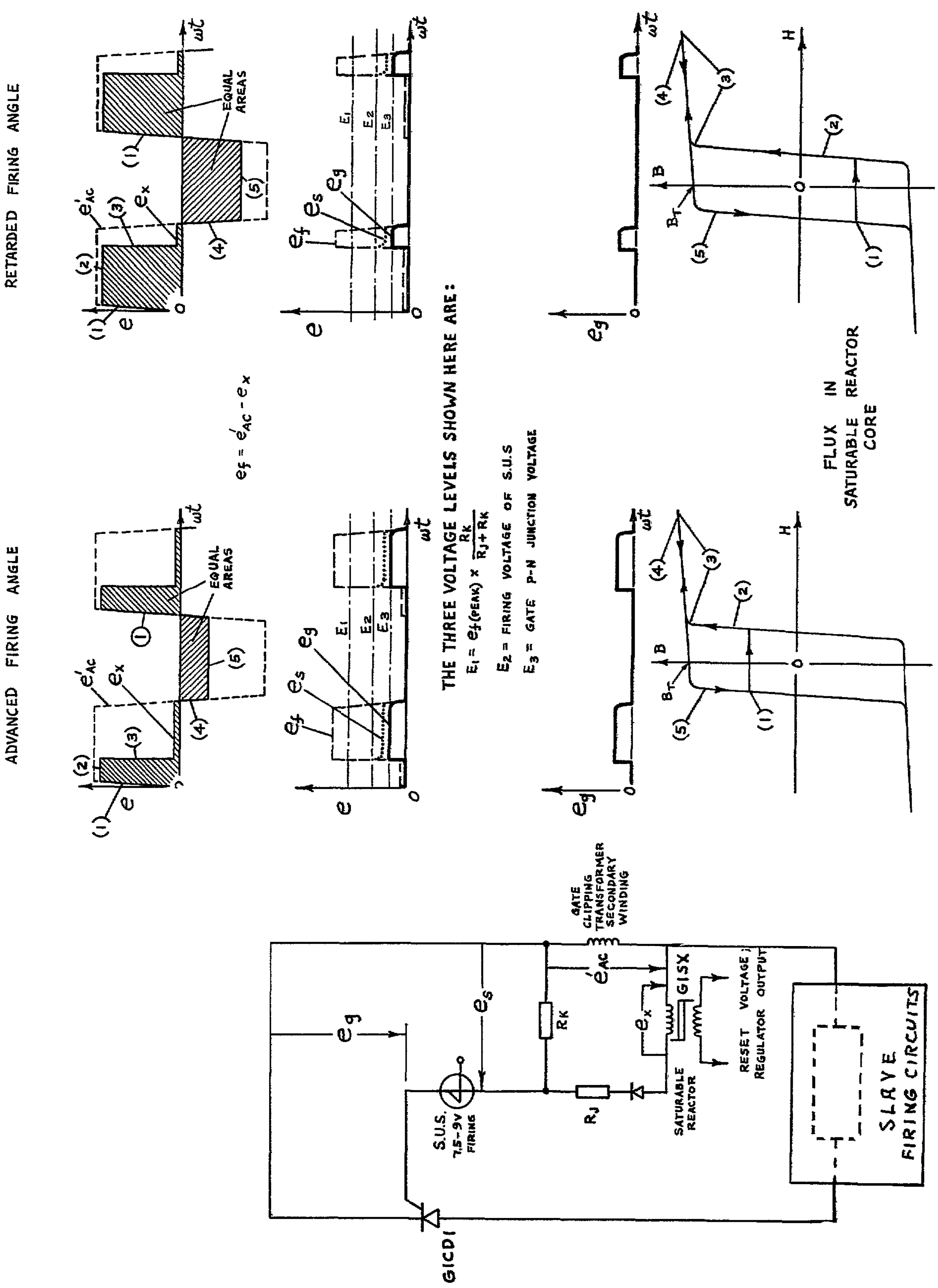
The Master SCR's use a saturable reactor-type firing and phase control circuit. This circuit is illustrated in Figure 3, which describes the firing of G1CD1. Firing for all six SCR's is identical but occurs at different times (Figure 2). Referring to Figure 2, it is necessary to vary the firing angle of the SCR's a full 180 degrees, to provide maximum positive to maximum negative voltage. For R1CD, the voltage of A' with respect to C' varies from zero to a positive maximum to zero in this interval. This voltage is used to generate the applied voltage waveform shown in Figure 3, e'_{AC}. Thus, the voltage e'_{AC}, used as the supply voltage for firing R1CD, is exactly in phase with $e_{A'C'}$. (The same supply voltage is used also for firing R4CD but 180° out-of-phase - accomplished by utilizing an identical winding on the gate clipping transformer, but connected into its master firing circuit in reverse polarity.)

The supply voltage e'_{AC}, from the anode potential transformer, is applied to G1SX, R_J, and R_K in series. The rectifier holds off e'_{AC} (prevents current flow) during the negative half-cycle, during which time the firing pulse for R4CD is generated in G4SX.

Numbers in parentheses indicate points of time (2) and relate voltage across the firing reactor, e_x, Figure 3 (top waveform) and flux in its core, Figure 3 (bottom B-H graphs). At the beginning of the cycle, the firing reactor G1SX is unsaturated (1); thus, its impedance is high and it allows only exciting current to flow through the resistors. This condition continues during (2) while the reactor is accumulating volt-seconds and its flux density B is increasing. At point (3), the reactor will saturate so that its impedance will drop sharply and cause most of the supply voltage to appear across the resistors. The core material is a square-loop type, so that the rising voltage across the series resistors, e_f, is quite steep.

The voltage across R_K would rise to a level given by $e_f \times \dfrac{R_K}{R_J + R_K}$, but this increasing voltage across R_K will cause the silicon unilateral switch (SUS) to trip at approximately 8 volts to apply the voltage of R_K to the SCR gate circuit, e_g. This voltage level is immediately clamped to 1-4 volts as G1CD1 fires. The voltage level is a characteristic of the SCR gate P-N junction. A zener diode and a resistor are connected between the gate and the cathode of each SCR as a back-up feature to protect the SCR gate from excessive voltage. When the SUS trips, current flows through the gate-to-cathode junction of the SCR. Since its anode is positive with respect to its cathode at this time, the SCR fires and allows current to flow through its anode-through gate to-cathode. The SCR is essentially the semiconductor equivalent of a thyratron tube. Once the SCR is fired, anode current will continue until it decays to zero or is commutated to another path, after which the SCR must be refired before it will conduct again. The SUS is similar to an SCR except that it is self-firing at a set anode voltage - in this case, 7.5 to 9 volts. Once the SUS has fired or tripped (an SUS is the semiconductor equivalent of a gas diode), its forward voltage drop is similar to a silicon rectifier -- approximately 1 volt (e_s minus e_g is approximately 1V). The SUS sets the voltage level where the SCR gate current begins, independent of the SCR anode characteristic or its gate resistance. It also prevents small voltage, such as noise, or the voltage due to G1SX exciting current, from firing the SCR. A capacitor is connected in parallel with R_K to shunt any high frequency noise in the firing circuit and also to provide a low impedance gate current source when the SUS trips.

The above description explains the Master SCR firing (1), (2), and (3) in Figure 3. After the SCR is fired, there is no change until (4) when the supply voltage, e'_{AC}, swings negative, and the rectifier then holds off the supply voltage, preventing reverse current in the gate winding of G1SX. The flux then returns to the B_r point. The regulator output applies a voltage to the Control winding of G1SX that causes exciting current to flow to produce a flux in the opposite direction from that resulting from the gate winding current, so the reactor begins accumulating volt-



SCR MASTER FIRING AND PHASE CONTROL CIRCUIT

Figure 3

seconds on the opposite side of the B-H loop, (5). At the end of the negative half-cycle (1), the exciting current again transfers back to the gate winding, which begins accumulating positive volt-seconds, (2).

The volt-seconds that must be accumulated before G1SX again saturates at (3) is determined by how much the flux was driven down the B-H loop (reset) during the previous negative half-cycle, (5). If the regulator output (reset voltage) is small during the negative half-cycle, the flux will not be pushed far down the B-H loop so few volts-seconds need be accumulated during the next positive half-cycle before G1SX will saturate. This is illustrated by the left graphs of Figure 3. If the regulator output (reset voltage) is large during the negative half-cycle, the flux will be pushed far down the B-H loop, so more volt-seconds will need to be accumulated during the next positive half-cycle before G1SX will saturate. This is illustrated in the right graphs of Figure 3.

Note in Figure 3 that for a positive half-cycle of G1SX voltage e_x, the area of the shaded portion (volt-second) must be equal to the preceding negative half-cycle volt-seconds. Thus, as regulator output increases, the firing angle is retarded, and the output voltage from the SCR circuit decreases.

The above description and Figure 3 illustrate firing of G1CD. The firing circuits for all other Master SCR's are identical. The regulator output (reset) is applied to all six firing reactors in parallel (G1SX through G6SX) so that all six Master SCR's are firing at the same respective angle thus achieving balanced firing.

The control signal for the Master SCR's requires three points: 0 volts (common), -24 volts DC, and a variable control voltage, 0 to -24 volts DC. See Figure 4. The common point is always connected to both the Automatic and Manual regulators through maintenance disconnect switches A4SW and D4SW. The minus volt point and the control point are switched between the Automatic regulator and the Manual regulator by transfer relay 43A. Contacts 6-7-8 on 43A relay connect the negative side of the reset voltage circuits to the proper regulator negative bus, while contacts 3-4-5 connect the firing circuit (reset) control line to the control voltage supplied by the proper output transistor. The output for the Automatic regulator is A4Q or A5Q transistor emitter (whichever is more positive) and the output of the Manual regulator is D2Q transistor emitter. The relay control circuits are to be explained later. The Null voltmeters indicate the difference between the output of the regulator controlling the firing circuit and the regulator not in use. The output of the unused regulator can then be varied by adjusting its operating level, to zero the Null voltmeter. With the meter zeroed, a transfer can then be made to the unused regulator without changing the SCR firing angle; thus, there is no "bump" in excitation.

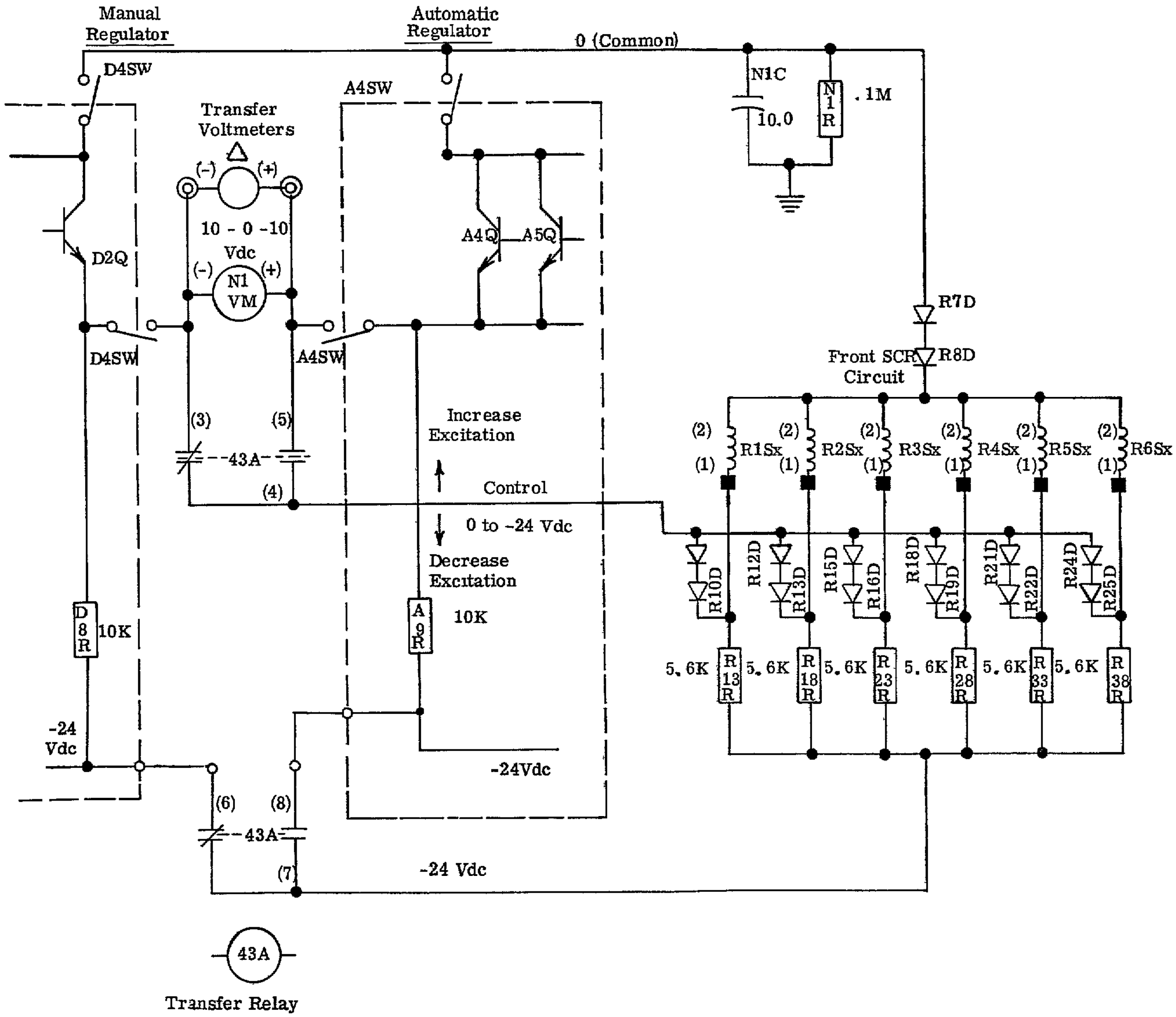
The SCR firing circuit illustrated in Figure 3 requires an AC supply voltage of reasonably constant magnitude. Since the generator voltage can vary over a wide range, it is necessary to convert this to a regulated supply. This is the purpose of the clipping circuit illustrated in Figure 5.

The input AC voltage is applied across the primary of the firing circuit supply transformer (R2T-P for the phase illustrated) and resistors R4RA and R4RB, in series. If two 40 volt Zener diodes (A) were connected across R2T-P, then the voltage across R2T-P could be limited as indicated in Figure 5(b). Applied voltage in excess of 40V would be dropped across the series resistors, R4RA and R4RB. The same clipping action could be accomplished by a single Zener diode across the DC terminals of a bridge rectifier loading a secondary winding of R2T (B). Since the same Zener diode would be clipping both the positive and negative half-cycles, the resulting "square" wave would be balanced. The clipping magnitude for a 24 volt Zener on the secondary would be the same as a 40 volt Zener on the primary if the transformer ratio were proportional.

If all transformers on a three-phase circuit were clamped by the same 24V Zener diode(B), the positive and negative half cycles of all three phases would be balanced. This is the actual circuit illustrated in Figure 5 except that the clamping action is provided by three parallel power transistors. This circuit acts to greatly increase the power dissipating capability of the Zener diode, while not appreciably degrading its voltage regulation characteristic. The three transistors (R1Q, R2Q, and R3Q) are controlled by R7ZD, R8R, and R9R. When the voltage across the circuit (P to N) tends to exceed approximately 24 volts, the Zener diode R7ZD allows current flow through R8R and R9R to provide a base-to-emitter current through the transistors. The transistors amplify this error current and permit current flow through R7R to keep the P to N voltage only slightly more than R7ZD breakdown voltage. Resistors R10R, R11R, and R12R assure current division among the three paralleled transistors. The resulting waveforms are illustrated in Figure 5 for one phase only (R2T).

Figure 5(a) illustrates supply voltage and R2T-P (Primary) voltage. Figure 5(b) illustrates voltage across resistors R4RA and R4RB and clamping transistor current. Figure 5(c) illustrates R2T-S (Secondary) voltage. Secondary voltage (at a 20 volt level) is applied to SCR firing circuits for R1CD and R2CD. Figure 5 - I, II, III illustrates clipping action at different exciter (supply) voltage levels.

Figure 6 illustrates the method used to control the firing angle of two SCR's in parallel. The firing of Master SCR G1CD1 causes current to flow in the primaries of pulse transformers R21T(front) and R21T(rear). The output of the pulse transformers secondaries are connected to gates of their corresponding front or rear bridge SCR's.



FIRING REACTOR CONTROL (RESET) AND TRANSFER CIRCUIT

Figure 4

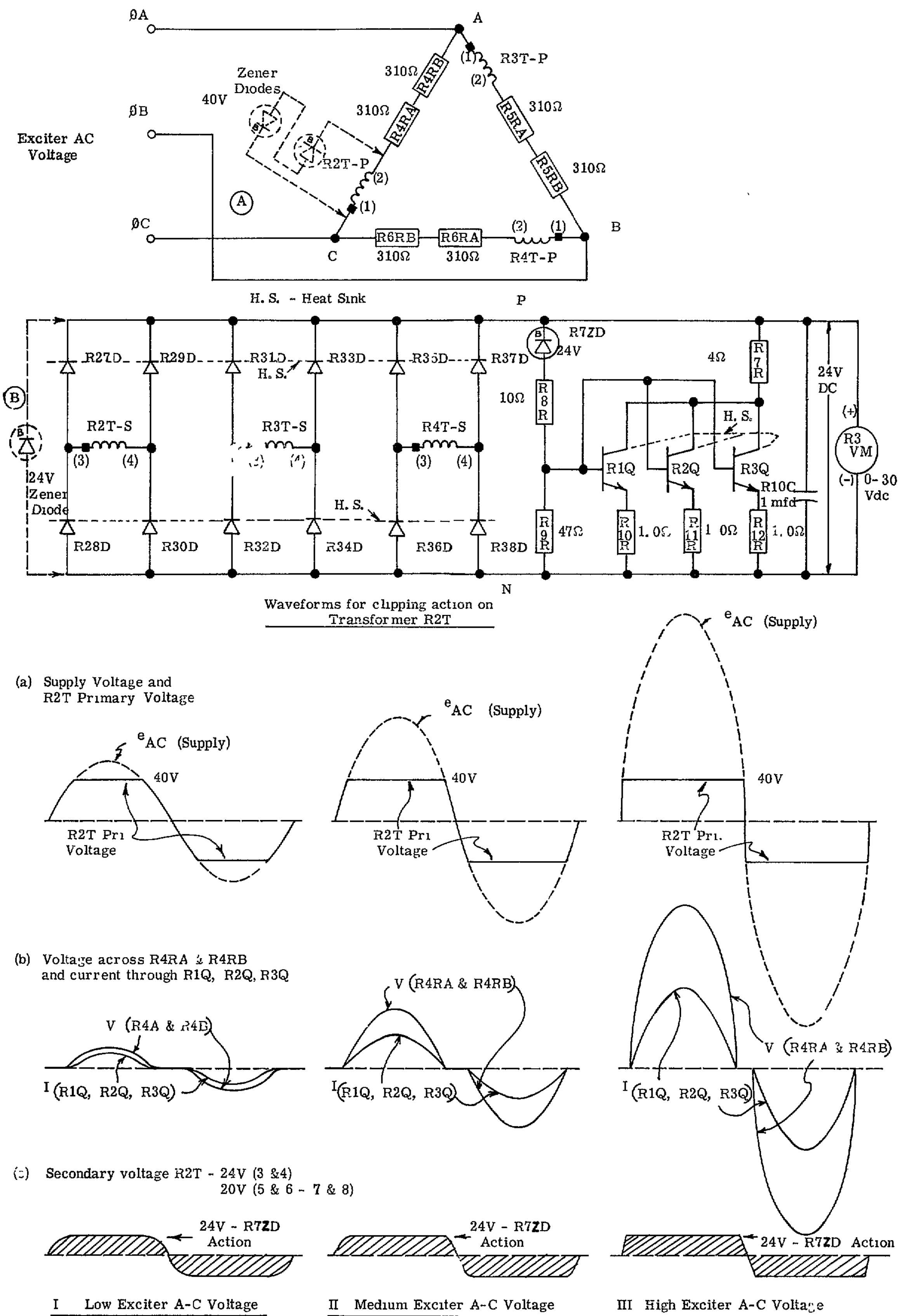
In series with each pulse transformer primary is a parallel RC circuit. The capacitor allows the full voltage from the clipping circuit transformer secondary to appear across the primary giving a fast rise time pulse to the gates of SCR's R1CD front and R1CD rear. The resistor limits the current in the primaries after they have saturated.

Reactors R1X (front and rear) ensures turn on of both SCR's by holding the line A to load voltage up for a short time during initial current flow. Current transformers 7CT and 8CT provide for current balance between the two bridges.

Figure 7 shows a simplified diagram of parallel full wave SCR bridges.

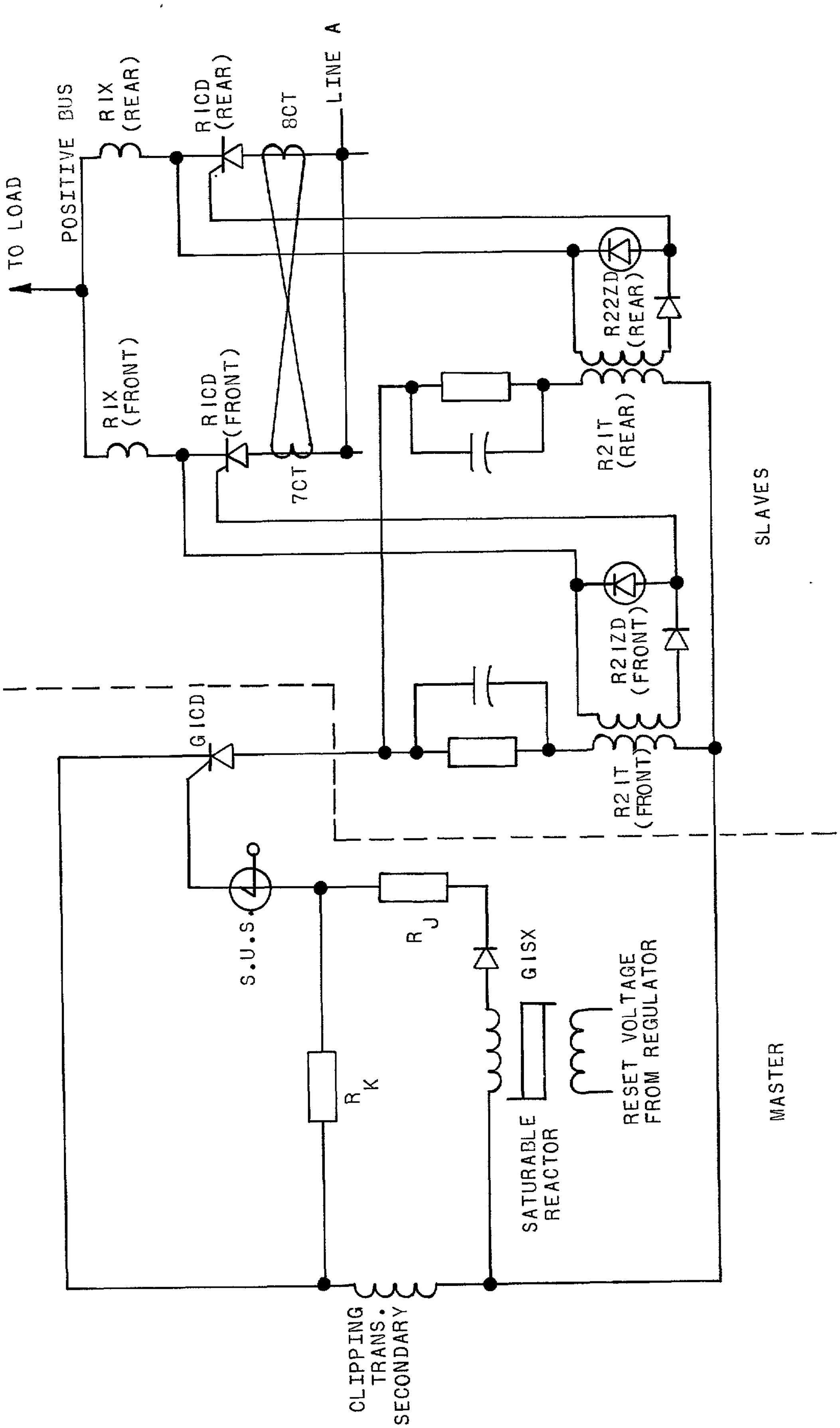
AUTOMATIC REGULATOR

Figure 8 shows a block diagram of the Automatic regulator. Regulation of the generator terminal voltage requires an input to the voltage regulator proportional to generator terminal voltage. This is accomplished by taking a signal from the P. T.'s, compensating it for Reactive Current and/or Active-Reactive Current and rectifying the AC signal in the sensing circuits to obtain a DC level. The output of the sensing circuits is used as a source for the zener power supply feeding the transistorized amplifier (A1PCB) in addition to being the generator reference input to the comparison circuits. The comparison circuits compare the sensing signal with the position of the Automatic voltage adjuster to determine if the generator terminal



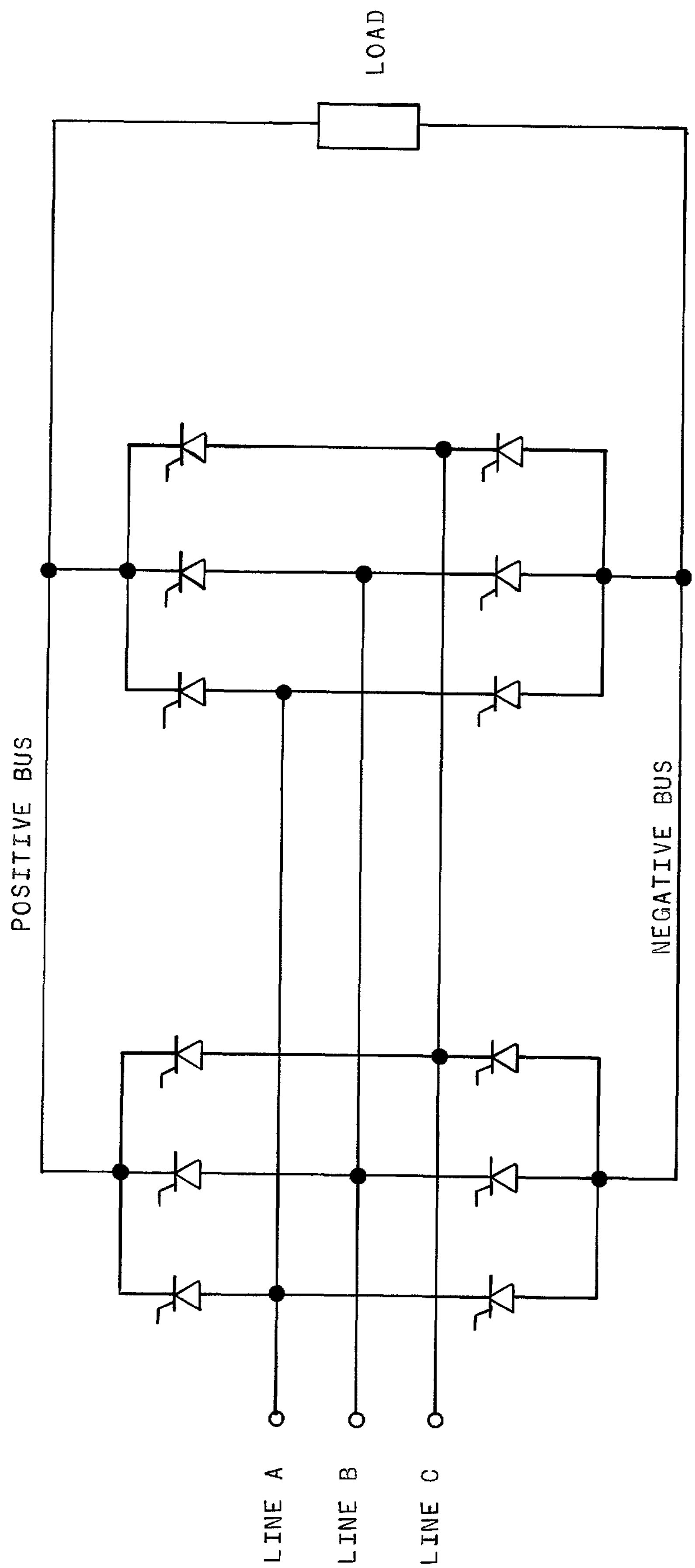
CLIPPING CIRCUIT FOR FIRING CIRCUIT SUPPLY

Figure 5



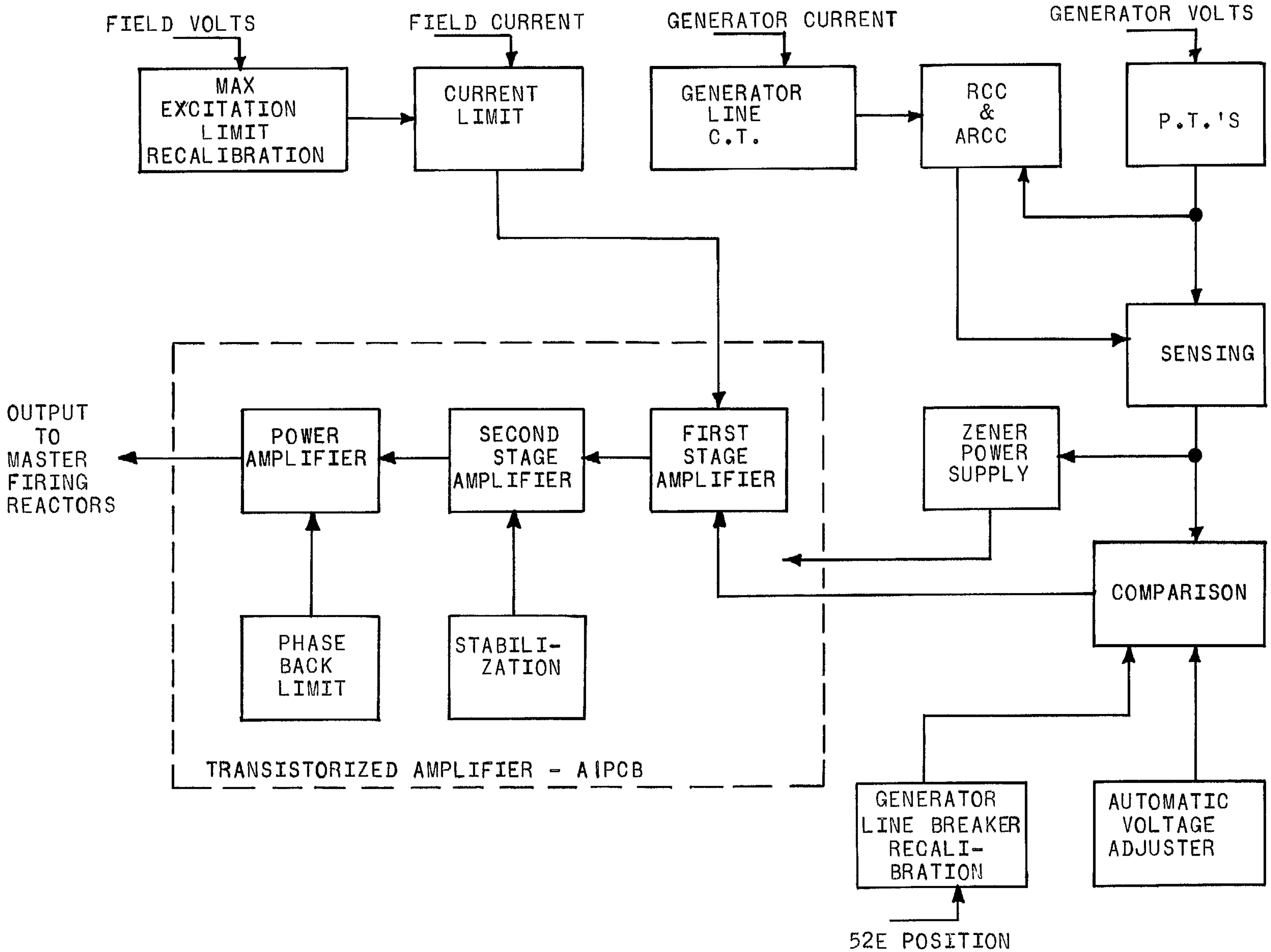
SCR FIRING AND PHASE CONTROL CIRCUITS

Figure 6



PARALLEL SCR BRIDGES

Figure 7



BLOCK DIAGRAM - AUTOMATIC REGULATOR

Figure 8

voltage is above or below the level it should be for the given setting of the Automatic voltage adjuster. The resultant of the comparison is then recalibrated in the direction to give a lesser generator terminal voltage if the generator line breaker (52E) is not closed. The output of the comparison circuits is fed into the first stage of the transistorized amplifier A1PCB along with the current limit signal which is recalibrated to a lower limit if the field voltage exceeds a safe level. The output of the first stage is fed directly to the second stage where series stabilization is accomplished. The stabilized signal is then fed into the power amplifier. A phase back limit circuit is incorporated to prevent the Master SCR's from being phased fully back to 180 degrees. The output of the power amplifier is the phase control signal to the master firing reactors described previously.

Elementary diagram 44C304408, Sheet 7, shows the Automatic regulator in detail. The output of the P. T.'s is fed into the regulator through A5SW, phase B being compensated for Reactive and/or Active-Reactive Current, to the primaries of A1T, A2T and A3T where the voltage is stepped down to approximately 40 VAC. The output of the transformers is then converted to DC by the full wave diode bridge A22D through A27D. The output of the diode bridge, a DC voltage proportional to generator terminal voltage, is then applied across voltage divider U6R, A10P (in parallel with the 52E recalibration circuit consisting of A45 R, A15P and the contacts of relay 2CR which are open when 52E is closed), A39R, A11P (in parallel with the Automatic Voltage adjuster 70MV) and A38R.

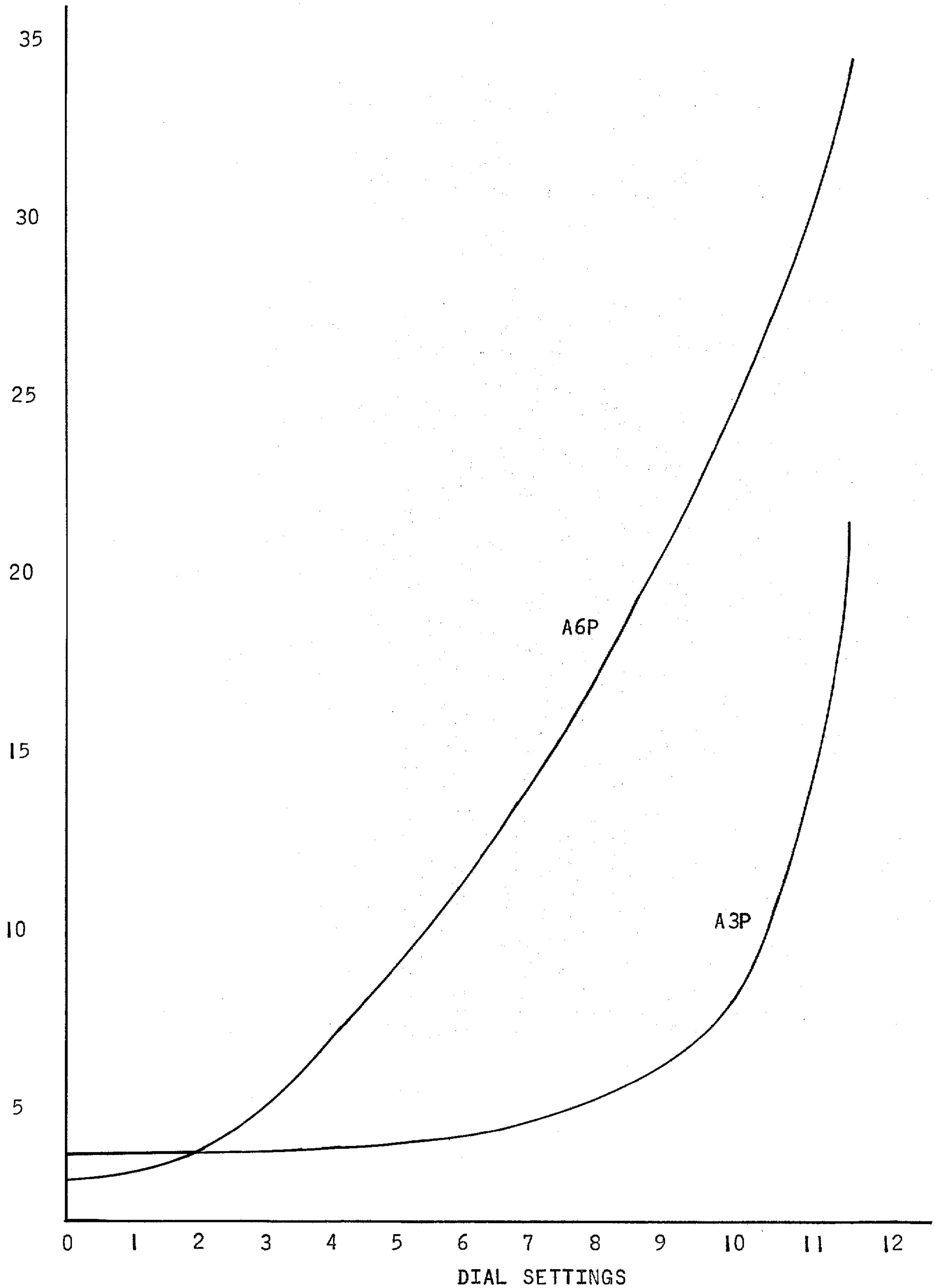
The bridge output is filtered by capacitors A8CA and A8CB. Power for the transistorized amplifier A1PCB is provided through U7R and U5R with zener diode A4ZD holding terminal A2TB-J at a constant minus 24VDC relative to the common terminal A2TB-L.

The Voltage on the wiper of 70MV is the control signal for the amplifier A2PCB. During normal operation the control signal is about minus 21 VDC relative to the common. If the generator terminal voltage increases, the output of transformers A1T, A2T, and A3T increases and terminal F of the diode bridge becomes more negative causing the wiper of 70MV to become more negative also. If the generator terminal voltage decreases, the reverse is true and the wiper of 70MV becomes less negative. The control signal is connected to the amplifier input terminal A2TB-D, then through A35R and A18D to the base of A11Q. The emitter of A11Q is connected to the minus 24 volt bus through A29R. The control signal, being less negative than the -24 volts, will forward bias the base to emitter junction of A11Q allowing the transistor to conduct. The current flowing through A27R, A28R, and A11Q will forward bias the emitter to base junction of A10Q. The voltage level at the junction of A6P, A25R, and A26R is determined by the conduction of A10Q, A11Q, and the setting of Gain Adjust potentiometer A6P. Figure 9 shows a plot of gain versus the dial setting of A6P. The amplified signal is coupled to A9Q through A25R. The residual ripple on the control signal amplified by A10Q and A9Q is removed by the ripple filter A24R and A4C connected to the base of A9Q. The series stabilization network consisting of A5P and A3C is also connected to the base of A9Q. The output of emitter follower A9Q is coupled to the base of A8Q through A22R. The operation of A7Q and A8Q is very similar to A10Q and A11Q. The gain of A7Q and A8Q is controlled by A3P. Figure 9 shows a plot of gain versus the dial setting of Gain Adjust potentiometer A3P. The amplified signal at the emitter of A7Q is direct coupled to base of the power amplifier A4Q. The emitter output of A4Q is the phase control signal to the master firing reactors. The phase back limit circuitry consisting of A5Q, A6Q, A16D, divider A11R, A2P, A12R and A13R, and A2ZD provides clamping at the emitter of A4Q to prevent the master SCR's from being phased back to 180 degrees. A2ZD regulates the voltage at the junction of A12R and A13R at minus 18 volts. For an SCR phase back limit of 150 degrees, A2P is adjusted for about 11 volts on the wiper. If the emitter of A5Q becomes more negative than 11 volts, A16D, A5Q and A6Q will be forward biased and the output will be clamped at slightly more than minus 11 volts.

During normal operation the control signal to the amplifier is about -21 VDC and the amplifier output about -5 VDC. If the generator terminal voltage should decrease, the control signal becomes less negative, A10Q and A11Q increase conduction. A9Q increases conduction because of a less negative voltage applied to its base and in turn applies a less negative voltage to the base of A8Q. A8Q and A7Q increase conduction which increases the base drive of output transistor A4Q. The increased conduction of A4Q causes the output to become less negative, or less volt seconds reset to the master firing reactors. The decreased reset voltage allows the SCR's to phase on increasing the bridge output to the generator field. Terminal voltage increases as generator field current increases and the control signal to the amplifier will move negative towards -21 volts causing the amplifier output to return to its normal -5 volts. In the event the generator terminal voltage should continue to rise, the control signal will become more negative, the amplifier output becomes more negative and the SCR's firing angles are retarded to give a lesser value of field current.

The system is stabilized by the damping action of the RC network A5P and A3C connected between the base of A9Q and the -24 volt bus. The transient gain of the amplifier is reduced by shunting current away from or supplying current to the base to emitter junction of A9Q. Stability adjustments are covered elsewhere in this instruction book.

The range over which the Automatic regulator will operate is controlled by the setting of the Range Adjust potentiometer A11P. A11P is adjusted to allow



STAGE GAIN VERSUS GAIN POTENTIOMETER DIAL SETTINGS

Figure 9

70MV to control the generator terminal voltage +10, -15% of normal. The Level Adjust potentiometer A10P is set to regulate the output of the P. T's at 120 VAC during normal operation.

The 52E recalibration circuit consisting of A45R, A15P, and the contacts of 2CRY provide for a downward change in the generator terminal voltage for 10 sec. if 52E should open. This offset allows the output of the amplifier to remain more negative than normal for a longer period of time which in turn will keep the SCR bridge output negative and decrease the field current to its normal no load (AFNL) value more rapidly. A15P is adjusted to give a 10% downward change upon the closure of Relay 2CRY contacts. Elementary diagram 44C304408, Sheet 9a, shows the circuitry for 2CRY operation.

Generator field current limit is provided by developing a take over signal proportional to generator field current. This is shown on Elementary diagram 44C-304408 Sheet 7 (A-2, 3, 4, 5) and Sheet 2 (B, C-4). The output of current transformers C1CT, C2CT and C3CT, whose primaries are in the 3-phase supply to the front and rear SCR bridges, is fed through switch A3SW to the full wave diode bridge A29D through A40D. The bridge output is filtered by capacitor A10C and the adjustable CT burden resistor U10R. U10R is factory set for the proper bridge output versus field current relation. Refer to Figure 10. The bridge output is connected across the voltage divider A44R, A13P and J1P in parallel with the normally closed contacts of relay J2KX. The wiper of Overcurrent Adjust Potentiometer A13P will be at some negative potential determined by generator field current as the positive leg of the diode bridge is connected to the amplifier common A2TB-L.

The current limit take over signal from the wiper of A13P is fed into the amplifier on A1TB-A and connected to the cathode of A28D. Recalling the control signal is about -21 volts and is fed to the base of A11Q through A35A and A18D, the anode of A28D (not normally conducting) is at the same potential as the junction of A35R, A36R, and A18D. Should the field current increase to the point at which the wiper of A13P becomes more negative than the anode of A28D, A28D will conduct and the current limit will "take over" control of the amplifier. A13P is set to limit the generator field current at 675 amps or about 1.7 per unit generator load.

The maximum excitation limit recalibration of the current limit take over signal consists of J1P, the contacts of J2KX on sheet 7, plus J1R, J2R, J1K on sheet 4 (c-4), and J2K, J2KX, J3K and J3KX on sheet 9 (B-D - 5 & 6). Figure 11 shows a simplified diagram of these circuits drawn in their condition for normal Automatic operation. If the generator field voltage should rise to 256 VDC, J1K will pick up closing its contact in series with the coil of J2K. To eliminate transients, J2K will not pick up for 40 seconds. If the overvoltage condition continues for 40 seconds, J2K will pick up which in turn will cause J2KX to pick up and seal in through its own contacts and those of 43. Referring back to sheet 7 of the elementary diagrams, J1P is now a part of the divider along with A13P. Insertion of the additional resistance causes the current limit signal from the wiper of A13P to move in a negative direction. J1P is set to recalibrate the current limit to 440 amps or about 1 P.U. generator load.

Referring back to Figure 11, J3K will pick up 10 seconds after J2K if the generator field voltage has not been reduced to allow J1K and J2K to drop out. The pickup of J3K will energize relay 83 which opens the contact in series with the coil of 43. Relay 43 then drops out transferring the phase control signal to the firing reactors to the Manual regulator. Relay J3KX is for positioning of the Manual voltage adjuster 70MR and will be discussed later.

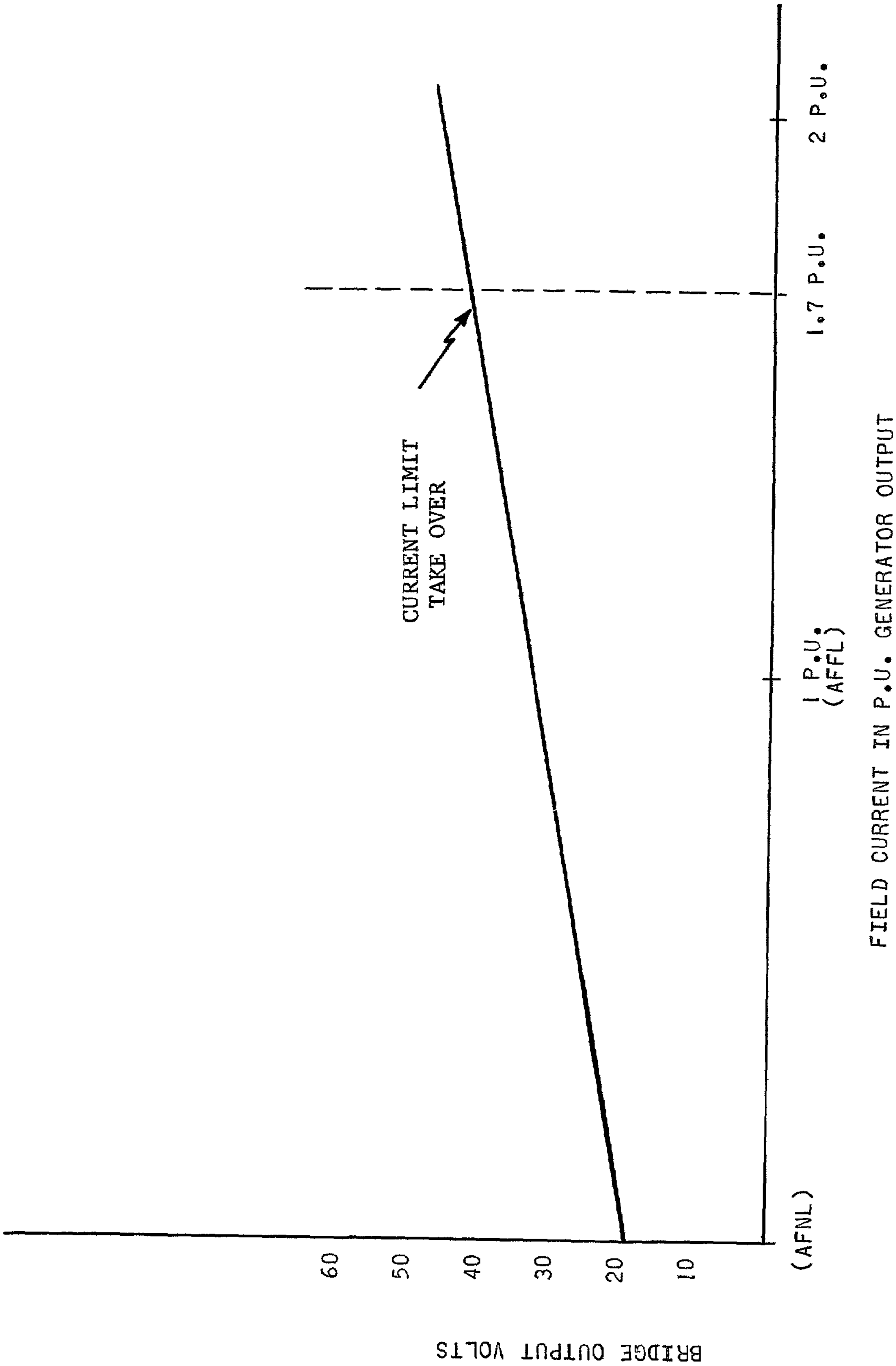
The reactive current compensator acts to cause the generator to tend to reject VARs as it "picks up" those VARs. Or, in the opposite action, it causes the generator to supply VARs, as it is rejecting those VARs. This equipment is provided to prevent the generator with the most responsive excitation system from supplying more than its share of reactive current to the power system, when the power system is accepting VARs, or from rejecting a disproportionate share of reactive current, when the power system is supplying VARs. Reactive current compensation is generally required on all, or on all but one generator, when there several generators in a power station.

The elementary and phasor diagrams are shown in Figure 12. The phase sequence of the generator and the polarities of the transformers cause a voltage to be introduced in the line from phase 2 before it is connected to the Generator Voltage Regulator front end, phased so that this voltage "cheats" the front end, making it appear that the generator terminal voltage has changed when it has not, when reactive current is supplied by the generator.

The consecutive phasor diagrams under part I of Figure 12 show that underexcited reactive current causes a decreased voltage signal to the regulator front end, resulting in an increase in excitation - thus reducing the underexcited reactive current. The next diagram shows that excitation resulting in 1.0 power factor operation of the generator does not appreciably affect the voltage to the front end of the regulator. The last diagram shows an opposite action to the first.

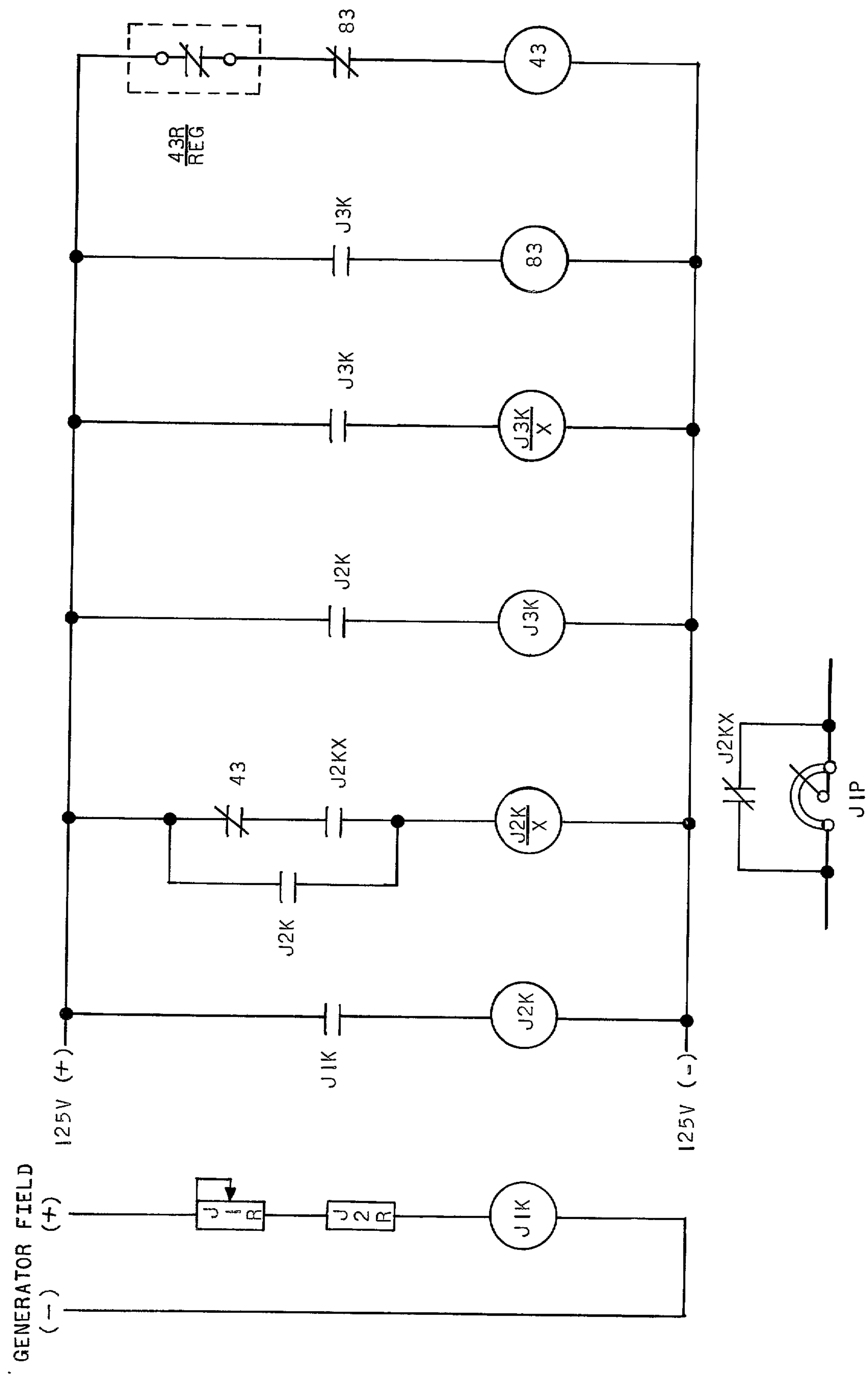
The reactive current compensator is often called the droop circuit, as its effect is to make the generator voltage versus reactive load characteristic curve have an artificial droop.

There are only three parts to the compensator; an isolating transformer/reactor and two selector switches which vary the transformer ratio from zero to its full turns ratio. One switch provides coarse steps in ratio,



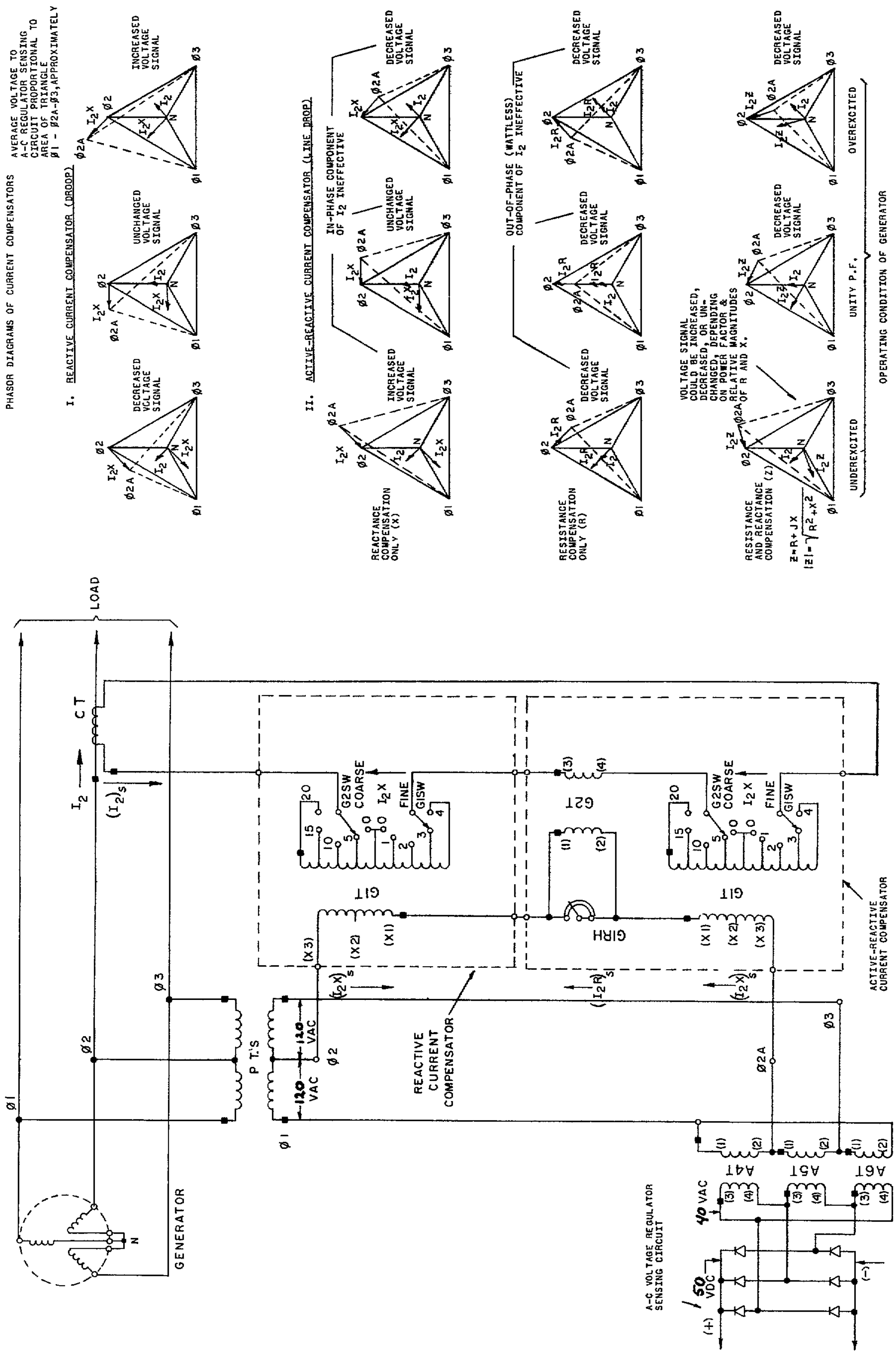
CURRENT LIMIT BRIDGE OUTPUT VERSUS FIELD CURRENT

Figure 10



MAXIMUM EXCITATION LIMIT - SIMPLIFIED DIAGRAM

Figure 11



ELEMENTARY AND PHASOR DIAGRAMS FOR REACTIVE CURRENT COMPENSATOR AND ACTIVE-REACTIVE CURRENT COMPENSATOR

Figure 12

and reactance while the other switch provides fine steps. The switch positions are numbered, 0 to 20 in four steps for the coarse switch, and 0 to 4 in four steps for the fine switch. The numbers are the actual voltage added in the regulator sensing circuit, for a current of 5 Amps in the signal CT secondary circuit. The signal CT ratio is usually set so that 5 amps will be induced in its secondary winding when rated generator line current is in its primary. Thus, rated reactive current can cause a 24 V change in the nominal 115 V phasor generator voltage triangle. This will change the average voltage from the rectifiers of the Regulator sensing circuit by 11%. So, the compensator can induce up to 11% voltage droop in the generator-regulator characteristic.

Note that the compensator can be connected in reverse polarity, to cause negative droop in the generator characteristic; this connection can be used to account for output transformer reactance, thereby improving system voltage regulation. IT IS ESSENTIAL THAT BOTH WINDINGS OF THE COMPENSATOR BE CONNECTED IN THE SAME GENERATOR PHASE-USUALLY PHASE 2.

The active-reactive current compensator consists of the reversed reactance connection described above, with identical components as the Reactive Current Compensator and in addition, it contains a rheostat in series with the reactance. The rheostat is used to cause a change in voltage to the regulator sensing circuit proportional to generator active current.

The active and reactive current compensator is used to reproduce in miniature at the regulator, the resistance and reactance between the generator and some predetermined point in the system. The function of the compensator is to lower the signal voltage to the AC regulator as the generator load increases, thereby causing the regulator to maintain normal voltage at some predetermined point in the system, regardless of changes in the voltage drop over the system impedance between the generator and this point. See Figure 12-II.

Where line-drop compensation is required on several generators in a station, provision can be made to prevent interference between the compensators. This is accomplished by special connections of the current transformer and compensators.

The resistance portion of the compensation is a 5 ohm rheostat which produces 25 volts drop in the regulator signal with five amperes in the C. T. secondary.

Figure 12 shows the connections for this device when used with a single generator. Insulating windings are provided for both the reactor and resistor to permit grounding the current and potential-transformer secondaries separately. <u>It is essential that the current transformer be in the same phase as the signal-voltage line in which the compensator is connected.</u>

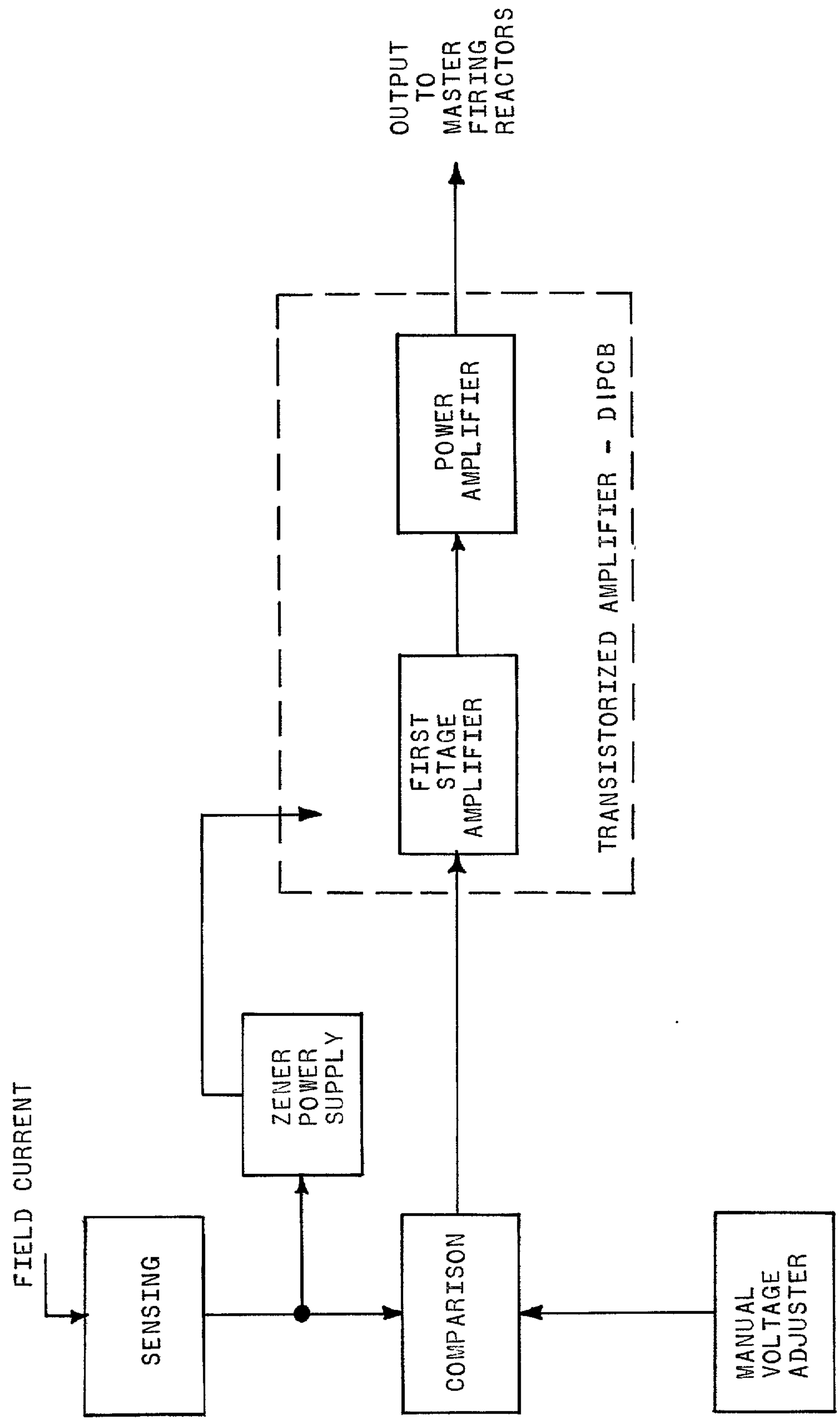
The final circuit of the Automatic Voltage Regulator is the error signal meter circuit. Components of this circuit are meter A2VM, potentiometers A12P and A14P, resistors A40R and A41R, and pushbutton switch A1PB. A voltage divider circuit is connected in parallel with the principal comparison circuit, across A8CB, the output voltage of the regulator front end.

The DC voltage from this divider circuit is proportional to generator terminal voltage; potentiometer A12P is used to "pick off" 24 volts (from the A40R end of the circuit), when the generator terminal voltage is at its desired value. A sensitive microammeter, in series with calibrating resistors (multipliers), then is used to make a differential voltmeter. This meter has a limited range, from minus 5% to plus 5%. It is located beside the regulator output voltmeter, A1VM, and provides a quick check of the regulator operation. When the error meter circuit is activated by pushing switch A1PB, the two meter pointers should be observed to move together - in the same direction, and approximately over the same arc. This indicates that the regulator output voltage is faithfully following the generator voltage deviation. Switch A1PB protects the meter when generator voltage is low during start-up, or when maintenance disconnect switch A1SW is open, or when the signal PTs are disconnected, etc.

MANUAL REGULATOR

A block diagram of the Manual regulator is shown in Figure 13. Regulation of generator field current requires an input to the Manual regulator proportional to field current. This is accomplished by inserting current transformers in the AC supply lines to the SCR bridges. The output of the C. T.'s is rectified in the sensing circuits to obtain a DC level. The output of the sensing circuit is used as a source for the zener power supply feeding the transistorized amplifier (D1PCB) in addition to being the generator field current reference input to the comparison circuit. The comparison circuit compares the sensing signal with the position of the Manual voltage adjuster to determine if the generator field current is above or below the level it should be for the given setting of the Manual voltage adjuster (70MR). The output of the comparison circuit is fed into the first stage of the transistorized amplifier D1PCB and then on to the power amplifier. The output of the power amplifier is the phase control signal to the master firing reactors.

Elementary diagram 44C304408, Sheet 6 shows the Manual regulator in detail. The output of current transformers 4CT, 5CT and 6CT, whose primaries are shown on sheet 2, is connected to switch D3SW and then to the 3-phase full-wave diode bridge D13D through D24D. The bridge output is connected across divider D11R, D2R, D1P, 70MR, D2P, and D3R. Filter capacitor D2C is across the major portion of the divider.



BLOCK DIAGRAM - MANUAL REGULATOR

Figure 13

The power for the amplifier is furnished through resistor D1R. Zener diode D1ZD holds amplifier terminal M at minus 24 VDC. D1R is adjusted for the proper zener current over the wide range of operation of the Manual regulator.

The control signal for the transistorized amplifier D1PCB is taken from the wiper of the Manual voltage adjust potentiometer 70MR and fed through D25D to the base of D3Q. The control signal, at minus 17 volts relative to the common terminal J, causes D3Q to be forward biased allowing current to flow through D4R and D5R. The voltage drop across D4R is sufficient to forward bias D1Q. The conduction of D1Q causes power amplifier D2Q to conduct, placing the output terminal N at about -5 volts. The output is the phase control signal to the master firing reactors when operating on the Manual regulator.

The Manual regulator maintains a constant field current by regulating the voltage at the wiper of 70MR. If the wiper of 70MR should move in the negative direction due to an increase in field current, D3Q conducts less, D1Q conducts less, D2Q conducts less causing the output terminal N to move more negative. A more negative phase control signal to the master firing reactors will reduce the output of the front and rear SCR bridges to the generator field. The decreased field current causes less output from the CT's which reduces the output of the diode bridge. The reduced bridge output causes the wiper of 70MR to move less negative to its normal -17 volts. If the field current should decrease, the wiper of 70MR would move in the positive (less negative) direction and the reverse would be true.

Range Adjust potentiometer D2P and Level Adjust potentiometer D1P are set to allow the Manual regulator to operate over a range from 25% normal generator terminal voltage (60 amps generator field current) to the field current required for 115% rated load and 105% rated voltage.

Manual voltage adjust potentiometer 70MR controls the level of generator field current. By moving the wiper of 70MR towards the common, more field current is required to develop a voltage which will keep the wiper of 70MR at about -17 volts. Moving the wiper of 70MR away from the common requires less field current to maintain its normal potential.

RELAYING AND CONTROL

Relay and control circuitry can best be described using Boolean Algebra expressions. Figure 14 illustrates a review of Boolean Algebra as applied to relay circuits. Figure 14(a) shows relay C can be energized if devices A AND B are closed. The Boolean expression for this is $C = A \cdot B$. Devices A and B can be any one of several two state devices (Switches, Relays, Contactors, etc.). In Figure 14(b), relay C is energized if either A OR B is closed and is expressed as $C = A+B$. In Figure 14(c), relay E is energized if A OR B AND C AND D are closed and is written $E = (A+B) \cdot C \cdot D$. In Figure 14(d), relay E can only be energized if relay A is not energized AND B OR C OR D are closed. This is written $E = \overline{A} \cdot (B+C+D)$.

Table I contains a listing of all the devices used in the relay and control, the elementary sheet number on which the coil is located, the function of the device, and the Boolean expression for the device to be energized. The first three devices listed are energized with analog signals which are not possible to express algebraically but their contacts do appear in other expressions. Also breakers 41 and 52E are latching type devices which makes it necessary to develope one expression for closing and another for opening. The limit switches 70LS and 90LS are controlled by the position of their respective voltage adjusters making it necessary to determine their state from the bar graphs on elementary sheets 10 and 11.

Looking at the Field Flashing circuit on elementary sheet 4 it can be seen 125VDC will be applied to the generator field through diode 53D and resistor F1R if relay 53 contacts 3 and 4 and 5 and 6 are closed. The Boolean expression (from Table I) for field flashing is: $53 = 13Y \cdot 1CR \cdot \overline{27} \cdot \overline{53TD}$ or field flashing relay 53 will be energized if 13Y is picked up AND 1CR is picked up AND 27 is not picked up AND 53TD is not picked up.

Substituting the expression for 1CR from Table I:

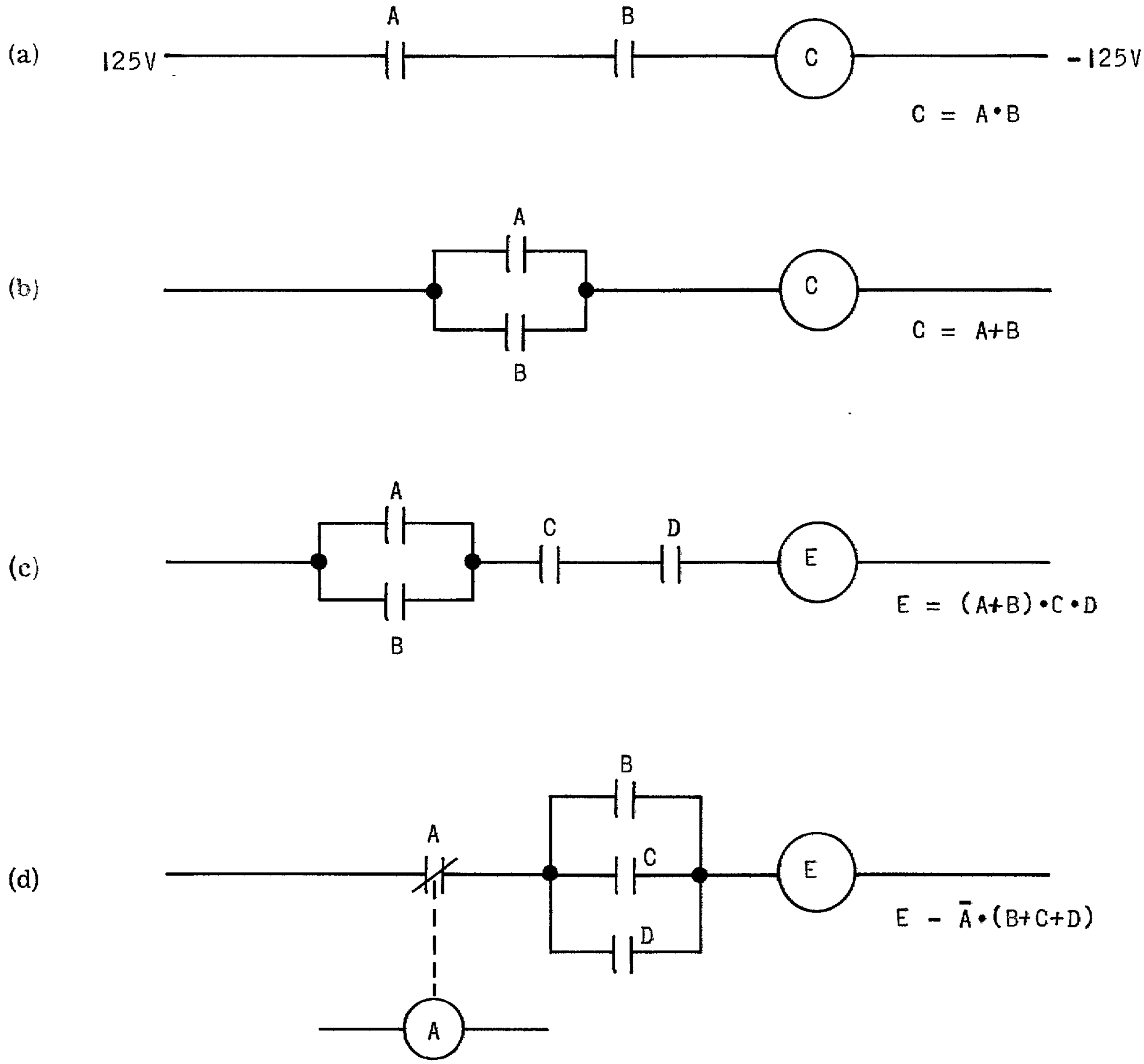
$$53 = 13Y \cdot \left[\left(1 + \frac{43R}{Test/Man}\right) \cdot 41 \cdot 52E\right] \cdot \overline{27} \cdot \overline{53TD}$$

Substituting the expression for 1 from Table I:

$$53 = 13Y \cdot \left\{\left[\left(\frac{43R}{Reg} \cdot 4\right) + \frac{43R}{Test/Man}\right] \cdot 41 \cdot 52E\right\} \cdot \overline{27} \quad \overline{53TD}$$

No further expansion is necessary as the expression now states: Field flashing (53) will occur if the generator speed is above the permissive set point (13Y), AND {[(43R is in regulate AND the unit start relay (4) is picked up), OR 43R is in the test or manual position] AND the field circuit breaker (41) is closed AND the AC line breaker (52E) is closed}, AND the generator terminal voltage has not reached 40% of its normal rated value (27), AND ten seconds have not elapsed since field flashing started (53TD). To put it more simply: If the two breakers are closed and the generator is up to speed, field flashing will occur by placing 43R in the Test or Manual positions or field flashing will also occur by placing 43R in the Regulate positon if the unit start relay is picked up.

The sequence of events for a programmed startup can be determined quite easily by using Table I



BOOLEAN ALGEBRA EXPRESSIONS OF RELAY CIRCUITS

Figure 14

TABLE I

Device	Elementary Sheet No.	Function	Boolean Expression
J1K	4	Max. Excit. Limit	Energizes at 256 VDC on generator field
59H, 59L	6	Regulator Voltage Matching	High and low contacts open when Man. Reg. and Auto. Reg. outputs are matched.
27	8	Field Flash Volt. Cutout	Energizes at 40% of rated generator terminal volts.
TV	8	Initiate Regulator Transfer	Energizes at 95% or rated gen. terminal voltage.
43A, 43B, 43BX	9	Manual/Auto Transfer	$43A, \hat{B}, BX = \overline{83} \cdot \left\{4CR + \left[\frac{4.3R}{REG} \cdot \left(43B + 96CR \cdot \overline{LC}\right)\right]\right\} \cdot 1.\overline{95}$
83	9	Auto/Manual Transfer	$83 = \left[\left(43B \cdot \frac{43R}{Reg}\right) + 4CR\right] \cdot \left[\left(1 \cdot \overline{13Y} \cdot \overline{96CR}\right)\right.$ $83 + J3K + \overline{1CR} \cdot \overline{96CR}$
1CR	9	41 and 52E position indication	$1CR = \left(1 + \frac{43R}{Test/Man.}\right) \cdot 41 \cdot 52E$
LCM	9A	Initiate Line Charge Mode	Customer Momentary contact closing.
2CR	9	41, 52 and 52E position indication	$2CR = \left(1 + \frac{43R}{Test/Man.}\right) \cdot 41 \cdot 52E \cdot 52$
53	9	Field Flashing	$53 = 13Y \cdot 1CR \cdot \overline{27} \cdot \overline{53TD}$
53 (10 sec T. D.)	9	Field Flash. Time Cutout	$53(TD) = 13Y \cdot 1CR \cdot \overline{27}$
LC	9 A	Line Charge Mode	$LC = 96SW \cdot \left[LCM + (LC \cdot 43B/X)\right]$
J2K (40 sec. T. D. C.)	9	Max. Excit. Limit	$J2K = J1K$
J2KX	9	Max. Excit. Limit	$J2KX = J2K + (43B \cdot J2KX)$
J3K (10 sec. T. D. C.)	9	Max. Excit. Limit	$J3K = J2K$
J3KX	9	Man. Volt. Adjust. Position	$J3KX = J3K$
70R	10	Man. Regulator Raise	$70R = \left[\frac{1MR}{Raise} + (J3KX \cdot 70LS\text{-}4) + (J3KX \cdot \overline{7CR} \cdot 70LS\text{-}6 \cdot 3CR)\right] \cdot 70RX \cdot \overline{70L}$
70L	10	Man. Regulator Lower	$70L = (\overline{70R} \cdot 70LX) \cdot \left\{\frac{1MR}{LOWER} + (J3KX \cdot 70LS4) + \left[\overline{J3KX} \cdot \overline{7CR} \cdot 70LS7 \cdot 70LS6 \cdot \left(3CR + 96CR\right)\right]\right\}$
6CR	10	Man. Regulator Runback	$6CR = 1CR \cdot 6CRX \cdot \overline{70L}$
7CR	10	Man. Regulator Position	$7CR = (3CR \cdot 70LS\text{-}6 \cdot 70LS\text{-}7 \cdot \overline{96CR}) + \overline{1CR}$
70RX	10	Man. Reg. Upper Limit	$70RX = 70LS\text{-}2$
70LX	10	Man. Reg. Lower Limit	$70LX = 70LS\text{-}1$
90R	11	Auto. Regulator Raise	$90R = \left[\frac{43R}{Reg/Test} \cdot \overline{3CR} \cdot \left(\frac{1V}{Raise} + \frac{L.P.B.}{Raise}\right)\right] + (60AR \cdot \overline{4CR}) \cdot \overline{90L}$

TABLE I (Continued)

Device	Elementary Sheet No.	Function	Boolean Expression
90L	11	Auto. Regulator Lower	$90L = \left\{\left[\left(\frac{43R}{Reg/Test} \cdot \overline{3CR}\right) \cdot \left(\frac{1V}{Lower} + \frac{L.P.B}{Lower}\right)\right] + (60AL \cdot \overline{4CR}) + (90Y \cdot 96CR)\right\} \cdot \overline{90R}$
1	12	Regulator Startup	$1 = \frac{43R}{Reg} \cdot 4$
TVTD (TD)	12	Terminal Voltage Permissive	$TVTD\ (TD) = 1 \cdot LC \cdot TV$
6CRY (250 msec. T.D.O)	12	Man. Regulator Permissive	$6CRY = \frac{43R}{Reg} \cdot 4 \cdot 6CR$
6CRX	12	Man. Regulator Permissive	$6CRX = \frac{43R}{Reg} \cdot 4 \cdot 6CRY$
13Y	12	Speed Permissive	$13Y = 13$
3CR	12	Man. /Auto. Transfer Permissive	$3CR = 1 \cdot \overline{43B} \cdot 1CR \cdot 2CR \cdot 13Y \cdot LC$
4CR	12	Man./Auto. Transfer	$4CR = 1 \cdot (4CR + 60AX) \cdot LC$
60AX(10 sec. T.D.C.)	12	Man./Auto. Transfer	$60AX = 1 \cdot \overline{3CR} \cdot \overline{60AL} \cdot \overline{60AR} \cdot \overline{7CR} \cdot LC \cdot TVTD$
60AR	12	Auto. Volt. Adjust. Position	$60AR = 1 \cdot 3CR \cdot 59H \cdot LC$
60AL	12	Auto. Volt. Adjust. Position	$60AL = 1 \cdot 3CR \cdot 59L \cdot LC$
OT	12	SCR Bridge Over-Temperature	$OT = RT1S + RT2S$
52E(Close)	13	A. C. Line Breaker	$52E(close) = (1 \cdot 6CR \cdot 6CRX) + \frac{IXE}{Close}$
52E(Open)	13	A. C. Line Breaker	$53E(open) = \frac{IXE}{Trip} + GE + GX$
41(Close)	14	Generator Field Circuit Breaker	$41(close) = (1 \cdot 6CR \cdot 6CRX) + \frac{IXE}{Close}$
41(Open)	14	Generator Field Circuit Breaker	$41(open) = \frac{IXE}{Trip} + GE + GX$
96CR	9a	Remote Station Control	$96CR = 96SW$
2CRX	9a	Auto Reg. Recalibrate	$2CRX = \left(1 + \frac{43}{Test/Man.}\right) \cdot 41 \cdot 52E \cdot 52$
2CRY	9a	Auto Reg. Recalibrate	$2CRY = 2CRX + 2CRZ$
2CRZ (10 Sec. T.D.C.)	9a	Auto Reg. Recalibrate	$2CRZ = \overline{2CRX}$
90X	11	Auto Reg. Position	$90X = 90LS4 \cdot 96SW$
90Y	11	Auto Reg. Position	$90Y = (90X + 90Y) \cdot 96SW$
95	5A	Clipper Current Recalibrate	$95 = \overline{27}$

and the Elementary diagram. They are:

A. Operator applies 125 VDC to exciter cubicle.

1. 70RX picks up if 70MR is below its upper limit.
2. 70LX picks up if 70MR is above its lower limit.
3. 2CRZ picks up.
4. 2CRY picks up.

B. Operator places 43R in Regulate.

C. Unit Start relay 4 is picked up.

1. Regulator Startup relay 1 picks up.
2. 6CRY picks up.
3. 6CRX picks up.
4. 70MR runs to its lower limit.
5. 70LX drops out.
6. 6CR picks up.
7. 41 closes.
8. 52E closes.
9. 6CRY drops out.
10. 6CRX drops out.
11. 1CR picks up.
12. 6CR drops out.
13. 6CRY picks up.
14. 6CRX picks up.

D. Generator speed above setpoint of 13.

1. 13Y picks up.
2. 53 picks up starting field flashing.
3. 27 picks up when generator terminal voltage is at 40% of rated.
4. 95 drops out.
5. 53 drops out.
6. 43A and 43B pick up

E. Operator uses 1V to position 70MV for normal generator terminal voltage.

F. Operator synchronizes and closes 52 breaker.

1. 2CR picks up.
2. 3CR is picked up.

G. Operator uses turbine speed control to adjust torque angle for desired watts and 1MV to adjust excitation for desired volt-amperes.

Any of the exciter relay and control functions sequence of events can be determined in a like manner. Taking the Maximum Excitation Limit circuitry and assuming the generator is being controlled by the Automatic Regulator we know the expression $43A, B = \overline{83} \cdot \left\{ 4CR + \left[\frac{4.3R}{REG} \cdot \left(43B + 96R \right) \right] \right\}$ must be satistied or 43A and 43B would not be energized and the generator could not be controlled by the Automatic Regulator. If a malfunction or inadvertant overload occurs sufficient to raise the generator field voltage to 256 VDC or greater, J1K will pick up.

Then:

1. After 40 seconds J2K = J1K is satisfied.
2. J2KX = J2K + (43B · J2KX) is satisfied.
3. Automatic regulator current limit take over is recalibrated downward.
4. Ten seconds after J2K; J3K = J2K is satisfied.
5. J3K satisfies

$$83 = \left[\left(43B \cdot \frac{43R}{Reg} \right) + 4CR \right] \cdot \left[\left(1 \cdot \overline{13Y} \cdot \overline{96CR} \right) \right.$$
$$\left. 83 + J3K + \left(\overline{1CR} \cdot \overline{96CR} \right) \right]$$

6. Now the expression for 43A and 43B is not satisfied because of 83 and relays 43A and 43B drop out transferring control of the generator to the Manual regulator.
7. Also J3K satisfies J3KX = J3K which positions the Manual voltage adjuster 70MR as determined by limit switches 70LS-4 and 70LS-5. These expressions are:

a) $70R = \left[\frac{1MR}{Raise} + (J3KX \cdot 70LS\text{-}4) + \right.$

$$(\mathrm{J3KX} \cdot \overline{\mathrm{7CR}} \cdot \mathrm{70LS\text{-}6} \cdot \mathrm{3CR})\Big] \cdot \mathrm{70RX} \cdot \overline{\mathrm{70L}}$$

$$\mathrm{70L} = (\overline{\mathrm{70R}} \cdot \mathrm{70LX}) \cdot \left\{ \frac{\mathrm{1MR}}{\mathrm{LOWER}} + (\mathrm{J3KX} \cdot \mathrm{70LS4}) + \left[\overline{\mathrm{J3KX}} \cdot \mathrm{7CR} \cdot \mathrm{70LS7} \cdot \mathrm{70LS6} \cdot \left(\mathrm{3CR} + \mathrm{96CR}\right)\right]\right\}$$

Looking at the time delays related to J2K and J3K the following can be determined:

1. If the generator field voltage returns to less than 256 VDC in less than 40 seconds, J1K will drop out terminating the sequence.

2. If the generator field voltage returns to less than 256 VDC after 40 seconds but less than 50 seconds due to the current limit recalibration, the generator control will not be transferred to the Manual regulator.

Expression J2KX = J2K + (43B · J2KX) shows that once J2KX is picked up it will remain picked up until generator control is transferred to the Manual regulator.

Other relay and control functions are:

Manual regulator operation
Automatic regulator operation
Regulator test
Regulator off
SCR bridge over-temperature
Automatic regulator local operation
Regulator Voltage Matching

TRANSFORMER PROTECTION

The protection circuitry for the separately mounted anode transformer is in part within the exciter cubicle. Relays 51A, 51B, 51C and 46E are mounted on the Transformer Protection panel in the breaker section of the exciter cubicle while the three current transformers are mounted within the anode transformer enclosure. Elementary diagram 44C304408 Sheet 2 shows the anode transformer protection circuits.

Three CT's in the primary of the anode transformer, with 15:5 ratios, are wye connected and their output is connected to the exciter cubicle through terminals R101, R102, R103, and R104. Relays 51A, B, and C are Time Overcurrent relays with Very-Inverse-Time characteristics. Figure 15 shows the Time-Current trip curve for relays 51A, B, and C. The relay time dial and current tap have been set at the factory to provide for this operation.

The current balance relay is factory set to pick up if the phase unbalance exceeds 37.5% providing at least 3 amps are flowing in each phase of the transformer primary.

If any one or more of the four protective relays pick up, the circuit between terminals R145 and R146 (elementary sheet 2, A-4) will be completed through the holding coil or seal in coil and contacts of the unit or units that have picked up. The user of this equipment determines what action is to be taken should an abnormal condition arise.

VOLTAGE SPIKE SUPPRESSION AND LINE FILTER

Figure 16 is a simplified diagram of the voltage spike suppression and line filter circuits. The line filter consisting of 7, 8, and 9C and R1, 2, and 3R is designed to minimize the spikes on the 3-phase anode transformer output caused by commutation of the front and rear SCR's. The value of the resistors and capacitors is dictated by:

1. Total per unit reactance on anode transformer.

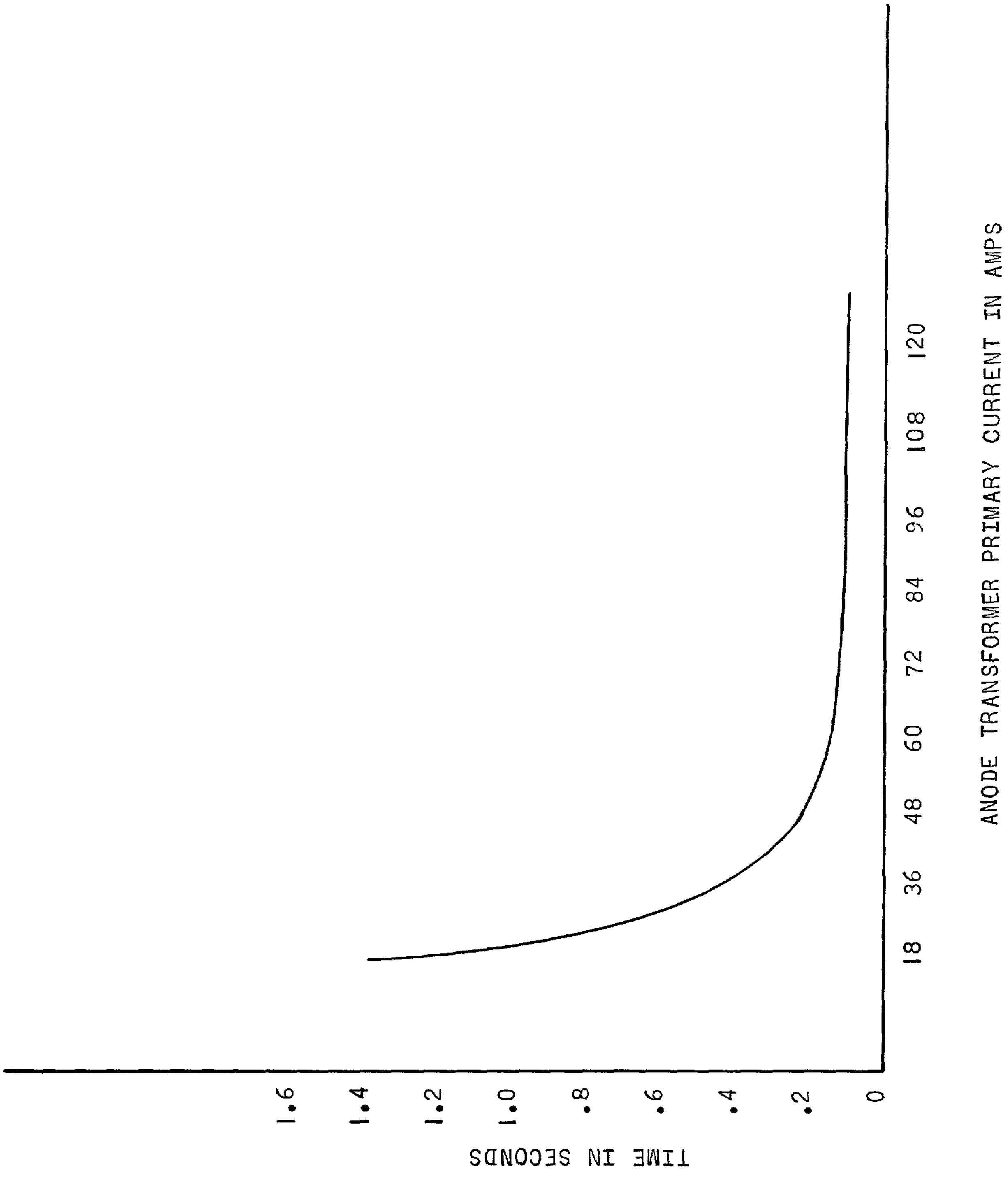
2. Rated generator field current.

3. Rated anode transformer output voltage rms line to line.

The voltage spike suppression circuit will be triggered in the event spikes should appear because of switching, etc. The 3-phase full wave diode bridge (1D through 6D) developes a DC voltage across S1R proportional to the output of the anode transformer. The diode commutating spikes are filtered by capacitors 1C through 6C. The output of the bridge is applied across the surge suppressor S1SS, a current limiting, triggered spark gap device. In the event the bridge output should suddenly rise to 1.6 times its normal value, the gas filled spark gap (A1) will be triggered by current flowing in the primary of the pulse transformer T1. The secondary of T1 is connected to the trigger electrode of A1 through C2 and R1. The trigger electrode starts the arc between the two arc runners allowing current to flow through L1, A1, L2 and the Thyrite* resistors placing a heavy load on the DC bus. The surge energy is dissipated in the main gap and the Thyrite resistors. The arc is driven along the arc runners by magnetic forces set up by L1 and L2. If the surge has not fallen below the threshold of the spark gap within the time cycle of the arc runner mechanism, the gap will re-strike. The surge suppressor will hold the DC bus to about twice its normal potential during transient voltage surges.

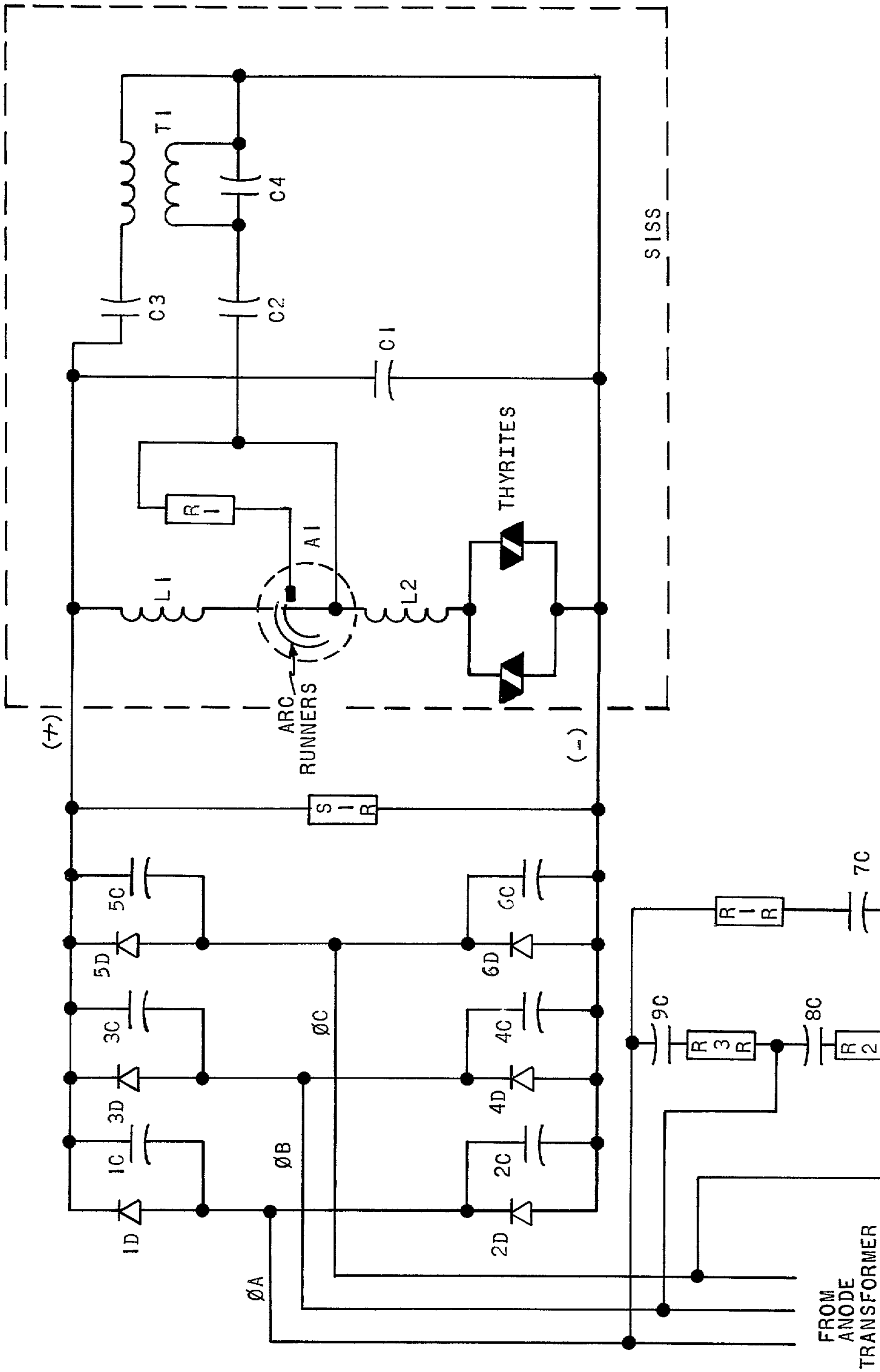
The voltage spike suppression circuits, when triggered, limits the magnitude of spikes appearing on the output of the anode transformer by applying a sudden heavy load through the spark gap. The rapidly increasing current causes a voltage drop across the reactance of the anode transformer, reducing the transformer output voltage and minimizes the chance of damaging one or more of the SCR's.

*Registered trademark of General Electric Company, USA



OVERCURRENT RELAY TIME - CURRENT TRIP CURVE

Figure 15



VOLTAGE SPIKE SUPPRESSION AND LINE FILTER

Figure 16

ADJUSTMENTS AND TESTS

GENERAL

With the exception of Automatic regulator stabilization, all controls have been set at the factory. If field experience and/or a malfunction should deem it necessary to change any of the controls, the procedures contained in this section should be followed.

FIELD FLASHING

A. Current Adjust (60 Amps)

1. Check Generator Field circuit breaker (41) open.
2. Remove 125 VDC from exciter cubicle.
3. Install a 100 amp shunt and a series resistor (capable of carrying 60 amps continuously) with a resistance of 0.35 to 0.40 ohms between terminals 1 and 3 of Generator Field circuit breaker (41). See Figure 17.
4. Connect a millivoltmeter with the correct range across the shunt.
5. Connect a single pole, single throw switch between terminals FF2 and FF7 on the Field Flashing Panel located in the Breaker Section of the exciter cubicle. Leave the switch OPEN.
6. Apply 125 VDC to the exciter cubicle.
7. Close the switch connected in Step 5 above. Current will flow through the shunt and resistor for 10 seconds and then stop. Determine the current from the millivolt drop across the shunt.
8. Open the switch installed in Step 5 above.
9. If the current is not between 56 and 64 amps, adjust the tap on resistor F1R on the Field Flashing Panel and repeat Steps 7 and 8.
10. Remove 125 VDC from exciter cubicle.
11. Remove the shunt, resistor, millivoltmeter, and switch.

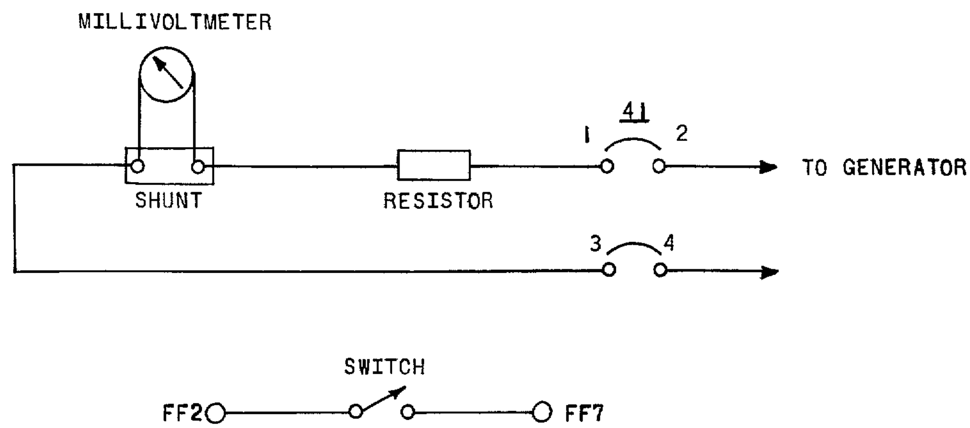
B. Cutout Adjust (40% generator terminal voltage)

1. Check Generator Field circuit breaker (41) open.
2. Remove 125 VDC from exciter cubicle.
3. Open switch A5SW located on AC Regulator Panel located in the front compartment of the Regulator Section.
4. Connect a single phase, 60 Hz, 115 VAC variac to 115 VAC 60 Hz. (Connect a breaker in the supply to the variac.)
5. Energize the variac and adjust the output to zero volts (or minimum).
6. Remove power from variac.
7. Connect the output of the variac to terminals K57 and K58 on the relay panel located in the rear compartment of the Regulator Section.
8. Energize the variac.
9. Slowly increase the output of the variac until relay 27 picks up. Relay 27 is located on the relay panel, lower row of relays, last relay on right.
10. Measure AC voltage between terminals K57 and K58.
11. Adjust variac output to zero and de-energize variac.
12. If relay 27 did not pick up between 46 and 50 VAC between terminals K57 and K58, adjust K1R (located on the Relay Panel) and repeat Steps 8 through 11 until desired results are obtained.
13. Remove variac
14. Close switch A5SW.

MANUAL REGULATOR

Range and Level Adjust (25% of normal generator terminal voltage to the excitation required for 125 % rated load.)

1. Remove 125 VDC from exciter cubicle.
2. Set the Manual Voltage adjuster (70MR) to its lowest position. This is done manually by pushing in on the small black knob and turning the large black knob to its full CCW position.
3. Open D3SW and D4SW on the Manual Regulator Panel.
4. Set potentiometers D1P and D2P (on the Manual Regulator Panel) to their mid position.
5. Connect a variable 150 VDC power supply between terminals J (Positive) and F (Negative) on the Manual regulator transistorized amplifier (D1PCB).
6. Adjust the DC power supply for 40 ±2 volts.



CONNECTION FOR FIELD FLASHING TEST

Figure 17

7. Adjust D1P for an indication of 5 volts on the installed meter labeled DC Regulator Volts (D1VM).
8. Set the Manual Voltage adjuster (70MR) to maximum position (full CW).
9. Adjust the DC power supply for 150 ±2 volts.
10. Adjust D2P for an indication of 5 volts on D1VM.
11. D1P and D2P are interacting. Repeat steps 6 through 10 until the desired results are obtained.
12. Disconnect 150 VDC power supply.
13. Close switches D3SW and D4SW.

AUTOMATIC REGULATOR

A. Range and Level Adjust (+10%, -15% generator terminal voltage)

1. Remove 125 VDC from exciter cubicle.
2. Connect a 3 phase, 60 Hz, 115VAC variac to 115 VAC 60 Hz. (Connect a breaker in the supply to the variac.)
3. Open A5SW on the Automatic Regulator Panel.
4. Connect the output of the 3 phase variac to bottom terminals 2, 4, and 6 of A5SW.
5. Locate terminal A14 on left side of the Automatic Regulator Panel and remove the #14 grey wire leaving the terminal board and entering the wire duct.
6. Set the Automatic Voltage adjuster (70MV) to its lowest position. This is done by pushing in on the small black knob and turning the large black knob to its full CCW position.
7. Set potentiometers A11P (on the transistorized amplifier) and A10P (on the Automatic Regulator Panel) to their mid position.
8. Energize the variac and adjust its output to 102 VAC L-L.
9. Adjust A11P for an indication of 5 volts on the installed meter labeled AC Regulator Volts (A1VM).
10. Set the Automatic Voltage adjuster (70MV) to its maximum position (full CW).
11. Adjust the variac output to 132 VAC L-L.
12. Adjust A10P for an indication of 5 volts on A1VM.
13. A11P and A10P are interacting. Repeat steps 8 through 12 until the desired results are obtained.
14. Disconnect the 3 phase variac.
15. Close switch A5SW.
16. Re-connect the wire removed from terminal A14 in step 5.

B. Offset for 52E recalibration. (10% change in generator terminal voltage)

1. Complete steps A. 1 through A. 5 of Automatic Regulator, Range and Level Adjust above.
2. Connect a single pole, single throw switch between terminal A13 and the wire removed from terminal A14. Leave the switch OPEN.
3. Adjust the output of the variac to 120 VAC L-L.
4. Set the Automatic Voltage adjuster (70MV) for an indication of 5 volts on (A1VM).
5. Adjust the output of the variac to 108 VAC L-L.
6. Close the switch installed in step 2 and adjust potentiometer A15P (on the Automatic Regulator Panel) for an indication of 5 volts on A1VM.
7. Disconnect the 3 phase variac.
8. Close switch A5SW.
9. Remove the switch installed in step 2 above and re-connect the wire to terminal A14.

C. Error Signal Adjust

1. Complete steps A. 1. through A. 5. of Automatic Regulator, Range and Level Adjust above.
2. Set potentiometers A12P and A14P (on the Automatic Regulator Panel) to their mid position.
3. Adjust the output of the 3 phase variac to 120 VAC L-L.
4. Depress pushbutton A1PB (on the Automatic Regulator Panel) and adjust potentiometer A12P for an indication of 0 on the installed meter labeled Error Signal (A2VM).
5. Adjust variac output to 116. 4 VAC L-L.
6. Depress A1PB and adjust potentiometer A14P for an indication of -3 on A2VM.
7. A12P and A14P are interacting. Repeat steps 4 through 7 until desired results are obtained.
8. Adjust variac output to 123. 6 VAC L-L.
9. Check indication of +3 on A2VM.
10. Disconnect 3 phase variac.
11. Close switch A5SW.
12. Re-connect wire removed from terminal A14.

D. Overcurrent Adjust. (1. 7 P. U. rated generator output and M. E. L. recalibrated to 1. 0 P. U.)

1. Complete steps A. 1. through A. 5. of Automatic Regulator, Range and Level Adjust above.
2. Open switch A3SW on Automatic Regulator Panel.
3. Connect a 50 VDC power supply between terminals N(+) and E(-) on Automatic regulator diode board A2PCB.
4. Locate terminal A3 on the Automatic Regulator Panel and remove the grey #14 wire marked A3 that leaves the panel.
5. Connect a single pole, single throw switch between terminals A3 and A4. Leave the switch CLOSED.
6. Adjust the output of the variac to 120 VAC L-L.
7. Adjust Automatic Voltage adjuster (70MV) for an indication of 5 volts on A1VM.
8. Adjust power supply output to 43 volts.
9. Adjust potentiometer A13P (on the Automatic Regulator Panel) until A1VM just starts to increase from 5 volts indication.
10. Open the switch installed in step 5 above.
11. Decrease the power supply output to 28 VDC.
12. Adjust J1P (on the Maximum Excitation Limit Panel) until A1VM just starts to increase from 5 volts indication.
13. Disconnect the power supply.
14. Close switch A3SW.
15. Disconnect the variac.
16. Close switch A5SW.
17. Disconnect the switch installed in step 5 above.
18. Re-connect the wire removed from terminal A3.
19. Re-connect the wire removed from terminal A14.

E. Transistorized Amplifer A1PCB.

1. Complete Steps A. 1. through A. 5. of Automatic Regulator, Range and Level Adjust above.
2. Adjust the output of the variac to 120 VAC L-L.
3. Adjust the Automatic Voltage adjuster (70MV) to its mid position.

4. First Stage Gain (5.75)

   a. Connect a digital voltmeter between the base of transistor A11Q(-) and the common terminal A1TB-C(+).

   b. Connect a digital voltmeter between the junction of A25R, A26R, and A6P(-) and the common terminal A1TB-C(+).

   c. Adjust A6P to give a change of 1.15 volts at the junction of A25R, A26R and A6P when 70MV is adjusted to give a 0.2 volt change on the base of A11Q.

5. Second Stage Gain (2.5)

   a. Connect the minus leads of the digital voltmeters to the base of A8Q and the emitter of A7Q.

   b. Adjust A3P to give a change of 2.5 volts at the emitter A7Q when 70MV is adjusted to give a change of 1.0 volt at the base of A8Q.

   c. Disconnect the digital voltmeters.

6. Phase Back Limit. (11.0 volts)

   a. Connect a digital voltmeter between terminals A1TB-D(+) and A1TB-E(-).

   b. Adjust the Automatic Voltage adjuster (70MV) to its lowest position (CCW).

   c. Adjust A2P for an indication of 11 volts on the digital voltmeter. A1VM should agree.

7. Disconnect the digital voltmeter.

8. Disconnect the variac.

9. Close switch A5SW.

10. Re-connect the wire removed from terminal A14.

F. Stabilization

1. Complete steps 1 through 16 of Initial Operation, Off Line Tests, Generator Running.

WARNING

THE EXCITATION SYSTEM IS FULLY ENERGIZED. DANGEROUS VOLTAGES EXIST THROUGHOUT THE EXCITER CUBICLE.

2. Connect an oscilloscope between the left and center knifes of switch A5SW on the Automatic Regulator Panel. This will display phase A-B 120 VAC output of PT's.

3. Adjust the sweep time of the oscilloscope to 0.1 seconds per centimeter.

4. Figure 18 shows the type of scope presentation to be expected.

5. Figure 19 shows the value of capacitors connected to terminal board A4TB located on the Automatic Regulator Panel.

6. Close the switch connected between terminals A13 and A14.

7. Check PT output decreases to 90% of normal.

8. Open the switch connected between A13 and A14.

9. Referring to Figure 18, determine whether the regulator is under stabilized, over stabilized or needs no adjustment.

10. Stabilize the regulator by adjusting potentiometer A5P and selecting the correct value of total capacity in series with A5P.

    NOTE: Stability is increased if A5P is decreased and/or the amount of capacity is increased.

MAXIMUM EXCITATION LIMIT

1. Remove 125 VDC from exciter cubicle.

2. Check Generator Field circuit breaker (41) open.

3. Connect a 300 VDC power supply between terminals J1 and J2 on the Maximum Excitation Limit Panel.

4. Adjust the power supply to 256 volts.

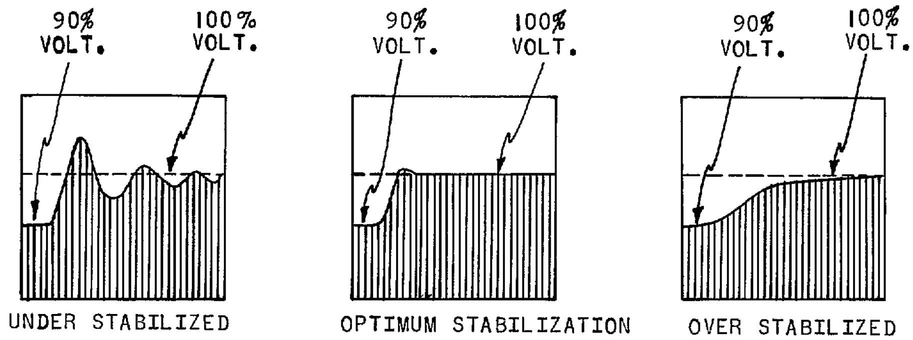
5. Adjust the slider of J1R to the point at which J1K just picks up.

6. Remove the power supply.

MAINTENANCE

This excitation control is static, having no moving parts except for operating inputs, so little maintenance should be required. The cubicles should be cleaned periodically with a vacuum cleaner or a blower, to prevent accumulation of dust. If an accumulation of moisture is evident, heaters should be added as required.

In some high ambient temperature applications, some cubicles may be equipped with ventilation fans. In unusually dusty conditions, ventilation filters may be used. If ventilation filters are supplied, they should be periodically cleaned by washing in warm, not hot, sudsy water.



OSCILLOGRAMS FOR STABILIZING ADJUSTMENT

Figure 18

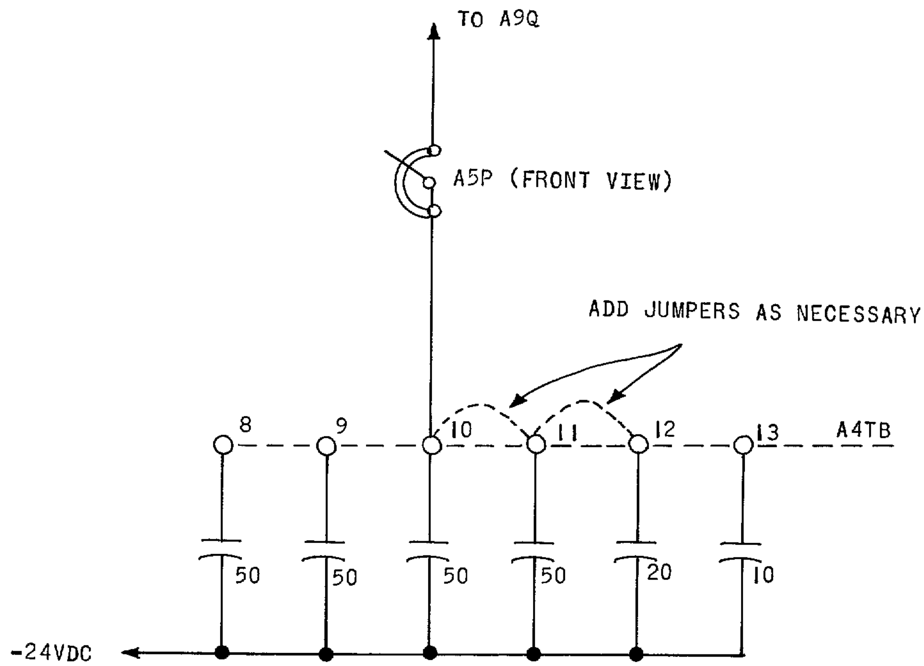


DIAGRAM FOR ADJUSTING STABILIZING CAPACITY

Figure 19

If excessive vibration is present, all screw connections should be checked periodically.

All thyristors should be checked weekly. All neon lights on each thyristor bridge must be lit. A neon light out indicates a faulty thyristor, blown fuse, or faulty lamp. The thyristors used in the bridges are of the silicon controlled rectifier type and are not known to age. Therefore, they are either good or faulty and if faulty they should be removed. Thyristors normally fail by short circuit and will have a very low and approximately equal forward and reverse resistance. No exact values can be given as different ohmmeters use different battery voltages and will, therefore, give different readings. The best way to obtain a calibration of what the forward and reverse resistance should be for a given meter is to actually measure these values on a thyristor known to be good.

If a thyristor is to be replaced, care should be taken to insure the replacement is of an identical grade as the removed thyristor.

The field breaker trip circuit indicating light should be checked weekly to indicate integrity of trip coil.

The generator should be transferred to the Manual regulator periodically, to check circuit operation. This transfer should be smooth and control on MANUAL operation should be smooth. The transfer back to the Automatic regulator should also be smooth. All transfers must be made with VR at 0 volts.

Magnetically operated contact-making devices should be inspected regularly in accordance with applicable instructions. Brushes in motors (for all motor-driven adjustments), all open rheostats, potentiometers and variable transformers should be inspected every six months 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.

For planned outages, the following maintenance should be performed:

1. General cleaning--blower or vacuum cleaner.

2. Check all brushes, motors, and rheostats.

3. Inspect all relays--operation and contacts.

4. Check for any loose connections on large wire, bus, and large thyristors.

5. Check all large thyristors and rectifiers (those requiring heat sinks) and all large fuses with an ohmmeter.

TROUBLESHOOTING

The best aid for troubleshooting is a thorough study of the particular circuit in the "Principles of Operation".

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.

GENERAL ELECTRIC 44C304408 CONT ON SHEET 1A SH NO 1

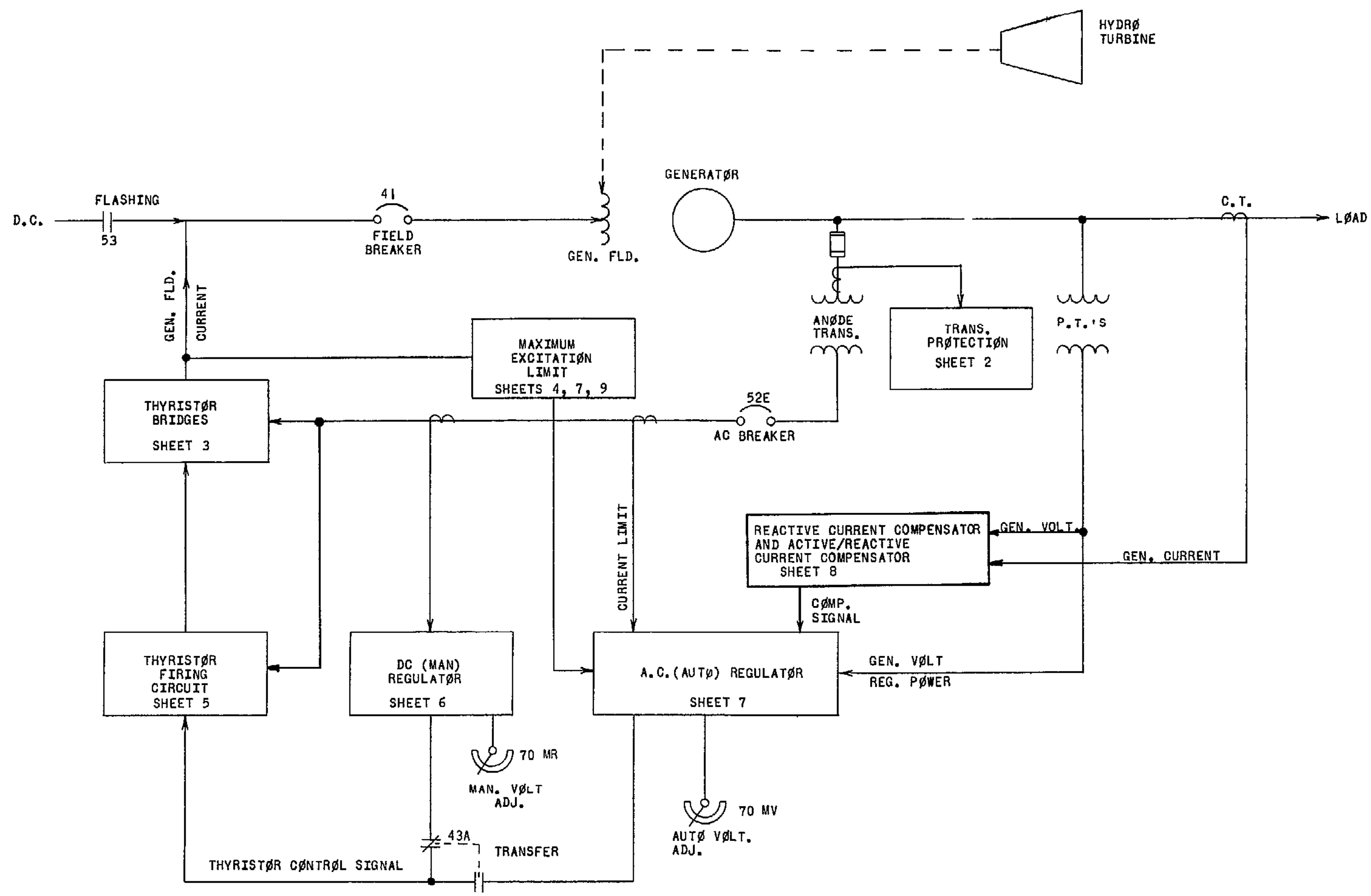
UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING — APPLIED PRACTICES | SURFACES | TOLERANCES ON MACHINED DIMENSIONS: FRACTIONS ± DECIMALS ± ANGLES ±

TITLE: HYDRO EXCITATION SYSTEM

FIRST MADE FOR 3S7931SA100A1

BLØCK DIAG. REQN. 471-87665-062-EXT 1

CØRPS ØF ENGINEERS
SNETTISHAM PRØJECT



REVISIONS | PRINTS TO
1. H. ... MAY 14 1971 | 1/1
2. W4 ... | 2-643

MADE BY R. Doust Oct 21, 1970 — ISSUED DEC 3 1970 — APPROVALS — COMM. & CONT. DEVICES DEPT. WAYNESBORO, VA. — 44C304408 CONT ON SHEET 1A SH NO 1

GENERAL ELECTRIC

44C304408 CONT ON SHEET 2 SH NO 1A

TITLE EXCITATION SYSTEM

FIRST MADE FOR 3S7931SA100A1

ELEM. DIAG.

UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING — APPLIED PRACTICES / SURFACES ✓ / TOLERANCES ON MACHINED DIMENSIONS: FRACTIONS ± DECIMALS ± ANGLES ±

43R

*△

HANDLE END		REGULATE	TEST	MAN	OFF	/DEVICE
1 1C 2C 2	1	X				1
	2	X				SPARE
3 3C 4C 4	3	X	X			90R,90L
	4	X				43A
5 5C 6C 6	5		X	X		1CR & 2CR
	6	X	X			
7 7C 8C 8	7		X			
	8			X		
9 9C 10C 10	9	X	X	X		
	10				X	

CONTACTS MAKE BEFORE BREAK

1XE

*△

CONTACTS HANDLE END		CLOSE		TRIP	
1 1C 2C 2	1	X			52E
	2			X	
3 3C 4C 4	3	X			41
	4			X	

SPRING RETURN

1MR & 1V

*△

CONTACTS HANDLE END		RAISE	NORMAL	LOWER	
1 1C 2C 2	1	X			70R,90R
	2			X	70L,90L

SPRING RETURN

1 - MASTER START RELAY

1CR - EXCITER BREAKER POSITION
2CR - GEN. LINE BREAKER POSITION
3CR - TRANSFER PERMISSIVE
4CR - MAN/AUTO TRANSFER
6CR - DC - REGULATOR START POSITION
6CR/X - DC - REGULATOR PERMISSIVE
7CR - DC REGULATOR STARTUP
8CR - MASTER FIRING POWER RELAYS

41 - GEN FIELD CIRCUIT BREAKER

43R - OFF/MANUAL/TEST/REGULATE TRANSFER SWITCH

43A,B, BX- VOLTAGE REGULATOR TRANSFER CONTACTORS
52E - AC LINE BREAKER
53 - EXCITER FIELD FLASHING RELAY

53TD - TIME DELAY RELAY FOR 53
59,60AR,AL,AX - REGULATOR VOLTAGE MATCHING
70MR- MANUAL VOLTAGE ADJUSTER DRIVE

70R,L- RAISE, LOWER RELAYS FOR 70MR

70MV- AUTOMATIC VOLTAGE ADJUSTER DRIVE

90R,L - RAISE, LOWER RELAYS FOR 70MV

J1K - MAXIMUM EXCITATION SENSING RELAY
J2K,KX - MAXIMUM EXCITATION TIME LIMIT
J3K,KX - MAXIMUM EXCITATION TRIP TO MANUAL
27 - LINE VOLTAGE PERMISSIVE
13/Y - SPEED PERMISSIVE
1XE - SUPPLY AND EXCITATION BREAKER CONTROL SWITCH
1MR - MANUAL VOLTAGE CONTROL SWITCH
1V - VOLTAGE ADJUST CONTROL SWITCH
51 - IAC OVERCURRENT RELAY
46E - IJC PHASE BALANCE CURRENT RELAY
83 - TRIP TO MANUAL RELAY
96SW - REMOTE STATION CONTROL BREAKER
96CR - REMOTE STATION CONTROL RELAY
2CRX,2CRY,2CRZ - AUTO REGULATOR RECALIBRATE
90X,90Y - AUTO VOLTAGE ADJUSTER POSITION

CUSTOMER NOTES:

1.) SYMBOLS USED:

* NOT FURNISHED BY WAYNESBORO G.E.

△ NOT MOUNTED BY WAYNESBORO G.E.

⊖ SPRING RETURN TO NORMAL

-o- INTERNAL FACTORY CONNECTION

◎ CUSTOMER CONNECTION POINTS IN CUBICLE

▭ GOVERNMENT WIRE NUMBERS

TV - 95% LINE VOLTAGE
LC - LINE CHARGE
TVTD - TRANSFER TIME DELAY

DRAWING NO / CONT ON SHEET / SH NO / REV NO

REVISIONS / PRINTS TO

1	H. Temple	MAY 1 1971	11
2	E.G. Ellen	MAY 19 1971	643
3	W.J. Chapman	Aug 4, 1971	
4	W.J. Chapman	Dec 17, 1971	
5	D. Hamphn	Apr 10, 1972	
6	E.G. Ellen	June 1, 1972	
7	E.G. Ellen	Aug. 3, 1972	
8	E. Chapman	NOV 25 1975	

MADE BY D. Smith Oct. 22, 1970 ISSUED DEC 3 1970 APPROVALS

COMM. & CONT. DEVICES WAYNESBORO, VA. DIV OR DEPT LOCATION

44C304408 CONT ON SHEET 2 SH NO 1A

GENERAL ELECTRIC

44C304408

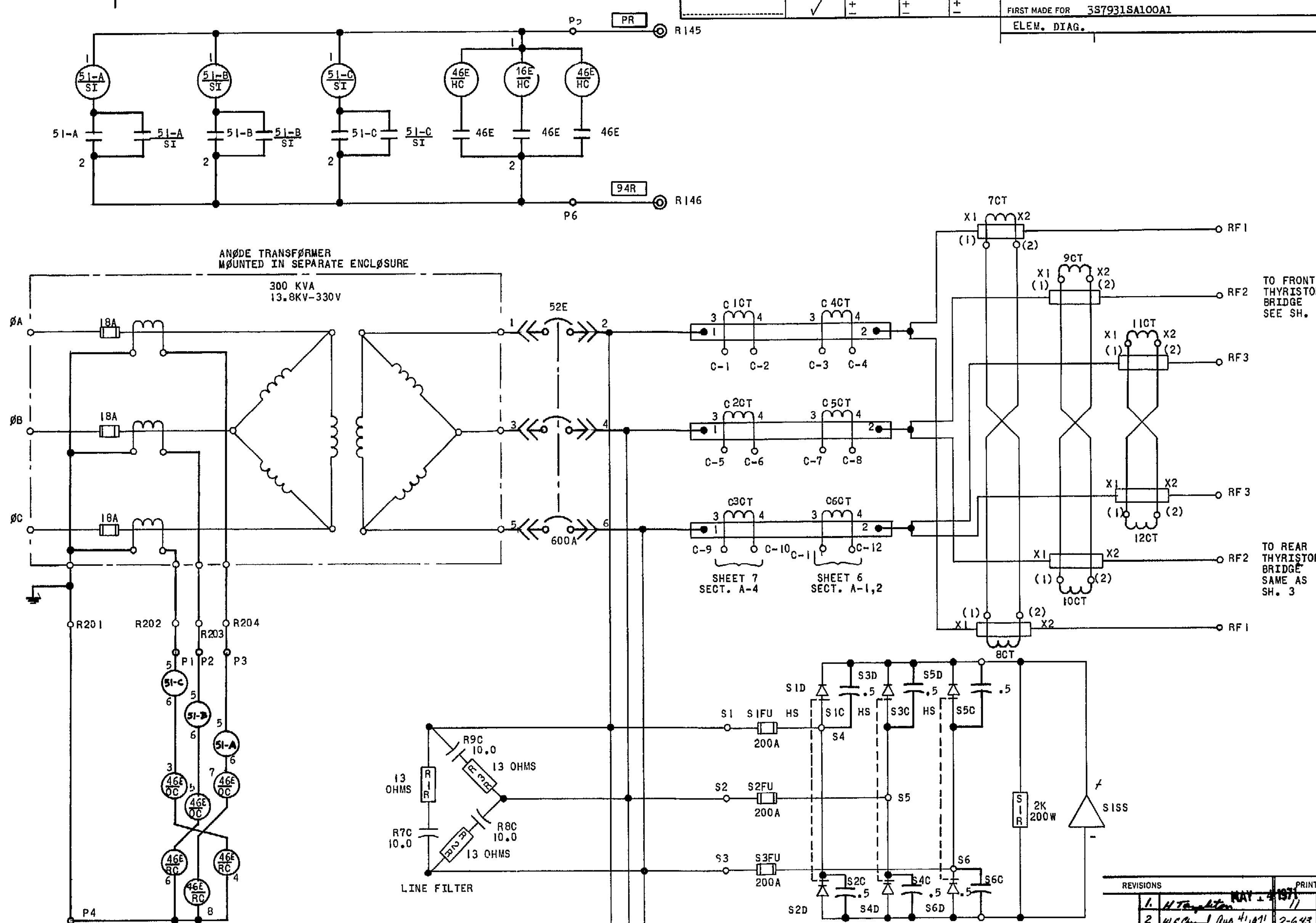
CONT ON SHEET 3 SH NO 2

UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING —				
APPLIED PRACTICES	SURFACES	TOLERANCES ON MACHINED DIMENSIONS FRACTIONS	DECIMALS	ANGLES
	√	±	±	±

TITLE HYDRO EXCITATION SYSTEM

FIRST MADE FOR 3S7931SA100A1

ELEM. DIAG.



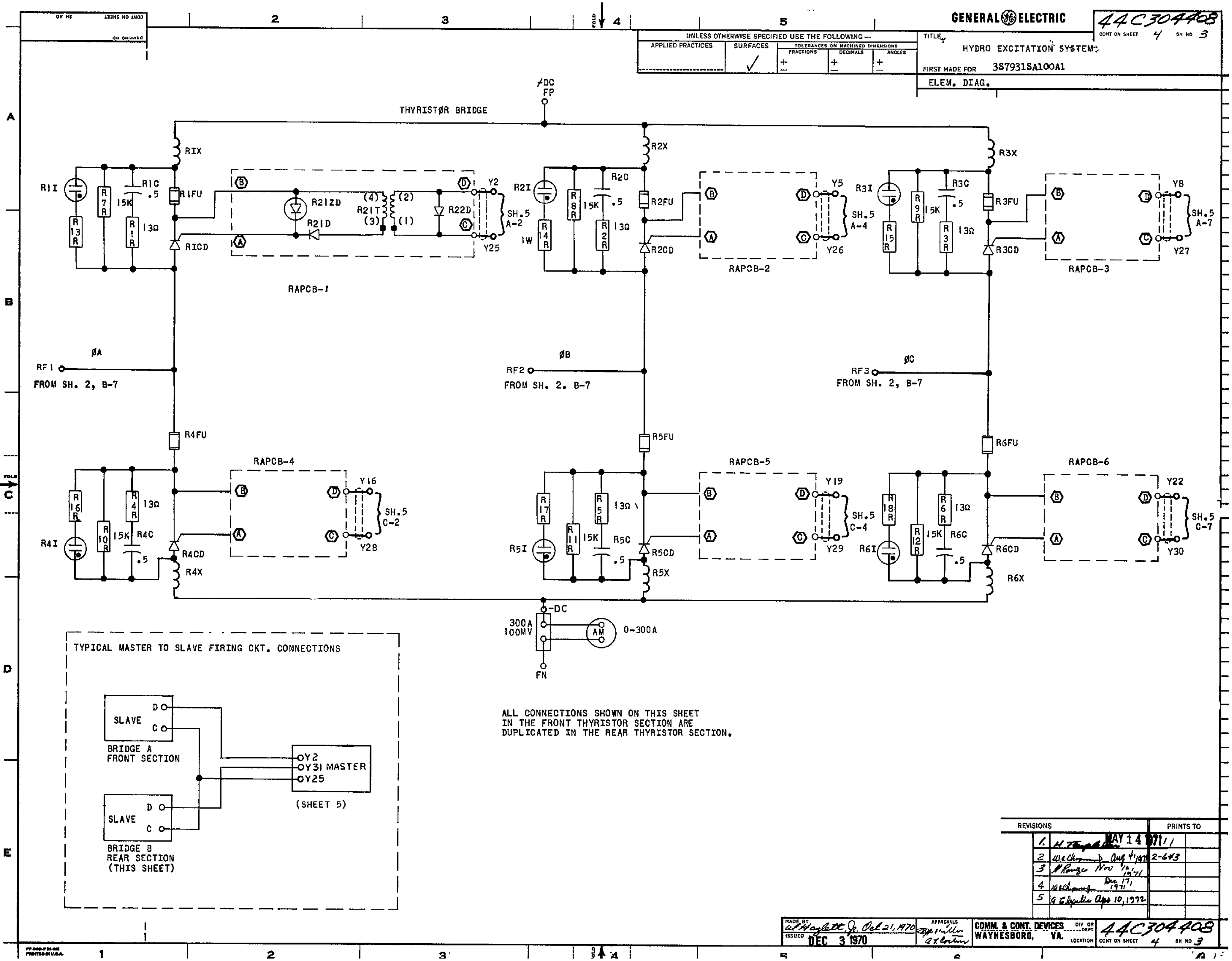
REVISIONS		PRINTS TO
1	H Templeton MAY 4 1971	11
2	W C Chapman Aug 4, 1971	2-643
3	K Kenzie Nov 16, 1971	
4	W G Chapman Dec 17, 1971	
5	D Naughton Apr 10, 1972	

MADE BY D. Smith Oct 21, 1970 ISSUED DEC 3 1970

APPROVALS

COMM. & CONT. DEVICES DIV OR DEPT
WAYNESBORO, VA. LOCATION

44C304408 CONT ON SHEET 3 SH NO 2


GENERAL ELECTRIC
44C304408
CONT ON SHEET 4 SH NO 3
UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING —
APPLIED PRACTICES
SURFACES
TOLERANCES ON MACHINED DIMENSIONS
FRACTIONS
DECIMALS
ANGLES
TITLE
HYDRO EXCITATION SYSTEM
FIRST MADE FOR 3S7931SA100A1
ELEM. DIAG.
THYRISTØR BRIDGE
+DC
FP
R1X
R1I
R1C
.5
15K
13Ω
R1FU
R1CD
R21ZD
R21D
R21T
(4)
(3)
(2)
(1)
R22D
Y2
Y25
SH.5
A-2
RAPCB-1
R2I
1W
R2X
R2C
R2FU
R2CD
RAPCB-2
Y5
Y26
SH.5
A-4
R3I
R3X
R3C
R3FU
R3CD
RAPCB-3
Y8
Y27
SH.5
A-7
ØA
RF1
FROM SH. 2, B-7
ØB
RF2
FROM SH. 2. B-7
ØC
RF3
FROM SH. 2, B-7
R4FU
R5FU
R6FU
RAPCB-4
Y16
Y28
SH.5
C-2
R4I
R4C
R4CD
R4X
RAPCB-5
Y19
Y29
SH.5
C-4
R5I
R5C
R5CD
R5X
RAPCB-6
Y22
Y30
SH.5
C-7
R6I
R6C
R6CD
R6X
-DC
300A
100MV
AM
0-300A
FN
TYPICAL MASTER TO SLAVE FIRING CKT. CONNECTIONS
SLAVE
BRIDGE A
FRONT SECTION
SLAVE
BRIDGE B
REAR SECTION
(THIS SHEET)
Y2
Y31 MASTER
Y25
(SHEET 5)
ALL CONNECTIONS SHOWN ON THIS SHEET
IN THE FRONT THYRISTOR SECTION ARE
DUPLICATED IN THE REAR THYRISTOR SECTION.
REVISIONS
PRINTS TO
MAY 14 1971
2-643
Aug 4, 1970
Nov 1971
Dec 17, 1971
Apr 10, 1972
MADE BY
Oct 21, 1970
ISSUED
DEC 3 1970
APPROVALS
COMM. & CONT. DEVICES
WAYNESBORO, VA.
44C304408
CONT ON SHEET 4 SH NO 3

GENERAL ELECTRIC

44C304408 CONT ON SHEET 5 SH NO 4

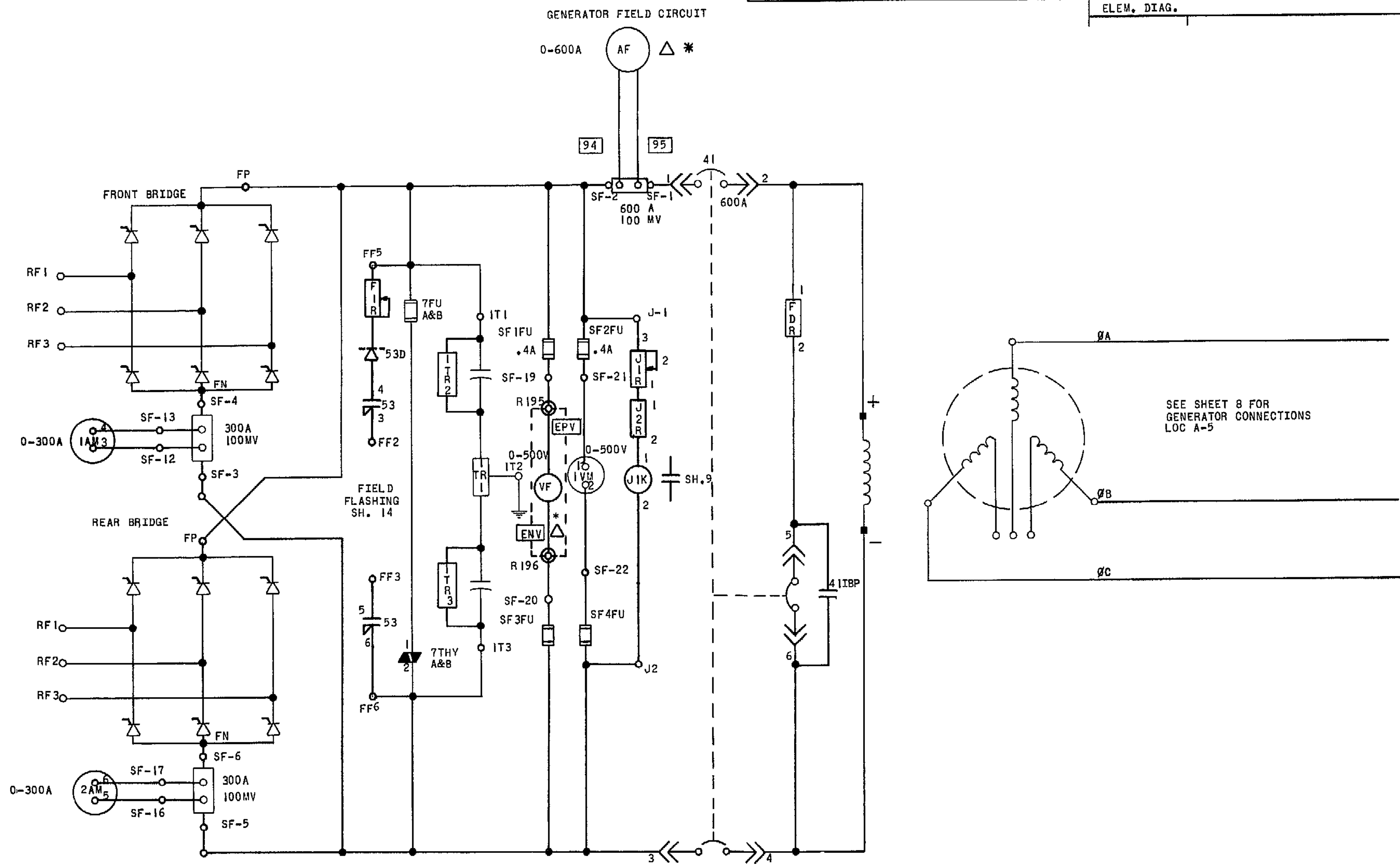
UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING —

APPLIED PRACTICES	SURFACES	TOLERANCES ON MACHINED DIMENSIONS: FRACTIONS	DECIMALS	ANGLES
	√	±	±	±

TITLE HYDRO EXCITATION SYSTEM

FIRST MADE FOR 3S7931SA100A1

ELEM. DIAG.



REVISIONS

		PRINTS TO
1	H. Thompson MAY 14 1971	
2	W.G. Chapman Aug 4 1971	2-643
3	H. Runge Nov 16, 1971	
4	W.G. Chapman Dec 17, 1971	
5	D. Wampler Apr 10, 1972	
6	E.A. Ellison June 1, 1972	

MADE BY D. Myers Oct 21, 1970

ISSUED DEC 3 1970

COMM. & CONT. DEVICES

WAYNESBORO, VA.

44C304408 CONT ON SHEET 5 SH NO 4

GENERAL ELECTRIC

44C304408 CONT ON SHEET 5A SH NO 5

UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING —

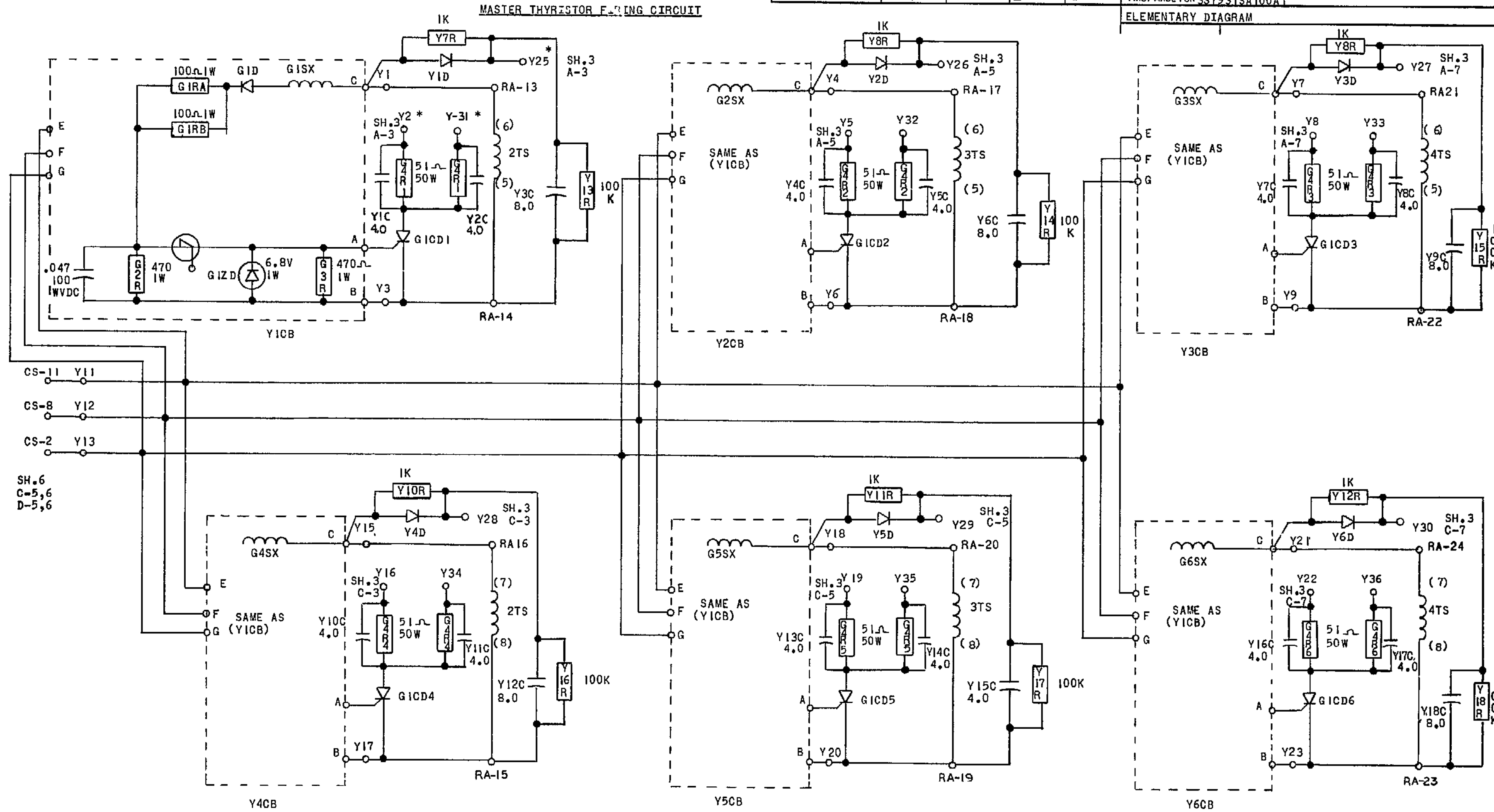
APPLIED PRACTICES	SURFACES	TOLERANCES ON MACHINED DIMENSIONS: FRACTIONS	DECIMALS	ANGLES
	✓	±	±	±

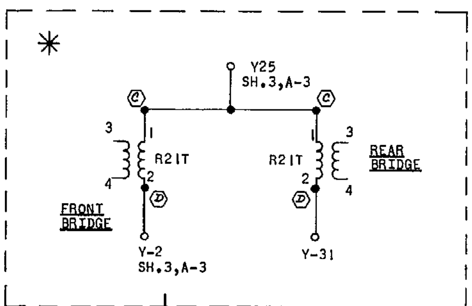
TITLE: HYDRO EXCITATION SYSTEM

FIRST MADE FOR 3S7931SA100A1

ELEMENTARY DIAGRAM

MASTER THYRISTOR FIRING CIRCUIT





NOTES:
1) PRIMARIES OF 2TS, 3TS AND 4TS ON SH. 5A, C-2 AND C-3
2) REAR SCR BRIDGE SLAVE FIRING CIRCUITS NOT SHOWN ON ELEMENTARY DIAGRAM.
3) CONTROL WINDINGS FOR G1SX THROUGH G6SX ARE SHOWN ON SHEET 6.

REVISIONS	
3	RE DRAWN W/CHGS H Templeton Nov 16, 1971
4	W.S. Chapman Dec 17, 1971
5	G Elgalie Aug 10, 1972

PRINTS TO: 11, 2-643

MADE BY L. DOVEL OCT 22, 1970
ISSUED D Moyer Dec 17, 1971
RE APPROVALS A.L. Carter

COMM. & CONT DEVICES
WAYNESBORO, VA.

44C304408 CONT ON SHEET 5A SH NO 5

GENERAL ELECTRIC

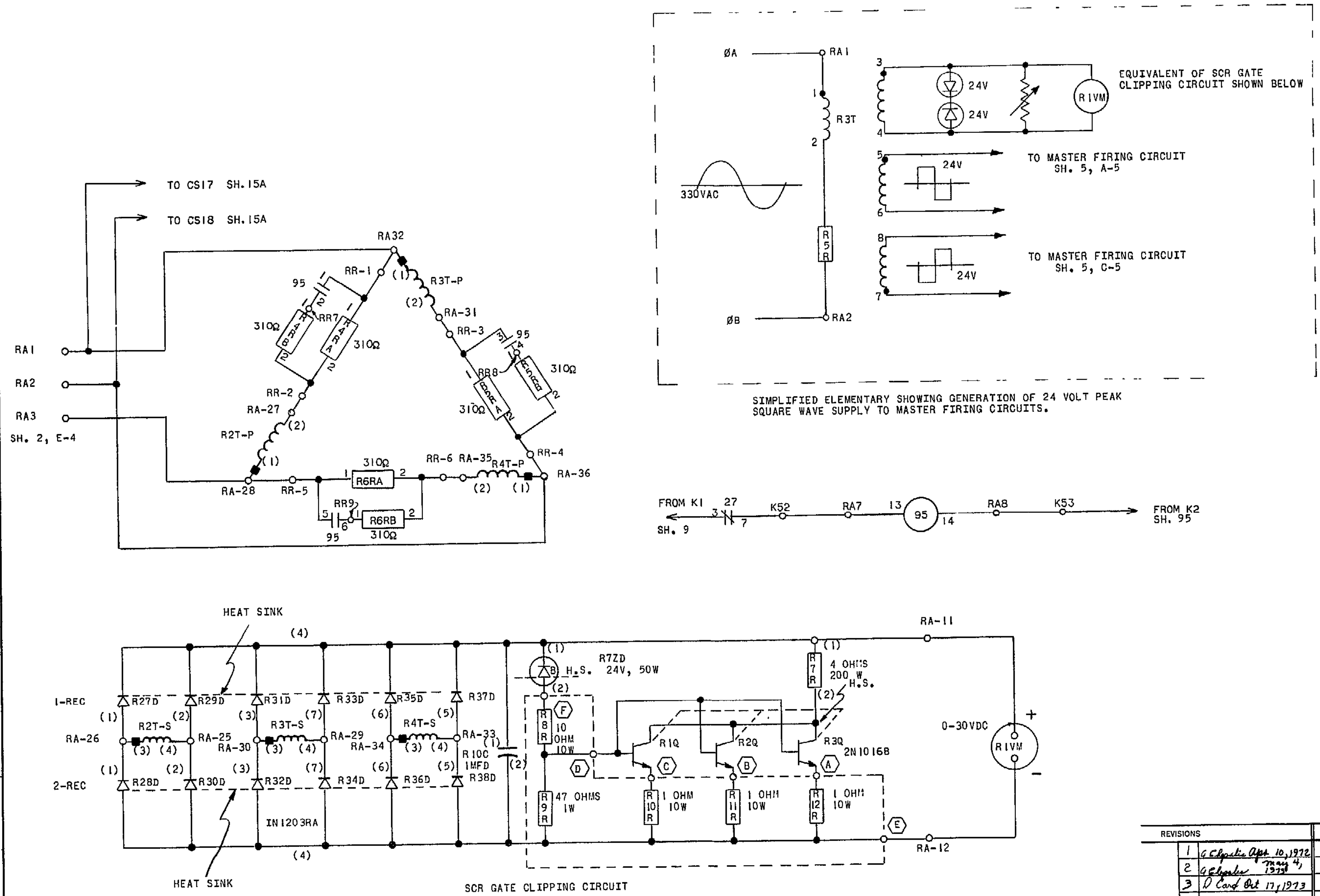
44C304408 CONT ON SHEET 6 SH NO 5A

TITLE HYDRO EXCITATION SYSTEM

FIRST MADE FOR 3S7931SA100A1

ELEMENTARY DIAGRAM

UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING — APPLIED PRACTICES | SURFACES ✓ | TOLERANCES ON MACHINED DIMENSIONS: FRACTIONS ± DECIMALS ± ANGLES ±



REVISIONS	PRINTS TO
1 G Elgalia Apr 10, 1972	11
2 G Elgalia May 4, 1973	2-643
3 D Card Oct 17, 1973	

MADE BY Kay Rowe 11-9-71 | ISSUED C. Lotto Nov 16, 1971 | APPROVALS | COMM. & CONT. DEVICES DIV OR DEPT | WAYNESBORO VA LOCATION

44C304408 CONT ON SHEET 6 SH NO 5A

GENERAL ELECTRIC

44C304408

CONT ON SHEET 7 SH NO 6

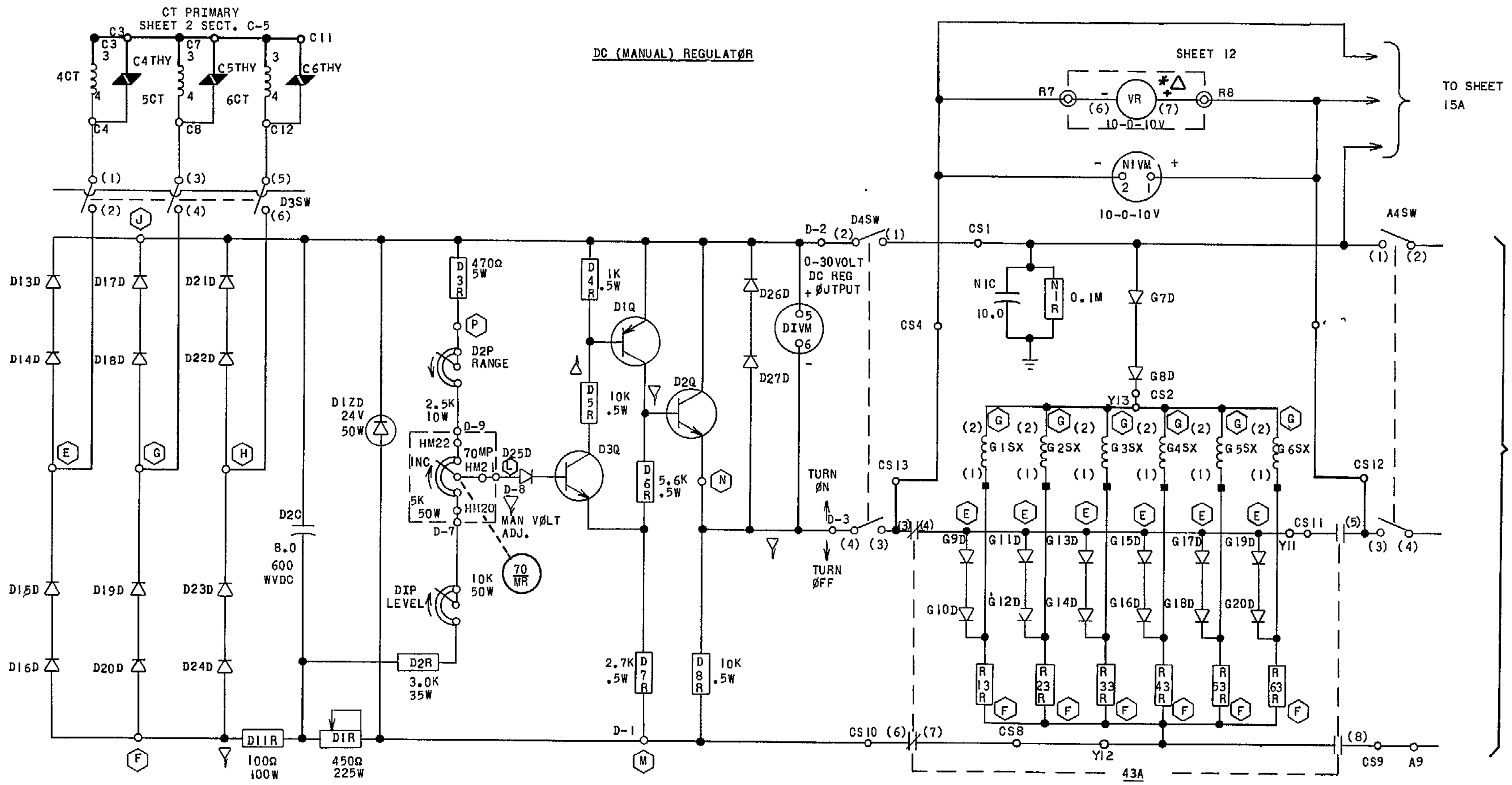
TITLE HYDRO EXCITATION SYSTEM

FIRST MADE FOR 3S7931SA100A1

ELEM. DIAG.

UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING — APPLIED PRACTICES | SURFACES ✓ | TOLERANCES ON MACHINED DIMENSIONS: FRACTIONS ± DECIMALS ± ANGLES ±

DC (MANUAL) REGULATØR



D1D-D27D = 800V 500MA

NOTES: 1) GATE WINDINGS FOR SATURABLE REACTORS G1SX THROUGH G6SX SHOWN ON SHEET 5.

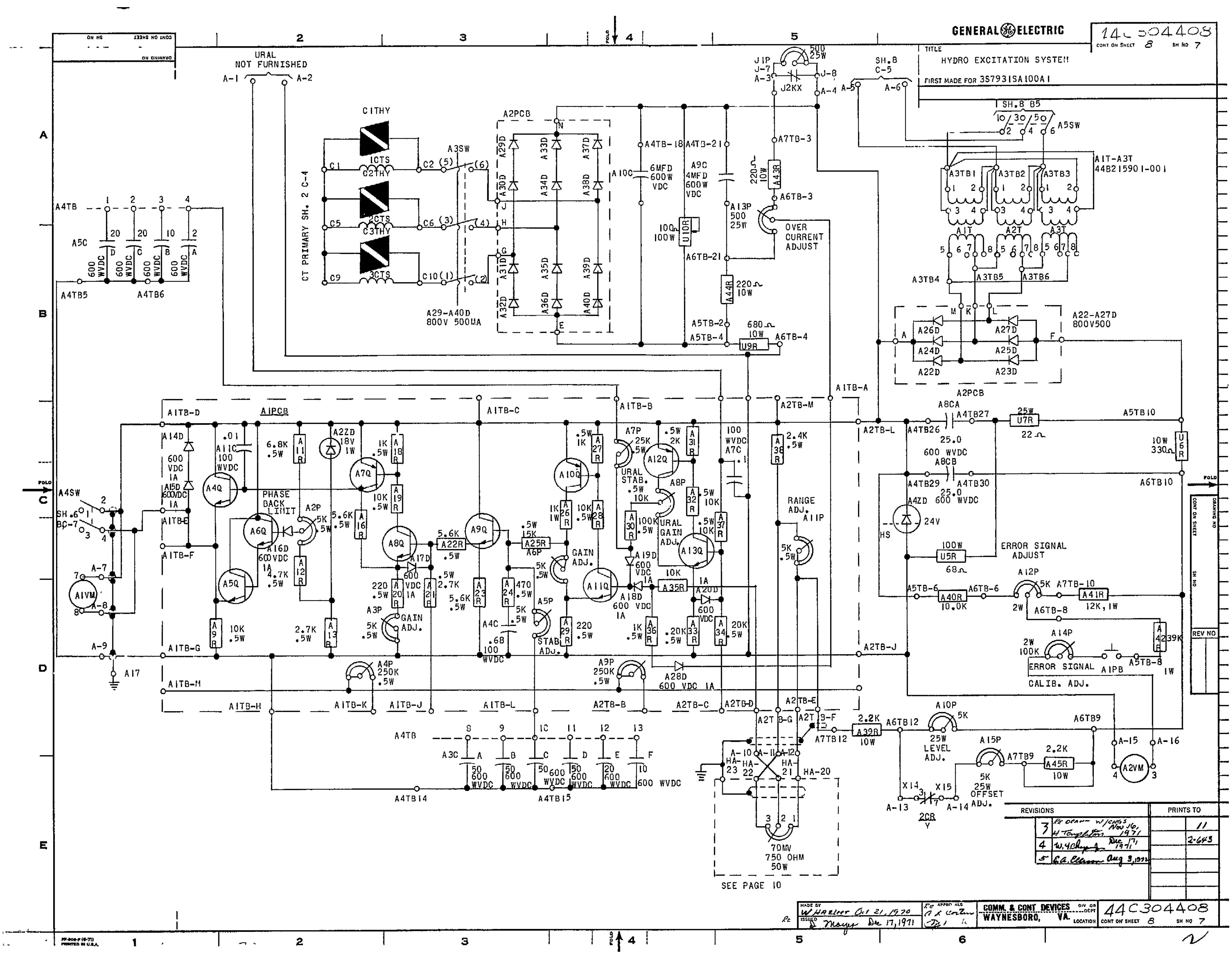
REVISIONS		PRINTS TO
1	H. Templeton MAY 14 1971	
2	W. J. Chapman Aug 11, 1971	2-643
3	H. Rouge Nov 16, 1971	
4	W. J. Chapman Dec 17, 1971	
5	D. Wangler Apr 10, 1972	
6	J. Clarke May 4, 1973	

MADE BY D. Myers Oct. 21, 1970 ISSUED DEC 3 1970

APPROVALS

COMM. & CONT. DEVICES WAYNESBORO, VA

44C304408 CONT ON SHEET 7 SH NO 6


GENERAL ELECTRIC
HYDRO EXCITATION SYSTEM
FIRST MADE FOR 3S7931SA100A1
44C304408
CONT ON SHEET 8
SH NO 7
URAL NOT FURNISHED
C1THY
CT PRIMARY SH. 2 C-4
A29-A40D 800V 500MA
A2PCB
OVER CURRENT ADJUST
A1T-A3T 44B215901-001
A22-A27D 800V500
A1PCB
PHASE BACK LIMIT
GAIN ADJ.
STAB. ADJ.
URAL STAB.
URAL GAIN ADJ.
RANGE ADJ. A11P
ERROR SIGNAL ADJUST
ERROR SIGNAL CALIB. ADJ.
LEVEL ADJ.
OFFSET ADJ.
70MV 750 OHM 50W
SEE PAGE 10
REVISIONS
PRINTS TO
COMM. & CONT. DEVICES
WAYNESBORO, VA.

GENERAL ELECTRIC

44C304408

CONT ON SHEET 9 SH NO 8

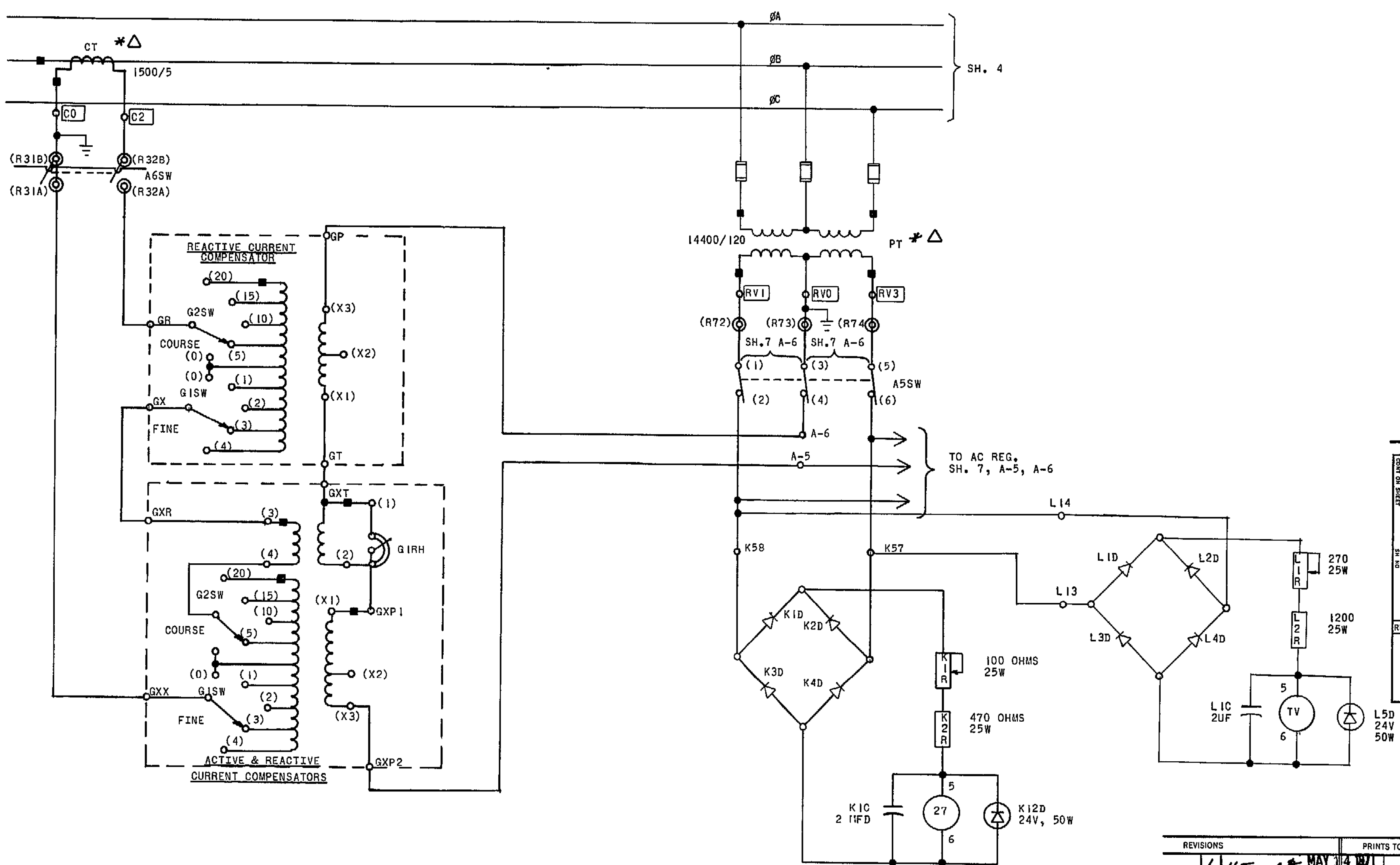
TITLE HYDRO EXCITATION SYSTEM

FIRST MADE FOR 3S7931SA100A1

ELEM. DIAG.

UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING — APPLIED PRACTICES | SURFACES ✓ | TOLERANCES ON MACHINED DIMENSIONS: FRACTIONS ± DECIMALS ± ANGLES ±

REACTIVE CURRENT COMPENSATION



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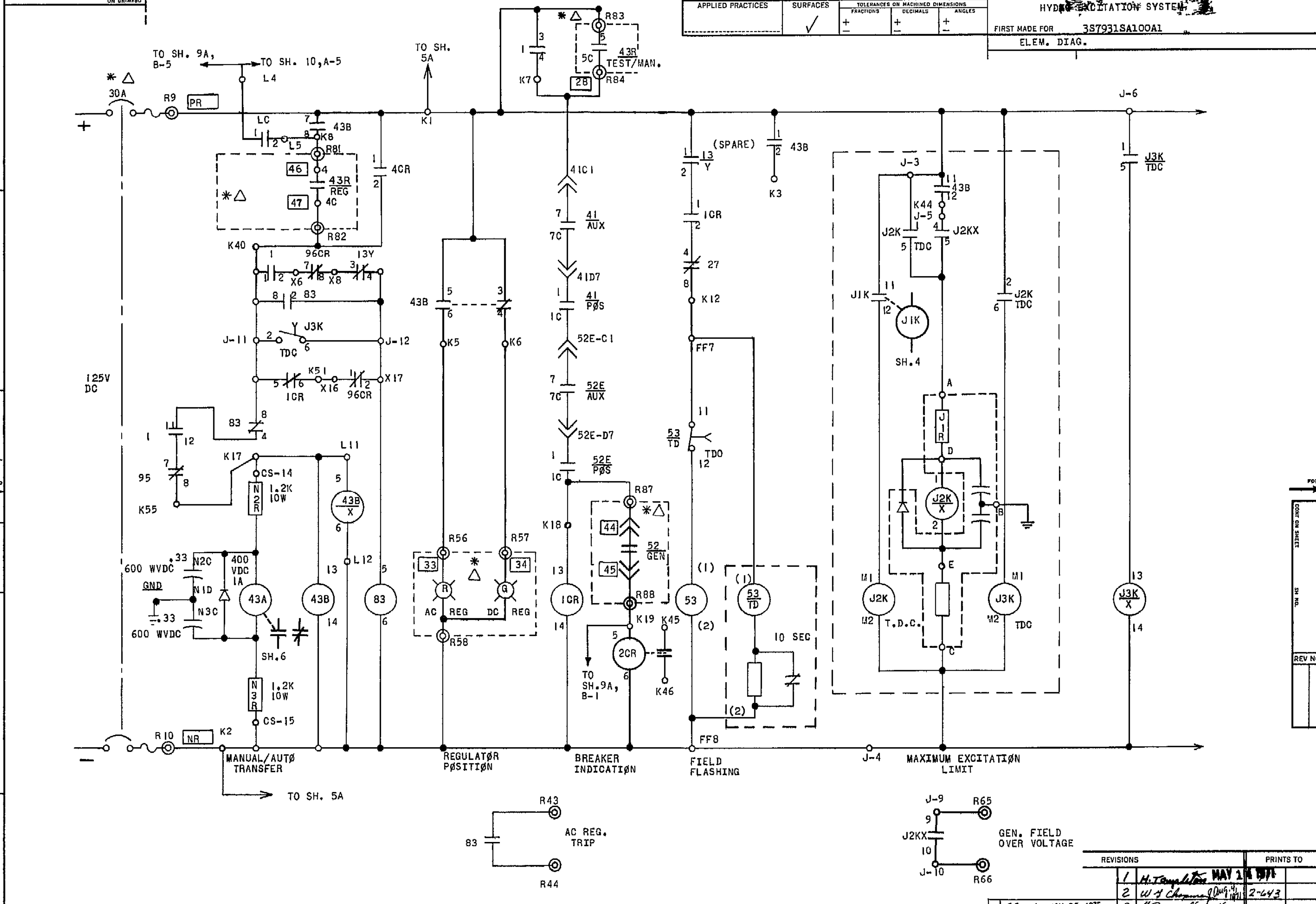
REVISIONS		PRINTS TO
1.	H Templeton MAY 14 1971	
2	W L Chapman Aug 4 1971	2-643
3	N Rugi Nov 10 1971	
4	W L Chapman Dec 1971	
5	D Wampler Apr 10 1972	
6	NOV 25 1975	

MADE BY D. Smith Oct. 22, 1970 ISSUED DEC 3 1970

APPROVALS

COMM. & CONT. DEVICES DIV OR DEPT WAYNESBORO, VA LOCATION

44C304408 CONT ON SHEET 9 SH NO 8



UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING —

APPLIED PRACTICES	SURFACES	FRACTIONS	DECIMALS	ANGLES
	✓	±	±	±

GENERAL ELECTRIC

TITLE HYDRO EXCITATION SYSTEM

FIRST MADE FOR 3S7931SA100A1

ELEM. DIAG.

44C304408 CONT ON SHEET 9A SH NO 9

REVISIONS

				PRINTS TO
		1	H. Templeton MAY 14 1971	
		2	W H Chapman Aug. 4, 1971	2-643
10	NOV 25 1975	3	N. Runge Nov. 16, 1971	
9	D Card Oct 17, 1977	4	W H Chapman Dec 1971	
8	May 4, 1973	5	April 10, 1972	
7	Oct. 3, 1972	6	C.A. Allen Aug. 3, 1972	

MADE BY D. Smith Oct. 21, 1970 ISSUED DEC 3 1970 APPROVALS

COMM. & CONT. DEVICES DEPT. WAYNESBORO, VA.

44C304408 CONT ON SHEET 9A SH NO 9

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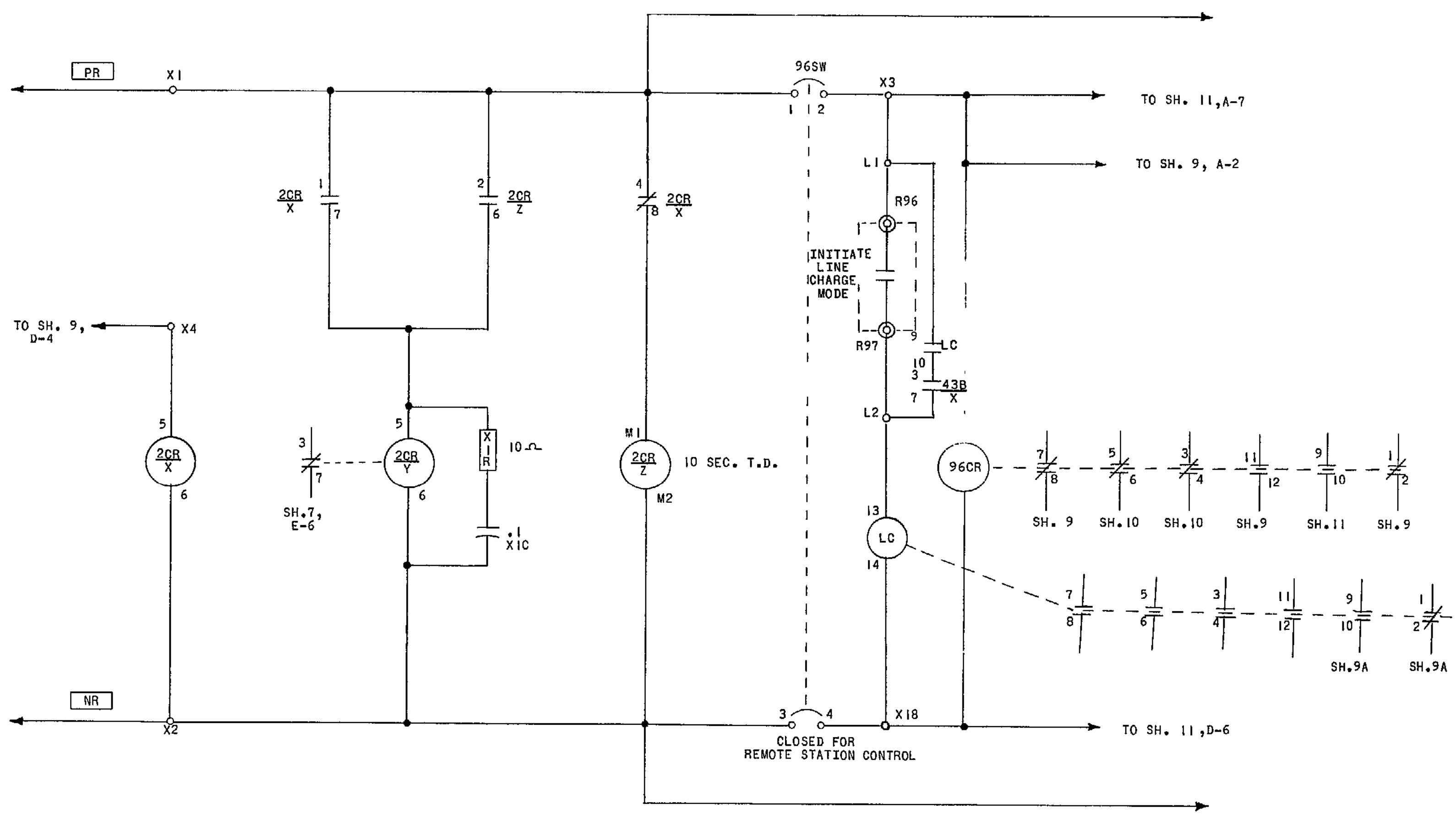
GENERAL ELECTRIC

44C304408
CONT ON SHEET 10 SH NO 9A

UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING —				
APPLIED PRACTICES	SURFACES	TOLERANCES ON MACHINED DIMENSIONS: FRACTIONS	DECIMALS	ANGLES
	√	±	±	±

TITLE
HYDRO EXCITATION SYSTEM
FIRST MADE FOR 3S7931SA100A1
ELEM. DIAG.

AUTO REGULATOR RECALIBRATE AND REMOTE STATION CONTROL



DRAWING NO 44C304408 CONT ON SHEET 10 SH NO 9A

REV NO

REVISIONS		PRINTS TO
1	E.A. Ellison Oct. 3, 1972	11
2	[signature] NOV 25 1975	

MADE BY ... Ellison 8/1/72 — ISSUED D. Moyer Aug 3, 1972 — APPROVALS A. L. Conta...

DRIVE SYSTEMS PROD DEPT — WAYNESBORO, VA.

44C304408 CONT ON SHEET 10 SH NO 9A

FF 809 F (4.72) PRINTED IN U.S.A.

GENERAL ELECTRIC

44C304408

CONT ON SHEET 11 SH NO 10

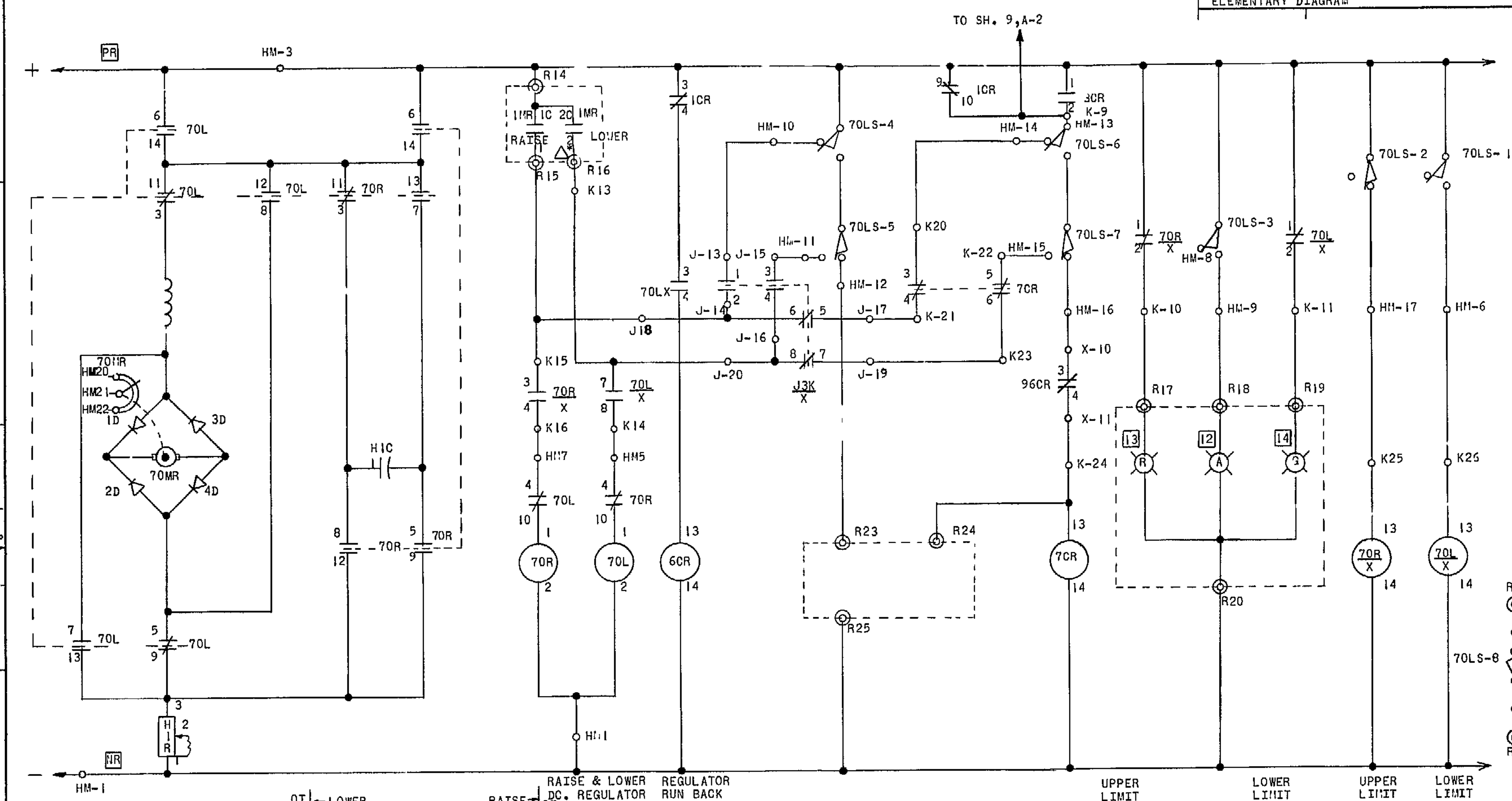
UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING —

APPLIED PRACTICES	SURFACES	TOLERANCES ON MACHINED DIMENSIONS: FRACTIONS	DECIMALS	ANGLES
	✓	±	±	±

TITLE HYDRO EXCITATION SYSTEM

FIRST MADE FOR 3S7931SA100A1

ELEMENTARY DIAGRAM



		OT ← LOWER … RAISE → OT
LS-2	NO	
	NC	
LS-1	NO	
	NC	
LS-3	NO	
	NC	
LS-4	NO	
	NC	
LS-5	NO	
	NC	
LS-6	NO	
	NC	
LS-7	NO	
	NC	
LS-8	NO	
	NC	

70% 50% 40%

70 MR LIMIT SWITCH SETTINGS
(SWITCHES SHOWN IN FULL LOWER).

■ CLOSED

□ OPEN

OT OVER TRAVEL

* FACTORY SETTING (CAN BE ADJUSTED BY CUSTOMER)

REVISIONS		PRINTS TO
3	RE-DRAWN W/CHGS. Nov 16, 1971	11
4	W Y Chap... Dec 17, 1971	2-643
5	...Hampton April 10 1972	
6	E A Ellman June 1, 1972	
7	E A Ellman Aug 3, 1972	
8	B K Moyer Oct 24, 1972	
9	D Card Oct 17, 1973	

MADE BY D SMITH OCT 27, 1970

ISSUED D Moyer Dec 17, 1971

APPROVALS G L Cantu

COMM. & CONT. DEVICES DEPT
WAYNESBORO, VA

44C304408

CONT ON SHEET 11 SH NO 10

GENERAL ELECTRIC

44C304408

CONT ON SHEET 12 SH NO 11

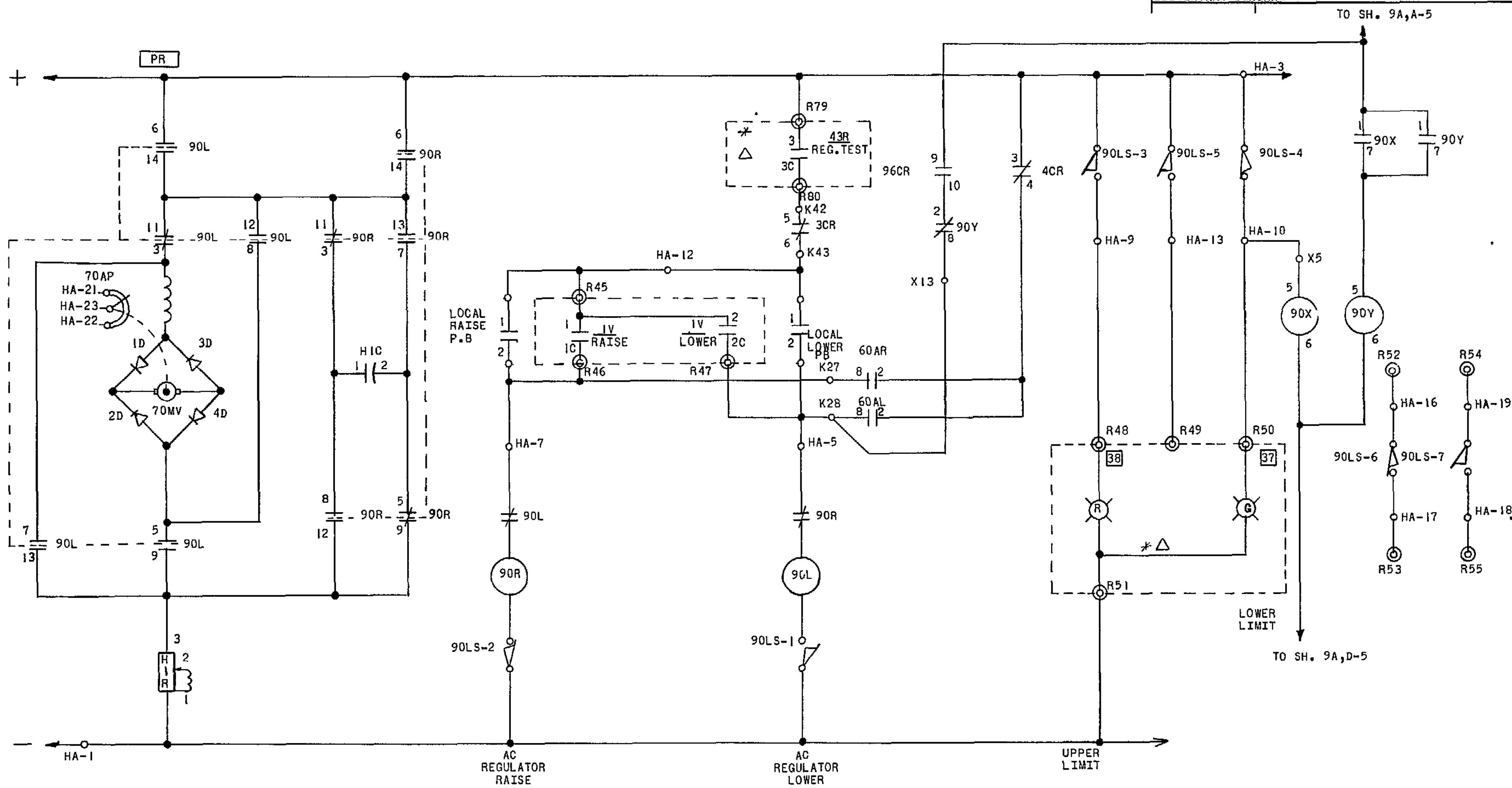
UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING —

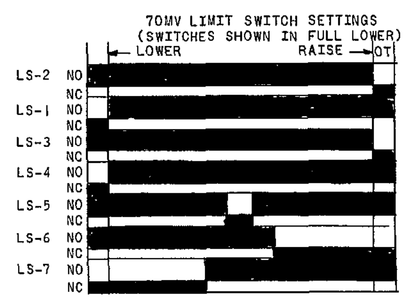
APPLIED PRACTICES	SURFACES	TOLERANCES ON MACHINED DIMENSIONS: FRACTIONS	DECIMALS	ANGLES
	✓	±	±	±

TITLE HYDRO EXCITATION SYSTEM

FIRST MADE FOR 3S7931SA100A1

ELEMENTARY DIAGRAM





REVISIONS

		PRINTS TO
3	REDRAWN W/CHGS. H. Tanaka Nov 16, 1971	11
4	W J Chap Dec 17, 1971	2-643
5	B. Wampler April 10, 1972	
6	C A Ellison June 1, 1972	
7	C A Ellison Aug 3, 1972	
8	C A Ellison Oct 3, 1972	

MADE BY W. HAZELET OCT 22, 1970

ISSUED D Moyer Dec 17, 1971

APPROVALS A L Carter

COMM. & CONT. DEVICES DIV OR DEPT

WAYNESBORO, VA LOCATION

44C304408

CONT ON SHEET 12 SH NO 11

GENERAL ELECTRIC

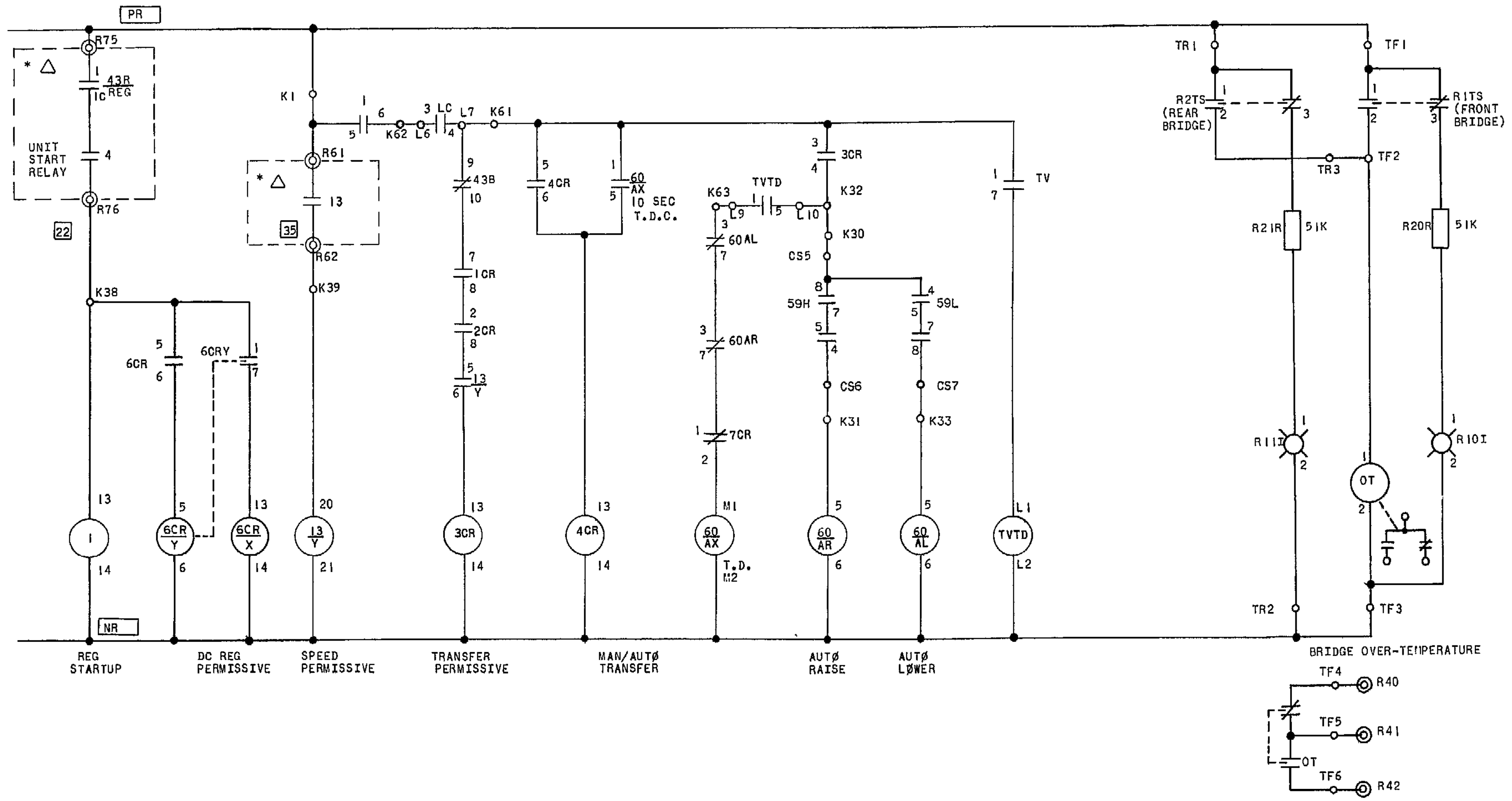
44C304408 CONT ON SHEET 13 SH NO 12

UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING — APPLIED PRACTICES | SURFACES | TOLERANCES ON MACHINED DIMENSIONS: FRACTIONS ± DECIMALS ± ANGLES ±

TITLE HYDRO EXCITATION SYSTEM

FIRST MADE FOR 3S7931SA100A1

ELEM. DIAG.



REVISIONS

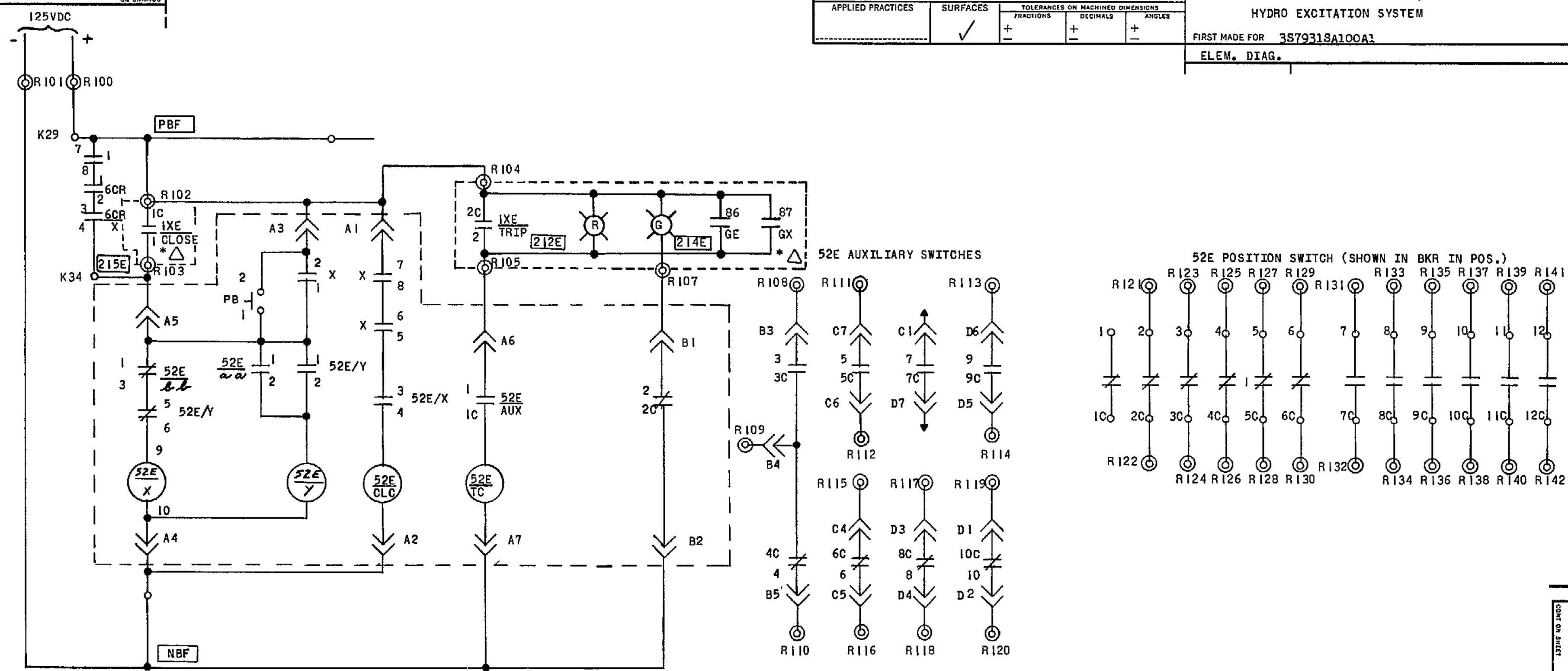
		PRINTS TO
1	C.A. Ellison MAY 4 1971	11
2	W.H. Chapman Aug 4, 1971	2-643
3	N. Runge Nov 10, 1971	
4	W.H. Chapman Dec 17, 1971	
5	G.C.Kyle May 4, 1972	
6	D. Card Oct. 17, 1973	
7	NOV 25 1975	

MADE BY L. Dowd Oct 22, 1970 ISSUED DEC 3 1970

APPROVALS

COMM. & CONT. DEVICES DIV OR DEPT WAYNESBORO, VA. LOCATION

44C304408 CONT ON SHEET 13 SH NO 12



GENERAL ELECTRIC

44C304408
CONT ON SHEET 14 SH NO 13

UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING —

APPLIED PRACTICES	SURFACES	FRACTIONS	DECIMALS	ANGLES
	✓	±	±	±

TITLE HYDRO EXCITATION SYSTEM

FIRST MADE FOR 3S7931SA100A1

ELEM. DIAG.

REVISIONS		PRINTS TO
1	G.A. Ellison MAY 14 1971	11
2	W.G. Chapman Aug 4, 1971	2-643
3	H. Rugis Nov 16, 1971	
4	G.A. Ellison June 1, 1972	

MADE BY Templeton 12-1-70

ISSUED DEC 3 1970

APPROVALS

COMM. & CONT DEVICES DIV OR DEPT

WAYNESBORO, VA. LOCATION

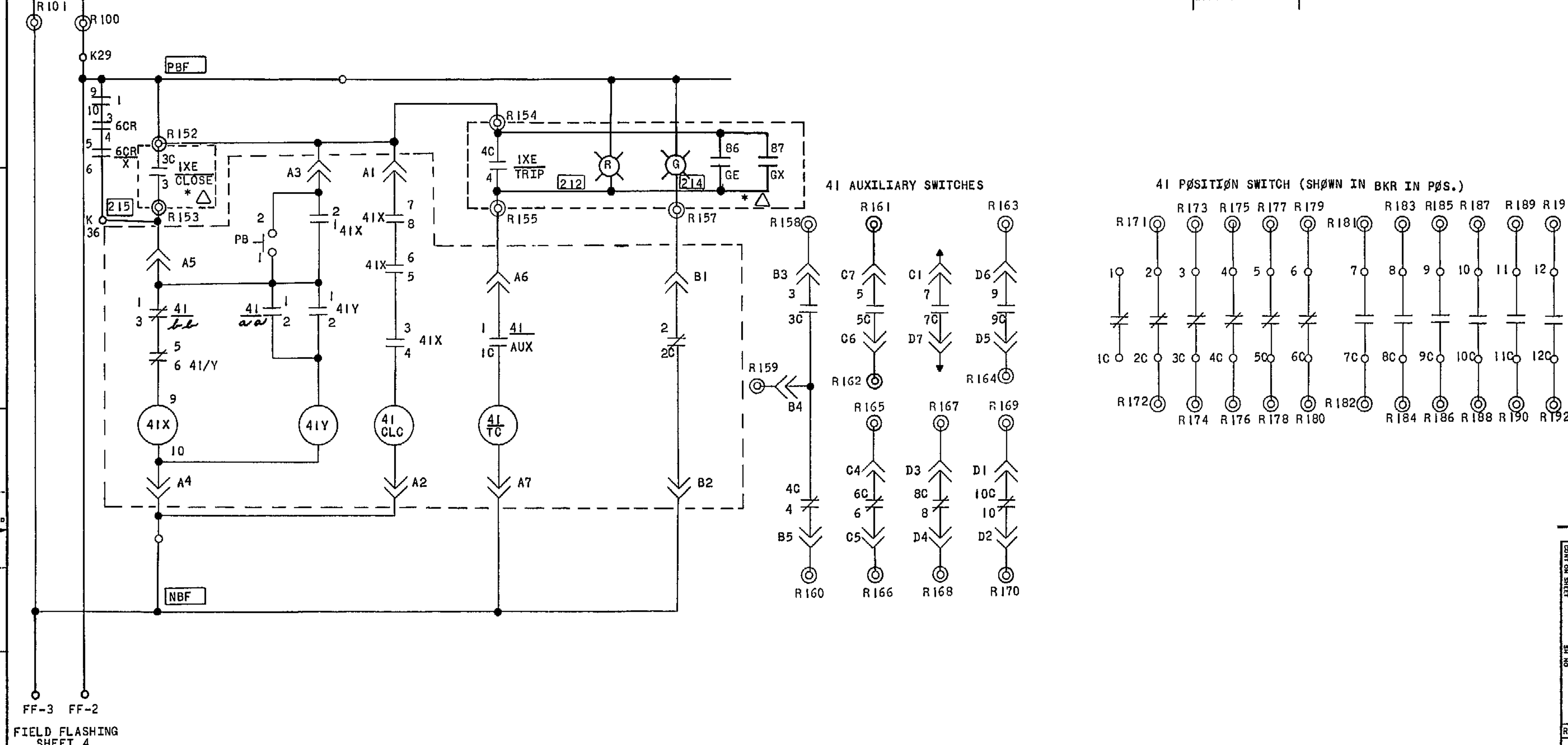
44C304408
CONT ON SHEET 14 SH NO 13

PF-809-F
PRINTED IN U.S.A.

1 2 3 4 5 6

A B C D E

5638311 2



GENERAL ELECTRIC

44C304408 CONT ON SHEET 15 SH NO 14

UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING —

APPLIED PRACTICES	SURFACES	TOLERANCES ON MACHINED DIMENSIONS: FRACTIONS	DECIMALS	ANGLES
	✓	±	±	±

TITLE HYDRO EXCITATION SYSTEM

FIRST MADE FOR 3S7931SA100A1

ELEM. DIAG.

REVISIONS

		PRINTS TO
1	G.A. Clemens MAY 1 1971	11
2	W.A. Chapman Aug 4, 1971	2-643
3	J Range Nov 16, 1971	
4	G.A. Clemens June 1, 1972	

MADE BY L. Dowel Oct 22, 1970

ISSUED DEC 3 1970

COMM. & CONT. DEVICES DEPT
WAYNESBORO, VA.

44C304408 CONT ON SHEET 15 SH NO 14

GENERAL ELECTRIC

44C304408 CONT ON SHEET 15A SH NO. 15

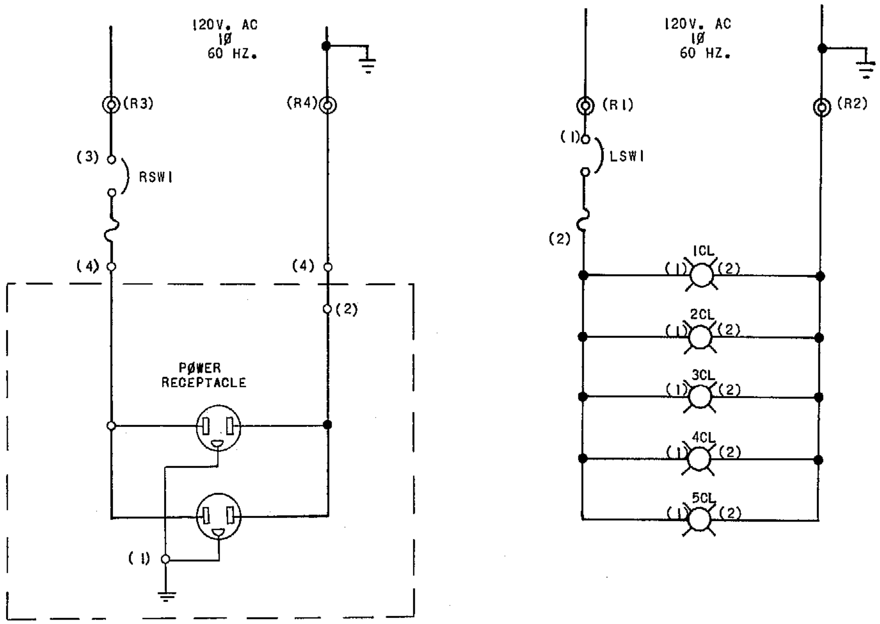
UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING:—

APPLIED PRACTICES	SURFACES	TOLERANCES ON MACHINED DIMENSIONS: FRACTIONS	DECIMALS	ANGLES
	✓	±	±	±

TITLE HYDRO EXCITATION SYSTEM

FIRST MADE FOR 3S7931SA100A1

ELEM. DIAG.



REVISIONS		PRINTS TO
1	C.A. Ellison MAY 1 1971	11
2	W.J. Chapman Aug. 4, 1971	2-643
3	A. Rouzi Nov. 16, 1971	
4	W.J. Chapman Dec. 17, 1971	
5	A. Elepalie May 4, 1973	

MADE BY L. Doul Oct 22, 1970 ISSUED DEC 3 1970 APPROVALS

COMM. & CONT. DEVICES DIV OR DEPT WAYNESBORO, VA. LOCATION

44C304408 CONT ON SHEET 15A SH NO. 15

GENERAL ELECTRIC

44C304408

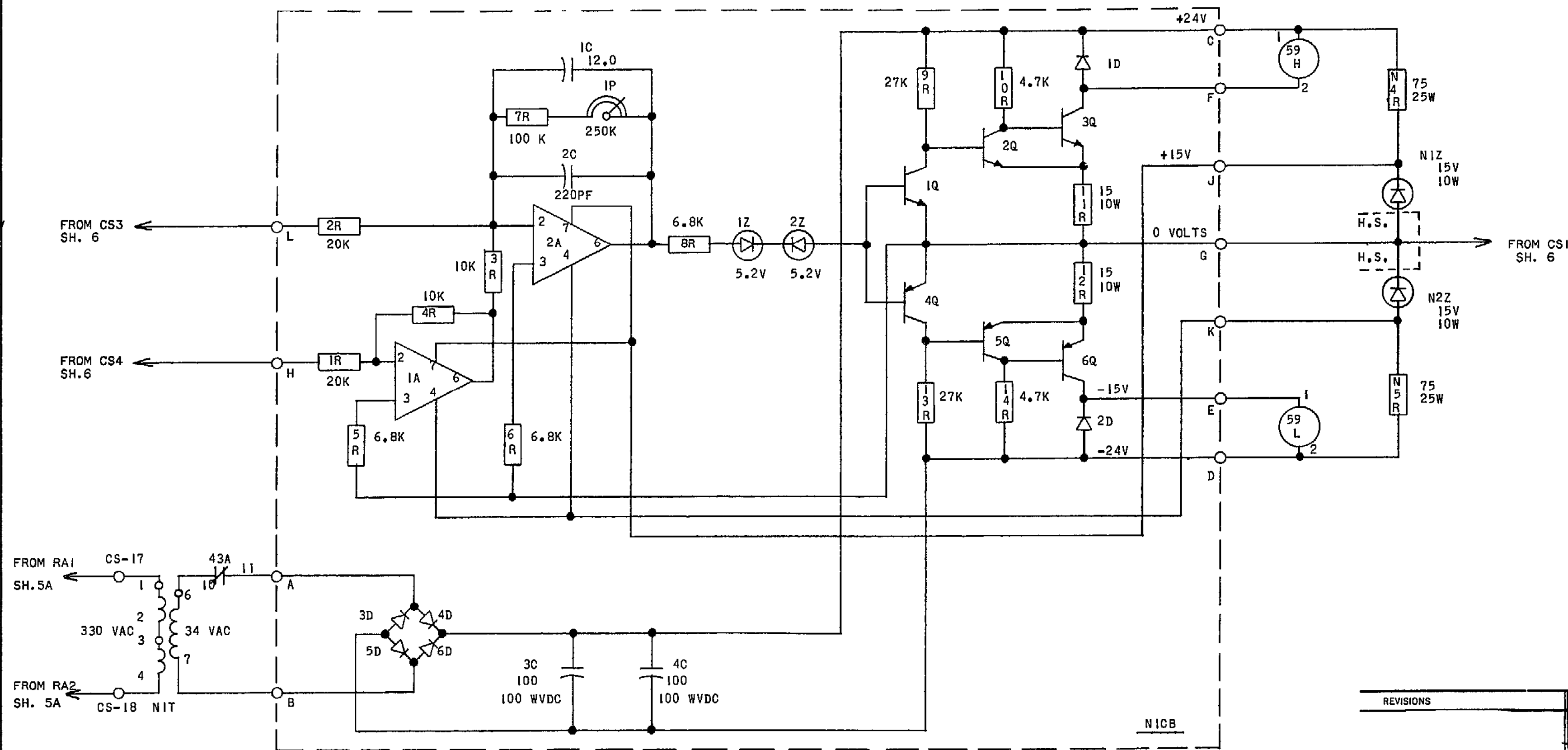
CONT ON SHEET 16 SH NO 15A

UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING —				
APPLIED PRACTICES	SURFACES	FRACTIONS	DECIMALS	ANGLES
	✓	±	±	±

TITLE HYDRO EXCITATION SYSTEM

FIRST MADE FOR 3S7931SA100A1

ELEM. DIAG.



REVISIONS

PRINTS TO 11

MADE BY G. Eleasla May 3, 1973

ISSUED D. Moyer May 4, 1973

APPROVALS R.G. ...

DRIVE SYSTEMS PROD. DEPT. WAYNESBORO, VA.

44C304408 CONT ON SHEET 16 SH NO 15A

MCK 34383A 1

FF-8O5-F (11 72) PRINTED IN U.S.A.

GENERAL ELECTRIC 44C304408

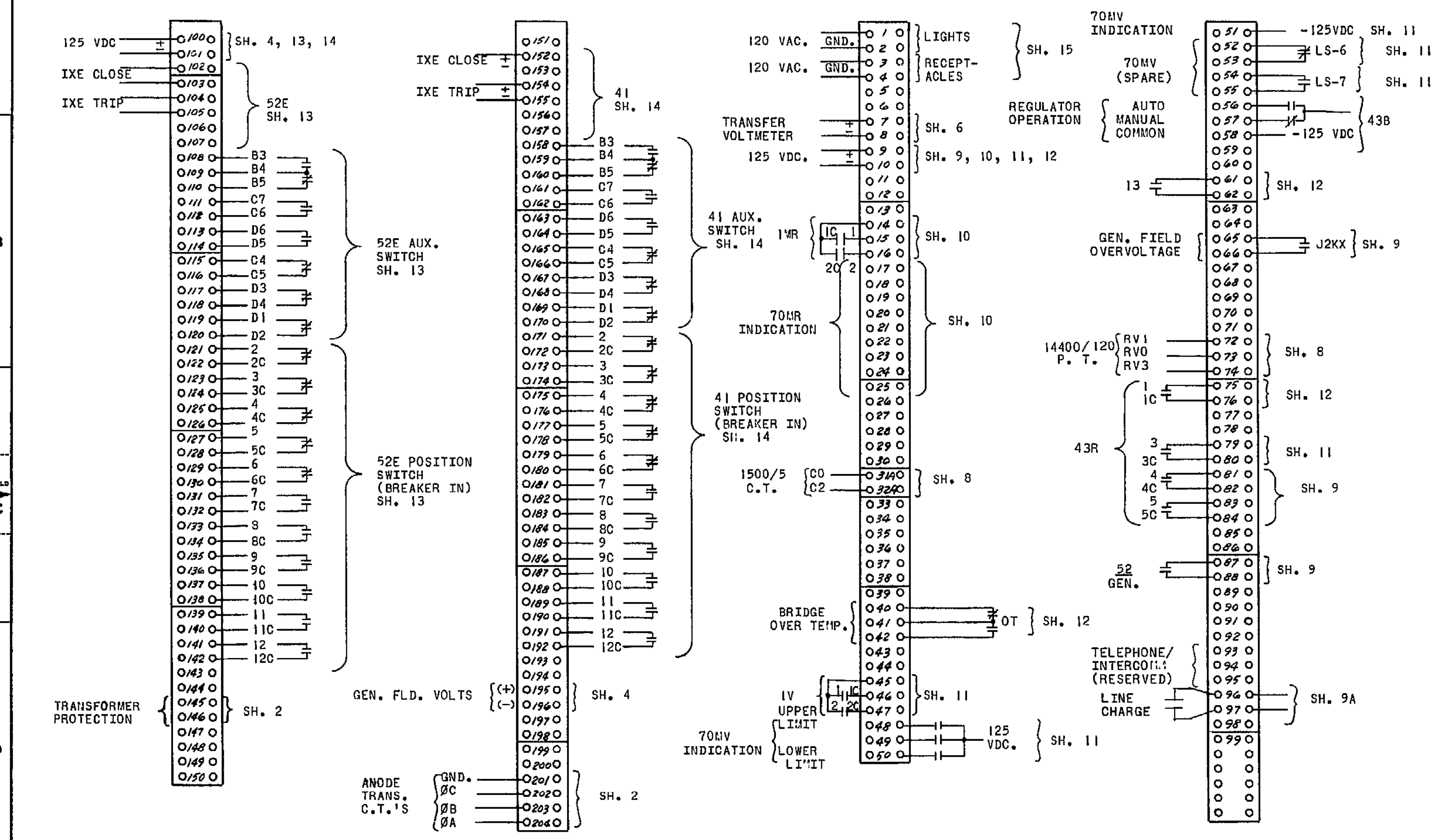
CONT ON SHEET FNC SH NO 16

UNLESS OTHERWISE SPECIFIED USE THE FOLLOWING — APPLIED PRACTICES / SURFACES ✓ / TOLERANCES ON MACHINED DIMENSIONS: FRACTIONS ± DECIMALS ± ANGLES ±

TITLE HYDRO EXCITATION SYSTEM

FIRST MADE FOR 3S7931SA100A1

CUST. CONN. DIAG.



NOTES: 1. CONNECT GENERATOR FIELD CURRENT SHUNT LEADS TO SF-9( ) AND SF-8(-) SHOWN ON SHEET 14.

REVISIONS		PRINTS TO
1	W.H. [illegible] Dec. 17, 1971	11
2	D. Hampler April 10, 1972	2-643
3	[illegible] NOV 25 1975	

MADE BY [illegible] 11-9-71

ISSUED E. Lotto Nov. 16, 1971

APPROVALS [illegible]

COMM & CONT DEVICES DIV OR DEPT

WAYNESBORO VA LOCATION

44C304408 CONT ON SHEET FNC SH NO 16