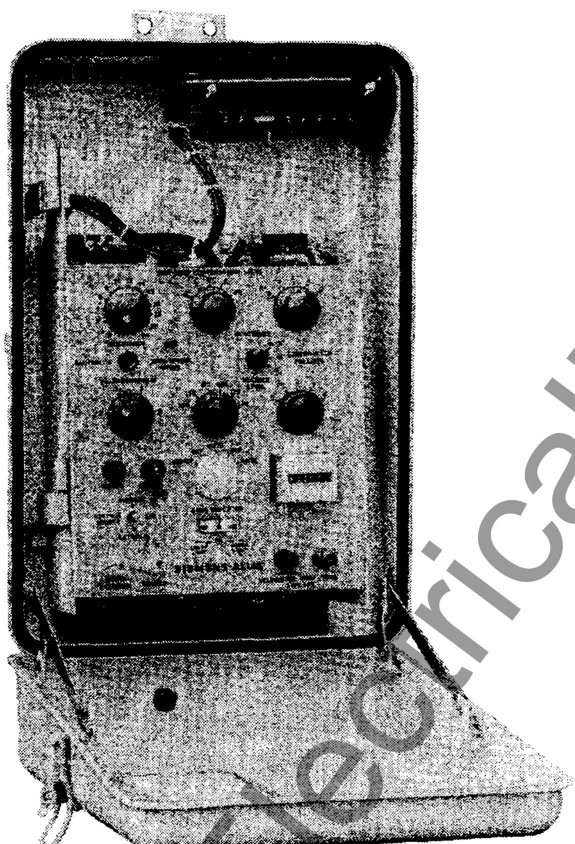
SIEMENS

Instruction and Service Manual

Instructions



TYPES IJ-2, IJ-2A
***ACCU/STAT* Controls**

21-115-527-008

Contents

ILLUSTRATIONS

1.0 INTRODUCTION

This manual describes the operation of the Types IJ-2 and IJ-2A *Accu/Stat* controls. Also included are instructions for checking, calibrating and trouble shooting.

The Types IJ-2 and IJ-2A controls maintain a Class I accuracy over a temperature range of -40°C to +65° C. The voltage level utilizes a tapped reactor and is snap action — adjustable from 105 to 134 volts in 1 volt increments. The line drop compensator resistance is continuously adjustable from 0 to 24 volts and the reactance is snap action adjustable from 0 to 24 volts in 1 volt steps. The time delay is continously adjustable from 15 to 120 seconds and the bandwidth from 1.5 to 6 volts. The control is designed for operation over an input voltage range from 90 volts to 145 volts and has a burden of approximately 10 VA over this range.

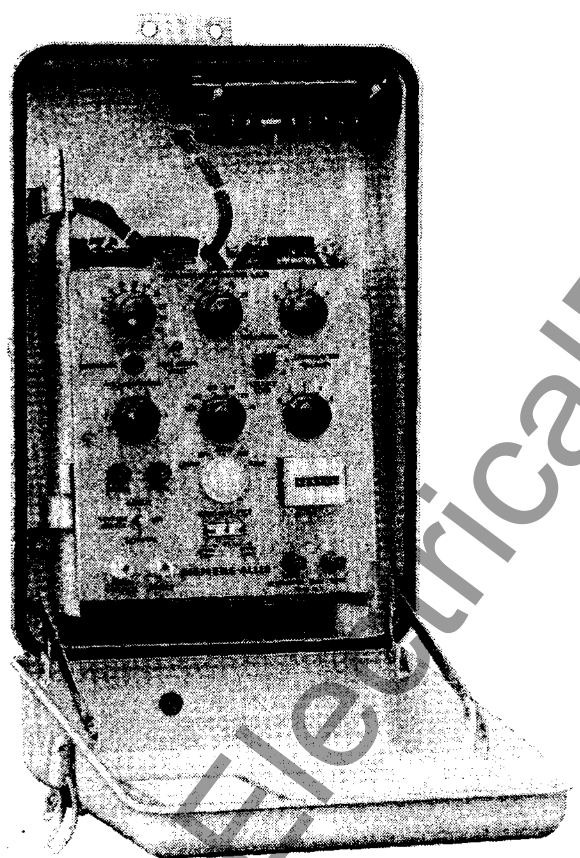


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Fig. 1 Front view of *Accu/Stat* control.

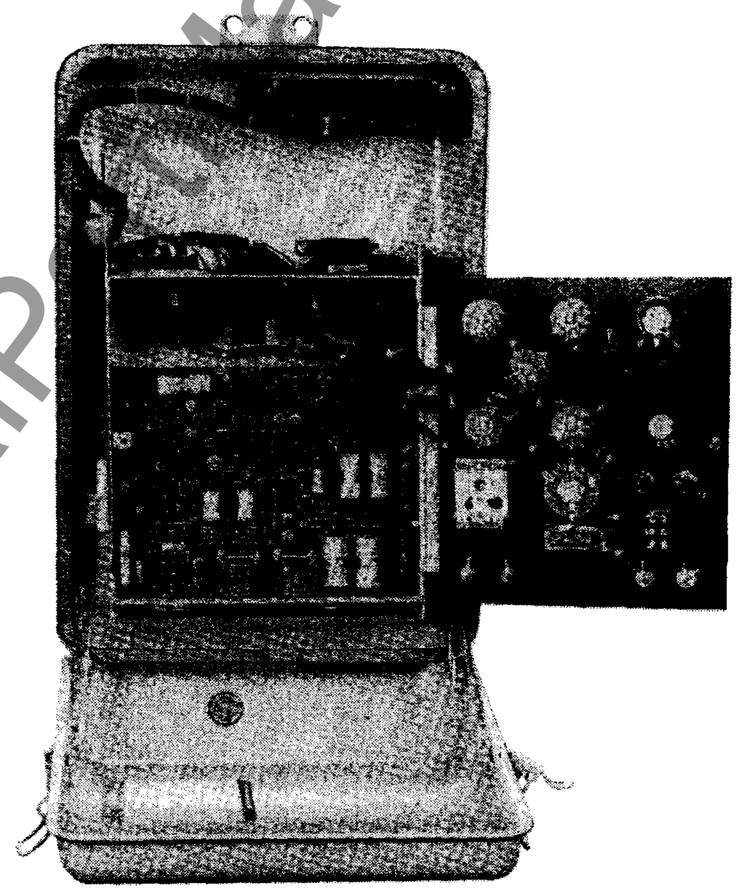

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Fig. 2 *Accu/Stat* control with faceplate open.

2.0 CONTROL FACEPLATE INFORMATION

(Refer to Figure 3)

2.1 TRANSFER SWITCH – The regulator can manually be made to "raise" or "lower" its voltage output by moving the transfer switch to its respective raise or lower position. When the switch is in either of these positions, no time delay should be realized before the tap changer motor is activated.

Regulators are usually used to automatically maintain a constant voltage output within a certain bandwidth. Moving the transfer switch to the "auto" position allows the control to automatically govern the movement of the tap changer motor.

2.2 VOLTAGE LEVEL SWITCHES – A potential transformer inside the regulator reduces the regulator's primary voltage output to a secondary output (around 120 volts – The exact value is shown on the nameplate). This secondary voltage is monitored by the control and when the transfer switch is in the auto position, the control will actuate either the lower or raise side of the tap changer motor in a direction to cause this secondary voltage to be decreased or increased to the values set by these voltage level switches.

2.3 BANDWIDTH SWITCHES – Since the regulator cannot maintain a secondary output voltage exactly equal to the settings on the voltage level switches it is necessary to have a deadband in which the control is satisfied. If the voltage goes outside this deadband the regulator will operate to bring the voltage back inside this deadband. This deadband is defined as bandwidth which is the voltage differance between the maximum and minimum regulator voltage output which can occur without the regulator operating. NOTE: The minimum bandwidth is determined by the step size of the regulator.

2.4 LINE DROP COMPENSATOR SWITCHES – Many times it is desired to automatically maintain a constant voltage equal to the voltage level switches at some point remote from the regulator location, usually referred to as load center. This can be accomplished by setting the R and X switches equal to the value on a 120 volt base of the voltage drop from the regulator to the load center. This voltage drop should be equal to that caused by the resistance and reactance of the line when current is flowing equal to the primary rating of the C.T. inside the regulator.

2.5 COMPENSATOR POLARITY SWITCH – This switch determines the polarity of the resistance and reactance in the control as compared to that on the line. (+R+X) means the impedance in the control is in polarity with that on the line. –R means the resistance is in opposite polarity to that on the line, but the reactance (though not designated) is + or the same polarity as that on the line. –X means the reactance is in opposite polarity and the resistance R is + (though not designated).

Therefore, for single phase or four wire grounded systems set the compensator switch on (+R+X). For open or closed delta systems, refer to the Allis-Chalmers User's Manual.

2.6 BAND INDICATOR – Provides continuous indication of whether the input panel voltage is within the bandwidth.

2.7 CONTROL SERIAL NUMBER – The last SJ-6 panel had S/N 604S-12552 and the first IJ-2 had S/N IJ201S-00001.

2.8 OPERATION COUNTER – The number of completed regulator tap changes is recorded by the operation counter. This is an excellent means of monitoring monthly the voltage variations on a system.

2.9 VOLTMETER TEST TERMINALS – A voltmeter across these terminals will measure the regulator's P.T. secondary output voltage. To determine the primary voltage refer to the nameplate and use the following formula:

$$\text{Pri Volt} = \frac{\text{Load Volts x Voltmeter Reading}}{\text{Pot. Sec. Volts}}$$

2.10 EXTERNAL SOURCE TERMINALS – When applying voltage externally, by means other than the regulator's internal potential transformer, use these terminals and place the voltage source switch on "external". This switch opens the internal P.T. circuit preventing the bushing terminals from being energized.

2.11 NEUTRALITE – An internally actuated switch causes this light bulb to indicate when the regulator tap changer is on the neutral position.

2.12 DRAG HANDS RESET BUTTON – The position indicator has two drag hands. One moves only in the raise direction with the pointer and the other only in the lower direction with the pointer. Pushing the reset button returns the drag hands to the pointer.

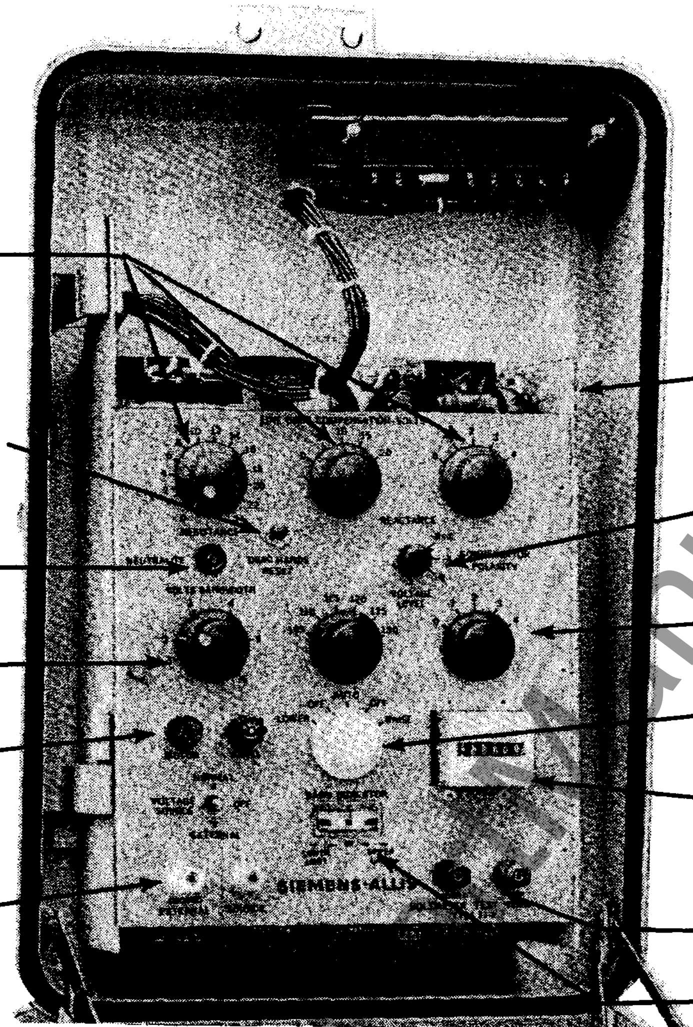


Fig. 3 Faceplate switches.

2.13 **FUSES** – One fuse, a 4 amp type AGX4A or 362-8AG4, protects the motor circuit and a 4/10 amp fuse type MDL 4/10 or 313-3AG 4/10 protects the panel circuit.

3.0 REPLACEMENT OF PREVIOUS CONTROLS WITH THE IJ-2 OR IJ-2A

Type UA-23-24-25 – Order Mounting Adapter Kit 01-11-1670.

Type UJ-4 & UJ-5 – Replace the 10 pin jack plug on the IJ-2 control with the existing 7 pin plug which does not have U10, U11, or U12 terminals. Tape up these leads U10 (operation counter), U11 (drag hand reset button), and U12 (neutralite). On UJ-4 panels install a jumper between the C1 and E terminals on the 7 pin plug. On UJ-4 or UJ-5 units without potential transformers (50 kva and below) a jumper must be added between P2 and U2 on the stationary portion of the jack plug. Remove the control to be replaced and insert the IJ-2 control on the enclosure hinges and swing closed.

Type UJ-5AC, UJ-5C, SJ-3, SJ-4, SJ-5, SJ-6 – The IJ-2 control is directly interchangeable with these controls. Merely swing the control to be replaced outward on its hinges, remove and insert the IJ-2 control in its place.

For controls other than the above, refer to the factory.

The IJ-2 or IJ-2A printed circuit board assembly (PCB) is not interchangeable with prior PCB's.

When replacing an IJ-2 or earlier control with an IJ-2A, connect leads "P" and "P_{14}" from the sensing transformer to terminal "20" on the IJ-2A control.

When replacing an IJ-2A with an IJ-2 or earlier control, the voltage level knobs must be set equal to the "Control and Motor" volts (E-P_2) shown on the nameplate.

When replacing an IJ-2A with an IJ-2A, be sure to connect the "P" and "P_{14}" leads from the control sensing transformer to the proper terminals corresponding to the operating voltage. Refer to the regulator nameplate for these connections.

4.0 EXCHANGING ACCU/STAT CONTROLS

A malfunctioning *Accu/Stat* Control can be exchanged for one which operates correctly. For exchange price refer to your nearest Siemens-Allis representative. The procedure for returning these controls is as follows:

1. Issue a Purchase Order to your Siemens-Allis representative and give him the serial number of the panel to be exchanged and the S/N of the regulator it was removed from.

2. Allis-Chalmers will then send you an exchange panel with an exchange credit card.

3. Remove the exchange panel from its container. Place the malfunctioning control in that container as described in section 5 below. Return the container to the address shown on the exchange credit card.

All panels returned on the exchange basis must be intact. Additional billing will be made for materials stripped from panels prior to their return. All panels must be returned to the factory within 60 days or billing for the full spare price will be made.

5.0 TO RETURN CONTROL

When returning the panels to the Factory, take the following precautions to prevent damage in shipment.

1. Wire down swing panel at latch or use locking screw. (IJ-2 has a special locking latch to prevent panel movement).

2. Tighten face plate thumb screw.

3. Turn down knob locking screws.

4. Tighten polarized jack plug wing nuts.

5. Repack faulty unit in same manner as replacement panel if returning for exchange panel.

6. Ship with face plate in up position.

6.0 REMOTE MOUNTING

The control can be remotely mounted in any position without affecting its operation. Remote mounting hardware for the IJ-2 and IJ-2A is identical to that required for the UJ-5AC, UJ-5C, SJ-3, SJ-4, SJ-5, and SJ-6 controls. Remote Mounting cables in lengths of 25 ft. or 30 ft. can be ordered from the factory.

7.0 TESTING PROCEDURE

When testing IJ-2 or IJ-2A controls, determine the trouble by using this manual. All panel voltage test point readings should be made with a good multimeter, i.e. Triplett or Simpson 20,000 ohms per volt DC or a vacuum tube voltmeter (VTVM). When testing across components or any other points (besides the designated test points) of the PC8, only a VTVM should be used. If the trouble cannot be determined, contact your nearest A-C representative. Do not indiscriminately turn the calibrating rheostat, unsolder or remove parts.

8.0 OPERATIONAL THEORY

(Refer to schematic diagrams — Fig. 12 for IJ-2 and Fig. 13 for IJ-2A.)

The secondary of the regulator's potential transformer is connected to the primary side of the sensing transformer TR-1 which has coarse tap sections of 5 volts each from 105 through 130 volts, and fine tap sections of 1 volt each from 0 to 4 volts. This allows the voltage level adjustment to be set at any level between 105 and 134 volts in one volt increments. The secondary of the sensing transformer (TR-1) has two windings; the (S1-NO) winding supplies voltage to the sensing circuit while the (A1-A2) winding supplies voltage for bias or reference.

The (S1-NO) secondary winding of the sensing transformer is connected in series with a line drop compensator (LDC). This LDC consists of a tapped reactor (TR-3) and variable resistor (RH-1). The output of the LDC circuit is then connected to a low pass filter (R8, C5, R9, C6) which is in parallel with the rectifier bridge (D5, D6, D7, D8). The filter eliminates the major effect of the line third harmonics from affecting the accuracy of the control. The conversion to DC by the rectifier bridge is necessary to utilize direct current devices in the sensing and timing stages of the control.

The (A1-A2) secondary winding supplies power for the circuit and is connected to rectifier bridge (D1, D2, D3, D4). The bridge has two outputs referenced to test point 0. One output is +25 volts D.C. and the other is −25 volts D.C. Each output is connected to a constant power supply. One supply maintains a constant +15V D.C. and the other a constant — 15V D.C. These supplies provide a proper bias voltage for electronic components throughout the circuit.

The +15V constant supply consists of an integrated circuit (IC-1), transistor T1 and resistors R3, R4 and R7. R7 is used for current limiting. This constant +15V supply keeps the "critical" bias current through the reference Zener (Z2) constant and supplies proper bias voltage for other circuit components.

The —15V constant power supply is provided through a simple series circuit consisting of Z1, T3 and R6. Current limiting is provided by R5 and T2. The output of the —15 volt constant supply is not as critical as the +15 volt constant supply. This is because it supplies bias voltage for circuit components which are not as critical as Z2.

Any voltage variations on the output of the regulator P.T. will cause a proportional change on the output of the rectifier bridge (D5, D6, D7, D8). This D.C. output voltage which is negative is added to the constant positive output of the Z2 Zener and the negative output from R16. These three outputs are connected to the inverter input (Pin 2) of differential amplifier IC-2A.

A differential amplifier (called Diff. Amp.) is an integrated circuit device biased by plus and minus constant voltage supplies. It has two inputs and one output and produces an output only when there is a voltage difference between its inputs. The magnitude of its output is proportional to the magnitude of the difference between its inputs.

One input (pin 3) of Diff. Amp. IC-2A, is tied to the circuit common (A10), and the other input (pin 2) receives its summed signal from R14, R15, and R16. Pin 2 is called the "inverter input" because the output of the Diff. Amp. is always inverted or opposite in polarity to Pin 2. When the regulator output voltage is equal to the voltage level setting on the control, the control is said to be balanced. When it is balanced the voltage difference between Pin 2 and Pin 3 is zero and the Diff. Amps. output is zero. When the regulator output voltage is higher than the voltage level setting then Pin 2 is negative with respect to Pin 3 and the Diff. Amps. output is positive. When the regulator output voltage is lower than the voltage level setting, then Pin 2 is positive with respect to Pin 3 and the Diff. Amps. output is negative. Summarizing, a high regulator output will cause a positive IC-2A output and a low regulator output will cause a negative IC-2A output.

The output of IC-2A is changed by varying the voltage difference between its two inputs. It is desired to do this without changing either the input to the IJ-2 control or the voltage level setting. By feeding back a portion of IC-2A's output into its — input (pin 2) the voltage difference between pin 2 and pin 3 is reduced. Varying the feedback varies the output of IC-2A. If the input difference between pin 2 and pin 3 is zero, IC-2A's output is zero and there is no feedback. Feedback is provided by connecting one end of R22, R20, C9 and variable resistor RH-3 to the output of IC-2A and the other end to pin 2. The feedback may be varied by RH-3 and this provides the bandwidth for the control. The larger the feedback the larger the bandwidth. The output of IC-2A changes a specific amount for a specific input voltage change to the control. Increasing the bandwidth requires greater changes to the input of the control to give the same IC-2A output change.

The two back-to-back Zener Diodes, Z3 and Z4, do not allow current conduction through them unless the output voltage of Diff. Amp. IC-2A exceeds the breakdown voltage of one of the Zeners. When an unbalance occurs, the output of the Diff. Amp. is either positive or negative depending on the polarity of Pin 2 relative to Pin 3. If the output is negative then Z3 acts like an ordinary diode to allow current conduction, but the Z4 Zener will not allow current to flow through it until its breakdown or Zener voltage is reached. The reverse is true if the Diff. Amps. output is positive.

If the output of IC-2A is positive and of sufficient magnitude to breakdown Z3, then this positive voltage will be applied to the base of transistors T4 and T5. Since T5 is a PNP transistor, this positive voltage on its base keeps it off. T4, though, is an NPN transistor and a positive voltage on its base will turn it on. The reverse is true when the output of IC-2A is negative enough to breakdown Z4. T4 will remain off and T5 will turn on. When T4 turns on then relay FR-R actuates, and when T5 turns on then relay GR-R actuates. Each of these relays have two contacts. One contact supplies a voltage through resistor R24 which adds to the Pin 2 input of IC-2A. This keeps the FR-R or GR-R relays from de-actuating when there are small input fluctuations to IC-2A. Resistor R26 is used to make the added voltage to the Pin 2 input equal for a raise operation as well as a lower operation because the plus and minus power supplies are not exactly equal. The other contact is used to apply power to one of the tap changer motor relays FR or GR and also start the timer. Because T11 is off only a small current passes through the FR or GR relay coil. This current is insufficient to energize the relay coil.

This small current through the relay coil is applied to the base of T6. This starts the timing cycle.

The timing section consists of four distinct parts: a comparison section (differential amplifier IC-2B), a capacitor charge section C11, a capacitor discharge circuit T7 and T6, and a timer reset circuit T13. The comparison circuit IC-2B compares the voltage input from capacitor C11 to that from variable resistor RH-4, which is the time delay rheostat. When the voltage input from C11 exceeds the voltage input from RH-4, the output of IC-2B switches from +15V to −15V turning T10 on which then turns T11 on and one of the motor relays (FR or GR) will actuate.

When the input voltage to the IJ-2 or IJ-2A control is within the bandwidth, then T6 is off, and T7 is on. When T7 is on, it puts a low resistance shunt across C11 allowing C11 to only partically charge. When the input voltage to the IJ-2 control goes outside the bandwidth, then the small current through the FR or GR relay coils to the base of T6 turns T6 on which turns T7 off. C11 charges through T9 which acts as a constant current generator. The voltage on C11 will increase until it exceeds the voltage set by potentiometer RH4. When this happens, the output of IC-2B reverses from positive to negative turning on T10. T10 will then turn on T11, which will pick up relay FR or GR, depending upon which relay contacts (FR-R or GR-r) were closed. When T11 turns on, T12 turns off, providing an input to T13 through R41 and R52. T13 turns on which rapidly discharges C11 and resets IC-2B and T10 to their original state. This resets the time delay circuit until a new timing cycle is started. T11 remains on until the FR-R or GR-R relay opens which removes the base drive on T11.

Once the GR or FR relay actuates, the motor power supply from the regulator is connected through contact GR-1 or FR-1 to the raise or lower side of the tap changer motor.

9.0 CHECKING THE BANDWIDTH

Open the control panel faceplate. Connect the negative lead of a voltmeter (30 to 50 volts, 20,000 ohms/volt D.C.) to test terminal ⟨8⟩ and the other lead to test terminal ⟨0⟩. Set the voltage source switch on the "External" position.

Connect the ground side of a variable 60 Hertz supply (such as a Variac, Powerstat) to the white external source terminal marked "ground" and the other side of the external source to the yellow source terminal. Set the bandwidth control to the desired value and adjust the voltage level setting to 120 volts. Increase the external supply voltage until its output reads 120 volts. This can be read directly from the voltmeter test terminals. The D.C. voltmeter should read zero and the band indicator meter hand should center to the "in" position. Gradually increase the variable supply voltage until the voltmeter hand suddenly deflects to approximately 15 volts. Observe the external supply voltage at which the meter suddenly deflects. This is the upper band-limit voltage.

Reverse the voltmeter leads at test points ⟨8⟩ and ⟨0⟩ and gradually decrease the supply voltage until the voltmeter hand again suddenly deflects to 15 volts. Observe the external supply voltage at which the meter hand suddenly deflects. This is the lower band limit voltage.

10.0 CHECKING THE VOLTAGE LEVEL

The voltage level calibration is equal to the average of the upper and lower bandwidth readings as determined in Section 9.

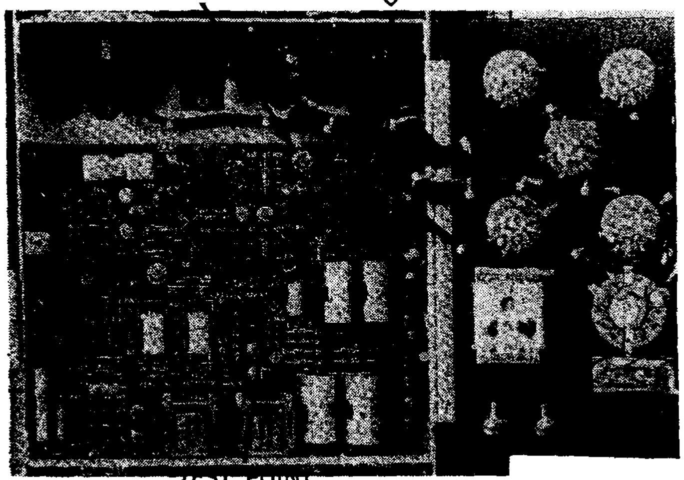
CAUTION: THE *ACCU/STAT* CONTROL CALIBRATING RHEOSTAT RH-2 IS PRESET AT THE FACTORY. THIS RHEOSTAT SHOULD NOT BE RESET UNLESS THE CONTROL IS ADJUSTED AS DESCRIBED IN SECTION 11.

11.0 CALIBRATING THE *ACCU/STAT* CONTROL

Recalibration of the *ACCU/STAT* control is not normally required unless parts have been replaced. Use either of the following procedures if recalibration is necessary.

A. RECALIBRATION OF THE CONTROL IN THE SHOP

A1. Set the voltage level control to 120 volts, the R & X compensation to zero and the bandwidth to 2 volts.



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A2. Apply exactly 120 volts a.c. into the external voltage source terminals.

A3. Connect a D.C. Voltmeter (at 2.5 volt D.C. or less) across test points ⟨7⟩ and ⟨0⟩.

A4. Loosen shaft locknut and adjust rheostat RH-2 until the D.C. Voltmeter reads zero. The control is now calibrated.

A5. Tighten shaft locknut.

B. RECALIBRATION OF THE CONTROL WITH THE REGULATOR IN SERVICE

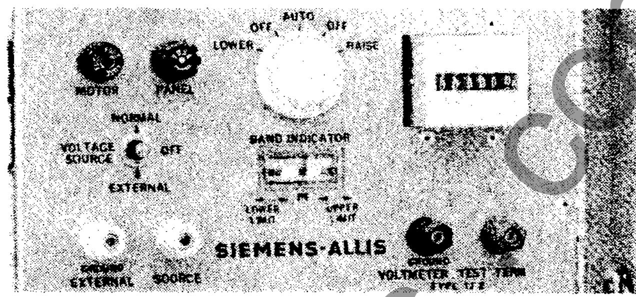
B1. Turn transfer switch (white knob on control faceplate) to the OFF position.

B2. Set the R & X compensation to zero and the bandwidth to 2 volts.

B3. Measure the voltage at the voltmeter test terminals and set the voltage level controls to the value measured.

B4. Check the band-indicator. If it is in the center of the dial, it is correctly calibrated. If not, loosen the locknut and adjust RH-2 until the band-indicator is centered. The control is now calibrated.

B5. If the voltage measured at the voltmeter test terminals is not a whole number but a whole number plus a fraction, (i.e. 121 1/2) then set the voltage level equal to the whole number (i.e. 121). If the needle is not 1/2 the distance between IN and Upper Limit



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then adjust RH-2 until the needle moves the fraction of the distance into the white area between the IN and UPPER LIMIT position (i.e. 1/2). The control is now calibrated.

11.1 IF THE CONTROL KNOBS SET SCREWS HAVE LOOSENED OR KNOBS ARE BEING REPLACED, ADJUST AS FOLLOWS:

BANDWIDTH KNOBS

Turn the bandwidth control shaft CW to extreme mechanical rotation.

Set knob on control shaft with knob mark over the dot on the faceplate (past the 6V bandwidth mark.) Tighten set screw on knob.

TIME DELAY KNOB

Turn time delay control shaft (RH4) CW to extreme mechanical rotation.

Set the knob on the control shaft with knob mark over the dot past the 120 second mark. Tighten the set screw on the knob.

11.2 CALIBRATING REPLACEMENT BAND INDICATORS

Refer to Section 21.10. When the input voltage to the control is equal to the voltage level setting and zero volts is read on a voltmeter connected between test points ⟨0⟩ and ⟨7⟩ and the indicator needle does not center in the "in" position, then reset the needle as follows:

1. Locate the small pointer at the top of the back of the band indicator.
2. Move the pointer to the right and the band indicator needle will move to the left. Move the pointer to the left and the indicator needle will move to the right. Move the pointer until the meter needle centers in the "IN" position.

TROUBLE SHOOTING

12.0 NO MANUAL OPERATION (FIRST CHECKS)

Refer to Figure 1 and Figure 12.

With the voltage source switch on external, apply approximately 120 volts to the external source terminals. Disconnect the PDS (jack plug) and turn the Raise-Auto-Lower Transfer Switch to the OFF position.

Zero volts should be measured from J to E and K to E on the PDS. Move the transfer switch to raise and approximately 120 volts should be measured from J to E and zero volts between K and E. Move the transfer switch to lower and approximately 120 volts should be measured from K to E and 0 volts from J to E. If these measurements are obtained then the problem is in the regulator not the control panel. If incorrect measurements are taken proceed through section 13.

13.0 NO MANUAL OPERATION (SECOND CHECKS) NO AUTOMATIC OPERATION (FIRST CHECKS)

13.1 Remove the polarized jack plug and check the tips of the male plugs and surface contact in the female part for tarnish and corrosion. Make sure pins are making contact with springs in the stationary disconnect plug.

13.2 Check and tighten all screws on the polarized jack plug and panel terminal block. If screws on the terminal block cannot be tightened, replace with binder head type 6/32 by 1/4 inch long.

13.3 Remove fuses and check for tarnish and corrosion. Sometimes a fuse may look good but is faulty. Try a new one.

13.4 Check the connecting wires to the printed circuit board. The insulator may be pushed down but the lug may not properly engage the extended tab.

13.5 Turn all knobs on the faceplate through their complete rotation several times, then return them to their set position. This will clean off any bad spot or poor contact due to corrosion or tarnish. Avoid tightening the locking screws until the panel is again operating properly.

13.6 Check the operation of the motor relays, GR and FR, by substituting a known good one.

14.0 MANUAL OPERATION OK

The control is operating correctly in the manual mode when the white transfer switch can be turned to LOWER and it causes the regulator to lower, and when set to RAISE, it causes the regulator to raise.

15.0 NO AUTOMATIC OPERATION

The first and most important method for locating the problem after the first checks have been made is to isolate the problem with voltage checks across circuits and components in the panel.

16.0 NO AUTOMATIC OPERATION (SECOND CHECKS)

Set the voltage source switch on external and apply 120 volts AC to the external source terminals. Set the control panel voltage level at 120 volts. (NOTE: Any panel voltage level setting can be used as long as the input voltage is the same as the voltage level setting. If other than 120 volts is used the test readings obtained will vary slightly from that shown in Figure 12.) Follow the testing sequence given in Figure 12 and determine the location of the trouble by using this manual. NOTE: The test readings in Figure 12 were made with an RCA volt ohmyst vacuum tube voltmeter (VTVM). If a D.C. resistance type voltmeter is used, the readings may be slightly less than would be read with a VTVM. When testing across individual components, only a VTVM is recommended since some D.C. resistance voltmeters have low enough input impedances to adversely affect the operation of the control.

Connect the common lead of the meter to test point ⟨0⟩ and start with test point ⟨1⟩ and read all test point voltages being certain to switch the meter to the appropriate scale and polarity. Record and compare the readings with test values in Figure 12. Review the circuit explanations given in the remaining portion of this book and if the trouble still cannot be determined, contact your nearest Allis-Chalmers representative.

Review the circuit explanations given in the remaining portion of this book and if the trouble still cannot be determined, contact your Siemens-Allis representative.

17.0 INPUT AND SENSING TRANSFORMER CIRCUIT (Fig. 4)

17.1 POLARIZED DISCONNECT SWITCH (PDS)
Removing the PDS automatically shorts the current transformer inside the regulator. Any terminal labeled "U" is normally powered by the tertiary winding inside the regulator. Any terminal labeled "E" (earth) is connected to ground. Any terminal labeled "C" (current) is connected to the current transformer. Any terminal labeled "P" (potential) is connected to the potential transformer. Terminal "J" goes to the raise side of the tap changer motor and terminal "K" goes to the lower side.

17.2 TR-1 (Multi-tapped Sensing Transformer). It has coarse and fine adjustment switches for selecting the desired voltage level. When energized, (either by external supply or regulator P.T.) the voltage across the upper winding (S_1 and N_0) should be about 50.5 VAC. If open, the voltage between S_1 and N_0 will be approximately zero. (Note, the jumper N_0 to N_{10} is on the top of the control panel) If TR-1 has shorted turns, it will overheat and have a low voltage from S_1 to N_0 running the regulator in the raise direction.

The IJ-2A has five additional taps on the primary side of the sensing transformer. These are for ratio correction when the control is used on a regulator with a single potential source for the control and motor circuits.
Connections are made to a terminal block on top of the swinging panel. The regulator nameplate shows proper connection of these taps.

17.3 TR-2 is an isolating auxiliary C.T. It converts the secondary regulator internal C.T. current from 0.2 amp to 0.135 amp when primary current is flowing equal to the primary current rating of the internal regulator C.T. If this component malfunctions, it will affect only the line drop compensator circuit. The secondary of this auxiliary C.T. allows current proportional to line current to flow through the multi-tapped choke TR-3 and the potentiometer RH-1. Current flow through this choke produces a 90° lagging voltage at the terminals (N2 and N_{10}) of TR-3 and an in phase voltage is produced across the potentiometer (RH-1). This voltage is added directly to the output of the secondary of the sensing transformer TR-1.

If **TR-3** secondary (not tapped side) opens, the voltage from test points ◇0 to ◇5 (shown in Fig. 12) will be approximately 0.

If TR-3 secondary (not tapped side) shorts, the sensing voltage will increase and the regulator will run one or more steps in the lower direction. There is no effect on the circuit if the primary (tapped side) is shorted except the reactive portion of the LDC will be inoperative.

If **RH-1** opens, the voltage from ◇0 to ◇5 will be approximately 0, and the regulator will run to the maximum raise position. If RH-1 shorts, it will keep the regulators output 5 to 6 volts below the voltage level setting.

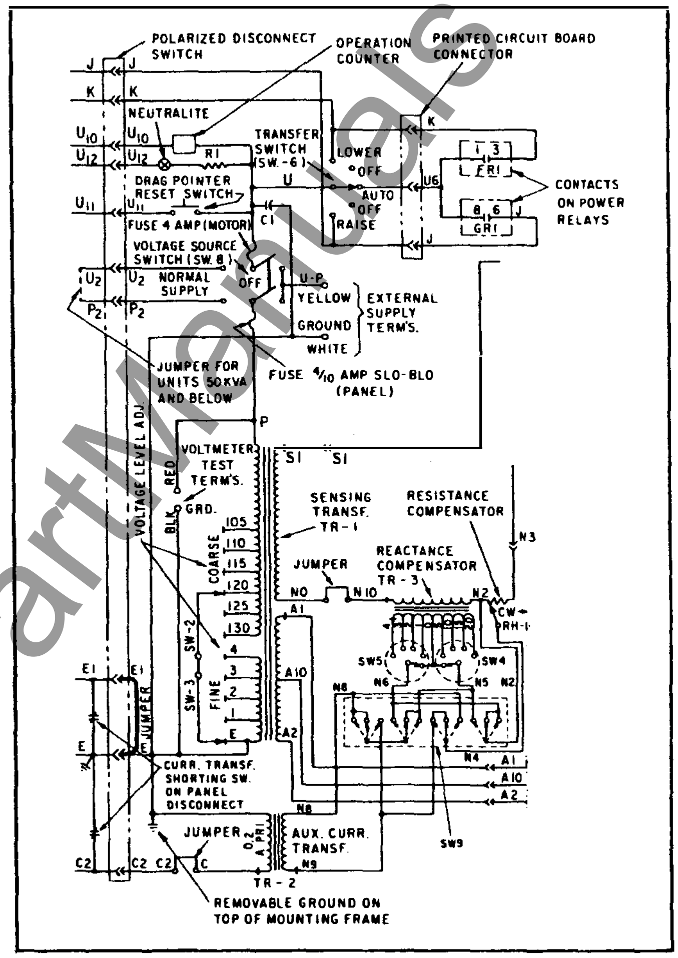


Fig. 4 IJ-2 input and sensing transformer circuit. (Refer to fig. 13, page 36 for IJ-2A input and sensing transformer circuit.)

17.4 THE COMPENSATOR POLARITY SWITCH (SW-9)
Current from the C.T. flows through resistance RH-1 and the tapped side of TR-3. This generates a voltage proportional to the current across TR-3 (non-tapped side) and RH-1. The magnitude of this voltage also depends upon the position of RH-1, SW-5, and SW-4. This voltage either adds or subtracts to the (S1—N0) voltage depending on the polarity switch SW-9 position. With SW-9 on +R+X the voltage subtracts, on —X the reactance voltage is added and the resistance voltage is subtracted. On —R the reactance voltage is subtracted and the resistance voltage is added. This allows compensation for both Delta and Wye Systems.

18.0 HARMONIC FILTER
(Fig. 5)

18.1 **R8, C5, R9, C6 (Harmonic Filter)** – These components are connected as a low pass filter and they prevent harmonic or transient voltages from affecting the sensing circuit.

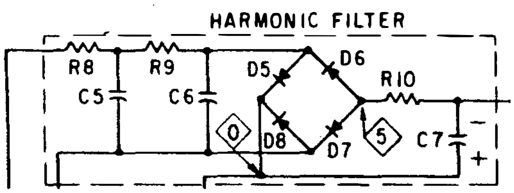


Fig. 5 Harmonic filter circuit.

If C5 or C6 shorts or R8 or R9 opens, the voltage from ⟨0⟩ to ⟨5⟩ will decrease to zero and the regulator will run to the full raise position, lower operation in automatic will be impossible. A shorted R8 or R9 will cause a higher than normal negative voltage from ⟨0⟩ to ⟨5⟩ and the regulator will maintain a lower than normal voltage output. If C5 or C6 opens, the voltage from ⟨0⟩ to ⟨5⟩ will increase to approximately 22 volts and run the regulator to the maximum lower position. A change in capacitance of C5 or C6 will cause the regulator to maintain an output different from the voltage level setting. Check the capacitance of each which should be about .47μF±5% and refer to Section 25.8.

18.2 **D5, D6, D7, D8 (Rectifier Bridge)** – These diodes rectify approximately 20V A.C. to approximately 17V D.C. full wave voltage. A leakage, short or open of any of these diodes will decrease the magnitude of the output voltage of this bridge and cause an increase in regulator output voltage, or if completely open or shorted, will run the regulator to the maximum raise position. An open diode will cause the bridge output to be about −7V D.C. A shorted diode will cause the bridge output to be about −11V D.C.

18.3 **R10, C7 (D.C. Filter)** – The D.C. output voltage of the rectifier bridge is a 60 Hz full wave. R10 and C7 smooth these ripples out and pass pure D.C. to the sensing circuit. If C7 shorts, the output from ⟨0⟩ to ⟨5⟩ will change but the end of R10 connected to C7 is now at 0 volts instead of its usual value of approximately −1.2 volts D.C. The sensing circuit to which it is connected will sense this as a low voltage and run the regulator to the maximum raise position. If C7 opens the D.C. ripples will be passed into the sensing circuit. The sensing circuit will not respond until the voltage goes outside the bandwidth. The relay which actuates (GR-R or FR-R) will then chatter at the rate of 60 cycles and no operation in automatic will be possible. If R10 shorts, the voltage from ⟨0⟩ to ⟨5⟩ will decrease to −10 volts and the regulator will run to the maximum lower position. Raise operation will not be possible. If R10 opens, the voltage from ⟨0⟩ to ⟨5⟩ will increase to approximately 28 volts and the regulator will run to the maximum raise position.

19.0 ±25 VOLT D.C. SUPPLY
(Fig. 6)

19.1 **The lower winding (A1 to A2)** – Secondary of TR-1 powers the plus and minus 25V D.C. Supply. The voltage from A1 to A2 should be about 38V A.C. and since A10 center taps A1 to A2 then A1 to A10 and A2 to A10 should read about 19V A.C. With an open in the A1 to A2 winding the A1 to A2 voltage will become zero and no automatic operation will be possible.

19.2 **D1, D2, D3, D4 (Rectifier Bridge)** – These diodes rectify the 38V A.C. to 50V D.C. The voltage from ⟨0⟩ to ⟨1⟩ or ⟨0⟩ to ⟨2⟩ should be 25V D.C. If D1 or D2 shorts the voltage from ⟨0⟩ to ⟨1⟩ will be about 8V D.C. The voltage from ⟨0⟩ to ⟨2⟩ will be correct. If D3 or D4 shorts the voltage from ⟨0⟩ to ⟨1⟩ will be correct but ⟨0⟩ to ⟨2⟩ will be about −8 volts D.C. If any of the diodes short the regulator will not operate in automatic and sensing transformer TR-1 will produce a steady hum and may burn out.

19.3 **C2, C3 (D.C. Filter Capacitors)** – Capacitors C2 and C3 filters or smoothes out the 60 Hz. ripples of the rectifier bridge (D1 through D4). If C3 shorts, the voltage from ⟨0⟩ to ⟨2⟩ will be zero. The regulator will run to the lowest position and raise operation in automatic will not be possible. If C2 shorts, the voltage from ⟨0⟩ to ⟨1⟩ will be zero and automatic operation in either the raise or lower direction will not be possible. If C3 opens, the voltage from ⟨0⟩ to ⟨1⟩ will be approximately 27 volts and the voltage ⟨0⟩ to ⟨2⟩ will be −19 volts. The motor relays will chatter as it trys to run the regulator to the maximum lower direction. If C2 opens, the voltage from ⟨0⟩ to ⟨1⟩ will be approximately 19V D.C. and ⟨0⟩ to ⟨2⟩ will be approximately −27V D.C. The regulator will not operate in automatic.

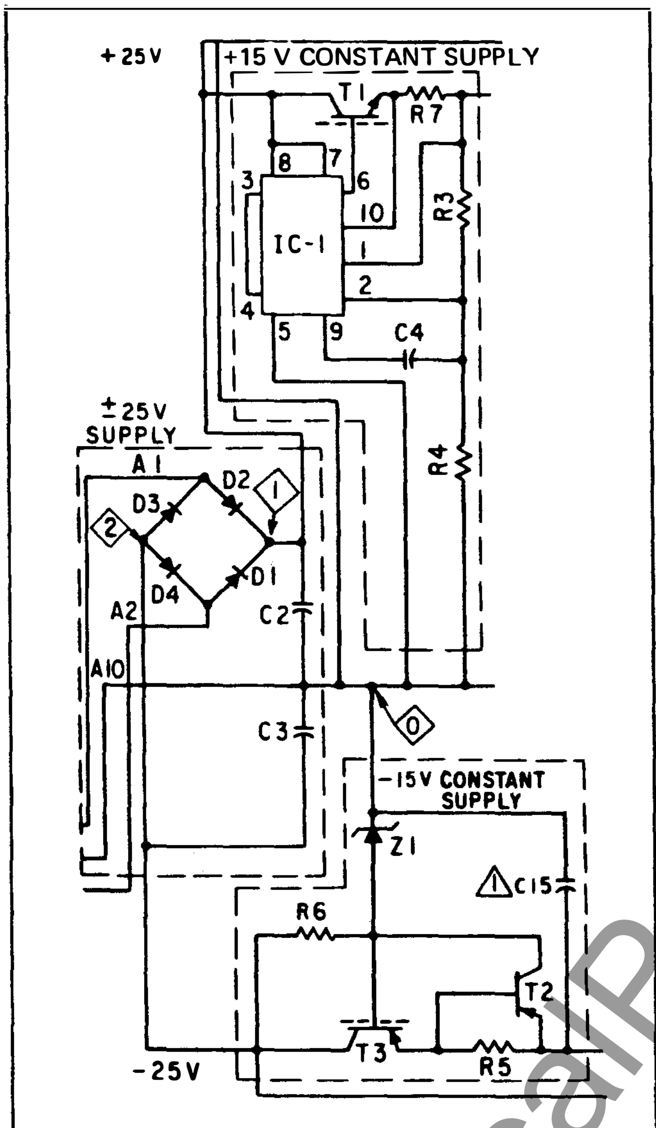


Fig. 6 ±25 volt D.C. supply and ±15 volt D.C. constant supply.

20.0 −15V AND +15V D.C. CONSTANT SUPPLIES (Fig. 6)

The basic power supply (D1 through D4, C2, C3) for the control circuit is a ±25 volt unconstant D.C. Some components in the circuit require a constant −15V D.C. and others require a constant +15V D.C.

20.1 **The −15V constant supply** consists of Z1, T3, and R6. The output of this supply is the Z1 voltage (16 volts) minus the voltage drop across the base to emitter junction of T3 and minus the drop across R5. This is equal to about −15 volts. The circuit load current flows through R5 and the emitter to collector of T3. Transistor T2 and R5 serve to limit the current through T3 in event of a short from the output to ground. With such a short the current through R5 reaches the base-emitter saturation of T2 then T2 turns on, T3 turns off and the full 25 volts appears across R6. Because of R6 the magnitude of the short circuit current is greatly diminished.

Capacitor C15 filters noise (high frequency ripple voltages) which prevents the noise from affecting the proper operation of the negative power supply. If C15 opens, no noticeable effect will occur; if C15 shorts the regulator will run to the maximum lower position.

If the base-emitter of T3 shorts, T3 will turn off and the load current will flow through R6. The panel will work correctly except the time delay will be slightly longer. If the base-collector shorts, 25 volts will be placed across Z1, Z1 will short and the regulator will run to the full lower position and raise operation in automatic will not be possible. If the collector-emitter of T3 shorts, raise operation will be O.K., but lower operation in automatic will not be possible. This short will cause Z1 to also short. If the base of T3 opens, the voltage from ◇0 to ◇3 will drop to approximately 11 volts, the band indicator will move to the upper limit and the control will not operate in automatic. If the collector opens, the control will operate as normal but the time delay will be slightly longer. If the emitter opens, the regulator will not operate in automatic.

If Z1 shorts, the regulator will run to the maximum lower position; raise operation in automatic will not be possible. If Z1 opens, the regulator will operate as normal except the time delay will be slightly longer.

A shorted or open R5 will have no noticeable effect on the control's operation.

20.2 **The +15V constant supply** consists of IC-1, T1, R7, R3, R4 and C4. IC-1 is a 10 pin integrated circuit constant supply. T1 acts as a constant current generator and R7 limits the available short circuit current. R3 and R4 act as voltage dividers to properly bias IC-1 while C4 filters noise. If correct voltage is measured from test points ◇0 to ◇1 but low voltage from ◇0 to ◇4 then check T1 for and open or short and R7, R3, and R4 for proper resistance values. Check C4 and C12 for a possible short. If the values are correct then IC-1 is probably faulty.

21.0 SENSING CIRCUIT
(Fig. 7)

21.1 OPERATION DESCRIPTION

The positive output from Z2 fed through RH-2 and R15 together with the negative output from rectifier bridge (D5, D6, D7, D8) through R14 and the negative input from R16 results in zero volts from Pin 2 of the differential amplifier to test point ⟨0⟩ under a balanced condition. Under this condition, the output of the amplifier should be zero. This may be checked by applying 120 volts into the control, setting the control level on 120 and measuring the voltage from ⟨0⟩ to ⟨7⟩. It is zero when the output of the Diff. Amp IC-2A is zero. If it is not zero, then RH-2 can be adjusted to make it zero. This is discussed in calibration section 11.0. When the regulator output increases, the voltage at Pin 2 of IC-2A becomes negative. The Diff. Amps. output becomes positive since the Diff. Amp. is connected in an inverted stage. An inverted connection means the varying input is always opposite in polarity to the output of the Diff. Amp. The magnitude of the Diff. Amp's output depends upon the magnitude of the voltage differential between its two inputs (Pins 2 and 3). Note the differential amplifier amplifies only the difference between Pins 2 and 3.

When the main line regulator output decreases, the voltage at Pin 2 becomes positive and the Diff. Amps. output goes negative.

A low voltage then on the output of the main line regulator will cause a negative IC-2A Diff. Amp. output voltage. A high voltage on the output of the main line regulator will cause a positive Diff. Amp. output voltage.

The differential amplifier amplifies the difference between its two inputs. Diff. Amp. IC-2A employs negative feedback with resistors R20, R22, and RH-3. Capacitor C9 acts as a filter to help eliminate ripple and noise. The output of the Diff. Amp. is fed back to the Pin 2 input. Since the output is opposite in polarity to the Pin 2 input this feedback (negative) will reduce the Pin 2 input's magnitude. By varying RH-3, the amount of feedback is varied, providing a means to vary the output of IC-2A. RH-3 is the bandwidth rheostat on the faceplate of the control.

21.2 A **shorted Z2** will result in only a negative voltage being applied to pin 2 of the Diff. Amp. This will cause a high positive voltage on the Diff. Amp's output which will run the regulator to the maximum lower position. Raise operation in automatic will not be possible.

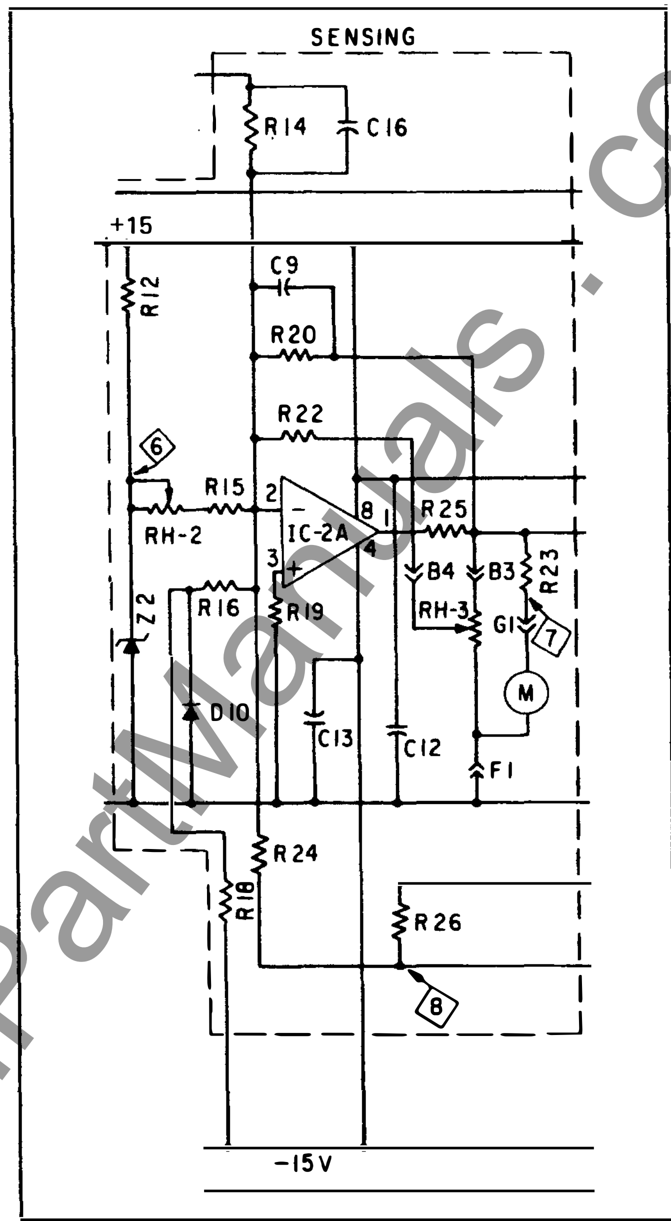


Fig. 7 Sensing circuit.

21.3 **An open Z2** will cause a positive voltage at pin 2 of the Diff. Amp. resulting in a negative output. The regulator will run to the maximum raise position. Lower operation in automatic will not be possible.

21.4 **An open RH-2 or R15** will result in only negative voltage being applied to the Diff. Amp's input

(Pin 2). This will cause a positive Diff. Amp. output running the regulator to the maximum lower position. Raise operation in automatic will not be possible. A shorted RH-2 or R15 will result in a positive voltage to the input of the Diff. Amp. causing a negative voltage on its output. The regulator will then maintain a higher output than set on the voltage level control.

21.5 **An open R12** will run the regulator to the maximum lower position, raise operation in automatic will not be possible. A shorted R12 will cause Z2 to short running the regulator to the maximum lower position.

21.6 **R16, R14**

The input to Pin 2 of the Diff. Amp. from R16 is negative since it is connected to the negative constant supply bus. If R16 opens, the voltage on Pin 2 of the Diff. Amp. will go positive causing a negative output on the Diff. Amp. This will result in the regulator maintaining a higher voltage output that is set on the voltage level control. If R16 shorts a high negative voltage will be added to the Diff. Amp's input running the regulator to the maximum lower position. Raise operation in automatic will not be possible.

If R14 opens the regulator will run to the maximum raise position. If R14 shorts it will run to the maximum lower position.

21.7 **Diode D10** is used to compensate the voltage changes of rectifier diodes D5 through D8 and capacitance changes of C5 and C6 due to temperature changes. If D10 shorts, the Diff. Amp's output will go negative causing the regulator to maintain a higher voltage level than is set on the control. If D10 opens, the regulator will run to the maximum lower position; raise operation in automatic will not be possible.

21.8 **R19** is a biasing resistor for the IC-2A Diff. Amp. If R19 opens, the Diff. Amp's output will go negative and the regulator will run to the maximum raise position. Lower operation will not be possible.

21.9 **IC-2A** is in the same package with IC-2B and both use the same +15 and −15 volt power supplies.

IC-2A may be checked by applying 120 VAC into the control. Set the bandwidth at 2 volts and the voltage level to 120 volts. If test point readings from ⟨4⟩ to ⟨0⟩ and ⟨3⟩ to ⟨0⟩ are correct then measure the voltage from pin 1 of IC-2A to test point ⟨0⟩. Approximately 0 volts should be measured. Turn the voltage level to 115 volts and if approximately plus 13 VDC is measured then turn the voltage level to 125 volts and if approximately minus 13 VDC is measured then IC-2A is functioning correctly. If one but not both of the above readings are incorrect then IC-2A is shorted. If IC-2A remains shorted for an adequate period of time C13 may short causing R5 and T2 to open. If both readings are incorrect then again set the voltage level to 115 volts. Measure the voltage from pin 2 to test point 0 and if more than minus .05 volts is measured then IC-2A is open.

21.10 **R20, R22, RH3, C9, C16**

Resistors R20, R22 and Rheostat RH3 are used for negative feedback across Diff. Amp. IC-2A. An open R20 or R22 will cause a decrease in bandwidth. With R20 or R22 shorted, no operation in automatic will be possible. An open RH3 will cause the bandwidth to decrease and with RH3 shorted, no automatic operation will be possible.

Capacitor C16 was added on panels after SN IJ201S01674. It was found that noise generated from motor relay contacts could sometimes cause the lower motor relay to "drop-out" after initial energization. By bundling and re-routing wires F1, B3 and B4, and adding C16, this noise problem was eliminated. If C16 opens, the problem as just described may occur. If C16 shorts, the regulator will run to the full lower position.

Capacitor C9 is used for additional filtering to help eliminate noise and ripple. If C9 shorts, the feedback into Pin 2 will increase and no automatic operation would be possible. If C9 opened, it would have little noticeable effect on the control except the bandwidth will slightly increase and the FR-R or GR-R relays will chatter with the voltage inside the bandwidth.

21.11 **R24, R26**

Once the motor relay circuit actuates, some means of holding the relay "in" is necessary to keep small input voltage fluctuations from de-actuating it. This is accomplished through contacts **FR-R** and GR-R. When contacts FR-R or GR-R closes, a voltage offset is supplied to the Pin 2 input of the IC-2A Diff. Amp. This is done by connecting the +15V or −15V power supply through resistor R24 to the amplifier input. Note the + power supply is connected also through R26 which makes the differential input voltage symmetrical for both a raise and lower operation. This is necessary because the positive and negative regulated power supply voltages are not equal. If R24 opens, the operation of the control will not be noticeably affected except the reed relays (FR-R or GR-R) may chatter when small input voltage variations occur. If R24 shorts, and the control senses a high or low voltage it will respectively run the regulator to the maximum lower or raise position.

If R26 opens, the control will not be affected noticeably except the reed raley GR-R may chatter when a low incremental voltage is detected by the control.

21.12 C13, C12

These capacitors act as additional filtering capacitors.

If C13 or C12 opens, no noticeable effect on the control will occur. If C13 shorts, the regulator will run to the maximum lower direction; raise operation will be impossible. If C12 shorts, no automatic operation will be possible.

21.13 R25, R23

Resistor R25 provides the output resistance of IC-2A. If R25 opens, no automatic operation will be possible. If R25 shorts, the bandwidth will decrease very slightly (.1v) otherwise the operation will not be affected.

Resistor R23 reduces the current to the band indicator meter to a useable value. If R23 opens, the indicator needle will not function. If R23 shorts, the band indicator needle will deflect "hard" to the upper or lower limit. The control will not function in automatic.

22.0 RELAY DRIVER CIRCUIT

(Fig. 8)

22.1 OPERATION DESCRIPTION

If the output of the differential amplifier is negative, Z3 Zener acts like an ordinary diode. Z4 Zener will not allow current to pass through it until the Diff. Amp. voltage output reaches the Z4 breakdown zener voltage. The reverse is true if the differential amplifier's output is positive.

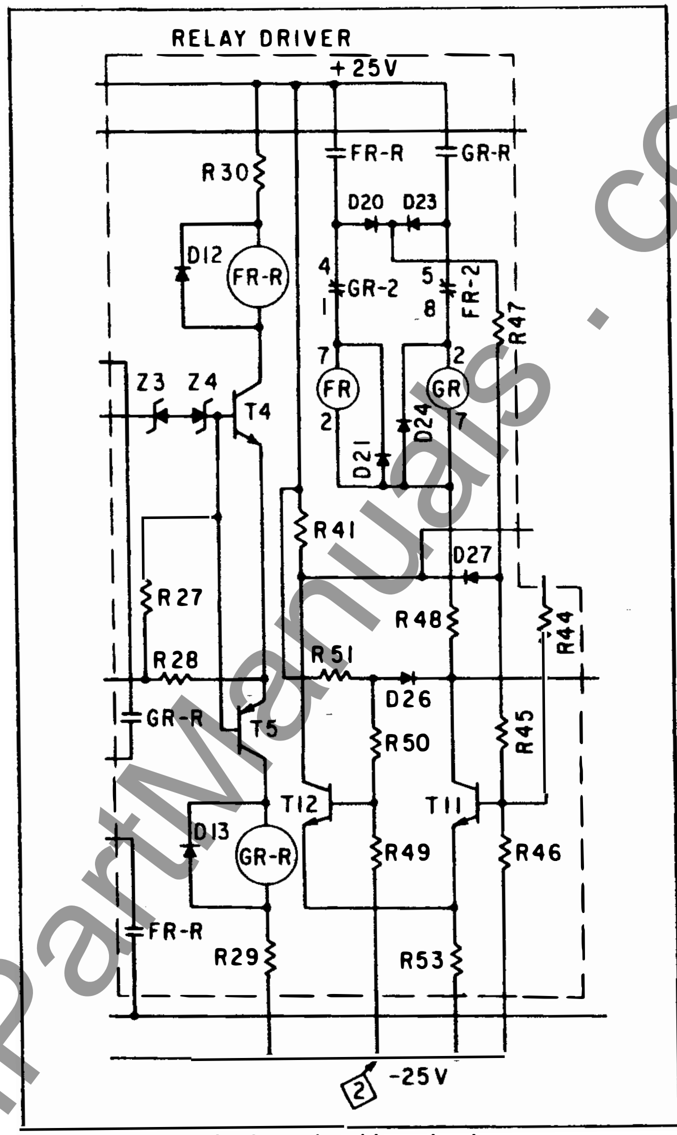


Fig. 8 Relay driver circuit.

When the Diff. Amp's output is sufficiently negative to breakdown Z4, T5 will turn on, current will flow through GR-R and the GR-R contacts will close.

When the amplifier's output is sufficiently positive to breakdown Z3, then T4 turns on, current flows through the FR-R relay and contacts FR-R will close. The next circuit to be actuated is the timer circuit which is described in the next section. After the timing circuit "times out", transistor **T11** turns on and sufficient current flows through either the FR or GR motor relay to actuate it. Which relay actuates depends on whether contact FR-R or GR-R is closed. When the motor relay actuates, contact GR-1 or FR-1 (not shown in Fig. 8) closes which actuates the tap changer motor.

Transistor T12 is normally on but when T11 turns on, T12 turns off and the timer circuit is immediately de-actuated. This is further discussed in Section 23.1.

22.2 **D20, D23**

When the FR-R or GR-R contact closes, positive bias is placed on the base of T11 through D20 or D23 respectively. This bias is not of sufficient magnitude to turn T11 on until a positive voltage from the timing circuit (once it times out) is received. These diodes also prevent current from flowing through both motor relays, FR and GR, once T11 turns on. If D20 opens, raise operation will be normal but lower operation in automatic will not be possible. If D23 opens, lower operation will be normal bur raise operation in automatic will not be possible. If D20 or D23 shorts, the wrong motor relay may actuate after the timing cycle is completed and the regulator will run to the full raise or lower position.

22.3 **D12, D13, D21, D24**

These diodes limit the voltage produced across the relay coils when the coils are initially energized. If D12 shorts, the control will not operate in the lower direction; if it opens, the control will still operate correctly. If D13 shorts, the control will not operate in the raise direction; if it opens, the control will still operate correctly.

If D21 shorts, raise operation is normal but lower operation would not be possible. If D24 shorts, lower operation would be normal but raise operation would not be possible. If either D21 or D24 opens the control will still function correctly.

22.4 **D26, D27**

D26 isolates the voltage at the collector of T11 during timing from the base of T12. This keeps T12 from turning off during the timing cycle. After timing T11 turns on and D26 conducts. Less current flows through R50 and R49. Less current through R49 causes the voltage on the base of T12 to decrease. T12 then turns off. If D26 opens, T12 will not stay on after the timing cycle. Since C11 has only partially discharged, the timing cycle will turn T11 back on. This will cause the motor relays to chatter and no automatic operation will be possible. If D26 shorts, no noticeable effect will occur except at extreme temperatures.

D27 prevents T11 from turning on during timing. After timing, D27 becomes reversed bias when T12 turns off. This keeps T11 on not allowing it to turn off until the FR-R or GR-R relay opens.

Resistors — **R41, R51, R50, R49, R53, R48, R45, R46, R44**

All these resistors act either as biasing resistors for their associated transistors, current limiting resistors or voltage divider resistors.

22.5 If **R41** opens, the timer will not reset to zero instantaneously after the circuit times out, but will decrease slowly. Therefore, when the voltage output of the regulator increases or decreases immediately after a preceding tap change, the regulator will operate much sooner than the time delay setting. If R41 shorts, it will burn out T12 and the regulator will not operate in automatic.

22.6 If **R51** opens, T11 will turn on immediately after the regulator output voltage goes outside the bandwidth. There will be no time delay before motor relay operation.

If R51 shorts, the base emitter of T11 will open and the regulator will not operate in automatic.

22.7 **R50, R49**

If R50 opens, T12 will turn off and T11 will be turned on each time the FR-R or GR-R relay is actuated. The result is no time delay before motor relay operation. If R50 shorts, T11 will turn on and T12 will turn off but immediately will turn back on turning T11 back off. The result is the motor relay will turn on but then immediately turn off. The time delay will again time-out and the relay will again turn on and then turn off. This cycle will continue.

If R49 opens, no noticeable effect will occur. If R49 shorts, T11 will turn on and no time delay will occur before relays FR or GR turn on.

22.8 If **R53** opens, relays FR and GR cannot operate resulting in no regulator operation in automatic. If R53 shorts, no noticeable effect will occur.

22.9 If R48 opens, no operation in automatic is possible. If R48 shorts, no noticeable effect will occur.

22.10 If R45 opens, T11 will not turn on and no operaation in automatic is possible. If R45 shorts, T11 will be turned on and no time delay will occur before relays FR or GR turn on.

22.11 If R46 shorts, T11 cannot turn on and the control will not operate in automatic. If R46 opens, the control will operate normally.

22.12 If R44 shorts, the bandwidth will increase; otherwise, the control will work normally. If R44 opens T11 cannot receive the base drive to turn it on; therefore, the control will not work in automatic.

22.13 T11 – If the base to collector shorts, the control will have no time delay. If the base to emitter shorts, the control will not operate in automatic. If the base, collector or emitter opens, no operation in automatic will be possible.

If the collector to emitter shorts, the control will have no time delay.

22.14 T12 – If the base to collector of T12 shorts, T11 will not stay on after the time delay is completed. Since T13 is not turned on, C11 will only slightly discharge and will turn T11 back on. The result is the motor relays chatter. If the base to emitter shorts, T12 will turn off which biases T11 on; therefore, no time delay will occur before the relays FR or GR "turn on".

22.15 **Z3, Z4**
If Z3 or Z4 shorts the bandwidth will decrease to one half its value. If Z3 or Z4 opens no operation in automatic will be possible.

22.16 **FR-R, GR-R, FR, GR**
If the FR-R or FR relay coil opens or shorts lower automatic operation will be impossible. If GR-R or GR relay coil opens or shorts raise automatic operation will be impossible.

22.17 **R28, R27**
If R28 opens the emitter bias on T4 and T5 is removed and no automatic operation is possible. If R28 shorts no noticeable effect will occur but T4 or T5 may eventually short or open. If R27 opens no noticeable effect will occur but if R27 shorts the control will not operate in automatic.

22.18 **R30, R29, T4, T5**
If R30 opens the control will not function in the automatic lower direction. If R30 shorts it may burn open T4.

If R29 opens the control will not function in the automatic raise direction. If it shorts it may burn open T5.

If the base to collector of T5 shorts the regulator will run to the full raise position. If the base to emitter of T5 shorts the regulator will not operate in automatic. If the base, emitter or collector opens the regulator will not operate automatically in the raise direction.

If the base to collector of T4 shorts the regulator will run to the full lower position. If the base to emitter shorts or if the base, collector or emitter opens the regulator will not operate automatically in the lower direction.

23.0 STATIC TIMER CIRCUIT
(Fig. 9)

23.1 OPERATION DESCRIPTION
Once the FR-R or GR-R contact closes, a base drive to T6 is supplied through the FR or GR coil, R48 and R31. When T6 turns on, T7 turns off. Capacitor C11 cannot charge when T7 is on (which is its normal mode) because T7 bypasses the current around C11. Once T7 turns off, capacitor C11 charges and supplies input to Pin 6 of the Diff. Amp. IC-2B through T8.

Transistor T8 is connected as a low leakage diode to prevent IC-2B leakage current from flowing into C11. The voltage on C11 increases at a set rate until it exceeds the voltage on Pin 5 set by time delay potentiometer RH4. The Diff. Amp. will then reverse its output from a positive 15 volts to a negative 15 volts, then T10 will turn on providing a positive base drive to T11. Transistor T11 then turns on and T12 turns off providing an input to T13 through R41 and R52 which then rapidly discharges C11 and resets IC-2B and T10 to their

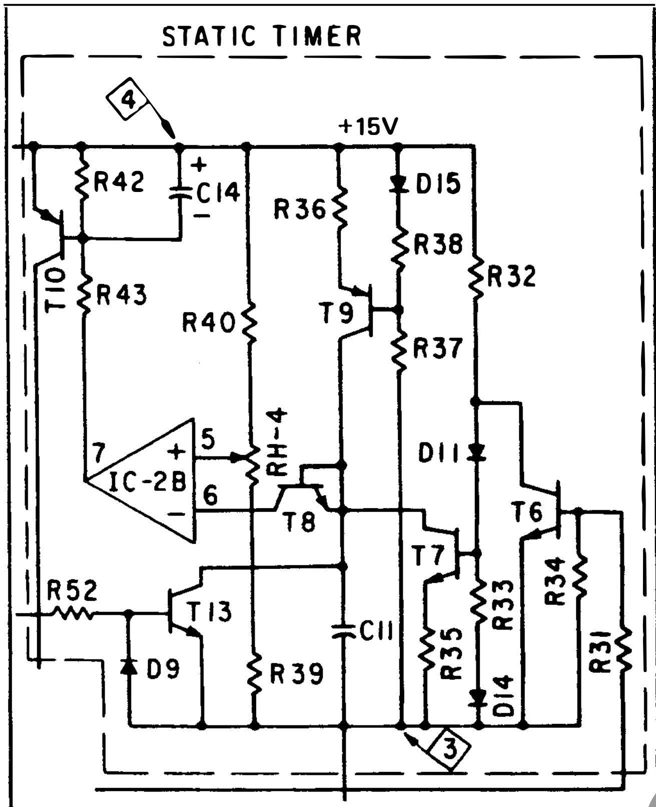


Fig. 9 Static timer circuit.

original state. Note this occurs almost instantaneously and one would not be able to measure the negative 15 volts on the output of IC-2B with a standard voltmeter. T11 remains on even though T10 turned off because of the base collector bias change on T11 when T12 turned off. T11 remains on until the GR-R or FR-R relay opens, removing the base drive on T11.

R31, R34, R32, R33, R35, R38, R37, R36, R40, R39, R42, R43, R52

All these resistors act either as biasing resistors for their associated transistors, current limiting resistors or voltage divider resistors.

23.2 If **R31** opens, T6 cannot turn on and the control will not operate in automatic. If **R31** shorts, no noticeable effect will occur until T6 burns out.

23.3 If **R34** opens, the regulator will operate normally. If R34 shorts, the base to emitter of T6 is effectively shorted and T6 will not turn on. The control then would not time-out and no operation in automatic would be possible.

23.4 If **R32** opens, T7 would turn off, capacitor C11 would be charged at all times resulting in very short time delay regardless of the setting. If R32 shorts, the control will still function normally until T6 burns out.

23.5 If **R33** opens the base of T7 will be at +15 volts turning it off and capacitor C11 will charge. This will result in a very small time delay regardless of the setting. If **R33** shorts, the base of T7 will be negatively biased with respect to the emitter turning T7 off. Capacitor C11 would then be constantly charged resulting in almost no time delay regardless of the setting.

23.6 If **R35** opens, T7 would turn off allowing C11 to be constantly charged resulting in almost no time delay. Capacitor C11 normally slowly discharges through T7. When the voltage moves outside the bandwidth, capacitor C11 begins charging. If the voltage moves back into the bandwidth, then C11 discharges slowly through T7 and R35. This provides an integrating time delay. If **R35** shorts, the control will function normally except without an integrating time delay.

23.7 If **R38** opens, the base drive to T9 is removed turning T9 off. Transistor T9 acts as a constant current supply for C11 but when T9 turns off, C11 cannot charge. This results in an infinite time delay and the regulator would not operate in automatic. If **R38** shorts, the base to T9 would become positive biased with respect to the emitter turning T9 off. C11 would not charge and the regulator would not operate in automatic.

23.8 If **R37** opens, T9 turns off, C11 cannot charge and the regulator will not operate in automatic. If R37 shorts, T9 is again biased to turn off and the regulator will not operate in automatic and T9 will burn out.

23.9 If **R36** opens, C11 cannot charge and the regulator will not operate in automatic. If **R36** shorts, C11 will charge rapidly resulting in a decreased time delay and burning out T9.

23.10 **If R40** opens, Pin 5 on the IC-2B will decrease in potential value, C11 will not have to charge to as high a positive potential before it exceeds the voltage on Pin 5. This will cause the time delay to be greatly reduced. If R40 shorts, the inverse to the above is true and the time delay will be extended when it is set above 90 sec. With the delay set below 90 sec. a R40 shorted will have little effect.

23.11 **If R39** opens, the voltage on Pin 5 of the Diff. Amp. is equal to the voltage supply of C11; therefore, C11 can never charge to a value to exceed the voltage on Pin 5. The control will not time out and automatic operation will not be possible.

If R39 shorts, the voltage on Pin 5 of the IC-2B Diff. Amp. will decrease and the time delay will be reduced slightly at the lower time delay settings.

23.12 **If R42** opens, transistor T10 is still biased correctly therefore, no difference in control operation will be noticed. If R42 shorts, transistor T10 becomes incorrectly biased and cannot turn on to turn T11 on to actuate the motor relays. The control will then not function in automatic.

23.13 **If R43** opens, T10 cannot turn on and the control will not function in automatic. If R43 shorts, the control will function normally.

23.14 **If R52** opens, T13 cannot reset C11 to zero volts after the motor is energized and the time delay will be shortened between successive time cycles at short intervals. If R52 shorts, T13 will turn on, not allowing C11 to charge. The control will not time out and automatic operation would not be possible.

23.15 **T6** is normally off but when either the FR-R or GR-R contact closes, T6 turns on. T6 is then biases T7 to turn off. If the base or collector or emitter of T6 is opened, T6 cannot turn on and the control will not function in automatic. If the base to collector shorts, T6 conducts and T7 turns off. This results in the control having practically no time delay.

23.16 **T7** is normally on and slowly discharges C11 through R35. This provides the integrating action of the time delay. If the base or collector or emitter opens, T7 turns off allowing C11 to stay charged resulting in the control having practically no time delay. If the base to collector shorts, C11 cannot charge and the control will not operate in automatic. If the base to emitter shorts, T7 turns off, C11 stays charged and the control has practically no time delay.

23.17 **T9** is the constant current supply for the timing capacitor C11. If the base or emitter or collector opens, C11 has no supply voltage to charge. Therefore, the control will not operate in automatic. If the base to collector shorts, C11 will rapidly charge resulting in no time delay. If the base to emitter shorts, T9 turns off and C11 cannot charge and the control will not operate in automatic.

If the collector to emitter shorts, C11 will charge immediately and there will be no time delay.

23.18 **T8** has its base and emitter shorted together allowing T8 to act as a low leakage diode preventing IC-2B leakage currents from entering capacitor C11. If the base, collector or emitter opens, the capacitor voltage of C11 will never be seen by the IC-2B Diff. Amp. resulting in the control not operating in auto-automatic.

23.19 **T10** is normally off since its base is reversed biased. When the voltage on Pin 6 of IC-2B exceeds the voltage on Pin 5, then IC-2B reverses its output from positive to negative putting a negative bias on T10.

T10 then turns on and turns T11 on allowing sufficient current to flow through relay GR or FR to actuate it. If the base or emitter or collector of T10 opens, T10 cannot be turned on and the control will not operate in automatic. If the base to collector shorts, T11 stays turned on and the control will have no time delay. If the base to emitter shorts, T10 will not turn on and the control will not operate in automatic.

23.20 **T13** is normally off and is biased to turn on when T12 turns off. T13 discharges C11 after each timing cycle. If the base or collector of T13 opens, **T13** will not turn on resulting in a shorter time delay with successive timing cycles. If the base to collector shorts, C11 cannot charge and the regulator will not operate in automatic. If the base to emitter shorts, or the base, emitter or collector opens, C11 will not instantaneously discharge to zero volts after each timing cycle. This results in a reduced time delay between successive operations.

23.21 **D14, D11, and D15**
D11, D14 and D15 are temperature compensator diodes.

With increase in temperature, Diodes reduce their forward voltage drop rather than increase it as normal components do. This allows proper temperature compensation of transistors over a wide temperature range. If D11 is shorted, no noticeable effect will occur. If D14 is shorted, there will be a slightly longer time delay. A shorted D15 will result in nearly twice the time delay.

If Diode D11 or D14 opened, T7 would turn off, C11 would charge and the control would have practically no time delay. If D15 opened, T9 would turn off, C11 could not charge and the control would not operate in automatic.

23.22 **D9** protects the base emitter of T13. If D9 opened, no noticeable effect would occur. If D9 shorted T13 could not turn on and the capacitor would not immediately discharge after the timing cycle resulting in a shorter time delay with successive timing cycles.

23.23 **IC-2B**

This differential amplifier is in the same container with IC-2A and both use the plus and minus 15 volt DC power supplies. Note that this supply is not shown on the IC-2B schematic for simplification. IC-2B switches its output from approximately +15 volts to −15 volts when the voltage on Pin 6 exceeds that on Pin 5. If IC-2B internally shorts or opens such that its output does not switch, T11 will not turn on and the control will not function in automatic. If IC-2B internally shorts, or opens such that its output is always negative, then T11 will remain on and the control will have no time delay.

24.0 MOTOR RELAYS GR AND FR

(Refer to Fig. 12)

These are the power relays that energize the tap changer motor. A relay with an open coil will prevent the control from automatically operating the regulator. This is easily determined by exchanging the two power relays or plugging in a good relay to find the faulty one. If a relay should get stuck in the energized position, when there is no coil voltage, it will run the regulator until the voltage gets outside the band limit to energize the other relay and result in motor lockout. FR is the lower motor relay and GR is the raise motor relay.

25.0 GENERAL SERVICING NOTES

25.1 Test point readings should be made with a good multimeter or preferably a **vacuum tube voltmeter (VTVM).** The advantage of a VTVM is that it has a very high input impedance and doesn't load the circuit. When voltage testing across components such as transistors, only a VTVM meter is recommended.

When checking test points ⟨8⟩ to ⟨0⟩ and the control has sensed a low voltage, a voltmeter other than a VTVM will measure less than 1.5 V DC. If the correct voltage from test point ⟨0⟩ to ⟨4⟩ is obtained and ⟨0⟩ to ⟨8⟩ does not measure zero then the panel is working correctly.

25.2 Whenever making **ohmmeter measurements,** be sure panel is de-energized and be sure the meter's output voltage does not exceed 5 volts when applied base to emitter on transistors.

25.3 Component **leads** in this control **are coated with a clear acrylic resin.** Therefore, when checking, make sure meter lead probes penetrate this coating to assure good contact.

25.4 **Semiconductor material** is hard and brittle and components in this control are hermetically sealed. Dropping these semiconductors or rough handling of semiconductor leads can fracture the semiconductor material.

25.5 **Bending wire leads back and forth** several times will usually cause it to break or fracture. Transistor leads are especially sensitive to bending where the leads enter or attach **to** the semiconductor and caution should be taken to try to keep sharp lead bends approximately 1/8" away from the transistor body.

25.6 **When unsoldering** or removing a component in this control, a **heat sink should be used** between the point being soldered and the body of the electronic component to be removed. Also, a sink should be connected to the adjacent component lead. The heat sink may consist of needle nose pliers or an alligator clip. Keep the heat sink on the lead while soldering and for a few seconds after.

25.7 When checking the **diode,** make sure the meter leads make good contact with the diode leads. An ohmmeter R x 10,000 scale will show the diode forward and reverse resistance. In general, low resistance should be read in the forward direction and high resistance in the reverse.

NOTE: The resistance reading changes as the ohmmeter scale is changed since a different battery supply is used.

25.8 The current through a capacitor varies directly with the change in voltage across it. Ideally, if there is no change in voltage across it, no current flow will occur. Capacitors are rated in farads which is a measure of its ability to store charge and is the proportionality constant between current and voltage change.

Capacitors vary widely in type for particular applications and are classified by naming the dielectric medium, example, mica capacitor. Types of capacitors available are air, gas, mica, ceramic, glass, oil and oil impregnated paper type. One additional important class of capacitors is the electrolytic type. An oxide film is usually formed on aluminum by electrolytic means. This film acts as a cathode and the aluminum as an anode forming a electrolytic capacitor. Controls usually use polarized (or direct current) electrolytic capacitors and since electrolytic capacitors should be used with current flow in only one direction, caution should be taken when replacing these polarized capacitors to be sure the plus and minus terminals are inserted in the same orientation they were removed. A capacitor may be tested to determine if opened or shorted by the following procedure.

1. Discharge the capacitor by shorting across its terminals.
2. Disconnect or isolate one of the capacitor's leads from the other circuitry.
3. Turn the switch on the ohmmeter to the highest ohms scale.
4. Connect the ohmmeter leads directly across the capacitor.
   a. If the ohmmeter needle deflects and remains at zero or near zero ohms, the capacitor is probably shorted.
      NOTE: Capacitors more frequently short than open.
   b. If the ohmmeter needle never deflects and continually indicates an infinite resistance, the capacitor is probably open.
      NOTE: If the meter's scale is not high enough, the capacitor may appear open even though it is good.
   c. If the ohmmeter needle deflects toward zero, returns toward an infinite resistance but does not "hold" and drops back a few ohms, the capacitor is probably "leaking". If suspected leaking compare its value to a good capacitor of equal rating.
   d. If the ohmmeter needle deflects toward zero and rapidly returns toward an inifnite resistance and holds the value, it is probably good.

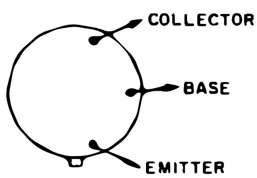
25.9 Resistors employed in the IJ-2 are either wire wound or metal film low temperature co-efficient types which insure little or no change in resistance throughout the life of the control. A resistor's function is to oppose or resist the flow of current through it. This results in a voltage drop across it directly proportional to the current through it. Resistors malfunction by shorting or opening but usually the latter. The exact resistor resistance may be tested with an ohmmeter and usually disconnecting one lead from the printed circuit is advisable since the resistor is usually in parallel with other circuits. Many resistors are color coded to indicate their resistance value. The band nearest the end gives the first figure of the resistance, the next is the second figure and the third gives the number of zeros to be added after the first two figures. The fourth gives the tolerance.

COLOR CODE	TOLERANCE
1 — Brown	Silver ±10%
2 — Red	Gold ±5%
3 — Orange	No fourth Band ±20%
4 — Yellow	
5 — Green	
6 — Blue	
7 — Violet	
8 — Gray	
9 — White	
0 — Black	

25.10 **A REACTOR OR COIL** resists the change of current through it. The voltage drop across it is in direct proportion to the rate of change of current through it. Reactors malfunction by opening or shorting and may be tested with an ohmmeter. An infinite resistance indicates an open and a very low resistance may indicate a short.

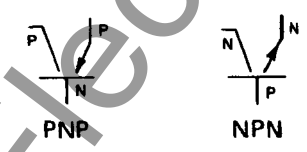
25.11 **Zener Diodes** are usually operated reversed biased in their "breakdown" region. As current varies through it the voltage drop across it stays approximately constant when operated in this manner. Zener diodes have a high resistance in the reversed biased direction and a low resistance in the forward biased direction. Since Zener Diodes usually partially short or partially open a resistance measurement may not determine whether the zener is good or bad unless comparative readings from a good zener are made. The best general method is to measure the voltage across it and compare it to what it should be. The voltage across Z2 should be within (5.89 - 6.51) volts DC and the voltage across Z1 should be within (14.25 - 15.8) volts DC. The voltage across Z4 should be 8.25 volts DC, ±5% during the raise operation and the voltage across Z3 should be 8.25 volts DC, ±5% during the lower operation.

25.12 **Transistors** are semiconductor devices used primarily for switching or power amplification. Three leads protrude from the transistor body and, looking from the transistor's base, has the following physical location:

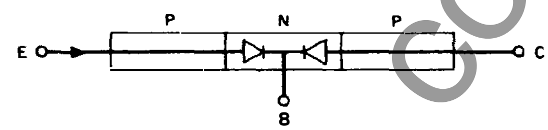


A transistor is made of two types of semiconductor materials. One type ("N" type) has an excess of electrons and the other types ("P" type) has a deficiency of electrons. By mating these materials to each other a junction is formed which has a high resistance to the flow of current through it in one direction (N to P) and a low resistance to the flow of current in the other direction (P to N). Transistors are mated either in a P-N-P or an N-P-N configuration.

In the transistor symbol, the arrow is always on the emitter lead and always points toward the "N" type material which is the direction of conventional current flow. If the arrow points inward the transistor is type PNP and if it points outward it is type NPN.



A transistor is termed "off" when the proper polarity base to emitter or base to collector saturated voltage level has not been reached. This voltage is usually less than 1.5 volts, but varies for different transistors. This means approximately zero current will flow from emitter to collector. A transistor termed "on" signifies the emitter to base and collector to base are voltage saturated and current can flow from collector to emitter or vice versa according to the direction of the emitter arrow. Base currents are usually very small and function only to turn the transistor on.

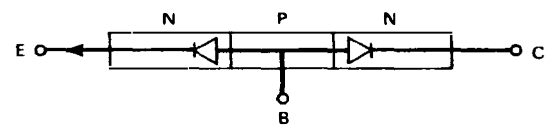


When testing a transistor, a mental image as follows simplifies the procedure.

Place the + ohmmeter lead on the emitter and the – lead on the base. The emitter to base should act like an ordinary diode and a low resistance reading should be obtained. Reverse the leads and a high resistance should be obtained.

CAUTION: Emitter to base maximum voltage on transistors in the IJ-2 is around 5 volts. When making ohmmeter readings, check to be sure this voltage is not exceeded. A resistance scale R x 100 or above is usually safe.

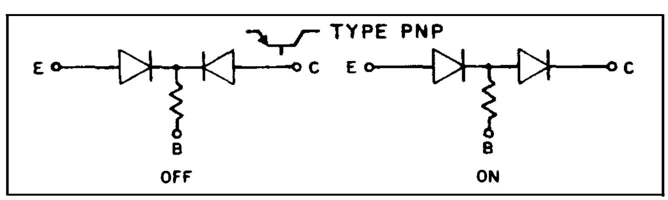
Test the collector to base junction by placing the + ohmmeter lead on the collector lead and the – lead on the base. A low resistance should be read. Reverse the ohmmeter leads and a high resistance should be read.

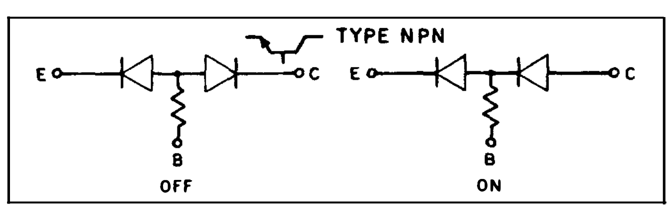


The NPN is tested in reverse to the PNP.

If a leaking transistor is suspected, comparative resistance readings on a good transistor with the same type identification number should be made.

NOTE: In understanding the transistors operation in the circuit, a mental image as follows could be used.



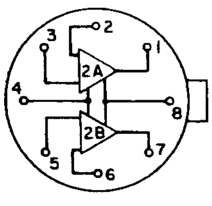


Remember base-emitter or base-collector current is very small whether on or off.

Transistors turned on have a lower emitter to collector voltage than transistors turned off. By placing a voltmeter from collector to emitter, one may determine if a transistor is on or off.

25.13 DIFFERENTIAL AMPLIFIER IC-2A and IC-2B
The above Diff. Amps. are constructed on a single monolithic chip and encapsulated in the same container as shown below:

T–PACKAGE
TOP VIEW



1. Output A
2. Inverting Input A
3. Noninverting A
4. V–
5. Noninverting Input B
6. Inverting Input B
7. Output B
8. V+

Diff. Amps. in the IJ-2 control may be damaged by applying excessive voltage (above 15 volts) from pin to pin (1-2-3) or (5-6-7) or reversing the power supply polarity on pins (4 and 8). Only a + supply should be connected to Pin 8 and only a — supply to Pin 4.

25.14 **IC-1** is a monolithic precision constant voltage supply, temperature and frequency compensated. If the voltage from test point ⟨0⟩ to ⟨4⟩ varies outside of (15 to 17) volts DC the constant supply may be bad. NOTE: Using a meter other than a VTVM may give indication of a faulty IC when it is actually good.

25.15 Power relays which energize the motor circuit are 24 V DC relays with contacts rated 10 amperes AC. These contacts interrupt currents which are only a fraction of their rating thus assuring long contact life.

25.16 When components are replaced, use only resin core solder (under no circumstances can acid core solder be used) and respray these connections with a clear acrylic resin made for electronic equipment.

CAUTION: DO NOT SPRAY CALIBRATING RHEOSTATS, COVER THE OPENINGS.

26.0 TROUBLE SYMPTOMS AND PROBABLE CAUSES

Trouble symptoms with probable causes are listed below for quick solutions to trouble in panel operation. This table does not include all possible causes and a thorough understanding of the previous reference material, especially section 8, will allow you to make a more comprehensive analysis of the trouble. (Note: All test point readings should be within ± 1 V DC). The voltage level setting should be 120 volts, bandwidth setting 2 volts and the input voltage 120 volts unless otherwise noted under the test condition.

TEST CONDITION–ABBREVIATIONS

- N denotes a Null (input is 120 volts)
- O denotes Outside either limit (input is less than 119 volts or more than 121 volts)
- OL denotes Outside Lower Bandlimit (input is less than 119 volts)
- OU denotes Outside Upper Bandlimit (input is more than 121 volts)
- T denotes during Timing
- AT denotes After Timing
- R denotes motor Relay is energized
- A Any condition

26.1	**Manual Operation OK But No Automatic Operation is Possible**					
26.1.1	No voltage on voltmeter test terminals	Fuse Blown	Voltmeter test terminals	N	120 V AC	0 V AC
		Wire Broken	Voltmeter test terminals	N	120 V AC	0 V AC
		Voltage Source Switch Faulty	Voltmeter test terminals	N	120 V AC	0 V AC
26.1.2	Normal voltage on voltmeter test terminals but the sensing transforme is not energized as indicated by no voltage across S1-NO or/and A1-A2	Voltage level switches faulty	S1-NO	N	50.5 V AC	0 V AC
		Wires to level switches broken	S1-NO	N	50.5 V AC	0 V AC
		Sensing transformer open	A1-A2	N	40 V AC	0 V AC
26.1.3	Voltage across test points ⟨4⟩⟨0⟩ is less than 10 V DC. Other test point voltage normal.		⟨4⟩⟨0⟩	N	15 V DC	7.5 V DC
		R7 Open	Across R7	N	.1 V DC	.8 V DC
		C4 Shorted	Across C4	N	10 V DC	0 V DC
		C12 Shorted	Across C12	N	15 V DC	0 V DC
			⟨4⟩⟨0⟩	N	15 V DC	0 V DC
		R3 Shorted	Across R3	N	8 V DC	0 V DC
		R4 Open	Across R4	N	7 V DC	7.5 V DC
26.1.4	Voltage across test points ⟨4⟩⟨0⟩ about normal but ⟨2⟩⟨0⟩ and ⟨3⟩⟨0⟩ voltages are below normal		⟨2⟩⟨0⟩	N	25 V DC	8 V DC
			⟨3⟩⟨0⟩	N	15 V DC	6 V DC
		D3 Shorted	Across D3	N	25 V DC	0 V DC
		D4 Shorted	Across D4	N	25 V DC	0 V DC
			⟨2⟩⟨0⟩	N	25 V DC	18 V DC
			⟨3⟩⟨0⟩	N	15 V DC	12 V DC
		C3 Open	Across C3	N	25 V DC	18 V DC
26.1.5	Voltage across test points ⟨2⟩⟨0⟩ and ⟨3⟩⟨0⟩ are normal but ⟨1⟩⟨0⟩ and ⟨4⟩⟨0⟩ voltages are below normal		⟨1⟩⟨0⟩	N	25 V DC	8 V DC
			⟨4⟩⟨0⟩	N	15 V DC	6 V DC
		D1 Shorted	Across D1	N	2.5 V DC	0 V DC
		D2 Shorted	Across D2	N	2.5 V DC	0 V DC
			⟨1⟩⟨0⟩	N	25 V DC	0 V DC
			⟨4⟩⟨0⟩	N	15 V DC	2 V DC
		C2 Shorted	Across C2	N	25 V DC	0 V DC
			⟨1⟩⟨0⟩	N	25 V DC	18 V DC
			⟨4⟩⟨0⟩	N	15 V DC	12 V DC
		C2 Open	Across C2	N	25 V DC	18 V DC
26.1.6	Relays GR and FR chatter after out	D26 Open	Across D26	N	0 V DC	11 V DC
				T	37 V DC	0 V DC
		T12 Base to collector shorted	Top of R49 to top of D27	N	0 V DC	0 V DC
				R	48 V DC	0 V DC
		T12 Collector to emitter shorted	Top of D27 to RHS of R53	N	0 V DC	0 V DC
				T	0 V DC	0 V DC
				R	48 V DC	0 V DC

[illegible]	[illegible]	[illegible]	[illegible]	TEST CONDITION	VOLTS NORMAL	VOLTS FAULTY
26.2	Control Hunts About a Certain Voltage	Z3 Shorted	Across Z3	O	8.2 V DC	0 V DC
		Z4 Shorted	Across Z4	O	8.2 V DC	0 V DC
26.3	Relays FR & GR Do Not Operate After Time Out (all test point readings are normal)	R50 Shorted	Across R50	N	8.5 V DC	0 V DC
		R44 Open	Across R44	N	0 V DC	.5 V DC
				O	0 V DC	.5 V DC
				AT	0 V DC	39 V DC
		T10 Collector, Emitter, or Base open	Across R43	N	0 V DC	0 V DC
				AT	0 V DC	27 V DC
		R43 Open	Top of R43 to test point "0"	O	15 V DC	15 V DC
				AT	15 V DC	12.5 V DC
		R39 Open	Across R39	A	3.5 V DC	39 V DC
26.4	Will Not Time Out To Energize Relays FR and GR With Normal Voltage at Test Points ⟨8⟩⟨0⟩ When Out of Bandlimits	R47 Open	Across R47	N	7 V DC	21 V DC
				T	64 V DC	54 V DC
		R48 Open	Across R48	N	0 V DC	22 V DC
				O	0 V DC	22 V DC
				R	16 V DC	37 V DC
		R53 Open	Across R53	N	1 V DC	10 V DC
				O	1 V DC	14 V DC
		R46 Shorted	Across R46	O	.8-1.5 V DC	0 V DC
		R45 Open	Across R45	O	.5-1.0 V DC	0 V DC
		T11 Base to emitter open or base open	Top of R46 to RHS of R48	N	0 V DC	0 V DC
		Collector of T11 open	Across D26	N	0 V DC	0 V DC
				O	0 V DC	0 V DC
				T	37 V DC	0 V DC
		C11 Shorted	Across D9	A	.5 V DC	0 V DC
		R40 Shorted (Time delay above 90 sec.)	Across D40	A	2.25 V DC	0 V DC
		R36 Open or T9 emitter open	Top of R36 to RHS of C11	N	27 V DC	18.5 V DC
		D15 Open	Across D15	N	.75 V DC	28 V DC
		R38 Open	Across R38	A	1 V DC	36 V DC
			Across D15	A	.75 V DC	0 V DC
		R37 Open	Across R37	N	28 V DC	33 V DC
			Across D15	N	.75 V DC	4.5 V DC
		R38 Shorted	Across R38	N	1 V DC	0 V DC
		T7 Collector to emitter shorted	Top of R35 to RHS of C11	N	0 V DC	0 V DC
				O	Gradually Increases	Constant
			Across R35	N	1 V DC	.5 V DC
		T7 Base to Collector Shorted	Top of R33 to RHS of C11	N	.5 V DC	0 V DC
				O	Gradually Increases	Constant
		R31 Open	Across R34	N	0 V DC	0 V DC
				O	.75 V DC	0 V DC
			Top of R32 to top of R31	N	2.25 V DC	2.25 V DC
				O	0 V DC	2.25 V DC
		R34 Shorted	Across R34	N	0 V DC	0 V DC
				O	.75 V DC	0 V DC

		Base to emitter of T6 Shorted	Top of R32 to top of R31	N O	2.25 V DC 0 V DC	2.25 V DC 2.25 V DC
		Base of T6 open	Top of R32 to bottom D14	N O R	2.25 V DC .5 V DC 1.5 V DC	2.25 V DC 2.25 V DC 2.25 V DC
			Across R34	N O	0 V DC .75 V DC	0 V DC 1.25 V DC
		Collector of T6 open	Top of R32 to bottom D14	N O R	2.25 V DC .5 V DC 1.5 V DC	2.25 V DC 2.25 V DC 2.25 V DC
			Across R34	N O	0 V DC .75 V DC	0 V DC .5 V DC
26.5	**Will Not Energize FR-R or GR-R Relays As Indicated By Low Voltage (About 7.5 V DC) On Test Points (8)(0)**		(8)(0)	O	15-16 V DC	0 V DC
		R28 Open	Across R28	O	.5-.75 V DC	15-30 V DC
		R27 Shorted	Across R27	O	1.5 V DC	0 V DC
		Z3 Open	Across Z3	OL	8.2 V DC	0 V DC
		Z4 Open	Across Z4	OU	8.2 V DC	0 V DC
		C7 Open	(8)(0) Across C7	O O	15-16 V DC 1 V DC	7.5 V DC 1 V DC
		R22 Shorted	(8)(0) Band Indicator	O O	15-16 V DC Movement	0 V DC No Movement
		R20 Shorted	Across R20	O	11 V DC	0 V DC
		C9 Shorted	Across C9	O	11 V DC	0 V DC
		R25 Open	Across R25	O	1-3 V DC	13-15 V DC
26.6	**Control Runs Regulator to Lowest Position, Raise Operation Not Possible**					
26.6.1	(5)(0) Test point voltage higher than normal	R8 Shorted	(5)(0) Across R8	N N	16 V DC 33.5 V AC	30 V DC 0 V AC
		R9 Shorted	(5)(0) Across R9	N N	16 V DC 15 V AC	22 V DC 0 V AC
		C5 Open	(5)(0) Across C5	N N	16 V DC 29 V AC	20 V DC 34.5 V AC
		C6 Open	(5)(0) Across C6	N N	16 V DC 20 V AC	25 V DC 29 V AC
26.6.2	Test point (3)(0) Voltage zero		(3)(0)	N	15 V DC	0 V DC
		R6 Open	Across R6	N	9.5 V DC	25 V DC
		C15 Shorted	Across C15	N	15 V DC	0 V DC
		C13 Shorted	Across C13	N	15 V DC	0 V DC
26.6.3	Test point (3)(0) voltage below normal	R5 Open	(3)(0) Across R5	N N	15 V DC 0 V DC	8 V DC 23 V DC
26.6.4	Test points (3)(0), (4)(0), (5)(0) voltages normal	R18 Shorted	Across R18	O	14 V DC	0 V DC
		R 16 Shorted	Across R16	O	.75 V DC	0 V DC
		D10 Open	Across D10	O	.5 V DC	8.5 V DC
		R15 Open	Across R15	O	5 V DC	13 V DC
		Z1 Shorted	Across Z1	O	15 V DC	0 V DC
		R12 Open	Across R12	O	9 V DC	22 V DC
		Z2 Shorted	Across Z2	O	6.2 V DC	0 V DC
		T4 Shorted (Cannot Null)	(8)(0)	–	0 V DC (at null)	-16 V DC

[redacted]						
26.6.5	Test points (2)(0), (3)(0), voltages are zero and other test point voltages are normal		(2)(0)	N	25 V DC	0 V DC
			(3)(0)	N	15 V DC	0 V DC
		C3 Shorted	Across C3	N	25 V DC	0 V DC
26.6.6	All test point voltages are normal	R14 Shorted	Across R14	N	1 V DC	0 V DC
26.6.7	Test points (5) to (0) measure about 10 V DC		(5)(0)	N	16 V DC	10 V DC
		R10 Shorted	Across R10	N	15.5 V DC	0 V DC
26.7	**Control Runs Regulator To Maximum Raise Position. Lower Operation Not Possible.**					
26.7.1	Test point (5)(0) voltage is zero volts DC	R8 Open	Across R8	N	33 V AC	50 V AC
		S1 Disconnect off terminal	Across C5	N	29 V AC	0 V AC
		S1-NO Sensing winding open	Across C5	N	29 V AC	0 V AC
		R9 Open	Across R9	N	15 V AC	40 V AC
		C5 Shorted	Across R8	N	33 V AC	48 V AC
		C6 Shorted	Across R9	N	15 V AC	22 V AC
26.7.2	Test Points (5)(0) voltage higher than normal		(5)(0)	N	16 V DC	43 V DC
		R10 Open	Across R10	N	15.5 V DC	50 V DC
			(5)(0)	N	16 V DC	22 V DC
		R14 Open	Across R14	N	1 V DC	19 V DC
26.7.3	Test Points (5)(0) voltage about 11 volts DC	D5 Shorted	Across D5	N	8 V DC	0 V DC
			Across D7	N	8 V DC	0 V DC
		D6 Shorted	Across D6	N	8 V DC	0 V DC
			Across D8	N	8 V DC	0 V DC
		D7 Shorted	Across D7	N	8 V DC	0 V DC
			Across D5	N	8 V DC	0 V DC
		D8 Shorted	Across D8	N	8 V DC	0 V DC
			Across D6	N	8 V DC	0 V DC
26.7.4	Test point (5)(0) voltage about 6 volts DC	D5 Open	Across D5	N	8 V DC	25 V DC
		D6 Open	Across D6	N	8 V DC	25 V DC
		D7 Open	Across D7	N	8 V DC	25 V DC
		D8 Open	Across D8	N	8 V DC	25 V DC
26.7.5	All test point voltages are normal	C7 Shorted	Across C7	N	1 V DC	0 V DC
		Z2 Open	Across Z2	N	6.2 V DC	18 V DC
		R15 Shorted	Across R15	N	5 V DC	0 V DC
		R19 Open	Across R19	N	0 V DC	17.5 V DC
		T5 Base to collector shorted	(8)(0) (Cannot null)	—	0 V DC (at null)	14.5 V DC (all times)
26.7.6	Test points (8)(0) read plus voltage at all times	GR-R2 contact stuck in closed position	Across GR-R2	N	40 V DC	0 V DC
26.8	**Lower Operation Is Normal But Raise Operation Does Not Function**		(8)(0)	OL	16 V DC	0 V DC
		R26 Open	Across R26	OL	2 V DC	0 V DC
		R29 Open	Across R29	OL	9 V DC	24 V DC
				N	0 V DC	5 V DC
		D13 Shorted	Across D13	OL	15 V DC	0 V DC
			Across R29	OL	9 V DC	24 V DC
		GR-R Relay coil shorted	Across D13	OL	15 V DC	0 V DC
			Across R29	OL	9 V DC	24 V DC
		GR-R Relay Coil open	Across D13	OL	15 V DC	25 V DC
			Across R29	OL	9 V DC	0 V DC
		T5 Collector Open	Across R29	OL	9 V DC	0 V DC
		D23 Open	Across D23	OL	.6 V DC	4.75 V DC
		GR Relay coil open	Across D24	T	0 V DC	38 V DC
				AT	33 V DC	52 V DC

26.9	Raise Operation Is Normal But Lower Operation Does Not Function		8 0	OU	15 V DC	0 V DC
		R30 Open	Across R30	OU	9 V DC	24 V DC
			Across R30	N	0 V DC	5 V DC
		D12 Shorted	Across D12	OU	15 V DC	0 V DC
			Across R30	OU	9 V DC	24 V DC
		FR-R Relay Coil Shorted	Across D12	OU	15 V DC	25 V DC
			Across R30	OU	9 V DC	0 V DC
		T4 Collector open	Across D12	OU	15 V DC	0 V DC
			Across R30	OU	9 V DC	0 V DC
		D20 Open	Across D20	OU	.6 V DC	4.75 V DC
		FR Relay coil open	Across D21	T	0 V DC	38 V DC
				AT	33 V DC	52 V DC
		D21 Shorted	Across D21	T	0 V DC	0 V DC
				AT	33 V DC	0 V DC
		T4 Collector open	Across R30	OL	9 V DC	0 V DC
26.10	**Voltage Level Setting Incorrect**					
26.10.1	Control maintains a higher voltage level than setting		4 0	N	15 V DC	22 V DC
		R4 Shorted	Across R4	N	7 V DC	0 V DC
		R3 Open	Across R3	N	8 V DC	22.5 V DC
		R18 Open	Across R18	N	14 V DC	14.5 V DC
			Across R16	N	.75 V DC	0 V DC
		R16 Open	Across R16	N	.75 V DC	1 V DC
			Across R18	N	14 V DC	13.5 V DC
		D10 Shorted	Across D10	N	.5 V DC	0 V DC
		Z2 Voltage Changes	Across Z2	N	5.9-6.5 V DC	Outside range
		R15 Decrease in value	Measure R15			
		C5 or C6 increase in value	Measure C5 & C6			
		R10 increase in value	Measure R10			
		Diodes D5-D8 with high leakage	Measure D5-D8			
		C7 High leakage	Measure C7			
		Shorted turns in TR-1				
		R14 increase in value	Measure R14			
26.10.2	Control maintains a lower voltage level than setting	R24 Shorted	Across R14	N	0 V DC	0 V DC
		Z2 Voltage Changes	Across Z2	N	5.9-6.5 V DC	Outside range
		R15 Increases in value	Measure R15			
		R14 Decrease in value	Measure R14			
		C5 or C6 Decrease in value	Measure C5 & C6			
		R10 Decrease in value	Measure R10			
26.11	**Bandwidth Setting Is Incorrect**					
26.11.1	Bandwidth less than set	R20 Open (Decreases Bandwidth to 1/2 of Setting)	3 0	N	15 V DC	12.5 V DC
			4 0	N	15 V DC	13.5 V DC
		B3 or RH-3 Open (Decreases Bandwidth to 1 volt regardless of setting)				
		R20 Increases in value	Measure R20			
		R22 Increases in value	Measure R22			
		B4 Lead Open				
26.11.2	Bandwidth Greater than set	F1 Open (Bandwidth increases to 6 volts regardless of setting)				

		R20 Decreases in Value R22 Decreases in Value C9 has high leakage	Measure R20 Measure R22 Measure C9			
26.11.3	Lower Bandwidth limit decreases	Z3 Shorted	Across Z3	OL	8.2 V DC	0 V DC
26.11.4	Upper Bandwidth limit increases	Z4 Shorted	Across Z4	OU	8.2 V DC	0 V DC
26.12	**Time Delay Incorrect**					
26.12.1	No time delay and relays FR & GR will be energized immediately	D27 Open	Across D27	N O	0 V DC 37 V DC	13 V DC 0 V DC
		D27 Shorted	Across D27	O R	0 V DC 37 V DC	0 V DC 0 V DC
		T12 Base Open	Top of R49 to top of D27	N	0 V DC	48 V DC
		T12 Collector Open or Emitter Open	Top of D27 to RHS of R53	N	0 V DC	54 V DC
		R49 Shorted	Across R49	N	2 V DC	0 V DC
		R51 Open	Across R51	N	39 V DC	53 V DC
		R50 Open	Across R50	N R	8.5 V DC 1 V DC	6.5 V DC 2 V DC
		R45 Shorted	Across R45	N O R	.75 V DC .75 V DC 10 V DC	0 V DC 0 V DC 0 V DC
		T11 Base to Collector Shorted	Top of R46 to bottom R48	N	8.5 V DC	0 V DC
		T11 Collector to emitter shorted	Bottom of R48 to RHS R53	N	8.5 V DC	0 V DC
		Emitter of T11 open	Across D26	N O	0 V DC 37 V DC	0 V DC 0 V DC
			Bottom R48 to RHS R53	N O	8.5 V DC 47 V DC	5 V DC 0 V DC
		Base to collector of T10 shorted	RHS of R44 to Test Point 4	N O	38.5 V DC 38 V DC	0 V DC 0 V DC
		Emitter of T13 open	Across D9	N O R	.5 V DC .5 V DC .5 V DC	0 V DC 0 V DC 29 V DC
		C11 Open	Across C11	N O	0 V DC Varies as Charges up	0 V DC Constant
		Base to collector of T9 shorted	Across R36	N R	1.25 V DC 1.25 V DC	25 V DC 28 V DC
		Collector to emitter of T9 shorted	Across R38	N R	1 V DC 1 V DC	15 V DC 20 V DC
26.12.2	Time delay very short regardless of setting	R40 Open	Across R40	A	2 V DC	29.5 V DC
		RH-4 Arm open	Top of R36 to top of R38	N	.25 V DC	1.75 V DC
		R35 Open	Top of R35 to top of R33	N O	1 V DC .25 V DC	4 V DC 4 V DC
		Base to emitter of T7 shorted	Top of R35 to top of R33	N O	1 V CD .25 V DC	0 V DC 0 V DC
		Base of T7 open	Across R35	N	1 V DC	0 V DC
			Top of R35 to top of R33	N O	.5 V DC 0 V DC	1.5 V DC 0 V DC
		Collector of T7 open	Across R35	N O	1 V DC .25 V DC	0 V DC 0 V DC
			Across C11	N O	1 V DC Gradually Increases	28 V DC 28 V DC

		R32 Open	Across R32	N	29 V DC	31 V DC
			Top of R32 to bottom D11	A	2.25 V DC	0 V DC
		D11 Open	Across D11	N	.75 V DC	30 V DC
				O	0 V DC	5 V DC
				R	.75 V DC	30 V DC
			Top of R32 to bottom D14	N	1.75 V DC	30 V DC
				O	0 V DC	0 V DC
				R	.75 V DC	30 V DC
		R33 Shorted	Across R33	N	1 V DC	0 V DC
				R	0 V DC	0 V DC
			Across D14	N	.75 V DC	.75 V DC
				T	0 V DC	0 V DC
				R	.75 V DC	.75 V DC
		R33 Open	Across R33	N	1 V DC	4-26 V DC
			Across D14	N	.75 V DC	0 V DC
				O	0 V DC	0 V DC
				R	.75 V DC	0 V DC
		D14 Open	Across R33	N	1 V DC	0 V DC
			Across D14	N	.75 V DC	4-26 V DC
		Base to collector of T6 shorted	Top of R32 to top of R31	N	2.25 V DC	0 V DC
				O	.5 V DC	0 V DC
				R	1.5 V DC	0 V DC
			Top of R32 to bottom D14	N	2.25 V DC	.75 V DC
				O	0 V DC	.75 V DC
				R	1.25 V DC	.75 V DC
		Emitter to collector of T6 shorted	Top of R32 to bottom D14	N	2.25 V DC	0 V DC
				O	0 V DC	0 V DC
				R	1.25 V DC	0 V DC
			Top of R32 to top of R31	N	2.25 V DC	0 V DC
				O	.5 V DC	.5 V DC
				R	1.5 V DC	0 V DC
26.12.3	Time delay longer than setting	D14 Shorted	Across D14	N	.75 V DC	0 V DC
		D15 Shorted	Across D15	A	.75 V DC	0 V DC
		R35 Shorted	Across R35	A	1 V DC	0 V DC
		R36 Increase in value	Measure R36	–	–	–
		C11 High leakage	–	–	–	–
		T8 High leakage	–	–	–	–
		T13 High leakage		–	–	–
26.13	**Erratic Operation**					
26.13.1	Wrong relay picks up when out of either limit	D20 Shorted	Across D20	N	.5 V DC	0 V DC
		D23 Shorted	Across D23	N	.5 V DC	0 V DC
26.13.2	Time delay will not reset to zero after motor relay is energized and time delay gets shorter with successive time cycles at short intervals	T13 Base open	Across R52	R	38 V DC	0 V DC
26.13.3	Time delay very short (1/2) below 30 second setting but about normal when set higher than 60 second setting	R39 Shorted	Across R39	N	3.5 V DC	0 V DC

27.0 COMPONENT MALFUNCTIONS THAT MAY HAVE LITTLE OR NO EFFECT ON CONTROL OPERATION AT ROOM TEMPERATURE

R7	Shorted	None
R5	Shorted	None
C4	Open	None
D1	Open	None
D2	Open	None
D3	Open	None
D4	Open	None
R24	Open	None
R19	Shorted	None
C13	Open	None
C12	Open	None
R23	Open	Band Indicator will not operate.
R25	Shorted	None – except Op-Amp may latch up under certain conditions.
R27	Open	May pick up reed relay at high temperature.
D12	Open	May damage T4.
D13	Open	May damage T5.
R29	Shorted	May damage T5 or GR-R.
R30	Shorted	May damage T4 or FR.-R.
D26	Shorted	Relays may chatter at high temperatures.
R48	Shorted	May damage relay coil.
R41	Open	Will cause incorrect time delay.
R49	Open	T12 may not turn off at high temperatures.
R53	Shorted	T11 & T12 may not turn off as req'd.
R46	Open	T11 may not turn off at high temperatures.
D9	Open	May damage T13.
R43	Shorted	May not turn T10 off at low temperatures.
R35	Shorted	Will not have integrating time delay.
D11	Shorted	None
R34	Open	T6 may not turn off at high temperatures and certain conditions.
Z1	Open	May exceed voltage rating of T11 & T12 and eventually damage them.
R28	Shorted	None – May change BW by approx. .2 volts.
R47	Shorted	May damage T11.

D1, D2, D3, D4, D5, D6, D7, D8, D10, D15, D26, D27 are IN5060 GE's or Unitrode's diodes.

D9, D11, D12, D13, D14, D20, D21, D23, D24 are IN4148 ITT or Fairchild's diodes.

Z1 Zener Diode is IN5568B Centralab or Unitrode.

Z2 Zener Diode is IN825 Motorola or Centralab.

Z3 & Z4 Zener Diodes are IN9598 Motorola or T.I.

T1, T4, T6, T7, T8, T11, T12, T13 transistors are 2N2102 RCA's or National's or Raytheon's.

T2, T3, T5, T10 transistors are National or Fairchild's 2N403.

T9 transistor is National or Fairchild's or Motorola's 2N2904.

IC-1 regulator is Motorola's type MC1723G or Fairchild's type U5R7723312.

IC-2 differential amplifier is Motorola's MC1558G or T.I.'s SN52558L or RCA's CA3558T.

28.0 INDIVIDUAL COMPONENT VOLTAGE CHART

(Measure with VTVM having 1 meg-ohm input impedance minimum)

TEST CONDITION – ABBREVIATIONS

- **N — a Null (input is 120 volts)**
- **O — Outside either limit (input is slightly less than 119 volts or slightly more than 121 volts)**
- **OL—Outside Lower Bandlimit (input is slightly less than 119 volts)**
- **OU—Outside Upper Bandlimit (input is slightly more than 121 volts)**
- **T —During Timing**
- **AT—After Timing**
- **R — Motor Relay is energized**
- **A — Any condition**

S1-NO	50.5 V AC	A
A1-A2	37.5 V AC	A
A1-A10	18.7 V AC	A
R3	7.5-8.3 V DC	A
R4	6.75-7.5 V DC	A
R5	.01-.46 V DC	A
R6	7.6-11.8 V DC	A
R7	.01-.46 V DC	A
R8	30.5-33.75 V AC	A
R9	14.5-16 V AC	A
R10	15.3-16 V DC	A
R12	7.8-9.8 V DC	A
R14	1.1-1.22 V DC	N
R15	4.3-6.5 V DC	A
R16	.55-.65 V DC	A
R18	13.3-16.74 V DC	A
R19	0 V DC	N
R20	0 V DC	N
	8.7-11 V DC	T
R22	0 V DC	N
	0-11 V DC	T
R23	0 V DC	N
	7.9-10.3 V DC	T
R24	0 V DC	N
	15.75 ± 1.25 V DC	T
R25	0 V DC	N
	1-3 V DC	T

R26	0 V DC	N
	1.5 V DC	OL
R27	0 V DC	N
	.7-1.75 V DC	T
R28	0 V DC	N
	.13-1.0 V DC	T
R29	0 V DC	N
	7-13 V DC	OL
R30	0 V DC	N
	7-13 V DC	OU
R31	.5 V DC	N
	37-44 V DC	T
	5.4-11.5 V DC	AT
R32	26-30.7 V DC	N
	28-33 V DC	T
R33	.93-1.14 V DC	N
	0 V DC	T & AT
R34	0 V DC	N
	.6 V DC	T
	.22-.46 V DC	AT
R35	.93-1.14 V DC	N
	0 V DC	T & AT
R36	.94-1.14 V DC	A
R37	27.7-31.3 V DC	A
R38	.94-1.14 V DC	A
R39	3.4-4.2 V DC	A
R40	1.8-2.4 V DC	A

R41	47-53 V DC	N & T
	.25 V DC	AT
R42	0-.14 V DC	N
	Pulse	AT
R43	0 V DC	N
	Pulse	AT
R44	0 V DC	N
	Pulse	AT
R45	.75 V DC	N
	.5-1 V DC	T
	10.5-14 V DC	AT
R46	1 V DC	N
	.8-1.5 V DC	T
	1.5-2.2 V DC	AT
R47	7 V DC	N
	46-52 V DC	T
	37-45 V DC	AT
R48	.1-.3 V DC	N & T
	14.2-19 V DC	AT
R49	1.5-2.2 V DC	N & T
	.75-1.4 V DC	AT
R50	9.9-14 V DC	N & T
	.5-1 V DC	AT
R51	37-45 V DC	N & T
	46-52 V DC	AT
R52	6-12 V DC	N & T
	38-44 V DC	AT
R53	.7-1.3 V DC	A

28.0 INDIVIDUAL COMPONENT VOLTAGE CHART (cont'd from Page 32)

C2	Same as 1-0	A
C3	Same as 2.0	A
C4	10 V DC	A
C5	27-30 V DC	A
C6	18.5-20.5 V AC	A
C7	1.1-1.25 V DC	A
C9	0 V DC	N
	8.7-11 V DC	T
C11	Timing Cap	
C12	14.3-15.7 V DC	A
C13	14.17.3 V DC	A
C14	0-.14 V DC	N
	Pulse	AT
C15	Same as 3-0	
C16	1.1-1.22 V DC	N
D1	25 V DC	A
D2	25 V DC	A
D3	25 V DC	A

D4	25 V DC	A
D5	8 V DC	A
D6	8 V DC	A
D7	8 V DC	A
D8	8 V DC	A
D9	.5 V DC	N
	.5 V DC	T
	.5 V DC	AT
D10	.5 V DC	A
D11	.75 V DC	N
	0 V DC	T
D12	0 V DC	N
	15 V DC	OU
D13	0 V DC	N
	15 V DC	OL
D14	.75 V DC	N
	0 V DC	T
D15	.75 V DC	A
D20	.5 V DC	A

D21	0 V DC	N
	33 V DC	OU-AT
D23	.5 V DC	A
D24	0 V DC	N
	33 V DC	OL-AT
D26	0 V DC	N
	41 V DC	T
D27	.56 V DC	N
	.68 V DC	T
	40 V DC	AT
Z1 (IN55678)	14.25-15.75 V DC	A
(IN55688)	15.25-16.75 V DC	A
Z2	5.9-6.5 V DC	A
Z3	0 V DC	N
	8.25 ± .4 V DC	OU
Z4	0 V DC	N
	8.25 ± .4 V DC	OL

29.0 RESISTANCE AND CAPACITANCE VALUES AT NORMAL ROOM TEMPERATURE

R3	7870	1	¼
R4	7150	1	¼
R5	10	5	½
R6	1000	5	½
R7*	8.2	5	½
R8	4000	1	2
R9	4120	1	2
R10	15000	1	2
R12	1000	1	¼
R14	1100	1	2
R15	4700	1	2
R16	8660	1	¼
R18	10700	1	¼
R19	2400	5	½
R20*	2050000	1	¼
R22	402000	1	¼
R23	10000	5	½
R24*	3240 K	1	¼
R25	100	5	½
R26	330000	5	½
R27	51000	5	½
R28	18	5	½
R29	390	5	½
R30	390	5	½
R31	330000	5	½
R32	27400	1	¼
R33	1000	1	¼
R34	12000	5	½
R35	249000	1	¼
R36	442000	1	¼
R37	28000	1	¼
R38	1000	1	¼
R39	7500	1	¼
R40	4220	1	¼
R41#	680	5	10
R42	1000	5	½
R43	10000	5	½
R44	6200	5	½
R45	1500	5	½
R46	2000	5	½
R47	5600	5	1
R48#	240	5	5
R49	2000	5	½
R50	1500	5	½
R51	5600	5	1
R52	100000	5	½
R53	13	5	½

C2	630 MFD	40
C3	630 MFD	40
C4	100 PFD	
C5	.47 MFD	100
C6	.47 MFD	100
C7	100 MFD	6
C9	.47 MFD	50
C11	10 MFD	50
C12	2.2 MFD	20
C13	2.2 MFD	20
C14	6.8 MFD	6
C15	500 PFD	
C16	.01 MFD	100

C2, C3, & C7 are electrolytic capacitors.
C4, C15 are disc ceramic capacitors.
C5, C6 are polystyrene capacitors.
C11, C9 are metallized mylar capacitors.
C12, C13, C14 are solid tantalum.
C16 is a mylar capacitor.

*Carbon resistor.
#Wire wound.

All 5%, 1/2-watt resistors are metal glaze, 200 PPM/°C (except R47 & R51, metal glaze or wire wound).

All 1%, 2-watt resistors are wire wound, 20 PPM/°C.

All 1%, 1/4-watt resistors are MIL type RN.

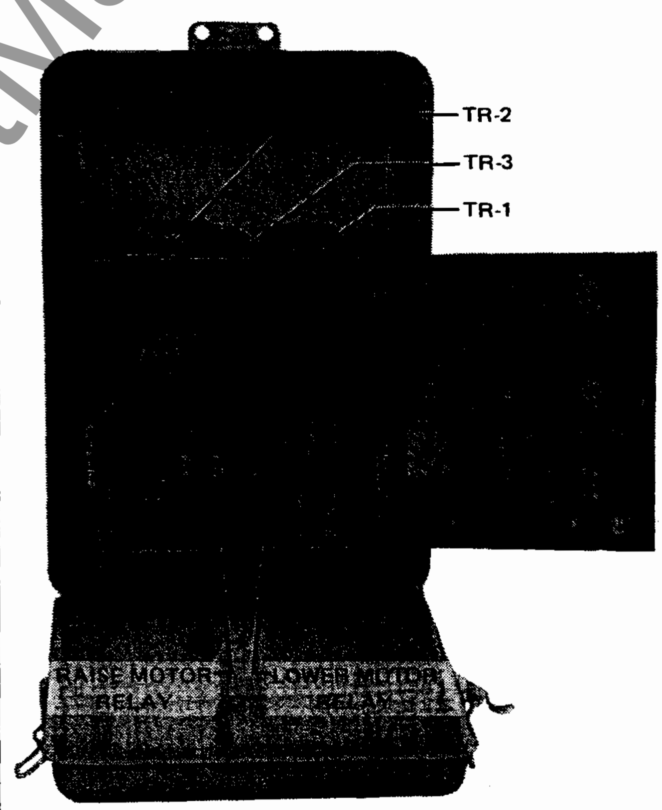


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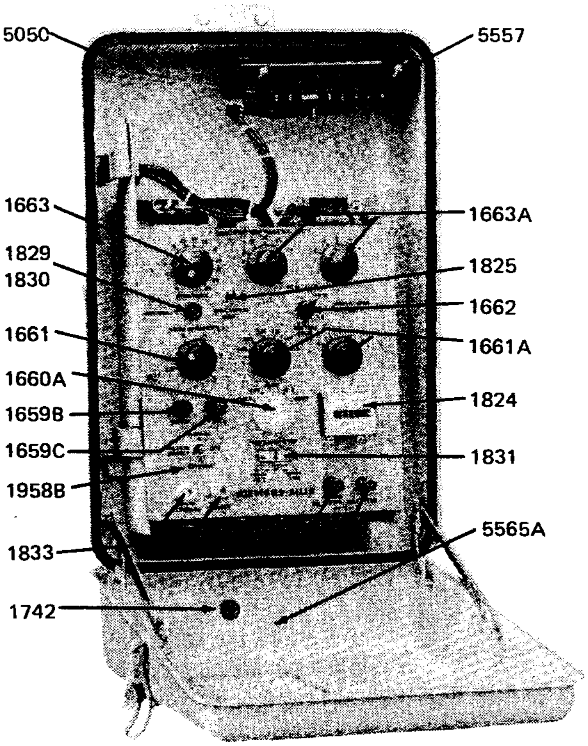
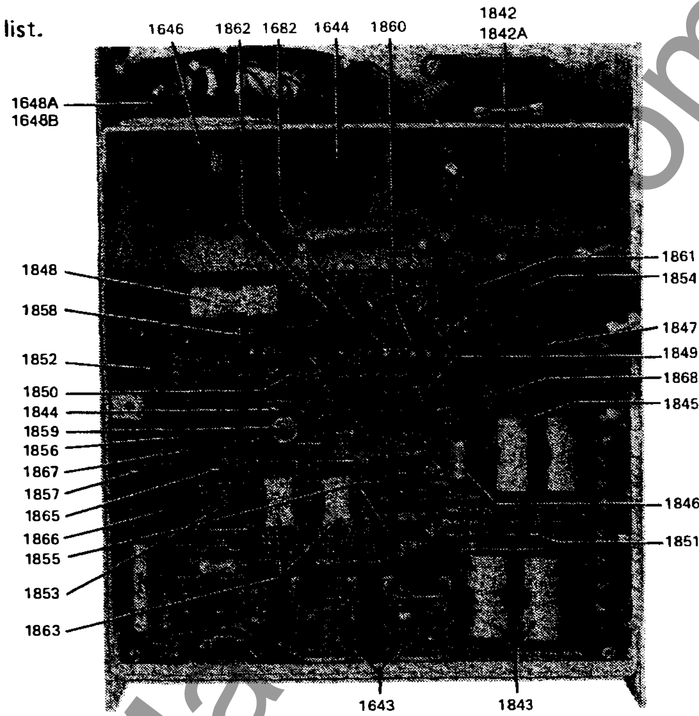
Fig. 10 Control panel close-up showing transformer and motor relay positions.

Accu/Stat control components are identified and listed on Page 34. When ordering, identify each part by item number and specify type of control — IJ-2 or IJ-2A. Order all resistors by appropriate "R" number — R3, R12, R41, etc.



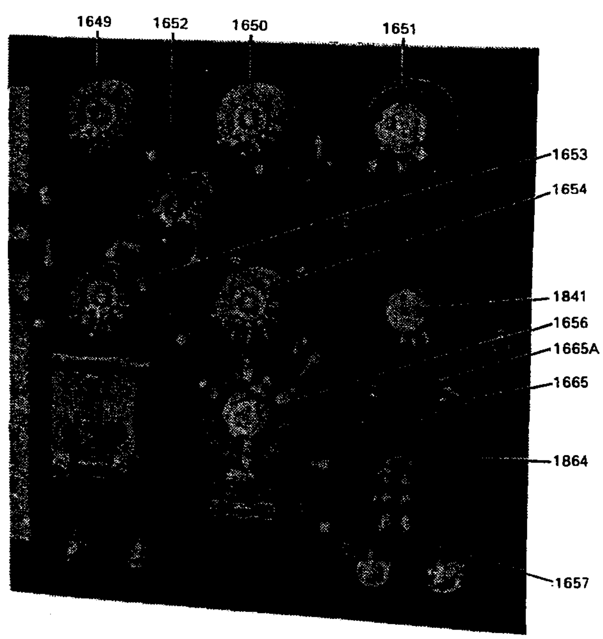
Parts list.



1640A	*Accu/Stat* Control Panel Complete
1640B	*Accu/Stat* Control Panel (Less Cabinet)
1641	Printed Circuit Board Complete
1643	Motor Relay
1644	Line Drop Compensator Reactor TR-3
1646	Auxiliary Current Transformer TR-2
1648A	Terminal Block – 4 Pole (IJ-2)
1648B	Terminal Block – 9 Pole (IJ-2A)
1649	Reactance Rotary Switch (Fine)
1650	Reactance Rotary Switch (Coarse)
1651	Resistance Rheostat
1652	Compensator Polarity Switch
1653	Voltage Level Switch (Fine)
1654	Voltage Level Switch (Coarse)
1656	Transfer Switch
1657	Voltage Source Switch
1658C	Panel Faceplate
1659B	4-Amp Motor Fuse
1659C	4/10 Amp *Slo-Blo* Panel Fuse
1660A	Control Knob (Transfer Switch)
1661	Control Knob (Black) Bandwidth Adjustment
1661A	Control Knob (Black) Voltage Level
1662	Control Knob – Compensator Polarity Switch
1663	Control Knob (Red) Resistance Rheostat
1663A	Control Knob (Red) Line Drop Compensator Switch
1665C	4 Amp Fuse Holder – for 16598 Fuse
1665D	4/10 Amp Fuse Holder – for 1659C Fuse
1682	Control Knob – Time Delay Rheostat
1742	Snap-in Breather Plug
1824	Operation Counter
1825	Drag Hand Reset Button and Switch
1829	Neutral Light – Bulb Only
1830	Neutral Light – Socket
1831	Bandwidth Indicator
1833	Terminal Posts – Specify Color
1841	Bandwidth Adjustment Rheostat
1842	Sensing Transformer (IJ-2)
1842A	Sensing Transformer (IJ-2A)
1843	C-2, C-3 Capacitor
1844	C-4 Capacitor
1845	C-5, C-6 Capacitor
1846	C-7 Capacitor
1847	C-9 Capacitor
1848	C-11 Capacitor

1849	C-12, C-13 Capacitor
1850	C-14 Capacitor
1851	D-1 thru D-8, D-10, D-15, D-26, D-27 Diodes
1852	D-9, D-11 thru D-14, D-20, D-21, D-23, D-24 Diodes
1853	Z-1 Zener Diode
1854	Z-2 Zener Diode
1855	Z-3, Z-4 Zener Diode
1856	T-1, T-4, T-6, T-7, T-8, T-11, T-12, T-13 Transistors
1857	T-2, T-5, T-10 Transistors
1858	T-9 Transistor

1859	IC-1 Voltage Regulator
1860	IC-2 Operation Amplified
1861	RH-2 Potentiometer
1862	RH-4 Potentiometer
1863	FR, GR Reed Relay
1864	C-1 Capacitor
1865	C-15 Capacitor
1866	T-3 Transistor
1867	Insulating Heatsink for T-1, T-3 Transistors
1868	C-16 Capacitor
5050	Gasket – Control Cabinet
5557	Terminal Block – 10 Pole
5565A	Control Cabinet



SIEMENS

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The information in this manual is intended to assist operating personnel by providing information on the general characteristics of equipment of this type. It does not relieve the user of responsibility to use sound engineering practices in the installation, application, operation and maintenance of the particular equipment purchased.

If drawings or other supplementary instructions for specific applications are forwarded with the manual or separately, they take precedence over any conflicting or incomplete information in this manual.

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SUGGESTED IJ VOLTAGE TESTING SEQUENCE

All voltage test point readings should be made with a good multimeter or preferably a vacuum tube voltmeter

(1) 1 to 0 +25V DC
(2) 2 to 0 −25V DC
(3) 3 to 0 −15V DC
(4) 4 to 0 +15V DC
(5) 5 to 0 −16V DC
(6) 6 to 0 + 6V DC
(7) 7 to 0 0V DC
(8) 8 to 0 −15V DC (Voltage level changed to 118 Vac)
8 to 0 +15V DC (Voltage level changed to 122 Vac. When using multimeters this voltage reading may be from 4 to 15 volts dc lower)

NOTE: (1) Readings taken with voltage level at 120 Vac and control input voltage of 120 Vac. Bandwidth set at 2 volts.
(2) All readings within ±1 V DC.

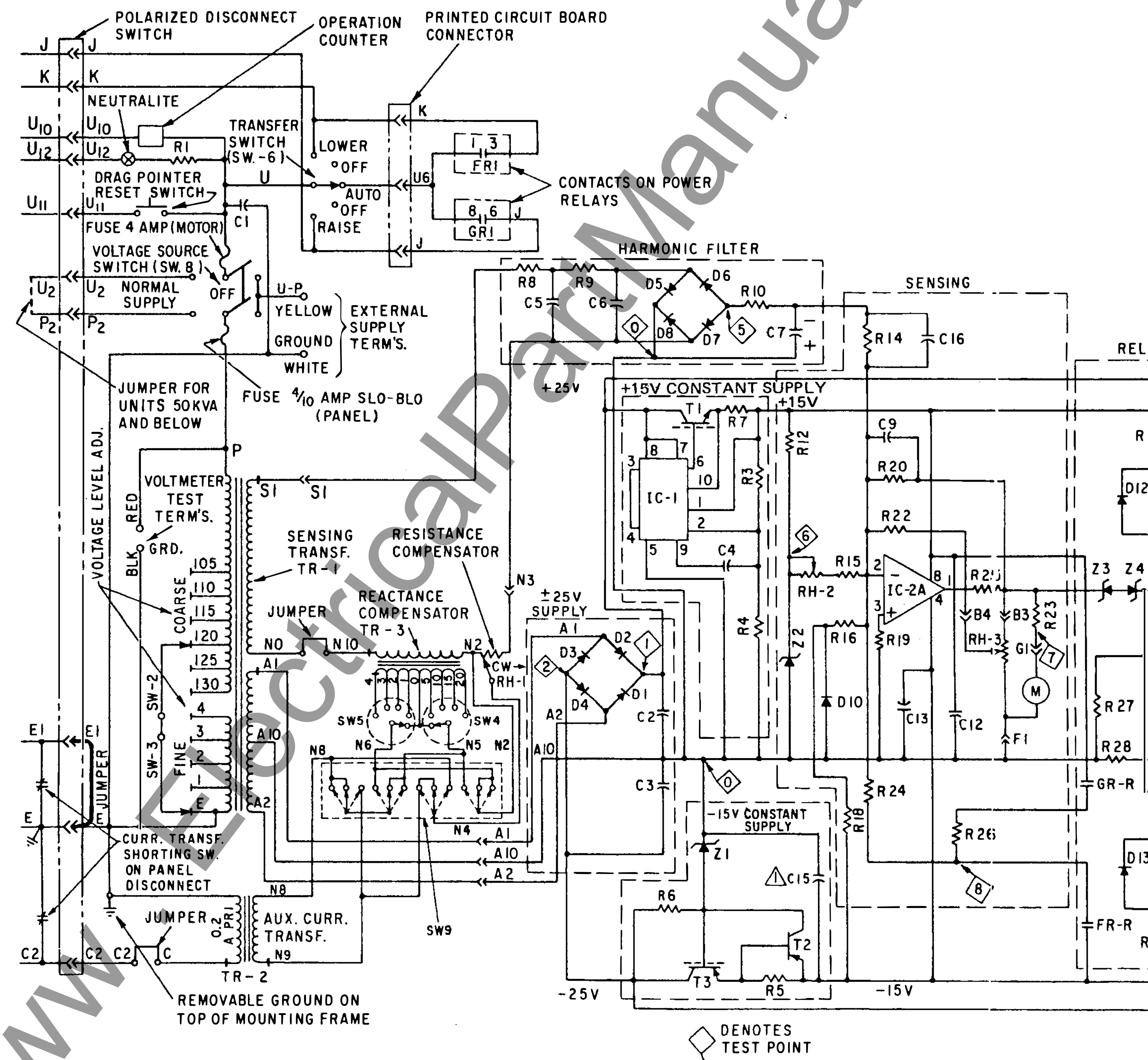
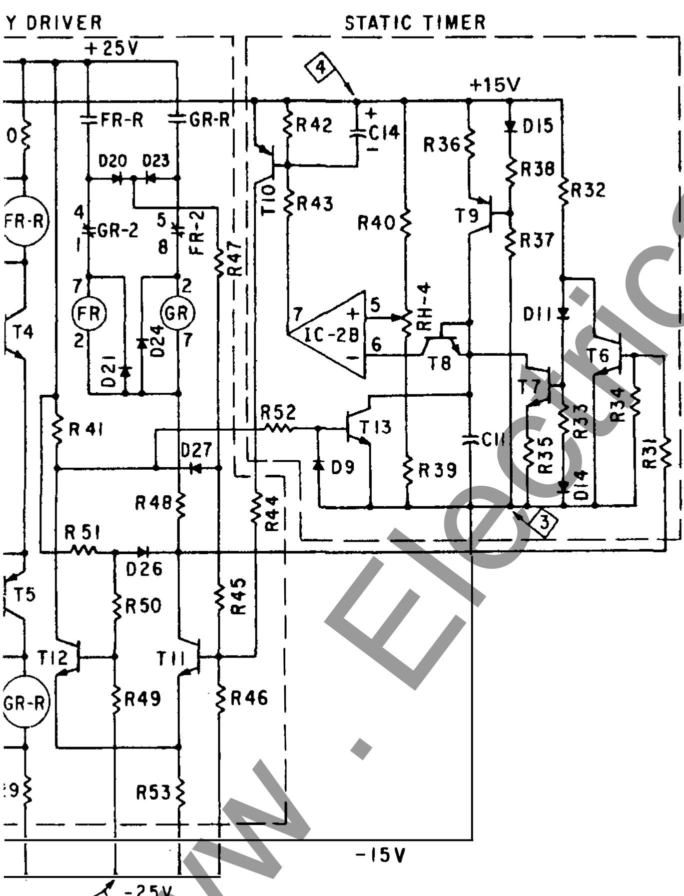


Fig. 12 IJ-2 control schematic and suggested voltage testing sequence.

POLARIZED DISCONNECT SWITCH (PDS) LABELING

Label	Function	Approx. Rough Voltage Reading from E to Label
C_2	Connected to internal C.T.	N/A
$E\text{-}E_1$	All E's interconnected and grounded	N/A
P_2	Connected to internal P.T.	120
U_2	Connected to internal tertiary (on units 51 kVA and larger) and provides power to the J or K lead	120
U_{11}	As above except energizes drag hands when switch is closed	120
U_{12}	As above except energizes neutralite when internal neutralite switch closes	120
U_{10}	As above except energizes operation counter when internal counter switch closes	120
K	Becomes connected to U_2 when control calls for "lower" which energizes lower side of tap changer motor	0 before lower operation called for 120 after lower operation called for
J	Becomes connected to U_2 when control calls for "raise" which energizes raise side of tap changer motor	0 before raise operation called for 120 after raise operation called for



LEGEND	
	TEST POINT
	CONNECTOR BLOCK JUMPER
	CAPACITOR
	RESISTOR
CW	RHEOSTAT ARROW INDICATES CLOCKWISE
	Y1-Y2 CIRCUIT CONTINUITY JUMPERS
	DIODE
SW 4, 5 & 9	MAKE BEFORE BREAK SWITCHES
	CONTACT N.O.
	CONTACT N.C.
	PRINTED CIRCUIT BOARD CONNECTOR
	NO ELECTRICAL CONNECTION
	ZENER DIODE
FR	POWER RELAY COIL
	TRANSFORMER (• POLARITY MARKS)
	REACTOR
	ELECTRICALLY CONNECTED
	DIFFERENTIAL AMPLIFIER
	NPN TRANSISTOR
	PNP TRANSISTOR
	TRANSISTOR WITH HEAT SINK
FR-R	REED RELAY

SUGGESTED IJ VOLTAGE TESTING SEQUENCE

All voltage test point readings should be made with a good multimeter or preferably a vacuum tube voltmeter

(1) 1 to 0 +25V DC
(2) 2 to 0 −25V DC
(3) 3 to 0 −15V DC
(4) 4 to 0 +15V DC
(5) 5 to 0 −16V DC
(6) 6 to 0 + 6V DC
(7) 7 to 0 0V DC
(8) 8 to 0 − (Voltage level changed to 118 Vac)
8 to 0 +15V DC (Voltage level changed to 122 Vac. When using multimeters this voltage reading may be from 4 to 15 volts dc lower)

NOTE: (1) Readings taken with voltage level at 120 Vac and control input voltage of 120 Vac. Bandwidth set at 2 volts.
(2) All readings within ±1 V DC.

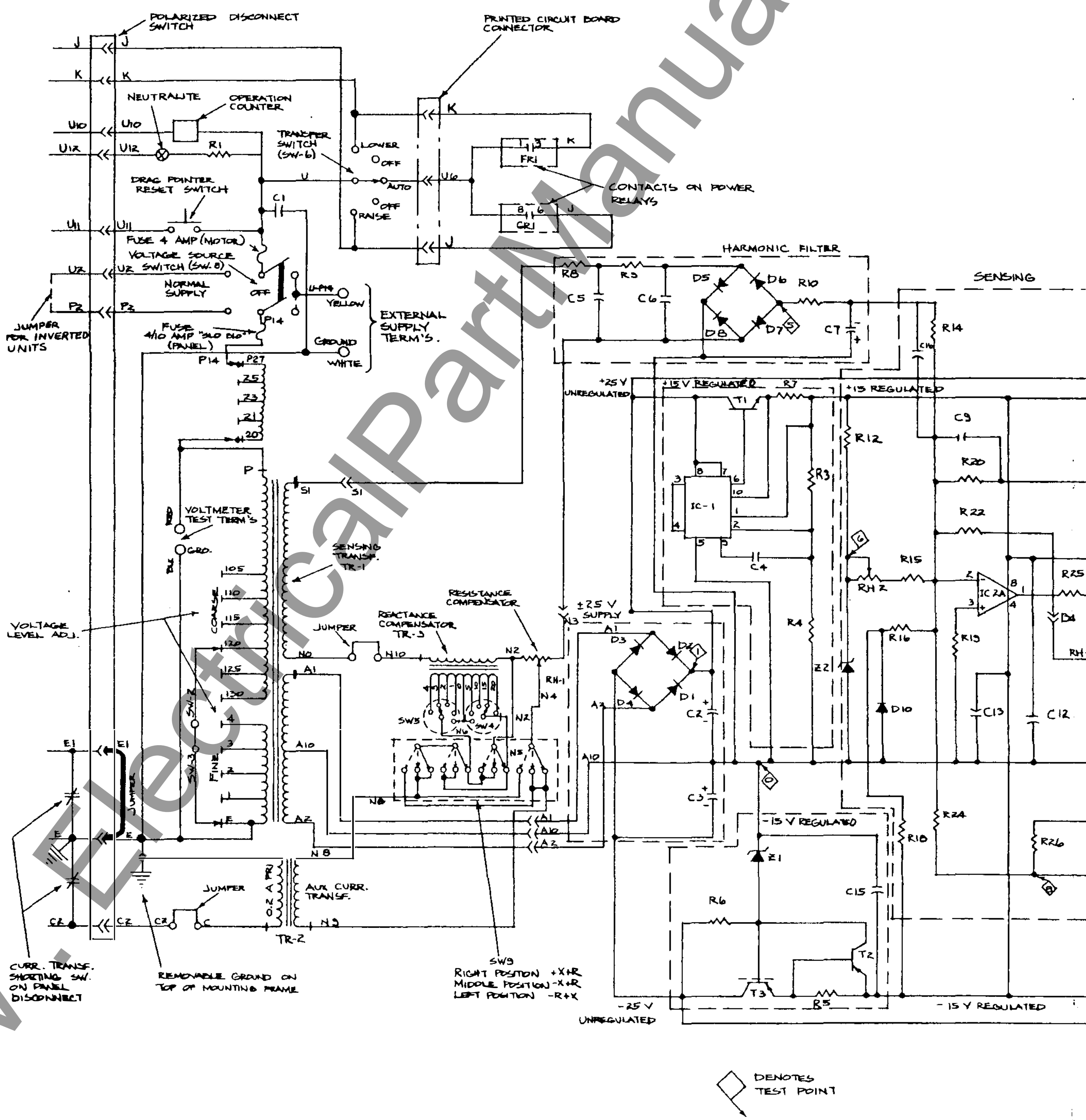
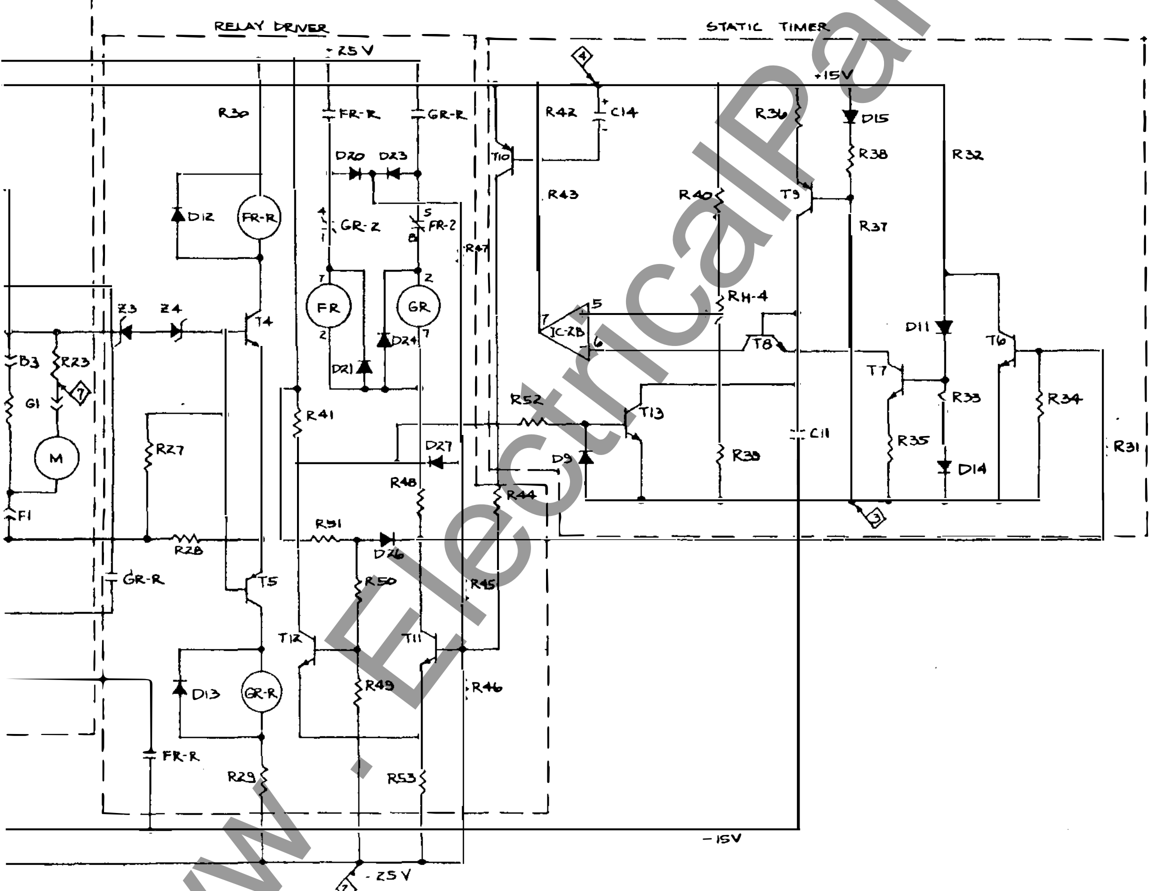


Fig. 13 IJ-2A control schematic and suggested voltage testing sequence.

POLARIZED DISCONNECT SWITCH (PDS) LABELING

Label	Function	Approx. Rough Voltage Reading from E to Label
C_2	Connected to internal C.T.	N/A
$E\text{-}E_1$	All E's interconnected and grounded	N/A
P_2	Connected to internal P.T.	120
U_7	Connected to internal tertiary (on units 51 kVA and larger) and provides power to the J or K lead	120
U_{11}	As above except energizes drag hands when switch is closed	120
U_{12}	As above except energizes neutralite when internal neutralite switch closes	120
U_{10}	As above except energizes operation counter when internal counter switch closes	120
K	Becomes connected to U_2 when control calls for "lower" which energizes lower side of tap changer motor	0 before lower operation called for 120 after lower operation called for
J	Becomes connected to U_2 when control calls for "raise" which energizes raise side of tap changer motor	0 before raise operation called for 120 after raise operation called for

NOTE: For connection of P and P_{14} see nameplate.



LEGEND	
	TEST POINT
	CONNECTOR BLOCK JUMPER
	CAPACITOR
	RESISTOR
CW	RHEOSTAT ARROW INDICATES CLOCKWISE
	Y1 -Y2 CIRCUIT CONTINUITY JUMPERS
	DIODE
SW 4, 5 9	MAKE BEFORE BREAK SWITCHES
	CONTACT N.O.
	CONTACT N.C.
	PRINTED CIRCUIT BOARD CONNECTOR
	NO ELECTRICAL CONNECTION
	ZENER DIODE
FR	POWER RELAY COIL
	TRANSFORMER (• POLARITY MARKS)
	¹ REACTOR
	ELECTRICALLY CONNECTED
	DIFFERENTIAL AMPLIFIER
	NPN TRANSISTOR
	PNP TRANSISTOR
	TRANSISTOR WITH HEAT SINK
FR-R	REED RELAY