ADVANCE I.B. 47-431-7A

DESCRIPTION • INSTALLATION • OPERATION

INSTRUCTIONS

VOLTAGE REGULATING RELAY

TYPE CVR

Applied to Step Regulator Control

WESTINGHOUSE ELECTRIC CORPORATION
SHARON PLANT • TRANSFORMER DIVISION • SHARON, PA.

SUPERSEDES I.L. 47-431-7

EFFECTIVE OCTOBER, 1957

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ILLUSTRATIONS

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VOLTAGE REGULATING RELAY TYPE CVR

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The type CVR Voltage Regulating Relay is in reality a "control package" designed to control the URL and URF tap changers. The major components of the CVR relay are an induction disk type voltage sensitive relay, two auxiliary or pilot relays, two motor control relays and a reactor. All components are in a drawout chassis so that the complete relay may be interchanged from unit to unit or removed for testing and inspection. The Flexitest* switch base is made an integral part of the CVR relay to facilitate connecting and testing the relay.

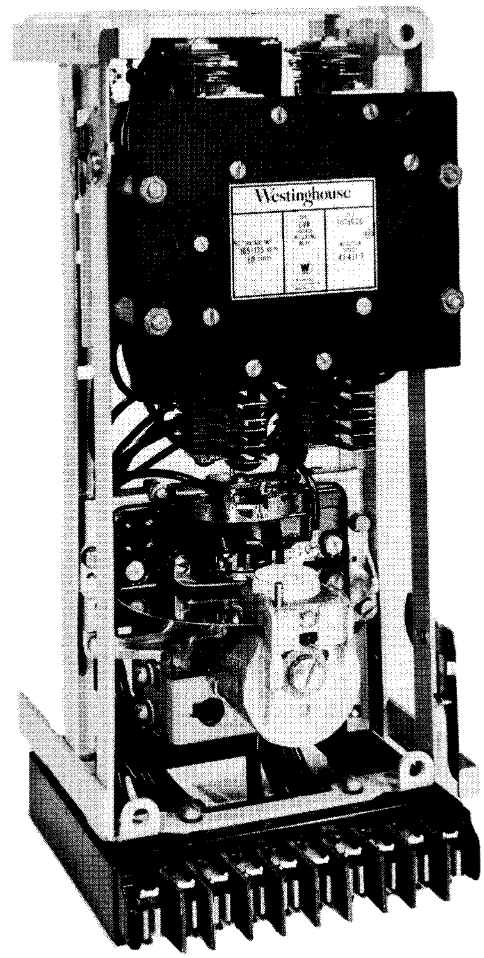

Figure 1 - CVR Relay Removed From Case

* Westinghouse Trade Mark

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The case in which the relay is mounted for the URL and URF regulator control is equipped with the mating portion of the Flexitest switch. A typical application showing the relay mounted in a regulator control panel with the relay cover removed is illustrated in Figure 2.

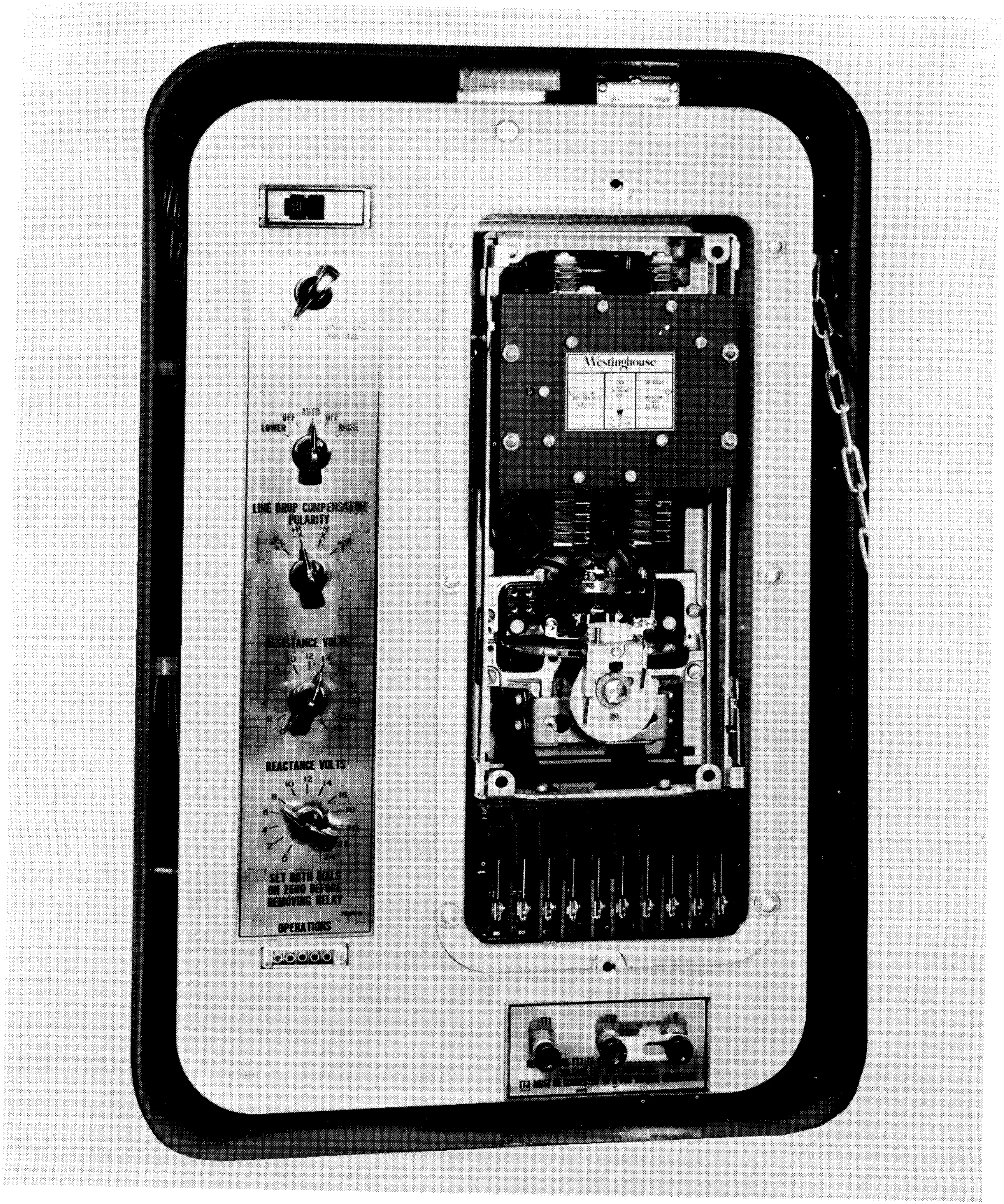


Figure 2 - Typical Regulator Control Panel With CVR Relay Installed

INSTALLATION

The CVR relay is usually mounted in the tap changer control panel. Before putting the relay in service, remove any blocking inserted for the purpose of securing parts during shipment; make sure that all parts operate freely, and inspect the contacts to see that they are clean and close properly. Check the gaps of the permanent magnet and of the electromagnet and clean them if any foreign material is present. Operate the relay to check the settings and electrical connections.

OPERATION

The sensing element of the CVR relay is an induction disk voltage relay with a set of single pole double throw contacts. Sealing circuits for the auxiliary relay are incorporated into the circuit to insure long contact life and positive operation.

Figure 3 shows schematically the relation of the CVR relay voltage sensing circuit while figures 4 and 5 show the internal schematic and internal wiring of the actual CVR relay.

A reactor connected in series with the voltage sensing element is a large portion of the impedance of this circuit. This feature minimizes the effect of resistance variations due to temperature changes and is used in the line drop compensator circuit.

The voltage coil on the lower pole of the voltage sensing element supplies a current to the coil on the upper pole by transformer action. The alternating fluxes induced in these poles are in quadrature. The alternating flux cutting the induction disk induces eddy currents in the disk of the relay which react with the flux in the air gap producing a torque. This torque is balanced against a spring torque to determine the balance position of the relay disk and its associated contacts.

Assume 120 volts has been applied to the relay long enough for the moving contact to come to rest at the 120 volt point on the relay scale. If the applied voltage were increased to 121 volts, the increased electro-magnetic torque would move the moving contact to the 121 volt point on the scale. If the voltage were reduced to 119 volts the decreased electromagnetic tor-

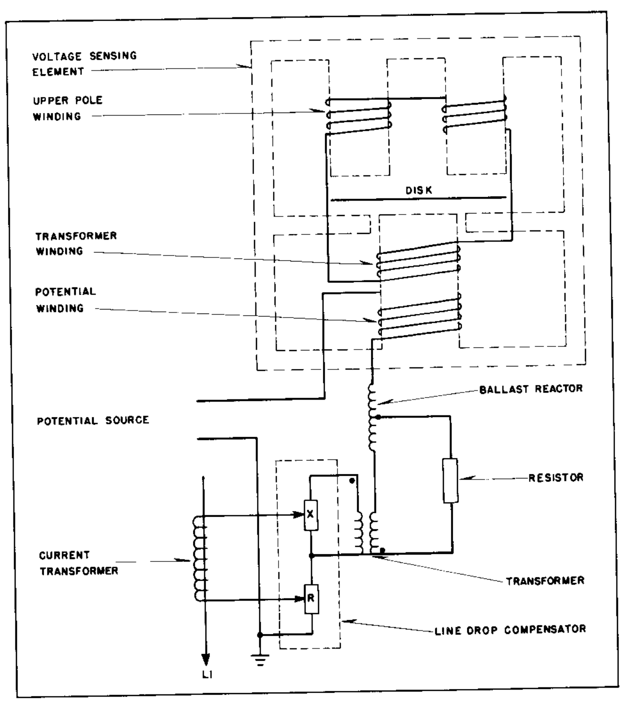


Figure 3 - Schematic Diagram of the CVR Relay Voltage Sensing Circuit

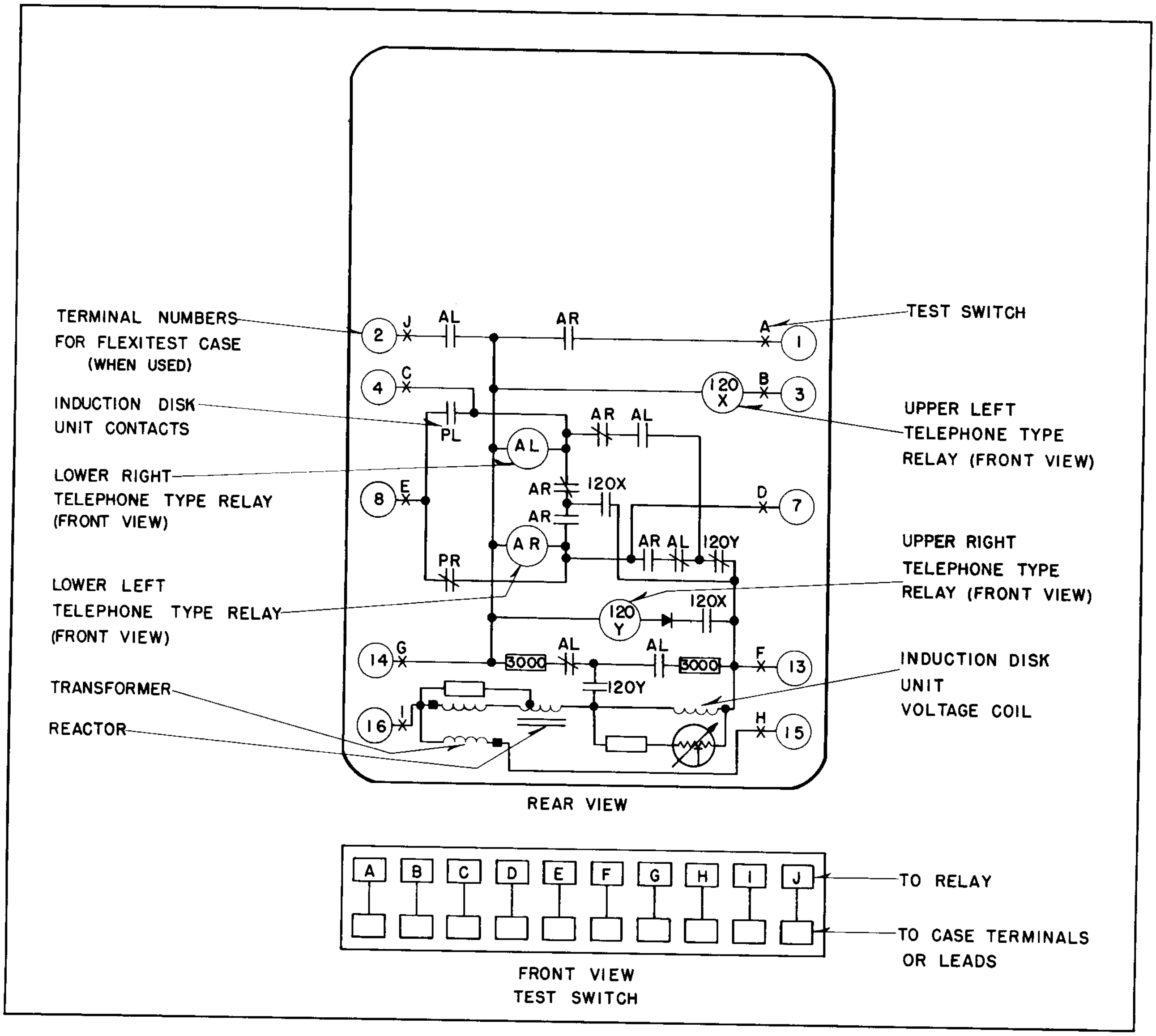


Figure 4 - CVR Voltage Regulating Relay Internal Schematic

que would allow the spring torque to move the contacts to the 119 volt position.

A permanent damping magnet is mounted on the relay with the induction disk between the pole faces of this magnet and the magnet keeper. Whenever the induction disk moves through the unidirectional flux produced by this permanent magnet a restraining force is produced to control the time required to change from one balanced position to another for a given change in voltage.

The position of the stationary PR and PL contacts determines the voltage level at which they will be closed to initiate tap changer operation to correct the voltage.

If the voltage falls below the setting of the left hand contact long enough for the disk operated PR contact to close, the relay AR is energized and seals itself in through the normally closed 120Y relay contact. Closing the AR relay motor contacts operates the tap changer to raise the voltage. Before the tap changer arcing contact has opened, a cam operated 120 switch in the tap changer closes to energize the 120X relay which in turn takes over the sealing of the AR relay by operating the 120Y slug delayed relay. The normally open 120Y relay contact closes and shorts the reactor with a 3,000 ohm resistor which increases the current through the voltage coil and tends to rotate the disk to open contacts PR, so that for small volt-

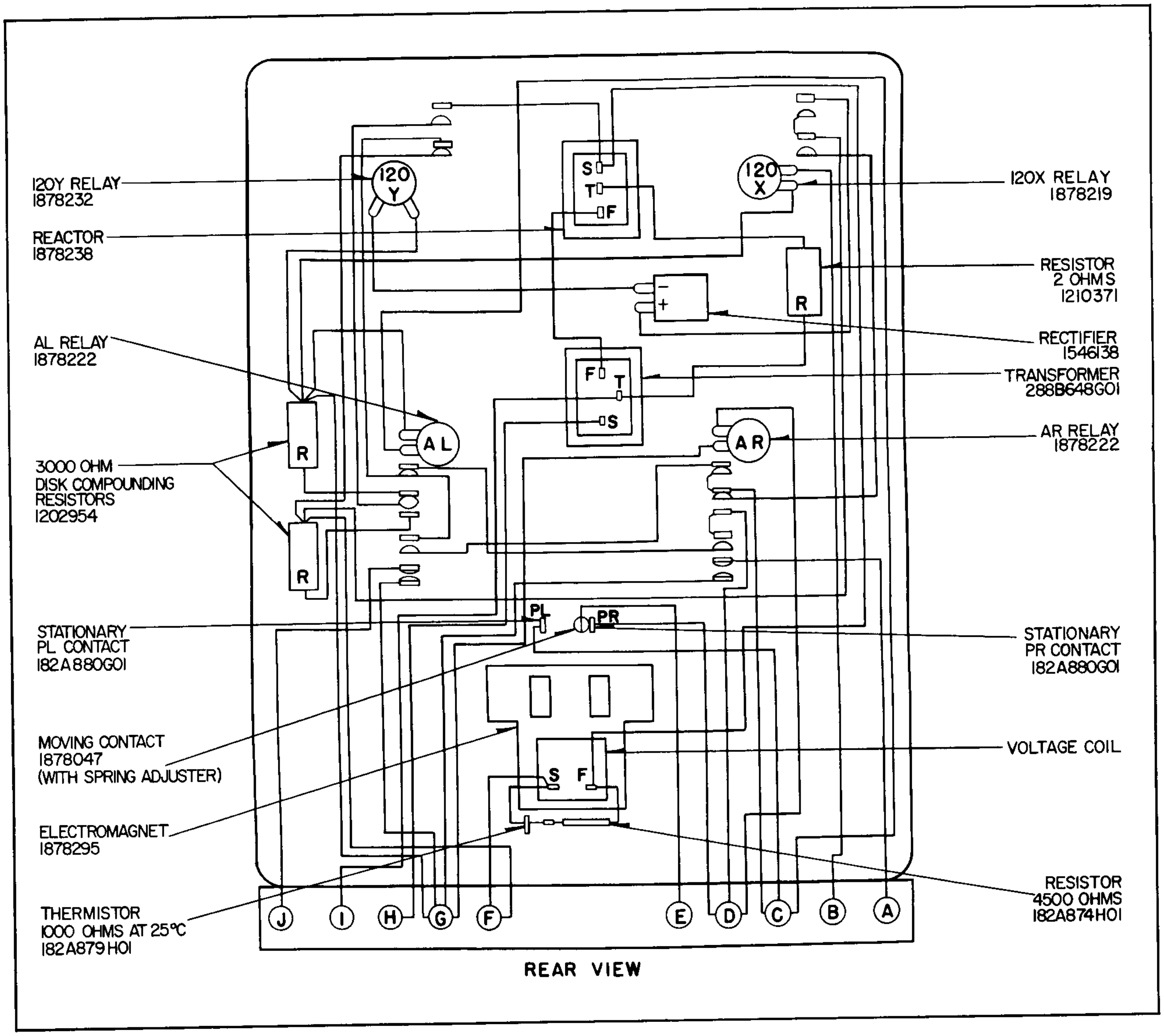


Figure 5 - CVR Relay Internal Wiring Diagram

age errors there will be a short delay between successive tap changer operations. After the tap changer arcing contact has closed on position, the 120 pilot switch opens, allowing the 120X relay to release the AR relay. The tap changer motor is stopped by the spring loaded cam brake. If the voltage is not corrected, the sequence is repeated until the voltage is corrected or a tap changer limit position is reached. A rise in voltage to close the right hand contact would initiate a similar sequence of operations to lower the voltage.

BANDWIDTH AND BALANCE VOLTAGE

The bandwidth of the voltage regulating relay is the difference in volts between the PR and PL contact setting.

Balance voltage is defined as the voltage midway between the PR and PL voltage settings and is the voltage which the relay will tend to maintain. A line drop compensator incorporated in the relay circuit enables the relay to adjust the tap changer to regulate the voltage at the load center rather than at the regulator itself. A current transformer installed in the regulator provides a small secondary current proportional to the current flowing through the regulator to the load. The secondary current of this current transformer is circulated through resistance and reactance elements to produce an impedance voltage which is combined with the control voltage to match the relation between the regulator output voltage and the line impedance drop. In this manner the resultant voltage applied to the relay is made to match the load center voltage. When these resistance and reactance drops are properly selected to match the line impedance drop from the regulator to the load center, the CVR relay will respond to load center voltage rather than regulator output voltage and will regulate the load center voltage rather than the voltage at the regulator output terminals.

SETTING THE CVR RELAY BY APPLYING AN EXTERNAL VOLTAGE

It is most convenient to set the CVR relay while mounted in the regulator panel. Turning the voltage adjustment knob clockwise a small amount snaps a switch in the motor circuit open without changing the voltage applied to the relay. (After the switch snaps, turning the knob farther inserts resistance between the auxiliary winding of the regulator and the CVR relay.) The relay operating points may be set by means of its scale which is calibrated in volts. For more exact setting an accurate voltmeter should be connected from TT1 to TT2 as shown in Figure 7. It is convenient to apply an external variable voltage source to TT1 and TT2 reading on the voltmeter the voltage at which the PR and PL contacts close.

Caution:

Extreme care must be taken to insure that the breaker in the regulator control circuit is in the OFF position and that the link G to TT2 is disconnected before applying an external voltage to the test terminals of the regulator. This precaution is necessary to avoid the possibility of energizing the regulator in reverse through the auxiliary winding producing high voltage on the regulator terminals. Link G to TT2 should also be disconnected to avoid the possibility of short circuiting the external supply through the ground connection.

To make the settings proceed as follows:

1. Set resistance and reactance compensator dials both on zero. Set PR lower and PL higher than their final settings.

Note: Always adjust PR and PL contacts by moving their scale pointers. See Fig. 6.

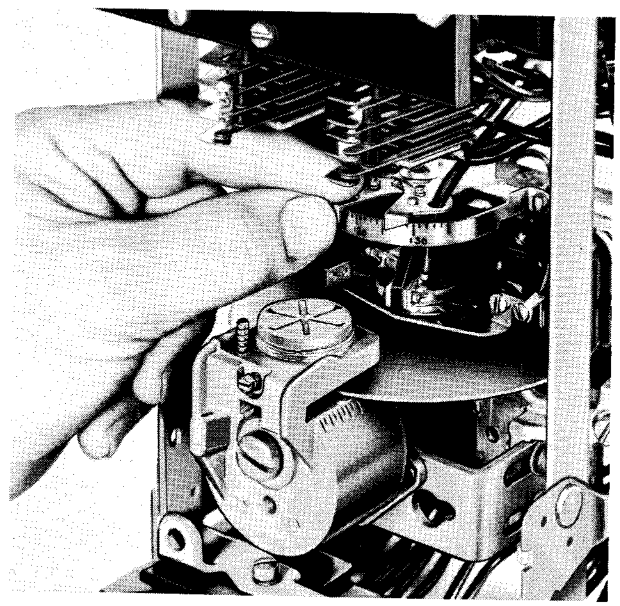


Figure 6 - Setting Voltage Level of CVR Relay

2. If the relay is not in service apply approximately 120 volts for one hour before making settings. This allows the relay to reach normal operating temperatures. If the relay is in service proceed immediately with step number 3.

3. Apply to the test terminals the exact voltage at which the tap changer is to operate in the raise direction. For example, consider 118.5 volts. Since the CVR is very highly damped the voltage should be held at this level for about one minute. The disk contact will now be at its 118.5 volt position. Set the control selector switch on "AUTO" and move the left hand scale pointer until the PR contact just touches the moving contact, picking up the auxiliary relay and operating the tap changer in the raise direction. Place control selector switch in "OFF" position.

4. Apply to the test terminals the exact voltage at which the tap changer is to operate in the lower direction. For example, consider 121.5 volts. Hold the test voltage at 121.5 volts for

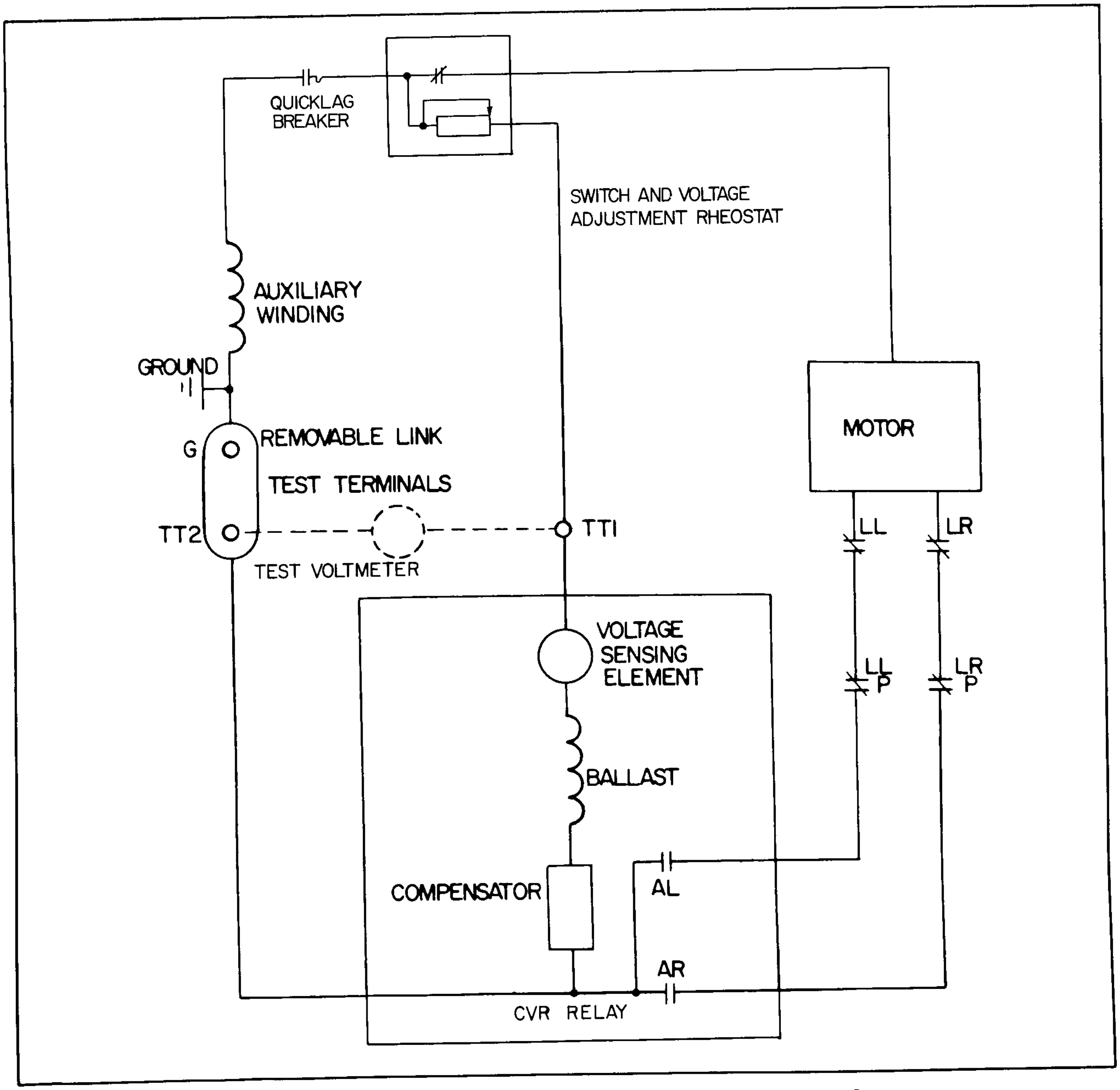


Figure 7 - Simplified Control Schematic with CVR Relay

about one minute to allow the disk contact to reach its 121.5 volt position. With the control selector switch on "AUTO" move the right hand scale pointer until the PL contact just touches the moving contact, operating the tap changer in the lower direction.

5. The CVR Relay is now set to hold regulated output between the limits of 118.5 and 121.5 volts or at a nominal 120 volt level (balance voltage) with a 3 volt bandwidth. ($\pm 1\frac{1}{2}$ volt bandwidth).

6. The CVR relay will operate satisfactorily with any combination of contact settings between 105 and 135 volts and the URL or URF regulator will provide excellent quality regulation with set bandwidths of 2 volts or greater, that is, balance voltage ± 1 volt.

7. For any other settings, determine the limit settings for PR and PL of the voltage regulating relays and proceed as outlined in 2 through 6.

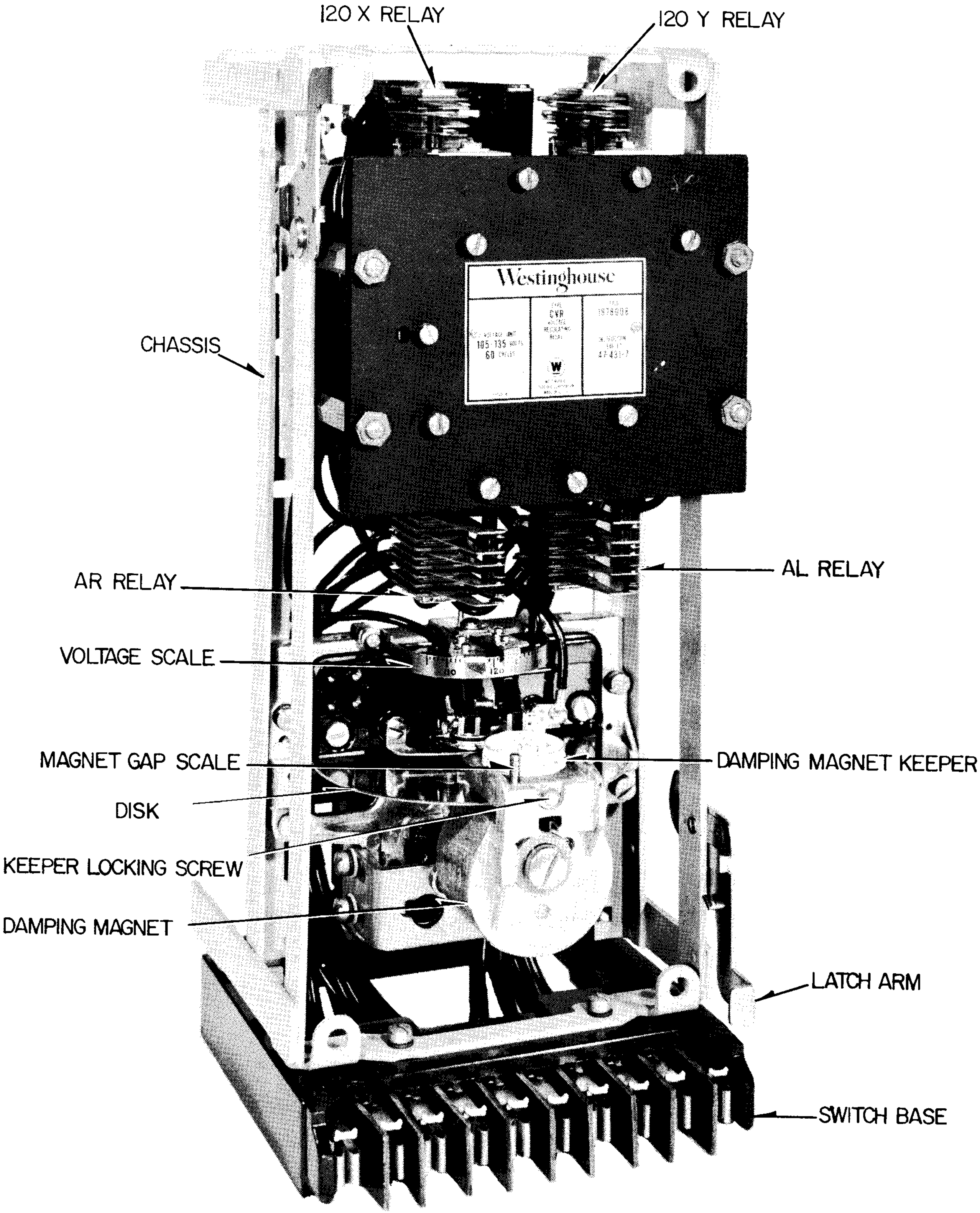


Figure 8 - CVR Relay Removed From Case

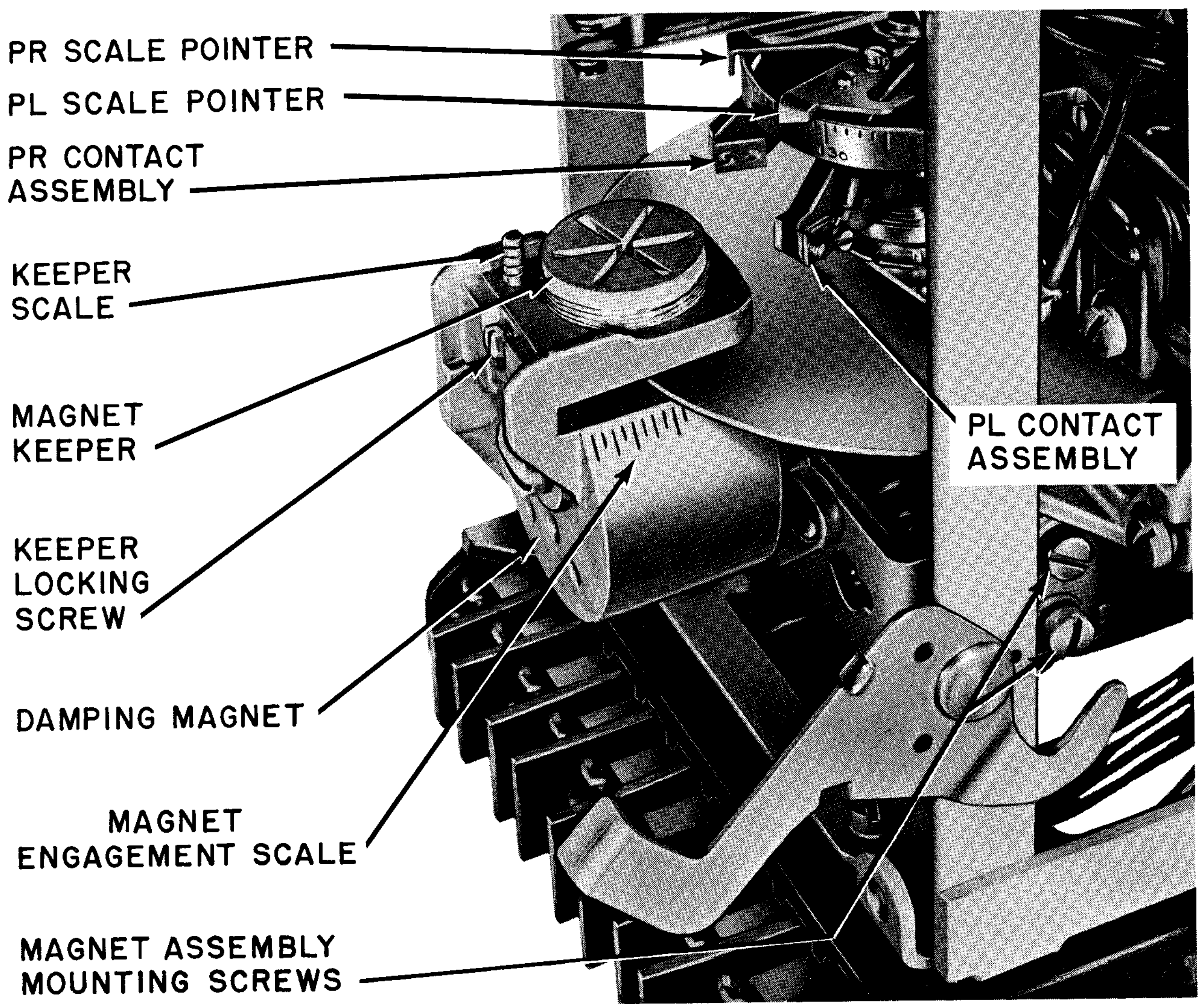


Figure 9 - Closeup of CVR Relay Adjustments

8. Set resistance and reactance compensation dials as required (see page 15).

9. When tests are completed return the voltage adjustment dial to the OFF position to close the motor circuit.

SETTING THE CVR RELAY WITH REGULATOR ENERGIZED

A test voltage adjustment rheostat is located on the control panel for your convenience. It makes possible setting the relay by using the control voltage with the regulator energized. Turning the voltage adjustment knob clockwise a small amount snaps a switch in the motor circuit open without changing the voltage applied to the relay. Turning the knob farther will adjust the voltage applied to the relay by means of the rheostat which is in series with the control voltage and is located ahead of the test terminals. (See Diagram Figure 7). An interlocked switch opens the motor circuit when the voltage level adjustment on the regulator control panel is moved away from the "OFF" position. Proceed as follows:

1. Manually operate the tap changer in the raise direction until a voltage 2 or 3 volts in excess of the PL contact setting is obtained on the test terminals.

2. Move the test voltage adjustment rheostat dial to the right. This opens the motor circuit.

3. Place control selector switch on "AUTO".

4. Adjust test voltage rheostat until desired voltages are obtained and proceed as described under "Setting the CVR By Applying An External Voltage".

5. When tests are complete return rheostat dial to "OFF" position which closes the motor circuit.

SETTING RELAY WHILE REMOVED FROM THE REGULATOR

When removed from its case, the type CVR relay may be checked conveniently by means of the circuit shown in Figure 10. This diagram illustrates the use of a Flexitest plug, Style No. 1164046 which may be plugged into the jack in the relay base. The circuit may also be made by means of clip leads connected to corresponding terminals on the relay.

Connect a 100 ohm 10 watt resistor between G and I and a 500 ohm 1 watt resistor between H and I.

Apply a variable voltage to points F and G (corresponding to TT1 and TT2 in the regulator) and follow the procedure under "Setting the CVR Relay by Applying an External Voltage." The self-sealing circuit of the CVR relay may be cleared by momentarily connecting a jumper from B to F. The 120 switch performs this function in the regulator, clearing the self sealing network and applying negative compounding to the disk of the CVR relay.

The circuit proposed in figure 10 provides all switching and indication required to calibrate the relay and check its performance while removed from the regulator.

Lights R_p and L_p indicate operations of contacts PR and PL while lights R_o and L_o indicate operation of the motor control relay contacts AR and AL.

With the switch in the "CAL" position, the operation of PR and PL contacts is indicated by lights R_p and L_p.

With the switch on "AUTO" position and relay functions in response to applied voltage as it would in a regulator control circuit. Operations are indicated by all four lights.

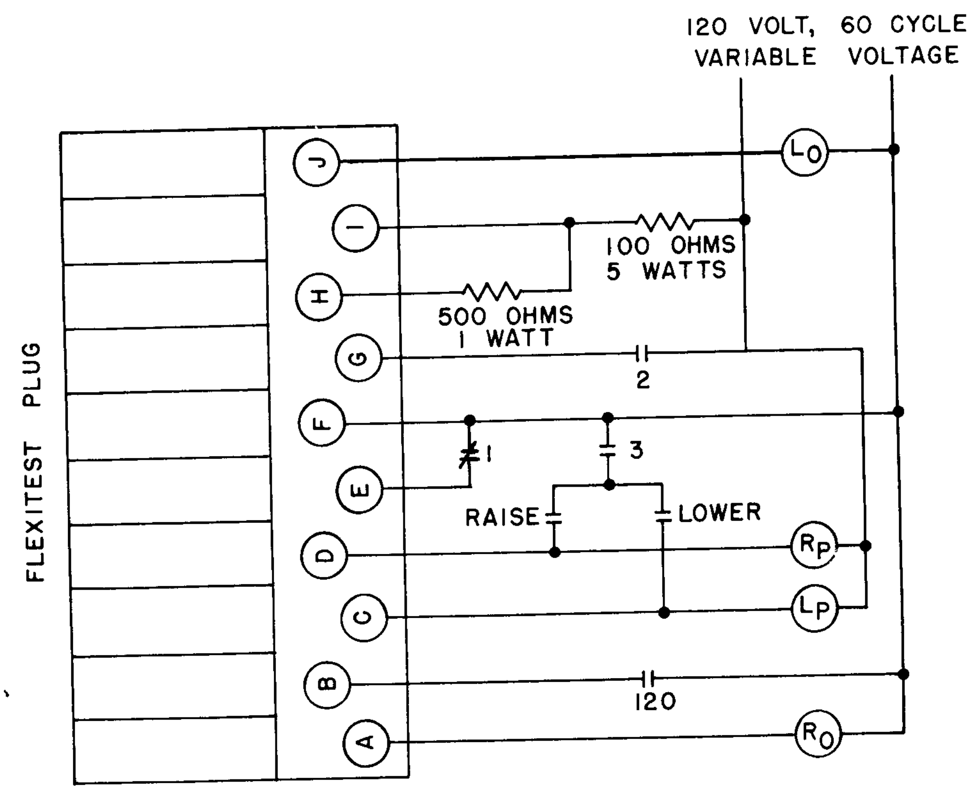
With the switch on "MAN" position the raise and lower switches control the auxiliary relays. R_p and L_p now indicate closing of the raise and lower pushbuttons. R_o and L_o still indicate operation of AR and AL contacts.

General operating data for the relay on 60 cycles is as follows:

Burden of the potential circuit at 120 volts	10VA
with auxiliary relays energized	39VA
Separate R and X compensation	24 volts
100% load compensation current	0.24 amps
Burden on compensating current transformer at 100% load, as applied to the regulator	13 VA

TIME DELAY ADJUSTMENT

The inverse time delay characteristic of the CVR relay enables it to maintain regulated voltage within close tolerance. Figure 9 shows the relay adjusted for a damping factor of one. Figure 12 shows a curve of relay adjustment



NORMALLY OPEN SPRING RETURN SWITCHES OR PUSH-BUTTONS

RAISE
LOWER
120

INDICATING LIGHTS ✱

R_P = RAISE DISK CONTACT
L_P = LOWER DISK CONTACT
R_O = RAISE OPERATE
L_O = LOWER OPERATE

✱ USE 1/25 OR 1/4 WATT NEON LAMPS WITH PROTECTIVE RESISTORS

CAL - AUTO - MAN
3 POSITION SELECTOR SWITCH SEQUENCE

CONTACT	SWITCH POSITION		
	CAL.	AUTO.	MAN.
1	X	X	
2		X	X
3			X
X INDICATES CONTACTS CLOSED			

Figure 10 - Circuit for Checking and Calibrating the CVR Relay

versus damping factors and Figure 13 shows a curve of relay performance when adjusted for a damping factor of one.

In some cases where cycling loads or other load conditions produce large voltage changes of short duration it may be desirable to increase the damping to obtain longer time delay and avoid unnecessary regulator operation. The time delay may be increased by decreasing the gap between the permanent magnet and its keeper. Relays are shipped set for a damping factor of one. The magnet keeper is set with its top even with the first ring below the top of the graduated pin beside it. This setting corresponds to a $\frac{3}{32}''$ gap setting. To change this setting the keeper locking screw must first be loosened. If, after loosening this screw, the keeper does not turn easily, remove the keeper locking screw completely and check the copper thread protector under the locking screw to see that it is free. The keeper gap settings can be gauged by means of the graduated post beside the magnet keeper. These graduations are $\frac{1}{16}''$ apart. One turn of the keeper will change the gap $\frac{1}{32}''$. The gap should never be set at less than $\frac{3}{32}''$ which corresponds to the top of the keeper being even with the first ring on the scale pin above the top surface of the magnet assembly. The maximum keeper setting is shown in the photograph Figure 9. After this adjustment has been completed the locking screw should again be tightened, but before tightening be sure that the piece of copper is still in the hole so that the keeper adjusting threads will not be damaged by the keeper locking screw. If reducing this gap setting to its minimum, $\frac{3}{32}''$, does not produce sufficient time delay, the engagement of the damping magnet and the disk may be increased. In any case the gap adjustment should be reduced to its minimum $\frac{3}{32}''$, before the magnet engagement is increased. This is to insure against possible interference with the stationary relay contacts.

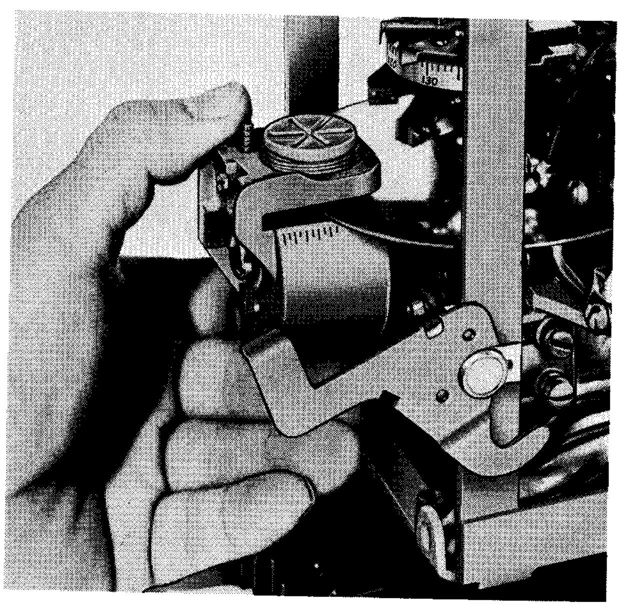


Figure 11 - Setting Magnet Engagement of CVR Relay

The magnet engagement setting is changed by loosening the four magnet assembly screws (see figure 9) and sliding the magnet assembly to its new position. A scale is engraved on the permanent magnet to facilitate setting the magnet engagement. This scale is referenced to the edge of the disk directly above it and is graduated in $\frac{1}{16}''$ intervals.

When changes in time delay settings are to be made, the required settings for a given damping factor may be approximated from the curve, Figure 12.

Example:

Assume that the tests indicate the relay has a 5 second delay for a given voltage change when set for a damping factor of one, and that a 15 second delay is desired to avoid needless tap changer operations and improve regulation.

$$\frac{15\ \text{(Sec. delay required)}}{5\ \text{(Sec. delay measured)}} = 3\ \text{(Damping Factor required)}$$

Figure 12 indicates that for a damping factor of three the keeper should be set at $\frac{3}{32}''$ and the magnet engagement should be set at 8½ (sixteenths from maximum engagement).

See figures 9 and 11.

The damping factor for any relay as set may be determined easily by the following procedure.

1. De-energize the relay.
2. Set PR scale pointer at 105 volts.
3. Set PL scale pointer at 135 volts.
4. Manually rotate the disk to close PL contacts.
5. Release the disk and measure the time to close the PR contact.
6. Divide the number of seconds measured

in step 5 by 5.4. The quotient is the damping factor for the relay as adjusted.

7. Move the PR and PL scale pointers to the desired limits for voltage band.

Having determined the relay damping factor, a new curve for relay performance may be plotted by multiplying the time values read from the curves in figure 13 by the damping factor.

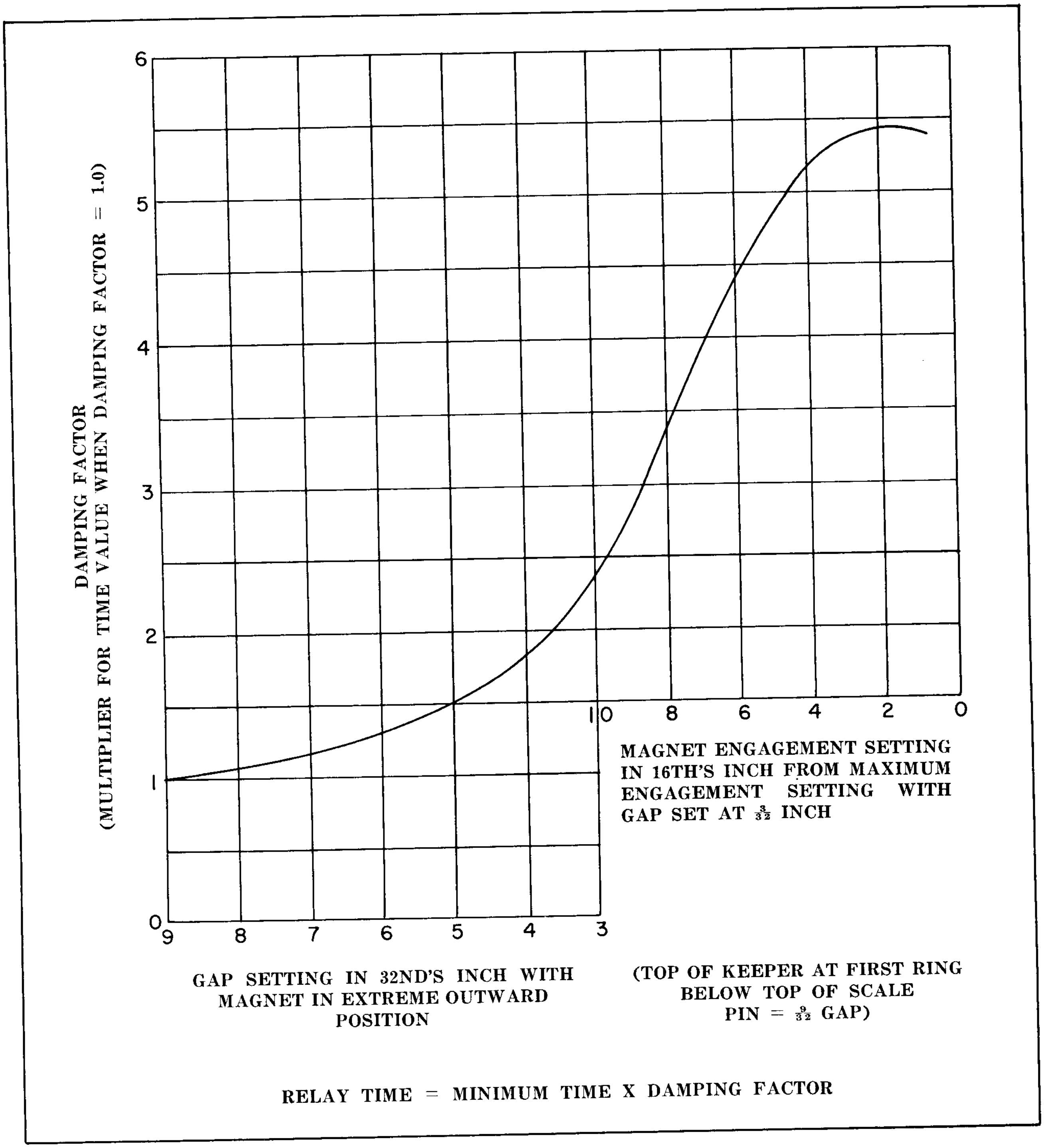
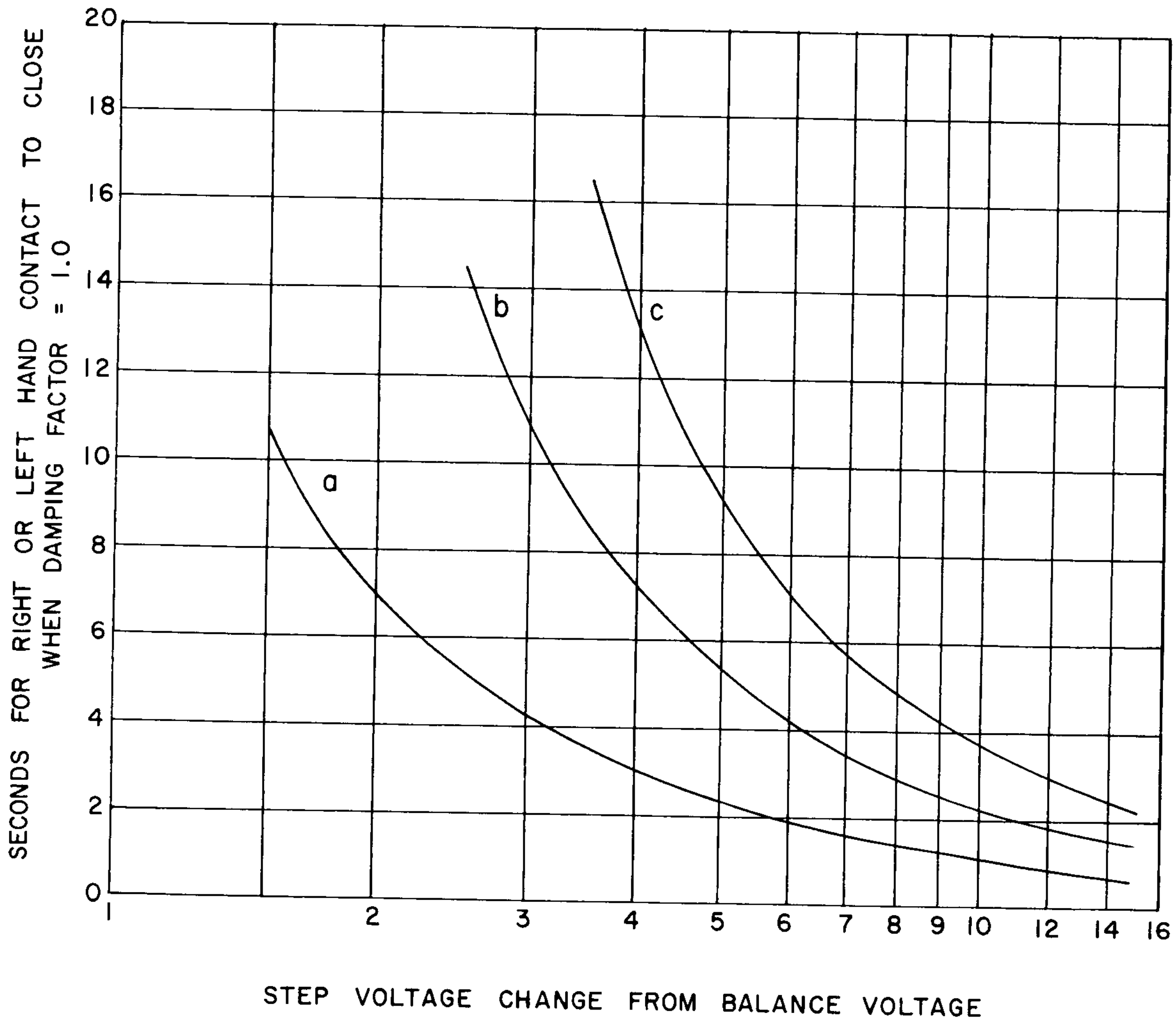


Figure 12 - Typical Damping Factors Versus Gap Setting and Magnet Engagement

Example:

Assume 10.8 seconds measured in step 5 above 10.8 ÷ 5.4 = 2, the relay damping factor. In Figure 13 we find that for a 2 volt bandwidth the time delay would be 3 seconds for a 4 volt change.

To determine the actual time to close relay contacts multiply 3 (seconds) x 2 (damping factor) = 6 seconds actual time delay.



CURVE	BAND WIDTH
a	2 VOLTS
b	4 VOLTS
c	6 VOLTS

Figure 13 - Time Delay Versus Step Change in Voltage Level For Type CVR Relay

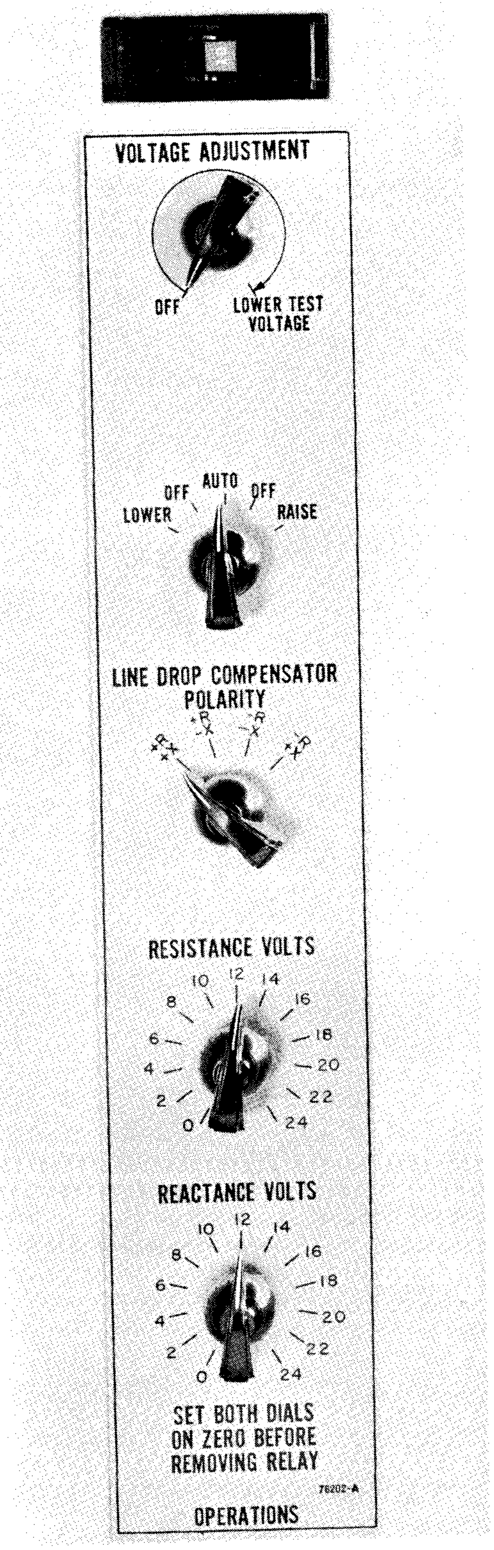


Figure 14 - Typical Adjustment and Control Switches Associated with the CVR Relay

ASSOCIATED RELAY CONTROL

Figure 14 shows typical adjustments and control switches associated with this relay, but which are actually part of the regulator control circuit.

The exact details of this equipment are not important to this discussion and could be different on a particular unit.

The control breaker, voltage adjustment, and control selector switch (Lower- OFF-Auto-OFF-Raise) have been referred to earlier. The following sections deal with line drop compensation, which is set by means of the lower three knobs on this panel.

The **Resistance Volts** dial is calibrated in volts drop, on a control voltage basis, and represents the line resistance vector voltage drop from the regulator to the load center. In the same manner the **Reactance Volts** dial is calibrated in volts drop on a control voltage basis, representing a vector voltage drop equivalent to the line reactance vector voltage drop from the regulator to the load center.

The way these compensating devices function in the relay circuit is developed on the following pages.

As will be seen in the discussions of line drop compensation on delta and open delta connected units, it is sometimes necessary to reverse the direction of compensation in a unit. This is accomplished by means of the **Line Drop Compensator Polarity** switch which is arranged so that either or both components may be reversed at will, by merely selecting the desired combination with this knob.

The number of tap changer operations is indicated on an operation counter mounted in the control panel directly below the line drop compensator control dials.

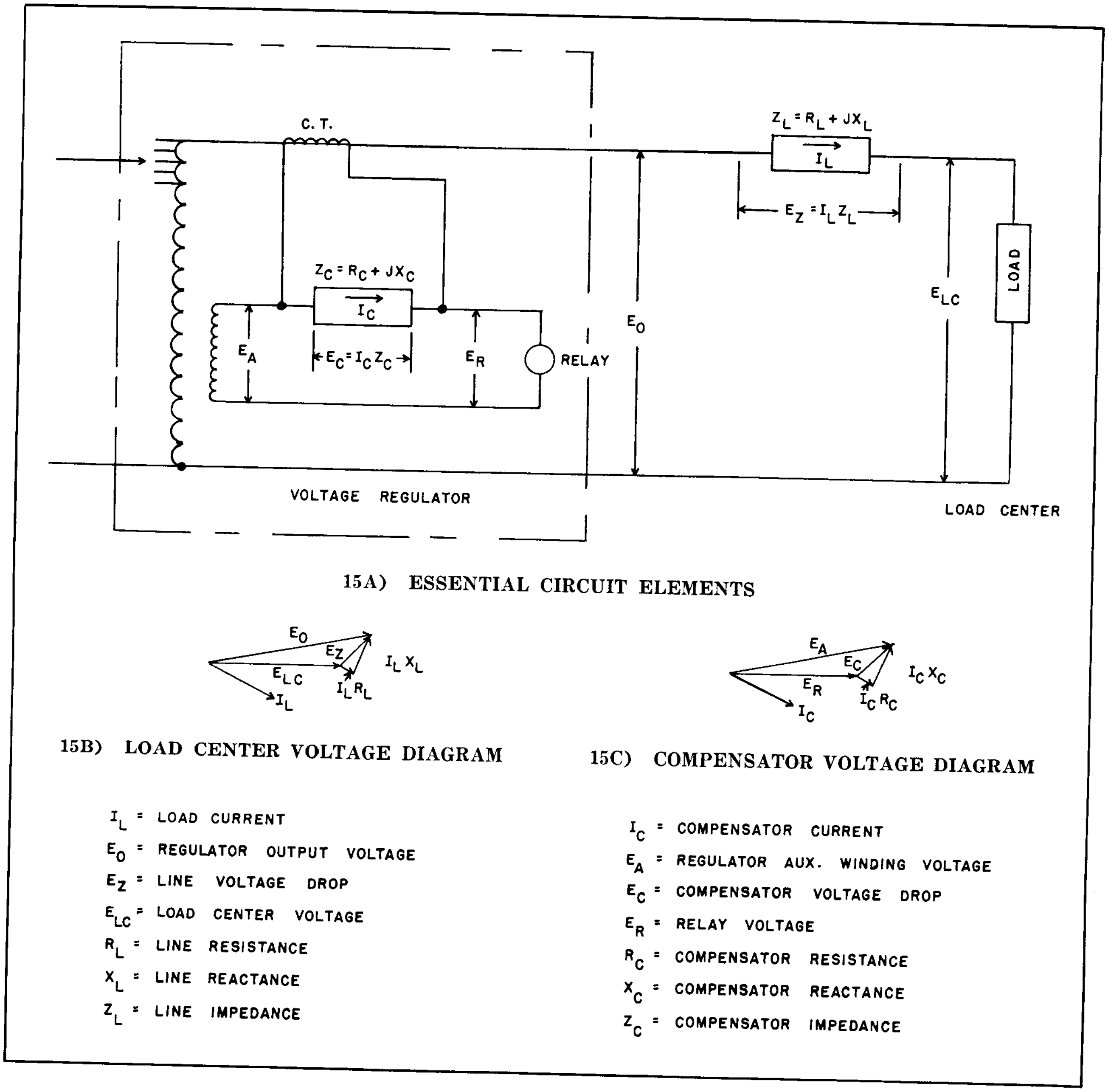


Figure 15 - Essential Elements of Load and Compensating Circuit and their Vector Diagrams For Type CVR Relay

LINE DROP COMPENSATOR

The current in the line from regulator to load center produces a voltage drop. The regulator should maintain constant voltage level at the load center.

The auxiliary voltage output represents regulator load terminal voltage. By subtracting from this voltage vector a line drop compensator voltage vector porportional to line drop, the resultant voltage will truly represent the load center voltage for all load conditions.

Proper line drop compensator voltage is obtained by circulating the output of a current transformer in the load circuit through separately adjustable resistance and reactance branches. Proper setting of resistance and reactance dials on the line drop compensator will insure that the CVR relay will respond to load center voltage. Figure 15 shows the essential elements of the load and compensating circuit and their vector diagrams.

In Figure 15A, the current I_L flowing through R_L and X_L produces a voltage drop E_Z which subtracts vectorily from the regulator output voltage E_O to produce a load center voltage E_{LC}. Figure 15B shows how these vectors are related.

Looking at the compensator portion of the circuit in 15A and its vector diagram in 15C, the compensator current I_C is proportional to the load current I_L. R_C and X_C are compensator impedance branches which are set to be proportional to R_L and X_L. When I_C flows through this compensating impedance a voltage drop E_C is produced. The vectors E_A and E_C combine to produce E_R, the resultant voltage vector applied to the CVR relay. Correctly selected resistance and reactance compensator dial settings will insure that the CVR relay will respond to load center voltage for all load conditions.

SINGLE PHASE OR WYE CONNECTED 3-PHASE LINE-DROP COMPENSATOR SETTINGS

The final settings on the line-drop compensator may most satisfactorily be made by field adjustment. Initial settings may be determined from line data using the curves shown in Figure 16 and 17. A sample calculation is shown below.

A typical installation might be:

Single Phase, 2-wire circuit

7200 volts (120 volts control)

3 volt bandwidth

2/0 copper conductor with 3 ft. spacing

4 miles to load center

100 amperes regulator with 100/.24 amp current transformer

80 amperes load current

Set the left contact at 118.5 volts and the right contact at 121.5 volts.

From the Resistance Chart the resistance is .45 x 2 = 0.9 ohms per mile and from the Reactance Chart the reactance is approximately .66 x 2 = 1.32.

The line-drop compensator setting is:

$$* \quad \text{CT Primary Rating x } \frac{\text{Control Voltage}}{\text{Line Voltage}} \text{ x}$$

ohms per mile x miles to the load center.

*Regulator Current Rating equals CT Primary Rating.

$$100 \text{ x} \frac{7200}{120} \text{ x } 0.9 \text{ x } 4 = 6.0 \text{ volts resistance}$$

$$100 \text{ x} \frac{120}{7200} \text{ x } 1.32 \text{ x } 4 = 8.8 \text{ volts reactance}$$

For a three phase line from regulator to load center, the values from the chart would not have been multiplied by two. Thus if the above had been a 3 phase line with the same wire size and effective spacing, the settings would have been 3 volts resistance and 4.4 volts reactance. For a symmetrical triangular configuration the distance between adjacent conductors is the effective spacing. Where 3 phase conductors are not in a symmetrical triangular configuration, the effective distance is the cube root of the product of the 3 distances between individual conductors.

$$D = \sqrt[3]{D_{AB} \text{ x } D_{BC} \text{ x } D_{CA}}$$

These 3 phase values may be used directly for wye connected regulators supplying 3 phase loads but must be further modified for open delta or closed delta connected regulators supplying 3 phase loads as outlined below.

As stated earlier, these settings may be adjusted as necessary based on voltage measurement made at the load center.

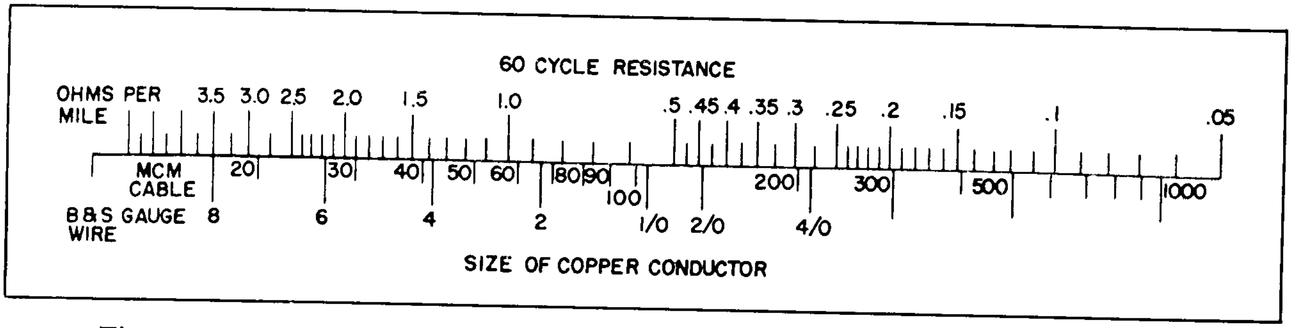


Figure 16 - Resistance Chart Showing Ohms Per Conductor Per Mile 60 Cycle Circuit

LINE DROP COMPENSATOR SETTINGS ON OPEN DELTA CONNECTED REGULATORS

For correct line drop compensation on open delta connected units the compensator settings calculated in the preceding examples must be modified as shown in the table below to compensate for the 30° displacement between regulator voltage and regulator current.

Use the R and X values calculated above to determine the modified R setting and X setting for the compensator dials by means of the following equations or the Wagner nomograph charts in figure 18. The tests outlined below may be used to determine whether the unit is a leading unit or a lagging unit.

Leading Unit
(Unit in which current leads voltage)
R setting = .866R + .5X
X setting = −.5R + .866X

Lagging Unit
(Unit in which current lags voltage)
R setting = .866R — .5X
X setting = .5R + .866X

LINE DROP COMPENSATOR POLARITY

If negative line drop compensator settings are calculated, a polarity switch on the regulator control panel will provide the proper combinations of positive and negative resistance and reactance dial settings, by simply setting the switch on the position needed. This polarity switch is of the shorting type, so that it may be operated with load on the regulator.

FIELD METHOD FOR DETERMINING THE OPEN DELTA UNIT WITH LEADING OR LAGGING CURRENT WITH RESPECT TO ITS VOLTAGE

To make the proper identification perform the following steps after the regulators are connected in open delta and carrying current.

1. Set the resistance compensator dial of both regulators on zero.

2. Set the reactance compensator dials at 12 on both regulators.

3. Place the control selector switch on "AUTO".

4. The lagging current unit will operate more positions in the raise direction than the leading current unit.

FIELD METHOD FOR DETERMINING WHETHER THE CURRENT IN THE REGULATOR WINDING IS LEADING OR LAGGING THE VOLTAGE IN A CLOSED DELTA BANK OF SINGLE PHASE REGULATORS

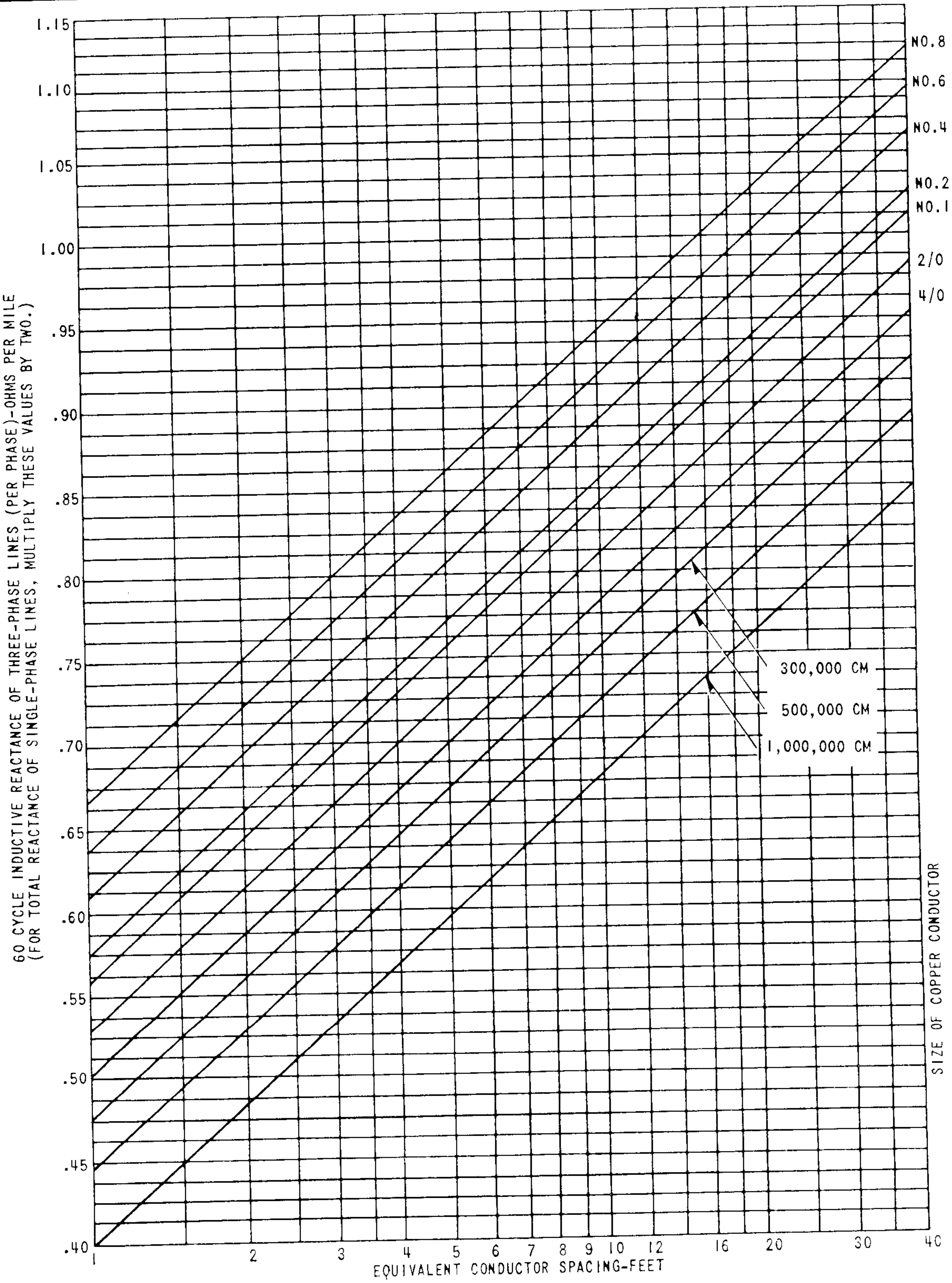
The compensator dial setting modifications described for open delta operation will give correct line drop compensation on closed delta connected regulators when they are on neutral position. On other than neutral positions the compensation will be approximately correct. (An error is introduced because the regulator current transformer is connected ahead of the delta connection.)

To determine whether the 3 single phase regulators in a closed delta bank are connected in such manner as to result in the winding current's leading or lagging the voltage of that phase, the following steps may be followed.

1. Set resistance compensator dials on all regulators on zero.

2. Set the reactance compensator dials on 12 on all 3 units.

3. Place the line drop compensator polarity selector switch on +R +X.



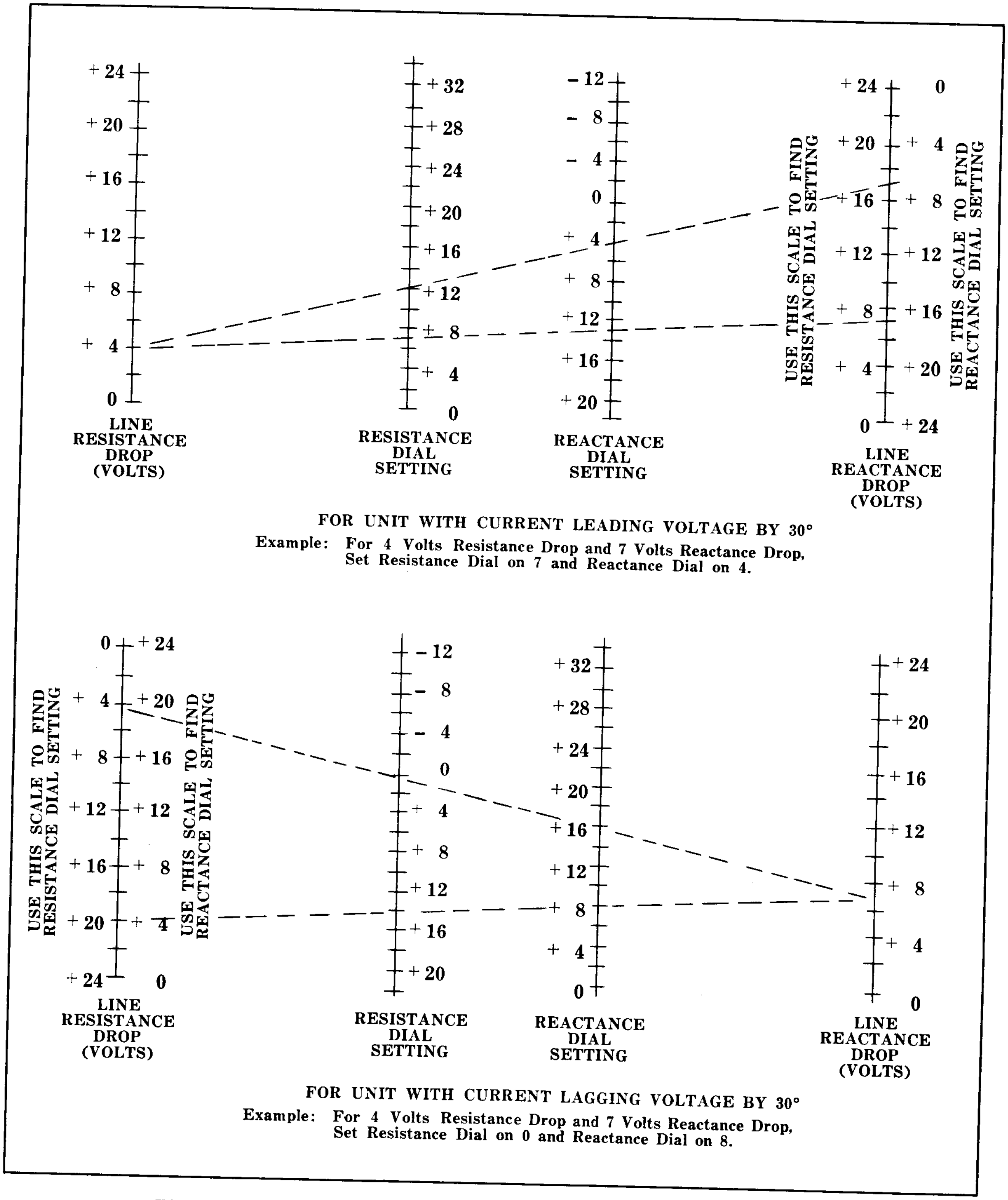
EQUIVALENT CONDUCTOR SPACING, D, OF UNSYMMETRICAL THREE PHASE LINES IS GIVEN BY THE EXPRESSION $D=\sqrt[3]{D_{AB} \times D_{BC} \times D_{CA}}$, WHERE

D_{AB}, D_{BC}, AND D_{CA} ARE THE DISTANCES IN FEET BETWEEN CONDUCTORS DESIGNATED BY THE SUBSCRIPTS.

NOTE:- WHERE $D_{CA} = 2\ D_{AB} = 2\ D_{BC}$: $D = 1.26\ D_{AB}$

Figure 17 - Reactance in Ohms Per Conductor Per Mile Versus Spacing For Single Phase or 3 Phase Lines

WAGNER CHARTS



FOR UNIT WITH CURRENT LEADING VOLTAGE BY 30°

Example: For 4 Volts Resistance Drop and 7 Volts Reactance Drop, Set Resistance Dial on 7 and Reactance Dial on 4.

FOR UNIT WITH CURRENT LAGGING VOLTAGE BY 30°

Example: For 4 Volts Resistance Drop and 7 Volts Reactance Drop, Set Resistance Dial on 0 and Reactance Dial on 8.

Figure 18 - Wagner Charts for Determining Line Drop Compensator Settings on Open Delta Connected Regulators

4. Set control selector switch on "AUTO". Regulators will operate to correct voltage. Observe tap changer position.

5. Switch polarity selector switch to +R-X

If the regulator now operates to raise its output voltage the regulators are connected as leading units. If the regulator now operates to lower its output voltage the regulators are connected as lagging units.

6. Obtain revised line drop compensator settings by means of the Wagner Scheme.

Note: The above test for the closed delta regulators is effective for load power factors between 90% lagging and 90% leading. The use of the Wagner scheme on closed Delta connections is valid for regulators in closed delta when the delta is closed by connecting the L terminals of one regulator to the SL terminal of the other regulator.

MAINTENANCE

The proper adjustments to insure correct operation of this relay have been made at the factory and should not be disturbed after receipt by the customer (with the exception of bandwidth or time delay settings). Repair work can be most satisfactorily done at the factory. If it is desired to check the adjustment at regular maintenance, the following instructions should be followed:

Note: Before opening the test switches set the line-drop compensator dials on zero and turn the power supply and manual control switches off.

Remove the cover by unscrewing the captive nuts of the cover. The relay can then be inspected and tested in the case or out of the case. External test circuits to the relay may be made with test clip leads or by means of a test plug.

To remove the chassis from the case, be sure the knife switches are fully open, grasp the two cam action latch arms, and pull outward. Using the latch arms as handles, pull the chassis from the case. A duplicate chassis may be inserted in the case or the blade portion of the switches closed and the cover replaced without the chassis.

When contacts require cleaning, they should be cleaned with a fine contact file similar to S#1002110 or a contact burnishing tool. Abrasive material should not be used because any small particles embedded in the contact surface will impair the contact operation.

For identification of relay parts, see Figure 5.

* * * * *

DESCRIPTION • INSTALLATION • OPERATION

INSTRUCTIONS

VOLTAGE REGULATING RELAY

TYPE CVR

Applied to Step Regulator Control

WESTINGHOUSE ELECTRIC CORPORATION
SHARON PLANT • TRANSFORMER DIVISION • SHARON, PA.

SUPERSEDES I.B. 47-431-7A

EFFECTIVE NOVEMBER, 1960

INDEX

ILLUSTRATIONS

INSTRUCTIONS

VOLTAGE REGULATING RELAY TYPE CVR
Applied to Step Regulator Control

The type CVR Voltage Regulating Relay is in reality a "control package" designed to control the URL and URF tap changers. The major components of the CVR relay are an induction disk type voltage sensitive relay, two auxiliary or pilot relays, two motor control relays and a reactor. All components are in a drawout chassis so that the complete relay may be interchanged from unit to unit or removed for testing and inspection. The Flexitest* switch base is made an integral part of the CVR relay to facilitate connecting and testing the relay.

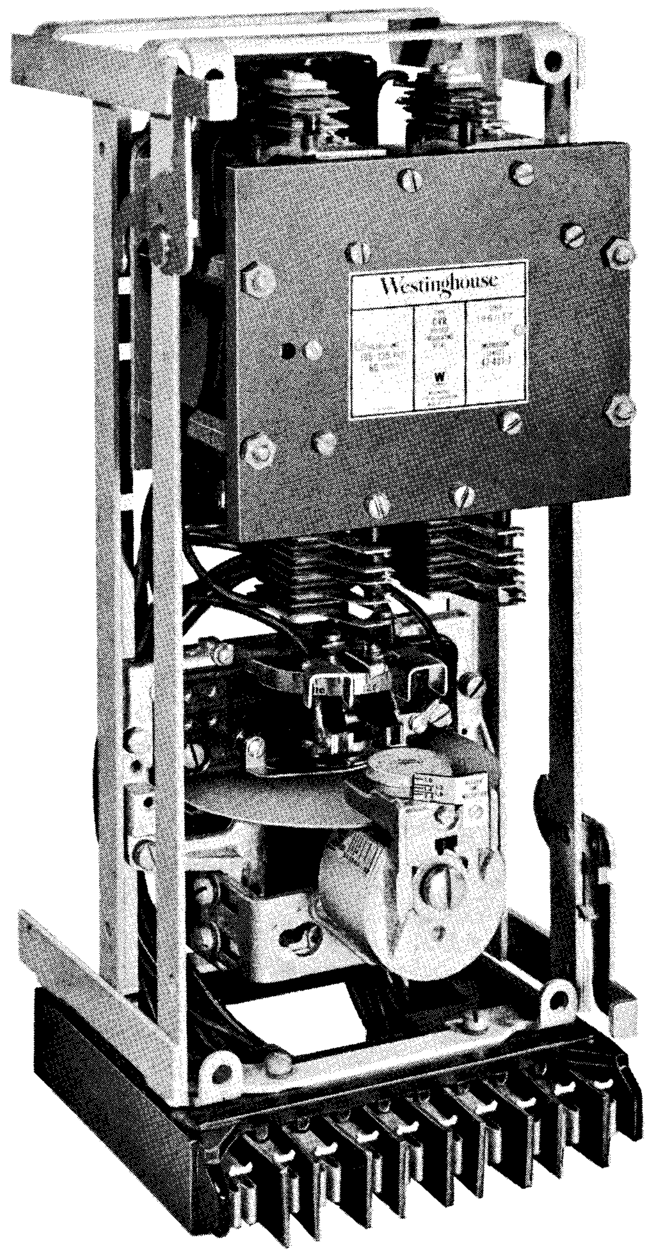


Figure 1 - CVR Relay Removed From Case

* Westinghouse Trade Mark

SUPERSEDES I.B. 47-431-7A

EFFECTIVE NOVEMBER, 1960

The case in which the relay is mounted for the URL and URF regulator control is equipped with the mating portion of the Flexitest switch.

A typical application showing the relay mounted in a regulator control panel with the relay cover removed is illustrated in Figure 2.

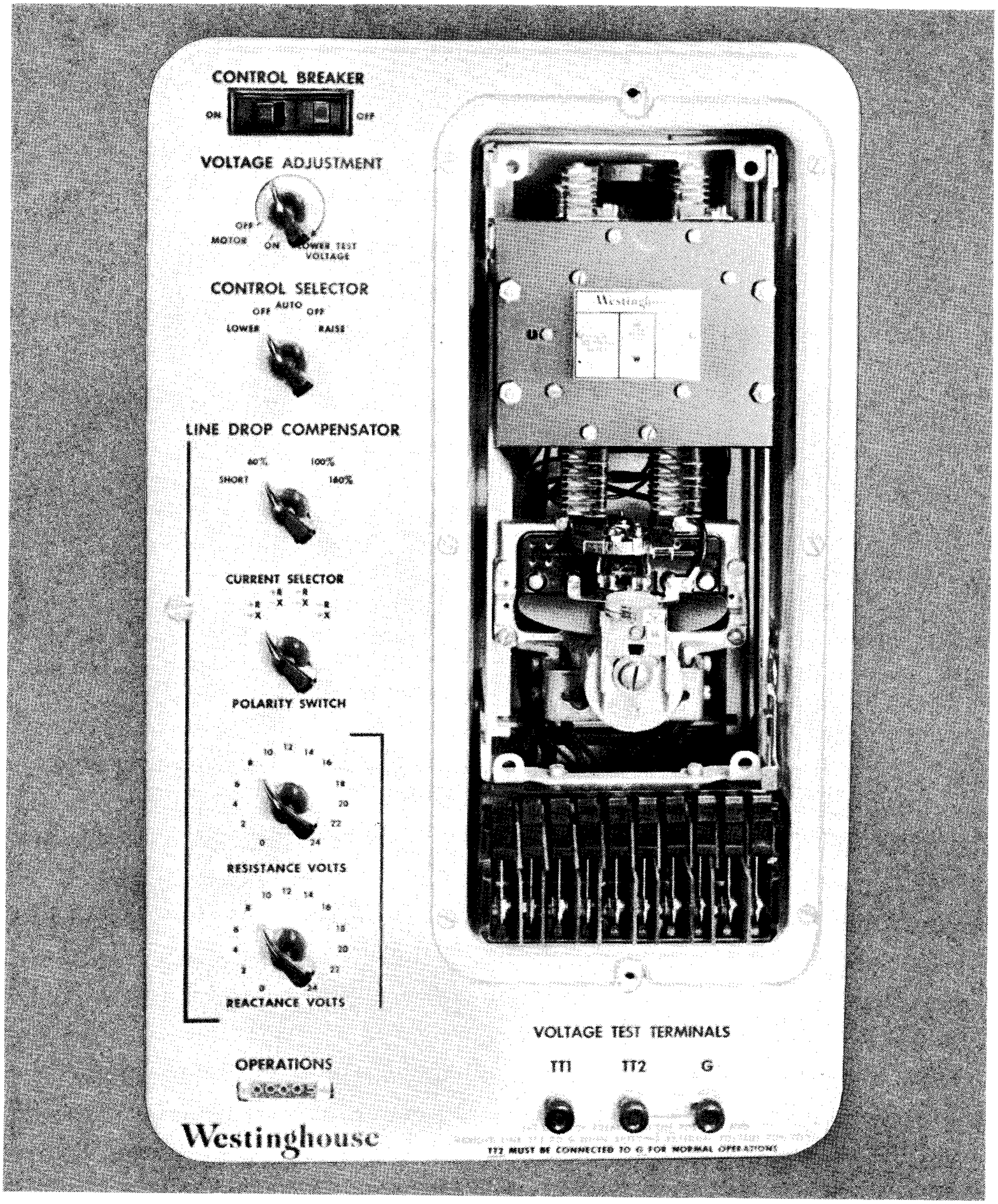


Figure 2 - Typical Regulator Control Panel With CVR Relay Installed

INSTALLATION

The CVR relay is usually mounted in the tap changer control panel. Before putting the relay in service, remove any blocking inserted for the purpose of securing parts during shipment; make sure that all parts operate freely, and inspect the contacts to see that they are clean and close properly. Check the gaps of the permanent magnet and of the electromagnet and clean them if any foreign material is present. Operate the relay to check the settings and electrical connections.

OPERATION

The sensing element of the CVR relay is an induction disk voltage relay with a set of single pole double throw contacts. Sealing circuits for the auxiliary relay are incorporated into the circuit to insure long contact life and positive operation.

Figure 3 shows schematically the relation between the principle components of the CVR relay voltage sensing circuit while figures 4 and 5 show the internal schematic and internal wiring of the actual CVR relay.

A reactor connected in series with the voltage sensing element is a large portion of the impedance of this circuit. This feature minimizes the effect of resistance variations due to temperature changes and is used in the line drop compensator circuit.

The voltage coil on the lower pole of the voltage sensing element supplies a current to the coil on the upper pole by transformer action. The alternating fluxes induced in these poles are in quadrature. The alternating flux cutting the induction disk induces eddy currents in the disk of the relay which react with the flux in the air gap producing a torque. This torque is balanced against a spring torque to determine the balance position of the relay disk and its associated contacts.

Assume 120 volts has been applied to the relay long enough for the moving contact to come to rest at the 120 volt point on the relay scale. If the applied voltage was increased to 121 volts, the increased electro-magnetic torque would move the moving contact to the 121 volt point on the scale. If the voltage was reduced to 119 volts the decreased electromagnetic tor-

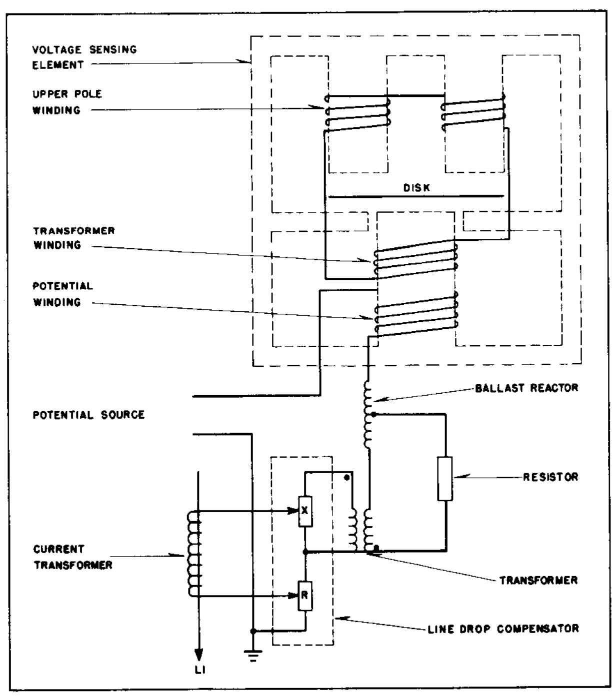


Figure 3 - Schematic Diagram of the CVR Relay Voltage Sensing Circuit

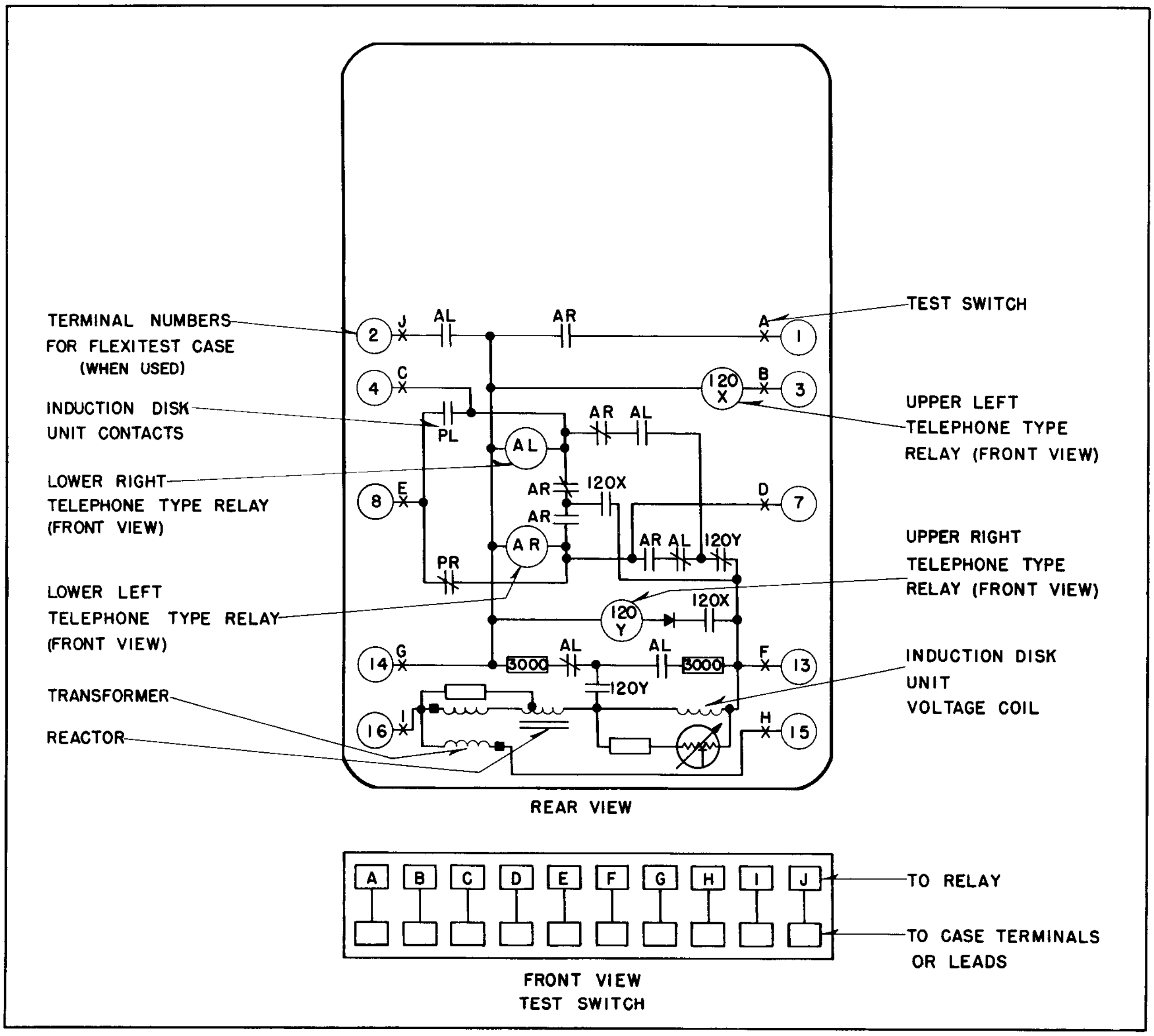


Figure 4 - CVR Voltage Regulating Relay Internal Schematic

que would allow the spring torque to move the contacts to the 119 volt position.

A permanent damping magnet is mounted on the relay with the induction disk between the pole faces of this magnet and the magnet keeper. Whenever the induction disk moves through the unidirectional flux produced by this permanent magnet a restraining force is produced to control the time required to change from one balanced position to another for a given change in voltage.

The position of the stationary PR and PL contacts determines the voltage level at which they will be closed to initiate tap changer operation to correct the voltage.

If the voltage falls below the setting of the left hand contact long enough for the disk operated PR contact to close, the relay AR is energized and seals itself in through the normally closed 120Y relay contact. Closing the AR relay motor contacts operates the tap changer to raise the voltage. Before the tap changer arcing contact has opened, a cam operated 120 switch in the tap changer closes to energize the 120X relay which in turn takes over the sealing of the AR relay through its 120X contact and operates the 120Y slug delayed relay. The normally open 120Y relay contact closes and shorts the reactor with a 3,000 ohm resistor which increases the current through the voltage coil and tends to rotate the disk to open contacts

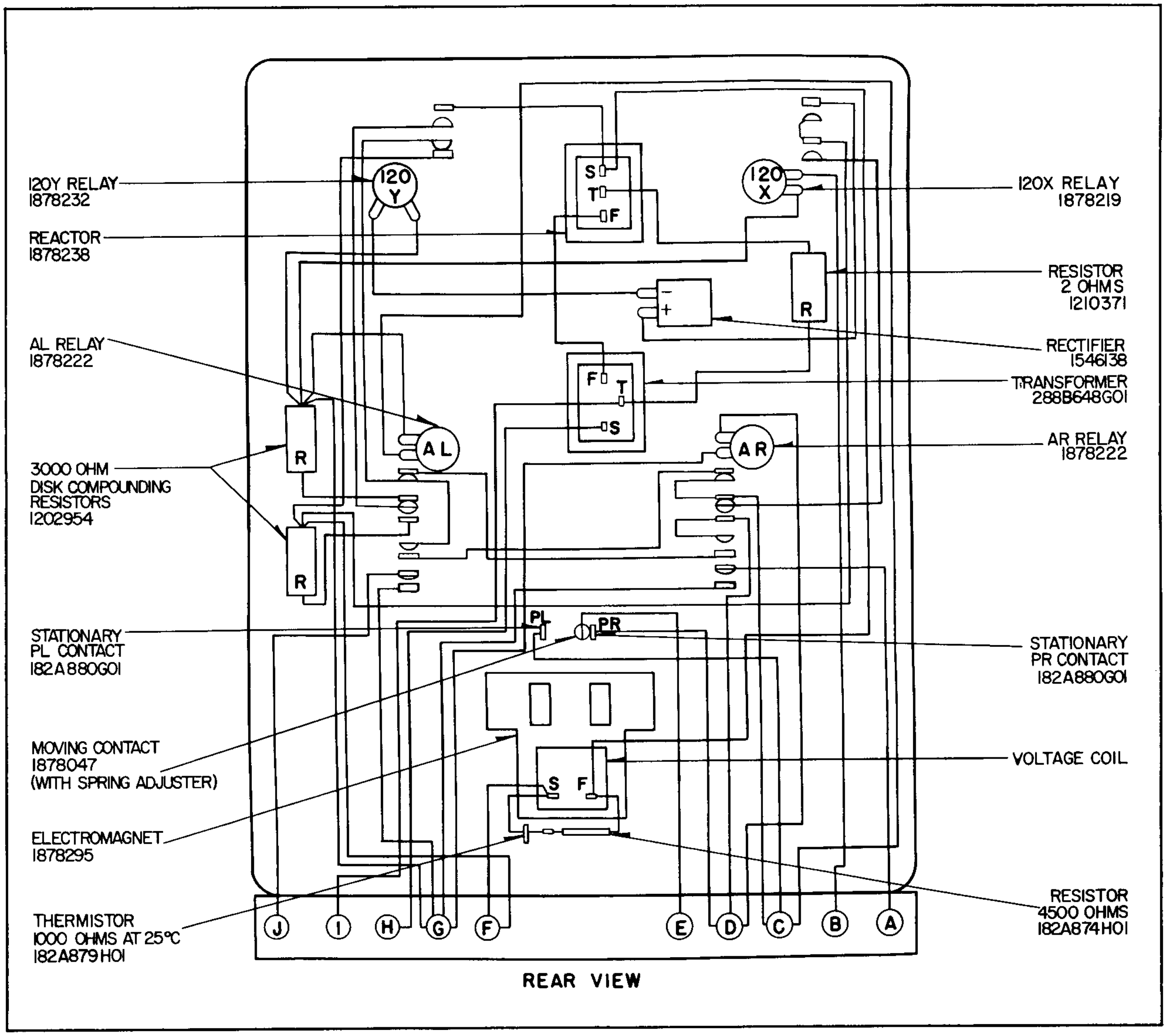


Figure 5 - CVR Relay Internal Wiring Diagram

PR, so that for small voltage errors there will be a short delay between successive tap changer operations. After the tap changer arcing contact has closed on position, the 120 pilot switch opens, allowing the 120X relay to release the AR relay. The tap changer motor is stopped by the spring loaded cam brake. If the voltage is not corrected, the sequence is repeated until the voltage is corrected or a tap changer limit position is reached. A rise in voltage to close the right hand contact would initiate a similar sequence of operations to lower the voltage.

BANDWIDTH AND BALANCE VOLTAGE

The bandwidth of the voltage regulating relay is the difference in volts between the PR and PL contact setting.

Balance voltage is defined as the voltage midway between the PR and PL voltage settings and is the voltage which the relay will tend to maintain. A line drop compensator incorporated in the relay circuit enables the relay to adjust the tap changer to regulate the voltage at the load center rather than at the regulator itself. A current transformer installed in the regulator provides a small secondary current proportional to the current flowing through the regulator to the load. The secondary current of this current transformer is circulated through resistance and reactance elements to produce an impedance voltage which is combined with the control voltage to match the relation between the regulator output voltage and the line impedance drop. In this manner the resultant voltage applied to the relay is made to match the load center voltage. When these resistance and reactance drops are properly selected to match the line impedance drop from the regulator to the load center, the CVR relay will respond to load center voltage rather than regulator output voltage and will regulate the load center voltage rather than the voltage at the regulator output terminals.

SETTING THE CVR RELAY BY APPLYING AN EXTERNAL VOLTAGE

It is most convenient to set the CVR relay while mounted in the regulator panel. Turning the voltage adjustment knob clockwise a small amount snaps a switch in the motor circuit open without changing the voltage applied to the relay. (After the switch snaps, turning the knob farther inserts resistance between the auxiliary winding of the regulator and the CVR relay.) The relay operating points may be set by means of its scale which is calibrated in volts. For more exact setting an accurate voltmeter should be connected from TT1 to TT2 as shown in Figure 7. It is convenient to apply an external variable voltage source to TT1 and TT2 reading on the voltmeter the voltage at which the PR and PL contacts close.

Caution:

Extreme care must be taken to insure that the breaker in the regulator control circuit is in the OFF position and that the link G to TT2 is disconnected before applying an external voltage to the test terminals of the regulator. This precaution is necessary to avoid the possibility of energizing the regulator in reverse through the auxiliary winding producing high voltage on the regulator terminals. Link G to TT2 should also be disconnected to avoid the possibility of short circuiting the external supply through the ground connection.

To make the settings proceed as follows:

1. Set resistance and reactance compensator dials both on zero. Set PR lower and PL higher than their final settings.

Note: Always adjust PR and PL contacts by moving the handles attached to the scales. See Fig. 6.

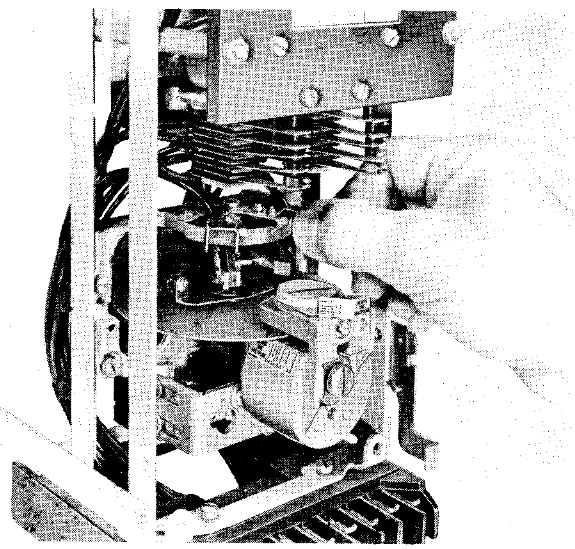


Figure 6 - Setting Voltage Level of CVR Relay

2. If the relay is not in service apply approximately 120 volts for one hour before making settings. This allows the relay to reach normal operating temperatures. If the relay is in service proceed immediately with step number 3.

3. Apply to the test terminals the exact voltage at which the tap changer is to operate in the raise direction. For example, consider 119 volts. Since the CVR is very highly damped the voltage should be held at this level for about one minute. The disk contact will now be at its 119 volt position. Set the control selector switch on "AUTO" and move the left hand scale pointer until the PR contact just touches the moving contact, picking up the auxiliary relay and operating the tap changer in the raise direction. Place control selector switch in "OFF" position.

4. Apply to the test terminals the exact voltage at which the tap changer is to operate in the lower direction. For example, consider 121 volts. Hold the test voltage at 121 volts for

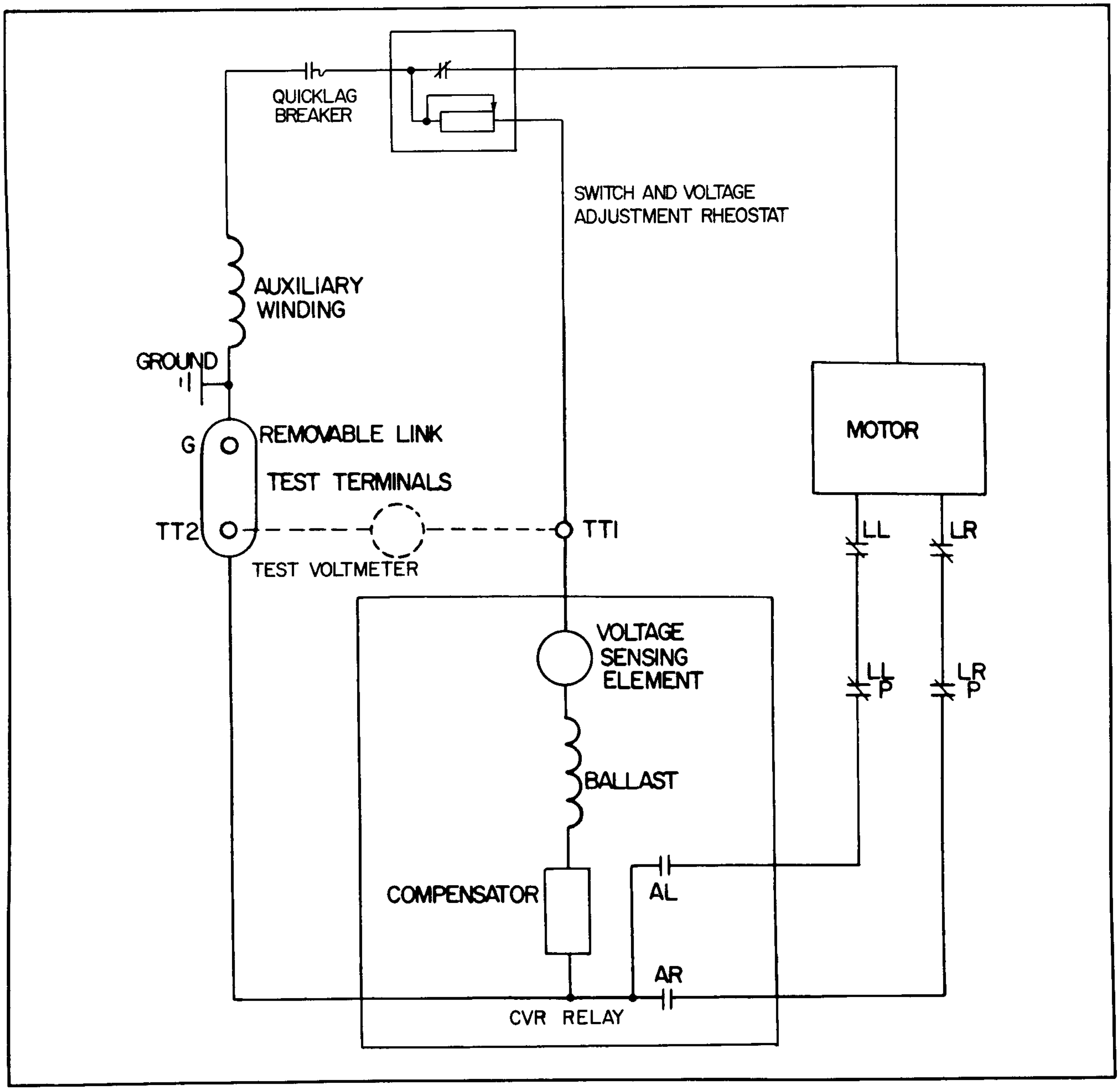


Figure 7 - Simplified Control Schematic with CVR Relay

about one minute to allow the disk contact to reach its 121 volt position. With the control selector switch on "AUTO" move the right hand scale pointer until the PL contact just touches the moving contact, operating the tap changer in the lower direction.

5. The CVR Relay is now set to hold regulated output between the limits of 119 and 121 volts or at a nominal 120 volt level (balance voltage) with a 3 volt bandwidth. ($\pm 1\frac{1}{2}$ volt bandwidth).

6. The CVR relay will operate satisfactorily with any combination of contact settings between 105 and 135 volts and the URL or URF regulator will provide excellent quality regulation with set bandwidths of 2 volts or greater, that is, balance voltage ± 1 volt.

7. For any other settings, determine the limit settings for PR and PL of the voltage regulating relays and proceed as outlined in 2 through 6.

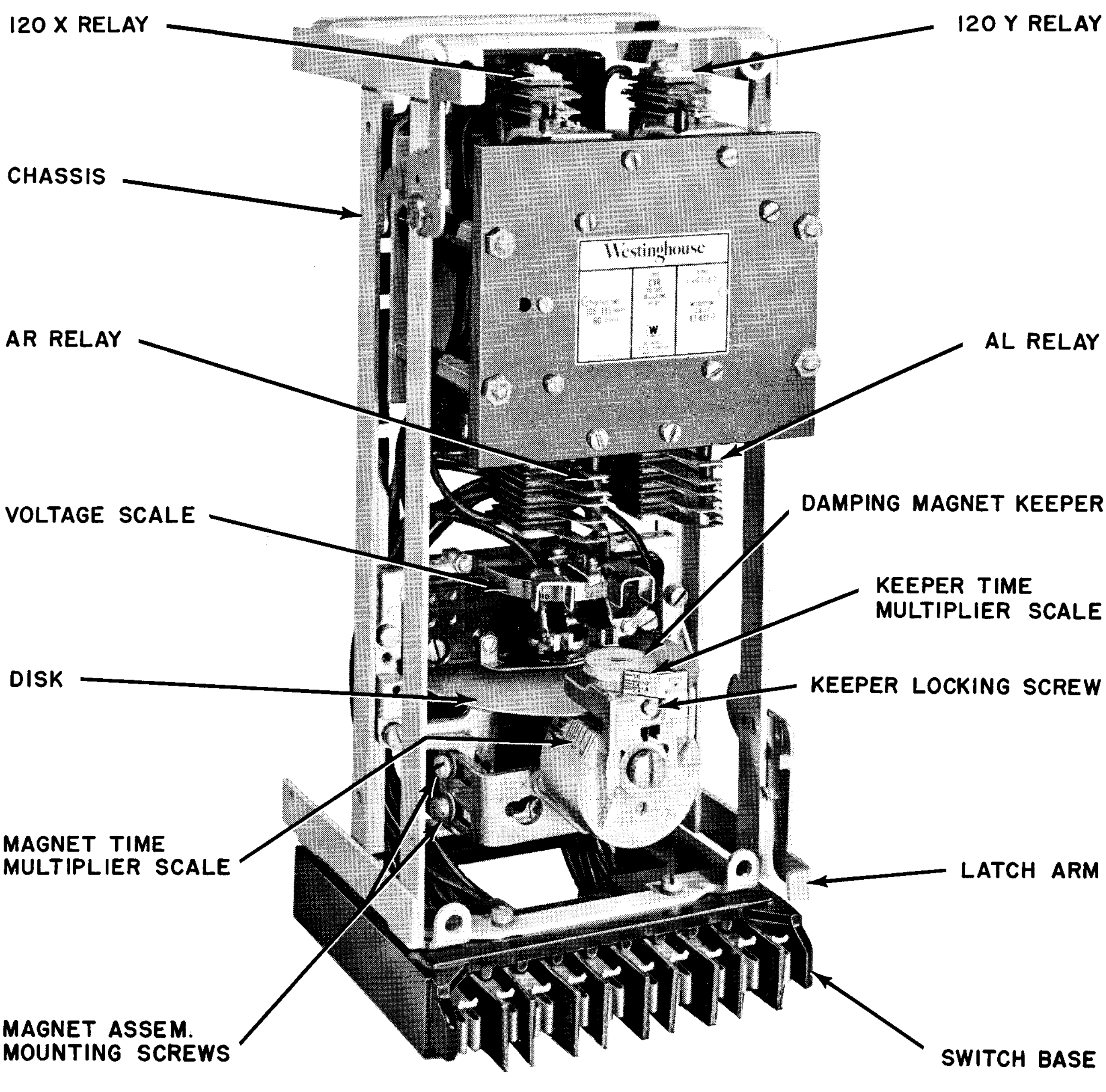


Figure 8 - CVR Relay Removed From Case

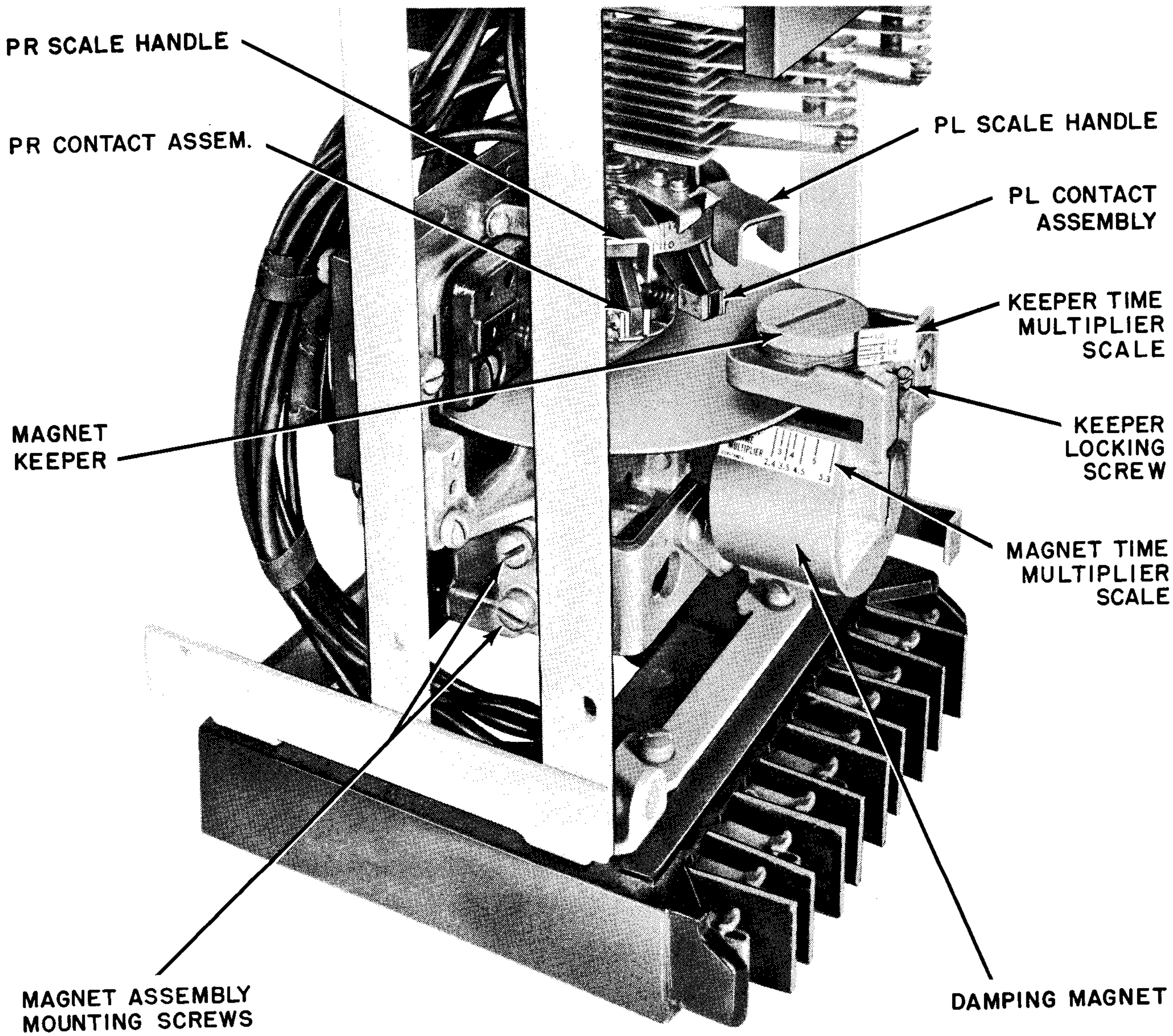


Figure 9 - Closeup of CVR Relay Adjustments

8. Set resistance and reactance compensation dials as required (see page 15).

9. When tests are completed return the voltage adjustment dial to the OFF position to close the motor circuit.

SETTING THE CVR RELAY WITH REGULATOR ENERGIZED

A test voltage adjustment rheostat is located on the control panel for your convenience. It makes possible setting the relay by using the control voltage with the regulator energized. Turning the voltage adjustment knob clockwise a small amount snaps a switch in the motor circuit open without changing the voltage applied to the relay. Turning the knob farther will adjust the voltage applied to the relay by means of the rheostat which is in series with the control voltage and is located ahead of the test terminals. (See Diagram Figure 7). An interlocked switch opens the motor circuit when the voltage level adjustment on the regulator control panel is moved away from the "OFF" position. Proceed as follows:

1. Manually operate the tap changer in the raise direction until a voltage 2 or 3 volts in excess of the PL contact setting is obtained on the test terminals.

2. Move the test voltage adjustment rheostat dial to the right. This opens the motor circuit.

3. Place control selector switch on "AUTO".

4. Adjust test voltage rheostat until desired voltages are obtained and proceed as described under "Setting the CVR By Applying An External Voltage".

5. When tests are complete return rheostat dial to "OFF" position which closes the motor circuit.

SETTING RELAY WHILE REMOVED FROM THE REGULATOR

When removed from its case, the type CVR relay may be checked conveniently by means of the circuit shown in Figure 10. This diagram illustrates the use of a Flexitest plug, Style No. 1164046 which may be plugged into the jack in the relay base. The circuit may also be made by means of clip leads connected to corresponding terminals on the relay.

Connect a 100 ohm 10 watt resistor between G and I and a 500 ohm 1 watt resistor between H and I.

Apply a variable voltage to points F and G (corresponding to TT1 and TT2 in the regulator) and follow the procedure under "Setting the CVR Relay by Applying an External Voltage." The self-sealing circuit of the CVR relay may be cleared by momentarily connecting a jumper from B to F. The 120 switch performs this function in the regulator, clearing the self sealing network and applying negative compounding to the disk of the CVR relay.

The circuit proposed in figure 10 provides all switching and indication required to calibrate the relay and check its performance while removed from the regulator.

Lights R_p and L_p indicate operations of contacts PR and PL while lights R_o and L_o indicate operation of the motor control relay contacts AR and AL.

With the switch in the "CAL" position, the operation of PR and PL contacts is indicated by lights R_p and L_p.

With the switch on "AUTO" position and relay functions in response to applied voltage as it would in a regulator control circuit. Operations are indicated by all four lights.

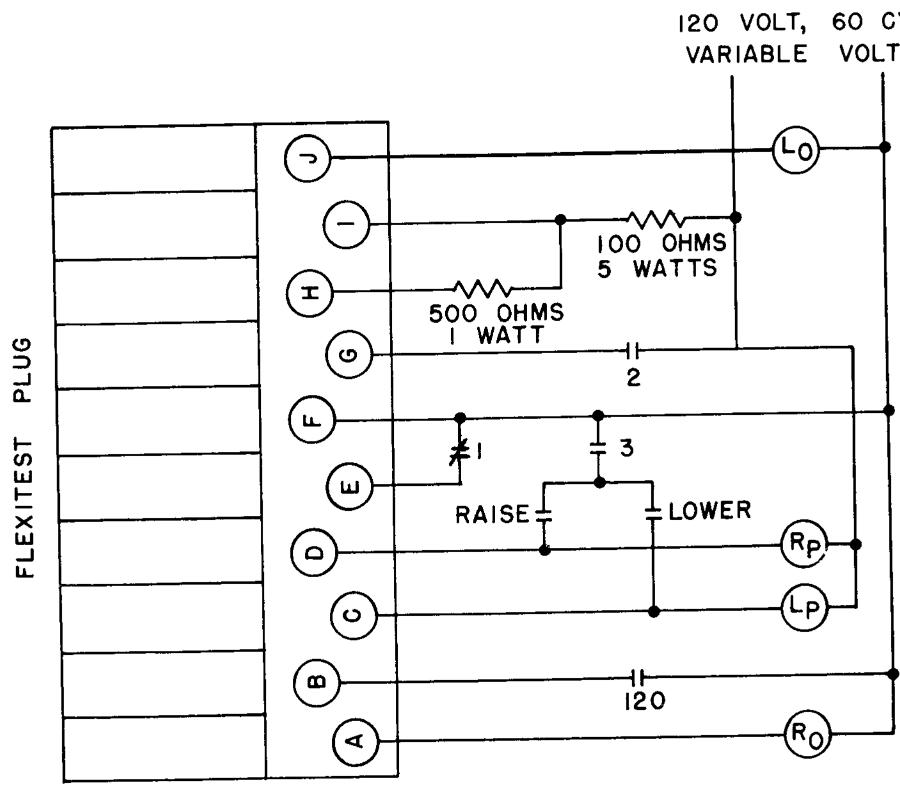
With the switch on "MAN" position the raise and lower switches control the auxiliary relays. R_p and L_p now indicate closing of the raise and lower pushbuttons. R_o and L_o still indicate operation of AR and AL contacts.

General operating data for the relay on 60 cycles is as follows:

Burden of the potential circuit at 120 volts	10VA
with auxiliary relays energized	39VA
Separate R and X compensation	24 volts
100% load compensation current	0.24 amps
Burden on compensating current transformer at 100% load, as applied to the regulator	13 VA

TIME DELAY ADJUSTMENT

The inverse time delay characteristic of the CVR relay enables it to maintain regulated voltage within close tolerance. Figure 9 shows the relay adjusted for a damping factor of one. Figure 12 shows a curve of relay adjustment



NORMALLY OPEN SPRING RETURN SWITCHES OR PUSH-BUTTONS

RAISE

LOWER

120

INDICATING LIGHTS *

R_P = RAISE DISK CONTACT

L_P = LOWER DISK CONTACT

R_O = RAISE OPERATE

L_O = LOWER OPERATE

* USE 1/25 OR 1/4 WATT NEON LAMPS WITH PROTECTIVE RESISTORS

CAL - AUTO - MAN

3 POSITION SELECTOR SWITCH SEQUENCE

CONTACT	SWITCH POSITION		
	CAL.	AUTO.	MAN.
1	X	X	
2		X	X
3			X
X INDICATES CONTACTS CLOSED			

Figure 10 - Circuit for Checking and Calibrating the CVR Relay

versus damping factors and Figure 13 shows a curve of relay performance when adjusted for a damping factor of one.

In some cases where cycling loads or other load conditions produce large voltage changes of short duration it may be desirable to increase the damping to obtain longer time delay and avoid unnecessary regulator operation. The time delay may be increased by decreasing the gap between the permanent magnet and its keeper. Relays are shipped set for a damping factor of one. The magnet keeper is set with its top even with the 1.0 graduation on the keeper time multiplier. The magnet engagement setting is at the 2.4 graduation on the magnet time multiplier. This gives a damping factor of one. To change this setting the keeper locking screw must first be loosened. If, after loosening this screw, the keeper does not turn easily; remove the keeper locking screw completely and check the copper thread protector under the locking screw to see that it is free. After making certain that the keeper locking screw turns easily, a damping factor of 1.0 to 2.4 can be secured by the top of the magnet keeper matching the graduation on the keeper time multiplier. The keeper magnet should never be turned down below the 2.4 graduation. The maximum keeper setting is shown in Figure 11. After this adjustment has been completed the locking screw should again be tightened, but before tightening, be sure that the piece of copper is still in the hole so that the keeper adjusting threads will not be damaged by the keeper locking screw.

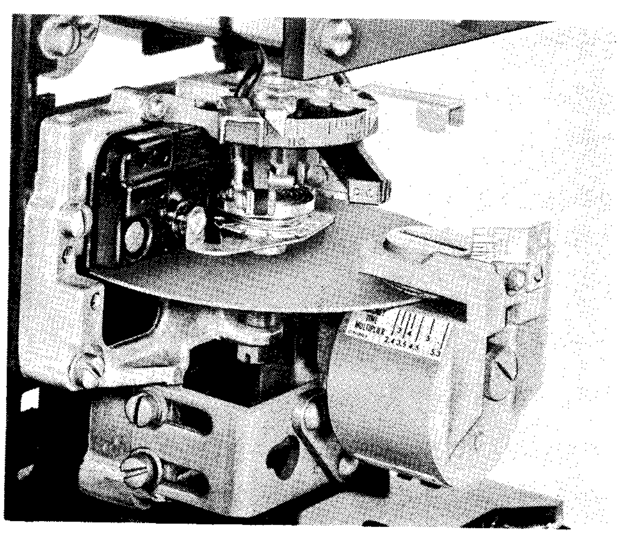


Figure 11 - Setting Magnet Engagement of CVR Relay

For a further increase in damping factor beyond 2.4 and up to 5.3 the engagement of the damping magnet and the disc may be increased. This is done by loosening the four magnet assembly mounting screws (See Figure 9) and sliding the magnet assembly to its new position. A magnet time multiplier scale is attached to the permanent magnet to facilitate setting the magnet engagement. This scale is referenced to the edge of the disc directly above it. To lower the damping factor after it has once been raised, use a reversal of the preceding procedure.

The damping factor for any relay as set may be determined easily by the following procedure.

1. De-energize the relay.
2. Set PR scale handle at 105 volts.
3. Set PL scale handle at 135 volts.
4. Manually rotate the disk to close PL contacts.
5. Release the disk and measure the time to close the PR contact.
6. Divide the number of seconds measured in step 5 by 5.4. The quotient is the damping factor for the relay as adjusted.
7. Move the PR and PL scale handles to the desired limits for voltage band.

Having determined the relay damping factor, a new curve for relay performance may be plotted by multiplying the time values read from the curves in figure 13 by the damping factor.

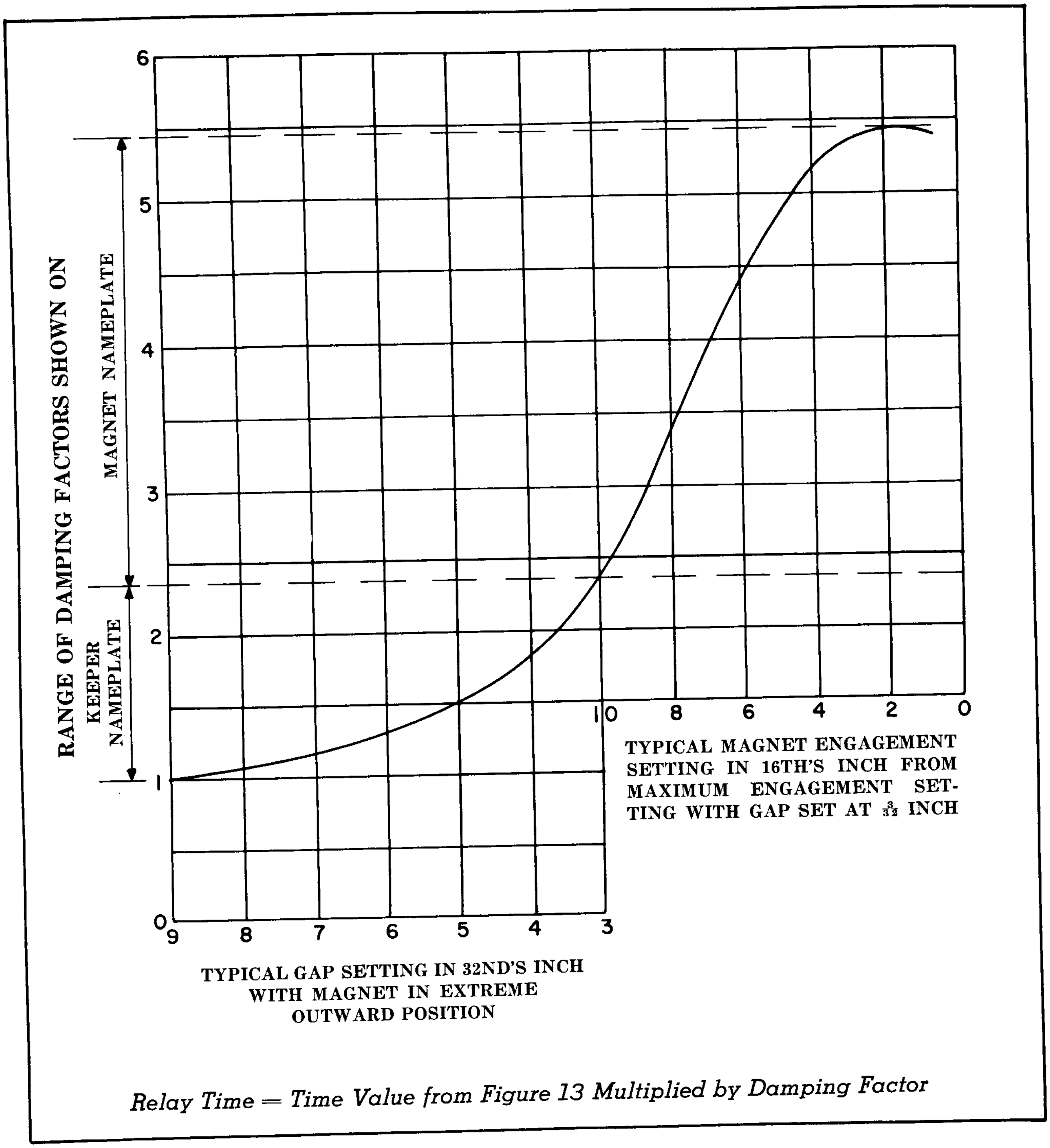
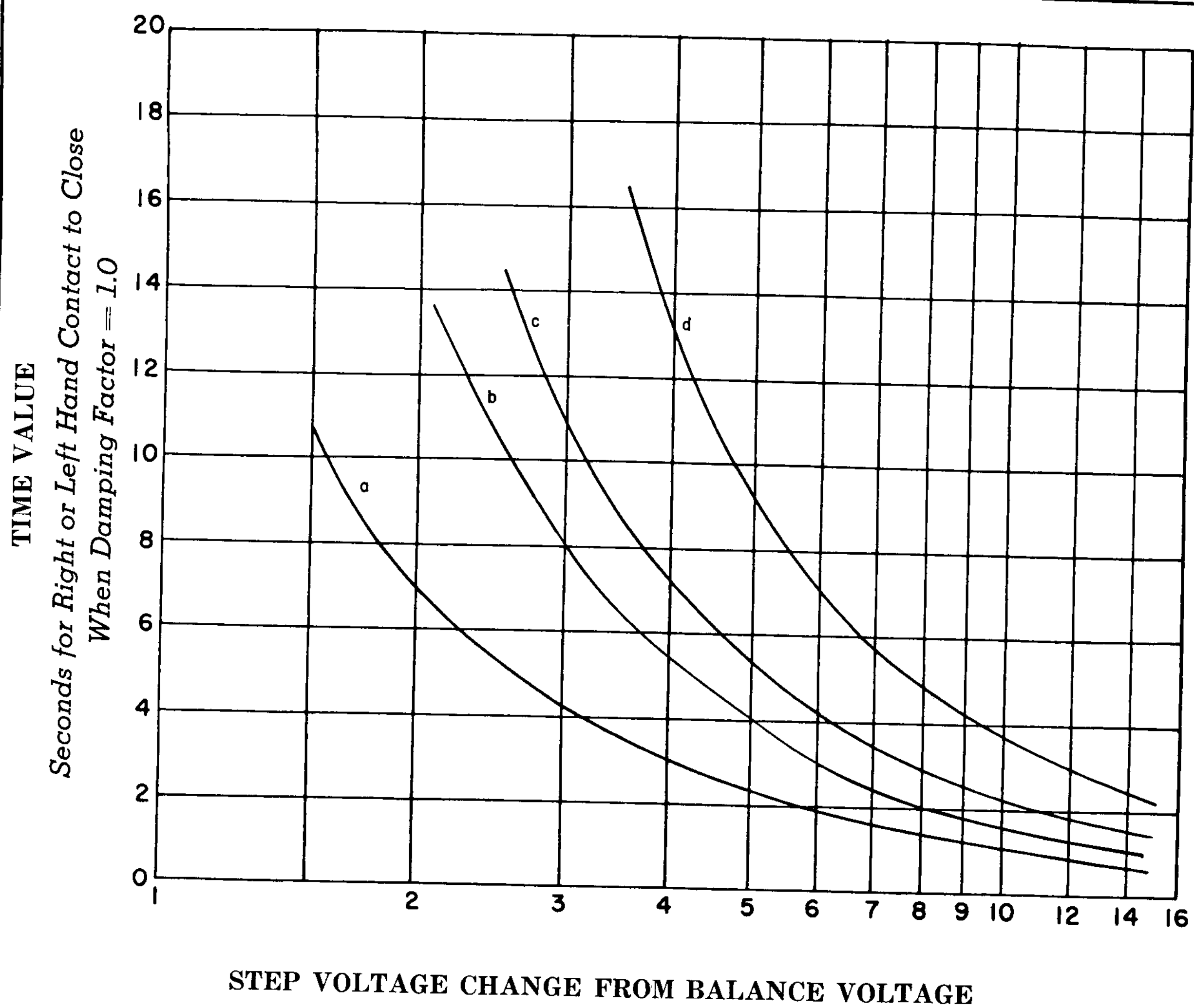


Figure 12 - Typical Damping Factors Versus Gap Setting and Magnet Engagement

Example:

Assume 10.8 seconds measured in step 5 above $10.8 \div 5.4 = 2$, the relay damping factor. In Figure 13 we find that for a 2 volt bandwidth the time delay would be 3 seconds for a 4 volt change.

To determine the actual time to close relay contacts multiply 3 (seconds) x 2 (damping factor) = 6 seconds actual time delay.



CURVE	BAND WIDTH
a	2 VOLTS
b	3 VOLTS
c	4 VOLTS
d	6 VOLTS

Relay Time = Time Value Multiplied by Damping Factor from Figure 12

Figure 13 - Typical Time Delay Versus Step Change in Voltage Level For Type CVR Relay

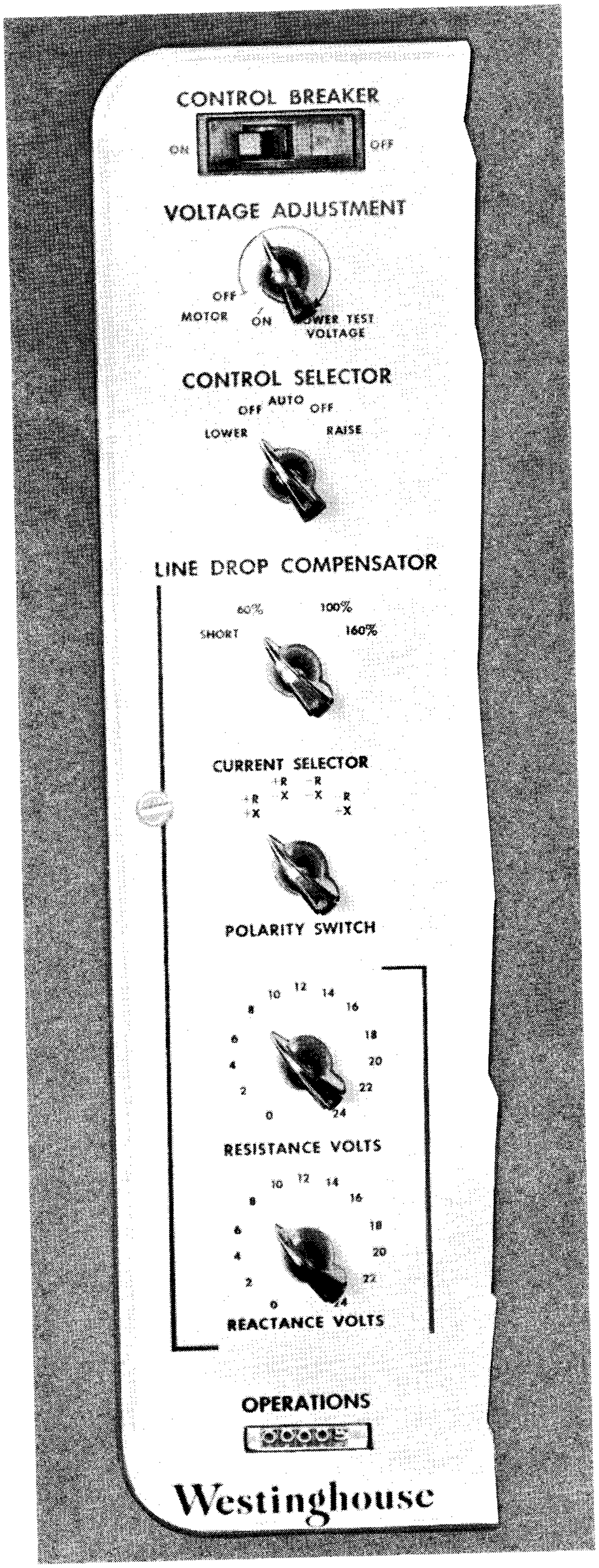


Figure 14 - Typical Adjustment and Control Switches Associated with the CVR Relay

ASSOCIATED RELAY CONTROL

Figure 14 shows typical adjustments and control switches associated with this relay, but which are actually part of the regulator control circuit.

The exact details of this equipment are not important to this discussion and could be different on a particular unit.

The control breaker, voltage adjustment, and control selector switch LOWER-OFF-AUTO-OFF-RAISE have been referred to earlier. The following sections deal with line drop compensation, which is set by means of the lower four knobs on this panel.

The **Resistance Volts** dial is calibrated in volts drop, on a control voltage basis, and represents the line resistance vector voltage drop from the regulator to the load center. In the same manner the **Reactance Volts** dial is calibrated in volts drop on a control voltage basis, representing a vector voltage drop equivalent to the line reactance vector voltage drop from the regulator to the load center.

The current selector dial changes taps on the current transformer to change the calibration of the resistance and reactance volt dials. The "short" position short-circuits the current transformer for safety during maintenance work on the control panel or for installations where line drop compensation is not required. The "60%", "100%", and "160%" positions cause the resistance and reactance volt dials to read the line drop compensator voltages directly in volts when the regulator is carrying 60%, 100%, and 160%, respectively, of its rating.

For any installation, the current selector switch should be set at a larger value than the maximum load expected on the feeder.

For ordinary usage, using the Load Range Selector capability of the regulator, the dial would be set on 160%, since load range selection permits loading above regulator rating.

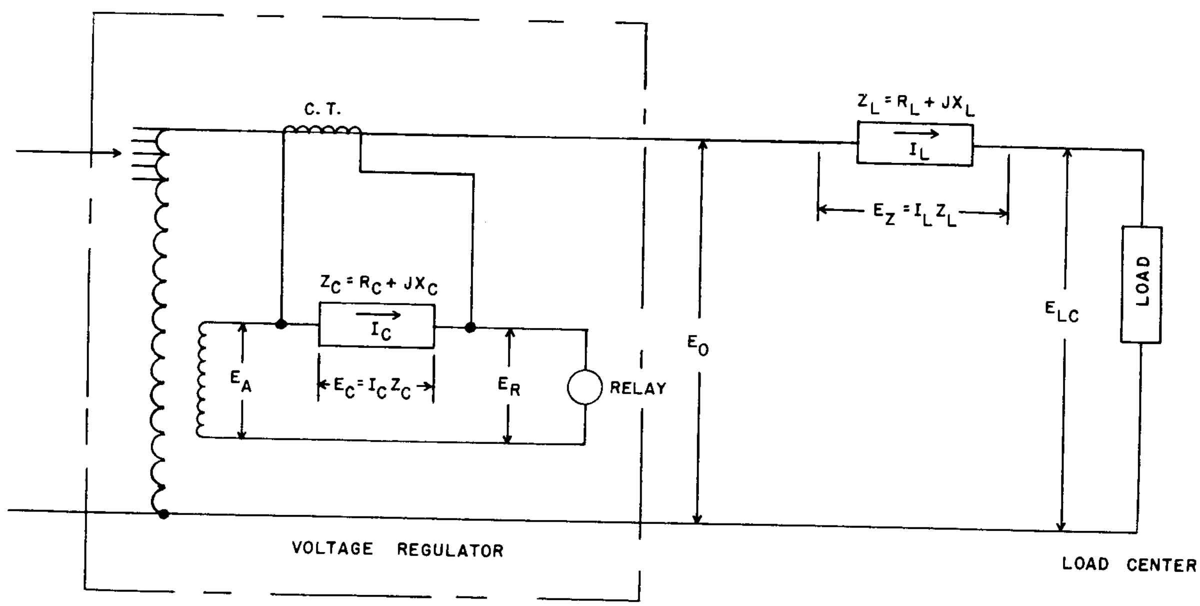
Where full ± 10% regulation is used, at the rated current of the regulator, the dial may be set at the 100% position. This makes available the full 24 volts resistance and 24 volts reactance line drop compensation. (With the 160% setting, the maximum obtainable at 100% current is 100/160 x 24 = 15 volts.)

The 60% setting adds to the versatility of the regulator by making available full line drop compensation at 60% of the regulator current rating for applications where a single rating of regulator is stocked for use on a wide variety of feeders, some of which may be loaded appreciably below the regulator rating.

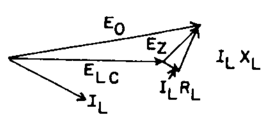
The way these compensating devices function in the relay circuit is developed on the following pages.

As will be seen in the discussions of line drop compensation on delta and open delta connected units, it is sometimes necessary to reverse the direction of compensation in a unit. This is accomplished by means of the **Line Drop Compensator Polarity** switch which is arranged so that either or both components may be reversed at will by merely selecting the desired combination with this knob.

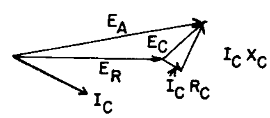
The number of tap changer operations is indicated on an operation counter mounted in the control panel directly below the line drop compensator control dials.



15A) ESSENTIAL CIRCUIT ELEMENTS



15B) LOAD CENTER VOLTAGE DIAGRAM



15C) COMPENSATOR VOLTAGE DIAGRAM

I_L = LOAD CURRENT
E_O = REGULATOR OUTPUT VOLTAGE
E_Z = LINE VOLTAGE DROP
E_{LC} = LOAD CENTER VOLTAGE
R_L = LINE RESISTANCE
X_L = LINE REACTANCE
Z_L = LINE IMPEDANCE

I_C = COMPENSATOR CURRENT
E_A = REGULATOR AUX. WINDING VOLTAGE
E_C = COMPENSATOR VOLTAGE DROP
E_R = RELAY VOLTAGE
R_C = COMPENSATOR RESISTANCE
X_C = COMPENSATOR REACTANCE
Z_C = COMPENSATOR IMPEDANCE

Figure 15 - Essential Elements of Load and Compensating Circuit and their Vector Diagrams For Type CVR Relay

LINE DROP COMPENSATOR

The current in the line from regulator to load center produces a voltage drop. The regulator should maintain constant voltage level at the load center.

The auxiliary voltage output represents regulator load terminal voltage. By subtracting from this voltage vector a line drop compensator voltage vector porportional to line drop, the resultant voltage will truly represent the load center voltage for all load conditions.

Proper line drop compensator voltage is obtained by circulating the output of a current transformer in the load circuit through separately adjustable resistance and reactance branches. Proper setting of resistance and reactance dials on the line drop compensator will insure that the CVR relay will respond to load center voltage. Figure 15 shows the essential elements of the load and compensating circuit and their vector diagrams.

In Figure 15A, the current I_L flowing through R_L and X_L produces a voltage drop E_Z which subtracts vectorily from the regulator output voltage E_O to produce a load center voltage E_{LC}. Figure 15B shows how these vectors are related.

Looking at the compensator portion of the circuit in 15A and its vector diagram in 15C, the compensator current I_C is proportional to the load current I_L. R_C and X_C are compensator impedance branches which are set to be proportional to R_L and X_L. When I_C flows through this compensating impedance a voltage drop E_C is produced. The vectors E_A and E_C combine to produce E_R, the resultant voltage vector applied to the CVR relay. Correctly selected resistance and reactance compensator dial settings will insure that the CVR relay will respond to load center voltage for all load conditions.

LINE DROP COMPENSATOR SETTINGS

Initial settings for the line drop compensator resistance and reactance dials may be calculated using the curves of Figures 16 and 17. Some final adjustment may be necessary following field experience since actual line loadings are seldom as simple as is assumed for calculation purposes.

The calculation of initial settings for the line drop compensator of the Type CVR relay, when applied to a Type URL or a Type URF voltage regulator is made using the following formulas.

Let r = resistive ohms per mile from Figure 16

x = reactive ohms per mile from Figure 17

d = distance in miles from regulator to load center

I_r = rated current at ± 10% regulation range of Type URL or Type URF voltage regulator from regulator nameplate

E_L = line voltage, from regulator nameplate, for potential connections being used

E_C = control voltage, from regulator nameplate, for potential connections being used

M = multiplier setting from current selector dial on control panel

R = resistance dial setting

X = reactance dial setting

For a single phase, 2 wire circuit:

$$R = \frac{2\ r\ d\ I_r\ M\ E_C}{E_L}$$

$$X = \frac{2\ x\ d\ I_r\ M\ E_C}{E_L}$$

For each regulator of a three-phase wye connection:

$$R = \frac{r\ d\ I_r\ M\ E_C}{E_L}$$

$$X = \frac{x\ d\ I_r\ M\ E_C}{E_L}$$

For the regulators of an open delta connection:

(a) For unit in which the current leads the voltage:

$$R = (1.5\ r + .866\ x)\ \frac{d\ I_r\ M\ E_C}{E_L}$$

$$X = (-.866\ r + 1.5\ x)\ \frac{d\ I_r\ M\ E_C}{E_L}$$

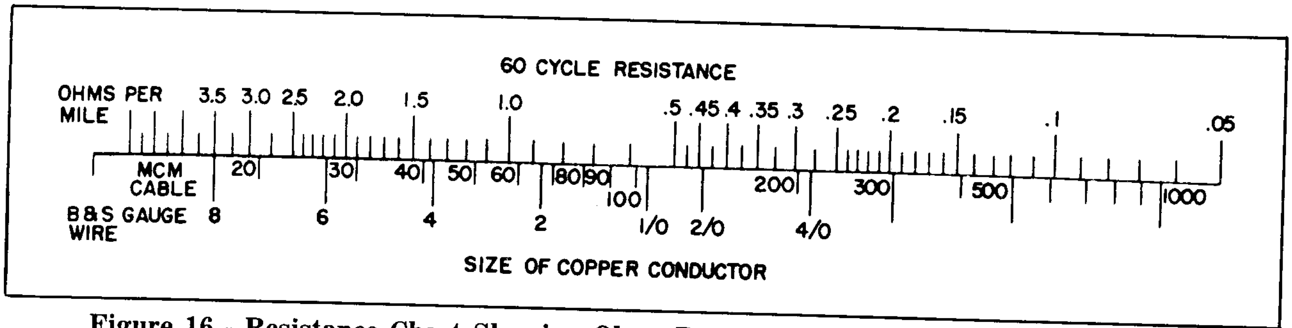


Figure 16 - Resistance Chart Showing Ohms Per Conductor Per Mile 60 Cycle Circuit

(b) For unit in which the current lags the voltage:

$$R = (1.5\ r - .866\ x)\ \frac{d\ I_r\ M\ E_C}{E_L}$$

$$X = (.866\ r + 1.5\ x)\ \frac{d\ I_r\ M\ E_C}{E_L}$$

For three regulators in delta connections:

Delta connections should be made at the "L" and "SL" terminals of the regulator in order that the potential supply to the voltage regulating relay will measure output line voltage. When this is done, the current transformer supplying the line drop compensator is inside the delta. Basically, therefore, the current in the line drop compensator must be multiplied by $\sqrt{3}$ and shifted 30° to equal the current flowing through the line impedance. This results in the same formulas given above for open delta connections. In the case of the full delta connection, however, the relationship is further modified by the tap changer position, which changes every time the tap changer operates.

Because the three phase delta connection does not usually permit using the full capability of single phase voltage regulators, and because the line drop compensation changes with tap changer position, this connection is not usually recommended, the open delta connection being preferred. If full delta must be used, the line drop compensator settings can be approximated by using the open delta formulas.

For example, consider two 7620 volt, 100 ampere voltage regulators being operated in open delta at the ± 6¼% range of load range selection on a 4800 volt, three phase three wire line of 2/0 copper with 3 foot conductor spacing and with 4 miles from the regulator to the load center.

r = .45 (From Figure 16)

x = .66 (From Figure 17)

d = 4 miles

I_r = 100 amperes

E_L = 5000 volts (nameplate potential setting for 4800 volt operation)

E_C = 125 volts (control volts from nameplate for 5000 volt setting)

M = 1.6 (at 6½% load range selection, load amps is 135%, therefore use 1.6 multiplier)

For regulator in which current leads voltage

$$R = (1.5 \times .45 + .866 \times .66) \times \frac{4 \times 100 \times 1.6 \times 125}{5000} =$$

$$(1.5 \times .45 + .866 \times .66) \times 16 = 19.95$$

$$X = (-.866 \times .45 + 1.5 \times .66) \times 16 = 9.60$$

For regulator in which current lags voltage

$$R = (1.5 \times .45 - .866 \times .66) \times 16 = 1.65$$

$$X = (.866 \times .45 + 1.5 \times .66) \times 16 = 22.08$$

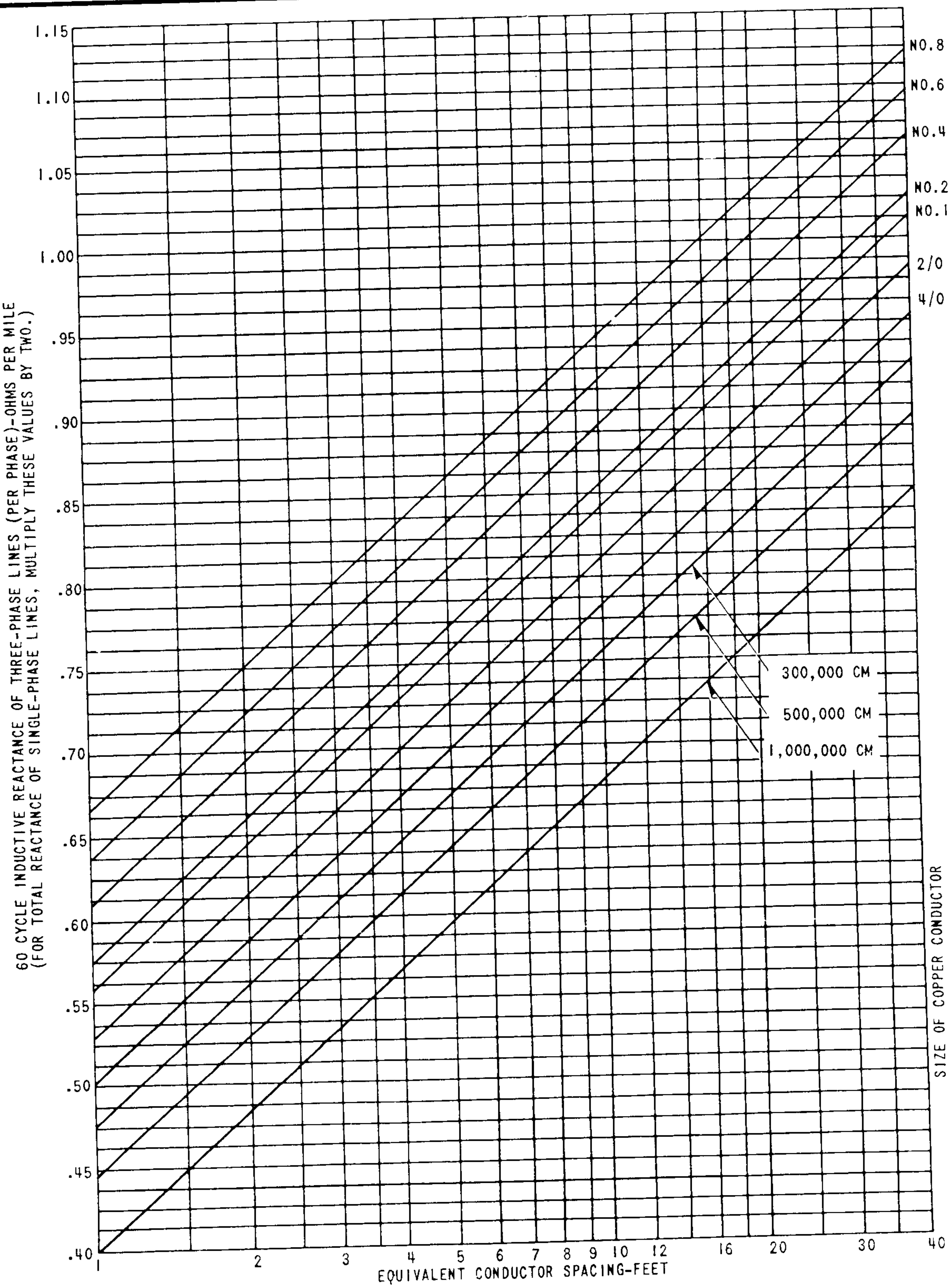
Therefore, the four dials on the control panels of these voltage regulators would be set as follows:

For the regulator with current leading voltage:

Current Selector = Set at 160%
Polarity Switch = Set at +R, +X
Resistance Volts = set at 20.0
Reactance Volts = set at 9.6

For the regulator with current lagging voltage:

Current Selector = Set at 160%
Polarity Switch = Set at +R, +X
Resistance Volts = set at 1.7
Reactance Volts = set at 22.1



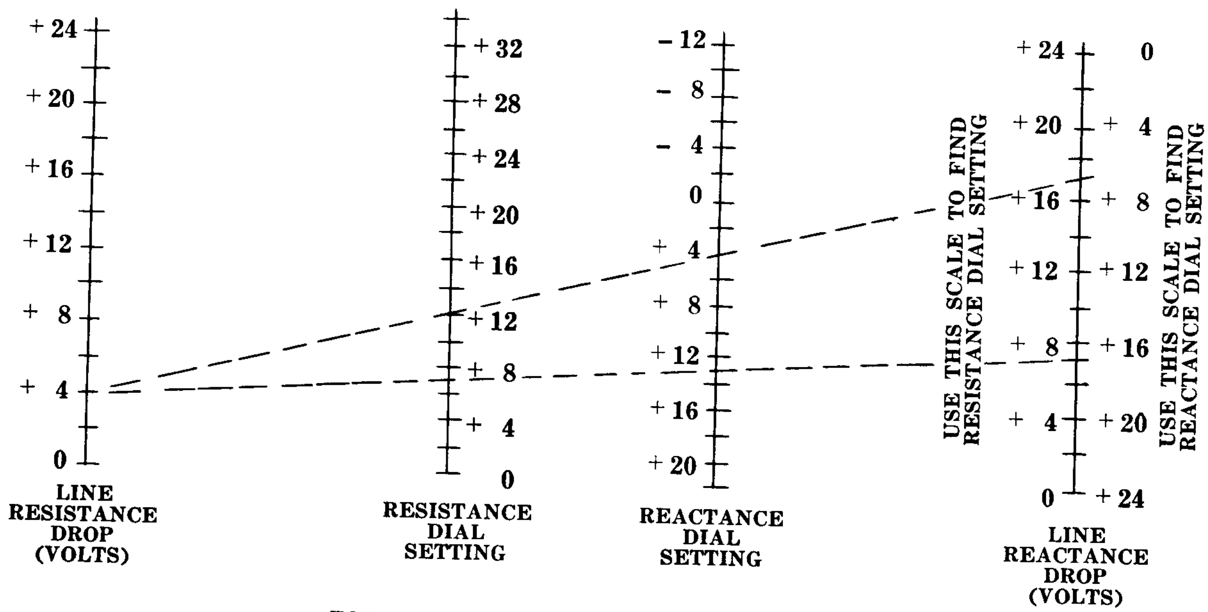
EQUIVALENT CONDUCTOR SPACING, D, OF UNSYMMETRICAL THREE PHASE LINES IS GIVEN BY THE EXPRESSION $D=\sqrt[3]{D_{AB} \times D_{BC} \times D_{CA}}$, WHERE

D_{AB}, D_{BC}, AND D_{CA} ARE THE DISTANCES IN FEET BETWEEN CONDUCTORS DESIGNATED BY THE SUBSCRIPTS.

NOTE:- WHERE $D_{CA} = 2\ D_{AB} = 2\ D_{BC}$; $D = 1.26\ D_{AB}$

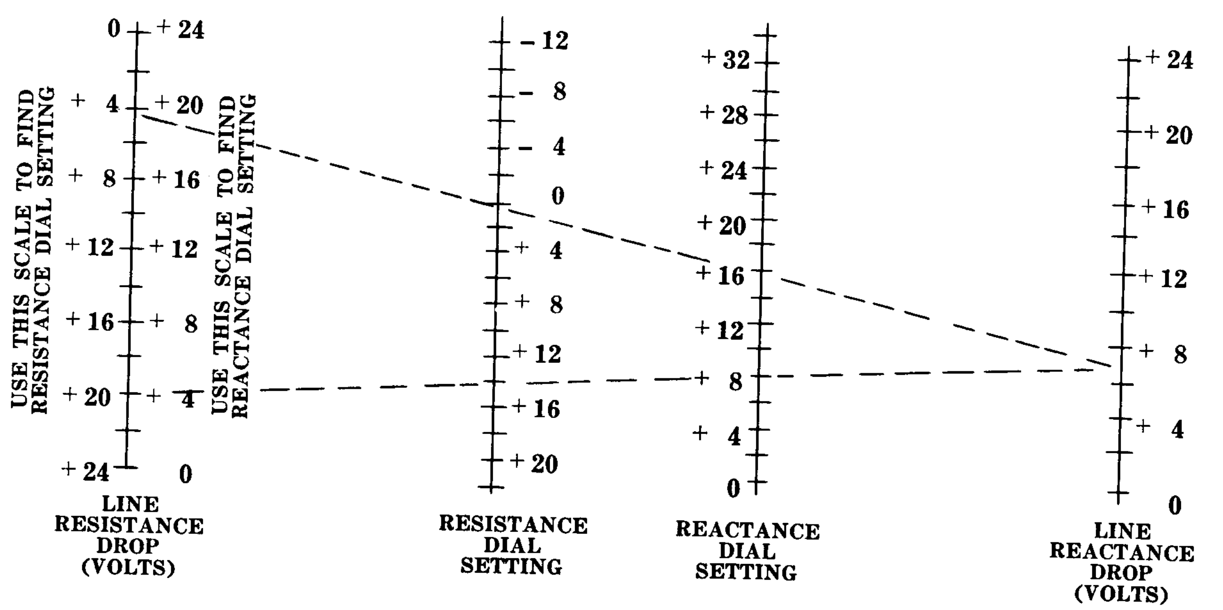
Figure 17 - Reactance in Ohms Per Conductor Per Mile Versus Spacing For Single Phase or 3 Phase Lines

WAGNER CHARTS



FOR UNIT WITH CURRENT LEADING VOLTAGE BY 30°

Example: For 4 Volts Resistance Drop and 7 Volts Reactance Drop, Set Resistance Dial on 7 and Reactance Dial on 4.



FOR UNIT WITH CURRENT LAGGING VOLTAGE BY 30°

Example: For 4 Volts Resistance Drop and 7 Volts Reactance Drop, Set Resistance Dial on 0 and Reactance Dial on 8.

Figure 18 - Wagner Charts for Determining Line Drop Compensator Settings on Open Delta Connected Regulators

FIELD METHOD FOR DETERMINING THE OPEN DELTA UNIT WITH LEADING OR LAGGING CURRENT WITH RESPECT TO ITS VOLTAGE

To make the proper identification perform the following steps after the regulators are connected in open delta and carrying current.

1. Set the resistance compensator dial of both regulators on zero.

2. Set the reactance compensator dials at 12 on both regulators.

3. Place the control selector switch on "AUTO".

4. The lagging current unit will operate more positions in the raise direction than the leading current unit.

FIELD METHOD FOR DETERMINING WHETHER THE CURRENT IN THE REGULATOR WINDING IS LEADING OR LAGGING THE VOLTAGE IN A CLOSED DELTA BANK OF SINGLE PHASE REGULATORS

The compensator dial setting modifications described for open delta operation will give correct line drop compensation on closed delta connected regulators when they are on neutral position. On other than neutral positions the compensation will be approximately correct. (An error is introduced because the regulator current transformer is connected ahead of the delta connection.)

To determine whether the 3 single phase regulators in a closed delta bank are connected in such manner as to result in the winding current's leading or lagging the voltage of that phase, the following steps may be followed.

1. Set resistance compensator dials on all regulators on zero.

2. Set the reactance compensator dials on 12 on all 3 units.

3. Place the line drop compensator polarity selector switch on +R +X.

4. Set control selector switch on "AUTO". Regulators will operate to correct voltage. Observe tap changer position.

5. Switch polarity selector switch to +R-X

If the regulator now operates to raise its output voltage the regulators are connected as leading units. If the regulator now operates to lower its output voltage the regulators are connected as lagging units.

6. Obtain revised line drop compensator settings by means of the Wagner Scheme.

Note: The above test for the closed delta regulators is effective for load power factors between 90% lagging and 90% leading. The use of the Wagner scheme on closed Delta connections is valid for regulators in closed delta when the delta is closed by connecting the L terminals of one regulator to the SL terminal of the other regulator.

MAINTENANCE

The proper adjustments to insure correct operation of this relay have been made at the factory and should not be disturbed after receipt by the customer (with the exception of bandwidth or time delay settings). Repair work can be most satisfactorily done at the factory. If it is desired to check the adjustment at regular maintenance, the following instructions should be followed:

Note: Before opening the test switches set the line-drop compensator dials on zero and turn the power supply and manual control switches off.

Remove the cover by unscrewing the captive screws of the cover. The relay can then be inspected and tested in the case or out of the case. External test circuits to the relay may be made with test clip leads or by means of a test plug.

Figure 19 shows the CVR relay preparatory to removing the chassis from the case. Note that the knife switches have been fully opened and that the two cam action latch arms have been pulled out and fully extended. Using the latch arms as handles, (see Figure 20) pull the chassis from the case. A duplicate chassis may be inserted in the case or the blade portion of the switches closed and the cover replaced without the chassis. Figure 21 shows the chassis completely removed from the case.

When contacts require cleaning, they should be cleaned with a fine contact file similar to S#1002110 or a contact burnishing tool. Abrasive material should not be used because any small particles embedded in the contact surface will impair the contact operation.

For identification of relay parts, see Figure 5.

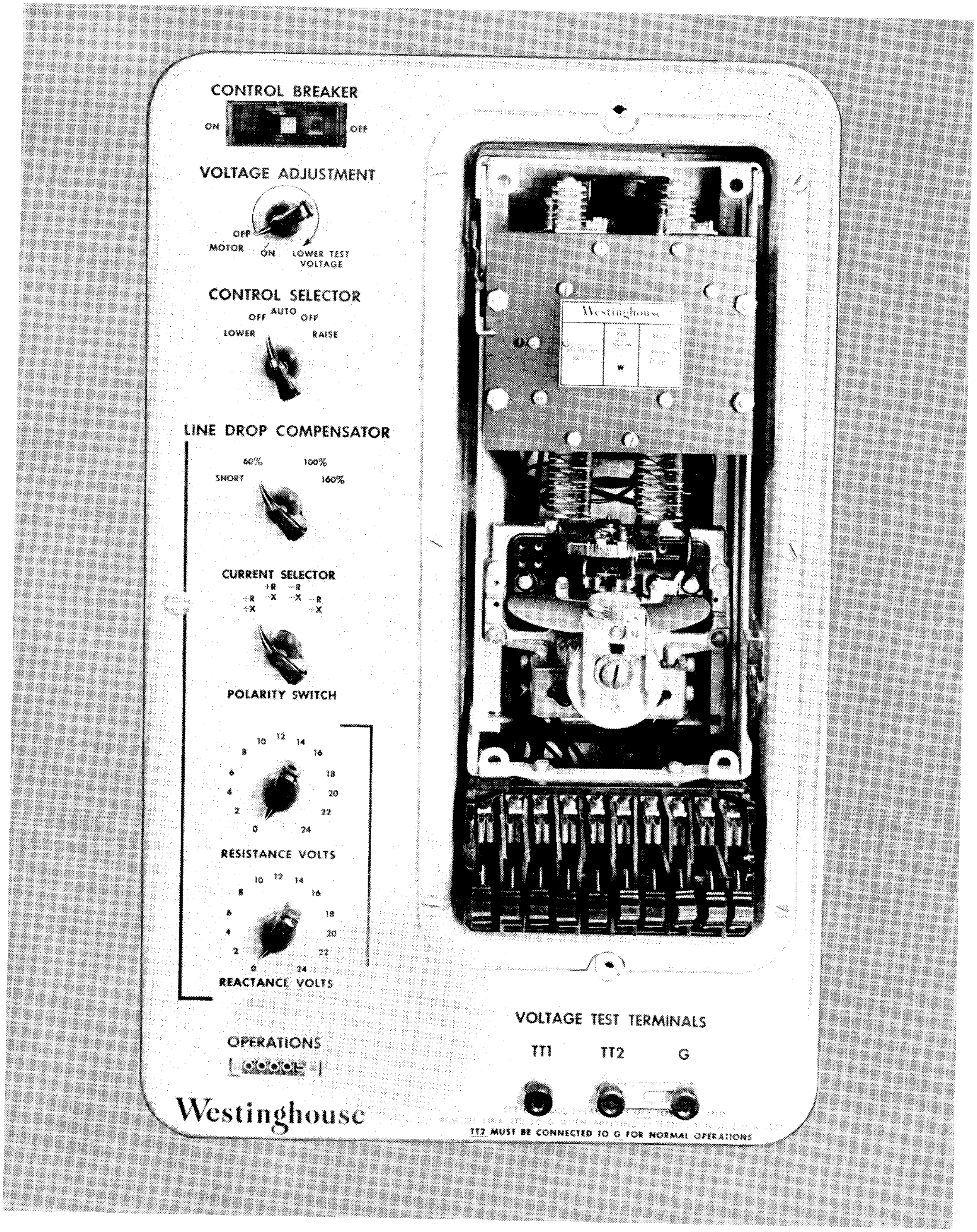


Figure 19 - CVR Relay Preparatory to Removing Chassis from Case

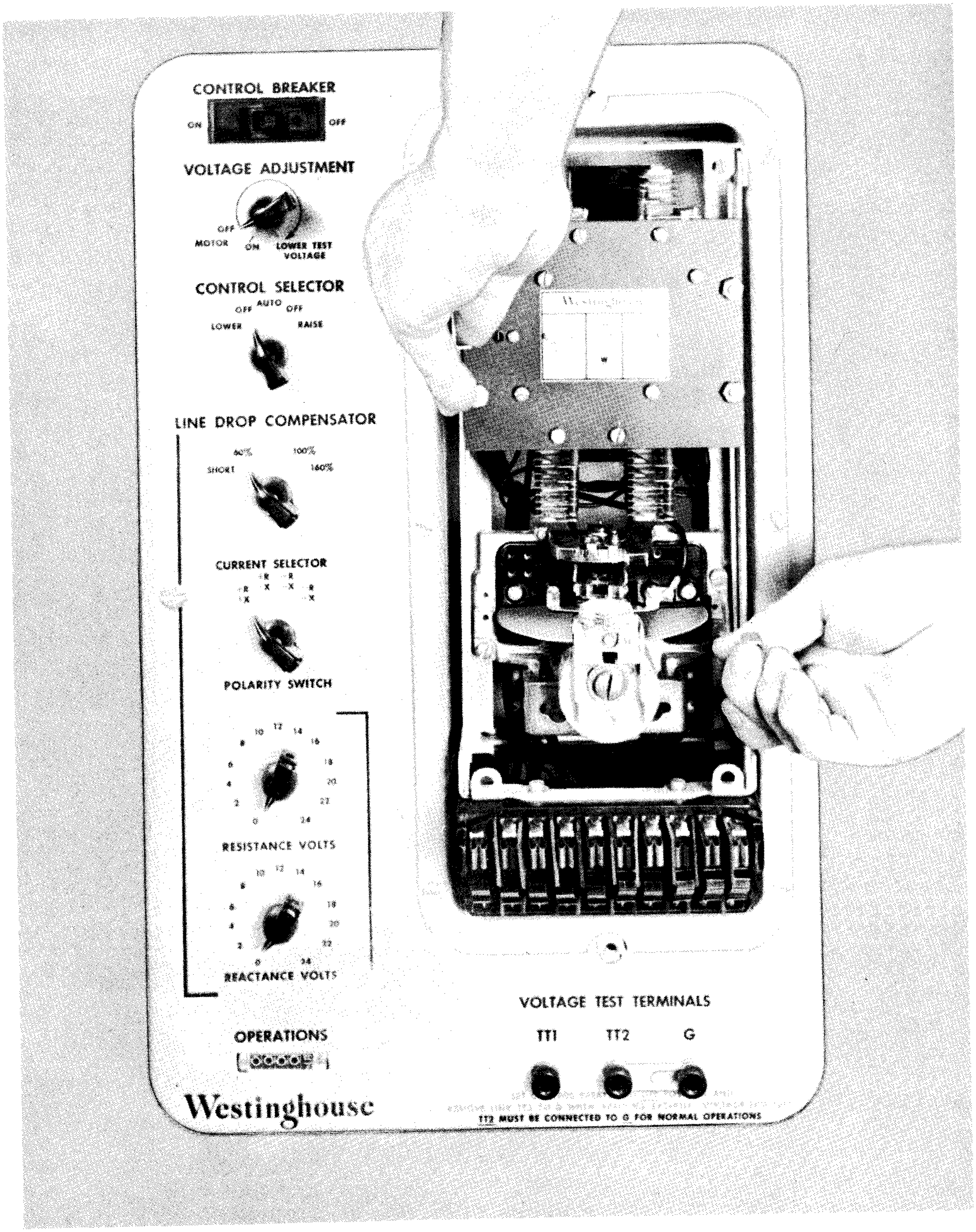


Figure 20 - CVR Relay with Cam Action Latch Arms Extended

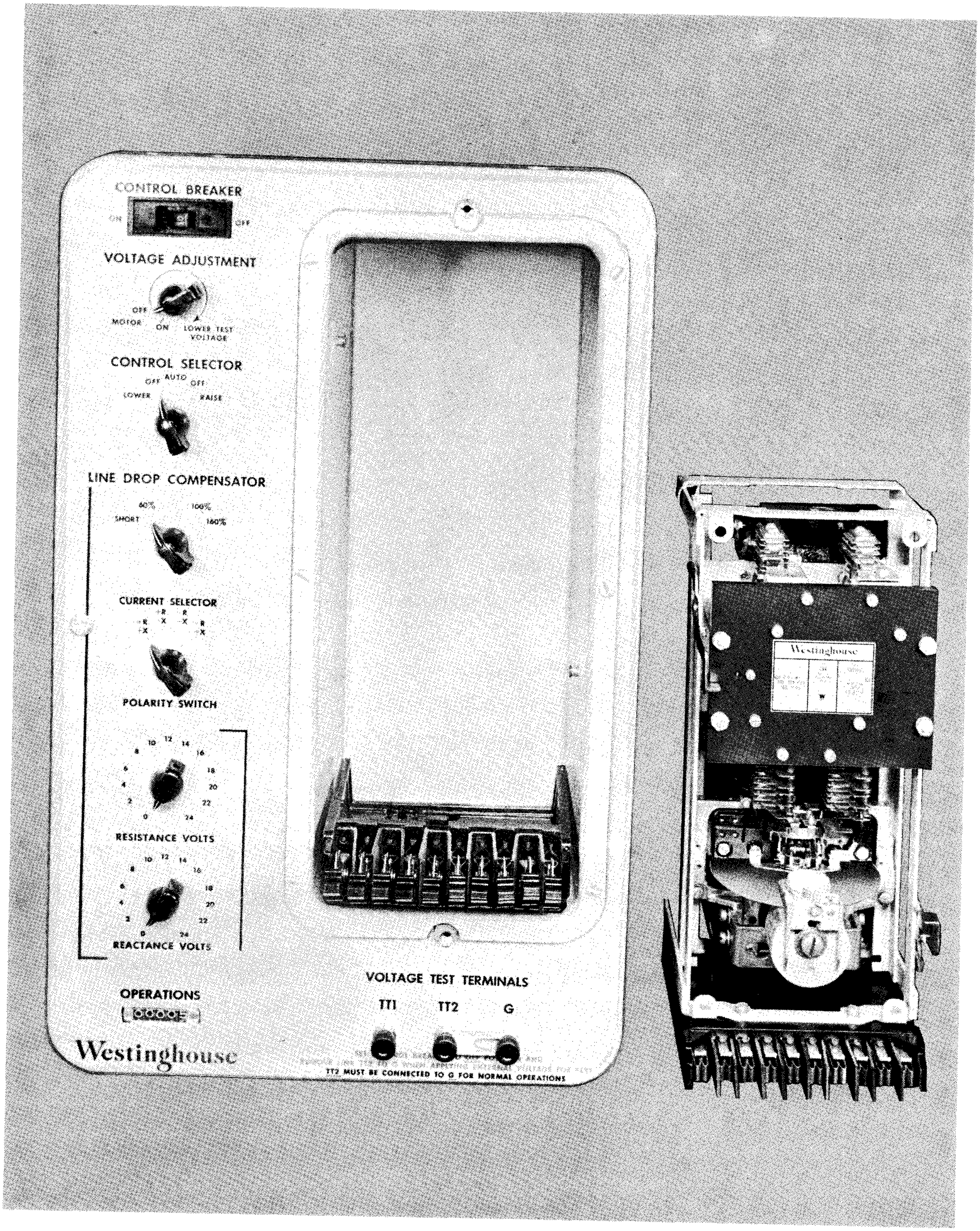


Figure 21 - Chassis Removed from Case

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