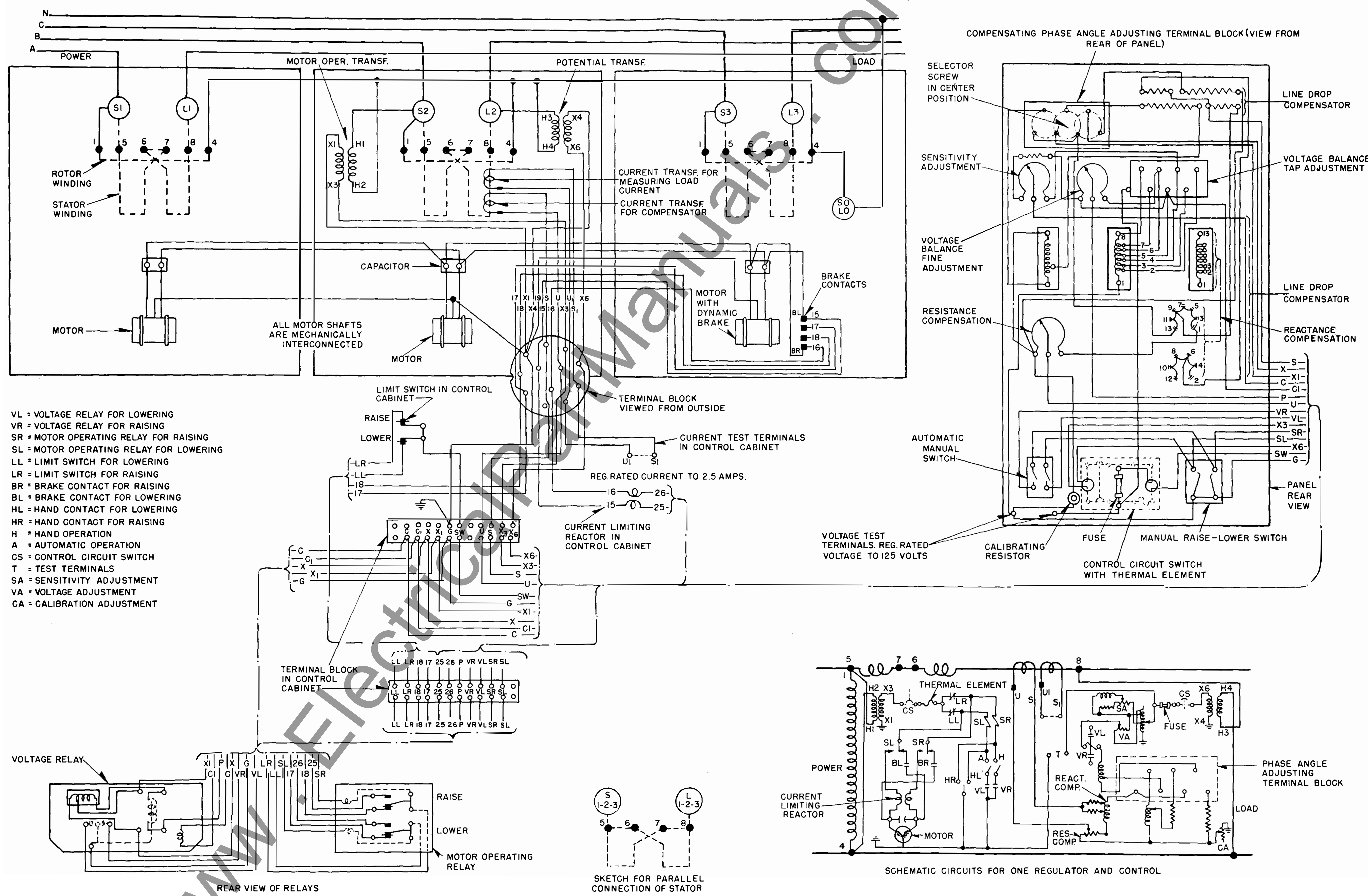
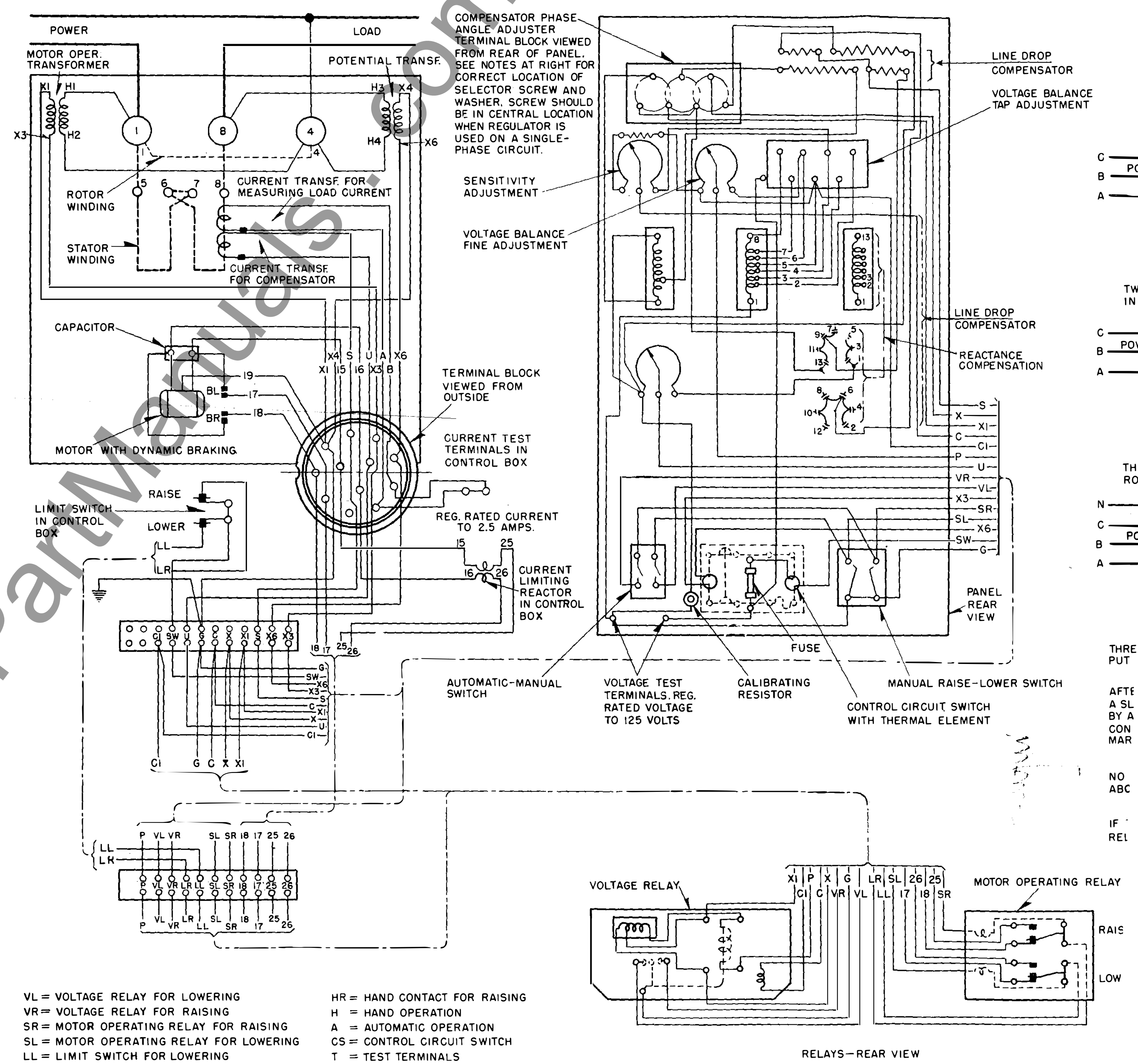


FIG. 14. Wiring Diagram of Typical Regulator, Type ST



VL = VOLTAGE RELAY FOR LOWERING
VR = VOLTAGE RELAY FOR RAISING
SR = MOTOR OPERATING RELAY FOR RAISING
SL = MOTOR OPERATING RELAY FOR LOWERING
LL = LIMIT SWITCH FOR LOWERING
LR = LIMIT SWITCH FOR RAISING
BR = BRAKE CONTACT FOR RAISING
BL = BRAKE CONTACT FOR LOWERING
HL = HAND CONTACT FOR LOWERING

HR = HAND CONTACT FOR RAISING
H = HAND OPERATION
A = AUTOMATIC OPERATION
CS = CONTROL CIRCUIT SWITCH
T = TEST TERMINALS
SA = SENSITIVITY ADJUSTMENT
VA = VOLTAGE ADJUSTMENT
CA = CALIBRATION ADJUSTMENT

INSTRUCTION BOOK

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OLD FILE Sec 109

INDUCTION VOLTAGE REGULATORS

Types SU and ST

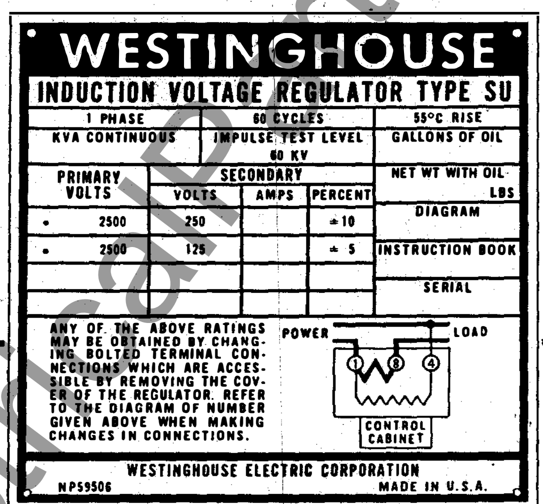
Westinghouse Electric Corporation

I. B. 47-310-1

SPECIAL INQUIRIES

When communicating with Westinghouse regarding the product covered by this Instruction Book, include all data contained on the nameplate attached to the equipment.* Also, to facilitate replies when particular information is desired, be sure to state fully and clearly the problem and attendant conditions.

Address all communications to the nearest Westinghouse representative as listed in the back of this book.



*For a permanent record, it is suggested that all nameplate data be duplicated and retained in a convenient location.

INSTALLATION • OPERATION • MAINTENANCE

INSTRUCTIONS

INDUCTION VOLTAGE REGULATORS

Types SU and ST

WESTINGHOUSE ELECTRIC CORPORATION
TRANSPORTATION AND GENERATOR DIVISION
EAST PITTSBURGH PLANT • EAST PITTSBURGH, PA.
NEW INFORMATION
EFFECTIVE AUGUST, 1952
Printed in U.S.A.

losses and keeps the secondary reactance down, particularly in the neutral position.

In operation, the primary winding is connected across the line, while the secondary winding is connected in series with the line. The voltage induced in the secondary winding (and therefore the amount of voltage that is added to or subtracted from the line) is varied by turning the rotor. All possible values of raise and lower are realized over a rotation of 180 degrees. The rotor is therefore restricted to this amount of travel by limit switches and mechanical stops. The limit switches are located in the control box behind the mechanical position indicator, while the mechanical stops are located on the worm gear.

The operating mechanism consists of a motor-driven gear reduction unit which drives the rotor by means of a solid worm and worm gear arrangement. (See Fig. 1). The worm is cut from a single piece of steel for maximum rigidity in withstanding short-circuit stresses. The worm gear is machined from steel to withstand short-circuit stresses. The worm gear is shrunk on and keyed to the rotor shaft. The motor is a ball-bearing, single-phase, capacitor type. The capacitor and motor are mounted side-by-side on top of the worm housing. External lubrication is unnecessary since the drive motor and gear reduction unit are completely submerged in the insulating oil.

Automatic operation is controlled by a voltage relay which responds to changes in the regulator output voltage. The voltage relay responds to changes in the regulator output voltage and, in turn, operates the secondary relay which operates the motor. The motor moves the regulator rotor in the proper direction to restore the output voltage to its normal value and the voltage relay to its balance position.

A line-drop compensator is inserted between the regulator output voltage (reduced to 125 volts through a potential transformer) and the voltage relay. This compensator allows the voltage to be held constant, within the limits of the machine, at a predetermined distance from the machine.

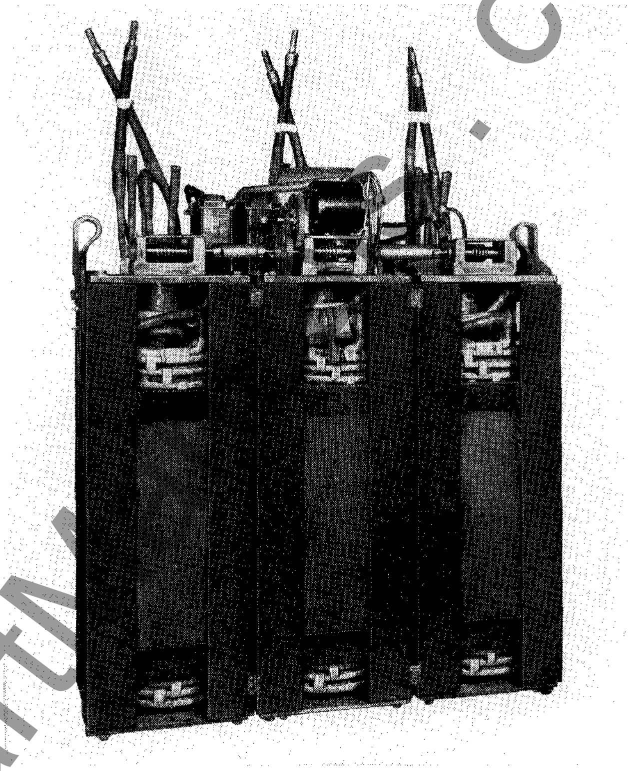


FIG. 2. Typical Triplex Regulator, Type ST, Removed from Tank

TYPE ST REGULATOR

The three-phase, Type ST regulator consists of three SU machines fabricated into a single unit (Fig. 2) and placed in a single large tank. The drive mechanisms are all coupled together so that each phase receives the same amount of voltage increase or decrease. The ST regulator has essentially the same automatic control and drive mechanism as the SU regulator. The control is energized by one-phase of the regulated three-phase feeder.

Type ST regulators are best suited for use on three-phase lines with balanced loads.

RECEIVING, HANDLING AND STORING

When received, the regulator should be carefully inspected for possible damage in transit. Notify the carrier immediately if any damage is found due to transportation. The following points should be checked:

1. At room temperature or approximately 25 degrees C, the oil level should reach the 25-degree C mark on the oil gauge.

2. Types SU and ST regulators are oil-filled under vacuum, sealed and pressure-tested at the factory. If inspection indicates that the seal may have been disturbed in transit, pressure-test the tank and test the oil for dielectric strength. The oil should test at least 20 kv using a 1⁄10-inch test gap. The tank should maintain an applied internal pressure of 5 pounds per square inch without appreciable drop over a six-hour period.

3. The relays and control panel (see Fig. 3) should be checked for proper operation. (Refer to "Control Panel and Relay Operation, Tests and Adjustments", pages 9 to 11, for procedure to be followed).

HANDLING

The regulators are shipped bolted to wooden skids long enough to provide stability in moving. They may be moved on these skids, or if a crane is available, by means of the lifting hooks welded to the sides of the tank. When using a crane, check the weight of the machine as indicated on the nameplate, against the capacity of the crane. The machines may also be moved short distances on metal rollers or a heavy dolly.

STORING

When stored for a considerable length of time, the regulators should be placed indoors, if possible, and preferably in a location that is dry and free from large temperature variations. Such variations are conducive to the condensation of moisture in machines when in storage. After SU or ST regulators have been stored for a considerable time, the oil should be tested for dielectric strength at 15 to 20 kv for a 1⁄10-inch test gap depending on the age of the oil.

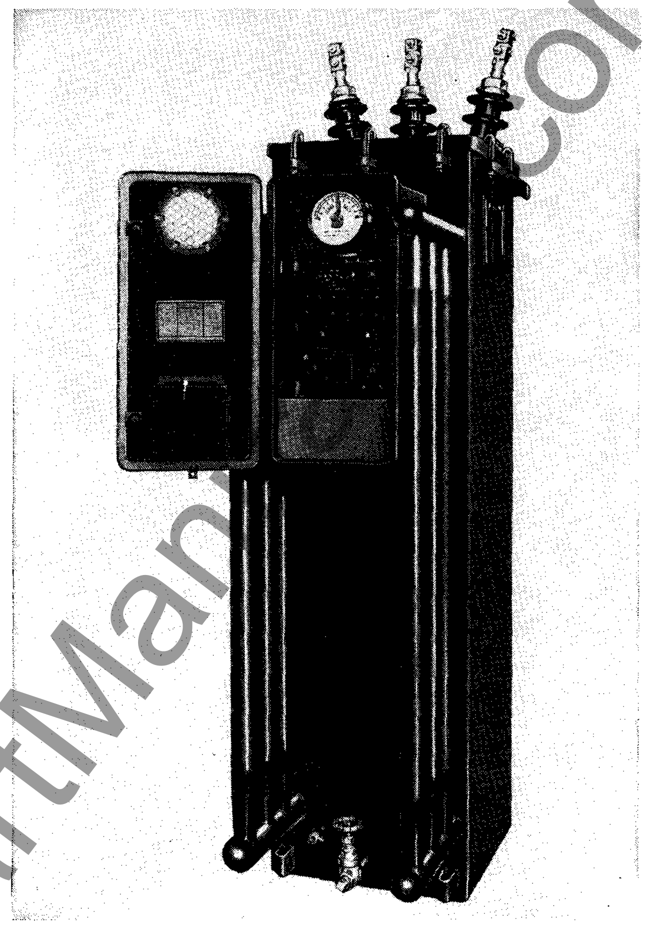


FIG. 3. Type SU Regulator with Control Cabinet Open Showing Controls

INSTALLATION

1. Types SU and ST regulators may be connected either to a de-energized feeder or to a live feeder without interruption of service, if proper precautions are taken. In either case, the following points should be checked first:

a. Make sure that the machine is suitable for the feeder which it is to control by checking the nameplate rating. Feeder voltage regulators having equal raise and lower ranges of regulation (not in excess of 10 percent raise and 10 percent lower) are capable of operating without exceeding the specified temperature rise provided the rated load current is not exceeded, and the input and output voltages are within the limits designated by NEMA. (See Table No. 14, "EEI-NEMA Preferred Voltage Ratings for A-C Systems and Equipment", NEMA Publication No. 117, dated May 1949 or subsequent revision).

b. Check the diagram sent with the regulator for special connections which may be slightly different from the typical diagrams shown in Figs. 13 and 14.

c. Make sure that the control supply switch is "off" and the automatic-manual switch is on "manual".

d. Make sure that the machine is in the "neutral" position as indicated by the mechanical position indicator. Type ST triplex machines have only one position indicator since the three single-phase units are coupled together.

e. After a regulator is installed and before it is actually placed in service, inspect it for possible damage in transit or handling. If the seal appears to have been disturbed, pressure-test the machine and dielectric-test the oil as outlined under "Receiving, Handling and Storing", page 4.

2. If the machine is to be connected to a deenergized feeder, the sequence of connections is immaterial. If the machine is being connected to a live feeder, the connections must be made in the sequence indicated below for each type of machine after checking the above points.

a. To connect a Type SU regulator to a live line:

1. Connect the primary or exciting winding across the line.

2. Connect the secondary or series winding into the line in parallel with a by-pass switch.

3. Open the by-pass switch to place the regulator in service.

4. The control supply switch may now be placed in the "on" position and the controls checked as outlined under "Control Panel and Relay Operation, Tests and Adjustments", pages 9 to 11.

b. To remove a Type SU regulator from a feeder without interrupting service:

1. Run the regulator to the "neutral" position by hand control.

2. Turn the control supply switch "off".

3. By-pass the secondary winding.

4. Open the secondary circuit by disconnecting the number 8 bushing (see Fig. 13).

5. Disconnect the regulator (bushings number 1 and 4) from the line.

c. When installing a Type ST regulator without interrupting service:

1. Make certain that the machine is in the "neutral" position, the automatic-manual switch on "manual" and the control supply switch "off".

2. If the machine is wye-connected, it will have a neutral bushing (S_0L_0 in Fig. 14). If the machine is being connected to a four-wire, three-phase line, connect the neutral bushing to the fourth wire. If the machine is being connected to a three-phase, three-wire ungrounded circuit, connect the neutral bushing to ground through a lightning arrester.

3. Insert a by-pass switch in each line.

4. Connect each primary bushing (S_1, S_2 and S_3 in Fig. 14) to the power side of one of the by-pass switches.

5. Connect each secondary bushing (L_1, L_2 and L_3 in Fig. 14) to the load side of one of the by-pass switches so that S_1 and L_1 are across one by-pass switch, S_2 and L_2 across the second, and S_3 and L_3 across the third.

6. Open the by-pass switches to place the machine in service.

7. Check the controls as outlined under "Control Panel and Relay Operation, Tests and Adjustments", pages 9 to 11.

d. To remove a Type ST regulator from a line without interrupting service:

1. Run the regulator to the "neutral" position by hand control, with the automatic-manual switch in the "manual" position.

2. Turn the control supply switch "off".

3. By-pass the secondary windings by means of a by-pass switch inserted in each line between S_1 and L_1, S_2 and L_2, and S_3 and L_3.

4. Disconnect the secondaries by opening the connections of L_1, L_2 and L_3 to the line.

5. Disconnect the primaries by opening the connections of S_1, S_2 and S_3 to the line.

6. Disconnect the neutral bushing (S_0L_0) from the fourth wire if such a connection exists by virtue of the type of machine and feeder (delta-connected machines have no neutral bushing).

Important. The primary of an induction regulator should not be disconnected while the secondary is in the line and carrying load current, as a high voltage may be induced in the windings.

All three phases of a Type ST regulator must be connected to the line before the machine will operate properly.

CONNECTIONS

Changes in the series-parallel arrangement of the primary or secondary windings are made by removing the tank cover to provide accessibility to the leads. The cover is removed by removing the bronze bushing caps and terminals, loosening the J-bolts and then raising the cover assembly complete with porcelains. The synthetic rubber gaskets provided with these regulators may be used again when the cover is reassembled on the tank.

The actual change is made by means of bolted connections. The rotor and stator leads terminate in flat terminals drilled so that they can be bolted together as required and marked as indicated on the wiring diagram to facilitate the changing of connections. When changing the primary connections of a 5-kv machine, the primary leads of the motor-operating transformer and the secondary tap of the control potential transformer must be changed also in accordance with the regulator wiring diagram. Unless otherwise specified, regulators are shipped connected in series and the nameplates marked accordingly.

GROUNDING, LIGHTNING PROTECTION AND SHORT-CIRCUIT PROTECTION

Types SU and ST regulators are provided with a copper grounding pad on the rear tank wall near the base. The pad has two 1/2-13 bolt-holes on 1 3/4-inch centers. The cross section of the grounding conductor should be at least equal to that of the maximum size cable that connects the regulator to the line. The control circuits have a single common ground located in the control cabinet behind the control panel.

For the best protection against voltage surges, lightning arresters should be mounted as close to the regulator as possible. An arrester should be connected to each terminal and grounded directly to the regulator tank. For single-phase applications it is recommended that 3-kv arresters be used on 2.5-kv machines, 6-kv arresters be used on 5-kv machines, and 9-kv arresters be used on 7.6-kv machines. For three-phase applications on grounded systems, the rating should be above the largest possible fault voltage. Three-phase, wye-connected machines which are used on four-wire circuits do not require an arrester on the neutral bushing since the fourth wire is grounded.

The regulator's impedance is too low to provide adequate protection against short-circuit currents. It is therefore recommended that reactors be provided between the source of power and the regulators. The reactance should be large enough to limit the short-circuit current through the regulator to not more than 25 times rated full-load current. Induction voltage regulators are designed to withstand 25 times full load current for two seconds without damage.

OPERATION

OPERATION OF MOTOR FROM AN EXTERNAL SOURCE OF POWER

When the regulator is de-energized, the motor may be operated from an external source of power. The connections for such operations are as follows:

1. Remove the ***ungrounded*** secondary lead of the motor-operating transformer from the upper terminal block. This is lead X-3 in Figs. 13 and 14. ***However, the lead designation may be different on a given machine due to special features. The correct designation for this lead should be obtained from the wiring diagram supplied with the regulator.*** The transformer lead is always connected to the top position of the terminal block as indicated in Figs. 13 and 14. Failure to remove this lead will tend to excite the regulator through the motor-operating transformer and eventually overheat the transformer.

2. If the external 240-volt source of power is ungrounded, it may now be connected directly between ground and the terminal block post from which the transformer lead was removed. (G and X-3 in Figs. 13 and 14). If the external power source is grounded, the ground connection to "G" should be removed first.

3. Before applying power to the circuit, make sure that the automatic-manual switch is in the "manual" position; otherwise, the machine will run to the maximum position as soon as the power is applied.

After applying the power and turning the control supply switch "on", the motor may be operated by means of the manual raise-lower knob on the panel.

DESCRIPTION OF CONTROLS

The controls of SU and ST regulators consist of two groups. One group is located in the tank submerged in the insulating oil and the other is located in the dust-proof control cabinet.

The tank group includes two potential transformers, two current transformers, the motor, capacitor and dynamic brake.

The motor-operating transformer provides the drive motor with a 250-volt source of power while the output potential transformer provides the control circuits with a 125 nominal voltage proportional to the output voltage.

One current transformer provides 0.29 ampere to the line-drop compensator at full load while the other is used to measure load current.

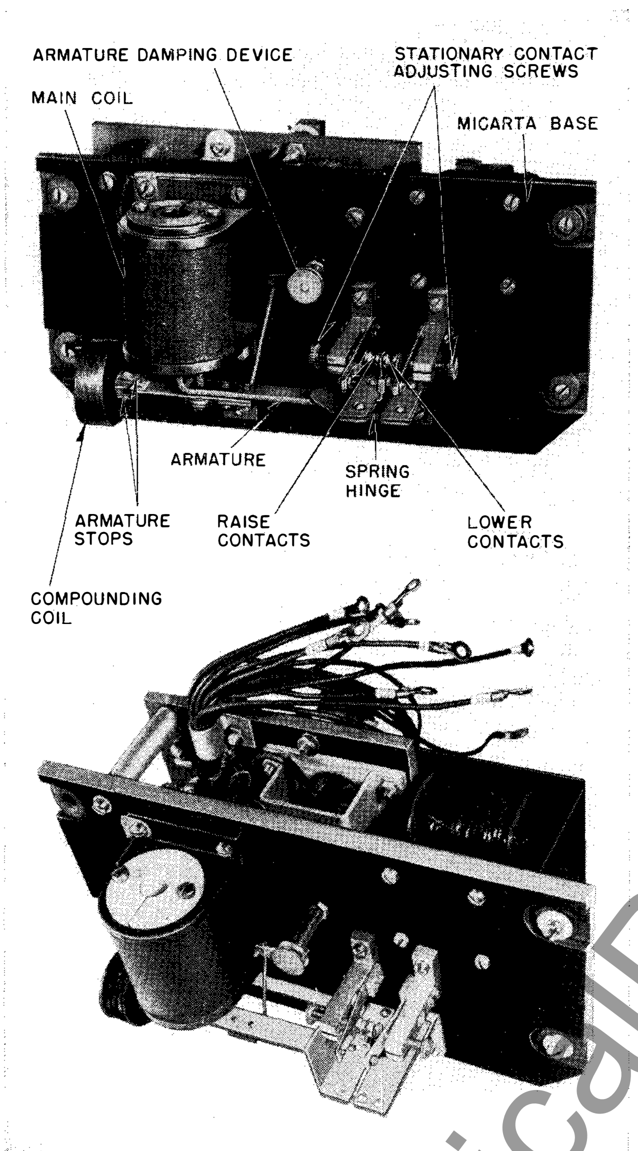


FIG. 4. Front View of Typical Voltage-Regulating Relay Assemblies

The motor, starting capacitor and dynamic brake are mounted side by side on top of the worm housing. (See Fig. 1). The motor is specially designed to develop a high starting torque. It is a reversible, single-phase, ball bearing motor. The motor actuates the dynamic brake to effect quick stops. The brake energizes the motor in the reverse direction as soon as the motor operating relay is deenergized and until the motor stops.

The control supply switch, automatic-manual switch, manual raise-lower switch, output voltage terminals, line-drop compensator, sensitivity adjustment, and balance volts adjustment are all mounted on the hinged control panel in the control cabinet. (See Figs. 1 and 6).

Above the control panel are located the mechanical position indicator (Fig. 1) with drag hands and reset knob, the limit switches behind the position indicator and the load current measuring terminals. A copper shorting jumper is located across the load current measuring terminals. The terminals consist of a double knob arrangement to allow the ammeter to be connected before the jumper is removed.

Below the control panel is located the voltage-regulating and motor-operating relay assembly. (See Figs. 1, 4 and 5). The main coil of the voltage-regulating relay (Fig. 4) is energized by the output voltage modified by the uncompensated volts setting and the line-drop compensator setting. The line-drop compensator setting is, in turn, modified by the phase-angle selector screw setting.

The compounding coil of the voltage-regulating relay (Fig. 4) is energized through the sensitivity adjustment. This provides an adjustable pull on the magnetic tip of the armature.

The left-hand contacts of the voltage-regulating relay run the regulator in the "raise" direction while the right-hand contacts run the regulator in the "lower" direction. (See Fig. 4).

The armature damping device and the stationary contact's leaf springs prevent bouncing of the voltage-regulating relay contacts.

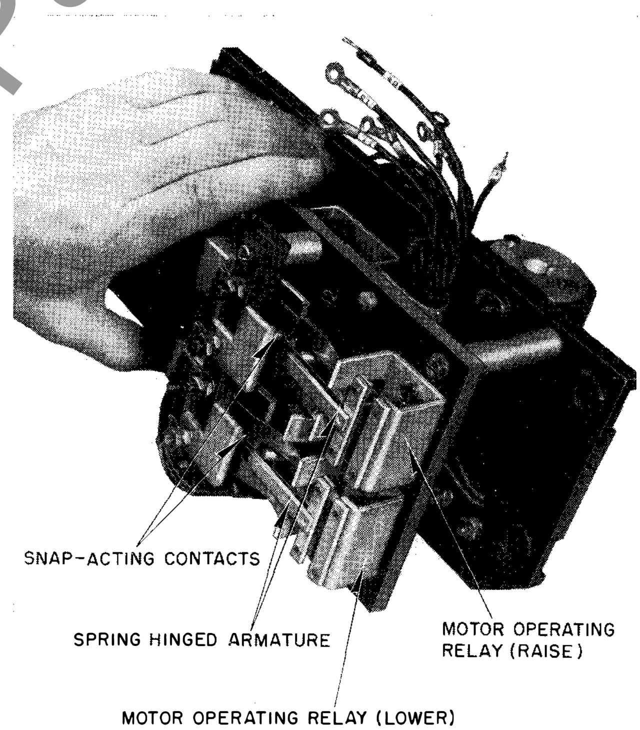


FIG. 5. Rear View of Voltage-Regulating Relay Assembly Showing Motor-Operating Relays

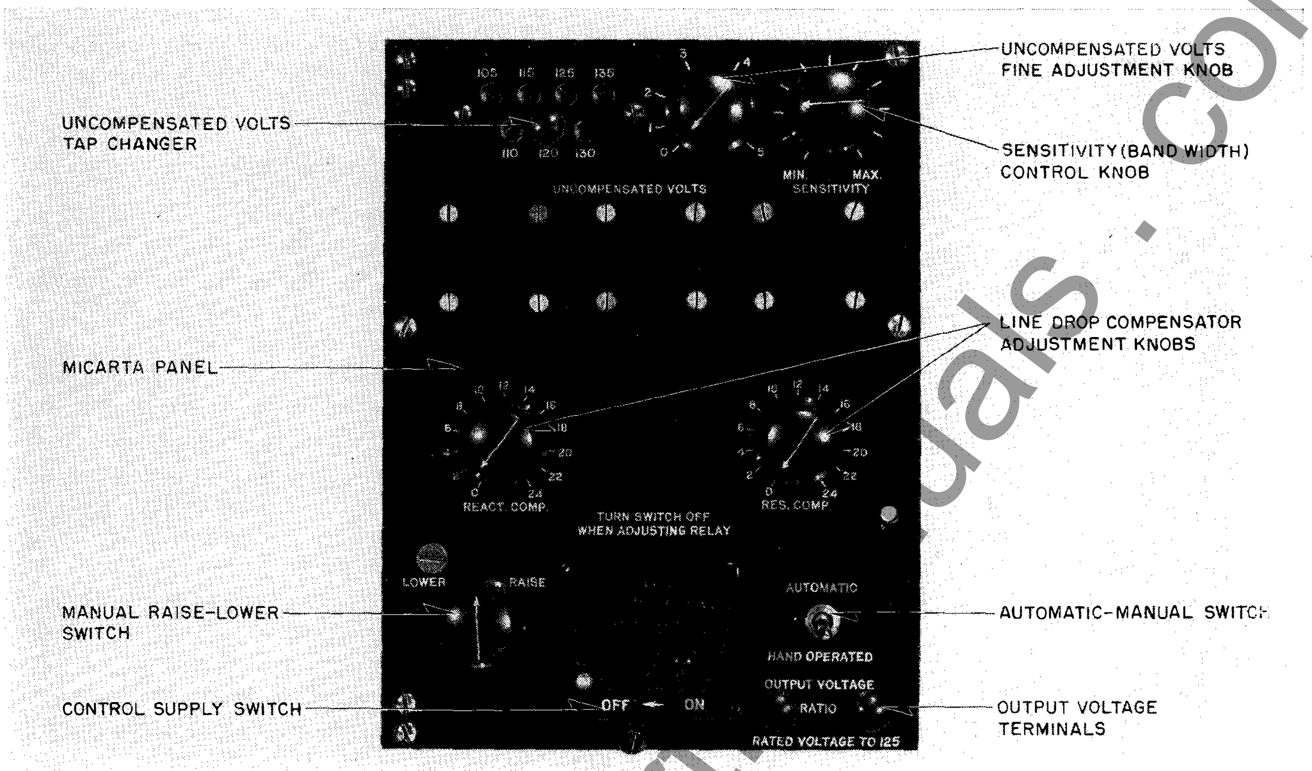


FIG. 6. Front View of Control Panel

All of the relays are spring-hinged to eliminate the need of pivots. This prevents sticking or binding of relay armatures.

CONTROL PANEL AND RELAY OPERATION

Control Supply Switch. (See Fig. 6). This Sentinel type switch provides power to the control panel from the motor-operating and potential transformers. It contains an overload thermal element in series with the motor-operating circuit. This element operates to open both the motor-operating circuit and the potential transformer circuit. In addition there is a fuse not integral with the switch but located in the potential transformer circuit to protect the control circuits.

Automatic-Manual Switch. This switch, when in the "manual" position, prevents automatic operation under control of the voltage-regulating relay. In the "automatic" position, this switch permits both automatic and manual operation in order to simplify the sensitivity adjustment. (Refer to "Control Panel and Relay Tests and Adjustments", page 10).

Manual Raise-Lower Switch. When the automatic-manual switch is in the "manual" position, and the control supply switch is "on", turning the raise-lower switch to the right causes the regulator to run toward the maximum "raise" position and turning it to the left causes the regulator to run toward the maximum "lower" position. The movements of the regulator can be observed on the mechanical position indicator.

Uncompensated Volts. This adjustment is used to set the voltage level at which the voltage regulating relay balances without any effect from line-drop compensation. The ratio of the potential transformer is such that when this adjustment is set at 125, the machine will maintain the line at full rated voltage. In other words, an uncompensated volts adjustment of 125 for the voltage-regulating relay corresponds to the full rated voltage of the machine. The actual adjustment is made by means of a tap changing plug for large increments of 5 volts and a calibrated knob for smaller increments from 0 to 5 volts. The tap changing plug should be set for the nearest 5 volt step below the desired voltage level. The calibrated knob is then set to indicate the increase of the desired voltage level

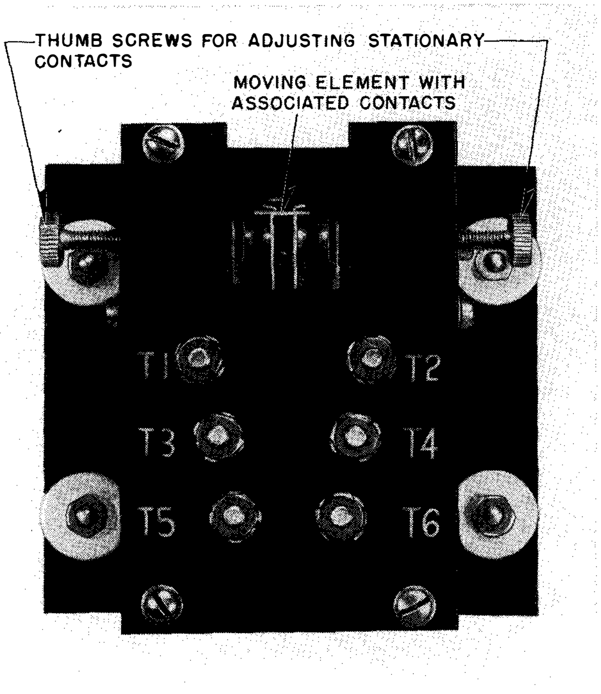


FIG. 7. Time Delay Relay

over the voltage setting of the tap changer plug. The uncompensated volts setting is then the sum of the tap changing plug setting and the calibrated knob setting.

Compensation Adjusting Knobs. These knobs are used to provide compensation for the varying resistance and reactance line drop between the regulator and the load center where the voltage is to be maintained constant. When the voltage is to be held constant at the regulator, these knobs are set at zero. (See "Line-Drop Compensator Settings", page 11, for procedure in making settings).

Sensitivity. This knob is used to adjust the regulation band width. (See "Control Panel and Relay Tests and Adjustments" in next column).

Phase Angle Selector. (Located on back of panel). The connections of this three-position switch are changed by changing the position of the screw and washer which acts to complete the circuits. The function of the phase angle selector is to compensate for the phase shift between the current and voltage transformer inputs to the control panel when the regulators are connected in delta. For single-phase operation of Type SU machines, the screw should be in the center position. See the machine wiring diagram or Fig. 13 for the correct position of this screw on Type SU machines being used on three-phase applications. Wye-connected Type ST machines do not require a phase shift, therefore, in this case the selector screw is in the center position. On delta-connected Type ST machines, the selector screw will be in either the left-hand or right-hand position depending on the phase rotation of the line.

Time Delay Relay. (See Fig. 7). This relay is not standard equipment on Type SU or ST regulators, however, many machines are supplied with it when specified. This relay provides up to 20 seconds time delay between the closing of the voltage-regulating relay contacts and the operation of the regulator. The regulator will respond only if the voltage-regulating relay contacts are closed for a period corresponding to the delay period. Thus the regulator does not respond to every self-correcting voltage fluctuation but rather to voltage shifts of time delay duration or more. This eliminates unnecessary regulator operations and extends the life of the mechanical parts. The relay operates on the thermal element principle. It has two moving contacts mounted on separate bimetallic straps. When a voltage-regulating relay contact closes, the corresponding bimetallic strap is heated until the operating contact touches its stationary contact. This energizes the motor-operating relay causing the regulator to operate in its usual manner. The two bimetallic straps are tied together to prevent both from making contact at the same time. The stationary contacts are adjustable by means of knurled thumb-screws. (See Fig. 7). The adjustment of the stationary contacts determines the duration of time delay.

Time Delay Switch. When in the "off" position, this switch eliminates the time delay, causing the regulator to respond instantly to an unbalance of the voltage-regulating relay. The same result may be obtained by adjusting the knurled thumb-screws of the time delay relay for zero time delay by bringing the stationary contacts into continuous contact with the moving element.

CONTROL PANEL AND RELAY TESTS AND ADJUSTMENTS

When testing or adjusting the regulator controls, a portable voltmeter must be used to read the output voltage. Connect the voltmeter to the output voltage testing terminals to read the regulated voltage. A reading of 125 volts on the meter corresponds to the rated voltage of the machine. Set the uncompensated volts adjustment for the desired voltage level as outlined under "Control Panel and Relay Operation" on page 9. With

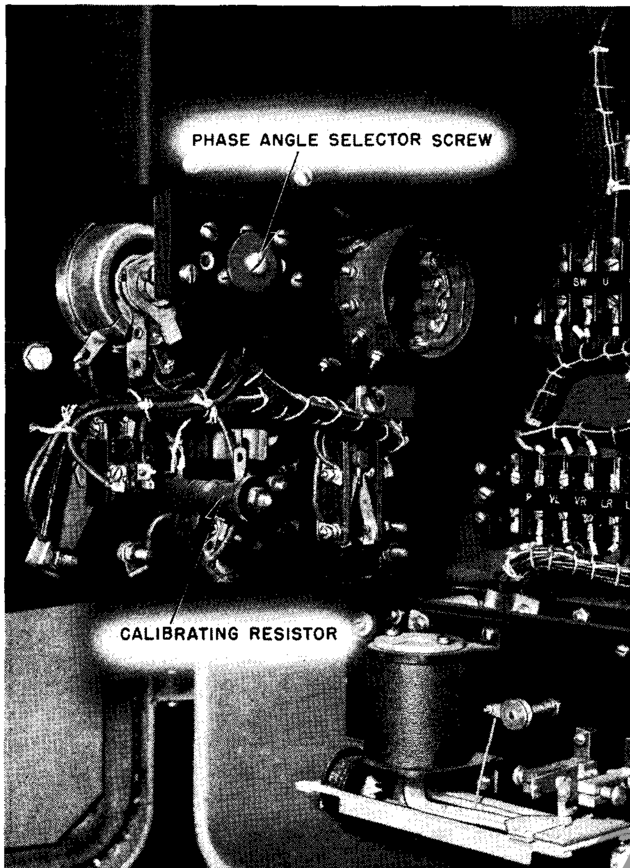


FIG. 8. Rear View of Control Panel

the automatic-manual switch on "automatic" and the compensation adjusting knobs on "zero", turning the control supply switch "on" will cause the machine to operate until the reading of the voltmeter agrees with the uncompensated volts setting. The machine may now be operated in small steps by means of the manual raise-lower switch to change the output voltage to a point where the voltage relay will make contact causing the regulator to operate automatically to bring the voltage back to a balance value. Operating the regulator both "raise" and "lower" in this manner and reading the voltage on the portable voltmeter at which the regulator operates will determine the sensitivity or band width. With the sensitivity knob in the "maximum" position, a band width of approximately 1 volt is obtained (uncompensated volts setting $\pm 1/2$ volt). With this knob in the "minimum" position, a band width of 4 or more volts is obtained (uncompensated volts ± 2 volts).

After several hours of continuous operation, the adjustment of the calibrating resistor on the back of the panel may be checked by observing that the uncompensated volts setting agrees with the voltmeter reading when the voltage relay is in the balance position. Adjustment of the calibrating resistor (Fig. 8) is made at the factory with the phase angle selector screw in the center position. No further adjustments of this calibrating resistor should be necessary unless the phase angle selector screw is moved to another position.

The voltage-regulating relay and the motor-operating relays are adjusted at the factory and should require no further adjustments. The contacts on these relays are silver and, therefore, do not require dressing or polishing. After a long period of time, the contact spacing on the voltage-regulating relay may need adjusting to compensate for wear. Approximate adjustment of these contacts should give a condition where the moving contact just touches a stationary contact when the balance arm tip is half-way between the holding magnet tip and the corresponding stop. Final adjustment of the contact spacing should be such that the regulator will restore the voltage on either raising or lowering to the center of the band. Increasing the contact spacing causes the voltage to be corrected further after contact is made, and decreasing the spacing causes it to be corrected less.

LINE-DROP COMPENSATOR SETTINGS

Correct settings of the line-drop compensator can be obtained by means of the formulas given

TABLE NO. 1

SIZE OF CONDUCTOR			R = 60-CYCLE, A-C RESISTANCE IN OHMS PER CONDUCTOR PER MILE AT 50°C.
Circular Mils	AWG	Strands	
1,000,000	—	61	0.0685
900,000	—	61	0.0752
800,000	—	61	0.0837
750,000	—	61	0.0888
700,000	—	61	0.0947
600,000	—	37	0.109
500,000	—	37	0.130
400,000	—	19	0.162
300,000	—	19	0.215
250,000	—	19	0.257
211,600	0000	7	0.303
167,806	000	7	0.382
133,077	00	7	0.481
105,535	0	7	0.607
83,690	1	1	0.749
66,370	2	1	0.945
52,630	3	1	1.192
41,740	4	1	1.503
33,100	5	1	1.895
26,250	6	1	2.390
20,820	7	1	3.014
16,510	8	1	3.800

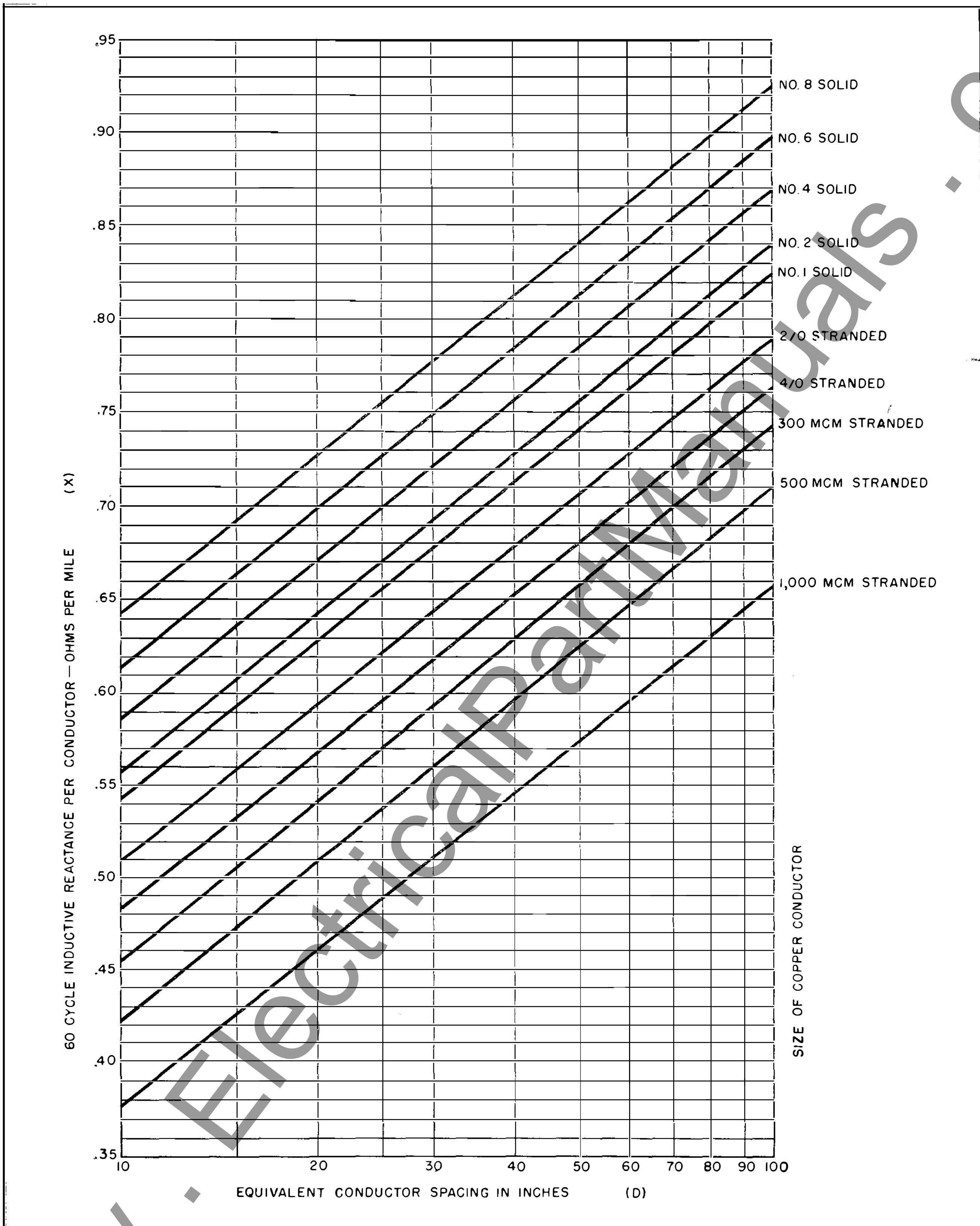


FIG. 9. Reactance Chart (60-Cycle Inductive Reactance vs. Equivalent Conductor Spacing for Various Sizes of Copper Conductor)

below. These settings can later be modified if voltage charts taken at the load center indicate variations. The modified settings are generally made on the basis of an error in the value of the length, L. Thus if the load center voltage falls at periods of high load, both resistance and reactance compensation are increased, and if the load center voltage rises at periods of high loads, both resistance and reactance compensation are decreased.

The resistance compensation setting can be found by means of the following formula:

$$\text{Resistance Setting} = 125\left(\frac{R\,L\,I\,K}{V} + \frac{Dr}{100}\right)$$

where R is the a-c resistance of the feeder in ohms per conductor per mile.

Table No. 1, page 11, gives values of R for various conductor sizes.

L is the length of the feeder in miles.

I is the rated full-load current of the regulator as indicated on the nameplate for the stator connection employed.

K is a constant determined by the application. For single-phase applications, the constant is 2; and for three-phase applications, it is 1.73.

V is the line-to-line voltage.

Dr is the percent resistance drop which occurs in any transformer and distribution line which may be located between the end of the feeder and the load center. This drop must be calculated on a basis of full-load current in the regulator.

The reactance compensation setting can be calculated by means of the following formula:

$$\text{Reactance Setting} = 125\left(\frac{X\,L\,I\,K}{V} + \frac{Dx}{100}\right)$$

where X is the reactance of the feeder in ohms per mile per conductor.

The curves in Fig. 9 give values of X for various conductors and equivalent conductor spacings. The equivalent conductor spacing D for single-phase feeders is taken as the distance between conductors. For three-phase feeders, D is equal to the cube root of the product of the three conductor spacings. Thus if the conductors form an equilateral triangle, the spacing between any two conductors is equal to D. If the conductors are in line, D is equal to the $\sqrt[3]{2}$ times the spacing between either end conductor and the center one.

L is the length of the line in miles.

I is the rated full-load current of the regulator as given on the nameplate for the stator connection employed.

K is a constant determined by the application. For single-phase applications, the constant is 2; and for three-phase applications, it is 1.73.

V is the line-to-line voltage.

Dx is the percent reactance drop which occurs in any transformer and transmission line located between the end of the feeder and the load center.

SAMPLE CALCULATIONS

Assume that three 50-kva, 10 percent regulation, Type SU regulators are to be wye-connected to a three-phase feeder. The feeder is rated at 1500 kva and is operated at 4330 volts line to line. Full load current is 200 amperes. The regulators are rated at 2500 volts and 200 amperes full load. Assume that the conductors are No. 4/0, stranded cable mounted in line horizontally with two feet between adjacent conductors. The feeder length is two miles and the percent drop in the transformer and distribution line is 2 percent for both resistance and reactance.

For the assumed conductor size, Table No. 1, page 11, gives R = 0.303 ohm per conductor per mile.

This value is then substituted in the resistance setting formula and gives: Resistance Setting =

$$125\left(\frac{0.303 \times 2 \times 200 \times 1.73}{4330} + \frac{2}{100}\right) = 8.6 \text{ volts}$$

For the assumed conditions $D = \sqrt[3]{2} \times 2 \times 12 =$ 30.2 inches.

For D = 30.2 inches and No. 4/0 conductor, Fig. 9 gives X = 0.62 ohm per conductor per mile.

Substituted in the reactance setting formula this gives: Reactance Setting =

$$125\left(\frac{0.62 \times 2 \times 200 \times 1.73}{4330} + \frac{2}{100}\right) = 14.9 \text{ volts.}$$

MAINTENANCE

OIL INSPECTION

Approximately once a year or oftener if operating conditions warrant, an inspection should be made to determine whether the oil level is correct and whether the oil is of sufficient dielectric strength. In checking the oil level, allowance should be made for the temperature at which the regulator is operating. Allow ½-inch increase in oil level for each 10 degrees of oil temperature above 25 degrees C.

Samples of oil for test purposes can be drawn off through the sampling valve located at the base of the tank. (Samples of oil should always be drawn off from the bottom since impurities and moisture tend to concentrate there). A dielectric test of the oil should give a breakdown value of at least 15,000 volts on a 1/10-inch test gap. If the oil strength is found to be less than this value, the oil should be filtered or centrifuged. If this does not return the oil's dielectric strength to normal, the oil should be replaced.

The appearance of the oil should be carefully checked as a discoloration may indicate contamination or oxidation. If the condition of the oil is still in question, further testing may be necessary. See Westinghouse Instruction Book 44-820-1 for further information on oil maintenance.

MECHANICAL PARTS INSPECTION

After ten years of operation and at ten year intervals thereafter, a complete inspection of the regulator should be made. It should be taken to a suitable service shop and be completely dismantled for this inspection. The inspection should cover the following points:

1. The rotor leads should be checked for chafing or weakened points which may later cause failures.

2. Windings should be checked for deformed coils due to short-circuit stresses or other abnormal operating conditions.

3. Gears (particularly worm and worm gear), bearings, dynamic brake switches, limit switches and position indicator should be checked for possible wear.

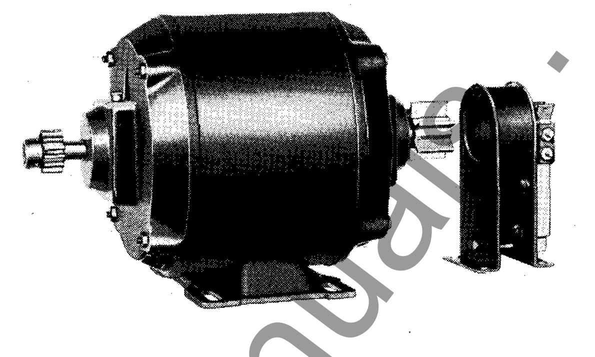


FIG. 10. Motor and Dynamic Brake

4. The air gap should be checked. The maximum difference between any two points around the rotor for any position of the rotor should not exceed 0.005 inch.

5. The worm housing (Fig. 11) should be checked for broken welds due to short-circuit stresses.

6. The motor and gear reduction unit are completely submerged in the insulating oil and therefore should not require maintenance. The motor position should be checked, however, to be sure that the motor pinion meshes properly with the Micarta spur gear.

7. The current transformers should be checked for possible damage due to short-circuit stresses.

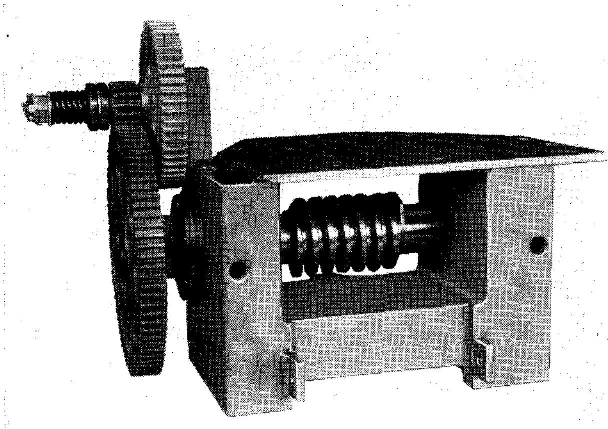


FIG. 11. Worm Housing Assembly

DISASSEMBLY OF MACHINE

1. When disassembly of the machine becomes necessary for maintenance or repairs, care should be taken to avoid damaging parts or dropping them into the regulator. For a thorough inspection or repairs it will generally be necessary to remove the regulator from the tank. This should be done as follows:

a. Remove the tank cover assembly complete with porcelains by removing the bronze caps and loosening the J-bolts.

b. Drain off sufficient oil to expose the stator top plate.

c. Release the tension on the position indicator drive wire by means of the two adjusting bolts.

d. Remove the large position indicator drive pulley by driving out the tapered pin.

e. Remove the position indicator case, indicator hand, and dialplate.

f. Loosen the packing nut behind the position indicator by reaching up from below after swinging the control panel out.

g. Drive the position indicator shaft out from the tank until it is approximately flush with the tank wall. Be careful not to damage the limit switches with the limit switch operating cam located on this shaft between the tank wall and position indicator. Clearance can be obtained by rotating the shaft.

h. Remove the four bolts which hold the locating brackets to the tank wall on opposite sides of the tank near the front. Remove the brackets from the centering lugs fastened to the stator top plate. One of these brackets may bind due to a shifting of the regulator's weight. In this case, the bracket can be removed after the crane is supporting the weight of the machine.

i. Disconnect the control wiring inside the tank from the terminals leading through the tank wall into the control box.

j. The machine may now be raised from the tank by means of the lifting bracket.

2. When the machine is out of the tank, the worm housing assembly may be removed as follows:

a. Remove the leads from the Micarta tube which runs through the lifting bracket. (Type SU only).

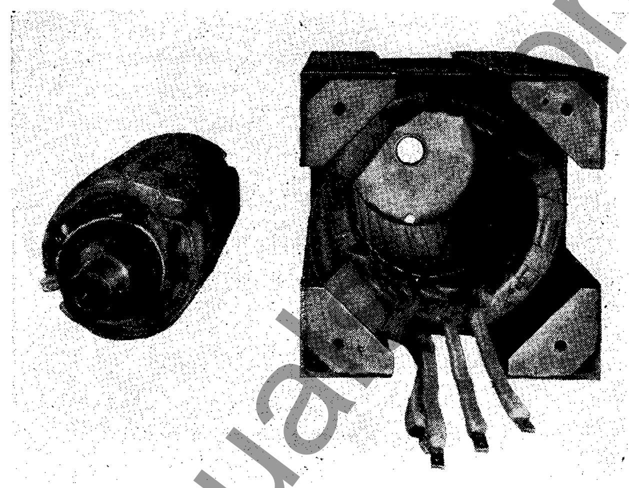


FIG. 12. Rotor and Stator

b. Chip fillet welds on either side of worm housing where locating pins are not used.

c. Remove the four bolts which hold the housing down on the stator top plate.

d. The worm housing assembly (Fig. 11) may now be removed as a unit. On Type ST machines, the coupling shaft or shafts between units will have to be removed before removing the housing.

3. When the regulator is out of the tank and the worm housing is removed, the worm gear may be removed as follows:

a. Remove the four bolts which hold the lifting bracket to the top plate and remove the bracket. (Type SU only).

b. Use a wedge to remove the pin which positions the worm gear on the rotor shaft.

c. Remove the worm gear with a heavy wheel-puller.

4. With the worm housing and worm gear removed, the rotor (Fig. 12) may be removed as follows:

a. Unhook the rotor leads from the rotor lead hanger on the underside of the stator top plate.

b. On Type ST machines, it may be necessary to remove a potential transformer which is fastened to two stator top plates. On Type SU machines, the potential transformers can be left on the top plate if care is exercised in removing the top plate.

c. Remove the stator top plate (four bolts hold it to the stator uprights) taking care not to damage the potential transformers or the main leads.

d. The rotor may now be raised using an eyebolt in the tapped hole in the top of the rotor shaft. Care should be taken to raise the rotor straight up. The rotor should be raised slowly and carefully to avoid damaging the rotor coils.

5. To remove the worm from the worm housing:

a. Remove the nut from the small end of the taper pin which holds the large spur gear on the worm shaft. (In cases where it is used).

b. Drive the pin out with a blunt soft rod to avoid damaging the threads.

c. Remove the spur gear.

d. Loosen the set-screws which hold the adjusting nuts in place.

e. Remove the adjusting nuts with a spanner wrench.

f. Remove the worm by tapping on either end of the shaft to drive one of the bearing cones out.

REASSEMBLY OF MACHINE

When reassembling the machine, a reverse procedure to that used in disassembly should generally be followed. When reassembling the worm housing, tap on the worm shaft lightly while tightening the adjustment nuts to make sure that the bearings are seated properly. Also position the worm by means of the adjustment nuts so that the spur gears mesh properly. Tighten the adjustment nuts so that a slight drag is felt when turning the worm by hand by means of the large spur gear. The idler gear should be removed for this adjustment.

When replacing the worm gear, heat it first in an oven or over a gas flame to about 300 or 400 degrees F. If the gear's position is marked before disassembly, it can be easily returned to its correct position before it tightens up on the shaft.

When replacing the worm housing, check for proper meshing of the worm and worm gear. There should be a backlash of approximately one tooth on the large spur gear.

By spot-marking the rotor winding and large spur gear in the neutral position while the machine is out of the tank, the machine can easily be set on neutral after it is tanked. This facilitates the proper location of the position indicator.

After the machine is completely reassembled, it should be pressure-tested to check its seal. This can be done by applying an internal pressure of five pounds per square inch. There should be no appreciable drop after a six-hour period. Leaks above the oil can be found by brushing the gasket-sealed joints with a suitable solution such as soap and glycerine.

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