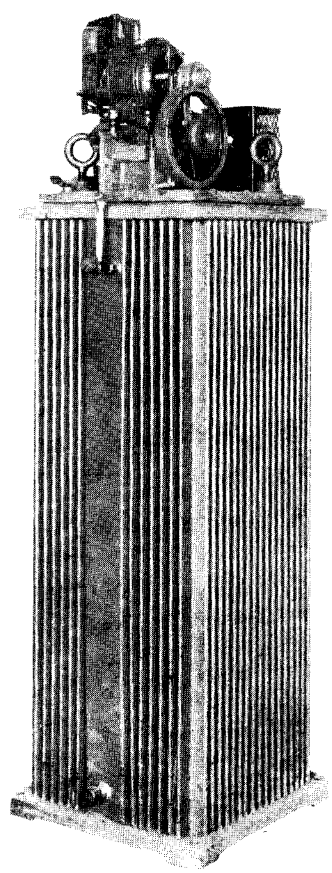
Westinghouse
Automatically-Controlled Induction Regulators

INSTRUCTION BOOK



Motor Operated Single Phase Induction Regulator

Westinghouse Electric & Manufacturing Company
East Pittsburgh Works East Pittsburgh, Pa.
I. B. 5137-D

IMPORTANT

Machinery of every kind requires some attention if a maximum of usefulness and long life is to be obtained from it. All electrical apparatus should be kept clean and dry. The moving parts should be properly but not excessively lubricated.

An automatically controlled regulator consists of a number of separate pieces of apparatus, and the incorrect adjustment or defective operation of any of them may cause unsatisfactory operation of the regulator as a whole. It is therefore essential that the following instructions be carefully read before installing, operating, adjusting, or repairing the regulator or its auxiliaries.

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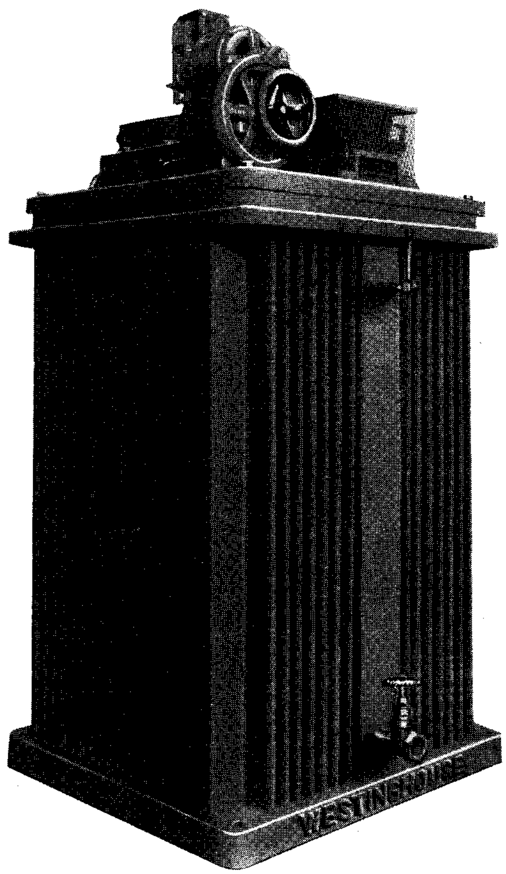

Motor Operated Three Phase Induction Regulator

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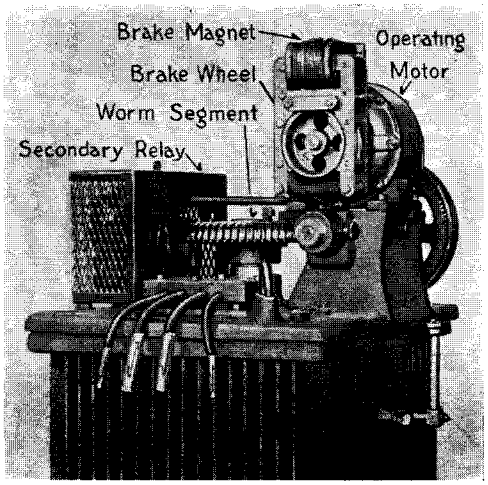

Fig. 1—Regulator Showing Mounting of Motor and Attachments

PURPOSE OF REGULATOR

A very large per cent of the regulators now in use are for the automatic voltage control of feeder circuits taking power from bus bars having practically constant voltage. The regulator is used to automatically increase or decrease the voltage of the outgoing feeder so as to compensate for the variable line drop or variable bus voltage and thus maintain a constant voltage at the center of distribution of the particular feeder.

STANDARD EQUIPMENT FOR SINGLE PHASE REGULATOR ON SINGLE PHASE CIRCUIT

The complete equipment consists of the following apparatus which should be connected as per Fig. 2:

(a) The Induction Regulator.
(b) A two or three phase operating motor which with its electrically operated brake is mounted on top of the regulator and is suitably geared to the main shaft of the regulator.
(c) The auxiliary relay which also is mounted on the regulator cover and performs the function of a motor switch and a limit switch for preventing over-travel of the regulator mechanism.
(d) The primary relay which is a sensitive contact making voltage relay for controlling the auxiliary relay.
(e) A voltage transformer.
(f) A Type KA line drop compensator S# 325035
(g) A current transformer.

STANDARD EQUIPMENT FOR 3-PHASE REGULATOR

The auxiliary apparatus for a 3-phase regulator is the same as for a single phase regulator on a single phase circuit, except that two current transformers and a 3-phase compensator S# 325036 are used. Two current transformers are necessary in order that, with 100% power factor, current and voltage which are in phase may be obtained for the operation of the compensator. On a 3-phase circuit at 100% power factor the current in any wire is 30 degrees out of phase with the voltage taken across this wire and one of the

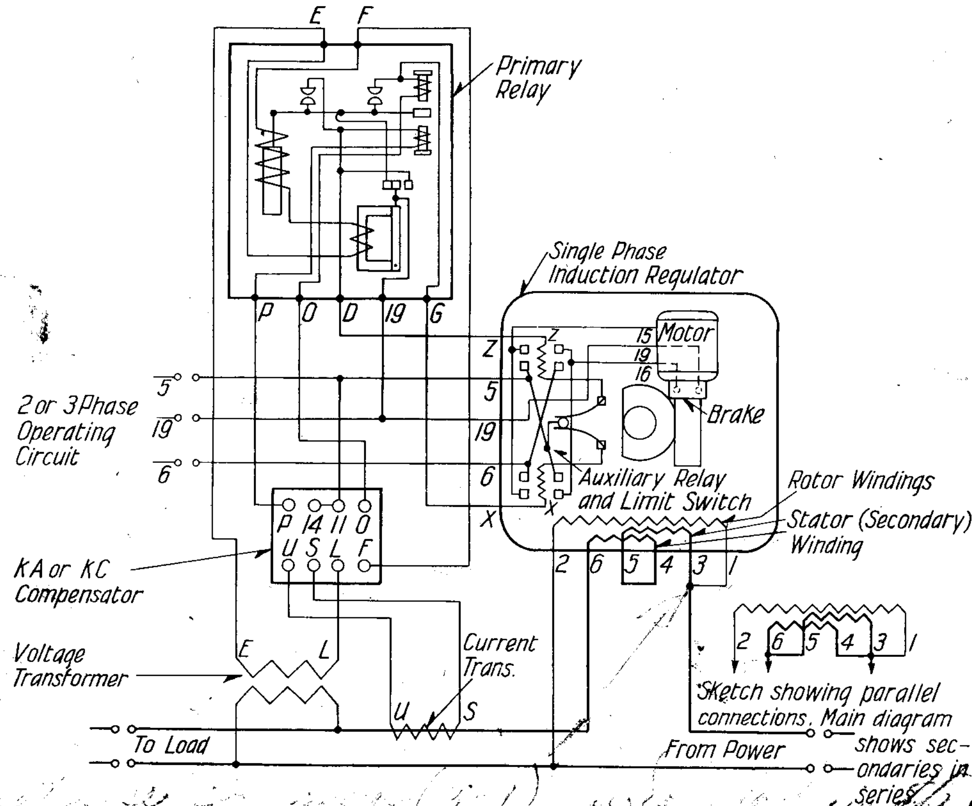

Fig. 2—Diagram of Connections for an Automatic Single Phase Regulator

other wires. By using a current transformer on each of two wires of a 3-phase balanced feeder and connecting the secondaries as shown in diagram Fig. 3, the current in the compensator will be equal to 1.73 times the current in either current transformer but it will be in phase with the voltage taken across these two wires. This is essential if satisfactory service is to be obtained from the compensator. The only difference between the two compensators is that the single phase compensator is wound for a maximum full load current of 5 Amps. while the 3-phase compensator is wound for 8.7 Amps. If suitable current transformers are selected the single phase compensator may be used on a 3-phase circuit.

ADDITIONAL AUXILIARIES

The auxiliaries previously enumerated are the essential auxiliaries which are supplied with standard automatic regulators. No reference is made to the circuit-breakers, fuses, protective reactances, disconnecting switches, transfer switches, lightning arrestors, meters, etc., which are ordinarily used in modern practice. Considerations of cost, continuity of service, capacity of power house, ease of operation, skill and reliability of attendants, will determine the number and quality of such auxiliaries which ought to be used.

On large systems where a large amount of power can be delivered to a short circuit, the use of protective reactors for each feeder circuit is strongly recommended. It only requires from 1 to 2 per cent of the normal feeder voltage to drive full load current through a regulator under short circuit conditions. Due to the saturation of the iron, the impedance of the regulator on heavy overloads is further decreased and reactors must be supplied if the short circuit current is to be reduced to a safe value.

Fuses in the primary of the voltage transformer are for protection against dead short circuits only and should have a capacity ten times the current capacity of the transformer.

Due to the nature of the service it is impossible to protect the operating motor and relays against overload by means of fuses or breakers. 30 Amp. fuses as a protection against dead short circuits are recommended. Time limit fuses or thermal cutouts may be used but there is some question as to whether

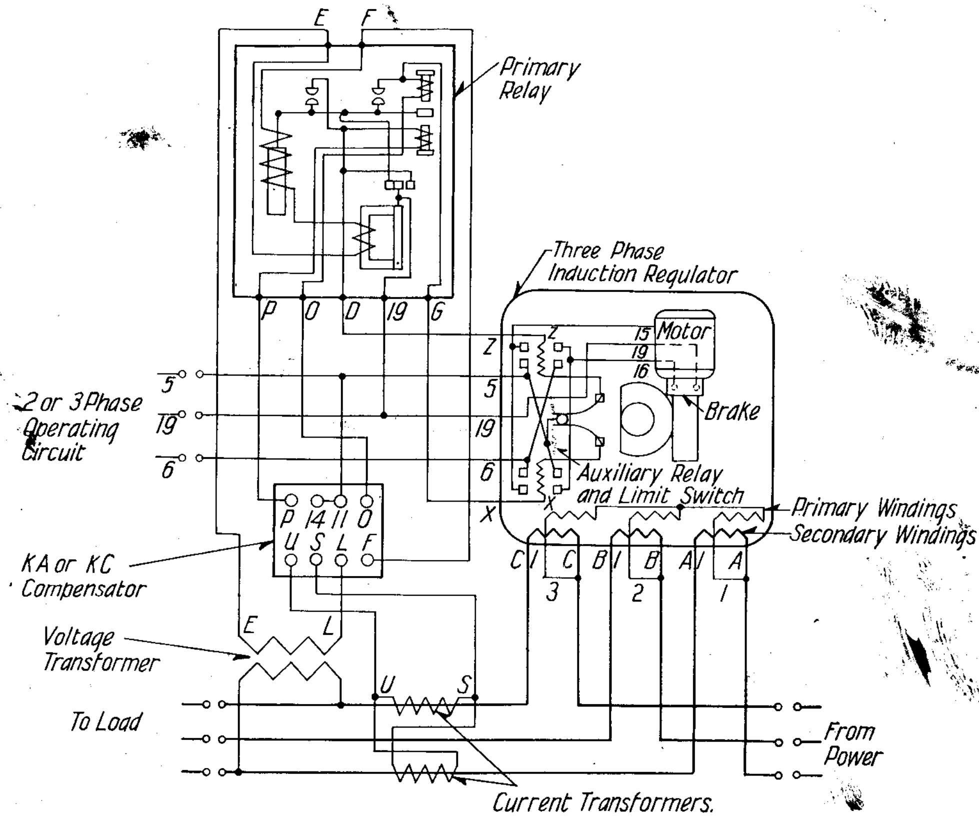

Fig. 3—Diagram of Connections for an Automatic Three Phase Regulator

they are necessary. Their chief use is to protect against single phase being thrown on a polyphase motor. The auxiliary apparatus however, is so reliable that with reasonable attention there is little danger of this occurring.

BRIEF THEORY OF AUTOMATIC SINGLE PHASE REGULATOR

Referring to Fig. 2 the standard apparatus listed is plainly indicated. The primary relay (See Fig. 4) is connected through the compensator to the voltage transformer and is sensitive to voltage changes of the outgoing feeder. Under normal conditions the moving arm in the primary relay is horizontal. With a change in voltage the plunger in the relay coil moves up or down and closes either the left hand or right hand set of contacts thereby causing the electrically operated secondary relay to close its contacts and start the operating motor in such direction as to lower or raise the voltage on the feeder as may be required to correct the change and bring the voltage back to normal. The purpose of the compensator is to so affect the primary relay that it will raise the voltage with increasing load as may be required to take care of the increasing line drop and thus hold a constant voltage at the center of distribution of the feeder.

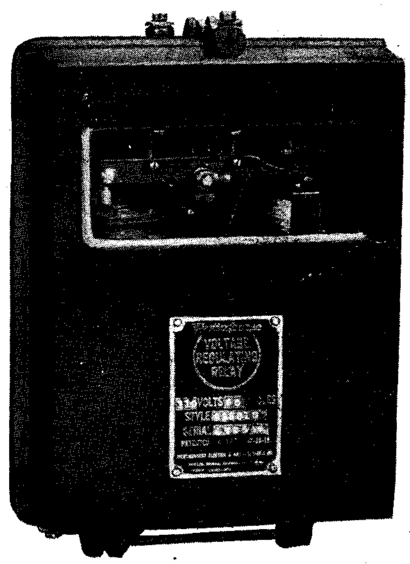

Fig. 4—Primary Relay

When it only is desired to hold a constant voltage at the point where the regulator is installed, compensator and current transformer are not required.

The two small coils on the right hand side of the primary relay (one above and one below the moving contact arm) are known as compounding coils and are used, 1st—to obtain more positive action just at the instant the contacts are making or breaking the circuit to the secondary relay; 2nd,—to obtain a voltage the average value of which is more nearly equal to the voltage midway between the limiting values at which the relay will operate.

Assume that the primary relay is set to keep the voltage at **110** volts plus or minus 1½ volts and that the compounding coils are adjusted for ½ volt compounding. The operation will then be as follows:

With **110** volts across the primary relay and its resistance, (E to L, Fig. 2) the lever supporting contacts will be in the horizontal, or mid position. If the voltage on the feeder rises, the main coil of the primary relay will pull up the plunger, and as soon as the voltage rises to 111.5 volts, one of the moving contacts will touch the stationary contact on the lefthand side. At this instant the lower compounding coil will be energized and will pull the moving contact more firmly against the stationary contact. The solenoid Z of the auxiliary relay also will be energized, closing the corresponding relay switch and will start the motor and turn the regulator to such a position as to bring the voltage back to normal. Due to the compound ing, the primary relay contact will not open the circuit to auxiliary relay as soon as the voltage is brought just slightly below 111.5 volts but will keep the motor circuit closed until the voltage is lowered to **111** volts. The contact will then open, the motor will stop, and the lever in the primary relay will swing approximately to the mid position, with practically no burning at the contacts. If the voltage on the feeder decreases to 108.5 volts, the primary relay contact at the right will make contact and the regulator will be operated in the opposite direction to increase the voltage and bring it back to normal.

THEORY OF AUTOMATIC THREE PHASE REGULATOR

Although three phase regulators differ quite materially from single phase regulators in theory and construction the method of automatically controlling them is the same, and the preceding paragraph will apply equally to the 3-phase regulator.

SHIPPING AND STORAGE

Regulators usually are shipped, completely assembled in the case without oil. The required amount of oil is shipped separately in sealed drums. The regulator should not be operated at rated voltage unless filled with oil.

In case the regulator is not to be immediately installed, it should be stored in a clean dry place. All machined parts should be well oiled especially the top bearing of the rotor shaft. A periodic inspection should be made to see that rusting has not started. It is well to cover the top of the regulator with some moisture-proof material, such as oilcloth.

INSTALLATION

Rating—Check the rating as indicated on the nameplate to see that the regulator is suitable for the circuit for which it is intended.

The nameplate gives the Kva. capacity, primary voltage, phase, frequency, secondary ampere capacity, per cent regulation, serial number and shop order number of the regulator.

When two voltage or current ratings are given on the nameplate it indicates that windings for series or parallel connections are available and special care must be taken to insure the correct connections being used. Unless care is taken it is very easy to get a **100**% overload on the regulator. When a single rating is given for a regulator with series—parallel windings it refers to the series rating.

The kilovoltampere rating of a single-phase regulator is equal to the product of the current times the voltage of the circuit times the per cent regulation. For example; a 2300-volt 100 ampere, 230 kilovoltampere, single phase circuit that is to be regulated **10** per cent up and down, would require a regulator rated at 100 x 2300 x $\frac{10}{100}$ = 23000 volt-amperes or 23 kilovoltamperes.

The kilovoltampere rating of a three-phase regulator is equal to the product of the current times the voltage of the circuit times the per cent regulation, times the square root of three. For example; a 2300 volt, 100 ampere, 400 kilovoltampere three-phase circuit, that is to be regulated 10 per cent up or down would require a regulator rated at

$100 \times 2300 \times \frac{10}{100} \times \sqrt{3} = 40000$ voltamperes. The voltage across the secondary or series windings of a regulator may be calculated as follows: For single-phase regulator the secondary voltage equals the per cent regulation times the line voltage, i. e., for 10 per cent, 2300 volt single-phase regulator the secondary voltage is $\frac{10}{100} \times 2300 = 230$ volts. This is the voltage with regulator in the maximum position. As the rotor is turned toward the mid position, the voltage across the series winding is reduced until in the mid position the voltage is zero.

For three-phase regulator the voltage across one of the three secondary windings equals the per cent regulation times the primary voltage divided by $\sqrt{3}$ i.e., for a 10 per cent 2300-volt, three-phase regulator the voltage across one of the series windings is $\frac{10}{100} \times 2300 \times \frac{1}{\sqrt{3}} = 133$ volts.

The secondary voltage of a three-phase regulator is practically constant for all positions of the rotor, but the phase relation changes.

The three phase regulator differs materially from the one phase regulator in this respect. An adjustable voltage is generated in the series coil of a single phase regulator and is added directly to the line voltage without changing its phase.

With the three phase regulator the constant voltage of the series winding is added vectorially to the line voltage and as a result the line voltage is slightly out of phase with the bus voltage except in the maximum and minimum voltage positions.

Regulators are usually wound so as to have at no load a secondary voltage from 5 to 20 per cent higher than is indicated by the above calculations. This is done in order that the full per cent regulation may be obtained when operating at full load.

Operating Circuit Characteristics—See that the operating circuit for the motor has the proper characteristics as indicated on the motor and auxiliary relay nameplates. A three-phase operating motor is usually furnished. If a two-phase motor is used it must be operated from a two-phase, three wire circuit. Mark the common wire 19 and connect as shown for three-phase motor. A two-phase motor for regulator service is provided usually with three leads only, marked, as shown for a three-phase motor, 15, 19 and 16; 19 being the common lead. If current at the proper voltage is not available it must be supplied by means of transformers. It is recommended that two standard 1½ kva. transformers connected in open delta be used for the motor on any regulator rated at 69 kva., one-phase or 40 kva. three-phase or less. When operating in groups one kva. of transformer capacity per regulator is sufficient.

Location of Apparatus—The regulator and the auxiliary apparatus should be installed so as to be readily accessible, and in a place free from dust, moisture and dirt. The relays must be mounted in a vertical position, and the primary relay in particular must be entirely free from vibration. The moving element in the primary relay is wedged in the coil to prevent movement during shipment. When installing, all wedges should be removed to permit free movement of plunger. If regulators can be located in a room fitted with an overhead crane it is a distinct advantage for convenience in handling. If a crane is not available, the regulator may be skidded or moved on rollers into position, but as a regulator is usually quite tall, extreme care must be taken that it is not tipped over. The tapped hole in the top end of the shaft is for an eye bolt to be used for lifting the rotor only, and should not be used for lifting the complete regulator.

Water cooled regulators depend almost entirely upon the flow of water through the coils for carrying away heat so that the temperature of the surrounding air has little effect upon that of the regulator. For this reason air circulation is of minor importance and water cooled apparatus should be located with regard to convenience in arranging the water piping rather than with regard to ventilation.

Self-cooled regulators are entirely dependant upon the surrounding air for carrying away the heat and it is essential that proper facilities for ventilation should be provided. The regulator must be placed in a room, so ventilated, that the heated air can readily escape and be replaced by cool air from outside. If the room is poorly ventilated there is small chance for this exchange of air and the temperature of the air in the room may become excessively high. At any given load, the temperature rise of the regulator will be a fixed number of degrees above the surrounding air and there is danger of operating the regulator at unsafe temperatures. For this reason it is vitally

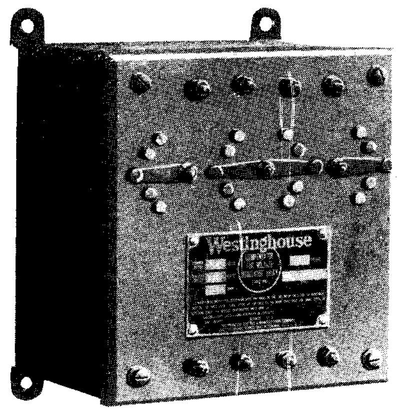

Fig. 8—Type KC Compensator

transformer having a secondary voltage of from 100 to 115 volts. For 116 to 125 volts it is necessary to remove the steel base plate and transfer lead F from 20 to Y. For 126 to 135 volts lead L also should be transferred from 4 to X.

This compensator is well adapted for lighting circuits or for circuits on which there is little change in power factor. Since it has no reactance element it is not strictly correct on a circuit where the power factor varies through wide limits. For feeders of this class a compensator with a reactance element such as the Type KC or KD should be used.

TYPE KC COMPENSATOR

The type KC compensator is shown in Fig. 8. Diagram Fig. 9 shows the internal connections. This compensator is the same as the Type KA except that a reactance element in the form of a reactance transformer is added. The resistance compensating steps are obtained on the outside dials as with the Type KA compensator. The double inside dial provides the reactance compensation. 5 volt steps can be obtained on the right and 1 volt steps on the left. As on the resistance dials the numbers on the contacts indicate the volts compensation obtainable. For example with the arms on 2R, 3 X, 15 X and 10 R 12 volts (2+10) resistance and 18 volts (3+15) reactance compensation will be obtained when the rated full load current is flowing in the series winding S to U.

Due to the double use of the resistance as in the KA compensator the power consumption is low. However, the volt-ampere load put on the current transformer as a result of adding the reactance element, amounts to approximately 80 volt-amps, so that it is advisable to use the current transformer for the compensator exclusively.

The compounding resistances and additional series resistance for the primary relay are also mounted within the case of the KC compensator. As shipped from the factory the compensator is connected internally for use with a voltage transformer having a secondary voltage of from 100 to 115 volts. For 116 to 125 volts it is necessary to remove the steel base plate and transfer the reactance coil lead Y from 20 R to Y. For 126 to 135 volts lead L also should be transferred from 4R to X.

VOLTMETER USED WITH COMPENSATOR

It is sometimes desired to read the compensated voltage i.e., the voltage at the center of distribution. This cannot be done when the KA or KC compensator is used except by using a very special voltmeter so designed that the primary relay resistance can be used also as the series resistance of the voltmeter. This meter preferably should be calibrated with the primary relay and compensator.

Sometimes it is desired to read the compensated voltage by means of a standard voltmeter. To meet this requirement the Type KD compensator should be used.

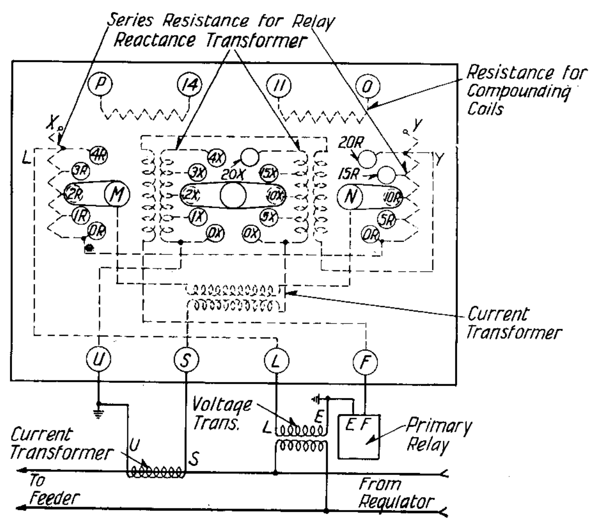

Fig. 9—Diagram of Connections for Type KC Compensator

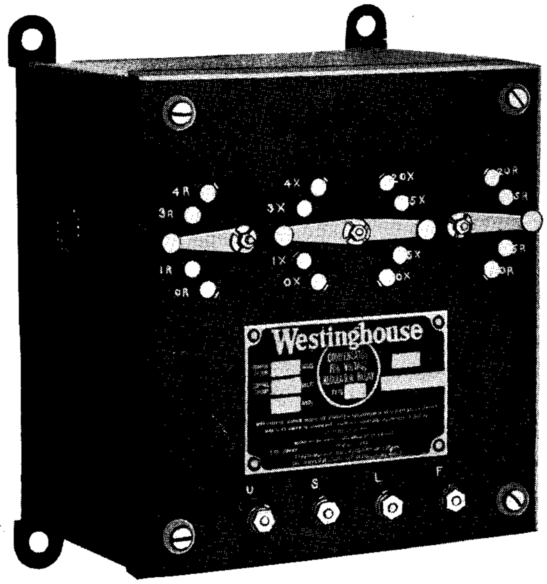

Fig. 10—Type KD Compensator

TYPE KD COMPENSATOR

The Type KD compensator in appearance is the same as the Type KC except that the 4 terminals at the top are omitted since the compensating resistors are not mounted in the same case with the compensator. This compensator is shown in Fig. 10. Diagram, Fig. 11 shows the internal connections and the method of connecting it to the line. This diagram also shows the separately mounted series and compounding coil resistance box S# 334366 which must be used with the KD compensator.

The compensator consists of a resistor and reactor with taps as shown in the diagram. A series insulating transformer, mounted within the compensator case, is used in order that both the current and voltage transformers may be grounded. This compensator has quite an appreciable loss at full load with maximum compensation as the resistor must carry 5 amperes at 24 volts resulting in a loss of 120 watts. This loss cannot be avoided because even with this loss the voltmeter, unless specially recalibrated will read about 2½% low. If designed for a lower loss the voltmeter error would be increased.

Volts	Connect		
100	F to 2	T to 7	3 and 6
105	F to 2	T to 7	4 and 6
110	F to 2	T to 7	3 and 5
115	F to 2	T to 7	4 and 5
120	F to 1	T to 8	4 and 6
125	F to 1	T to 8	3 and 5
130	F to 1	T to 8	4 and 5

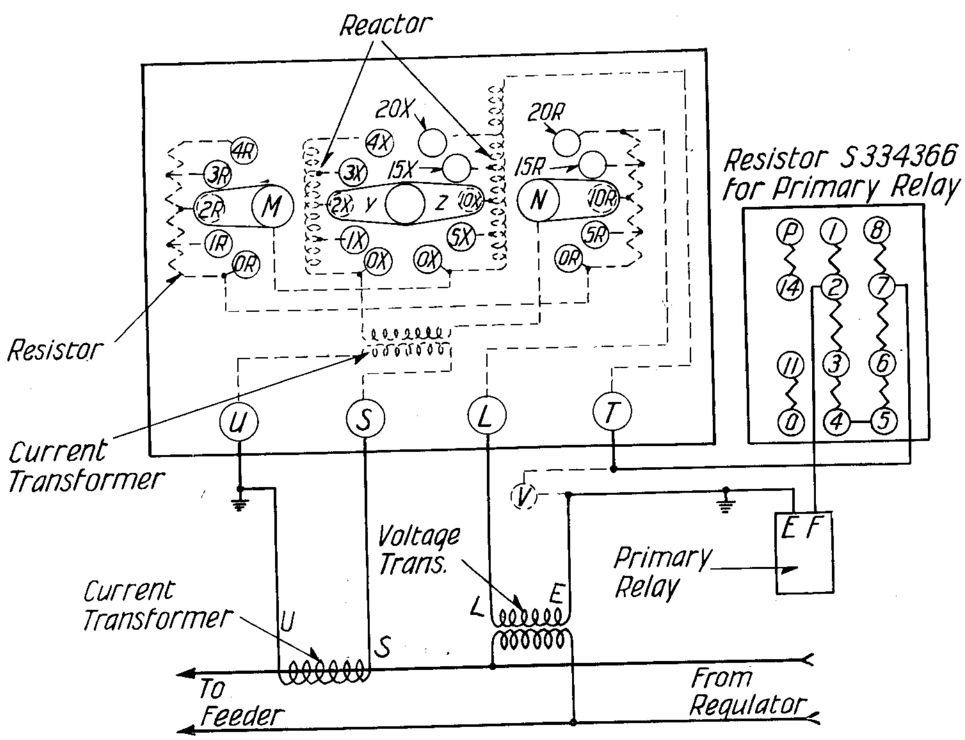

Fig. 11—Diagram of Connections for Type KD Compensator

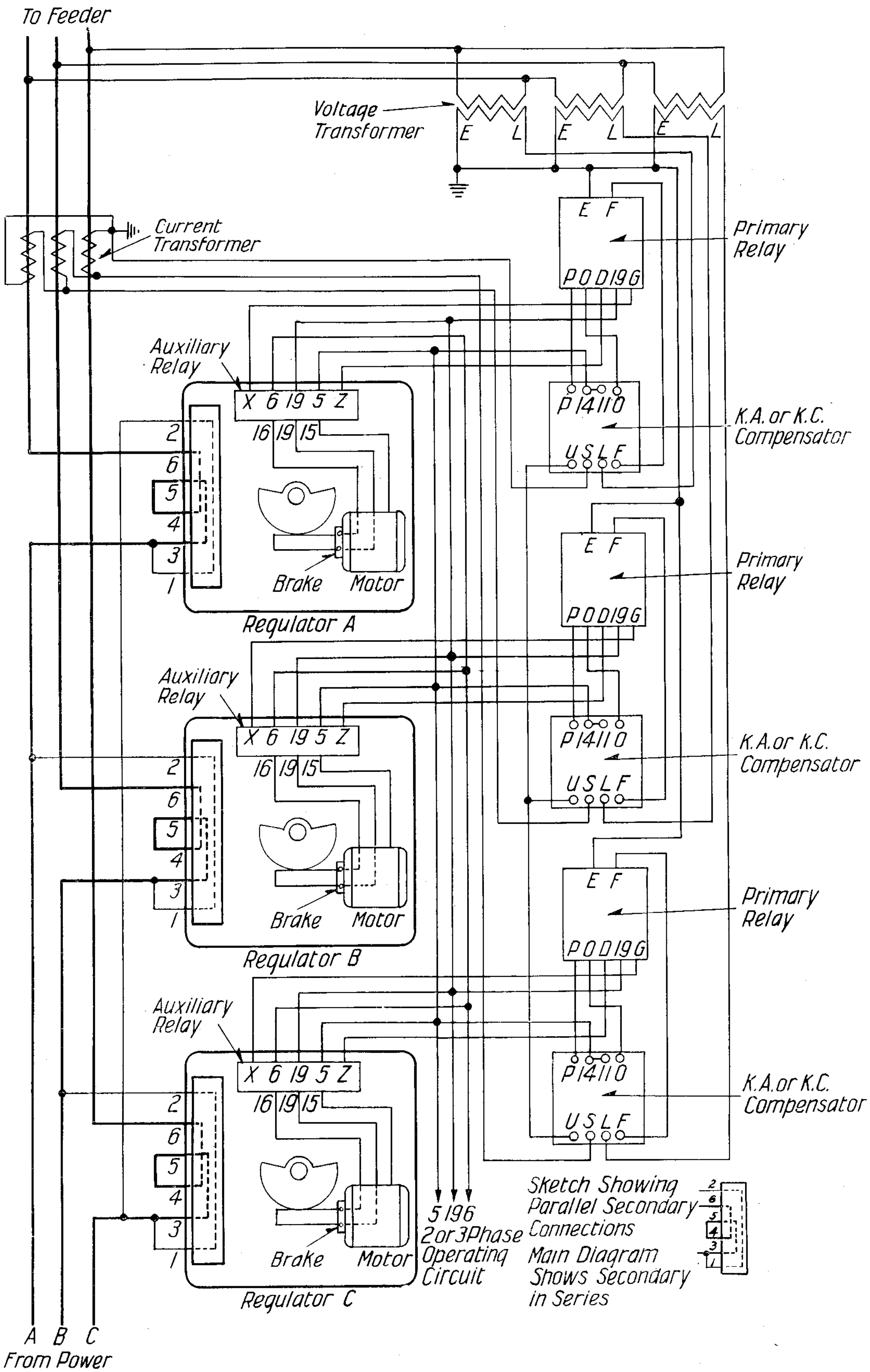

Fig. 14—Diagram of Connections for Three Single Phase Regulators on a Three Phase, Three Wire Circuit

SINGLE PHASE REGULATORS ON THREE PHASE CIRCUITS

Single Phase regulators can be used on three phase circuits in several different ways. The use of three standard single phase regulators on a three phase 4 wire circuit is probably the most common method.

Diagram Fig. 12 shows this arrangement. This diagram shows a neutral compensator and a current transformer connected to the neutral wire. These in most cases may be omitted as the drop in the neutral wire is usually negligible unless the load is considerably unbalanced. When the neutral compensator is not used the leads shown connected to F,L, and U of the neutral compensator should be connected together.

Single phase compensators with 5 ampere windings are used. The auxiliaries and connections for each regulator are practically the same as for a single phase regulator on a single phase circuit.

Two single phase regulators are frequently used to regulate a three phase 3 wire circuit. Two three phase compensators and three current transformers are required. Diagram Fig. 13 shows the connections.

Of course since the regulators are controlled by relays across only two phases, only two phases will have their voltage accurately adjusted. It is sometimes suggested that a three phase circuit be regulated with two single phase regulators and that after a time when the load increases a third regulator be added to take care of the increased load as is done frequently with transformers. This however, cannot be done as the addition of the third regulator does not increase the current carrying capacity of the equipment but increases the per cent regulation obtainable approximately 50%. For example, two 100 ampere 10% regulators will provide 10% regulation on a three phase 100 ampere circuit and when the third regulator is added the three 10% regulators will provide approximately 15% regulation on a 100 ampere three phase circuit.

Diagram Fig. 14 shows the connections for three single phase regulators on a three phase 3 wire circuit. Since a voltage relay on each phase is used, practically perfect regulation can be obtained. Three, three phase compensators and three current transformers are required.

On all three phase 3 wire circuits whether regulated by means of single phase or three phase regulators inter-connected current transformers must be used if approximately correct results are required. This results in the current through the compensator being $\sqrt{3}$ times the current in the secondary of the current transformer but the resultant current in the compensator at 100% power factor is in phase with the voltage obtained from the voltage transformer as explained on page 6.

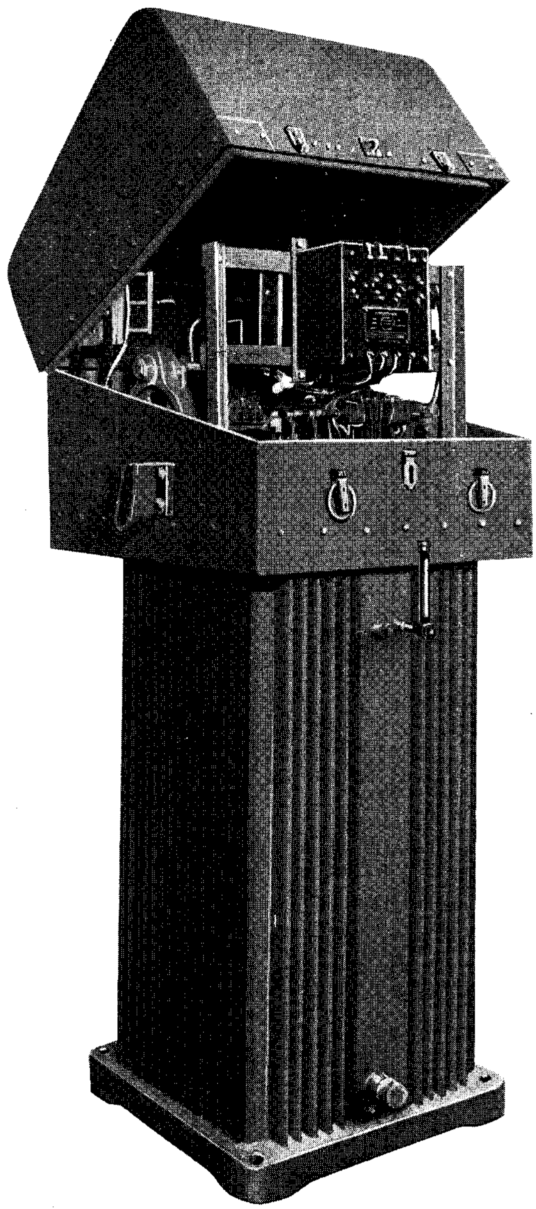

Fig. 15 Outdoor Type Single Phase Induction Regulator

OUTDOOR TYPE INDUCTION REGULATORS

Outdoor type regulators are very similar to the indoor type except that they are provided with suitable hoods or coverings to permit their being installed outdoors.

Fig. 15 shows a single phase outdoor type regulator with the hood raised to permit inspection of the auxiliaries. As these regulators are usually placed at the load centers, compensators and current transformers are not required. Outdoor type regulators usually are supplied with a special insulating oil of low freezing point. These regulators should be installed so that they may be easily inspected. All the instructions given for the insulation and operation of indoor regulators apply also to the outdoor type.

REPAIR PARTS FOR RELAYS

The following should be ordered by style number when it is desired to replace contacts:

Style No. Moving Contact	Style No. Stationary Contact		Description
163319	**163317**	For Primary Relay	Style No. 163320-A or Style No. 238610
159707*	**147746**	For Secondary Relay	Style No. 146029-A or Style No. 236633

*Complete with Spring.

A complete set of contacts for primary relay consists of two moving contacts and two stationary contacts. A complete set of contacts for auxiliary relay consists of four moving contacts and four stationary contacts.

REPAIR COILS FOR REGULATORS

When ordering coils for regulators always give the complete reading of the name plate of the regulator including the shop order number and the serial number. Since single phase regulators have coils of different sizes in the same machine it is important that the coil or coils required be definitely described. It is recommended that the following descriptive forms be used:— "Longest rotor coil", "Next to longest stator coil", "Shortest stator coil", etc. Do not use the words "primary" and "secondary" but use the words "rotor " and "stator" when describing coils or parts of a regulator. Frequently stator coils are called primary coils when as a matter of fact they are secondary coils.

For single phase stator coils it is advisable also to specify whether coils are to be used in group having leads marked 4 and 6, or in group having leads marked 3 and 5. This information will insure the coils being furnished with the coil leads so formed that they can be installed with the least trouble.

Westinghouse Electric & Manufacturing Company

East Pittsburgh, Pa.

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Westinghouse

Automatically Controlled

Type C

Single-Phase

Induction Regulators

INSTRUCTION BOOK

Westinghouse Electric & Manufacturing Company

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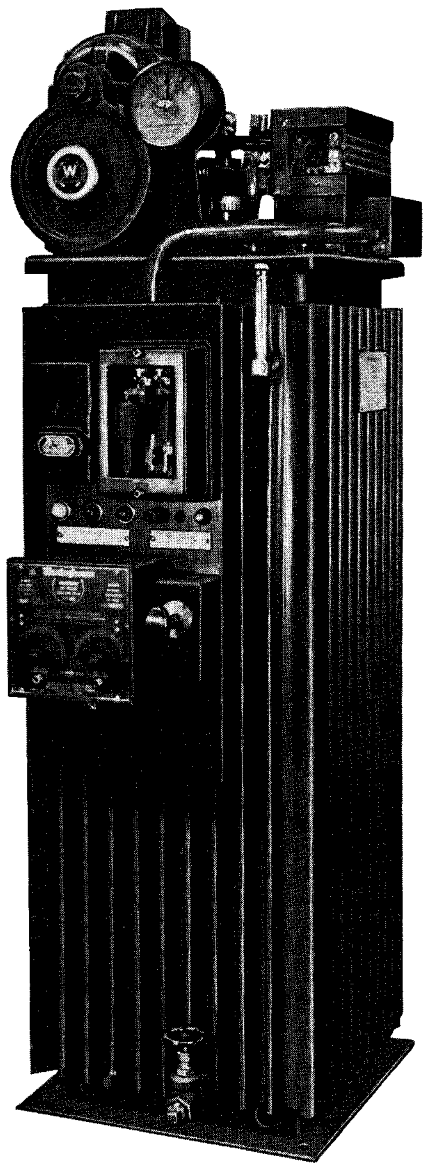
I. B. 5137-H

Printed in U.S.A.



Indoor-Type Induction Voltage Regulator
with Panel Mounted Accessories

Westinghouse

Automatically Controlled Type C Single-Phase Induction Regulators

Purpose of Regulator

1. A very large percent of the regulators now in use are for the automatic voltage control of feeder circuits taking power from bus bars having practically constant voltage. The regulator is used to automatically increase or decrease the voltage of the outgoing feeder so as to compensate for the variable line drop or variable bus voltage and thus maintain a constant voltage at the center of distribution of the particular feeder.

Standard Equipment For Single-Phase Regulator on Single-Phase Circuit

2. The complete equipment consists of the following apparatus which should be connected as per Fig. 1:

(a) The Induction Regulator.
(b) A one, two or three-phase operating motor which with its electrically operated brake is mounted on top of the regulator and is suitably geared to the main shaft of the regulator.
(c) The auxiliary relay, also mounted on the regulator cover, performs the function of a motor switch and a limit switch for preventing over-travel of the regulator mechanism.
(d) The primary relay, which is a sensitive contact making voltage relay for controlling the auxiliary relay.
(e) A voltage transformer.
(f) A Type RC or KC line drop compensator.
(g) A current transformer.
(h) A dial type position indicator operated from regulator rotor shaft.
*(i) A neutral return and manual switch.
*(j) A set of indicating lamps to indicate the neutral and the extreme positions of the regulator.
*(k) Testing terminals for use with a voltmeter to read regulated voltage.

*Furnished only with panel mounted accessories.

Additional Auxiliaries

3. The auxiliaries previously enumerated are the essential auxiliaries which are supplied with standard automatic regulators. No reference is made to the circuit-breakers, fuses, protective reactances, disconnecting switches, transfer switches, lightning arresters, meters, etc., which are ordinarily used in modern practice. Considerations of cost, continuity of service, capacity of power house, ease of operation, skill and reliability of attendants, will determine the number and quality of such auxiliaries which ought to be used.

4. On large systems where a large amount of power can be delivered to a short circuit, the use of protective reactors for each feeder circuit is recommended. It only requires from 1 to 2 percent of the normal feeder voltage to drive full load current through a regulator under short circuit conditions. Due to the saturation of the iron, the impedance of the regulator on heavy overloads is further decreased and reactors must be supplied if the short circuit current is to be limited to a safe value.

5. Fuses in the primary of the voltage transformer are for protection against dead short circuits only and should have a capacity ten times the current capacity of the transformer.

6. Due to the nature of the service it is impossible to protect the operating motor and relays against overload by means of fuses or breakers. 30 amp. fuses as a protection against dead short circuits are recommended. Time limit fuses or thermal cutouts are standard equipment but their chief use is to protect against single-phase being thrown on a polyphase motor and to protect motor in case of hunting.

6a. The use of lightning arresters is recommended for best protection against lightning and switching surges. For protection against lightning, the arresters should be connected from line to ground. For switching surges, special arresters are required, and should be connected directly across the line wires.

Brief Theory of Automatic Single-Phase Regulator

7. Referring to Fig. 1 the standard apparatus listed is plainly indicated. Fig. 2 employs the same apparatus with the accessories panel mounted. The primary relay (See Figs. 3 and 4) is connected through the compensator to the voltage transformer and is sensitive to voltage changes of the outgoing feeder. Under normal conditions the moving arm in the primary relay is horizontal. With a change in voltage the plunger in the relay coil moves up or down and closes either the left hand or right hand set of contacts thereby causing the electrically operated secondary relay to close its contacts and start the operating motor in such direction as to lower or raise the voltage on the feeder as may be required to correct the change and bring the voltage back to normal. The purpose of the compensator is to so affect the primary relay that it will raise the voltage with increasing load as may be required to take care of the increasing line drop and thus hold a constant voltage at the center of distribution of the feeder. See paragraphs 66 to 88.

8. When it is desired only to hold a constant voltage at the point where the regulator is installed, compensator and current transformer are not required. See Fig. 17.

9. The two small coils on the right hand side of the primary relay (one above and one below the moving contact arm) are known as compounding coils and are used, 1st—to obtain more positive action just at the instant the contacts are making or breaking the circuit to the secondary relay; 2nd—to obtain a voltage the average value of which is more nearly equal to the voltage midway between the limiting values at which the relay will operate.

10. Assume that the primary relay is set to keep the voltage at 110 volts plus or minus 1½ volts and that the compounding coils are adjusted for ½ volt compounding. The operation will then be as follows.

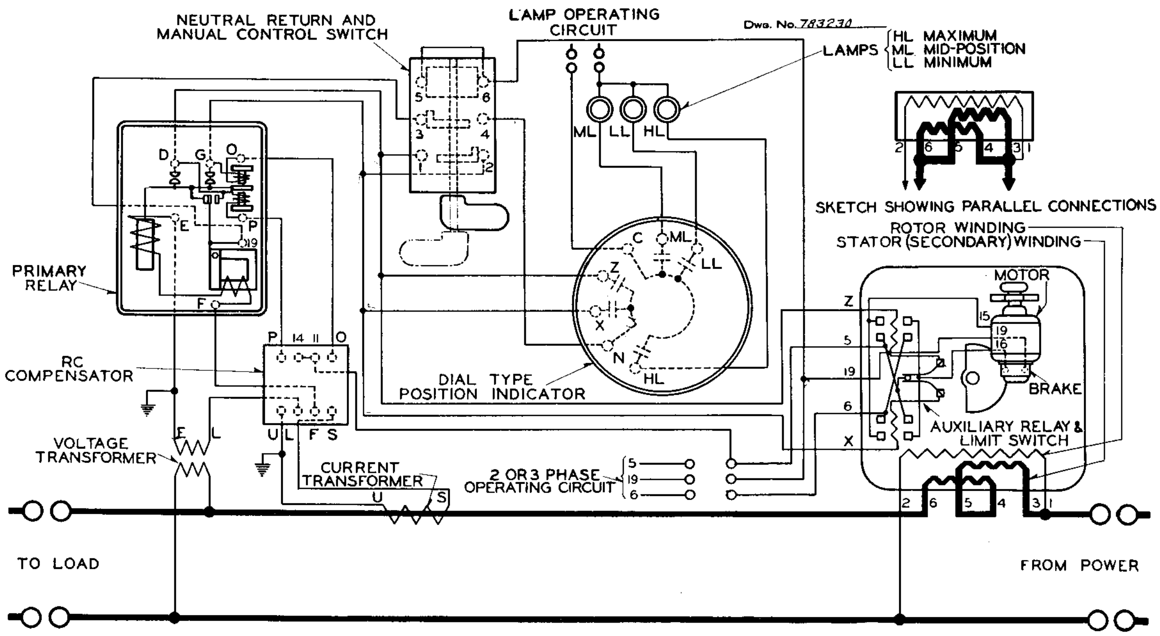


Fig. 1—Diagram of Connections for an Automatic Single-Phase Induction Regulator

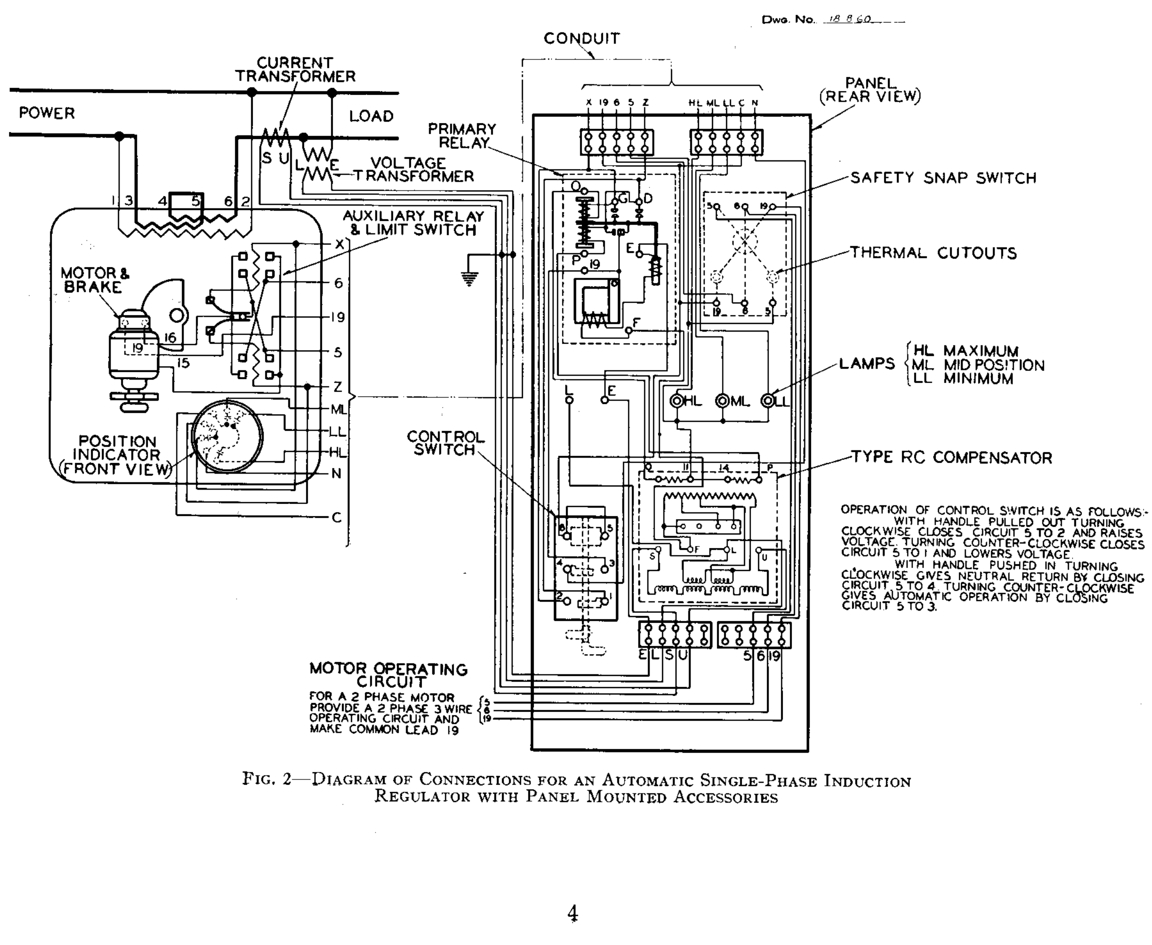


Fig. 2—Diagram of Connections for an Automatic Single-Phase Induction Regulator with Panel Mounted Accessories

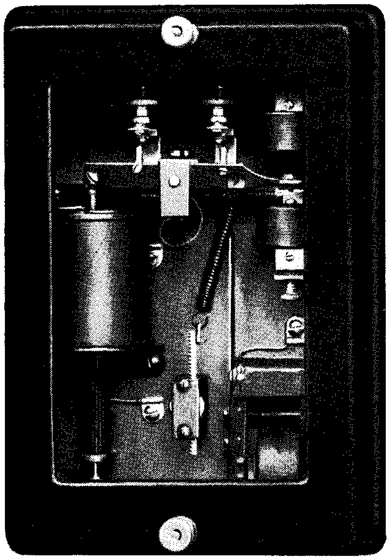


FIG. 3—PRIMARY RELAY

11. With 110 volts across the primary relay and its resistance, (E to L, Fig. 1) the lever supporting contacts will be in the horizontal, or mid position. If the voltage on the feeder rises, the main coil of the primary relay will pull up the plunger, and as soon as the voltage rises to 111.5 volts, the left hand moving contact will touch the stationary contact. At this instant the lower compounding coil will be energized and will pull the moving contact more firmly against the stationary contact. The solenoid Z of the auxiliary relay also will be energized, closing the corresponding relay switch and will start the motor and turn the regulator to such a position as to bring the voltage back to normal. Due to the compounding, the primary relay contact will not open the circuit to auxiliary relay as soon as the voltage is brought just slightly below 111.5 volts but will keep the motor circuit closed until the voltage is lowered to 111 volts. The contact will then open, the motor will stop, and the lever in the primary relay will swing approximately to the mid position, with practically no burning at the contacts. If the voltage on the feeder decreases to 108.5 volts, the primary relay contacts at the right will make contact and the regulator will be operated in the opposite direction to increase the voltage and bring it back to normal.

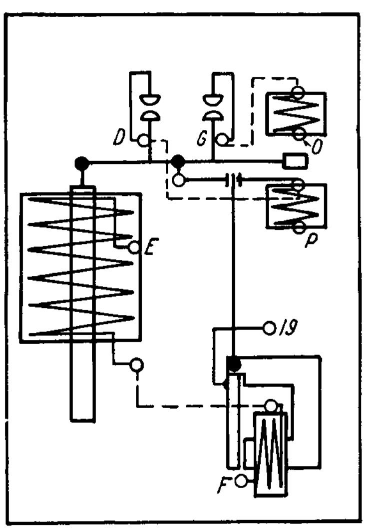


FIG. 5—DIAGRAM OF PRIMARY RELAY (FRONT VIEW)

Shipping And Storage

12. Regulators usually are shipped completely assembled in the case without oil or with only a small quantity of oil. The additional amount of oil is shipped separately in sealed drums. The regulator should not be operated at rated voltage unless filled with oil.

13. In case the regulator is not to be immediately installed, it should be stored in a clean dry place. All machined parts should be well oiled especially the top bearing of the rotor shaft. A periodic inspection should be made to see that rusting has not started. It is well to cover the top of the regulator with some moisture-proof material, such as oilcloth.

Installation

14. Rating—Check the rating as indicated on the nameplate to see that the regulator is suitable for the circuit for which it is intended.

15. The name plate gives the kv-a. capacity, primary voltage, phase, frequency, secondary ampere capacity, percent regulation, serial number and shop order number of the regulator.

16. When two voltage or current ratings are given on the nameplate it indicates that windings for series or parallel connections are available and special care must be taken to insure the correct connections being used. Unless care is taken it is very easy to get a 100% overload on the regulator. Refer to the diagram of connections furnished with the regulator for proper series or parallel connections.

17. The volt-ampere rating of a single-phase regulator is equal to the product of the current and the voltage of the circuit times the percent regulation. For example, a 2300-volt 100 ampere, 230 kilovolt-ampere, single-phase circuit that is to be regulated 10 percent up and down, would require a regulator rated at $100 \times 2300 \times \frac{10}{100} = 23000$ volt-amperes or 23 kilovolt-amperes.

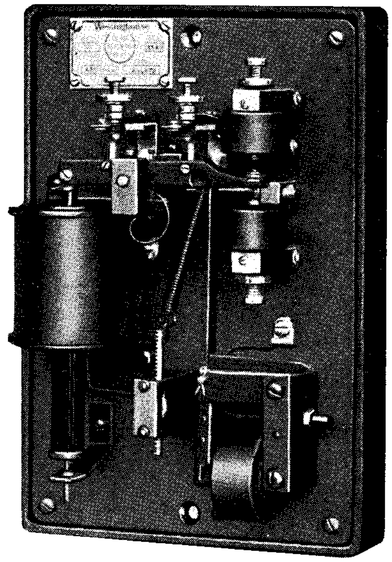


FIG. 4—PRIMARY RELAY (COVER REMOVED)

18. Regulators are usually wound so as to have at no load a secondary voltage from 5 to 20 percent higher than is indicated by the foregoing calculations. This is done in order that the full percent regulation may be obtained when operating at full load.

19. Operating Circuit Characteristics—See that the operating circuit for the motor has the proper characteristics as indicated on the motor and auxiliary relay nameplates. A three-phase operating motor is usually furnished. If a two-phase motor is used it must be

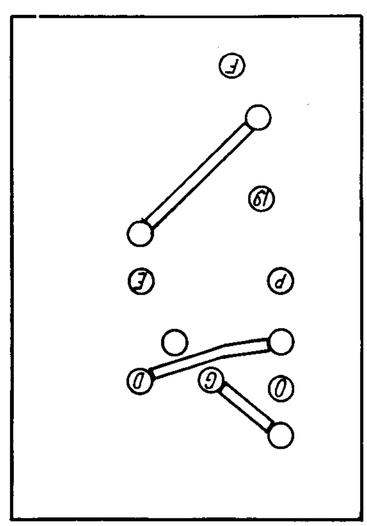


FIG. 6—DIAGRAM OF PRIMARY RELAY (REAR VIEW)

operated from a two-phase, three wire circuit. Mark the common wire 19 and connect as shown for three-phase motor. A two-phase motor for regulator service is provided usually with three leads only, marked, as shown for three-phase motor, 15, 19 and 16; 19 being the common lead. If current at the proper voltage is not available it must be supplied by means of transformers. It is recommended that two standard 1½ kv-a. transformers connected in open delta be used for the motor on any regulator rated at 69 kv-a. or less. When operating in groups, one kv-a. of transformer capacity per regulator is sufficient.

20. Location of Apparatus—The regulator and the auxiliary apparatus should be installed so as to be readily accessible and in a place free from dust, moisture and dirt. The relays must be mounted in a vertical position, and the primary relay in particular must be entirely free from vibration. The moving element in the primary relay is wedged in the coil to prevent movement during shipment. When installing, all wedges should be removed to permit free movement of plunger. If regulators can be located in a room fitted with an overhead crane it is a distinct advantage for convenience in handling. If a crane is not available, the regulator may be skidded or moved on rollers into position, but as a regulator is usually quite tall, care must be taken that it is not tipped over.

21. Water-cooled regulators depend almost entirely upon the flow of water through the coils for carrying away heat so that the temperature of the surrounding air has little effect upon that of the regulator. For this reason air circulation is of minor importance and water cooled apparatus should be located with regard to convenience in arranging the water piping rather than with regard to ventilation.

22. Self-cooled regulators are entirely dependent upon the surrounding air for carrying away the heat and it is essential that proper facilities for ventilation should be provided. The regulator must be placed in a room, so ventilated, that the heated air can readily escape and be replaced by cool air from outside. If the room is poorly ventilated there is small chance for this exchange of air and the temperature of the air in the room may become excessively high. At any given load, the temperature rise of the regulator will be a fixed number of degrees above the surrounding air and there is danger of operating the regulator at unsafe temperature. For

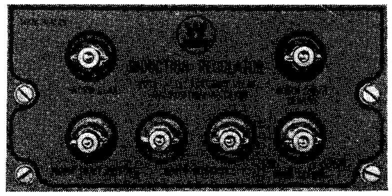


Fig. 7—Centeralized Lubricating System

this reason it is vitally important to provide a room sufficiently well ventilated to permit operation of regulators at reasonable temperatures.

23. Self-cooling regulators should always be well separated from one another and from adjacent walls. The separation should not be less than 24 to 36 inches, depending on size. Where regulators must be placed closer than this, it is advisable to provide some degree of forced ventilation.

24. The cases of all self-cooled regulators should be grounded. This is not necessary with water-cooled regulators as the case is already well grounded through the water pipes.

25. Before installing, carefully inspect regulator and auxiliaries to see that no parts have been sprung or damaged during shipment.

Lubrication

26. A central lubricating station Fig. 7 is located on the motor side of the regulator. If a ball bearing motor is used, the bearings have been packed at the factory and should not be greased for a year or more of service. If sleeve bearing motor is used, the oil well should be filled to the overflow plug. The top bearing worm gear and worm shaft bearing should be greased with a good quality soft grease each month while regulator is in motion. The indicator shaft bearing, brake shoe bearing and auxiliary relay

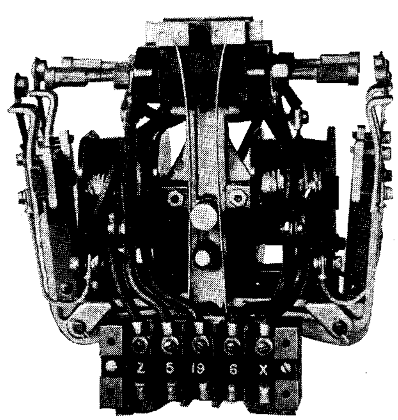


Fig. 8—Cover Mounted Type Auxiliary Relay for Mounting on Top of Regulator Cover

bearings should be oiled with a good quality machine oil.

27. Care should be taken to use a low freezing point oil and grease for outdoor type regulators and regulators used in unheated substation.

28. Insulating Oil—If the regulator is of the oil-insulated type, fill the case with oil of the proper quality until the oil appears approximately one inch in the oil gauge. The oil level should never be allowed to fall to such a degree that oil is not shown in the gauge. As the oil heats up with the machine under load it will expand and rise higher in the gauge.

29. If the regulator is of the water-cooled type see that the inlets and outlets of the water cooling coils are properly connected, that all valves work satisfactorily, that water flows freely, and if there are two or more parallel coils, at approximately the same rate through all coils. It is important that the water enter the cooling coils at the bottom and pass out at the top. For further information and complete instructions regarding insulating oil, oil treatment, oil testing and the general instructions covering oil insulated, self and water cooled apparatus, reference should be made to Instruction Book 5094 covering oil insulated transformers.

Connections

30. Connect the regulator and auxiliaries according to the diagram furnished with the regulator. Standard regulators using auxiliaries as listed on Page 3 should be connected according to diagrams, Fig. 1 or 2. If the leads are not brought through the bushing block in the same order as shown in the diagram, check to see if the same number of leads, similarly marked are available and connect them to agree with diagram disregarding the location in the bushing. Regulator diagrams as a rule do not show the various additional auxiliaries referred to on Page 3, but the use of these accessories is strongly recommended.

31. The regulator tanks or frames should always be well grounded so as to eliminate the possibility of obtaining static shocks, or of being injured due to the accidental grounding of any of the windings to the frame of the regulator. Water-cooled regulators are sufficiently well grounded through the water cooling pipes.

32. If the diagram does not fully cover all the apparatus and there is any question regarding the performance or connections of the apparatus apply to the nearest Sales Office for information. Requests should give complete nameplate readings of each device because different diagrams will be required, depending upon the auxiliary apparatus which is to be used with the regulator. Be sure to give the number of our shop order (S.O.) as this is an excellent means of identification and assists in quickly locating our records covering the apparatus.

33. Checking Connections—After the regulator is completely connected and before throwing on power check the wiring carefully. The following tests, made in the order indicated, are recommended. These instructions refer specifically to standard regulators with cover mounted secondary relays as shown in diagrams, Fig. 1 and 2 but with slight modifications apply to all regulators.

34. Checking Limit Switch—Operate manual control switch, turning handle clockwise with handle pulled out, should cause regulator to go in the "raise" voltage direction. Observe regulator closely as it approaches limit of travel and preferably "inch" it along so it will be under control in case limit switch is incorrectly connected and does not cut out motor at end of travel. In case limit switch does not stop motor, reverse control leads Nos. 5 and 6 to operating circuit so as to reverse rotation of motor. If this reversal of 5 and 6 is made at the secondary relay terminals make sure that the connection from 11 and 14 connects to the lead from terminal 5 of the secondary relay and not to the lead from terminal 6. If this connection is made to terminal 6, the secondary relay may stick and not operate properly. Care should be observed never to reverse phase rotation of operating circuit after regulator is once properly installed as this will operate the motor in the wrong direction and the limit switch will not stop motor properly. An interlocked limit switch is provided which stops motor in case of incorrect phase rotation supplied to motor. This interlocking limit switch only functions after the normal limit switch is open and therefore in case of incorrect phase rotation the regulator must be returned by hand when regulator has been run beyond the normal limit. The mechanical stop is not intended to act as a stop if limit switch is incorrectly connected but is primarily intended to act as a stop when regulator is turned by hand.

35. Checking Primary Relay—Connect a voltmeter temporarily across the secondary of the voltage transformer EL. Close the power switch (with the load switch open) and operate the regulator by connecting lead No. 19 alternately to Z and X or by operating manual control switch and note if the desired voltage range is obtainable.

36. Adjusting Primary Relay—With a portable voltmeter connected across EL regulated voltage, turn the regulator until the voltmeter across EL indicates the voltage which it is desired to maintain at the end of the feeder. Adjust the tension of the spring in the primary relay until the movable arm is horizontal, i. e., until the compounding armature at end of the arm is midway between the two compounding coils at right of lever. If the voltage across EL is considerably higher than 110, so that by spring adjustment alone the contact arm cannot be brought to the mid position, additional resistance must be inserted in the relay circuit. For method of doing this see paragraphs 69 and 77, describing compensators.

37. Except for checking current transformer and compensator connections and adjusting the compensator, the regulator is now ready for service. Before closing the load switch, unbalance the primary by hand to change the voltage. Then release the lever and observe the action of the relay, in correcting the voltage. Read carefully Paragraphs 44 to 55 on "Adjustments" and "Hunting" so that any necessary changes may be made intelligently.

38. Polarity of Current and Potential Transformers—All induction regulator diagrams are made so that the current and potential transformer connections are such that terminals of the same instantaneous polarity are as indicated in Fig. 9. It is immaterial whether the polarity markers are on the load or power side, so long as the secondaries are properly connected. For example, referring to Fig. 1, if the polarity marked (white button) primary lead of the current transformer is connected to "6" regulator lead, then the polarity marked secondary lead must connect to "S" of the compensator. If, however, the polarity marked primary lead of the current transformer is connected to the load, then the polarity marked secondary lead must be connected to "U". It is essential that all transformers of a three-phase bank of regulators be similarly connected.

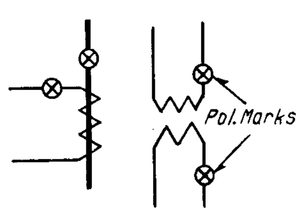


Fig. 9

39. Reversed polarity of either the potential or current transformer results in erratic operation. For single-phase installations, it results in the regulator lowering the voltage with increase of load. For three-phase installations a reversal of one current transformer causes the current in the compensator circuit to be of incorrect phase relation as well as of the wrong magnitude. This may result in seemingly incorrect compensation, as for example, increasing the resistance compensation may cause the regulator to decrease the voltage instead of increasing, while increasing the reactance compensation causes regulator to increase. A careful check of the current transformer connections will reveal the trouble.

40. Compensator Setting—Set the compensator for the compensation required for the particular circuit. If the resistance and reactance of the line are known or can be calculated it is preferable to calculate the percentage drop at full load and to set the compensator dials accordingly. See paragraph describing the particular type of compensator which is being used. The voltage compensation given on the nameplate will be obtained only when current as stamped on the nameplate is flowing in the compensator. With smaller currents the voltage compensation will be proportionately reduced. If the resistance and reactance of the line are not known, this setting of the compensator must be made by trial. This can best be done by the use of a recording meter at the station (if the station bus is not constant) and one at the center of distribution. After comparing simultaneous readings at different loads make trial adjustments until the proper combination is obtained.

41. If telephonic communication between the center of distribution and the station can be had, adjustments can be made as follows: Two carefully calibrated voltmeters should be used and the result of changes in the compensator setting can be noted immediately. On a circuit of widely varying power factor it is advisable to adjust the resistance dial only at high power factor and to adjust the reactance dials only at very low power factor. If the regulator causes the voltage on the feeder to decrease instead of increase as the load increases, the secondary leads from the current transformer or from the voltage transformer must be reversed. See paragraphs 38 and 39.

42. There is another scheme which gives good results and for which the following setup must be made: Adjust the primary relay to balance at the regulated voltage, say 115 volts, which it is desired to maintain at the load center. Set the primary relay contacts as close as possible without causing hunting. Establish telephone connections between the regulator installation and the load center, and connect a portable voltmeter at the load center to read the regulated voltage at this point. Better results will be had if the feeder is carrying at least 50 percent of full load during the test, as the varying of the resistance and reactance units will then produce a greater effect on the primary relay. The power-factor of the load should be either the maximum or minimum possible. A set of readings can now be taken, starting with the lowest point on the resistance unit of the compensator and finding a point on the reactance unit which will give the desired voltage at the load center. This can be continued, progressing one step at a time on the resistance unit, and for each step finding a point on the reactance unit which gives the desired voltage at the load center. The results should be tabulated. Repeating this test with the opposite condition of power-factor gives two sets of data from which two curves can be plotted.

43. The curves are plotted from test data obtained as described above. See Fig. 10. The compensator units are then given permanent settings, at the values of resistance and reactance corresponding to the point where the curves intersect. It is evident that this is the proper setting, since the two curves are taken at the two extreme power-factor conditions. This can be checked by a graphic voltmeter chart run through a complete cycle of load and power-factor change. It should indicate a constant voltage at the load center through the entire period.

Adjustments

44. Primary Relay Adjustments—When first installed the spring in the primary relay may have to be adjusted to change the normal setting of the relay as may be required for the particular circuit. Except for this adjustment it is recommended that no other adjustment be made until the operation is carefully observed for a time so that any change in adjustment may be made intelligently.

45. A "hit or miss" adjustment is almost certain to cause the regulator to hunt, but if these instructions are carefully read so that the principle of operation is understood, no trouble should be experienced.

46. As shipped from the factory, relays are adjusted for a normal voltage of 110. This adjustment is made by connecting 110 volts across the main coil and a series resistor of approximately 220 ohms and adjusting the spring tension until the armature is midway between the compounding coils. The normal setting may be varied between 95 and 120 volts by changing the tension of this adjusting spring. For higher voltage the series resistance must be increased. This series resistor is mounted within the compensator and forms a part of the compensator. When no compensator is used a separately mounted series resistor must be furnished. (See Fig. 17).

47. After adjusting the tension of the spring to change the normal voltage of the relay, see that the loop of the spring which is attached to the moving arm is at right angles to the moving arm, and also see that the adjusting nuts are properly tightened.

48. As shipped from the factory, stationary contacts are adjusted to make contact when the voltage increases or decreases 1½ volts from normal. This sensitiveness may be increased or decreased by moving the stationary contacts down or up by means of the adjusting screws. It should never be made less than ¾ volts plus or minus and a wider range is strongly recommended. The maximum sensitiveness which can be used successfully depends upon the characteristics of the circuit as regards voltage changes, also upon the speed of the regulator (time required for the regulator to move through its complete range) and upon the condition of the brake shoes.

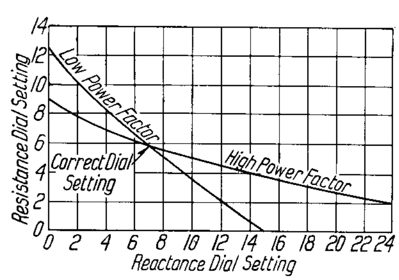


Fig. 10

49. The compounding coils are arranged to hold the moving contact arm in either extreme position until the regulator has adjusted the voltage to nearly normal. When the voltage has been changed sufficiently to release the moving contact, the arm should move at once to approximately the mid position. If it over-travels, compounding may be too great, and can be decreased by turning out adjusting screws in the center of the compounding coils. Read carefully paragraph 54 on "hunting" before making any change in the adjustment of compounding coils. As shipped from the factory, these are adjusted to hold the contacts closed until the voltage has changed 0.4 percent.

50. Auxiliary Relay Adjustments—This relay requires practically no adjustment except the contacts. These are adjusted at the factory so that the contact spring on the moving contact is deflected between $\frac{1}{32}$ and $\frac{1}{16}$ inch when the armature hits the magnet pole. (See Fig. 8). As the contacts burn down this spring deflection will decrease, and from time to time the stationary contacts should be screwed out on the threaded support so that the spring deflection will not become less than $\frac{1}{32}$ inch.

51. The contacts should be replaced before they become worn to such an extent that they cannot be rigidly held in place. Care should be taken that the deflection of the moving contact is not so great that the spring strikes the guide on the moving armature when the contacts are closed; that is, when the contacts are closed the contact spring should not touch the sides of the hole in the guide through which the spring projects. Bearings should be oiled occasionally with a light oil.

52. Motor and Brake Adjustments—These require practically no adjustment until considerable wear takes place on the brake shoes. The air gap in the brake magnet (inside the brake coil) should not be more than $\frac{1}{16}$ inch when there is no current on the motor and brake; that is, when the brake is set. This can be noted by observing the distance which the magnet core moves into the magnet coil when the brake is released and the air gap closed. When the travel of the magnet becomes excessive, the brake shoe should be relined with new leather, or spacers should be placed behind the old linings. If the leather linings become hard and smooth so that there is little friction between the brake shoes and brake wheel, a small amount of belt dressing should be applied to soften the leather.

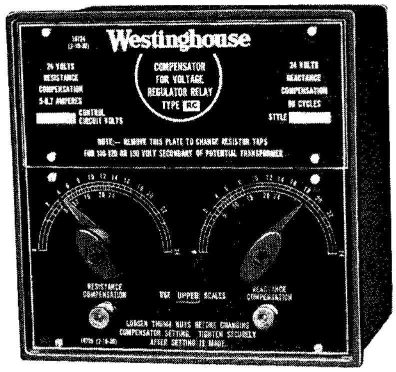


FIG. 11—TYPE RC COMPENSATOR

53. Both brake shoes should lift off the brake wheel an equal amount, and if this is not the case the pin bearings in the brake magnets should be examined, and if they have become gummed up they should be thoroughly cleaned and oiled. If the brake magnet becomes noisy it probably indicates that dirt has settled in the air gap of the magnet inside the coil. The brake shoes and coil should in this case be dismantled so that the pole faces of the magnet inside the coil can be cleaned.

Hunting

54. If the regulator starts to "hunt" or to operate continuously first in one direction and then in the other, on a feeder with fairly constant load, steps should be taken at once to correct this. The causes of "hunting" are.

(a) Too Close Setting of the Primary Relay Contacts—The relay should normally not be set for less than ¾ percent plus or minus: 1½ percent plus or minus gives the best all around results when everything is taken into consideration.

(b) Rough or Dirty Primary Relay Contacts—This may cause the contacts to stick together very slightly so that they will not open the circuit to the auxiliary relay and stop the operating motor immediately after the voltage has been returned to normal, but will permit the regulator to overtravel to a greater or lesser degree.

(c) Friction in Bearings of Primary Relay—This may also prevent the relay from stopping the regulator immediately after a voltage change has been corrected.

(d) Too Much Compounding of Primary Relay—This will cause the regulator to over-travel and is remedied by turning out the adjusting screws in the center of the compounding coil. As a rule the more sensitive the relay the weaker must be the compounding, and the weaker the compounding the more noticeable will be the burning of the contacts.

(e) Faulty Operation of the Brakes—The object of the brake is to stop the motor and regulator as soon as possible after the current is thrown off the motor.

55. In case the brake shoe lining becomes hard and smooth so there is little friction between the brake shoes and brake wheel thus permitting the motor to drift, belt dressing should be applied as directed under "Adjustment of Motor and Brake".

Disconnecting Regulators

56. Never under any circumstances open the primary or magnetizing circuit of a regulator when the current is flowing in series winding, unless regulator is in the neutral position. If this is done a high voltage may be induced in the windings and the insulation damaged.

57. The line switch or circuit-breaker that connects the regulator to the source of power should always be opened before making any changes in the regulator connection.

58. A single-phase regulator may be disconnected without interrupting the service by proceeding as follows.

(a) Turn the regulator to the mid, or zero position. This can be done by turning manual control switch to the neutral return position. Open control circuit switch so that regulator cannot be operated.

(b) Place a jumper across the series leads, thus short circuiting the series windings.

(c) Open the primary and then entirely disconnect the regulator. A single-phase regulator can thus be disconnected without disturbing the line, but it is strongly recommended that if possible, the power be taken off the regulator before making any changes in the connections.

59. If the single-phase regulator is not turned to the mid position when disconnecting without interrupting the service, a high voltage may be induced in the windings.

Fuses

60. Never put fuses or circuit-breakers in the primary of any regulator unless they have a capacity of approximately five times the normal current of the regulator. The primary of the voltage transformer and the secondary, which delivers power to the primary relay, should also be fused for eight or ten times normal current in the circuits, so that the circuits will not be opened except under extremely abnormal conditions.

Compensator

61. The object of the compensator is to so affect the indications of the primary relay that the regulator will automatically increase the voltage as the load increases and take care of the increasing drop in the feeder thus maintaining a constant voltage at the center of distribution.

62. As regards compensator requirements, distribution circuits may be divided into three classes.

(a) Outgoing feeder circuits fed from a bus-bar of practically constant voltage.

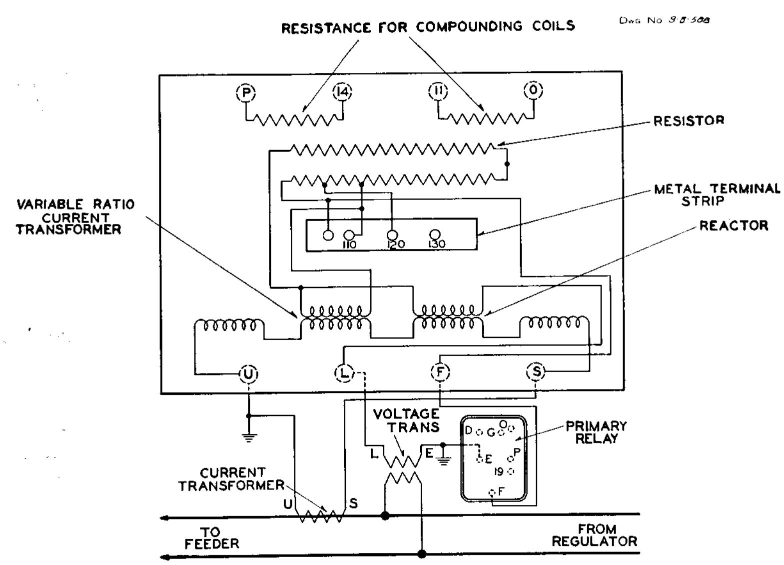


FIG. 12—DIAGRAM OF CONNECTIONS FOR TYPE RC COMPENSATOR

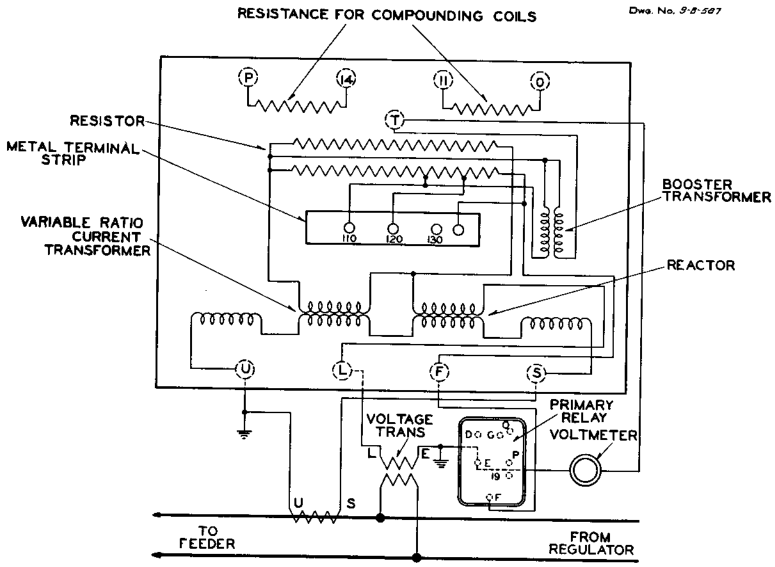


FIG. 13—DIAGRAM OF CONNECTIONS FOR TYPE RD COMPENSATOR

(b) Incoming feeder circuits fed from a distant power plant and coming into a substation for local distribution.

(c) Incoming feeder circuits (being a combination of (a) and (b) which are fed from a distant power plant and come into a substation but are for distant distribution.

63. For circuits of class (a), a compensator is required having a range in percent equal to twice that of the rated percent regulation of the regulator. At no load there is no drop in the feeder and the regulator bucks the bus voltage down to the same value as the voltage desired at the center of distribution. As the load increases the drop increases and at full load the regulator boosts the voltage as may be required to take care of the drop. The total change in the voltage of the outgoing feeder, expressed in percent, which must be taken care of by the compensator, may equal twice the rated percent regulation of the regulator.

64. For circuits of class (b), although the incoming voltage may vary up or down through the complete range of the regulator, the relay is connected directly (through a voltage transformer) to the center of distribution which is practically at the regulator so that no compensator is required.

65. The circuits of class (c) require compensators having a range in percent equal to the maximum drop in the circuit from the regulator to the center of distribution. This percent drop may be considerably less than the complete range of the regulator, since the regulator must also take care of a variable incoming voltage. Westinghouse compensators are made in several types: Types RC, RD, KC and KD. They

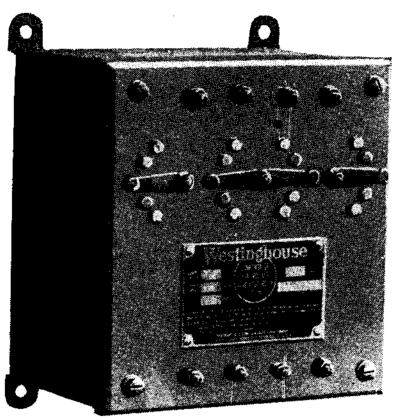


FIG. 14—TYPE KC COMPENSATOR

are wound for a normal full load current at 5 or 8.7 amperes. The 8.7 ampere compensators are used on three-phase circuits where interconnected current transformers must be used.

Type RC Compensator

66. The Type RC compensator is shown in Fig. 11. Diagram Fig. 12 shows the internal connections and method of connecting to the feeder. The compensator consists essentially of an adjustable reactance and an adjustable resistance voltage.

67. The reactor consists of a miniature induction regulator with the primary and secondary connected in series so that in a position where the rotor winding opposes the stator winding, the reactance is practically zero. When the windings aid each other, that is when the rotor is rotated 180 degrees from the position where they oppose each other the reactance is the maximum. An additional winding is placed on the rotor so as to insulate the potential from the current circuit.

68. The resistor of the compensator is also the series resistor for the primary relay. This double use of the resistor results in a considerable saving in the amount of total energy consumed. A variable ratio current transformer is obtained by use of the induction regulator principle. Here, also the potential and current circuit are separate.

69. The compensators, as shipped, are for use with a voltage transformer having a secondary voltage of from 105 to 115 volts. Additional series resistance for operating with voltage transformer voltage of 120 or 130 volts may

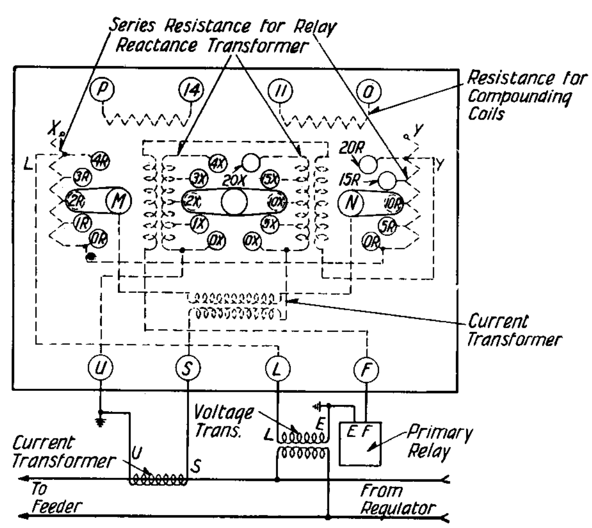


FIG. 15—DIAGRAM OF CONNECTIONS FOR TYPE KC COMPENSATOR

be inserted by simply removing the upper compensator nameplate and changing the screw plug to the proper hole in the metal terminal block.

70. The volt-ampere burden on the current transformer varies with the compensator setting. At maximum setting and full load current the burden amounts to approximately 44 volt-amperes.

71. The Type RC compensator is wound for both 5 and 8.7 amperes. Two scales are provided, the upper scale being for a normal full load current of 5 amperes such as obtained when operating compensator on a single-phase circuit, a three-phase four-wire circuit or when two regulators are operated on a three-phase, three-wire circuit in conjunction with a phase angle transformer. The lower or 8.7 ampere scale is used on three-phase, three wire circuits when three current transformers are used. See paragraphs 92, 96 and 97. To facilitate the operator in knowing which scale is being used, a small sliding nameplate is provided which states that either "upper" or "lower" scales are to be used. To change this indication, simply loosen the four screws holding lower portion of nameplate and slide nameplate either to left or right depending on whether "lower" or "upper" is wanted.

72. For convenience the compounding resistance P to 14 and O to 11, for use with the compounding coils in the primary relay, are also mounted within the compensator case although they are not essentially parts of the compensator.

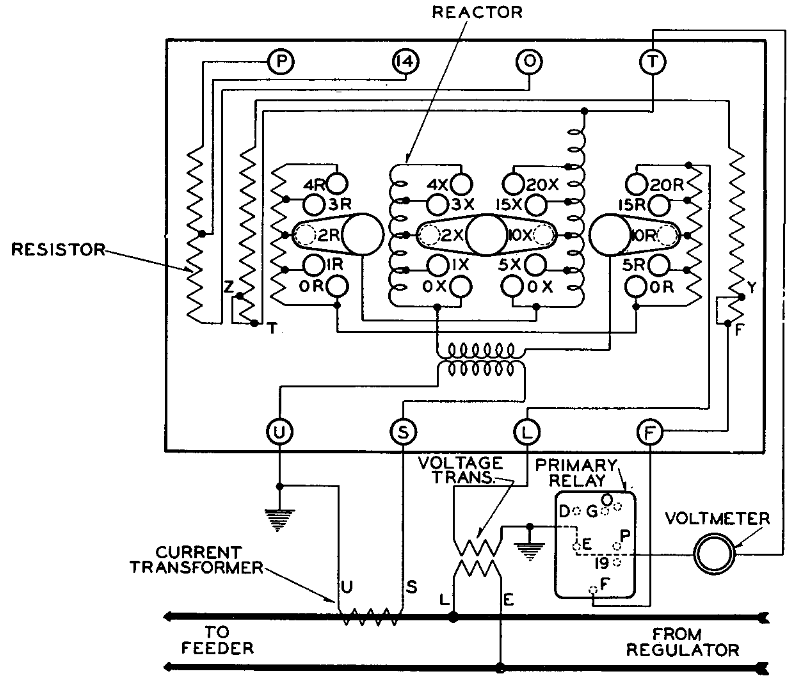
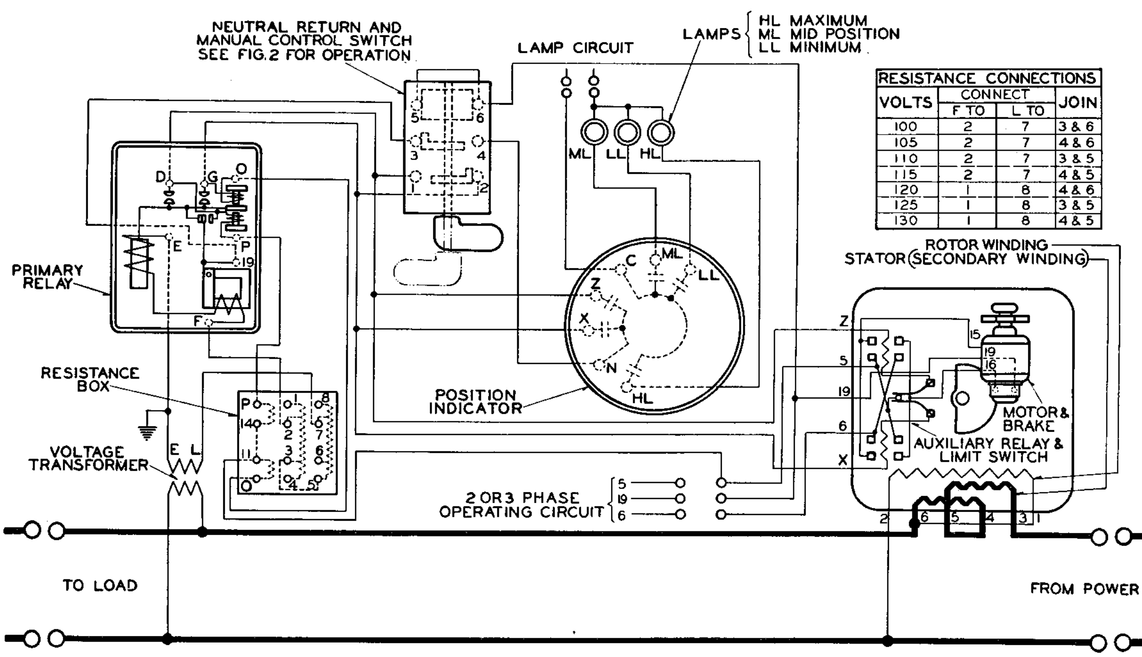


FIG. 16—DIAGRAM OF CONNECTIONS FOR TYPE KD COMPENSATOR

Type RD Compensator

73. This compensator shown in diagram Fig. 13 is similar to Type RC except that the primary relay resistor and compensator resistor are separate although both are mounted in the same case. In addition the compensators are wound for either 5 or 8.7 amperes (but not for both) so that different compensators are required when the regulators are to be used on three-phase three-wire systems when three current transformers are used.

74. The separation of the relay and compensator resistors makes possible the reading of the compensated as well



RESISTANCE CONNECTIONS			
VOLTS	CONNECT F TO	CONNECT L TO	JOIN
100	2	7	3 & 6
105	2	7	4 & 6
110	2	7	3 & 5
115	2	7	4 & 5
120	1	8	4 & 6
125	1	8	3 & 5
130	1	8	4 & 5

FIG. 17—DIAGRAM OF CONNECTIONS FOR AN AUTOMATIC REGULATOR INSTALLED AT THE LOAD (COMPENSATOR AND CURRENT TRANSFORMER NOT REQUIRED)

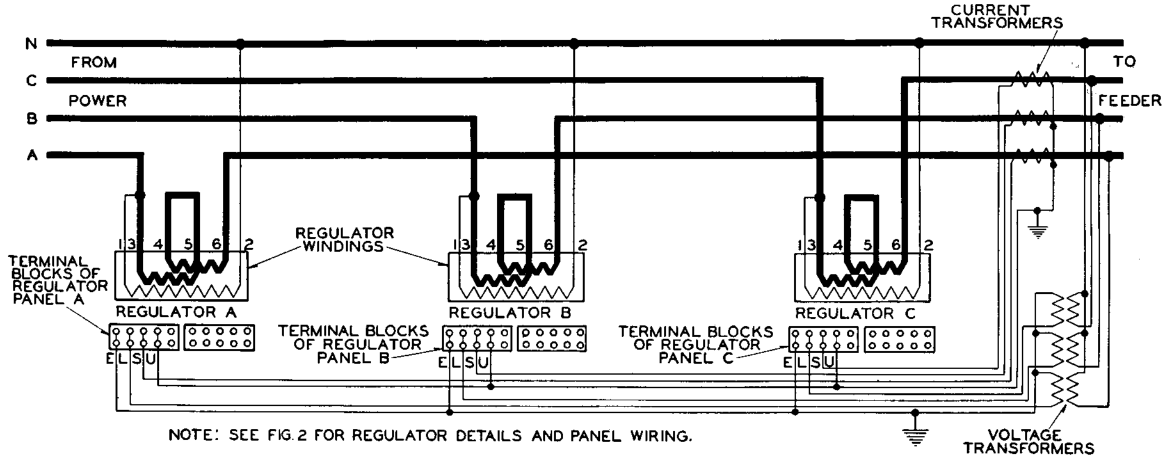


Fig. 18—Diagram of Connections for Three Single-Phase Regulators on a Three-Phase, Four-Wire Circuit

as regulated voltage. A small booster transformer is used in the voltmeter circuit to partially compensate for the drop due to the relay current flowing through the compensator resistor. A small error is introduced due to the voltmeter current being taken through the compensator and depends upon the amount of current drawn by the voltmeter. The loss and volt-ampere burden of this compensator is greater than the Type RC compensator, the burden being approximately 65 volt-amperes.

Type KC Compensator

75. The Type KC compensator is shown in Fig. 14. Diagram, Fig. 15, shows the internal connections and the method of connecting to the feeder. The compensator consists essentially of a reactor transformer, a resistor and a current and insulating transformer. In this compensator the series resistor for the primary relay is provided with taps which connect to two 5 point dials so that transformed current proportional to the line current is forced through more or less of this series resistance. As the line current increases the voltage drop across the resistance is increased requiring a higher feeder voltage to keep the relay contact arm balanced in the mid position. For zero resistance compensation, both outside contact arms should be moved to the lower contacts marked OR. The current transformer ratio and the taps on the resistors are so arranged that one volt and five volt resistance compensation steps can be obtained respectively on the left hand and right hand dials. It is thus possible to get from 0 to 24 volts resistance compensation in 24 one volt steps. The double inside dials provide the reactance compensation. Five volt steps can be obtained on the right and one volt on the left. As on the resistance dials the numbers on the contacts indicate the volts compensation obtainable. For example with the arms on 2R, 3X, 15X and 10R, 12 volts (2+10) resistance and 18 volts (3+15) reactance compensation will be obtained when the rated full load current is flowing in the series winding S to U.

76. For convenience, the compounding resistances P to 14 and 0 to 11, for use with the compounding coils in the primary relay, are also mounted within the compensator case although they are not essential parts of the compensator.

77. Additional series resistance for the primary relay when operated on higher voltages, also is provided. The compensators as shipped are connected for use with a voltage transformer having a secondary voltage of from 100 to 115 volts. For 116 to 125 volts it is necessary to remove the steel base plate on separate mounted compensators, and transfer lead F from 20 to Y. For 126 to 135 volts lead L also should be transferred from 4 to X. For panel mounted compensators, one link on front of compensator should be removed for 116 to 125 volts and both links removed for 126 to 135 volts.

78. The double use of the resistor as series relay and compensator resistance results in a considerable saving in the total power consumed by the relay series resistance and compensator.

79. However, the volt-ampere load put on the current transformer as a result of adding the reactance element, amounts to approximately 80 volt-amperes, so that it is advisable to use the current transformer for the compensator exclusively.

Type KD Compensator

80. It is sometimes desired to read the compensated voltage, i.e., the voltage at the center of distribution. This cannot be done when the KC or RC compensator is used except by using a special voltmeter so designed that the primary relay resistance can be used also as the series resistance of the voltmeter. When this is done the special voltmeter must be calibrated with the compensator and a special adjusting rheostat for adjusting the normal setting of the relay must also be provided.

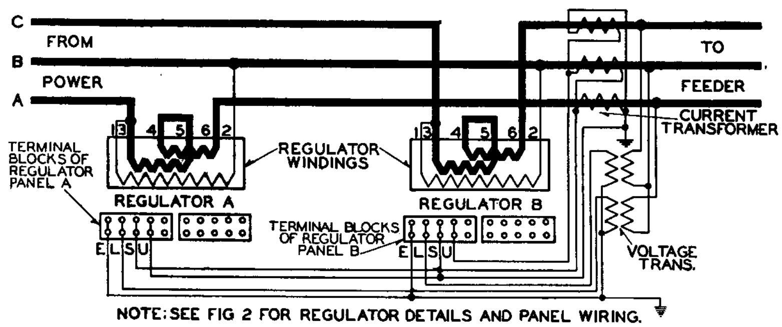


Fig. 19—Diagram of Connections for Two Single-Phase Regulators on a Three-Phase, Three-Wire Circuit

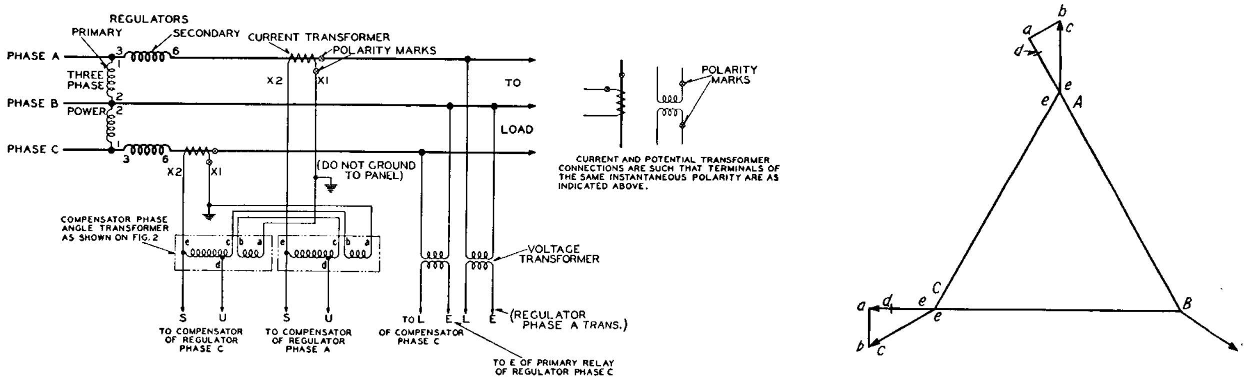


FIG. 20—SCHEMATIC DIAGRAM FOR PHASE ANGLE TRANSFORMERS

81. When it is essential that the compensated voltage be indicated, it is therefore advisable to use the Type KD or RD compensator.

82. The Type KD compensator in appearance is the same as the Type KC. Diagram, Fig. 16, shows the internal connections and the method of connecting it to the line.

83. The compensator consists of a resistor and reactor with taps as shown in the diagram, Fig. 16. A series insulating transformer, mounted within the compensator case, is used in order that both the current and voltage transformers may be grounded. This compensator has quite an appreciable loss at full load with maximum compensation, as the resistor must carry 5 amperes at 24 volts resulting in a loss of 120 watts. The voltmeter, unless specially recalibrated will read about 2½% low. If designed for a lower loss the voltmeter error would be increased.

Special Compensator

84. Various special compensators which are modifications of the KC and KD compensators have been developed.

Type KA Compensator

85. This compensator is the same as the KC compensator except that the reactance element is omitted. It does not compensate for reactive drop but is satisfactory on circuits which do not have wide variation in power factor. The volt-ampere load taken from the current transformer by the Type KA compensator is much lower than that taken by any other compensator so that the same current transformer may be used for the compensator and for any meters which may be required. When any other compensator is used it is recommended that the current transformer for the compensator be used exclusively for the compensator.

Type KE Compensators

86. The Type KE compensator is the same as the Type KD except that the insulating transformer and primary relay series resistor are omitted. It is chiefly used as a 4th wire compensator when three single-phase regulators are used on a three-phase four-wire system.

87. It can also be used instead of the Type KD provided both the current and voltage transformers are not grounded and an external series primary relay resistor is used.

Rear Connected Compensators

88. When compensators are mounted on panels, connecting studs are brought out through the rear of the compensators so that all wiring may be kept on the rear of the panel.

Single-Phase Regulators On Three-Phase Circuits

89. Single-phase regulators can be used in three-phase circuits in several different ways. The use of three standard single-phase regulators on a three-phase four-wire circuit is probably the most common method.

90. Diagram Fig. 18 shows this arrangement for the indoor type and Fig. 24 for the outdoor type.

91. Single-phase compensators with 5-ampere windings are used. The auxiliaries and connections for each regulator are practically the same as for a single-phase regulator on a single-phase circuit.

92. Two single-phase regulators are frequently used to regulate a three-phase

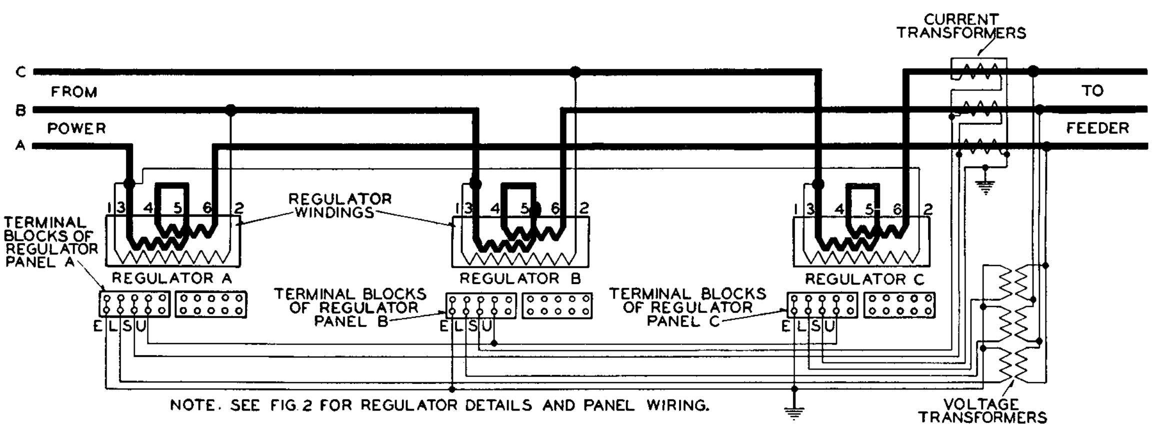


FIG. 21—DIAGRAM OF CONNECTIONS FOR THREE SINGLE-PHASE REGULATORS ON A THREE-PHASE, THREE-WIRE CIRCUIT

three-wire circuit. Two three-phase compensators and three current transformers are required, or single-phase compensators may be used with current transformers having an extended winding so as to give 2.89 amperes in secondary with full load on primary. Fig. 19 shows connections for indoor type and Fig. 25 for outdoor type.

93. The third current transformer may be replaced with two small phase angle transformers as shown schematically in Fig. 20. The use of either the third current transformer or the phase angle transformers is necessary so as to obtain the proper phase relation between the current and voltage in the compensator circuit. The line current and the line to line voltage of a three-phase system are 30 degrees out of phase at unity power factor and it is necessary that they be in phase in the compensator circuit. The vector diagram shown in Fig. 20 is drawn for unity power factor.

94. Fig. 26 shows the application of the phase angle transformers to an outdoor installation. The majority of outdoor installations use the phase angle transformer because of the inconvenience of mounting the third current transformer.

95. Since the regulators are controlled by relays across only two-phases, only two-phases will have their voltage accurately adjusted. It is sometimes suggested that a three-phase circuit be regulated with two single-phase regulators and that after a time when the load increases a third regulator be added to take care of the increased load as done frequently with transformers. This however, cannot be done as the addition of the third regulator does not increase the current carrying capacity of the equipment but increases the percent regulation obtainable approximately 50%. For example, two 100 ampere 10% regulators will provide 10% regulation on a three-phase 100-ampere circuit and when the third regulator is added the three 10% regulators will provide approximately 15% regulation on a 100-ampere three-phase circuit.

96. Diagram, Fig. 21 shows the connections for three single-phase indoor regulators on a three-phase three-wire circuit. For outdoor type see Fig. 27. Since a voltage relay on each phase is used, practically perfect regulation can be obtained. Three three-phase compensators and three current transformers are required, or single-phase compensators and current transformers with extended secondary winding.

97. On all three-phase three-wire circuits regulated by means of single-phase regulators inter-connected current transformers must be used if approximately correct results are required. This results in the current through the compensator being $\sqrt{3}$ times the current in the secondary of the current transformer except in case phase angle transformers are used but the resultant current in the compensator at 100% power-factor is in phase with the voltage obtained from the voltage transformer.

Outdoor Type Induction Regulators

98. Outdoor type regulators are very similar to the indoor type except that they are provided with suitable hoods or coverings to permit their being installed outdoors.

99. Fig. 22 shows a single-phase outdoor type regulator.

When these regulators are placed at the load centers, compensators and current transformers are not required. These regulators should be installed so that they may be easily inspected. All the instructions given for the installation and operation of indoor regulators apply also to outdoor type.

100. The outdoor hood is square with doors in front and two sides. The back is removable for changing connections and gaining access to instrument transformers. The two side doors give access to the motor secondary relay and greasing station and the front door gives access to the handwheel and position indicator.

101. The panel is mounted in a weatherproof control box and can be swung forward for connecting the control leads by removing the two machine screws located at the top of the panel. See Fig. 22. Fig. 23 shows connections for outdoor type regulator.

Regulators With Series and Exciting Transformers

102. Induction regulators are difficult to insulate for high voltage small capacity. Standard 2400 volt regulators may be used in combination with exciting and series transformers to regulate the voltage of a high voltage line. Fig. 30 shows the connections for two single-phase regulators on a three-phase three-wire system. The series transformer has the same rating as the induction regu-

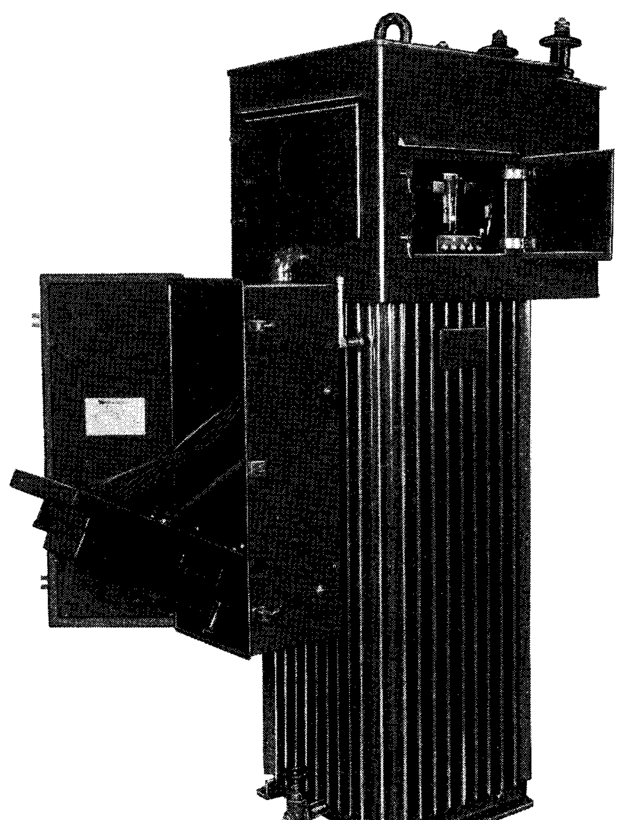


Fig. 22—Outdoor Type Single-Phase Induction Regulator

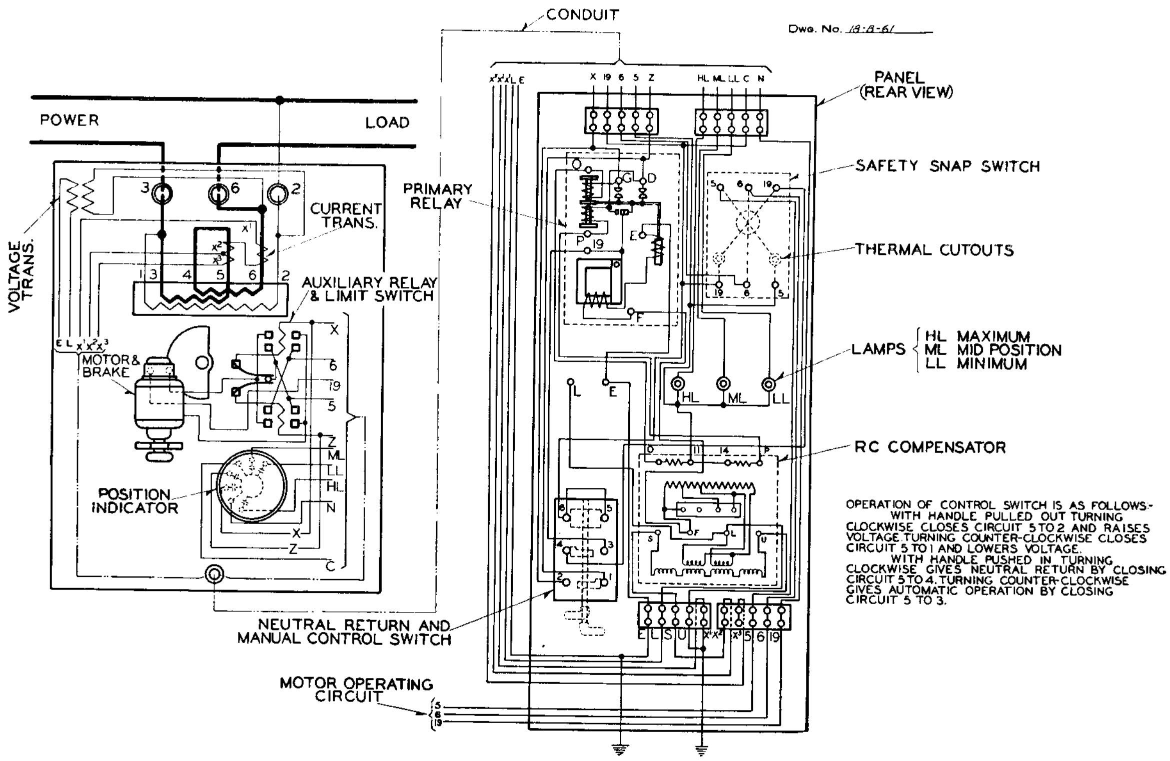
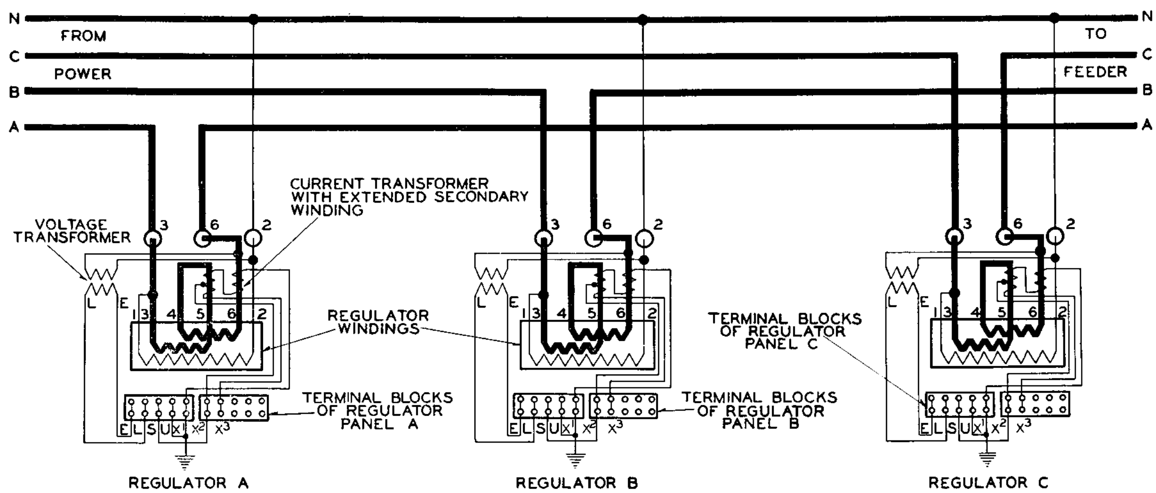
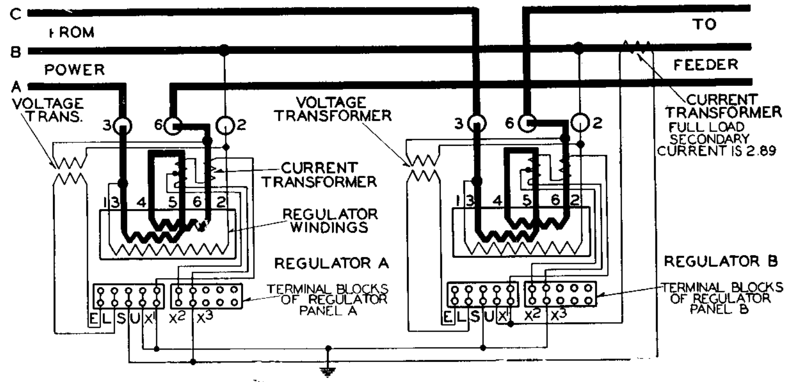


FIG. 23—DIAGRAM OF CONNECTIONS, OUTDOOR TYPE AUTOMATIC INDUCTION REGULATOR



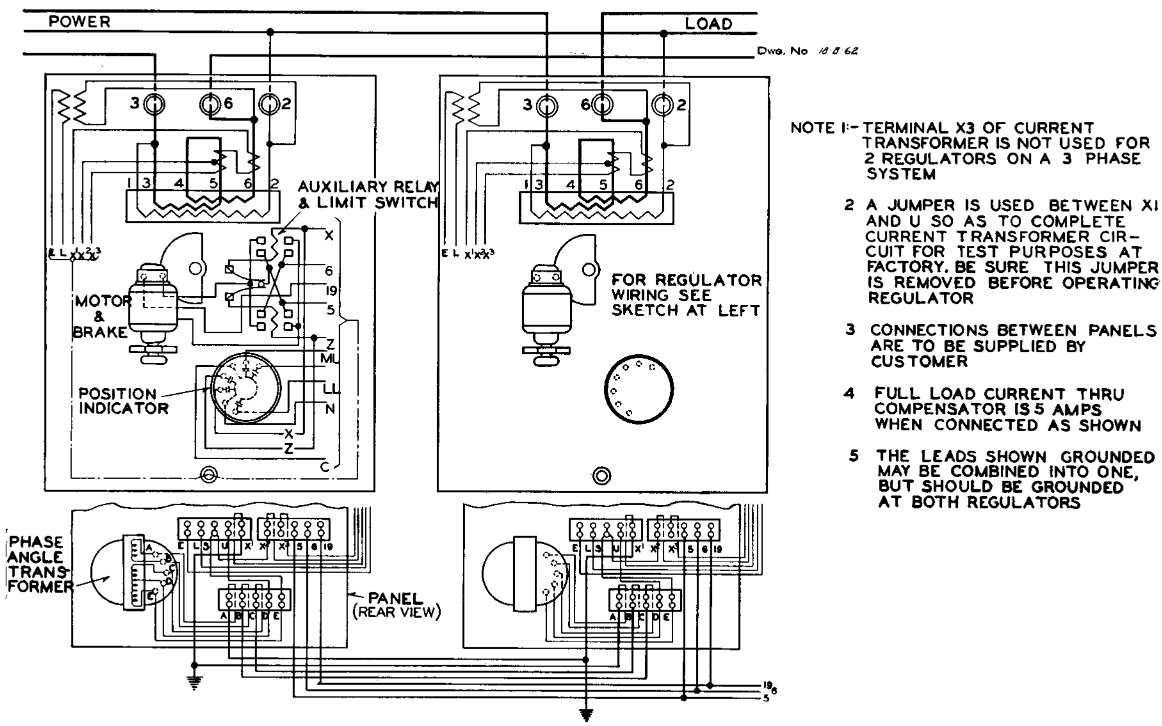
NOTE: SEE FIG. 23 FOR REGULATOR DETAILS AND PANEL WIRING.

FIG. 24—DIAGRAM OF CONNECTIONS FOR THREE SINGLE-PHASE REGULATORS ON A THREE-PHASE, FOUR-WIRE CIRCUIT (OUTDOOR TYPE)



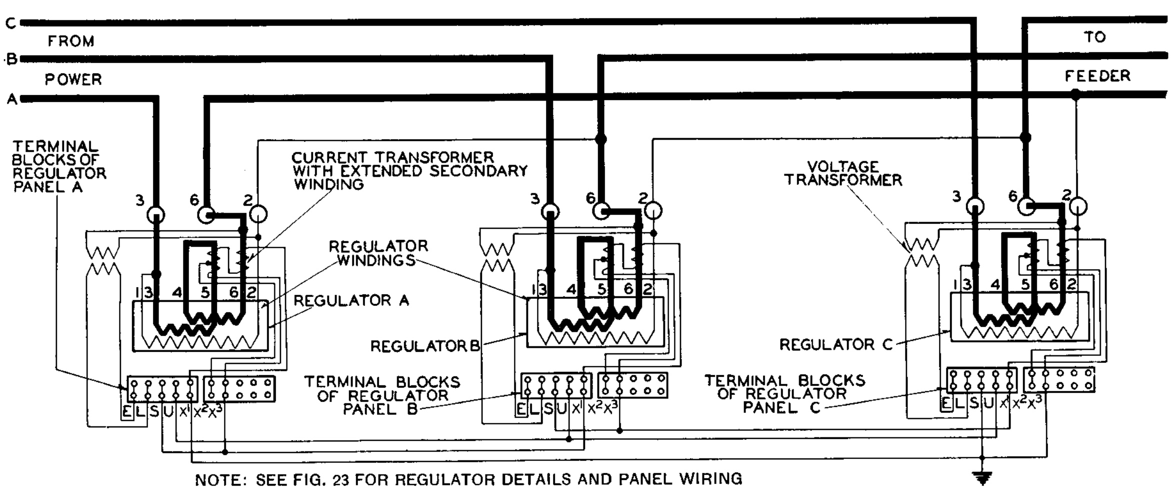
NOTE: SEE FIG. 23 FOR REGULATOR DETAILS AND PANEL WIRING

Fig. 25—Diagram of Connections for Two Single-Phase Regulators on a Three-Phase, Three-Wire Circuit (Outdoor Type)



NOTE:- SEE FIG. 23 FOR PANEL WIRING.

Fig. 26—Diagram of Connections for Two Single-Phase Regulators on a Three-Phase Three-Wire Circuit Using Phase Angle Transformers



NOTE: SEE FIG. 23 FOR REGULATOR DETAILS AND PANEL WIRING

Fig. 27—Diagram of Connections for Three Single-Phase Regulators on a Three-Phase, Three-Wire Circuit (Outdoor Type)

lator, while the exciting transformer must have a rating, from 15 to 25% greater than the regulator, because of the impedance drop and exciting current of the regulator.

Panel And Accessories

103. Fig. 28 illustrates the type of panel used with automatic accessories. The rear view shows a phase angle transformer mounted in place.

Indicator

104. The indicator is operated from the rotor shaft. It has two drag-hands which can be reset by means of the knob in front. The drag-hands indicate the maximum travel of the regulator since they were last reset. The contacts for neutral return control and for the indicating lamps are controlled by a single cam. The cam is self-lubricating. The bearing should be oiled occasionally with a light oil. The contacts should maintain their adjustment for a long period. They can be adjusted to take care of wear.

Renewal Parts For Relays

105. A complete set of contacts, for primary relay, consists of two moving contacts, and two stationary contacts. A complete set of contacts for auxiliary relay, consists of four moving contacts and four stationary contacts.

Renewal Coils For Regulators

106. When ordering coils for regulators always give the complete reading of the name plate of the regulator including the shop order number and the serial number. Since single-phase regulators have coils of different sizes in the same machine it is important that the coil or coils required be definitely described. It is recommended that the following descriptive terms be used:—"Longest rotor coil", "Next to longest stator coil", "Shortest stator coil", etc. Do not use the words "primary" and "secondary" but use the words "rotor" and "stator" when describing coils or parts of a regulator. Frequently stator coils are called primary coils when as a matter of fact they are secondary coils. Fig. 29 shows the details of the regulator construction.

107. For single-phase stator coils it is advisable also to specify whether coils are to be used in group having leads marked 4 and 6, or in group having leads marked 3 and 5. This information will insure the coils being furnished with the coil leads so formed that they can be installed with the least trouble.

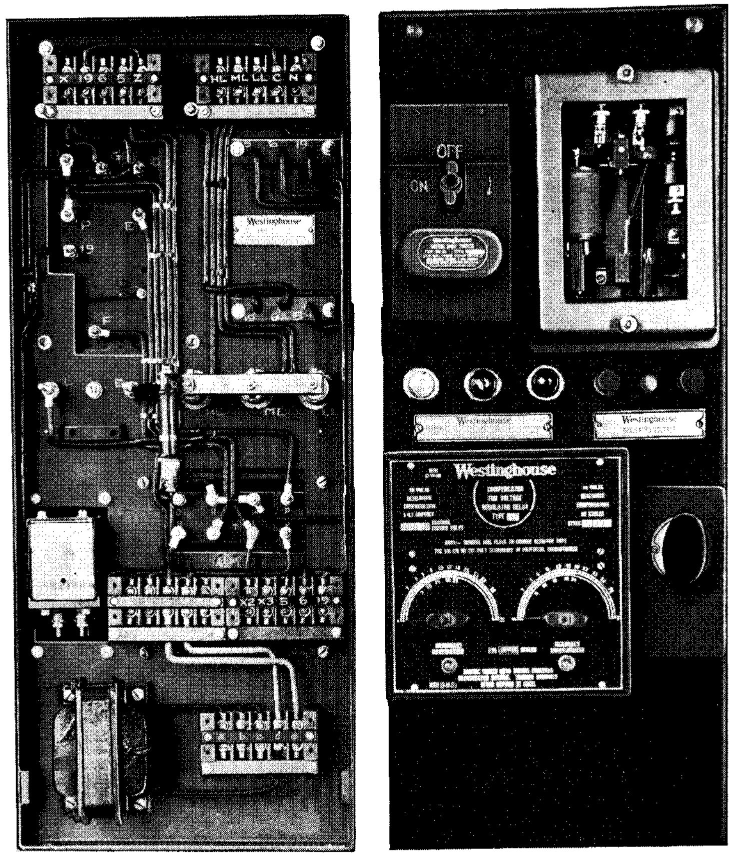


Fig. 28—Panel

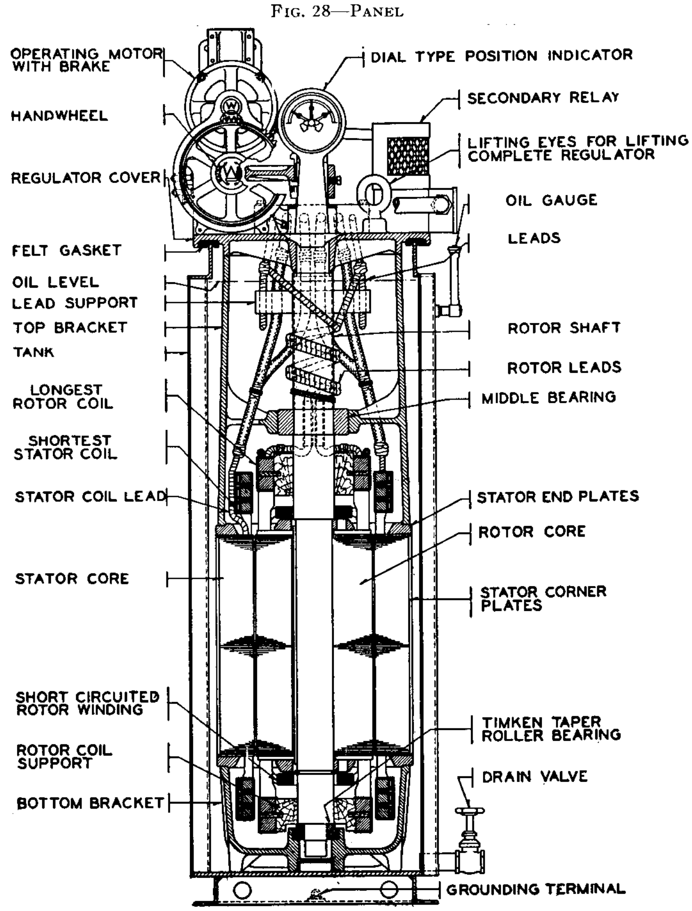


Fig. 29—Details of Regulator Construction

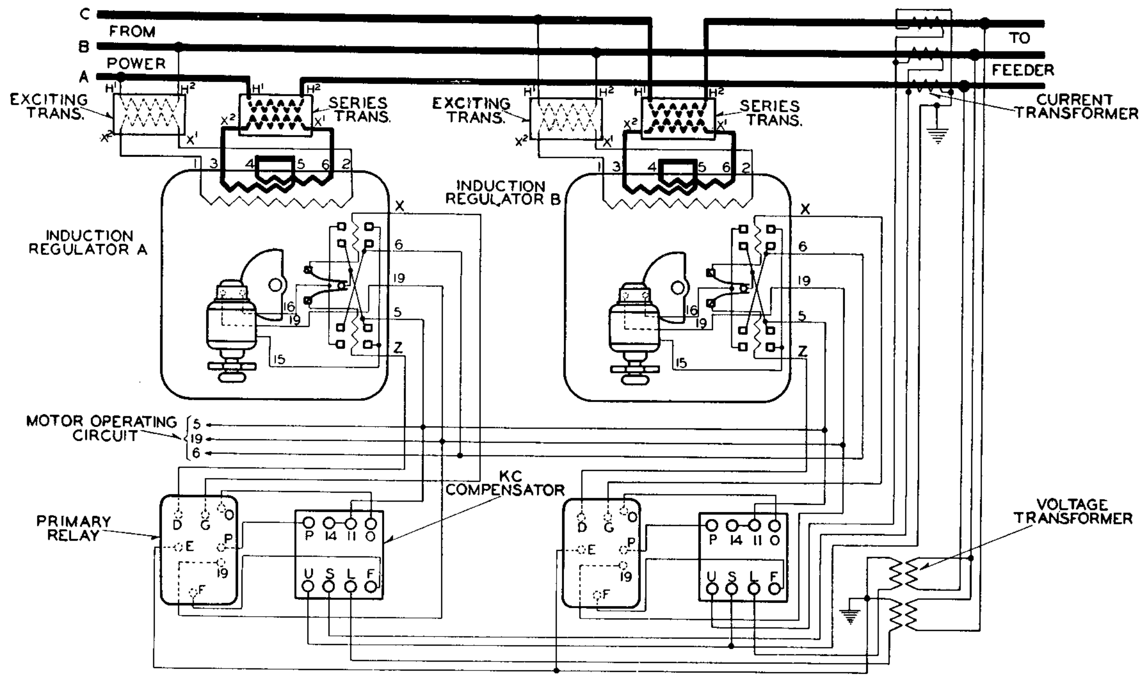


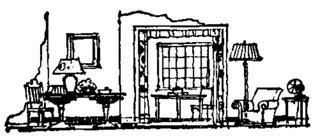
Fig. 30—Two Induction Regulators with Series and Shunt Transformers on a High Voltage Three-Phase Circuit

The following is a list of the Renewal Parts and the minimum quantities of each that should be carried in stock. These are the parts most subject to wear in ordinary operation, and to damage or breakage due to possible abnormal conditions. The maintenance of such stock will minimize service interruptions caused by breakdowns.

Name of Part	No. Per Unit	Recommended for Stock			Style No.
Units in use up and including		2	5	15	
Type KC Compensators—S# 307112-3—S# 431136-7—S# 462606-7					
Resistor tube 4000 Ohms	1	1	1	2	303003
Resistor tube 155.8 Ohms	1	1	1	2	316854
Resistor tube 110.2 Ohms	1	1	1	2	316855
Type KD Compensator—S# 417538-9—S# 458148—S# 462608-9					
Resistor tube 2 Ohms	2	1	1	3	326285
Resistor tube .8 Ohms	1	1	1	2	326288
Resistor tube 4000 Ohms	1	1	1	1	303003
Resistor tube 133 Ohms	2	1	1	3	392167
Secondary Relay—S# 236633					
Moving contact with spring	4	2	4	8	159707
Stationary contact	4	1	2	4	147746
Tension spring for limit switch	1	1	2	4	238715
Armature spring	2	1	2	4	157934
Secondary Relay—S# 670726					
Moving contact with spring	4	4	8	16	159707
Stationary contact	4	1	2	4	573943
Tension spring for limit switch	1	0	1	1	238715
Armature spring	2	0	1	2	157934
Primary Voltage Regulating Relay—S# 163320—S# 238610—S# 430944					
Moving contact	2	4	8	16	163319
Stationary contact	2	4	8	16	163317
Spring for moving contact lever arm	1	0	1	2	163334
Operating coil for S# 163320	1	0	0	1	172140
Operating coil for S# 238610	1	0	0	1	242045
Operating coil for S# 430944	1	0	0	1	406174
Compounding coil for S# 163320—238610	1	0	0	1	172139
Compounding coil for S# 430944	2	0	1	1	406173
No voltage release for S# 238610	1	0	0	1	242152
Operating Motors					
Motor—# 743 "CA" 220 V., 3 ph., 60 cyc., 900 rpm	1	0	0	0	219116
Motor—# 743 "CA" 220 V., 2 ph., 60 cyc., 900 rpm	1	0	0	0	230024
Motor—# 765 "CSA" 220 V., 3 ph., 60 cyc., 900 rpm	1	0	0	0	308421
Motor—# 743 "CSA" 220 V., 3 ph., 60 cyc., 900 rpm	1	0	0	0	592158
Motor—# 743 "CA" 220 V., 2 ph., 60 cyc., 900 rpm	1	0	0	0	594741
Motor—# 765 "CSA" 220 V., 3 ph., 60 cyc., 900 rpm	1	0	0	0	594748
Brake Coil—220 V., 60 cyc., brake	1	1	1	2	284647-A

When ordering renewal parts, give the name plate reading. Always give the name of the part wanted, also the stock order number or style number of the apparatus on which the part is to be used.

Westinghouse Products

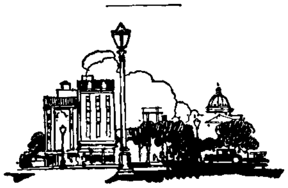


Homes—Farms

Air Heaters
Auto Engine Heaters
Automatic Irons
Automatic Percolators
Automatic Ranges
Cozy Glow Heaters
Curling Irons
Fans
Hot Plates
Light and Power Plants
Lighting Equipment
Mazda Lamps
Motors for
  Buffers and Grinders
  Ice Cream Freezers
  Ironers and Washers
  Refrigerators
  Sewing Machines
  Vacuum Cleaners
Newel Posts
Panelboards
Radio Equipment
Rectigon Chargers for
  Automobiles and
  Radio Batteries
Rectox Trickle Charger
Refrigerators, Electrical
Safety Switches
Sollaire Luminaires
Sol-Lux Luminaires
Solar Glow Heaters
Table Stoves
Tumbler Water Heaters
Turnover Toasters
Vacuum Cleaners
Wall-Type Heaters
Waffle Irons
Warming Pads
Water Heaters

Buildings

Arc Welding Equip.
Circuit-Breakers
Elevators and Control
Glue and Solder Pots
Instruments and Relays
Kitchen Equipment
  Bake Ovens
  Hot Plates, Ranges
Lighting Equipment
  Brackets, Newels
  and Lanterns
  Reflectors & Lamps
  Sol-Lux Luminaires
Lightning Arresters
Micarta Trays
Meters
Meter Service Switches
Motor Generators
Motors and Control for:
  Coal and Ash-Handling Equipment
  Compressors
  Elevators
  Fans and Blowers
  Laundry Equipment
  Refrigerating Equip.
  Vacuum Cleaners
  Water & Sump Pumps
Panelboards
Radio Equipment
Synchronous Converters
Safety Switches
Solar Glow Heaters
Stokers
Switchgear
Transformers

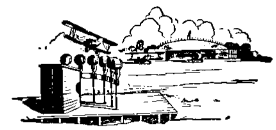


City Improvements

Airport Floodlights
Automatic Substations
Constant Current Regulators
Control Apparatus
Elec. Railway Equip.
Lighting Units
Mazda Lamps
Ornamental Standards
Parkway Cables
Street Brackets
Streethoods

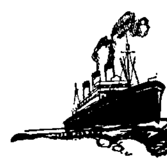
Offices and Stores

Air Heaters
Bread-baking Oven
Elevators and Control
Fans, Desk and Exhaust
Fuses
Lighting Equipment
Mazda Lamps
Meters
Micarta Desk Tops
Motors for
  Adding Machines
  Addressing Machines
Motors for
  Coffee and Meat
  Grinders, etc.
  Dictaphones
  Envelope Sealers
  Fans and Blowers
  Pumps
  Refrigerating Machines
Panelboards
Safety Switches
Switches
Tumbler Water Heaters



Aviation

Approach, Boundary,
  Hangar, and Obstruction Lights
Arc Welding Equip.
Floodlight Projectors
Motor-Generators
Reflectors
Transformers
Mazda Lamps
Micarta
  Cabin-lining Plate
  Fairleads
  Hinge Bearings
  Propellers
  Pulleys
  Tailwheels
Radio Equipment

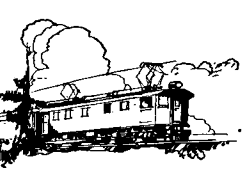


Ships

Circuit-Breakers
Condensing Equipment
Deck Winch Motors
Elec. Heating Appar.
Eng. Room Auxiliaries
Fans and Blowers
Fuses
Generating Equipment
Instruments
Light and Power Plants
Lighting Equipment
Micarta Trays
Motors and Controllers
Ovens, Ranges and
  Galley Equipment
Panelboards
Propulsion Equipment
  Diesel-Electric
  Geared Turbine
  Turbine Electric
Radio Equipment
Safety Switches
Switchgear

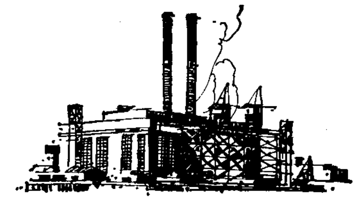
Electric Railways

Arc Welding Equip.
Automatic Substations
Babbitt, Solder & Pots
Baking Ovens
Circuit-Breakers
Elec. Trolley Coaches
Fans
Gas Electric Coaches
Gears and Pinions
Generators
Insulating Material
Insulators
Lighting Fixtures
Lightning Arresters
Line Material
Manual Substations
Mazda Lamps
Meters
Motors and Control
Panelboards
Portable Substations
Relays
Signal Equipment
Supervisory Control
Switchgear
Synchronous Convert's
Transformers
Trolley Poles



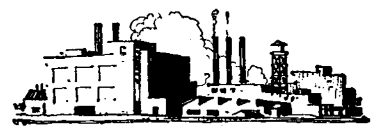
Railroads

Arc Welding Equipment
Automatic Substations
Babbitt, Solder & Pots
Baking Ovens
Battery Charging Equip.
Cars—Multiple-Unit.
  Gas-Elec., Oil-Elec.
Circuit-Breakers
Control Apparatus
Elec. Heating Apparatus
Fans
Gears and Pinions
Generators
Headlight Equipment
Instruments
Insulating Materials
Insulators
Lighting Equipment
Lightning Arresters
Line Material
Locomotives—Electric
  Gas-Elec., Oil-Elec.
Manual Substations
Mazda Lamps
Micarta Gears
Motors and Control
Outdoor Substations
Panelboards
Power House Apparatus
Radio Equipment
Safety Switches
Signal Equipment
Stokers
Supervisory Control
Switchgear
Transformers
Yard Lighting Equip.



Electric Service Companies

Automatic Switching
  Equipment
Circuit-breakers
Condensers
Cutouts
Fans
Frequency-converters
Fuses
Generators
Instruments & Meters
Insulating Material
Insulators
Line Material
Lighting Equipment
Lightning Arresters
Micarta
Motors and Control
Motor-Generators
Network Protectors
Network Transformers
Oil Testing and Purifying Equipment
Outdoor Substations
Panelboards
Porcelain Insulators
Relays
Safety Switches
Steam Turbines
Stokers
Supervisory Control
Switchgear
Synchronous Conden'rs
Synchronous Conv'ters
Transformers
Turbine Generators
Voltage Regulators

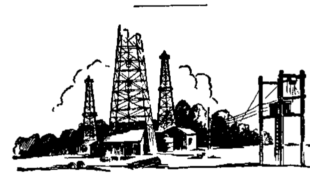


Mills and Factories

Arc Welding Equip.
Automatic Starters
  and Controllers
Babbitt & Babbitt Pots
Capacitors
Circuit-Breakers
Condensers
Fans, Desk and Exhaust
Furnaces and Ovens
Fuses
Generating Equipment
Insulating Materials
Knife Switches
Larry Car Equipment
Lighting Equipment
Lightning Arresters
Locomotives—Electric
  Gas-Elec., Oil Elec.
Mazda Lamps
Meters and Relays
Micarta Gears
Motors and Controllers
Panelboards
Pipe Fittings (Struct'al)
Power House Apparatus
Safety Switches
Solder & Glue Pots
Space Heaters
Stokers
Switchgear
Transformers
Turbines

Mines

Arc Welding Equip.
Auto. Feeder Equip.
Automatic Starters
  and Controllers
Automatic Substations
Battery Charging Equip.
Circuit-Breakers
Clamps
Elec. Heating Apparatus
Fans
Gears and Pinions
Headlights
Insulating Materials
Insulators
Larry Car Equipment
Lightning Arresters
Line Material
Locomotives
Manual Substations
Mazda Lamps
Meters & Instruments
Micarta
Motor Generators
Motors for Hoists,
  Pumps, Tipples,
  and Breakers
Panelboards
Portable Substations
Relays
Safety Switches
Switchgear
Synchronous Conv'ters
Transformers
Ventilating Outfits



Oil Fields

Arc Welding Equip.
Change House Heaters
Floodlight Projectors
Gear Units
Insulators
Mazda Lamps
Motors and Control
Panelboards
Reflectors
Rig Lighters
Safety Switches
Small Light Plants
Transformers
Vapor Proof Fixtures

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