Westinghouse

Automatically Controlled

Three-Phase

Induction Regulators

INSTRUCTION BOOK

Westinghouse Electric & Manufacturing Company

East Pittsburgh Works

East Pittsburgh, Pa.

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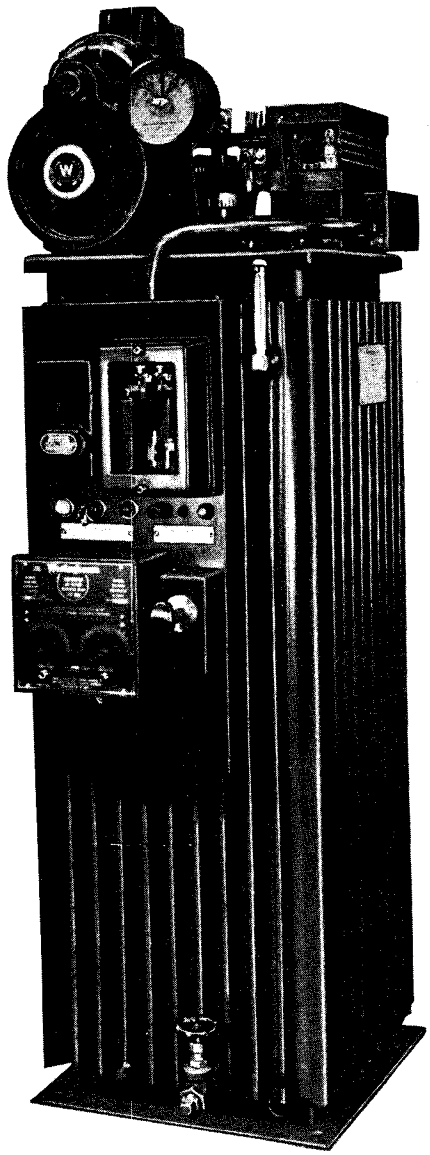

Indoor-Type Induction Voltage Regulator
with Panel Mounted Accessories

Westinghouse

Automatically Controlled Three-Phase Induction Regulators

Purpose of Regulator

1. A very large percentage 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 Three-Phase Regulator

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

(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, 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) Two current transformers.

(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 extreme positions of the regulator.

*(k) Testing terminals for use with a voltmeter to read regulated voltage.

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 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.

5. 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.

6. 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 Three-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 67 to 84.

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.

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:

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

* Furnished only with Panel Mounted Accessories.

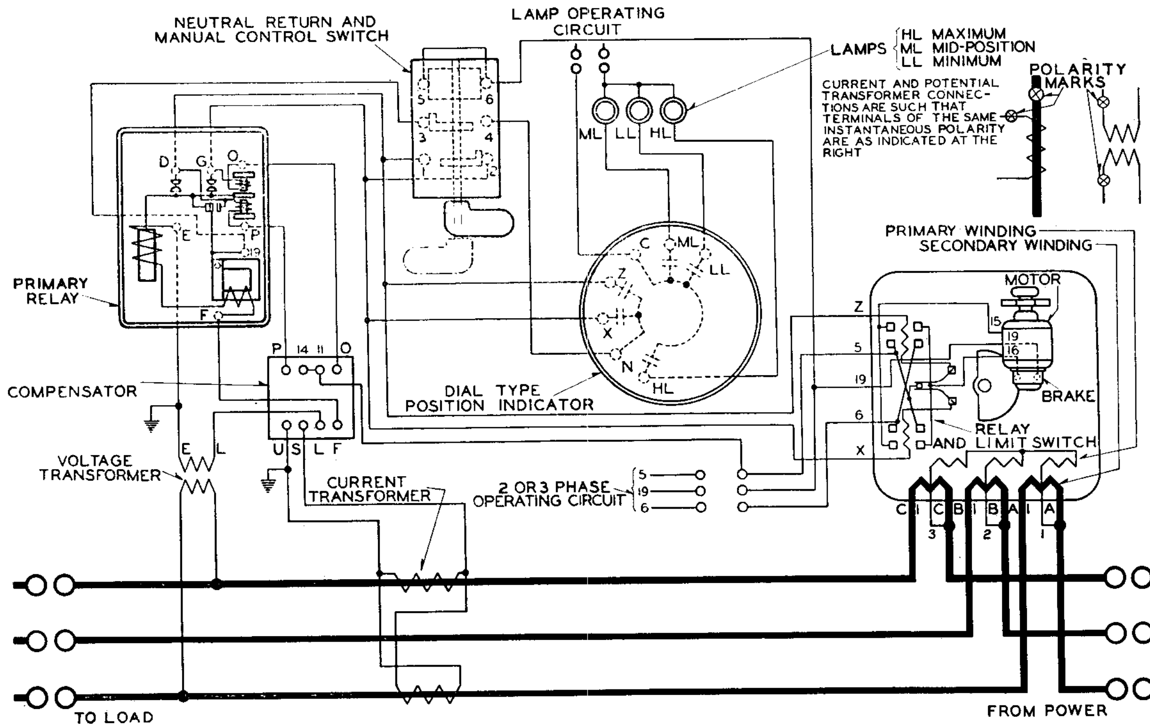

FIG. 1—DIAGRAM OF CONNECTIONS FOR AN AUTOMATIC THREE-PHASE INDUCTION REGULATOR

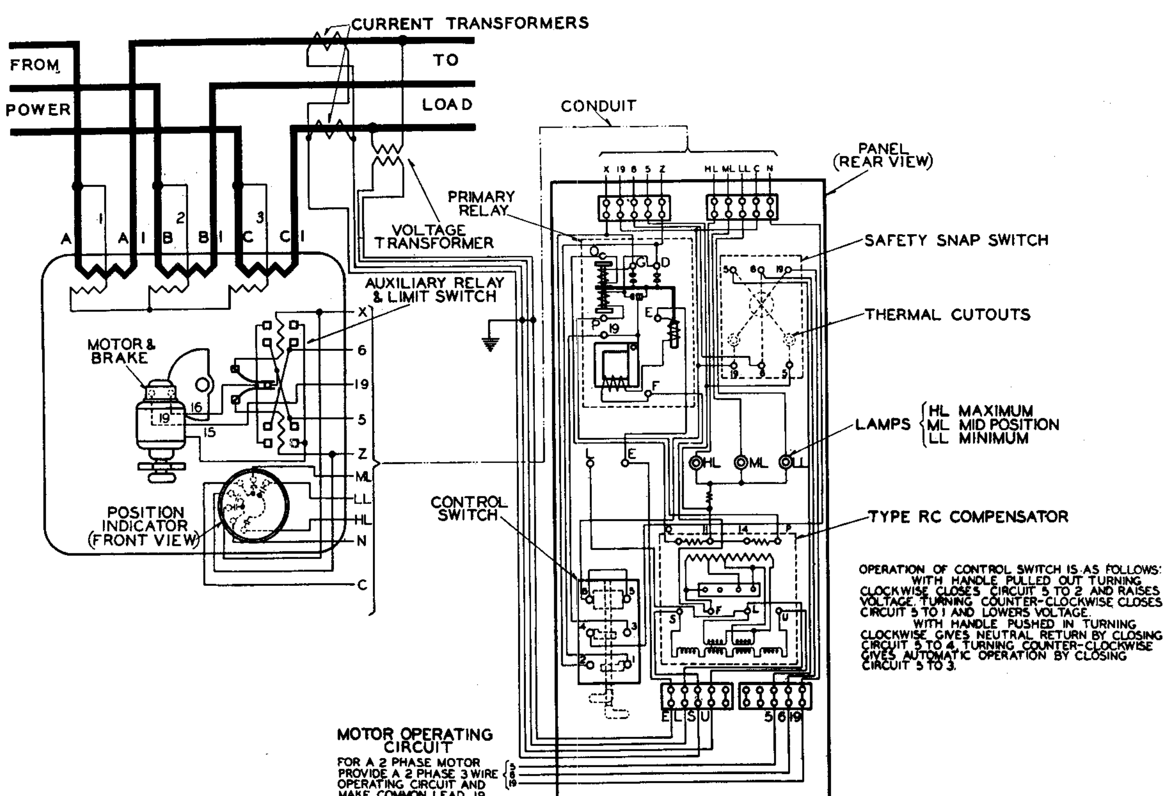

FIG. 2—DIAGRAM OF CONNECTIONS FOR AN AUTOMATIC THREE-PHASE INDUCTION REGULATOR WITH PANEL MOUNTED ACCESSORIES

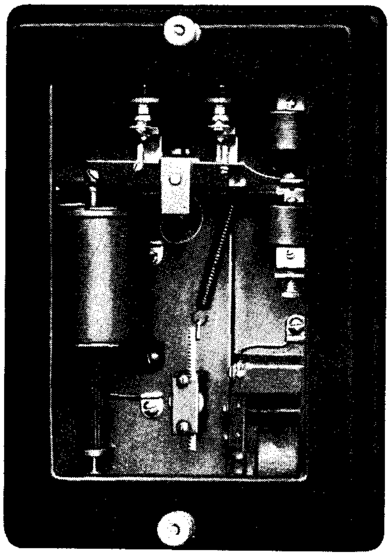

FIG. 3—PRIMARY RELAY

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 due to the time necessary for the auxiliary relay to open and the motor to stop 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.

12. Two current transformers are necessary in order that the current in the compensator circuit will have the correct phase relation with the primary relay circuit voltage. At unity power factor, the line current of a three-phase three-wire circuit is thirty degrees out of phase with the line to line voltage so that to get 100% power factor for the operation of the compensator two current transformers are used.

13. Three-phase induction regulators control the feeder voltage by adding to the incoming line voltage, a voltage which is constant in magnitude but having a variable phase relation with the line voltage. That is, the secondary voltage of a three-phase induction regulator is nearly constant in magnitude but its phase relation with the primary voltage is dependent upon the rotor position. See Fig. 7. As a result, the regulated voltage is slightly out of phase with the bus voltage except in the maximum and minimum positions. Fig. 7 is a voltage vector diagram of a three-phase regulator in a position that the regulated voltage is equal to the bus voltage OA is the generator or bus voltage, OA1 is the regulated or feeder voltage, AA1 is the secondary voltage induced on one phase of the induction regulator. The end of vector AA1 will be in the semi-circle depending upon the position of the rotor.

Shipping and Storage

14. 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.

15. 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.

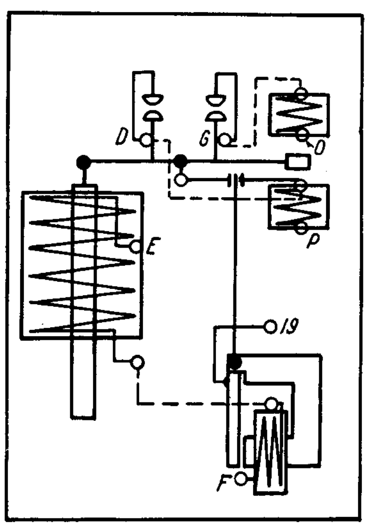

FIG. 5—DIAGRAM OF PRIMARY RELAY (FRONT VIEW)

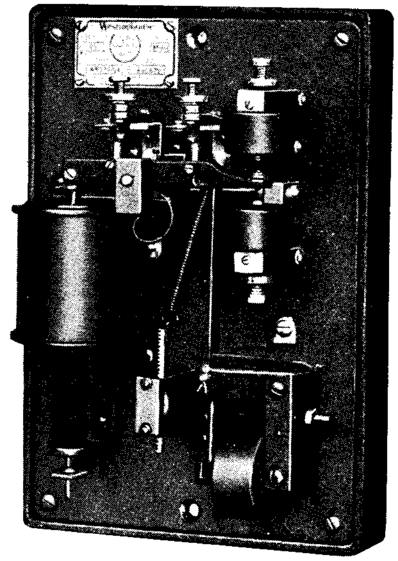

FIG. 4—PRIMARY RELAY (COVER REMOVED)

Installation

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

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

18. When two voltage or current ratings are given on the name plate 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.

19. The volt-ampere rating of a three-phase regulator is equal to the product of the current and the voltage of the circuit times the per cent regulation times the square root of three. For example, a 2300 volt 100 ampere, 230 kilovolt-ampere, three-phase circuit that is to be regulated 10 per cent up and down, would require a regulator rated at $100 \times 2300 \times \frac{10}{100} \times \sqrt{3} = 40000$ volt-amperes or 40 kilovolt-amperes.

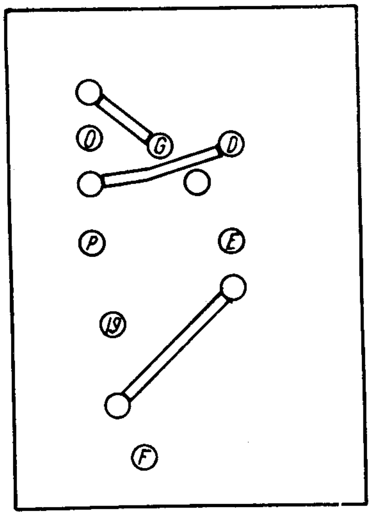

Fig. 6—Diagram of Primary Relay (Rear View)

20. The voltage across the secondary of a three-phase regulator is practically constant and is equal to the product of the per cent regulation and the line voltage divided by the square root of three. That is, in the above example the voltage across one of the series windings is $\frac{10}{100} \times 2300 \times \frac{1}{\sqrt{3}} = 133$ volts.

21. 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 foregoing calculations. This is done in order that the full per cent regulation may be obtained when operating at full load.

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

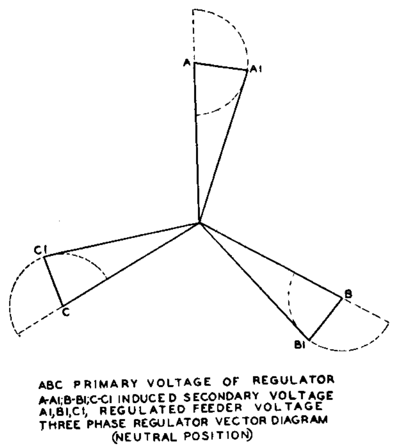

Fig. 7—Voltage Vector Diagram

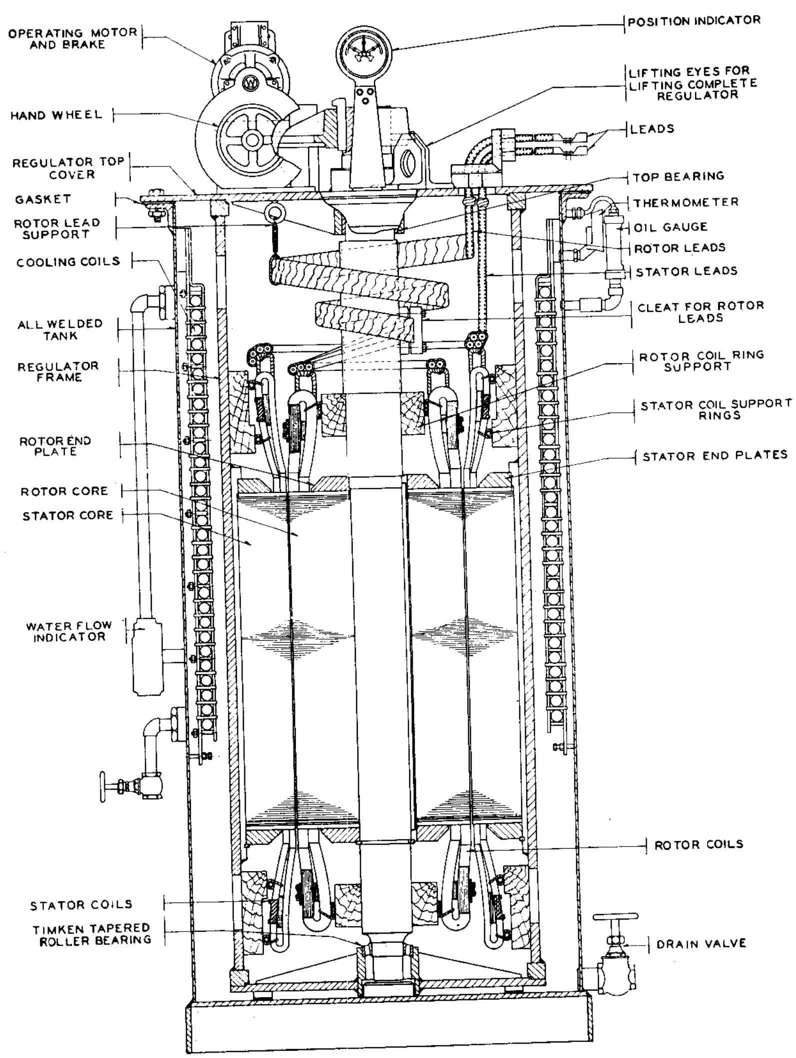

Fig. 8—Details of Water-Cooled Regulator Construction

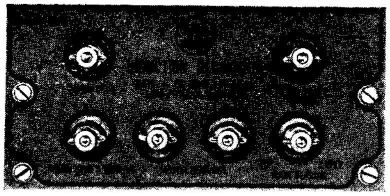

Fig. 9—Centralized Lubricating System

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 60 kv-a. or less. When operating in groups, one kv-a. of transformer capacity per regulator is sufficient.

23. 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

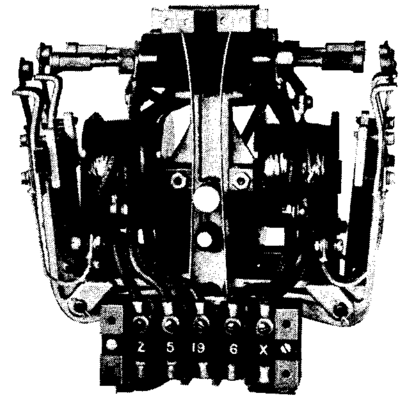

Fig. 10—Cover Mounted Type Auxiliary Relay for Mounting on Top of Regulator Cover

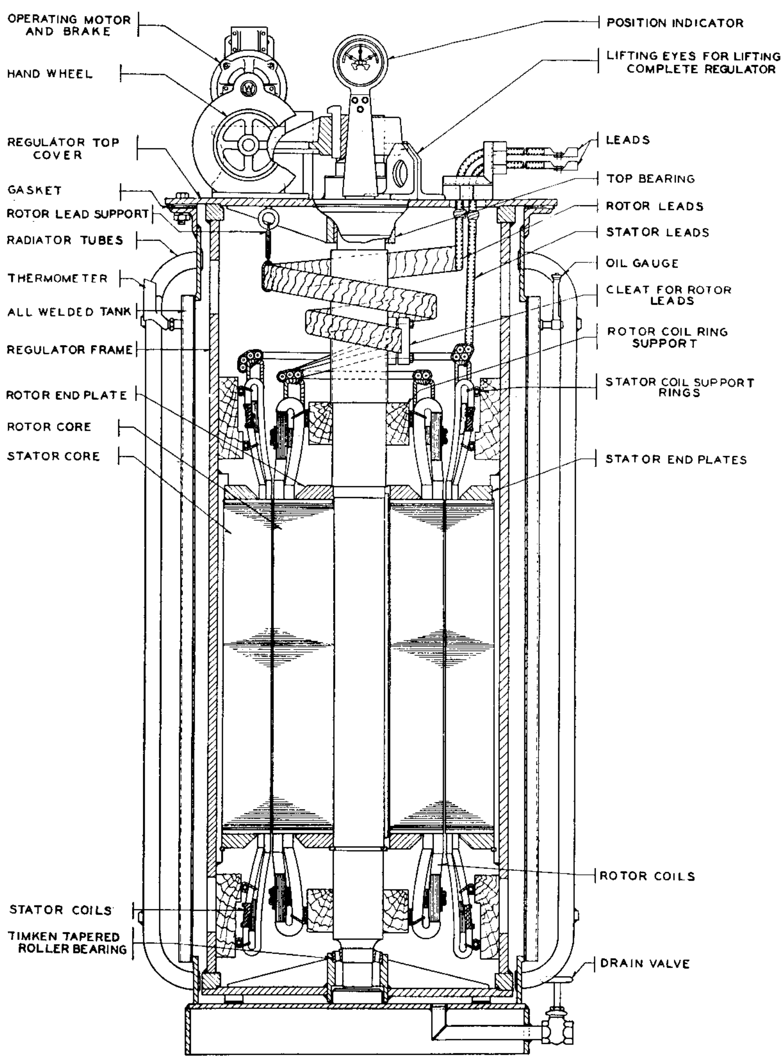

Fig. 11—Self-Cooled Regulator Construction

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.

24. 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. See Fig. 8.

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

26. Self-cooling regulators should always be well separated from one another and from adjacent walls. This 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. See Fig. 11.

27. 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.

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

Lubrication

29. A central lubricating station Fig. 9 is usually located on the motor side 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 bearings should be oiled with a good quality machine oil.

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

31. 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.

Note—Insulating Oils are covered more thoroughly by Instruction Book 5336. Copies of this book may be obtained upon request.

32. If the regulator is of the water-cooled type (Fig. 8) 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

33. 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, Figs. 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.

34. 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.

35. 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 District Office for information. Requests should give complete name plate 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.

36. Checking Connections—After the regulator is completely connected and before throwing on the 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, Figs. 1 and 2 but with slight modifications apply to all regulators.

37. 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.

38. Checking Primary Relay—Connect a voltmeter temporarny 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.

39. 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 paragraph 62, describing compensators.

40. 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 relay by hand to change the voltage. Then release the lever and observe the action of the relay in correcting the voltage. Read carefully Paragraphs 46 to 57 on "Adjustments" and "Hunting" so that any necessary changes may be made intelligently.

41. Polarity of Current Transformers—The current transformer connections can be checked by placing one ammeter in lead S of compensator and also an ammeter in the secondary of one current transformer (Fig. 1). With a balanced load on the feeder the ammeter in lead S should read approximately 73% higher than the other ammeter. If the two readings are equal, one of the current transformer secondaries is reversed and must be corrected. The connections can also easily be checked by observing the polarity marks on the transformer and checking the circuit with the diagram. Erratic compensation will result if the current transformers are incorrectly connected.

42. Compensator Setting—The compensator should be set for the compensation required for the particular circuit. The required compensation can be determined by several methods.

(a) If the resistance and reactance of the line to the center of distribution are known or can be calculated, the drop at full load can be calculated and the compensator set accordingly. See paragraphs describing particular type of compensator being used

(b) If the impedance drop to the load cannot be conveniently calculated, the compensator setting can be made by trial. By using two recording voltmeters, one at the station bus and one at the center of distribution and comparing simultaneous readings at different loads, trial adjustments can be made until the proper combination is obtained.

(c) The following set-up is another scheme which gives good results. 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 regulated voltage at this point. Better results will be had if the feeder is carrying at least 50 per cent 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 then 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 the test with the opposite condition of power factor gives two sets of data from which two curves can be plotted.

The curves are plotted from actual test data obtained as described above. See Fig. 12. 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 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.

43. The compensators are calibrated in volts so that the compensator setting for known values of line resistance and reactance can be obtained by dividing the line drop at full load by the ratio of the potential transformer. This is assuming that the current transformer is of the correct ratio to give normal full load current in the compensator circuit with full load on the feeder. For example, the compensator setting for a 2400 volt, 250 ampere feeder having 1 ohm resistance and 1½ ohms reactance is as follows. The reactance drop at full load is 250 x 1½=375 volts. Using a 20/1 ratio potential transformer and a 250/5 ampere current transformer, the reactance compensator setting is

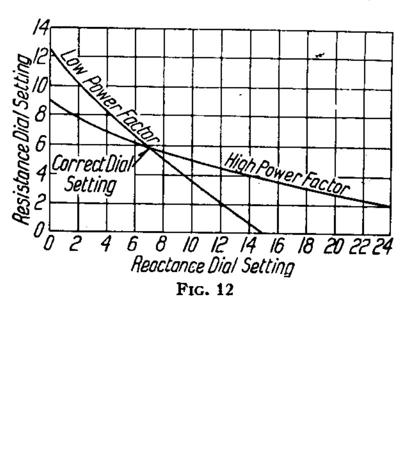

FIG. 12

375 x 1/20=18.8 or practically 19 volts. Similarly the resistance compensator is 250 x 1 x 1/20=12½ volts. If a 300 to 5 current transformer were used instead of 250/5, the compensator would have to be increased in the ratio of 300/250 since at full load 250 amperes the current in the compensator circuit would be less than the normal full load value by the inverse of this ratio.

44. **Primary Current Check for Three-Phase Regulators.** Since the primary current of a polyphase regulator under load increases or decreases as the regulator is turned to the mid or neutral position, depending upon the phase rotation of the magnetic field within the regulator, it becomes necessary to check installation that it may be so connected with the field rotation in the proper direction.

45. When thus connected, the primary current and the resulting loss are a minimum. After connecting up a polyphase regulator, place an ammeter temporarily in one of the primary or shunt leads of the regulator. With load on the regulator note whether the current increases or decreases materially as the regulator is turned from either extreme position toward the neutral or mid-position. If the current increases as the regulator is turned toward the mid position, reverse two of the supply leads to the regulator. In order not to reverse the phase rotation of the feeder also reverse the same two lines as they leave the regulator. For example on Fig. 1 reverse A and B at the power switch and reverse A-1 and B-1 at the load switch. Three-phase regulators are usually designed so that with A, B, C, phase rotation on the feeder, the primary current and resulting loss is a minimum.

Adjustments

46. **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.

47. 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.

48. 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.

49. 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.

50. 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 volt 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.

51. 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 56 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 to normal.

52. **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. 10). 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.

53. 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.

54. **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.

55. 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.

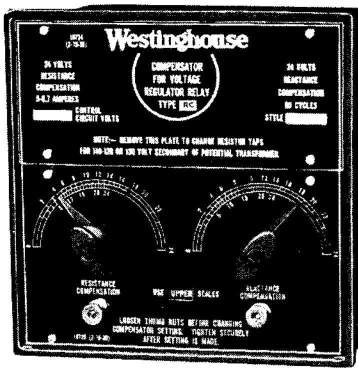

Fig. 13—Type RC Compensator

Hunting

56. 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 per cent plus or minus: 1½ per cent plus or minus gives the best all-round 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 over-travel 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.

57. 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

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

59. 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.

60. If it is essential that a polyphase regulator be removed from the line without interrupting the service, arrangements must be made for first connecting a spare regulator in parallel with the regulator to be removed before the latter is taken off the line. The rotors of both regulators must be turned to the same angular position and the phase rotation must be the same before they are connected in parallel. A reactor may be used instead of a paralleling regulator. The reactor is first shunted across the series windings of the regulator and then the regulator removed forcing the load current through the reactor. The reactor is then shorted out.

Fuses

61. 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

62. 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.

63. 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.

(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.

64. For circuits of class (a), a compensator is required having a range in per cent equal to twice that of the rated per cent 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

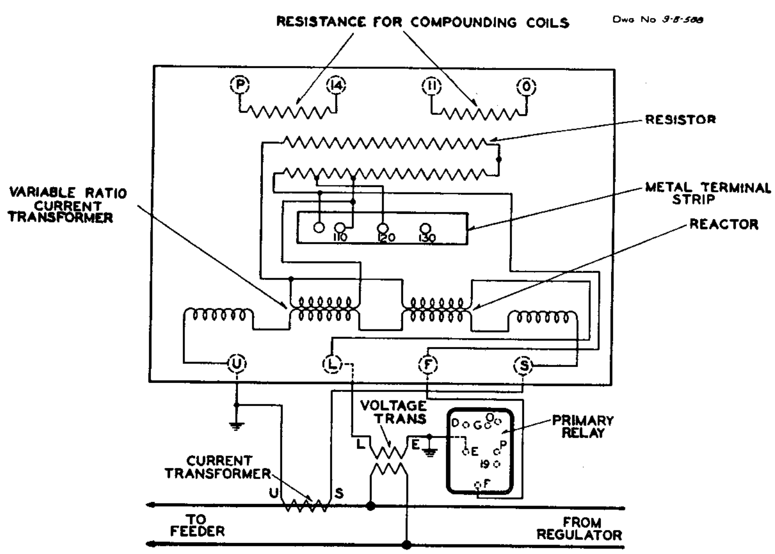

Fig. 14—Diagram of Connections for Type RC Compensator

care of the drop. The total change in the voltage of the outgoing feeder, expressed in per cent, which must be taken care of by the compensator, may equal twice the rated per cent regulation of the regulator.

65. 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.

66. The circuits of class (c) require compensators having a range in per cent equal to the maximum drop in the circuit from the regulator to the center of distribution. This per cent 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.

Type RC Compensator

67. The Type RC compensator is shown in Fig. 13. Diagram Fig. 14 shows the internal connections and method of connecting to the feeder. The compensator consists essentially of an adjustable reactor and an adjustable resistance voltage.

68. 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.

69. 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.

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

71. 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

72. 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 at 8.7 amperes 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-phase regulators are used. See Par. 41. To facilitate the operator in knowing which scale is being used, a small sliding name plate 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 name plate and slide name plate either to left or right depending on whether "lower" or "upper" is wanted.

73. 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 essential parts of the compensator.

Type RD Compensator

74. This compensator shown in diagram Fig. 15 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 additon, the compensators are wound for either 5 or 8.7 amperes. **8.7-Ampere compensators are required when the regulators are three-phase.**

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

76. The Type KC compensator is shown in Fig. 16. Diagram, Fig. 17, 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

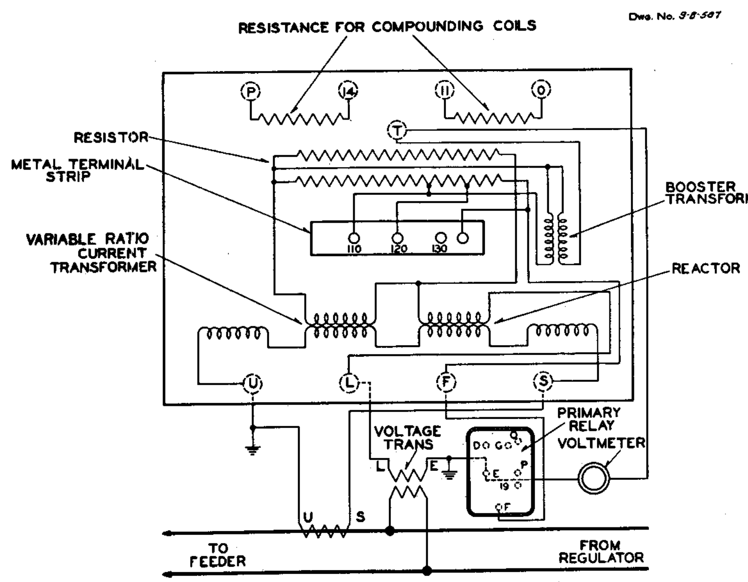

Fig. 15—Diagram of Connections for Type RD Compensator

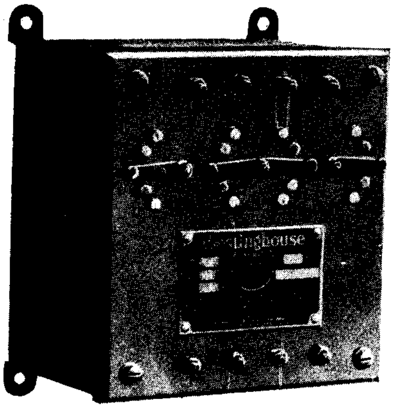

FIG. 16—TYPE KC COMPENSATOR

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.

77. 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.

78. 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.

79. 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.

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

Type KD Compensator

81. 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.

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

83. The Type KD compensator in appearance is the same as the Type KC. Diagram, Fig. 18, shows the internal connections and the method of connecting it to the line.

84. The compensator consists of a resistor and reactor with taps as shown in the diagram, Fig. 18. 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.

Outdoor Type Induction Regulators

85. 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.

86. Figures 20 and 21 show two types of three-phase out-door regulators.

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.

87. The outdoor hood on the 10 kv-a. to 120 kv-a. 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.

88. The panel is mounted in a weatherproof control box and can be swung forward for connecting the control leads

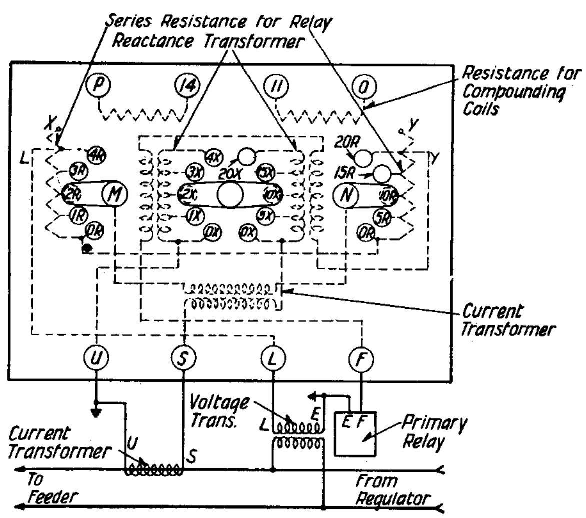

FIG. 17—DIAGRAM OF CONNECTIONS FOR TYPE KC COMPENSATOR

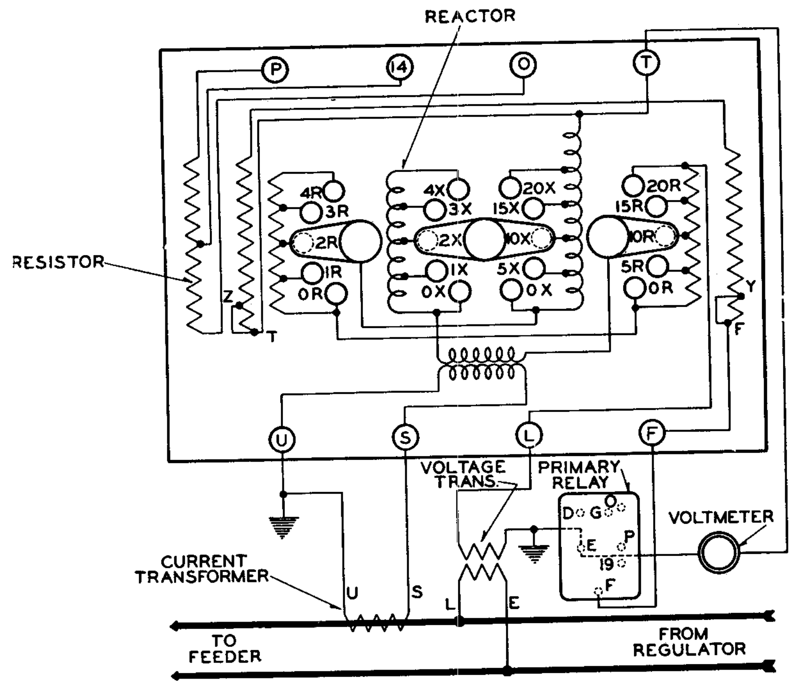

FIG. 18—DIAGRAM OF CONNECTIONS FOR TYPE KD COMPENSATOR

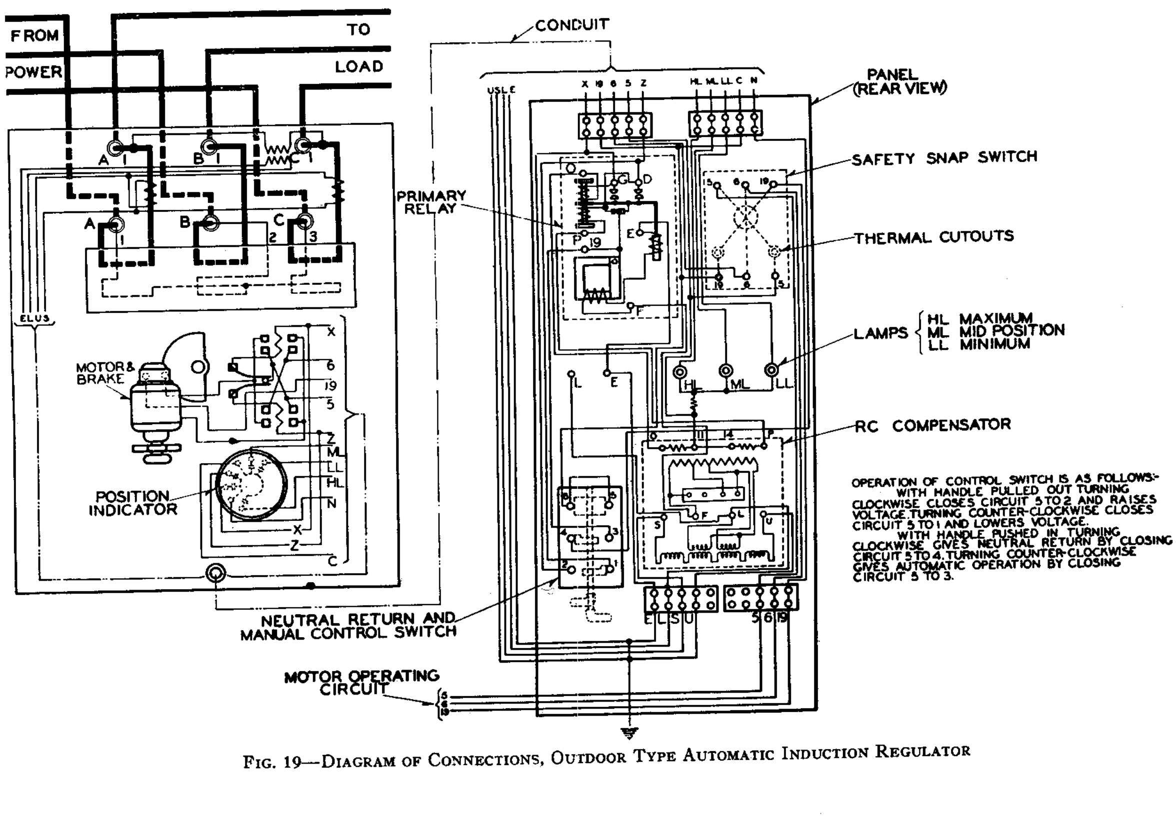

FIG. 19—DIAGRAM OF CONNECTIONS, OUTDOOR TYPE AUTOMATIC INDUCTION REGULATOR

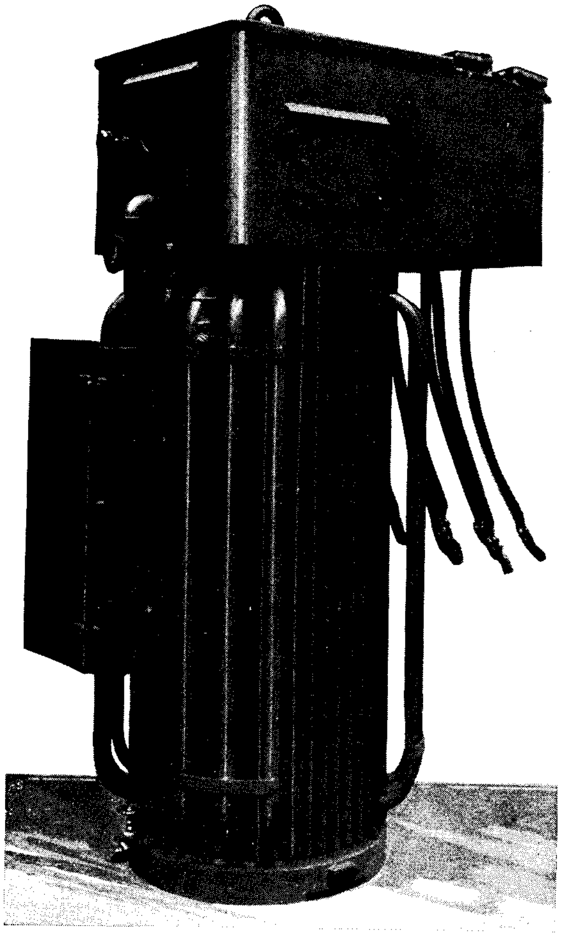

FIG. 20—OUTDOOR TYPE INDUCTION REGULATOR WITH VERTICAL BUSHINGS REMOVED AND LEADS BROUGHT OUT UNDERNEATH HOOD

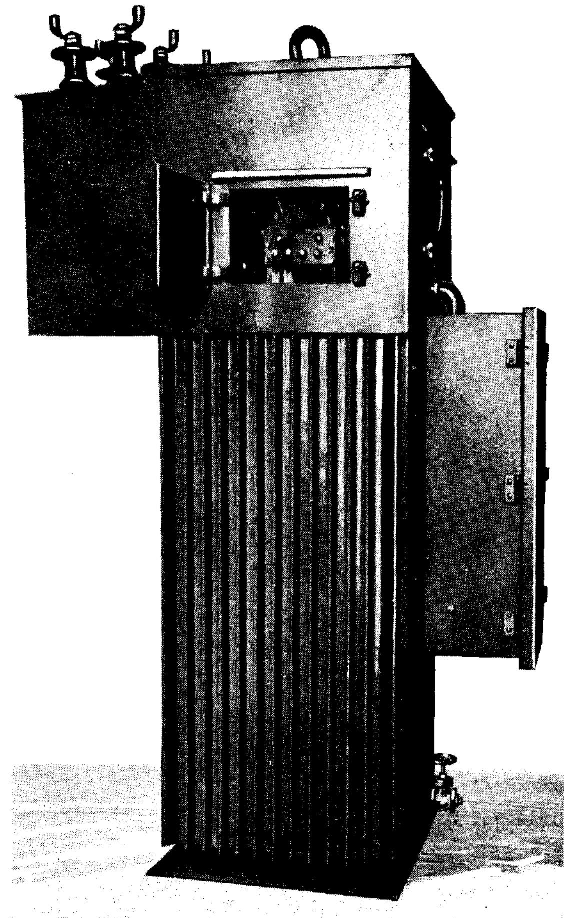

FIG. 21—OUTDOOR TYPE INDUCTION REGULATOR WITH VERTICAL BUSHINGS

by removing the two machine screws located at the top of the panel. Fig. 19 shows connections for outdoor type regulator.

Regulators with Series and Exciting Transformers

89. 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. The series transformer has the same rating as the induction regulator, 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.

Indicator

90. 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

91. 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

92. 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.

RENEWAL PARTS

This is a list of the Renewal Parts and the quantities of each that we recommend should be stocked by the user of this apparatus to minimize service interruptions caused by breakdowns. The parts recommended are those most subject to wear in normal operation, or to damage or breakage due to possible abnormal conditions.

This list of Renewal Parts is given only as a guide. When continuous operation is a primary consideration, additional insurance against shutdowns is desirable. Under such conditions more renewal parts stock should be carried, considering the severity of service and the time required to secure replacements.

Units in use up to and including		Recommended for Stock: 1	5	
Name of Part	No. Per Unit			Style No.
TYPE RC COMPENSATOR—S 697331				
Resistor tube 4000 Ohms	1	1	1	710919
Resistor tube 133 Ohms	1	1	1	760815
Resistor tube 133 Ohms	1	1	1	760856
TYPE RD COMPENSATOR—S 697332				
Resistor tube 4000 Ohms	1	1	1	710919
Resistor tube 248 Ohms	1	1	1	774791
Resistor tube 18 Ohms	1	1	1	774792
TYPE KC COMPENSATOR—S 307112-3—S 431136-7—S 462606-7				
Resistor tube 4000 Ohms	1	1	1	303003
Resistor tube 155.8 Ohms	1	1	1	316854
Resistor tube 110.2 Ohms	1	1	1	316855
TYPE KD COMPENSATOR—S 417538-9				
Resistor tube 2 Ohms	2	1	1	326285
Resistor tube .8 Ohm	1	1	1	326288
Resistor tube 4000 Ohms	1	1	1	303003
Resistor tube 133 Ohms	2	1	1	392167
TYPE KD COMPENSATOR—S 458148—S 462608-9				
Resistor tube .2 Ohms	2	1	1	326285
Resistor tube .8 Ohm	1	1	1	326288
Resistor tube 4000 Ohms	1	1	1	303003
SECONDARY RELAY—S 236633				
Moving contact with spring	4	2	4	159707
Moving contact for limit switch	2	1	2	409344
Stationary contact	4	1	2	147746
Stationary contact for limit switch	1	0	1	247288
Tension spring for limit switch	1	1	2	238715
Armature spring	2	1	2	157934
SECONDARY RELAY—S 670726				
Moving contact with spring	4	4	8	159707
Moving contact for limit switch L.H.	1	1	2	670710
Moving contact for limit switch R.H.	1	1	2	670711
Stationary contact	4	1	2	573943
Stationary contact for limit switch	1	0	1	670704
Tension spring for limit switch	1	0	1	238715
Armature spring	2	0	1	157934
PRIMARY VOLTAGE REGULATING RELAY—S 163320—S 238610—S 430944—S 455210				
Moving contact	2	4	8	163319
Stationary contact	2	4	8	163317
Spring for moving contact lever arm	1	0	1	163334
Brake Coil—220 Volts, 60 cycle for Motor S219116	1	1	1	284647-A
Brake Coil—220 Volts, 60 cycle for Motor S592158	1	1	1	573381

ORDERING INSTRUCTIONS

Name the part and give its style number. Give the complete name plate reading. State whether shipment is desired by express, freight or by parcel post. Send all orders or correspondence to nearest Sales Office of the Company. Small orders should be combined so as to amount to a value of at least one dollar, as order-handling and shipping expenses prevent us from billing a smaller amount.