Westinghouse

Graphic __________ meter

Solenoid-Operated

INSTRUCTION BOOK

For..........................Circuits

Style No.. Serial No..

............Amperes ....Volts

..........Millivolts drop across shunt terminals at.......................Amperes

...............Cycles

The complete device comprises the items that are checked below: –

Graphic Instrument

External Shunt

Two Leads for Shunt

..........External Resistors for the Element

External Resistor for Control Circuit

Recording Paper Style No................................

Calibrating Weight............................Grammes

Special Recording Ink

..................................Voltage Transformer

..............................Current Transformers

This instrument is calibrated to read full scale at..

....and to record correctly when used with paper...

Style No.........................., and Transformers having a ratio of..to

...........................ampere current, and..........................to..........................voltage.

Control Circuit..

Westinghouse Electric & Manufacturing Company

Newark Works **Newark, N. J.**

I. B. 5096

Per.. **Date**..
Inspector

INDEX

Westinghouse

Graphic Instruments

Solenoid-Operated

Unpacking

1. Unpack according to the full directions given on the paster attached to the packing box, and preserve the packing case for use in the future, whenever it may become necessary to either store or reship the instrument.

Installing

2. Carefully observe the following directions and execute them in the order in which they are given:

a—Thoroughly familiarize yourself with all the information given in this Instruction Book.

b—Remove the glass case and mount the instrument upon the switchboard or other support, using a spirit level to place it in a perfectly horizontal and vertical position. The support should be rigid or as free as possible from vibration.

c—Trace out all external electrical connections carefully and correctly according to the proper diagram. In all cases external connections are shown on diagrams as viewed from the rear of the switchboard.

d—Release the moving element and the pendulum escapement, which have been secured against motion during Shipment.

e—The dashpot cylinders are located partly within the solenoids; there are two of them; the bottom one is shown at *B*, Fig. 2. Give the cylinders a half turn and draw them downward carefully, out of the solenoids; fill each one about half-full of glycerine and replace them in their proper position. The cylinder should contain sufficient glycerine to keep the dashpot pistons completely immersed during the entire travel of the recording pen between its extreme positions; but great care should be taken to prevent any overflow of glycerine.

f—Hang the piston of the element dashpot on the movable contact arm of the element. See that the piston hangs freely without touching the sides of the cup, shown at *C*, Fig. 2. Remove the cup and fill it with glycerine to within ⅛-inch of the top, then replace it. Take care that no glycerine gets on the contacts.

g—Insert the roll of paper in the position shown in Fig. 2, with the free end of the paper outward and upward. Loosen the knurled knob *A*, at the left of the driving cylinder, and start the paper around the back of the cylinder, taking care to have the edges pass under the guides at the ends of the cylinder, and to have the driving pegs fit properly into holes in the paper. Note the proper arrangement of paper as shown in Fig. 2.

h—Hang the clock pendulum and start it swinging. Make sure that it does not strike and that it ticks evenly; an uneven ticking is due either to wrong leveling of the instrument or to an accidental bend in the pendulum escapement rod. Good results cannot be obtained if the ticking is uneven.

i—Connect the two extreme right-hand binding posts (rear view); to a control circuit of the character and voltage on the nameplate of the instrument. The control circuit in the case of alternating-current control instruments, must not be obtained from the voltage transformer supplying the element.

j—Watch for the first winding period of the clock, and see that it rewinds satisfactorily.

k—Mix the special ink with water, as instructed on the bottle, and fill the pen, using the pen-filler supplied. Remove the excess ink from the stand-pipe opposite the pen point by means of a blotter. Insert the pen in the holder and adjust its position by slipping it up or down so that it will draw a line opposite the index arrow marked on the paper end guide. Test the accuracy of this position by moving the pen by hand across the paper. The line drawn by the pen across the paper should be straight and in exact alignment or parallel to the time lines. Do not start the instrument with the pen only half full of ink. Place the metal cup provided, loosely upon open end of pen, to prevent the ink from evaporating.

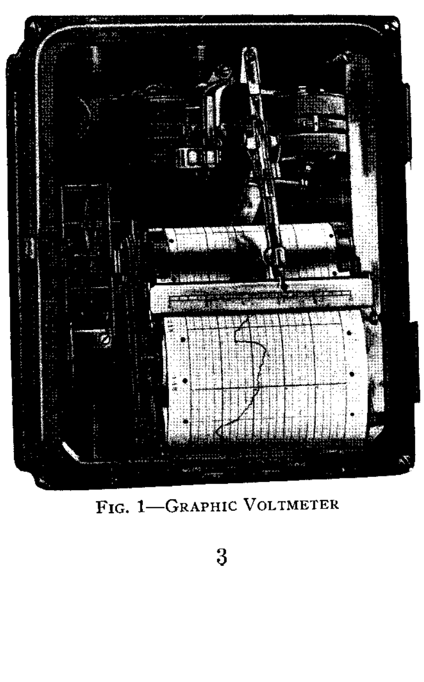


Fig. 1—Graphic Voltmeter

l—Attach the calibrating weight and see if the instrument calibration responds to the test described in paragraph 37. Test the pen for friction by moving the pen arm slightly to the right or left, and observe whether the pen point returns to within $\frac{1}{16}$ inch of its original position. If it does not, there is friction in the instrument. Examine the pivots of the movable part of the element, and clean and readjust them if necessary.

m—Remove the calibrating weight and keep it for future use.

n—Replace the glass case, taking care, in so doing, not to injure any part of the instrument mechanism.

o—Connect the remaining binding posts to the circuit to be metered.

p—**Frequency meters** should read the normal frequency, either 25 or 60 cycles, with the control circuit on and the circuit to be metered off. At this point the mechanical forces acting on the element are in balance, making the readings independent of the voltage.

To make the frequency meter reading correct at all parts of the scale and any voltage, adjust the external sliding resistor to the normal or usual operating voltage, as marked on the resistance box nameplate.

q—In installing **direct-current wattmeters** having separate series coils, the series coils should be secured to the switchboard, properly leveled according to the position of the hook, and then connected permanently to the bus-bars. After this is done, the more delicate element mechanism, which is mounted upon a separate base casting, should be hung from hooks on the series coil, and leveled.

Note:—Frequency meters and power factor meters do not have calibrating weights. Power factor meters do not have a dashpot at the movable contact of the element.

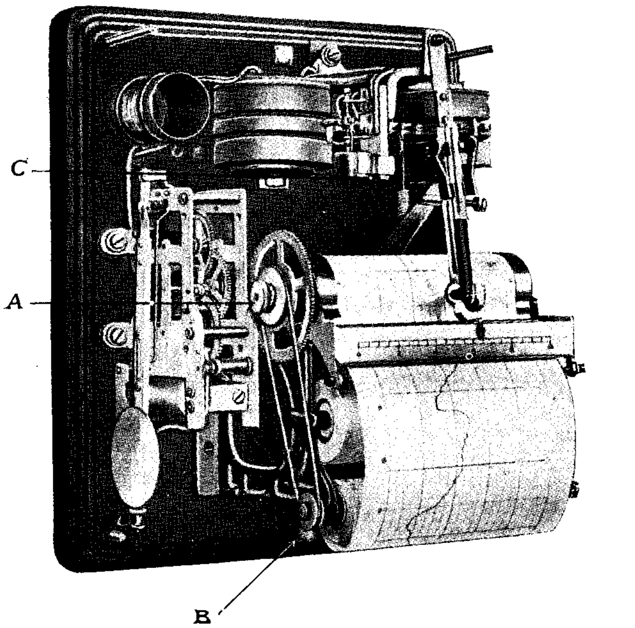


FIG. 2—GRAPHIC VOLTMETER FOR A-C. OR D-C. CIRCUITS (COVER REMOVED)

3. Graphic instruments are shipped from the Works properly calibrated and are ready to be installed. The foregoing directions for installing, if followed closely and intelligently, will insure satisfactory operation, unless the instrument has sustained injury during shipment or handling. In general, no other adjustments should be found necessary, nor ought any to be attempted without a comprehensive knowledge of the principles and construction of the instruments.

It must be thoroughly understood that these instruments are designed to make records of a degree of excellence and accuracy which heretofore has been considered impossible of attainment by this class of instruments. Therefore, they require and deserve more intelligent attention than the other forms of graphic instrument but it will be found that the amount of necessary attention has been reduced to a minimum, and the results obtained will more than compensate for what additional attention may be required.

4. Freedom from Errors—In order to prevent unnecessary inquiries, it may be stated here that these graphite instruments are free from errors due to the following electrical and other conditions, which always have been causes of inaccuracy in other types of graphic instruments:

- Changes in temperature.
- Self-hearing
- Frequency error in ammeters, voltmeters, and wattmeters.
- Effect of external fields.
- Residual errors.
- Wave-form
- Excessive energy taken from instrument transformers.
- Unbalancing in polyphase wattmeters.
- Low power factor in wattmeters.

General Description

5. General Construction—The Westinghouse graphic instruments described herein are of the relay type, and have three general elements: 1—the measuring or the element; 2—the recording element, comprising the pen and the pen actuating levers and solenoids; 3—the clock for feeding or moving the record paper.

6. The measuring element of voltmeters, alternating-current ammeters, wattmeters, and frequency meters consists of a system of fixed and movable coils, arranged in a manner similar to those of the Kelvin standard laboratory balances. They can be used upon either alternating or direct-current circuits up to the limits of their rated capacities.

The measuring elements of the power factor meters embody the **magnetic vane principle.**

The measuring elements of the direct-current ammeters are of the **permanent magnet moving coil type,** employing a set of two movable coils pivoted within the magnetic field of two permanent magnets and astatically arranged so as to be free from the influence of stray magnetic fields. Direct-current ammeters operate from external shunts of the same design as those used with the shunted type of indicating ammeters.

Detailed Description

7. General Principles of Operation The voltmeters, alternating-current ammeters, alternating-current wattmeters, and frequency meters operate upon the same principle, and differ in construction only in the windings of the measuring element, as described in paragraphs 21, 22, 24, 25 and 28. The construction of the voltmeter elements is shown diagrammatically in Fig. 3.

8. The measuring element is composed of two pairs of fixed coils, *A-B* and *C-D*, and the movable coils *E* and *F*, located between the fixed coils and mounted on the lever pivoted at *G*. The movable coil *E* is pivoted with a movable relay contact *J*, located between the stationary relay contacts *H* and *I* of the solenoid circuits of the recording element. The contacts *H* and *I* are adjustable.

9. The recording element comprises the pen-actuating solenoids *K* and *L*; their iron plungers K^1 and L^1, which are supported by the T-shaped lever arm *M*, pivoted at *N*; the pen arm *O*, connected to *U* by pin bearings *P* and provided at the upper end with a pin *R* which moves in the stationary guide slot *V*; and the recording pen *S*, arranged to pass across a suitable record paper T moved by clockwork not shown in the diagram.

10. The control spring consists of the helical spring *U* mechanically connecting the movable coil system of the element with the movable pivoted supporting arm *M* of the recording element.

11. The electrical connections are as shown in Fig. 3 the coils *A, B, C, D, E,* and *F* are all connected in series and their terminals connected to binding posts 3 and 4

The solenoid coils *K* and *L* are connected to the stationary relay contacts *H* and *I*, respectively, as shown, with their junction brought out to binding post 2. The contact *J* of the movable coil system of the element, is connected to binding post 1.

Leads from the control circuit are brought to binding posts 1 and 2, and leads from the circuit to be metered are brought to binding posts 3 and 4.

12. An external resistance is employed in the measuring circuit of all capacities and in the solenoid control circuit for potentials of 500 volts direct current, in order to eliminate injurious sparking at the contacts.

It will be noted that the connections for the clock and the motor employed to wind it, and which is operated from the solenoid control circuit, are not shown in the diagram.

13. Action of Instrument on Rising Voltage—The arrangement of the fixed and movable coils of the element is such that when the current flows through them the coil (Fig. 3) *E* is repelled by *A* and attracted by *B*, while at the same time the coil *F* is repelled by *D* and attracted by *C*. Therefore, if the contact *J* is midway between the contacts *H* and *I*, and the recording pen *S* is at zero position on the chart when connection is made to the solenoid and metered circuits through binding posts 1-2 and 3-4, respectively, the contact *J* will be forced down against the contact *I*, thus completing the circuit through the solenoid *L*, energizing the latter and causing it to pull its plunger *L*' downward, thereby turning the arm *M* about the pivot *N*. This movement of *M* swings the pen arm *O* to the right, causing the latter to move across the chart toward full scale position.

This movement of *M* also places the control spring *U* under a tension which continues to increase with the downward movement of the solenoid plunger *L*', until it balances the torque of the movable coil system *E-F*, thus drawing the contacts *I* and *J* apart, and breaking the circuit through the solenoid *L*. The line drawn by the pen during this operation represents the increase of voltage on the metered circuit.

The dimensions and weights of the various parts of the instrument and the control spring are so proportioned that the entire moving system, including solenoids, pen-actuating arms, and measuring coils, now remain stationary in the position occupied when the solenoid circuit was broken. In the meantime, the clock continues to move the record paper forward, thereby causing the stationary pen to draw a line lengthwise on the chart. This line represents the voltage which is being maintained on the metered circuit, for the time being.

If the voltage of the metered circuit continues to rise, the contact *J* is again forced down against the contact *I*, and the entire operation already described is repeated until the increased tension of the control spring *U* again balances the increased torque of the moving coils and opens the solenoid circuit, thus causing the recording system to again remain stationary until another change occurs in the voltage of the metered circuit.

14. Action of Instrument on Falling Voltage—On the other hand, if the voltage decreases, the contact (Fig. 3) *J* is forced against the upper stationary relay contact *H*, thereby completing the circuit through the solenoid *K*. This causes the latter to pull its plunger *K*' downwards, thus returning the supporting arm *M* to the left and causing the pen arm to move the pen across the chart towards zero or minimum scale value. This movement continues until the arm *M* has been sufficiently tilted up to relieve the tension on the spring *U*, thus restoring the balance between the actuating forces of the element and the spring, causing the contact *J* to leave the contact *H* and breaking the circuit through the solenoid *K*.

Thus the voltage variations in the metered circuit cause the contact *J* to move up or down between the contacts *H* and *I*, thereby making or breaking the circuit through either one or the other of the pen-actuating solenoids. The corresponding oscillating motion of the pen, combined with the uniform motion of the clock-driven record paper, results in the drawing of a line, the irregularities of which accurately represent the magnitude and duration of the voltage variations in the metered circuit.

15. Comparison with Siemens' Dynamometer—The principle of operation described is very similar to that of a Siemens' dynamometer in which the knurled thumb-nut has been turned until the torsion of the control spring has drawn the pointer attached to the movable coils back to zero, so that the pointer operated by the knurled thumb-nut will indicate the circuit voltage. The movable contact (Fig. 3) *J* of the graphic instrument corresponds to the zero-reading pointer of the dynamometer, and the solenoid-operated recording pen of the instrument corresponds to the manually-operated indicating pointer of the dynamometer.

16. The straight line pen movement necessary for securing scales having rectangular co-ordinates, is obtained by the mechanical arrangement of the solenoid supporting arm (Fig. 3) *M* and the pen arm *O*. By construction, the distances *PN*, *PS* and *PR*, are constant, and the pin *R*, rigidly attached to the upper end of the pen arm *O*, is arranged to slide up and down in the guide slot *V*.

When the supporting arm *M* is rotated upon its pivot *N*, thereby swinging the pen arm *O* either to the right or left, the movement of the pin *R* in the slot *V* gives the pen a straight line motion across the chart. The parallel motion arrangement thus obtained is extremely simple, effective, and free from friction.

17. The pen-actuating solenoids are wound for operation from direct-current circuits having nominal potentials of either 110, 220, or 550 volts, or from alternating-current circuits of 110 volts, 25 cycles and 60 cycles.

18. The control circuit voltage may vary temporarily plus or minus 25 per cent without affecting the satisfactory operation of the instrument; but suitable means should be employed to guard against greater-variations. If the direct-current bus-bars are connected to exciters controlled by Tirirll regulators, alternating-current control instruments should be selected.

When alternating-current control is used, the current should be taken from some source other than the instrument transformer. If it is essential to operate from the same voltage transformer from which the element is operated, the transformer should have a capacity of at least 100 watts.

Adjustments to Suit the Service

19. Dashpots—The motions of all the moving parts of the meter and recording elements are rendered dead beat by means of suitably arranged pistons working is glycerine dashpots. The movements of the solenoid plungers are damped by the action of pistons attached to their lower ends and working in dashpots located below and partly within the solenoid coils. One of these is shown at *B*, Fig. 2. The action of the pistons relieves the plungers of excess momentum, thus preventing them from overshooting and hunting. The magnitude of this control can be readily varied by changing an adjustable opening in the washer located just below the pistons. Quick pen action is readily obtained by increasing the size of the opening, or by using a light grade of oil; while the use of a heavy grade of oil will give extreme slowness of action on badly fluctuating loads. In general it will be found most satisfactory to have the pen travel across the paper in from 15 to 20 seconds.

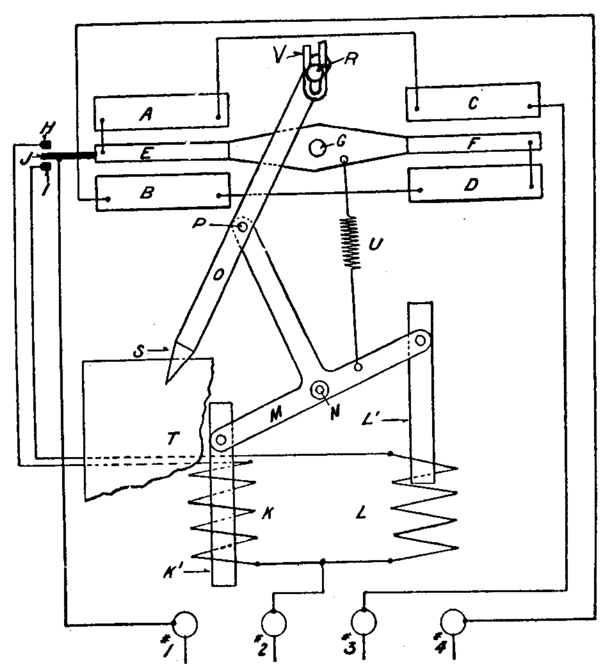


Fig. 3—Diagram of Graphic Voltmeter Elements. (Clock and Clock Control Circuit Connections Not Shown)

In all instruments except power factor meters a piston working in the dashpot shown at *C*, Fig. 2, damps the motion of the movable coils of the element, thereby preventing the movable contact from vibrating against the stationary relay contacts.

20. The sensitiveness of the instrument may be readily controlled by varying the distance between the stationary relay contacts. With the contacts adjusted close together, the line drawn on a rapidly fluctuating load will be very irregular. A more regular curve can be obtained, however, by increasing the distance between the stationary contacts.

It should be clearly understood that the accuracy of the measuring element remains constant under all conditions, and that the character of the record is the feature actually effected by varying the distance between the stationary relay contacts.

21. Voltmeters have coils wound with fine wire, connected in series with each other,and with an external resistance. They can be used on either direct-current or alternating-current circuits without error, and on any frequency. They are furnished in the following standard capacities:

90-140, 180-280, 250-450, 360-560, 450-700 volts.

For alternating - current capacities higher than 700 volts, the 90-140-volt capacity instruments may be used in connection with voltage transformer having a secondary winding of 100 volts, and a primary suitable for the circuit to be metered.

Special voltmeters of high sensitiveness, having a resistance of 50 ohms per volt capacity, are made of direct-current circuits where the instruments have to be installed in stations and operated from pressure wires brought in from points of distribution.

22. Alternating-current ammeters employ fixed and moving coils wound for 5 amperes capacity and connected in series. They can be used on any frequency. On circuits exceeding 5 amperes or 1,000 volts, the meters are operated from current transformers having 5-ampere secondaries and primaries suitable for the circuit to be metered, as follows:

A current transformer is installed with each ammeter for a capacity above 5 amperes, and a current transformer, ratio one to one, is installed with each 5-ampere meter where the potential is 1,000 volts or higher.

23. Direct-current ammeters employ a measuring system having fixed permanent magnets instead of fixed coils. The movable coils are circular and fit into annular air-gaps in the magnets. They are connected in series with each other and, through a small calibrating resistance, to the two left-hand binding posts of the instrument, from which connection is made to the terminals of an external shunt in series with the load. The shunt is the same as that used with shunted type indicating ammeters, and the movable coils operate upon the same drop, approximately 50 millivolts.

Where desirable, the shunted type of graphic ammeters can be operated from shunts of other ammeters already installed, and therefore have a very decided advantage over the series type of graphic ammeter, especially in the larger capacities, for the reason that frequently the extra busses and leads required to connect a series meter cost more than the instrument itself.

24. Single-phase wattmeters have fixed or current coils identical with those of alternating-current ammeters, and are operated from current transformers in the same manner. The movable or potential coils are wound with fine wire connected in series with each other, and through an external resistance are connected across the circuit to be metered. These instruments are correct on any frequency, and are supplied in the following capacities: 5 amperes and 100, 200 or 500 volts.

A current transformer is required with each instrument of more than 5 amperes capacity and a voltage transformer on potentials above 500 volts.

25. Polyphase wattmeters have fixed or current coils of the same capacity windings as the single-phase instruments and alternating-current ammeters, but these coils are connected in two groups. The left-hand pair of fixed coils are connected in series with each other, and the terminals are connected to the secondary of one current transformer whose primary is in series with one phase of a polyphase system. The right-hand pair of fixed coils are similarly connected, but they are operated from a transformer connected in the opposite phase of a two-phase, or one of the remaining phases of a three-phase system.

The movable or potential coils are similar to those of the single-phase instrument. They are arranged in two circuits—the left-hand coil connected, through an external resistance, to the same phase as the left-hand current coils, and the right-hand coil similarly connected to the same phase as the right-hand current coils. This arrangement gives two magnetically independent measuring systems, operating a common movable contact.

These instruments can be used on any frequency, and will correctly register the energy of a polyphase system regardless of how badly the system may be unbalanced. They are furnished in the same capacities as the single-phase instrument, and are also equally accurate on single-phase circuits.

Since polyphase wattmeters have only three voltage binding posts, they cannot be used on two-phase interconnected circuits without the employment of a voltage transformer, so as to permit of the two phases being connected together at the common voltage binding post.

26. General Note on Alternating-Current Wattmeters—The maximum standard capacities are 5 amperes and 500 volts.

On circuits in excess of 5 amperes and not exceeding 600 volts, use 5-ampere meters of proper potential in connection with current transformers having a primary suitable for the circuits to be metered.

On circuits of all capacities exceeding 600 volts, use 5-ampere 100-volt instruments, with the necessary current and voltage transformers.

Polyphase instruments require two current and two voltage transformers, except for six-phase and four-wire three-phase circuits, where three instead of two current transformers, are required.

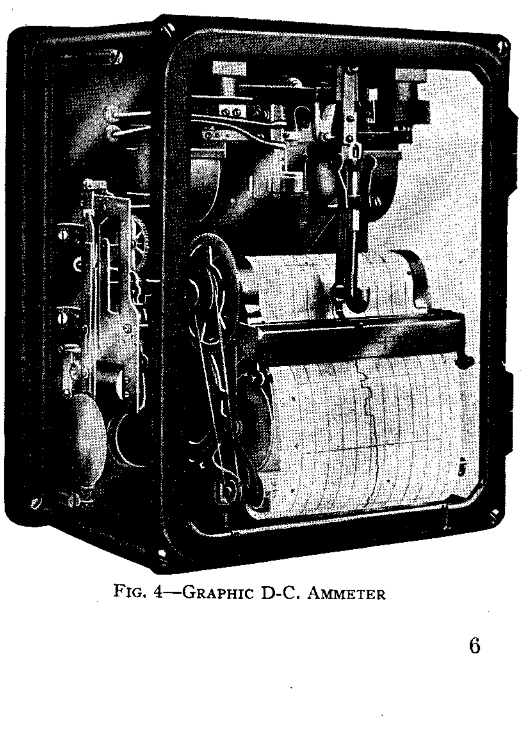


FIG. 4—GRAPHIC D-C. AMMETER

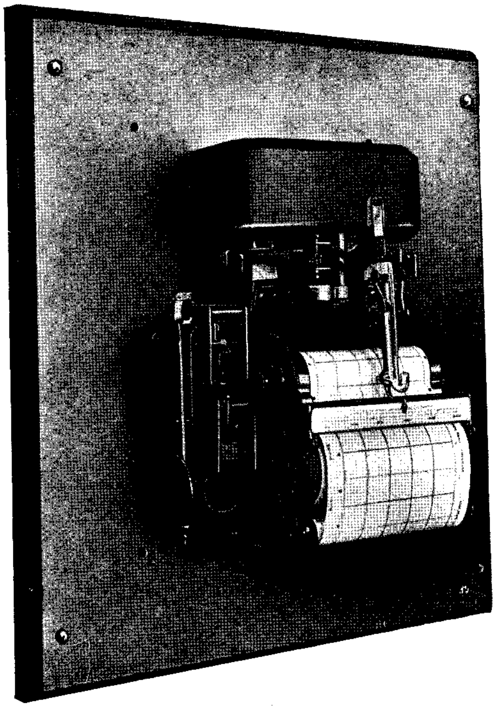


FIG. 5—GRAPHIC D-C. WATTMETER 10,000 AMPERES, 500 VOLTS (COVER REMOVED)

If necessary, the instruments may be used on circuits of potentials 25 per cent above or below the normal rating of the instrument.

27. Direct-current wattmeters are similar to the alternating-current wattmeters, except that the current coils are designed to carry the total current. The heavy capacity instrument, Fig 5, is designed and constructed to obviate the usual troubles experienced with direct-connected switchboard instruments, such as the inconvenience of handling due to heavy circuits, the great difficulty of recalibration, the amount of labor involved in removing the instrument for making repairs, and the necessity of interrupting the circuit.

The element, complete with clock, voltage coil, and pen and paper-actuating mechanism, are mounted upon a separate base, hung from the current coil. This arrangement permits of the removal of the instrument proper from the circuit for repairs, recalibration, etc., without disturbing the current coil, which is left in place on the switchboard. The glass case is independently mounted on the marble, and encloses both the current coil and the element.

A record of the calibration and the value of the magnetic field produced by the current coil is kept at the Works; therefore, if at any time it should become desirable to send the instrument to the Works for recalibration or repairs, all that is necessary to send is the removable element without the current coil.

These instruments are furnished in standard capacities from 10 to 30,000 amperes for potentials of 100-125, 200-250, and 500-650 volts.

Special instruments supplied for three-wire systems have the same kilowatt capacity, but one-half the ampere capacity of the regular instruments.

28. Frequency meters are of the same type of construction as voltmeters, except that the coils are wound differentially in two circuits and connected to an external resistor comprising an inductive and a non-inductive circuit. The current in the non-inductive circuit is independent of the frequency, and the current in the inductive circuit varies inversely with the frequency. Therefore, the relative pulls of the instrument coils change as the frequency varies, thus causing the moving coils of the element to maintain contact until the movement of the pen-actuating element places sufficient tension on the control spring to equalize the forces acting on the moving coil system and thus break contact.

The control spring and the counterweight on the moving element are so related that when the element circuit is open and the control circuit is on, the pen remains stationary at the normal frequency point (25 or 60 cycles as the case may be.) This feature renders the instrument absolutely independent of voltage variations at or near the point of normal frequency,

A calibrated adjustment is provided on the external resistor, which should be set as marked, to suit the normal or average voltage of the alternating-current system, and thus make the instrument readings correct at all parts of the scale. Varying this resistance when frequency is normal will have no effect on the reading.

Frequency meters are supplied for frequency ranges of 21-29 cycles for 25-cycle circuits, and 52-68 cycles for 60-cycle circuits.

The element is always wound for 110 volts, normal.

A voltage transformer is required on potentials above 125 volts.

Special instruments are supplied for use on 30, 40, and 133-cycle circuits.

29. Power factor meters have the same general construction as the other instruments, but the element differs.

The single-phase element is shown in Fig. 7. It consists of three stationary coils, *A*, *B*, *C*, and a moving system comprising an iron armature *E*, rigidly attached to a shaft *G*, suitably pivoted and mounted on jewel bearings. A light arm on the armature shaft *G* carries a contact which plays between the stationary adjustable contacts *H* and *I*, carried by the arm O_1 and connected in the circuits of the solenoids *K* and *L*.

The coils *A* and *B* are potential coils, placed at right angles to each other with their axis in the same vertical plane. The coil *C* is a current coil, located within the potential coils with its axis in a horizontal plane at right angles to the axial plane of the potential coils. Acting under the influence of the fields of coils *A* and *B* it serves to magnetize the iron armature *E*, attached to the shaft *G* which carries the movable relay contact for making and breaking the solenoid circuits as already explained in the case of the voltmeter, paragraphs 13 and 14.

30. Electrical Connections, Single-Phase Power Factor Meter—The internal connections are as shown in Fig, 7. The potential coils *A* and *B* are wound with fine wire and connected in split-phase relation, through reactor *Y* and a resistor *X*, respectively, and the two circuits are brought out to the binding posts 3 and 4 for connection with the metered circuit,

The current coil *C* is wound with wire of 5 amperes capacity. It is non-inductive and its terminals are brought out to binding posts 5 and 6, for connection with the metered circuit.

The terminals of the pen-actuating solenoid circuit are brought out to binding posts 1 and 2.

The external connections are shown in Fig. 19, the potential and current coils being connected to the line through suitable voltage and current transformers, respectively, and the pen-actuating solenoid circuits connected to the control circuit through a suitable series resistance.

31. Action of Single-Phase Power Factor Meter—With the instrument connected as shown in Fig. 7, the current

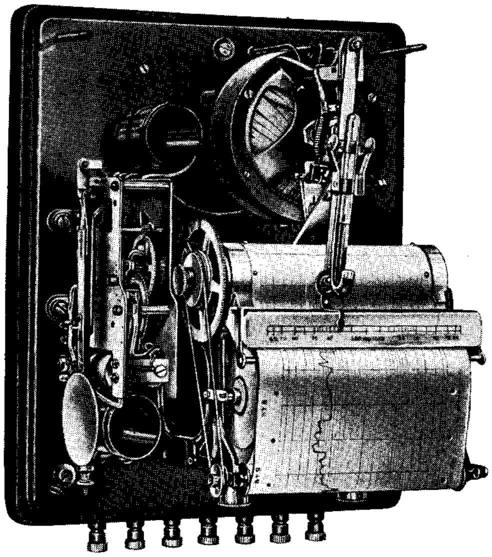


FIG. 6—GRAPHIC POWER FACTOR METER (COVER REMOVED)

in coil *B* will be in phase with the voltage of the metered circuit, and the current in coil *A* will lag approximately 90 degrees behind the current in coil *B*, owing to the impedance of the reactor *Y*. Consequently the current in *B* will be a maximum when the current in *A* is zero, and *vice versa*, thereby producing a rotary magnetic field having a speed of rotation depending upon the frequency of the metered circuit.

The effect of this rotary magnetic field on the armature *E*, operating the movable contact for making and breaking the solenoid circuits, is as follows: Since the coil *C* is non-inductive and connected in series with the circuit, its current will be in phase with the voltage of the metered circuit, and under the influence of the fields of coils *A* and *B* the armature *E* will assume a position in which the zero of the magnetizing field will coincide with the zero of the rotary field. Thus, if the current in *C* is in phase with the current in *A*, the axis of the armature will be parallel to the axis of *B*; and if the current in *C* is in quadrature with the current in *A*, the axis of the armature will be parallel to that of *A*. It is evident that a zero rotary field can occur at any point between the maximum and zero currents in the coil *A*, thereby causing the armature to assume a position with its axis at an intermediate point between the extreme positions defined above, depending upon the phase relation between the currents in the two circuits.

The line drawn by the recording pen in response to these movements of the meter element armature represents in degrees the magnitude of the phase displacement between these two currents.

32. The two-phase power factor element is shown in Fig. 8. It is similar in construction to the single-phase element, except that the coils are transposed in position. In other words, the outer coils are current coils wound with wire of 5 amperes capacity, and the inner or magnetizing coil is a potential coil, wound for 100 volts.

The small diagram on the right shows the position of the armature *R*, the armature shaft *G*, and the movable contact *J*.

The two-phase instrument has seven binding posts. The coil *A* is connected to post 5, the coil *B* is connected to post 4, and their common connection is brought out to post 3, as shown. The other internal connections are similar to those of the single-phase instrument.

33. The three-phase power factor element is shown in Fig. 9. It is similar to the two-phase element, except that three instead of two outer or current coils are employed. These coils are placed with their axis 60 degrees apart, in the same vertical plane, and are *Y*-connected. With this arrangement of the current and voltage coils the *power factor recorded* by the Westinghouse instrument is based on the value of the *average angle of lag* between the currents and voltages in the polyphase circuit, instead of being merely a record of the displacement of only one of the phases as in the case with instruments of other makes.

34. Transformers for Power Factor Meters—All power factor meters have current coils wound for 5 amperes capacity and potential coils for 100 volts.

Above 100 volts one voltage transformer must be used with each instrument.

All single-phase instruments above 5 amperes capacity require one current transformer.

Two current transformers must be used with all capacities of two-phase and three-phase instruments.

The instruments attain their highest accuracy with from 3 to 5 amperes flowing in the current coils and with 75 to 125 percent of normal voltage. Therefore, the current and voltage transformers used should be of sufficient capacity to give secondary values within the above limits as nearly as possible. The transformers may be either the switchboard or the portable type.

Under these conditions the instruments will record true power factor within an electrical angle of 2 degrees, but the record will not be so reliable when the currents are less than 2 amperes.

Accuracy of Graphic Instruments

35. Limits of Allowable Error—These instruments are adjusted at the Works to operate within the following limits of accuracy, which, owing to the excellence of their construction they will retain unimpaired for long periods of service:

Voltmeters—Accurate within **1 percent** of reading at all points.

Direct-Current Ammeters—Accurate within **1 percent** of full scale value, considered as a millivoltmeter.

Alternating-Current Ammeters—Accurate within **1 percent** of full scale value.

Wattmeters—Accurate within **1 per cent** of full scale value.

Power Factor Meters—Accurate within **2 degrees** of reading at all points.

Frequency Meters—Accurate within **1 percent** of reading at all points.

Calibration of Graphic Instruments

36. The accuracy of graphic instruments can be checked by comparing them with known standards in the same manner as indicating instruments.

The calibration of graphic **voltmeters, ammeters,** and **wattmeters** can be varied by changing the distance of the control spring from the center of the movement.

The lateral position of the scale or the zero can be varied by changing the position of the counterweight on the moving element.

The adjustments of the lower end of control springs are for the purpose of varying the proportionality of the scale, and, therefore, should not be disturbed except for that purpose.

37. Self-Calibrating Weight—This is a small weight furnished with **voltmeters, alternating-current and direct-current ammeters,** and **wattmeters,** and is stamped with the serial number of the instrument. It affords a convenient means of checking the instrument calibration to determine whether or not it has changed under the influence of mechanical causes, and also provides a simple means of recalibration.

This weight should be used as follows: Make sure that the instrument reads zero with only the control circuit on; then attach the weight to the small hook on the left-hand moving coil. This should cause the pen to move to the right and stop at a *point exactly 2⅝ inches from zero.* Then, when the pen is deflected either to right or left, by hand, it should return to that point, within the limits of allowable error prescribed in paragraph 35.

If the pen fails to stop at the point specified, it indicates that the calibration has changed and must be corrected. This can be accomplished by means of the calibrating weight, provided the movable parts have not been damaged in shipment, as follows:

With the **calibrating weight on,** readjust the position of the control spring so as to make the pen stop at the point specified, and at the same time adjust the balance weight so that the instrument will read zero with the **calibrating weight off.**

38. Notes on Self-Calibrating Weight Method—The following facts should be noted in this connection:

a—The movement of the pen to the point exactly 2⅝ inches to the right of the zero line of the record paper brings it exactly to the middle of the paper, but not necessarily to the line representing the middle value of the capacity markings in the case of alternating-current and direct-current-voltmeters, and alternating-current ammeters, in which the scales are not uniform.

b—In the case of voltmeters, the suppression of the zero makes the graduation line on the extreme left correspond to the zero line of the other instruments.

c—The calibrating weight method of correction is not applicable where the changes in calibration are due to accident such as short or open circuits in the windings. Such changes are of very rare occurrence, however, and generally manifest themselves in other ways also. Furthermore, the weight will not calibrate the instrument if a wrong series resistor has been employed. This fact can be ascertained by comparing the serial numbers on the instrument and the resistor.

d—As a general rule, if the instrument correctly responds to the calibrating weight test, etc., its indications may be thoroughly relied upon, and errors which may be manifested subsequently would be traceable to improper connections or applications, or to lack of proper attention to the instructions accompanying the instrument.

e—After the work of calibration, the calibrating weight should be removed and the instrument operated without the same. The weight should be carefully put away for future use, and record of its weight in grammes should be made so that it can be duplicated in case of loss.

39. Direct-current series type wattmeters can be sent to the Works for recalibration or repairs at any time, without removing the current coil or interrupting the circuit. An exact duplicate of the current coil of each instrument is kept at the Works for use in recalibration; therefore, the complete element only, together with its base and the clock, need be returned.

40. Frequency Meters—The proportionality of the scale or range of reading is varied by alternating the position of the top of the control spring, thereby varying its effective strength. The lateral location of the scale, as a whole depends upon the extension of the spring and the position of the counterweights, which should be so related to the spring extension as to cause the pen to assume the position of normal frequency: 25 or 60 cycles; with all the element binding posts disconnected.

However, if the instrument fails to read thus correctly, read the description of the principle of operation of frequency meters given in paragraph 28, and proceed as follows:

a—Observe whether or not the instrument increases its reading with an increase in frequency. If it fails to do so, the external resistor has been improperly connected, and the leads between it and the instrument should be transposed in position.

b—If the readings are incorrect in other respects, disconnect the three element binding posts, leaving the control circuit binding posts on. When this is done, the pen should move to the position of normal frequency; for example, to the 60-cycle line if the instrument is one designed for 60-cycles. If it fails to do so, the counter-weight on the moving coil should be shifted until the pen will assume the position of normal frequency.

c—Now see that the external sliding resistor is adjusted to the point marked as corresponding to the normal voltage of the circuit. Reconnect the element binding posts to the circuit. The instrument should now read correctly.

d—If there are errors in the readings at points near the ends of the scale, but not near the normal point, with the external resistor correctly set and the instrument reading the normal frequency with the element finding posts disconnected, as explained in *b* and *o*, the trouble may be corrected by shifting the upper end of the control spring, thus changing the scale proportionately, and then calibrating to bring the normal point to the correct position. Moving the spring away from the center will tend to **condense the**

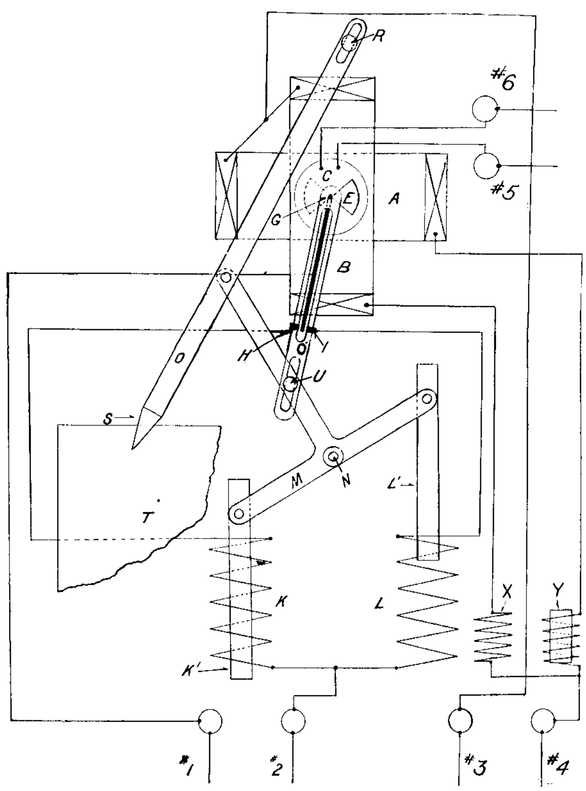


FIG. 7—DIAGRAM OF GRAPHIC SINGLE-PHASE POWER FACTOR METER ELEMENTS

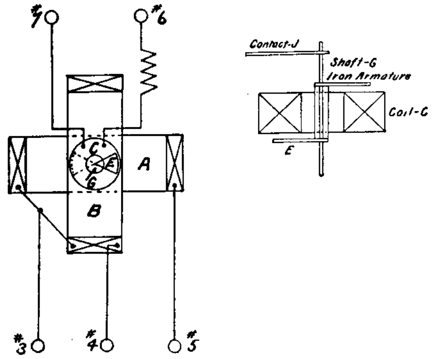


FIG. 8—DIAGRAM OF MEASURING ELEMENT OF A GRAPHIC TWO-PHASE POWER FACTOR METER

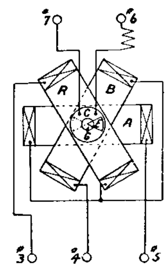


FIG. 9—DIAGRAM OF THE ELEMENT OF GRAPHIC THREE-PHASE POWER FACTOR METER

scale or bring its outer points nearer normal; while moving the spring toward the center will tend to **expand the scale.**

41. Power factor meters are recalibrated by balancing the element mechanically and then shifting the position of the contact arm on the armature shaft.

Either a portable instrument or a switchboard instrument should be connected in circuit to obtain a comparison, but if such an instrument is not available, the power factor may be determined by reference to the readings of the wattmeters, ammeters, and voltmeters in the same circuit.

In this connection it will be understood that these instruments measure the average angle of lag of the phases of the circuit and indicate the cosine of that angle, or a value that is slightly different from the true average power factor of the circuit, which is the ratio of the real and apparent watts obtained from the ammeter, voltmeter, and wattmeter readings. The difference between the two values is so small, however, that it is negligible.

For satisfactory operation a power factor meter should have at least 2 amperes flowing in the current coils. (See Paragraph 34.)

Clock Adjustments

42. Running Condition—The clock movements are similar to those used by the Western Union Telegraph Company on their time service circuits, and are, therefore, familiar to all clock repairers who do the work for that company.

In order to maintain their time-keeping qualities, the following facts and directions should be carefully observed:

a—The clock of graphic instruments are sent out completely wound and may be started as soon as the pendulum is attached. In operation, they are wound automatically by a small motor which is mounted in the lower part of the clock frame.

b—If a clock is allowed to run before connecting up the control circuit, it will stop at the end of two winding periods. However, as soon as the control circuit voltage is applied the clock will wind itself completely, and may be restarted by swinging the pendulum.

c—The clock winds itself regularly, once, twice, or four times every hour, according to the rate or paper feed employed; but if the control voltage happens to be off at any winding period, the clock will continue to run to the next winding period, and then rewind completely. If the control voltage is off at the next succeeding winding period, the clock will repeat this action; or, in other words, it will continue to run for two winding periods before stopping, but it will not rewind itself at any time unless the control voltage is on.

d—If the clock fails to wind itself when the control circuit voltage is applied, first make sure that the voltage of the control circuit is correct, then proceed as follows: Open the control circuit and allow the clock to run down. Observe the position of the winding contacts. If they are closed they are in the correct winding position and the clock should rewind itself when the control circuit is closed. However, if the clock fails to rewind, the cause of the trouble will be elsewhere than at the winding contacts, especially if the position of lower contact spring is such as to give sufficient gap to interrupt the arc formed upon breaking contact.

e—If the clock fails to run at all, disconnect the paper-driving cylinder by loosening the thumb-nut *A*, Fig. 2, and observe whether or not the pendulum swings freely and if the escapement ticks loudly and regularly. If the clock continues to run perfectly with the paper roll disconnected, the stopping is due to excessive friction in the paper-driving mechanism.

f—However, if the clock fails to run continuously when freed from the paper-driving mechanism, disconnect the control circuit, remove the pendulum escapement pallet, and carefully allow the clock to unwind, by letting the escapement wheel rub against the finger. The clock should stop with the contacts in the winding position, as specified in *d*. If it fails to do so, move it around until it closes the contacts and is just ready to re-open them. Replace escapement pallet and pendulum and apply the control voltage. If the spring fails to wind up two full revolutions, the rectification of the trouble will require the services of an expert. Substitute a spare clock and send the one out of order to the Works for repairs. In general, it should be observed that the ticking of the clock is always loud and regular when driving the paper.

43. Adjustment of Winding Circuit Contacts—When the center winding cam comes in connection with the lower contact springs, the end of the latter should be about $\frac{1}{32}$ inch from the edge of the incline. After winding, the upper contact spring should always clear the lower one by $\frac{1}{32}$ inch. When these springs touch each other, they should be perfectly parallel.

44. Cleaning and Oiling Clock Movements—The construction of the movements is such that all parts needing periodical cleaning and oiling can be reached without the necessity of dismantling them. In cleaning, proceed as follows:

a—Brush all the bearings and pivot holes thoroughly with benzine, using a stiff marking brush. Allow the benzine to soak in for about two minutes, then blow off all of it. Apply fresh benzine, and at the expiration of one or two minutes more, blow off all of it as before. This procedure will force all the old oil out of the holes on to the surface of the plates.

b—Wrap a piece of cheesecloth around a small piece of flat wood, and clean the dirty benzine and oil off the plates and arbors, then apply fresh clock oil to all the pivots and bearings. Replace the dial train, heart-shaped seconds socket, and synchronizing lever if used, and observe that motor and center winding contact springs are clean and free from benzine or old oil.

c—If for any reason it should become necessary to take the movement apart, *do not start the screws in the back plate.* Remove the front plate only. When taking out center arbor, be careful the center winding contact knockaway pieces do not drop off the arbor. If they do, put them back with one-and-a-half or two turns taken up on the main spring.

45. Synchronizing Attachment—When required, a synchronizing device can be supplied for connecting the instrument clock with a master clock or other time circuit. It consists of an electric magnet energized from the circuit controlled by the master clock, which absolutely compensates for any variation from the normal in the running of the instrument clock. By the use of these devices any number of instruments in the same station or upon the same system can be kept running synchronously.

Ink, Pen, and Paper

46. The ink furnished for use with these instruments is made from intense aniline dye. For convenience it is shipped in concentrated form, and must be diluted with pure water before using. A green color has been chosen because it contrasts favorably with the red graduation lines on the record paper and holds in solution a minimum of solid matter for a given intensity of record line.

Other colored ink made from aniline dyes may be used at the discretion of the operator, but, of course this Company cannot be responsible for the results obtained.

Ordinary fountain pen or commercial inks should never be used, because they contain too much solid matter and other impurities.

47. The recording pen is constructed of glass and of such capacity that one filling is sufficient for several weeks use. The pen point is a capillary tube of iridium alloy of heavy wall and small bore, giving maximum strength with minimum width of line. It feeds by capillary attraction.

48. Method of Filling the Pen—Fill the special filler provided for this purpose with ink. Invert the pen and insert the special filler in the open end of the tube located behind the pen projection, and force in ink until the glass tube is full. Now right the pen in position, close the open end of the tube, and place it in the holder on the instrument. In so doing, take care not to drop the pen point against the driving cylinder, otherwise it may become broken and consequently useless. Remove all excess ink from the glass tube by means of a blotter.

Should the pen happen to become clogged by the ink drying up in the capillary tube, the latter can be readily cleared by inserting a fine wire.

If the pen oscillates rapidly, thereby tending to wear through the paper, its action must be modified by increasing the distance between the stationary solenoid contacts and also by slowing up the action of the solenoid dashpot pistons, as explained in paragraphs 19 and 20.

49. The record paper is of specially calendered and ruled grade. It is furnished in rolls, each having a strip of paper 248 feet in length, which is sufficient for making continuous records for 62, 31, and 15½ days at the standard rates of feed of 2, 4, and 8 inches per hour.

The paper is 6¾ inches wide and provided with perforations along both edges for engagement by the pins projecting from the surface of the driving cylinder, so as to insure a perfect alignment of the graduation lines on the paper with the lateral motion of the recording pen.

50. The graduation lines on the paper form a system of rectangular coordinates, consisting of two sets of parallel lines ruled at right angles to each other. The lines running lengthwise of the paper represent the instruments calibration, the spacing of the lines and the markings being different for the various types and capacities of instruments. Where the capacity markings differ from those of the standard paper, the former is obtained from the instrument regularly supplied by the addition of shunts and instrument transformers.

The lines ruled across the paper or at right angles to the calibration lines represent time intervals. On standard paper the lines are 1 or ¾ inch apart and represent 30, 15 or 10 minutes respectively, on the paper fed at 2, 4, or 8 inches per hour.

51. The record paper scales are 5¼ inches in length, and their distribution is uniform in wattmeters and direct-current ammeters. The scales in alternating-current ammeters, power factor meters, frequency meters, and voltmeters, although not entirely uniform, have a very uniform distribution over the working part.

52. Special paper for use on very high rates of feed can be obtained for experimental and test purposes, with only the capacity figures on and the time figures omitted. If necessary, the time can be marked in by hand while running test.

53. Extra high rates of feed can be provided for in connection with the clock feeding at the regular rates of 2, 4, and 8 inches per hour by the employment of a device for throwing the pendulum escapement out of gear and throwing in a high-speed escapement. The paper used in this connection may be either special paper without time or capacity markings, or the standard paper, the time markings thereon being disregarded and the time corresponding to the test intervals marked in pencil.

This arrangement for obtaining high-speed records is useful for special experiments, motor performance tests, and investigations relative to the operation of hoists, machine tools, etc.

54. Blue-Prints—The paper is of such a thin and tough texture that it can be used readily for reproducing the pen records by blue-printing or other similar processes.

55. Paper-Collecting Roll—Where it is desirable to remove the records at least once every week at two inches per hour feed, the paper-collecting roll may be used with advantage. Otherwise, the paper should be fed out through the slot in the instrument case and into a basket, as is the practice with stock tickers.

The collecting roll is not intended to wind up tight, but merely to properly roll up the paper as fast as the record is made.

Care of Contacts

56. The contact mechanism is so designed as to make the action as nearly as possible free from variation. The contact points of a movable contact are carried by a swiveled piece, producing a wiping effect on the contact surfaces, thus automatically keeping them clean and preventing "freezing" or poor contact.

The outer end of the movable contact arm carries a piston which works in the glycerine dashpot provided for damping the movements of the movable coils of the element, as explained in paragraph 19. It is important to keep the contacts free from all traces of glycerine, as its presence causes a black deposit to form on the contact points, resulting in pitting or excessive wear of the points. Contact points showing any trace of such a deposit should be carefully cleaned with cloth dipped in gasoline, and polished with the finest "crocus paper" or emery paper. With reasonable care the contact points should last indefinitely; but any points that should happen to become badly pitted should be replaced with new ones at once.

Causes of Unsatisfactory Records

57. Sluggishness of action, indicated by the record not showing actual variations in load, may be due to one or all of the following causes: *a*—Friction in the movable system of the element; *b*—friction in the pen-actuating mechanism; *c*—dirt on the contact points; *d*—excessive vibration.

a—Friction in the movable system of the element can best be detected by noting whether or not a slight deflection of the pen, say ⅛ inch, will cause a motion of the movable contact. If it does not, friction is present and should be eliminated by an experienced instrument man.

b— Friction in the pen-actuating mechanism is readily detected by removing the glycerine from the dashpots, the control circuit being off.

c—If the contact points touch mechanically but do not complete the circuit, the contact points are dirty and should be cleaned, as directed in paragraph 56.

d—Excessive vibrations, such as those called *frequency pulsations* due to the proximity of alternating-current machines, may prevent current from flowing in the solenoid coils, as the self-induction of the circuit will not allow sufficient time for the control current to magnetize the solenoid plungers. This trouble can be readily detected by the sense of touch, and can be corrected only by mounting the instrument in a place free from vibration.

53. Overshooting or exaggeration of variations in the metered circuit may be due to the following causes: *a*—Too quick an action of the pistons in the solenoid dashpots; *b*—dirt on contacts; *c*—friction in the movable system of the element. These faults can be remedied as explained in paragraph 57.

59. Pumping—A periodic motion of the pen, not accounted for by the actual variations in the metered circuit, may be due to the following causes: *a*—Lack of balance in the pen-actuating mechanism; *b*—stationary contacts adjusted too close for the character of the circuit; *c*—dirt on contacts; *d*—friction in the element; *e*—too quick an action of the solenoid dashpot pistons; *f*—too high a voltage on the control circuit.

60. Incorrect Registration—If the instrument responds properly to the calibrating weight and is correct mechanically, incorrect registration may be due to the following causes: *a*—Incorrect setting of the pen in the holder; *b*—use of incorrect series resistor; *c*—use of incorrect shunt (direct-current ammeters); *d*—incorrect transformer connections (particularly important in polyphase wattmeters and power factor meters); *e*—use of voltage or current transformers having different ratios from those for which the instrument is calibrated.

61. Correspondence relative to unsatisfactory operation of graphic instruments, with the Westinghouse Company, should state all the facts as fully as possible, and give sufficient data to enable the Company's engineers to locate the cause of trouble. Always send a sample chart or record, showing the trouble in question.

Repairing

62. Repairing can be done most satisfactorily at the nearest Westinghouse service station. Interchangeable renewal parts listed on this page can be furnished, however, and customers equipped for doing repair work will find that the construction of the instrument facilitates this.

Recommended List of Renewal Parts

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 damage or breakage due to possible abnormal conditions. The maintenance of such stock will minimize service interruptions due to breakdowns.

Style No.	Name of Part	No. per Instrument	Recommended Stock for 10 Duplicate Instruments	20	30	40	50
......	*Clock	1	1	1	1	2	2
108505	Upper Main Contact of Clock	1	1	1	2	2	3
108506	Lower Main Contact of Clock	1	1	1	2	2	3
124900	Moving Contact Complete—Except for Power Factor Meters	1	2	4	8	10	12
......	‡Clock Winding Motor	1	1	1	2	2	3
148367	Brush for Clock Motor	2	4	4	6	6	10
148366	Brush Spring	2	4	4	6	6	10
122429	Glass Pen	1	2	2	3	5	10
72449	Rubber Pen Filler	1	1	2	3	4	5
122429	Capillar Reservoir Pen	1	1	1	1	2	2
122430	Holder for Pen (Style No. 122429)	1	1	2	3	4	5
108067	Green Ink in Concentrated Form	1	10	20	30	40	50
......	†Solenoid Coil	2	2	2	4	6	8
72442	Dash Pot Cylinder	2	0	0	1	2	2
105159	Stationary Contact	1	4	4	6	8	10
296324	Brush for Control Motor	2	4	4	6	6	8
269194	Leather Belt for Reroll	1	2	2	2	4	6
219079	Pen Cleaning Wires	1 pkg.	2	4	6	8	10

*—Clock suitable for driving paper at the rate of 2, 4, 8 or 24 inches per hour, Style No 124982.
Clock suitable for driving paper at the rate of 4 inches per hour, Style No. 124981.
Standard clock for driving paper at the rate of 2 inches per hour, Style No. 124980.

‡—Clock winding motor, 60 cycles, 110 volts, for any of above clocks, Style No. 124983.
Clock winding motor, 25 cycles or direct current for any of above clocks, Style No. 124984.

†—Solenoid Coil for 110-Volt, 25-Cycle Control, Style 72446.
Solenoid Coil for 110-Volt, 60-Cycle Control, Style 72447.
Solenoid Coil for 110-Volt, D-C. Control, Style 72444.
Solenoid Coil for 220-550 Volt, D-C. Control, Style 72445.

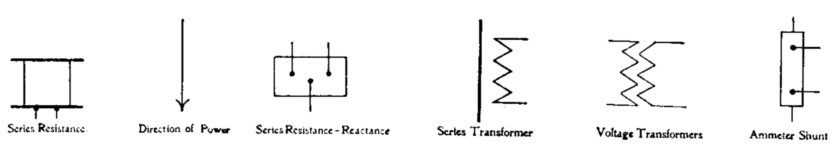
Accessories

Style No.		Description
121556 121557	Pinion Gear	For driving paper 24 inches per hour from clock Style No. 124982.
115200 115201	Pinion Gear	For driving paper at the rate of 8 inches per hour from clock, Style No. 124982; 4 inches per hour from clock Style No. 124981; or 2 inches per hour from clock Style No. 124980.
115202 115203	Pinion Gear	For driving paper at the rate of 4 inches per hour from clock, Style No. 124982; or 2 inches per hour from clock, Style No. 124981.
112605	Resistor	for connection in series with motor Style No. 124984 when used on 110 volts, 25 cycles.
112605	Resistor	for connection in series with motor Style No. 124984 when used on 110 volts, direct current. Order paper by Style No. on paper previously used.

Ordering Instructions

When ordering renewal parts or accessories, give the name plate reading of the instrument. 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.

External Connection Diagrams



Note—One primary and one secondary lead of instrument transformers having like polarity, are painted red.

FIG. 10—CONVENTIONAL SIGNS USED IN CONNECTION DIAGRAMS

External Connection Diagrams—Cont'd

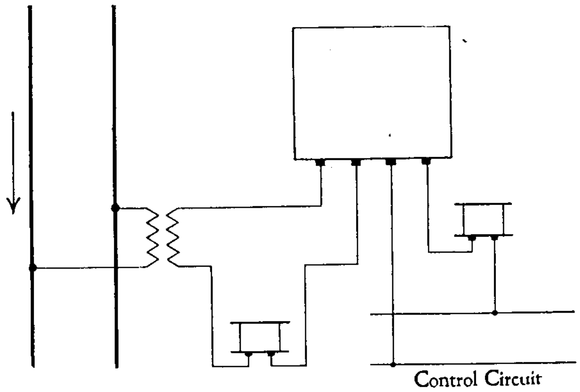


FIG. 11—A-C. AND D-C. VOLTMETER—REAR VIEW*

Note—Connections shown are for alternating-current circuits exceeding 700 volts. On lower voltage the voltage transformer is omitted and the instrument connected directly across the circuit in series with its series resistance.

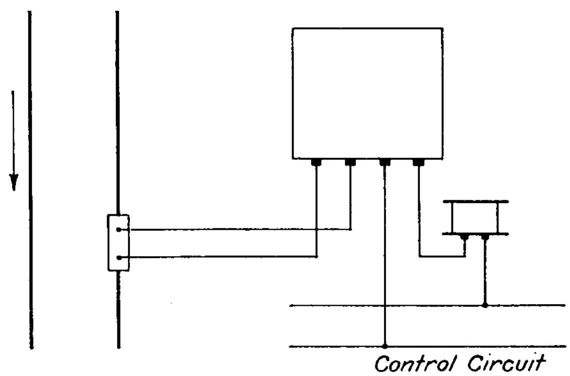


FIG. 13—D-C. AMMETER—REAR VIEW*

Note—Ammeter shunt is shown connected in the negative side of the circuit.

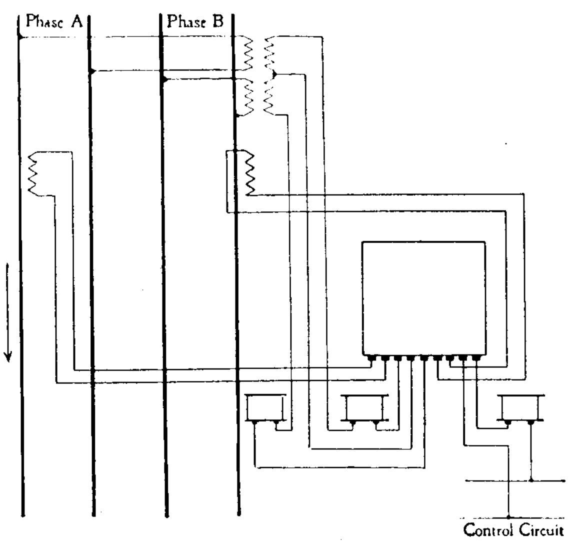


FIG. 15—WATTMETER FOR TWO-PHASE FOUR-WIRE CIRCUIT
REAR VIEW*

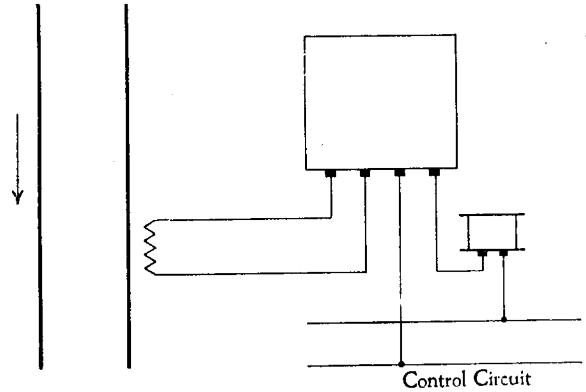


FIG. 12—A-C. AMMETERS—REAR VIEW*

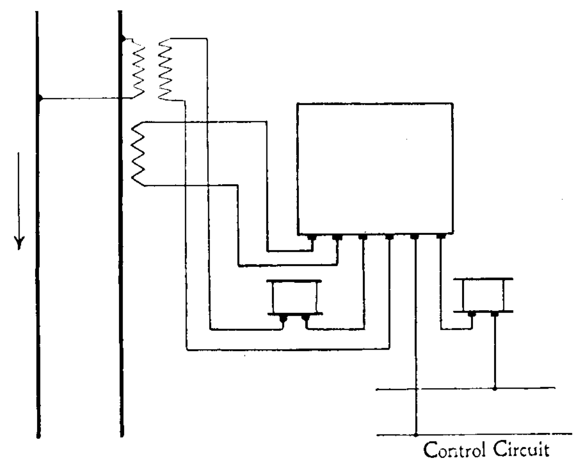


FIG. 14—SINGLE-PHASE WATTMETER—REAR VIEW*

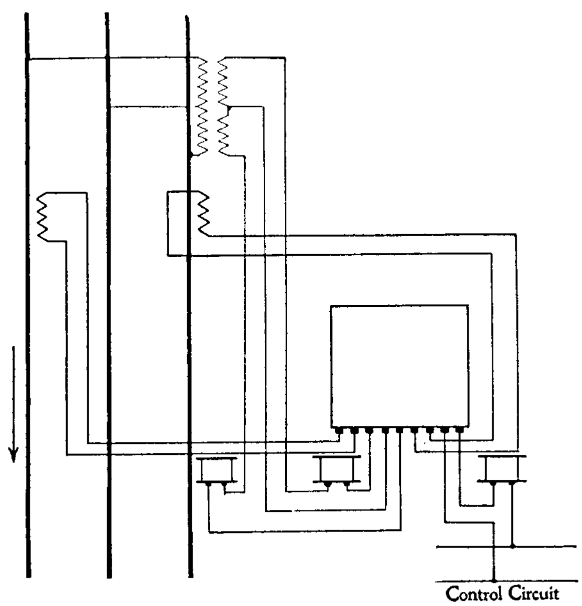


FIG. 16—WATTMETER FOR THREE-PHASE THREE-WIRE CIRCUIT
REAR VIEW*

***Note—Series resistance is used only on 500-volt control circuit.**

External Connection Diagrams—Cont'd

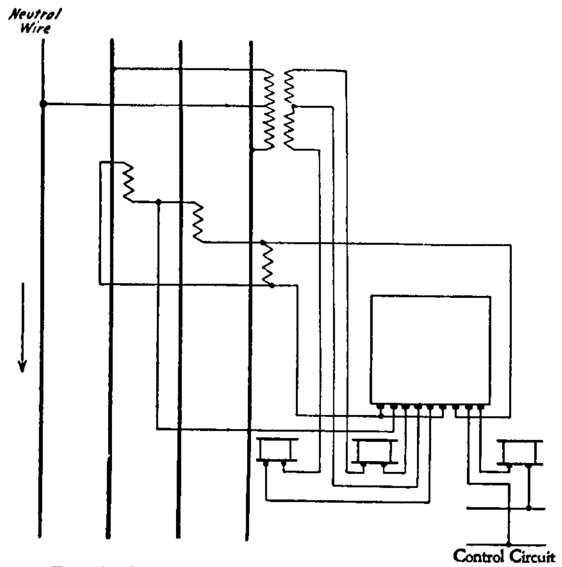


Fig. 17—Wattmeter for Three-Phase Four-Wire Circuit Rear View*

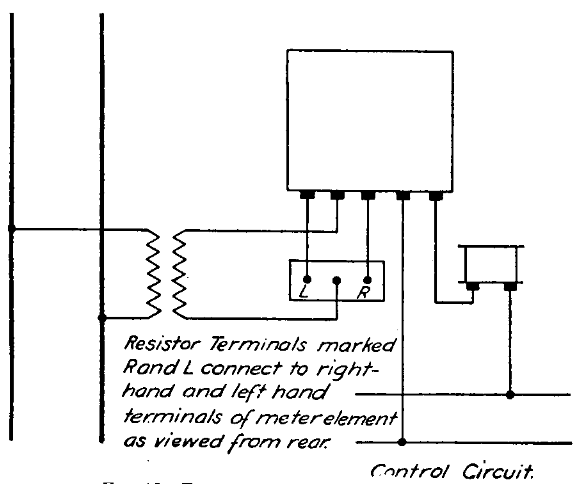


Fig. 18—Frequency Meter—Rear View*

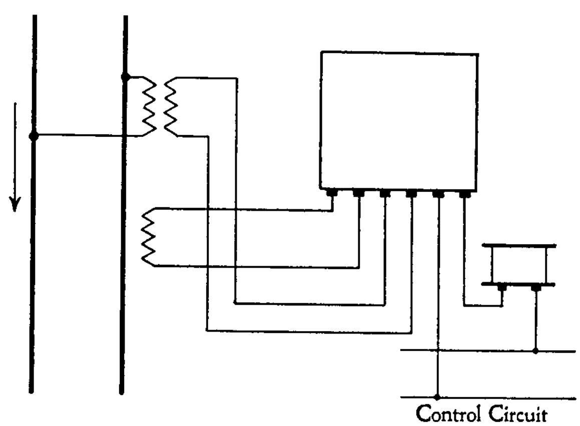


Fig. 19—Single-Phase Power Factor Meter Rear View*

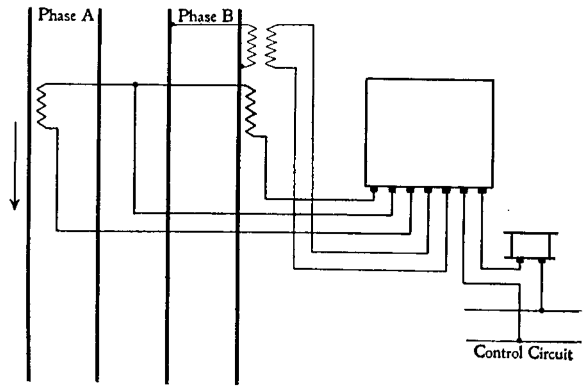


Fig. 20—Power Factor Meter for Two-Phase Four-Wire Circuit—Rear View*

Note—For two-phase three-wire circuits the adjacent wires of the two phases are replaced by a common wire.

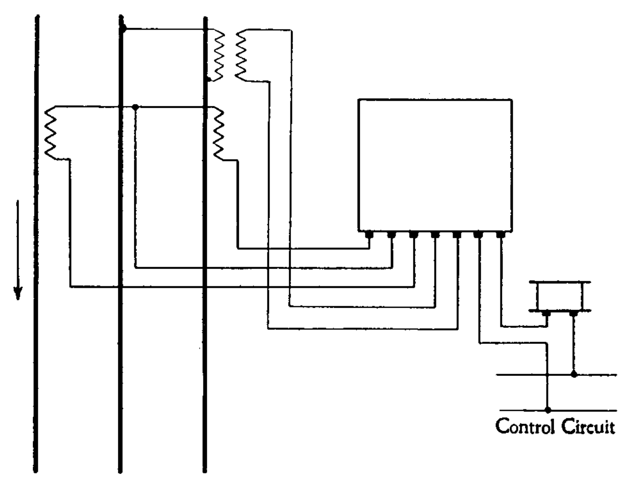


Fig. 21—Power Factor Meter for Three-Phase Three-Wire Circuit—Rear View*

Note—For three-phase, four-wire circuits the connections are as shown, there being no connection between the instrument transformers and the neutral wire.

***Note—Series resistance is used only on 500-volt control circuit.**

Internal Connection Diagrams

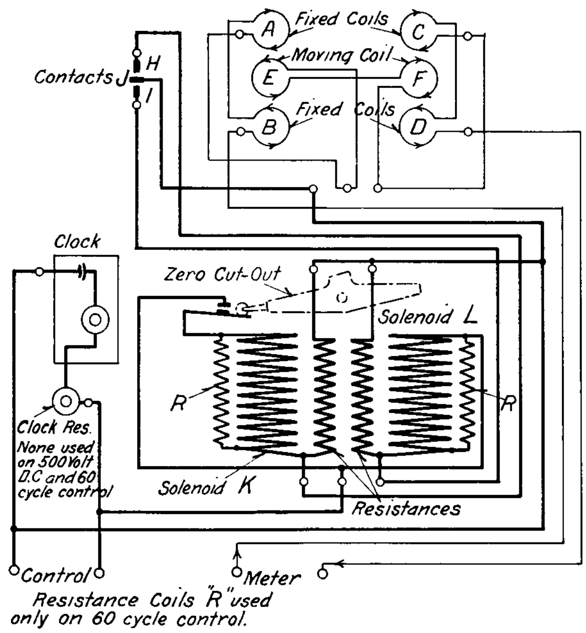


FIG. 22—A-C. OR D-C. VOLTMETER—FRONT VIEW

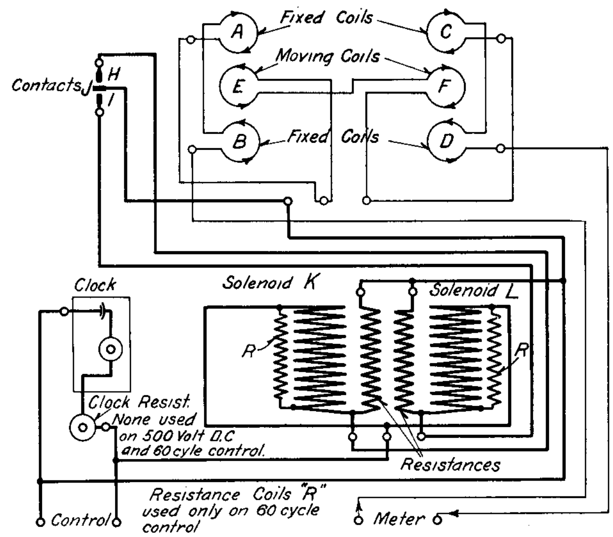


FIG. 23—A-C. AMMETER—FRONT VIEW

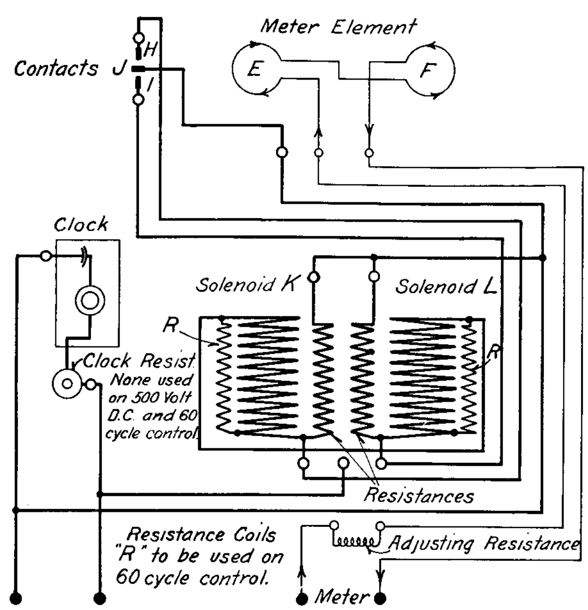


FIG. 24—D-C. AMMETER—FRONT VIEW

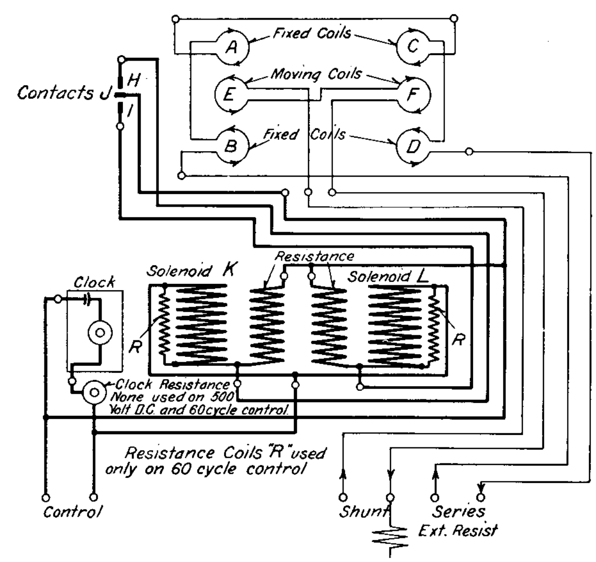


FIG. 25—SINGLE-PHASE WATTMETER—FRONT VIEW

Internal Connection Diagrams Cont'd

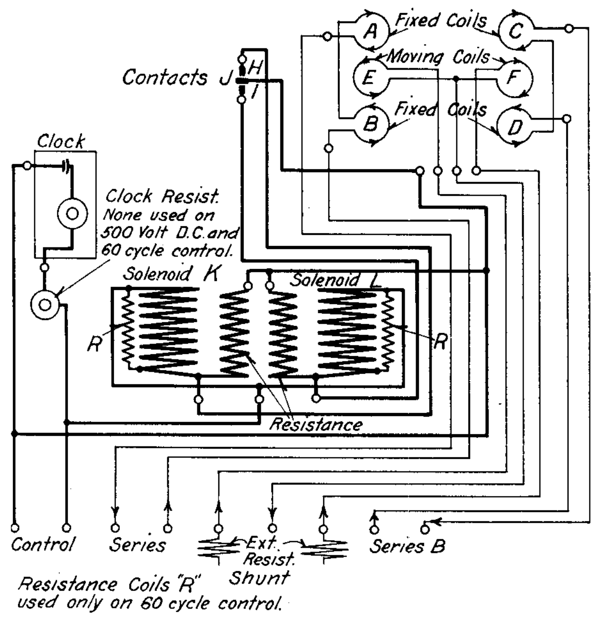


Fig. 26—Polyphase Wattmeter—Front View

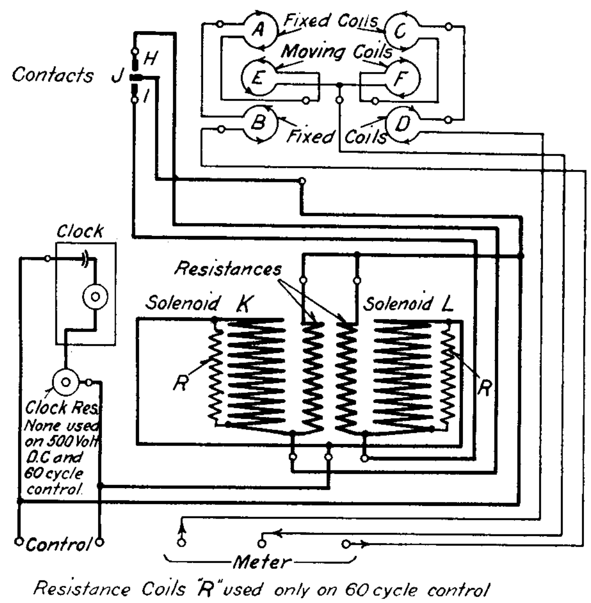


Fig. 27—Frequency Meter—Front View

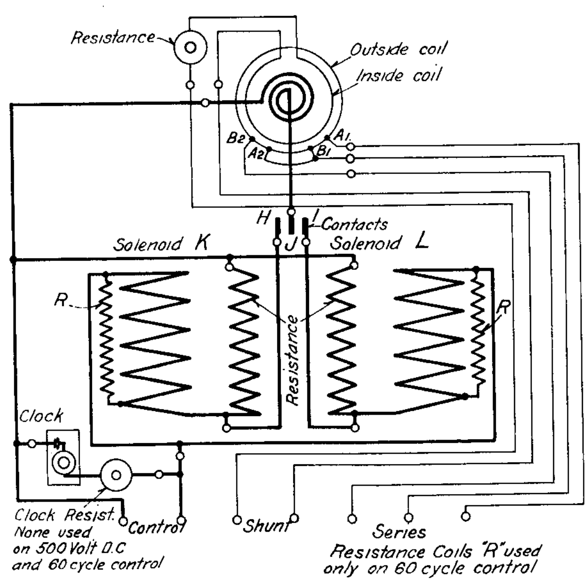


Fig. 28—Power Factor Meter for Two-Phase and for Three-Phase Circuits—Front View