Westinghouse

Type U Graphic Meters

Westinghouse Electric & Manufacturing Company
East Pittsburgh Works East Pittsburgh, Pa.

INDEX

Westinghouse

Type U Graphic {Am— / Volt—} Meter

Style..... **Serial**.....

The complete set of apparatus comprises:

1 Graphic Meter

.....Charts, Style.....

.....Charts, Style.....

1 Small phial of ink for insertion in meter cover.

1 Glass reservoir and tube for supplying ink to pen.

1 2-ounce bottle of ink.

and the auxiliary devices checked (√) in list below:

1 Resistor having same serial number as meter.

1 Voltage transformer...../100 volts.

1 Current transformer...../amperes.

1 Calibration curve No.....

This meter is calibrated to read full scale on..... {Amperes / Volts} when connected to a {.....cycle / direct-current} circuit. If the apparatus listed above includes a transformer, multiply chart readings by.....when the transformer is used.

Westinghouse Electric & Mfg. Co.

Per.....
Inspector

Newark Works

Newark, N. J.....19.....

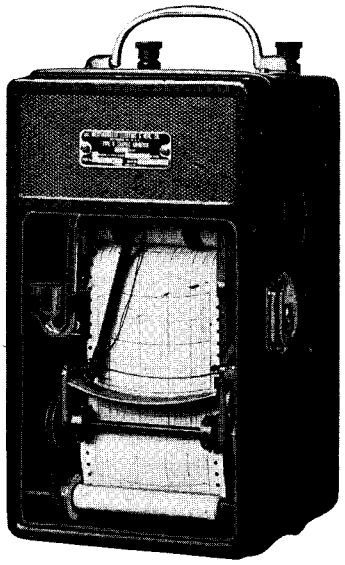


Fig. 1—Type U Graphic Voltmeter

I. L. 43-405★
(Filing No. 43-000)

Westinghouse

Type U Recording Instruments

INSTRUCTIONS

General

1. Unpack carefully, reading these instructions before releasing movement or changing any adjustment.

Mounting

2. Type U recorders have universal mounting features. The case is equipped with handle and feet for general portable use, mounting lugs for wall mounting, and mounting studs for switchboard mounting.

3. Due to high torque, extremely accurate levelling is unnecessary, although instruments should be mounted as near vertical as can be judged by eye.

4. Resistors which are mounted on the sides of voltmeters for convenience in carrying, should preferably be mounted apart from the instrument when installed permanently on a circuit.

5. Switchboard or permanent mounting generally is carried out with more regard for appearance than is required for temporary installations. The handle should be removed. Resistors for voltmeters should be mounted at the rear of the panel. Always leave at least four inches clear space at the right of the recorder, to allow free access when changing paper, or rewinding clock. Leave three-inch space below to allow the removal and replacement of the dashpot.

How to Put the Recorder into Service

6. Connect as shown in the wiring diagram Fig. 2, page 4.

NOTE—All type U voltmeters have external resistors which must be connected in series with them.

7. To release the movement, unscrew the square-head clamping screw shown at A in the illustration, using the clock key for this purpose.

8. To insert chart remove chart holder cover B by pressing the springs together inside the case and pulling it outward.

Place the chart in the holder, having first broken the seal and release the end of the paper. The printed side of the paper must be on the outside as the chart is unrolled in the instrument.

Loosen the knurled nut C, pull the end of the chart down through the guide **under the wire near the pen-point,** and under the driving sprockets. See that the paper lies smoothly in the chute, with the edges under the guides throughout their length and that the holes in the paper mesh accurately with the teeth on driving sprockets.

Adjust the position of the chart to give correct time indication on the time scale at the point of the pen, and tighten nut C.

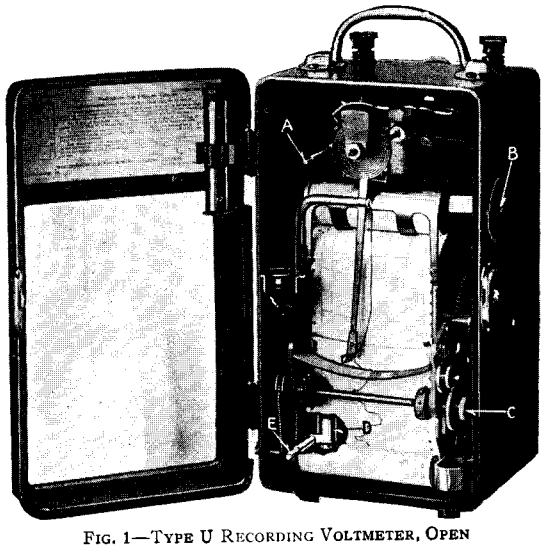


FIG. 1—TYPE U RECORDING VOLTMETER, OPEN

Pass end of paper through the reroll spool and fasten by making one or two turns to prevent the end from slipping out of the slot.

9. Put some ink in the pen, being careful to see that the pen is clean and that no solid matter is placed in it with the ink. Moisten the point if necessary, to start the ink flowing freely. For instructions regarding extra ink supply for long records see paragraphs 16 and 17.

10. To Wind Spring Clock—A clock key will be found in a receptacle inside the case, at the top. Insert it from the outside of the case, through the keyhole near the lock. If the clock does not start after being wound, start the balance wheel gently with a small piece of paper. The clocks are of the 8 day type, and should be wound weekly.

Hand winding is of course not necessary on synchronous clocks.

11. Damping, other than that inherent in the design of movement is not always necessary or desirable, but if the circuit being metered is very unsteady or is liable to be switched off suddenly at intervals, the oil dashpot should be used per Par. ★14.

12. Collecting the Record—The reroll is designed to collect a full roll of paper. However, in most cases, a one day record is desired. The reroll spool is easily removed by pressing back the support spring which will allow the operator to remove the portion of the chart desired.

When the above instructions have been complied with, the recorder should be drawing a curve having time and the quantities to be recorded as co-ordinates. Observe its action for a sufficient length of time to make sure that the several elements are operating correctly together without any tendency to bind or stick.

13. When removing the recorder from a circuit do not forget to remove the oil, if any, from the dashpot, and the ink from reservoir before laying the recorder down. Remove all ink from pen and clean the pen point if it is to remain

★Superseding I. B. 5152E

is removed, it will be necessary to recalibrate the meter after it is reassembled.

Direct-current meters may sometimes exhibit friction due to a pull of the core toward the side of the solenoid. As long as the core is centrally located in the coil, this condition will not occur, as it will be attracted equally toward all sides, but if the core is off center, it will be attracted toward the nearest part of the coil. This condition is due to the bending or displacement of some parts and can be overcome by replacing the parts in the correct positions. There is a slight difference between readings on ascending scale and on descending scale at the same point in direct-current meters, due to hysteresis in the iron core.

33. Frequency errors are entirely negligible if the frequency of the circuit is anywhere near the normal frequency for which the meter is calibrated. A voltmeter, having been adjusted for correct scale distribution on one frequency, will not have correct scale distribution at another frequency, although it can be made to read correctly at any one point of the scale at the other frequency by changing its resistance. The difference scale distribution is caused by the different relative change in inductance of the coil as the position of the core changes. See also Paragraph 31.

34. Temperature errors—The Temperature errors in these instruments are well within the limits of scale accuracy.

Renewal Parts

35. When ordering renewal parts, give the name of the part wanted and the style number and serial number of the instrument, which appear on the nameplate. Failure to give this information may result in delay.

Repairs

36. If an instrument is to be returned to the factory for repairs, write to the dealer or nearest Westinghouse Sales Office, for a return material tag, so that the apparatus will be properly identified at the factory.

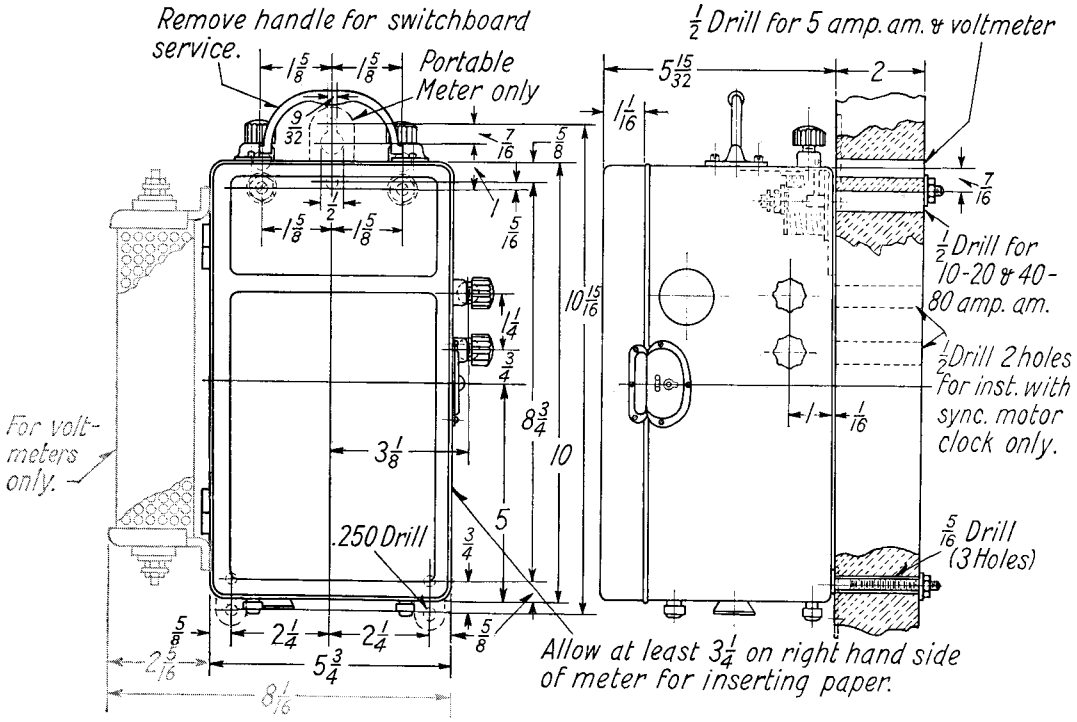
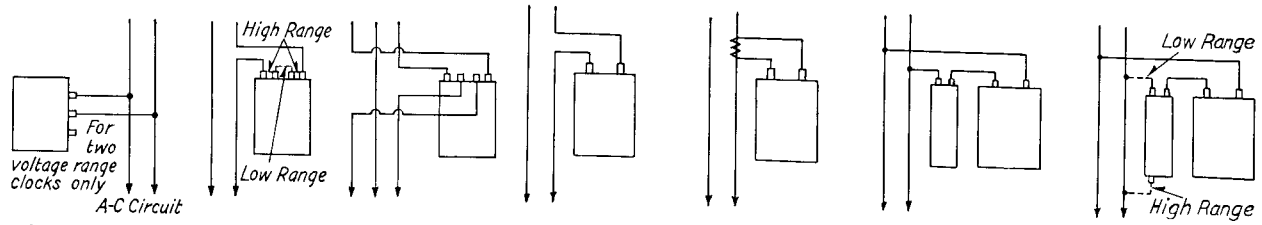


FIG. 2—OUTLINE AND DRILLING PLAN FOR TYPE U RECORDING INSTRUMENT

Connections



CONNECTIONS FOR SYNCHRONOUS CLOCK CIRCUITS ONLY | DOUBLE RANGE SELF-CONTAINED AMMETER | THREE WIRE D-C. SELF-CONTAINED AMMETER | SELF-CONTAINED AMMETER (UP TO 750 V. SERVICE) | AMMETER WITH CURRENT TRANSFORMER | VOLTMETER FOR DIRECT CONNECTION TO LINES (BELOW 750 V. SERVICE) | DOUBLE-RANGE VOLTMETER

Potential Transformers must be used on A-C. circuits above 750 V.

FIG. 3

Westinghouse Electric & Manufacturing Company

Printed in U.S.A. (Rev. 12-40)

Meter Div., Newark, N. J.

Westinghouse

Type U Graphic Meters

GENERAL

1. Unpack carefully, checking off the various parts with the list on page 3. Read these instructions before releasing movement or changing any adjustment.

MOUNTING

2. When installed temporarily, as in ordinary portable service for recording circuit conditions for a period of from a few hours to a day or two, the meter may be left standing on a shelf or table. The reroll mechanism will take care of a full roll of paper or any fraction of the roll, so that in all cases the reroll should be used in place of leaving the case door open, so as to permit the chart to be fed out without rerolling. When the door is left open, all parts of the meter are subject to dust which will cause clock trouble as well as friction in the instrument.

3. For longer runs the meter may be hung on the wall by means of the lugs attached to the base. The top lug has a keyhole slot in it which makes it convenient for slipping over a round-head wood screw. While supported by the upper lug the meter should be leveled and should then be fastened in place by means of a screw in one or both of the lower lugs. Usually the accuracy of leveling can be determined satisfactorily by inspection, or, if preferred, a plumb bob can be used. The right-hand edge of the meter case when the door is open is the most convenient part of comparing with the plumb line.

4. Resistors which are mounted on the sides of voltmeters for convenience in carrying should preferably be mounted apart from the meter when installed permanently on a circuit. The usual rules governing the installation of resistance devices apply. In order that the size and weight of these resistors shall be minimum, making them conveniently portable, they are designed to operate at a temperature considerably higher than is usual for other Westinghouse meter resistors. All materials used in them are non-combustible and their resistance is not affected by variations in temperature. Therefore, no uneasiness should be felt on account of their operating at temperatures comparable to the operating temperatures of fireproof rheostats and similar apparatus.

5. Switchboard or permanent mounting generally is carried out with more regard for appearance than is required for temporary installations. The flat mounting lugs and the flat-head machine screws which hold them can be removed and No. 14-24 machine screws long enough to extend through the panel from the rear and ¼-inch into the meter base can be substituted. The handle should be removed. Resistors for voltmeters should be mounted at the rear of the panel. Always leave at least 4 inches clear space at the right of the meter, to allow free access when changing paper, or rewinding clock. Leave three-inch space below the meter to allow the removal and replacement of the dashpot.

6. Ammeters for high-voltage circuits differ from the standard design in that they have larger cases, made of insulating material and are arranged for permanent mounting only. These meters are used as part of the permanent equipment of lighting circuits almost exclusively, and, therefore, are not provided with handles or other parts which are useful only on meters for portable service. Meters of this type are useful for keeping a record of the variation of current in lighting circuits but should not be used as standards for adjusting the current to normal value. For that purpose, an accurate indicating meter should be used.

HOW TO PUT THE METER INTO SERVICE

7. Connect as shown in the wiring diagram Fig. 4, page 11.

NOTE—All type U voltmeters have external resistors which must be connected in series with them.

8. To release the movement, unscrew the square-head clamping screw shown at *A* in the illustration on page 7, using the clock key for this purpose.

9. To insert chart remove chart holder cover *B* by pressing the springs together inside the case and pulling it outward.

Place the chart in the holder, having first broken the seal and released the end of the paper. The printed side of the paper must be on the outside as the chart is unrolled in the meter.

Loosen the knurled nut *C*, pull the end of the chart down through the guide, **under the wire near the pen-point,** and under the driving sprockets. See that the paper lies smoothly in the chute, with the edges under the guides throughout their length and that the holes in the paper mesh accurately with the teeth on driving sprockets.

Adjust the position of the chart to give correct time indication on the time scale at the point of the pen, and tighten nut *C*.

Pass end of paper through the reroll spool and fasten by making one or two turns to prevent the end from slipping out of the slot.

10. Put some ink in the pen, being careful to see that the pen is clean and that no solid matter is placed in it with the ink. Moisten the point if necessary, to start the ink flowing freely. For instructions regarding extra ink supply for long records see paragraphs 18 and 20 on Ink Reservoir and Ink. Pressure of pen on paper should be very light, or just enough to make the record, as otherwise, friction will prevent accurate recording.

11. To Wind Clock—A clock key will be found in a receptacle inside the meter case, at the top. Insert it from the outside of the case, through the key-hole near the lock. If the clock does not start after being wound, rock the balance wheel gently with the finger or a small piece of paper, the latter method being specially recommended if the operator is not accustomed to handling small apparatus. The balance wheel is located at the lower end of the clock, just back of the chart guide.

12. Damping, other than that inherent in the design of movement is not always necessary or desirable, but if the circuit being metered is very unsteady or is liable to be switched off suddenly at intervals, the oil dashpot should be used.

13. Collecting the Record—The reroll is designed to collect a full roll of paper. However, in most cases, a one day record is desired. The reroll spool is easily removed by pressing back the support spring which will allow the operator to remove the portion of the chart desired. (See also paragraph 2 on mounting.)

When the above instructions have been complied with, the meter should be drawing a curve having time and the quantities to be recorded as co-ordinates. Observe its action for a sufficient length of time to make sure that the several elements are operating correctly together without any tendency to bind or stick.

14. When removing the meter from a circuit do not forget to remove the oil, if any, from the dashpot, and the ink from reservoir before laying the meter down. Remove all ink from pen and clean the pen point if the meter is to remain out of service for an indefinite period. If it will be put back in service within a few hours, only the excess ink which would be likely to spill out of the pen need be removed. When the ink reservoir and wick have been in use, fold the wick back into the glass tube where it cannot fall against the chart. Clamp the moving element by means of the screw *A* to keep it from swinging.

15. The dashpot shown at *D* in Fig. 2 consists of an oil cup and piston for damping the swing of the movable element. To remove the oil cup, release the clamp screw *E* by means of the clock key and pull out the oil cup from below the base. Fill the cup to within $\frac{1}{16}$-inch of the top with average machine oil or transformer oil, and replace. Avoid forcing the oil cup in too suddenly, and see that the piston clears the sides properly. This can be tested by moving the pen arm slowly by hand while replacing the cup, thus detecting any interference.

Where extra heavy damping is necessary a thick machine oil or cylinder oil may be used, but no liquid which will form a gum on the parts should be used as it will tend to close up the hole through which the guide rod of moving element passes, and thus cause friction.

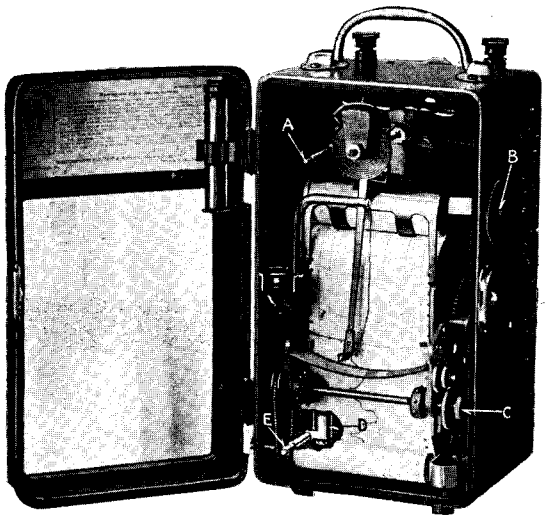


Fig. 2—Type U Graphic Voltmeter, Open

The buoyant effect of any machine oil on the piston is entirely negligible as compared with the strength of the spring, and, therefore, there is no difference in the calibration of the meter whether used with or without oil in the dash-pot.

16. Ink Reservoir—Ink enough to last 100 hours or more on the average circuit can be held in the pen. If the meter is to be left several days on an unsteady circuit without attention, an additional supply of ink should be placed in the glass reservoir at the side of the paper chute, and the yarn wick should be used for carrying this ink over to the pen. Before putting the ink into the glass cup, push a small wire down through the tube and attach one end of the wick to a hook on the end of the wire. Pour the ink into the cup and saturate the wick with it before pulling the wick up through the tube. Place the end of the wick in the pen as shown in Fig. 1, arranging it so that the ink will flow down the wick directly into the pen and not over the back or sides. The rate at which ink is supplied to the pen can be regulated by varying the position of the reservoir. Raising the reservoir makes the ink feed faster, and lowering it reduces the rate of feed. In case the ink flows too freely with the reservoir in the lowest position, reduce the size of the wick by splitting the yarn lengthwise. Standard wicks furnished with meter consist of one strand of a fine woolen yarn.

A very low rate of feed from reservoir to pen is recommended, unless the circuit being metered is subject to exceptionally large and frequent changes, thus requiring a relatively large quantity of ink to make the record. Keep in mind the probable average demand during the entire run and adjust the feed rate accordingly.

17. A blotter is mounted immediately below the pen for the purpose of preventing any small drops of ink, which may overflow from, or splash out of the pen, from falling on the lower part of the chart. Care should be taken to prevent ink from dropping or splashing upon the bearings of the paper-driving shaft, as it is liable to corrode them and cause friction.

18. Ink for use in graphic meters must be kept perfectly clean, and the bottles should be kept tightly corked to prevent evaporation. There are certain limits in the condition of the ink, between which it will give good results. If too thin, it will penetrate the paper, making a blurred record and sometimes causing the pen point to wear through the paper. If too thick, it will not flow freely enough, resulting in failure to leave a complete record. It must evaporate rapidly enough to dry on the chart before the chart is rolled up or comes in contact with anything that would blur it, but the evaporation must not be too rapid or ink will dry in the point of the pen and prevent marking. The ink supplied with type U meters is carefully prepared and has the various ingredients in correct proportion to produce the condition desired. It will retain this condition indefinitely if kept in a closed bottle and not exposed to extremely low temperature. A small phial of ink is placed in a clip inside the cover of the meter for convenience. The ink in this phial should all be used and the phial should be washed before replenishing it from the main supply. Any ink that has stood in the open cup of ink reservoir for a week or more should be emptied out, and the reservoir washed before being used again. Never add new ink to ink which has been standing in the reservoir for several days.

19. Colored inks which contrast well with the imprinted marking on the paper make the most legible record. Either green or red ink can be supplied. Unless the color is specified when ordering, red ink will be furnished.

20. Pen—The pen is of the open-top, V-point type which has been used in one form or another in a variety of graphic instruments and

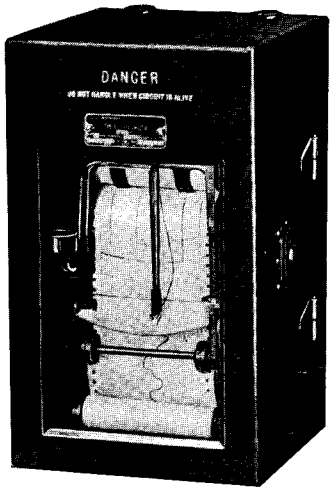


Fig. 3—Type U High-Tension Graphic Ammeter

is familiar to the majority of meter men. This kind of point has minimum weight and can be kept in good working order with a minimum amount of attention. All parts are accessible for cleaning and usually can be cleaned with a cloth or paper. Pens which have been left with ink in them and have been out of service until the ink has dried, should be soaked in water or in alcohol before cleaning with a cloth. The pen and pen arm can be taken off the meter without disturbing its calibration.

Pen points which have become dulled can best be sharpened by the use of a small emery stone.

21. The pressure of the point against the chart is determined by the weight of the pen and requires no adjustment other than seeing that it hangs without friction in the bearings.

22. Clock—The clock is a standard American jeweled movement designed for use in high-grade eight-day clocks. It has an exceptionally strong spring and is substantially built. Driving the chart of a graphic meter places a higher load on the movement than it has to carry in ordinary time-keeping, therefore, to insure continuous running, the clock should be wound twice a week.

If the clock fails to run at all, disconnect the paper-driving cylinder by loosening the knurled nut *C*, Fig. 2, and observe whether or not the balance wheel operates freely and whether 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.

23. 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 bearing 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 onto the surface of the plates.

b. Wrap a piece of cheesecloth around a 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.

Periodic cleaning of the clock is necessary to maintain its accuracy. The length of period during which it will operate satisfactorily after cleaning varies, depending upon the amount of exposure to dust and moisture. As a rule, one oiling in two years is sufficient.

24. The regulator for adjusting the speed of the clock is at the lower right-hand corner of the clock movement. A lever projects outward from the clock frame on the opposite side of the jewel screw from the slotted guide through which the outer turn of the hair-spring passes. To make the clock run faster, push the lever back towards the rear of the meter case. To make the clock run slower pull the lever forward.

25. Change gears for increasing or decreasing the rate of feed of paper consist of two separate attachments for each speed. One attachment is a train of gears assembled with side plates, as a unit; the other is the gear for mounting directly on the paper-driving shaft. Markings to indicate the length of chart fed per hour are stamped on the outer side plate of the gear train and on the outer side of the gear for the driving shaft. A slot for the mounting screw that secured the gear train in place allows adjustment of the train to obtain accurate mesh with gears on the clock and the driving shaft. The screw should be tightened firmly, while the gears mesh positively but not tightly at each end of train.

The higher the speed of the paper, the more attention must be paid to reducing friction of all parts of the paper-driving mechanism to a minimum, because any increase in the speed of the paper means a proportionate increase in the lever arm through which the friction opposes the torque of the clock spring.

26. The paper-driving sprockets are adjustable on their shaft. Flat spots for the set screws in sprockets to bear against, keep the bosses on the rim in alignment and allow a small lateral adjustment toward either side. Correct adjustment is made at the factory and it is not likely that readjustment of these parts will be necessary except when the meter is dismantled for cleaning. It is important that the distance between centers of the two sprockets shall be exactly equal to the distance between centers of holes in chart. End play of about $\frac{1}{32}$-inch should be allowed. In locating the shaft and before tightening the set screws of sprockets, clamp the gear in place against the shoulder at the right-hand end of the shaft and fix the position of the sprockets so that, at the point of contact of the gear with the pinion in the gear train, the end play is about equally divided between the two sides of the gear.

27. Charts having time scales marked for one inch per hour are 16 feet long. Two-inch per hour charts are 32 feet long of thinner paper.

28. Scale numerals, indicating the load corresponding to scale readings are printed in line with the main divisions on the chart at intervals of 6 or 12 inches. Charts with standard scale ranges as listed in catalogue are always available at the Works for immediate shipment. When transformers are used in connection with meters for measuring loads higher than those provided for on the standard scales, the standard scale, having markings for some even decimal part of the load, should be used. The readings can readily be multiplied by 10 or 100. If the multiplier is 1000, the scale may be read directly in higher units, the kilo-ampere, kilovolt and megawatt being more convenient than the lower units for use in reference to heavy power circuits and high voltages. For voltmeter scales reading from zero to full load, use ammeter charts with suitable multiplier.

Always refer to the style number of the chart when ordering a supply.

GENERAL CONSTRUCTION AND PRINCIPLE OF OPERATION

29. The measuring element of the voltmeter or ammeter consists of a solenoid of copper wire, and a core of soft iron wire which is drawn into it with a force dependent upon the current in the solenoid. Alternating-current ammeters operate either with the line connected directly through them, or on the secondaries of current transformers. For this reason there is no upper limit to the range of alternating currents that can be measured with the type U line of ammeters, but direct-current measurements are limited to the currents for which the solenoid itself can be wound. For heavy direct currents the relay type meter of different design for operating in connection with a 50-millivolt shunt should be used.

Voltmeters and ammeters both operate on the same principle, the only difference being that the voltmeter is wound for small currents, has a relatively high resistance in series with the solenoid, and is calibrated to read in terms of the voltage applied instead of in terms of the amperes in the coil.

Between the main shaft carrying the pen and the iron core of the solenoid there is a lever arm having sufficient resilience to damp out quick vibrations such as those set up in the core by alternating currents in the coil. The torque transmitted to the shaft through this arm is opposed by a spiral spring.

30. The recording element consists of a V-point pen, chart, ink, and a clock, with the necessary details for feeding the chart through the meter at a uniform rate so that the time indicated by the time scale on the chart for the point where the pen touches the paper always corresponds with the time of day.

CALIBRATION AND ERROR

31. Calibration—All type U meters are correctly adjusted and calibrated before leaving the Works. Occasional recheck should be made by comparison with standard indicating meters. Graphic ammeters are connected in series with the indicating ammeter, and graphic voltmeters in multiple with the indicating voltmeter for comparison.

Three-wire ammeters should have their two coils connected in series with each other, and should then read full scale on their rated current. Current readings on these meters

refer to the current in each outside wire, or equivalent currents if the load is unequally divided between the two sides. Alternating-current ammeters specially calibrated in connection with split type transformers are not readily adjustable to record correctly on the charts, owing to variations in the transformation ratio between different outfits. Transformers of the split type are not interchangeable between meters, but will give good results if carefully installed and used with meters that have been calibrated in connection with them. A curve showing the reading corresponding to any given primary current is sent with each set. In checking the calibration or installing the transformer, it is important to see that one-half of the transformer is evenly seated against the other, making a good magnetic circuit.

32. Zero Adjustment—To adjust the zero reading, loosen screw at the top of the movement support and move the slotted spring-holder as required. A rough adjustment can be made by loosening the set screw in the spring collar and turning collar on shaft, if desirable to keep spring-holder approximately central. Tighten screws securely after adjusting. Do not attempt to adjust the zero readings of meters having suppressed scales, such as 90 to 130-volt scales. The spring in such a meter should press the movement solidly against the stops when current is off. When the pen is at either limit of its travel, about $\frac{1}{16}$-inch outside of the ruled portion of chart, the pen holder should strike the spring stop. At the same time, the end of the arm which supports the iron plunger should strike the solid stop above or below it. By suitable adjustment of these stops, the pen with two day's supply of ink can be brought to rest without throwing ink when current is switched off, rendering the use of oil in the dashpot unnecessary.

33. Ammeters are adjusted for full scale readings by adjusting the strength of the spring. **Voltmeters also** are adjusted at the Works by means of the spring, but can be adjusted by varying the external resistance. At the lower part of the scale of voltmeters having suppressed scales, additional adjustment is obtainable by means of a pivoted counterweight which is picked up by the moving element when passing mid-scale point on falling voltage. Increasing the distance between this counterweight and its pivots, increases the reading corresponding to a given voltage at the lower end of scale, without affecting readings at points above the middle of the scale. Thus the object of this adjustment is to regulate the scale distribution, or proportionality of the scale. Voltmeters having complete scales, reading from zero up, do not require this counterweight. They have the same characteristics as ammeters and are adjusted in the same way.

34. Scale distribution is, in general, adjusted by changing the relative positions of solenoid and core. The solenoid is attached to the base by means of four screws, passing through slotted feet and allowing adjustments to higher or lower positions. Raising the coil contracts the upper end of scale and expands the lower part; lowering it has the opposite effect.

This adjustment will, of course, affect the full scale reading and must be made before the final adjustment of spring is made.

35. Friction in the measuring element may be located and removed as follows:

First see that the pressure of the pen on the paper is correctly adjusted as explained in paragraph 23. Clean all pivots and oil them with a slight amount of good watch oil. Then test the end play of the shaft, resetting pivot screws if necessary. The end play should be as little as it can be made without binding. The pivots at the upper end of the solenoid core should be cleaned and oiled. If the friction is not entirely removed by the above method, it may be necessary to take out the solenoid and clean the core and the inside of the tube. In case the solenoid is removed, it will be necessary to recalibrate the meter after it is reassembled.

Direct-current meters may sometimes exhibit friction due to a pull of the core toward the side of the solenoid. As long as the core is centrally located in the coil, this condition will not occur, as it will be attracted equally toward all sides, but if the core is off center, it will be attracted toward the nearest part of the coil. This condition is due to the bending or displacement of some parts and can be overcome by replacing the parts in the correct positions. There is a slight difference between readings on ascending scale and on descending scale at the same point in direct-current meters, due to hysteresis in the iron core. While the iron wire used in these cores is soft enough to avoid any serious

errors, even when operating over a range of load from zero to beyond full scale on direct current, hysteresis is not entirely absent.

For the reasons mentioned, alternating-current meters are capable of producing more accurate records than can be obtained with direct-current meters. Also, the vibration of the core caused by the alternating current reduces the effect of any friction that may be present and thus promotes accuracy.

36. Frequency errors are entirely negligible if the frequency of the circuit is anywhere near the normal frequency for which the meter is calibrated. Sixty-cycle meters read about 6 per cent high on 25 cycles and about 20 per cent high on direct current. The exact difference cannot be stated accurately enough for use in correcting records taken at a frequency other than normal, as the correction varies in different meters and at different parts of the scale. Taps in the external resistors of voltmeters, with resistance adjusted to different values for different frequencies should not be employed because the scale distribution is different at different frequencies. A voltmeter, having been adjusted for correct scale distribution on one frequency, will not have correct scale distribution at another frequency, although it can be made to read correctly at any one point of the scale at the other frequency by changing its resistance. The difference in scale distribution is caused by the different relative change in inductance of the coil as the position of the core changes.

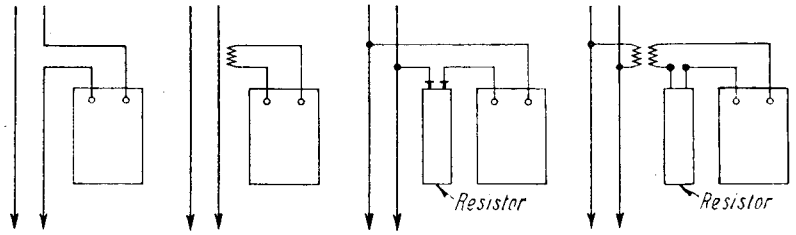
37. Temperature errors in ammeters are too small to affect the results, being due only to the slight weakening of the spring at higher and strengthening at lower temperatures than normal. Normal temperature, as maintained in the Works test rooms, where meters are calibrated is 25 degrees Centigrade. The tendency is for ammeters to read high at high temperatures, but the coils are designed to operate cool so that practically the only variation in temperature will be the variation in atmospheric temperature to which they are subjected. Voltmeter windings have about 5 per cent copper resistance, the copper all being in the meter case where it operates at low temperature. External resistors for voltmeters are wound with an alloy having an extremely small temperature co-efficient. The temperature co-efficient of the winding, which is positive and tends to make the meter read low at high temperature, is balanced by the temperature co-efficient of the spring, which is negative, making voltmeters independent of variations in temperature.

38. Correspondence relative to unsatisfactory operation of graphic meters, 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

39. Repairing can be done most satisfactorily at our Works. Interchangeable repair parts can be furnished, however, and customers equipped for doing repair work will find that the construction of the instrument facilitates this.

CONNECTIONS



Low Voltage Self-Contained Ammeter | High Voltage Ammeter with Transformer | Low Tension Voltmeter for Voltages not Over 750 V. | High Tension Voltmeter with Transformer

Fig. 4

Westinghouse Electric & Manufacturing Company

East Pittsburgh, Pa.

WESTINGHOUSE SALES OFFICES

ALBANY, N. Y., Journal Bldg.
ATLANTA, GA., Candler Bldg., 127 Peachtree St.
BAKERSFIELD, CAL., 2224 San Emedio St.
BALTIMORE, MD., Westinghouse Elec. Bldg., 121 E.Baltimore St.
BIRMINGHAM, ALA., Brown-Marx Bldg., 2000 First Ave.
BLUEFIELD, W. VA., Law and Commerce Bldg., Federal and Raleigh Streets.
BOSTON, MASS., Rice Bldg., 10 High St.
BRIDGEPORT, CONN., Bruce & Seymour Streets.
BUFFALO, N. Y., Ellicott Square Bldg., Ellicott Square.
BURLINGTON, IOWA, 315 North Third St.
BURLINGTON VT., 19 Fletcher Place.
BUTTE, MONT., Montana Electric Co. Bldg., 52 East Broadway.
CANTON, OHIO, (Box 292-Mail and Telegrams)
CEDAR RAPIDS, IOWA, 1705 C Avenue, E. (Mail P.O. Box 1067)
CHARLESTON, W. VA., Kanawha National Bank Bldg., Capito and Virginia Streets.
CHARLOTTE, N. C., Commercial Bank Bldg., 200 S. Tryon St.
CHATTANOOGA, TENN., Hamilton National Bank Bldg., 701 Market Street.
CHICAGO, ILL., Conway Bldg., 111 W. Washington Street.
CINCINNATI, OHIO, Westinghouse Elec.Bldg.,Third and Elm Sts.
CLEVELAND, OHIO, Hanna Bldg., Euclid and East 14th St.
COLUMBUS, O., Interurban Terminal Bldg., Third and Rich Sts.
DALLAS, TEX., Magnolia Bldg., Akard and Commerce Streets.
DAYTON, O., Reibold Bldg., 14 West Fourth Street.
DENVER, COLO., Gas & Electric Bldg., 910 Fifteenth St.
DES MOINES, IOWA, 608 Securities Bldg., 416 W. Seventh St.
DETROIT, Mich., Westinghouse Elec. Bldg., 1535 Sixth St.
DULUTH, MINN., 511 Alworth Bldg., 306 West Superior St.
ELMIRA, N. Y., Hulett Bldg., 338-342 Water St.
EL PASO, TEX., Mills Bldg., Oregon and Mills St.
FORT WAYNE, IND., 3143 Broadway.
FRESNO, CAL., Griffith-McKenzie Bldg., J and Mariposa Sts.
HAMMOND, IND., (Mail—P.O. Box 238; Telegrams—1188 Garfield St.)
HARTFORD, CONN., 220 Market St.
HOUSTON, TEX., Union National Bank Bldg., Main and Congress Sts.
HUNTINGTON, W. VA., Westinghouse Electric Bldg., Cor. Second Ave. and Ninth St.
INDIANAPOLIS, IND., Traction Terminal Bldg., Illinois and Market Sts.
JACKSON, MICH., 704 Peoples National Bank Bldg.
JACKSONVILLE, FLA., Union Terminal Warehouse, East Union and Ionia Sts.
KANSAS CITY, MO., Orear-Leslie Bldg., 1012 Baltimore Ave.
LITTLE ROCK, ARK., 2311 State Street.
LOUISVILLE, KY., Marion E. Taylor Bldg., 312 Fourth Ave.
LOS ANGELES, CAL., Westinghouse Elec. Bldg., 420 S. San Pedro St.
MEMPHIS, TENN., Exchange Bldg., 130 Madison Ave.
MIDDLESBORO, KY., (P.O. Box 518)
MILWAUKEE, WIS., First National Bank Bldg., 425 E. Water St.
MINNEAPOLIS, MINN., Northwestern Terminal 2303 Kennedy St., N. E.
NEWARK, N. J., 38-40 Clinton St.
NEW HAVEN, CONN., Liberty Bldg. 152 Temple St.
NEW ORLEANS, LA., Maison Blanche Bldg., 921 Canal St.
NEW YORK, N. Y., G. Benenson Investing Bldg., 165 Broadway.
NIAGARA FALLS, N. Y. Gluck Bldg., 205 Falls Street.
OKLAHOMA CITY, OKLA., Tradesman's National Bank Bldg., Main & Broadway Sts.
OMAHA, NEB., 1102 Woodman of the World Bldg., 1319 Farnam St.
PHILADELPHIA, PA., Widener Bldg., 1325-1329 Chestnut St.
PITTSBURGH, PA., Union Bank Bldg., 306 Fourth Avenue.
PORTLAND, MAINE, Peakes Island.
PORTLAND, ORE., Porter Bldg., Sixth and Oak Sts.
RALEIGH, N. C., 522 Fayetteville Street.
RICHMOND, VA., Room 912 Virginia Rwy. and Pr. Bldg., Seventh and Franklin Sts.
ROCHESTER, N. Y., Chamber of Commerce Bldg., 119 E. Mani Street.
ROCK ISLAND, ILL., 2319 Third Avenue.
SACO, MAINE, R. F. D. No. 2.
ST. LOUIS, MO., Westinghouse Elec. Bldg., 717 So. Twelfth St.
SALT LAKE CITY, UTAH, Walker Bank Bldg., Second South and Main Sts.
SAN ANTONIO, TEXAS, 1105 Denver Blvd.
SAN FRANCISCO, CAL., First National Bank Bldg., 1 Montgomery St.
SEATTLE, WASH., Westinghouse Elec. Bldg., 3451 E. Marginal Way.
SPOKANE, WASH., Old National Bank Bldg., Riverside & Stevens Sts.
SPRINGFIELD, ILL., Public Service Bldg., 130 S. Sixth St.
SPRINGFIELD, MASS., 82 Worthington Street.
SYRACUSE, N.Y., University Bldg., S. Warren and E.Wash. Sts.
TACOMA, WASH., W.R. Rust Bldg. S. 11th and Commerce Sts.
TOLEDO, O., Ohio Bldg., Madison Avenue and Superior Street.
TUCSON, ARIZ., Immigration Bldg., 90 Church Street.
TULSA, OKLAHOMA, P.O. Box 1511.
UTICA, N. Y., City National Bank Bldg., 110 Genesee St.
*WASHINGTON, D. C., Hibbs Bldg., 723 Fifteenth St., N. W.
WILKES-BARRE, PA., Miner's Bank Bldg., W. Market and Franklin Sts.
WORCESTER, MASS., Park Bldg., 507 Main Street.
YOUNGSTOWN, O., Home Savings and Loan Bldg., Federal & Chestnut Sts.
Hunt-Mirk & Company, San Francisco, Cal., 141 Second St., Marine Dept., Special Pacific Coast Representatives.
The Hawaiian Electric Company, Ltd., Honolulu, T.H.—Agent

*Government business.

WESTINGHOUSE AGENT-JOBBERS

ATLANTA, GA., Gilham Schoen Electric Co.
BATIMORE, MD., H. C. Roberts Electric Supply Co.
BIRMINGHAM, ALA., Moore-Handley Hardware Co.
BLUEFIELD, WEST VIRGINIA, Superior Supply Co.
BUFFALO, N. Y., McCarthy Bros. & Ford
BUTTE, MONTANA, The Montana Electric Co.
CHICAGO, ILL., Illinois Electric Co.
CHARLOTTE, N. C., Carolina States Electric Co.
CLEVELAND, OHIO, The Erner Electric Co.
DENVER, COLO., The Mine & Smelter Supply Co.
DETROIT, MICH., Commercial Electric Supply Co.
EL PASO, TEXAS, The Mine & Smelter Supply Co.
ERIE, PA., Star Electrical Co.
EVANSVILLE, IND., The Varney Electrical Supply Co.
HOUSTON, TEXAS, Tel-Electric Co.
HUNTINGTON, WEST VIRGINIA, Banks Supply Co.
INDIANAPOLIS, IND., The Varney Electrical Supply Co.
JACKSONVILLE, FLA., Pierce Electric Co.
KANSAS CITY, MO., Satterlee Electric Co.
LOS ANGELES, CAL., Illinois Electric Co.
LOUISVILLE, KY., Tafel Electric Co.
MEMPHIS, TENN., The Riechman-Crosby Co.
MILWAUKEE, WIS., Julius Andrae & Sons Co.
NEW HAVEN, CONN., The Hessel & Hoppen Co.
NEW ORLEANS, LA., Electrical Supply Co.
NEW YORK, N. Y., Alpha Electric Co.
OKLAHOMA CITY, OKLAHOMA, United Electric Co.
OMAHA, NEB., The McGraw Co.
PHILADELPHIA, PA., H. C. Roberts Electric Supply Co.
PITTSBURGH, PA., Robbins Electric Co.
PORTLAND, ORE., Fobes Supply Co.
RICHMOND, VA., Tower-Binford Electric & Mfg. Co.
ROCHESTER, N. Y. Rochester Electrical Supply Co.
SALT LAKE CITY, UTAH, Inter-Mountain Electric Co.
SAN FRANCISCO, CAL., Fobes Supply Co.
SCRANTON, PA., Penn. Electrical Engineering Co.
SEATTLE, WASH., Fobes Supply Co.
SIOUX CITY, IOWA, The McGraw Co.
SPOKANE, WASH., The Washington Electric Supply Co.
ST. JOSEPH, MO., Columbian Electrical Co.
ST. LOUIS, MO., The McGraw Company.
ST. PAUL, MINN., St. Paul Electric Co.
SYRACUSE, N. Y., H. C. Roberts Electric Supply Co.
TAMPA, FLA., Pierce Electric Co.
WASHINGTON, D. C., H. C. Roberts Electric Supply Co.
WICHITA, KANSAS, United Electric Co.

WESTINGHOUSE SERVICE SHOPS

ATLANTA, GA.....Cor. Markham & Mangum Streets
BALTIMORE, MD.....501 East Preston Street
BOSTON, MASS.....12 Farnsworth Street
BRIDGEPORT, CONN.....Bruce Ave. and Seymour Street
BUFFALO, N. Y.....141-157 Milton Street
CHICAGO, ILL.....2201 W. Pershing Road
CINCINNATI, OHIO.....Third and Elm Streets
CLEVELAND, OHIO.....1255 West Fourth Street
DENVER, COLO.....1909-11-13-15 Blake Street
DETROIT, MICH.....1535 Sixth Street
HARTFORD, CONN.....220 Market Street
HUNTINGTON, W. VA.....9th Street & Second Ave.
INDIANAPOLIS, IND.....St. Clair and Senate Aves.
JOHNSTOWN, PA.....47 Messenger Street
LOS ANGELES, CAL.....420 S. San Pedro Street
MINNEAPOLIS, MINN.....2303 Kennedy St., N. E.
NEW YORK, N. Y.....467 Tenth Avenue
PHILADELPHIA, PA.....214-220 North 22nd Street.
PITTSBURGH, PA.....6905 Susquehanna Street
PROVIDENCE, R. I.....393 Harris Ave.
ST. LOUIS, MO.....717 South Twelfth Street
SALT LAKE CITY, UTAH.....573 W. Second South Street
SAN FRANCISCO, CAL.....1400 Fourth Street
SEATTLE, WASH.....3451 East Marginal Way

WESTINGHOUSE MARINE SERVICE PORT ENGINEERS

BALTIMORE.....501 E. Preston Street
NEW ORLEANS.....1028 South Rampart Street
NEW YORK.....160 Seventh Street, Brooklyn
PHILADELPHIA, Westinghouse Electric and Manufacturing Co., ...South Philadelphia Works
SAN FRANCISCO.....1400 Fourth Street
SEATTLE.....3451 E. Marginal Way

CANADIAN COMPANY

CANADIAN WESTINGHOUSE COMPANY, LTD., Hamilton, Ontario

WESTINGHOUSE ELECTRIC INTERNATIONAL COMPANY

165 BROADWAY, NEW YORK, U. S. A.

8-23

Westinghouse Press
Printed in U.S.A.