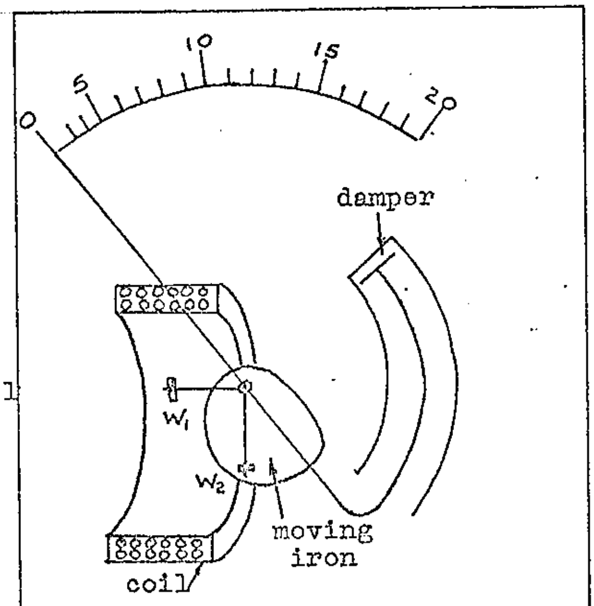
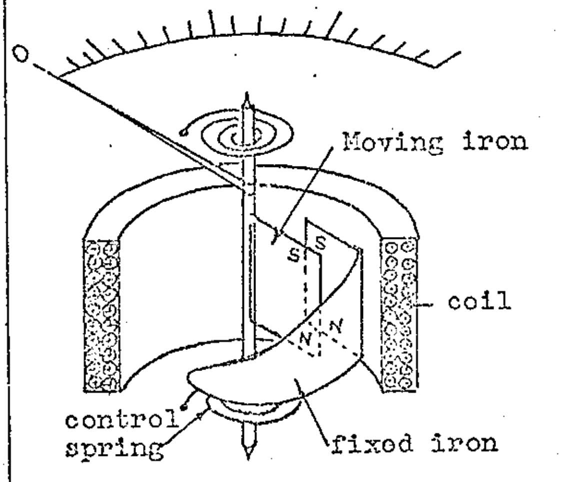


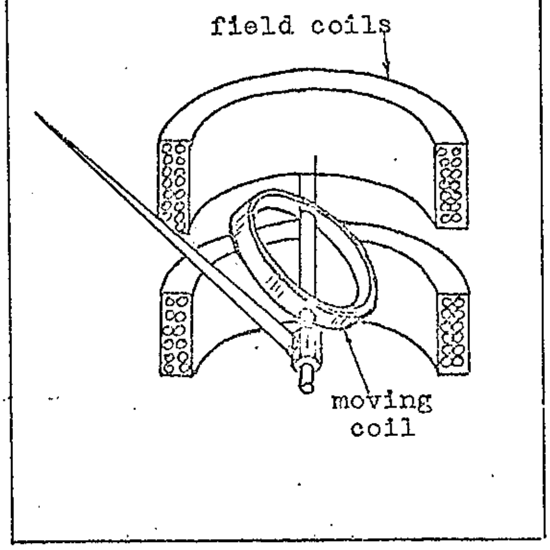
The damper is used to prevent oscillations caused by the control weights acting like a pendulum.
This type of movement produces a scale which is NON-UNIFORM.

<u>The repulsion type</u> is more widely used as it is more accurate, reliable, and uniform.
A small soft iron plate is attached to the centre spindle which is free to rotate. Parallel to and almost touching this plate is a second, curved and tapered plate. When a current passes through the coil, both plates become magnetised to the <u>same</u> polarity. This causes repulsion between the two plates causing the smaller one to move. Because the larger plate is tapered, its effect is reduced as it becomes smaller.
This, together with the return or control springs, allow the scale to be graduated more uniformly.
Because the movement is independent of coil polarity, it is used for either AC or DC meters.



<u>Dynamometer</u>

Two identical fixed field coils arranged parallel to each other provide a magnetic field when a current passes through them.
A third moving coil is mounted on a spindle having control springs which is located inside the fixed field coils.
All three coils are connected in series, and each produces a magnetic field.
The fields produced by the two outer coils combine to create one stronger field.
The field produced by the moving coil is in opposition to the fixed coils, thus causing deflection.
The polarities of the coils remain related regardless of the direction of the current and is therefore suitable for AC or DC measurements.



All meter movements may be made as ammeters or voltmeters. Ammeters will have relatively FEW turns of HEAVY gauge wire except on the moving coils. A SHUNT is required for measuring higher current ranges. Voltmeters will have MORE turns of FINE gauge wire and will require a MULTIPLIER when used on higher voltage ranges.
Shunts and Multipliers are explained later.

TITLE:- MEASURING INSTRUMENTS

LECTURER:-

DATE:-

EQUIPMENT:- Voltmeter (a.c. d.c.) Ammeter (a.c., d.c.), Wattmeter, Watthour meter, power factor meter

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It is often necessary to take accurate measurements of various electrical quantities. A number of instruments have been designed for this purpose, some of which are:-

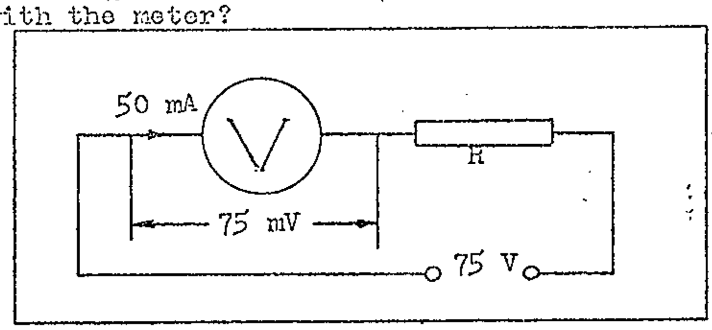
Voltmeter, ammeter, wattmeter, watthour meter, power factor meter, and maximum demand meter.

1. Voltmeter

A voltmeter may be either moving coil, moving iron, or dynamometer type. The moving coil may be used to measure d.c. voltages directly, or by adding a RECTIFIER, they may be used to measure a.c. The moving iron type and the dynamometer will both measure ac or dc directly. All will have windings of many turns of fine gauge wire.

The maximum voltage which may be applied to the actual meter movement is approximately 75 millivolt, i.e. 0.075 volts for full scale deflection. For use on higher voltages it is necessary to connect a MULTIPLIER in SERIES with the meter.

To determine the ohmic value of this multiplier or resistor, it is necessary to know the current and voltage for f.s.d.
e.g. A voltmeter has a f.s.d. of 50 mA at 75 mV. It is required to use the meter on 75 Volts. What value of resistance must be placed in SERIES with the meter?

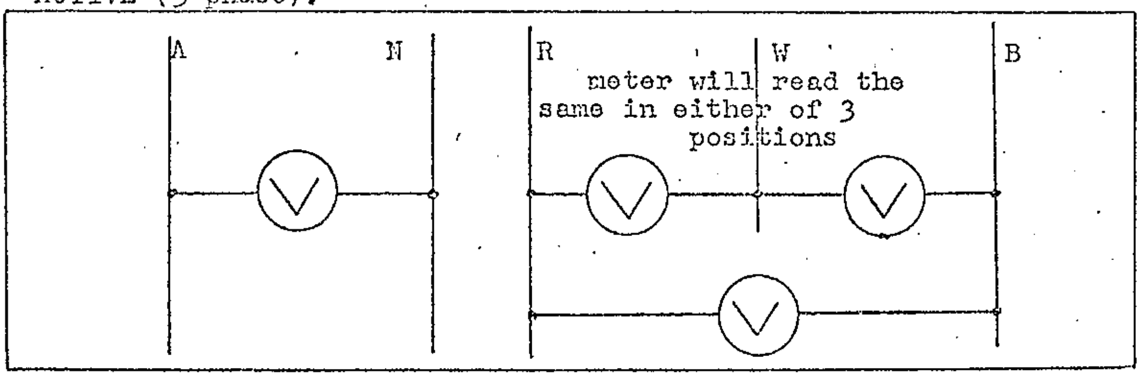


Current through Resistor R = 50 mA
Voltage across Resistor R = 75 - 0.075 = 74.925 Volts.
Resistor R $= \frac{74.925}{.05} = 1498.5$ ohms

Almost all voltmeters have a multiplier connected internally so that if the scale reads up to 250 volts, then that voltage will cause the pointer to deflect fully when applied to the external terminals.

It will usually be found that moving iron instruments are encased in a steel or iron case to shield the components from the effects of stray magnetic fields.

A voltmeter is connected ACROSS (between) ACTIVE & NEUTRAL or ACTIVE - ACTIVE (3 phase).

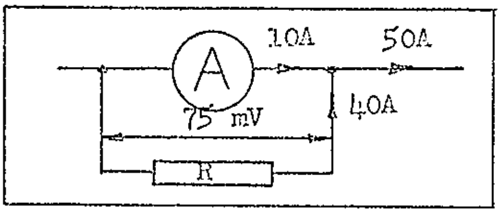


2. Ammeter

An ammeter is used to measure either a.c. or d.c. values of current. The fixed coils are wound of a heavier gauge of thicker wire, while the moving coils are the same as for voltmeters.

Again, the moving coil may only carry about 50 mA at 75 mV, and must be connected to a resistor. This resistor is connected in PARALLEL to the meter and is called a SHUNT. Its purpose is to bypass most of the current. It should be noted that the resistance will be a very LOW value, but it must be capable of carrying the total current being measured without becoming hot. It usually takes the form of a copper strap

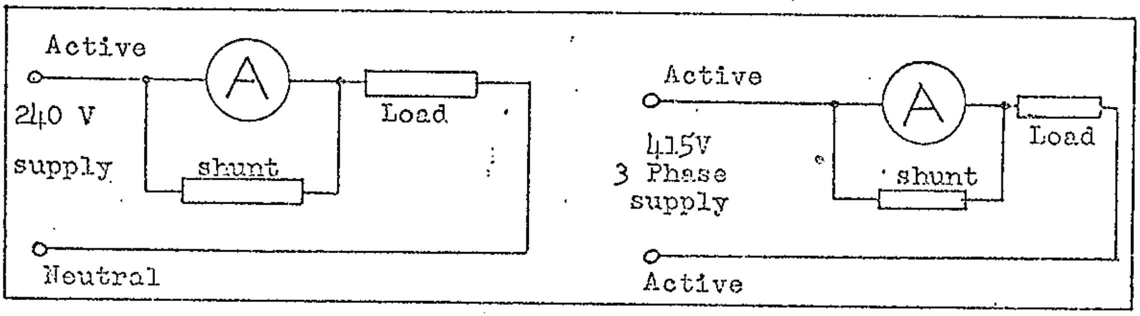
e.g. An ammeter has an internal shunt to allow it to read 10 A. It has a voltage drop across it of 75 mV. What value of external shunt would be required to allow the meter to read 50 Amp.



Current through R = 40A
Voltage across R = 75 mV
Resistance of R = $\frac{.075}{40}$

= .00187 Ohms

An ammeter is connected in SERIES with the load.

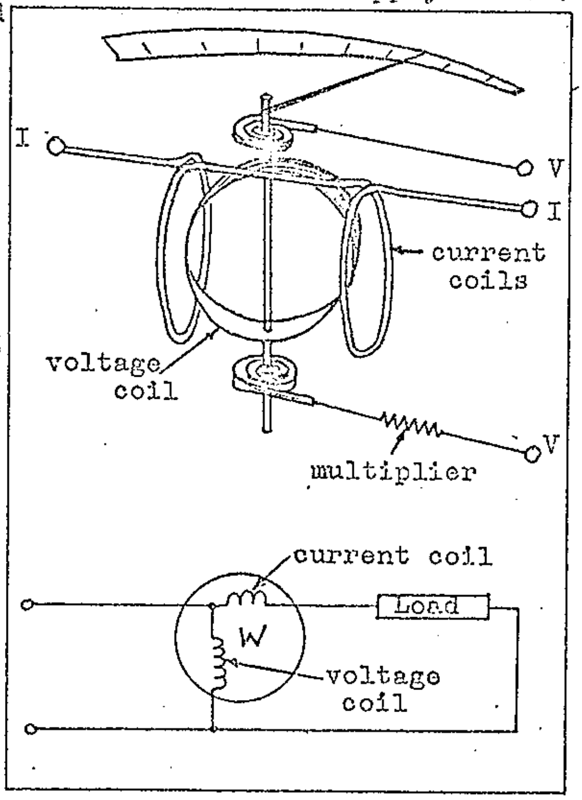


3. Wattmeter

A wattmeter measures the amount of power taken from a supply source. Electrical power can be calculated by multiplying current x voltage together, i.e. E x I = WATTS. This is what a wattmeter does using the dynamometer movement. Two sets of coils are used,
1. The fixed coils are heavy gauge wire with few turns and are connected in SERIES with the load (as an ammeter). 2. The moving coil is of fine gauge wire with many turns and is connected through a multiplier to the ACTIVE and NEUTRAL terminals (as a voltmeter).

When the current passing through the fixed coils is zero, then there is no magnetic field and hence no deflection. When a current flows, then the magnetic field set up by the fixed coil interacts with the field made by the moving coil thus causing a deflection.

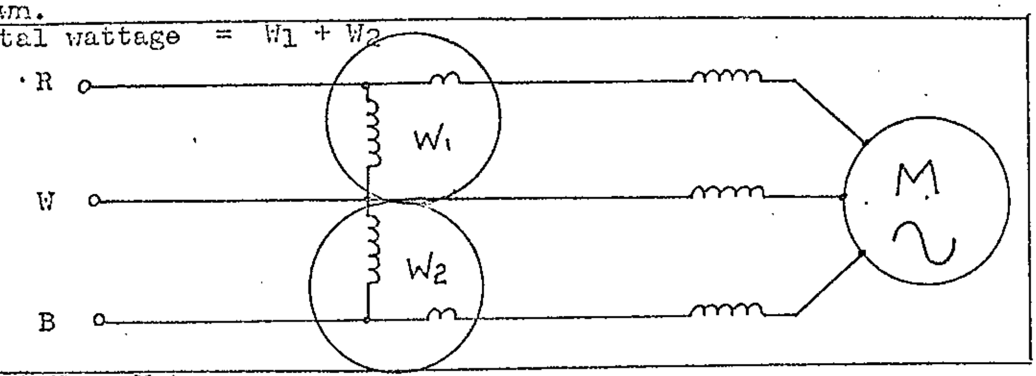
Power in a single phase supply may be measured using one wattmeter as shown.



To measure power in a BALANCED 3-phase supply requires the use of one wattmeter. The reading on the

wattmeter must be multiplied by 3 to give the total power.
An unbalanced load may be measured by using two wattmeters connected as shown.

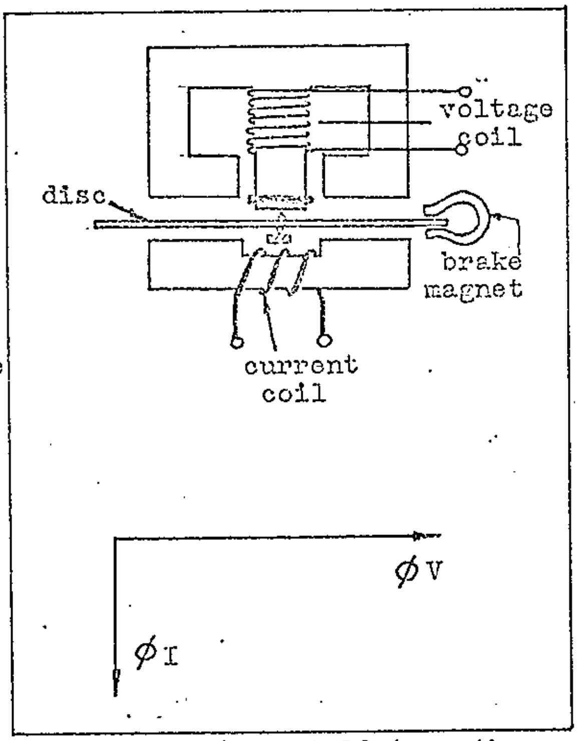
The total wattage = $W_1 + W_2$



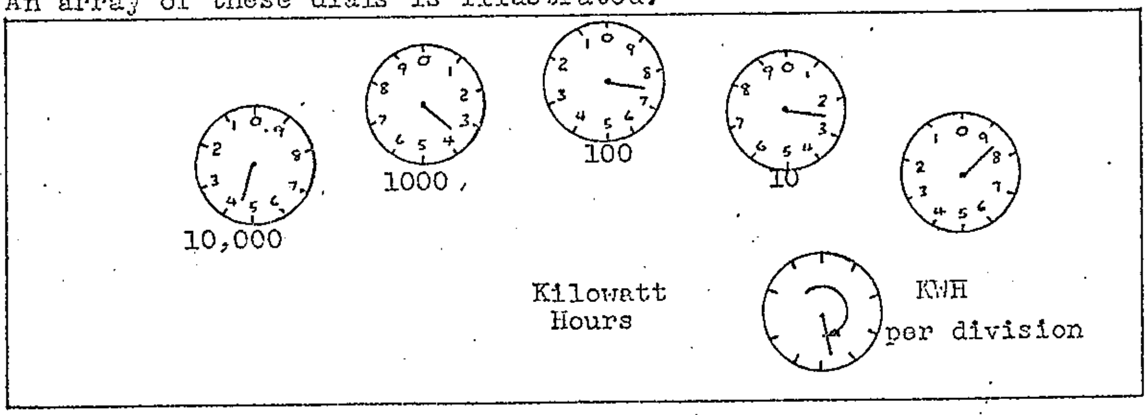
4. Watt Hour Meter

To enable generating authorities to recoup costs of generating electrical energy, each consumer has a watthour meter, or Kilowatt-hour meter to measure power consumed over a period of time i.e. Kilowatts per hour.
The Kwh meter performs this function.

Construction & operation A laminated, 3 limb core is wound with many turns of very fine wire. A short circuited loop is placed around the centre limb. A voltage applied to this highly inductive arrangement produces a magnetic flux which acts on the aluminium disc.
A second laminated core is wound with few turns of heavy gauge wire through which is passed the load current. A second magnetic field is produced. The net result is that the two magnetic fields are displaced by 90° due to the large difference in their individual inductances, causing the flux from the voltage coil to LAG behind the flux of the current coil by 90°.



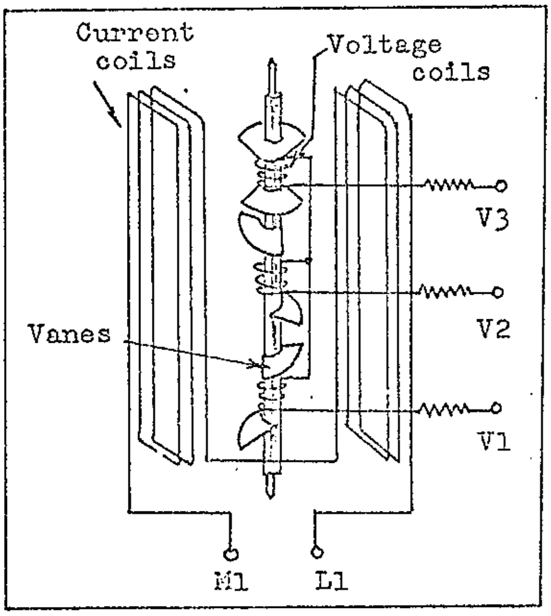
This resultant flux causes the disc to rotate at a uniform speed which is directly proportional to the current i.e. If the disc completes 10 revs/min. at 10 Amp, then it will rotate at 20 r.p.m. when the current is 20 Amps.
The fixed magnet has a braking effect on the disc to prevent "free running" of the disc when the current is zero.
The centre of the disc is attached to a spindle which passes through a train of gears to a number of dials which indicate energy consumption.
An array of these dials is illustrated.



When reading this type of meter, read from Left to Right.
Write down the number which each pointer has passed
i.e. the reading of the above meter would be 43728.4 Kwh.

5. Power Factor Meter

Because industrial circuits use loads such as motors, transformers etc. which are highly inductive, the current taken from the supply LAGS behind the voltage.
What this means is that the energy taken from the supply is greater that the energy used in performing work when the p.f. is large.
This excess energy must be paid for by the consumer and in the case of a large company can amount to many thousands of dollars per month.
It is of extreme importance that the p.f. be properly monitored to enable steps to be taken for its correction.
The meter illustrated is a 3 phase p.f. meter.
A centre spindle is fitted with vanes which come under the influence of the magnetic fields created by the coils. They are displaced by 120° per pair.
The coils wound around the centre spindle are connected to the supply voltages on each phase.
The two larger coils are current coils which are connected in series with one of the phases.
The meter illustrated is for measuring BALANCED 3 phase loads only. For measuring unbalanced loads, 3 current coils are required to measure the current taken in each phase.



5. Maximum Demand Meter

To enable supply authorities such as E.T.S.A. to plan their power distribution systems with respect to cable sizes, transformer sizes, they must know how much power is required by each consumer.
Because most consumers do not operate all their plant at the same time, the total power requirement is not equal to the total kw ratings of motors, lights, heaters etc. which a consumer has.
e.g. a consumer may have equipment with a total rating of 10,000 watts, but at any one time, he would not use more than, say, 5000 watts, i.e. 50%. This 50% is the demand factor.
The cost of buying electricity is greatly reduced if the consumer makes an agreement with the supply authority not to exceed this example of 5000 watts. This is the Maximum Demand that the consumer will make on the supply authority for electrical power. If this figure is exceeded, then additional costs are incurred to the consumer.
Measuring of this maximum demand is done by a Maximum Demand meter which operates over a 15 minute period.
Two pointers are used on the scale. One indicates the actual power being taken by the consumer per 15 minutes, while the other indicates the Maximum demand over the same time period.
If the first pointer passes the second pointer, then the Maximum demand has been passed and excess charges are incurred.
To prevent this happening, the substation operator switches off power to certain sections of the plant when the two pointers come close together.

TITLE:- TESTING INSTRUMENTS

LECTURER:

DATE:-

EQUIPMENT: Avo, Pocket multimeter, megger, Bridge Megger, Wheatstone's Bridge, Tong tester, Phase tester.

The electrician, in the course of his work, is required to carry out a number of tests to ensure that an installation is functioning properly and safely and to assist him in diagnosing faults. Common faults are short circuits, open circuits, earth faults, insulation failure, overload etc.
A variety of meters have been developed to make this job of fault finding easier and quicker. It is essential for the electrician to familiarise himself with the equipment available, and to fully understand its safe use and operation, and how to interpret the readings and results obtained.
Some of the common testing instruments covered in these notes are Avometer, "pocket"multimeter, megger, bridge megger, wheatstone Bridge, Tong tester, phase tester.

1. Avometer

The avometer is a multi purpose meter, capable of measuring Current (a.c. & d.c.) Voltage (a.c. & d.c.) Ohms, capacitance, power, decibels, power factor, and watts. Only the first 4 will be dealt with in these notes.
Before connecting the leads onto any piece of equipment ENSURE THAT THE METER IS SET ON THE PROPER RANGE otherwise serious damage or injury could result.
Place the meter on a flat horizontal surface, and take readings by viewing the pointer from directly overhead. A mirror is placed in the instrument to ensure accurate readings. The pointer and its reflection should coincide.

Ohm's Range

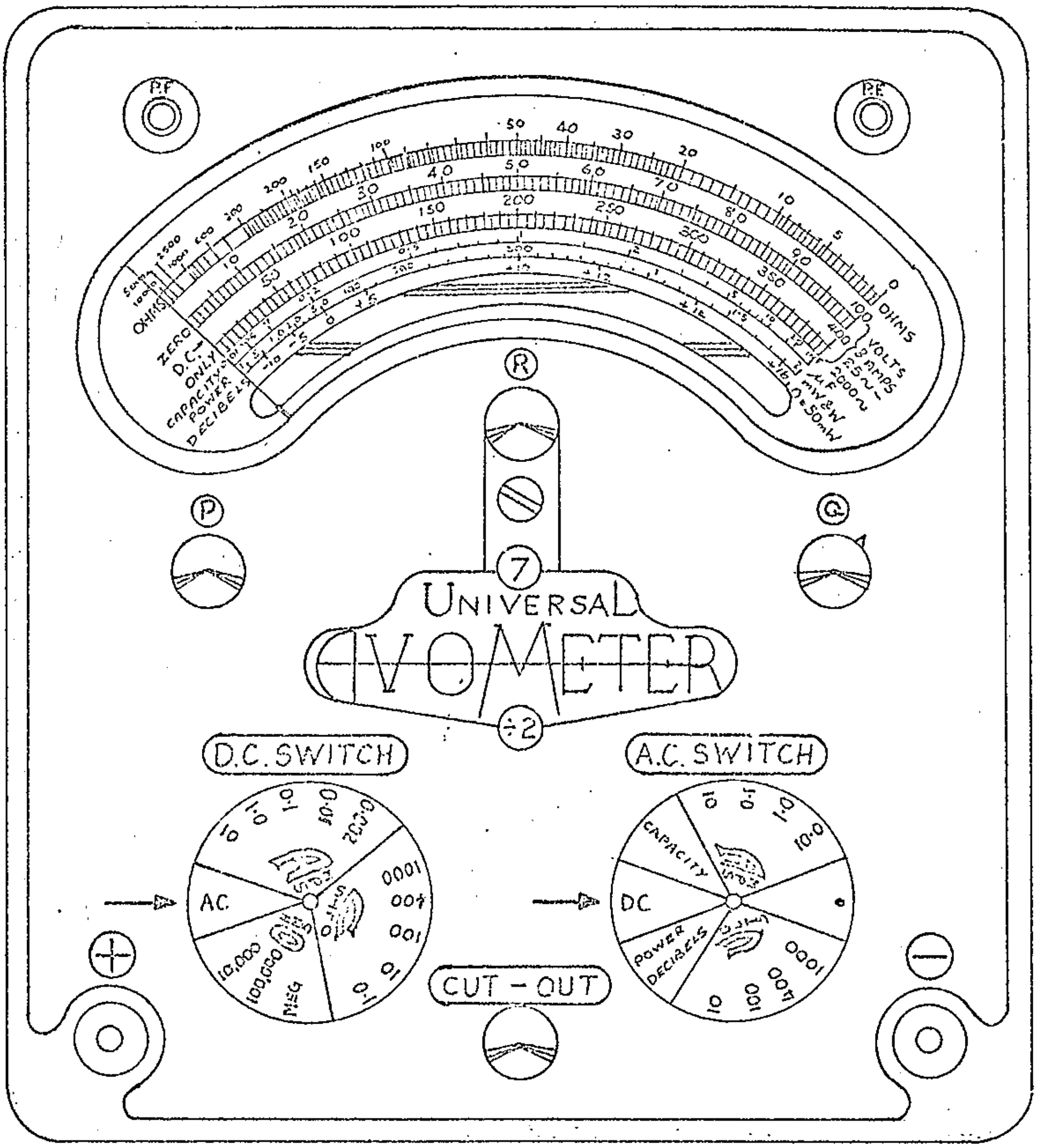
10,000 and 100,000 ohm ranges use a 1½ Volt cell, as the voltage in this cell gradually decreases with use, it may be compensated by adjusting knobs 'P' and 'R'.
Before commencing tests on these ranges, it is advisable to adjust these knobs as follows -

1. Connect the leads together.
2. Set D.C. switch to 100,000 ohms.
3. Adjust 'P' until pointer shows zero ohms.
4. Switch to 10,000 ohms range.
5. Adjust 'R' if necessary to zero ohms.
6. Switch to 100,000 ohms range again.
7. If necessary, re-adjust knob 'P'.

The objective is to make the pointer indicate Zero on both ranges.
When taking readings, switch to the scale which makes the pointer more to centre-scale area when this is possible.
Megohm range uses 2 x 4½ Volt cells in series. Before using this range, the meter must be "set" to zero in the following manner:-

1. Connect the leads together.
2. Set D.C. switch to the 1 megohm range.
3. Raise and turn knob Q and rotate clockwise until the pointer indicates zero.

Do not hold the resistance terminals or meter lead ends during this test or body resistance will cause errors.
Return knob Q to its normal position after this test.
If it is impossible to obtain zero on either of the above tests, replace the relevant batteries.
Do not allow discharged batteries to remain in the meter, and ensure that the D.C. switch is returned to the A.C. position after use to prevent drain on the batteries.
Do not connect the meter to ANY external source of voltage whilst set on any of the OHMS ranges as the meter movement may become damaged.



MODEL 7 UNIVERSAL AVOMETER

+	Connection for RED lead
-	Connection for BLACK lead
P	Potentiometer adjustment for Ohms scale
R	Potentiometer adjustment for Ohms scale
Q	Potentiometer adjustment for Megohm's scale, and for infinity adjustment on CAPACITY scale
P.F.	Connection to "Power factor and Wattage" unit
÷2	To increase meter range on AMPS or VOLTS only

D.C. SWITCH - Selector for measuring d.c. values or resistance values.

A.C. SWITCH - Selector for measuring all a.c. values

Current measurement
1. Set the instrument to the required range - AC or DC, and preferably to the highest value, i.e. 10 Amps AC or DC.
2. SWITCH OFF the circuit to be tested.
3. Connect the meter in SERIES with the load.
4. Switch on the power to the circuit.
5. Adjust the appropriate switch to allow the pointer to indicate as close to centre scale as possible.
DO NOT TOUCH EXPOSED CONNECTIONS DURING THIS TEST.
Do not switch the meter to any other position during this test, whilst the power is ON or the leads connected, otherwise damage could result to the switch contacts or meter movement.
The "÷2" button may be used during this test. This button provides intermediate ranges between those indicated on the switches, i.e. it HALVES the value shown on the switch e.g. When the switch is set on the 10A range, by pressing the "÷2" button, that range becomes 5A.
If over half scale deflection is shown, DO NOT PRESS the 2 button, as this effectively doubles the pointer deflection.

Voltage measurement
1. Set the meter to the appropriate range. If the voltage value is unknown, set to the highest range (1000V).
2. SWITCH OFF the supply if possible.
3. Connect the meter leads.
4. Switch on the power - DO NOT TOUCH ANY EXPOSED LIVE CONNECTIONS.
5. Adjust the appropriate switch to allow the pointer to indicate as close to centre scale as possible.
The "÷2" button may also be used in a similar manner as explained previously.
Do not switch the meter to any other position whilst the power is on or the leads connected.
If it is possible to avoid measuring voltages to determine the required data, it is advisable to do so as this test is the most hazardous of all.

Capacitance test
When it is required to determine the value in microfarads of an unknown capacitor, carry out the following steps:-

1. Set A.C. switch to "CAPACITY".
2. Connect meter leads to 50 c.p.s. supply (from 65 to 250 Volts).
3. Switch on the supply.
4. Raise and turn knob 'Q' until meter indicates infinity (INF).
5. Switch off the supply.
6. Connect capacitor in series with meter.
7. Switch on the supply.
8. Meter will indicate capacitor value in microfarads.

DO NOT TOUCH EXPOSED LIVE CONNECTIONS.
On completion of this test, the supply should be switched OFF and the capacitor DISCHARGED before disconnecting.
Return the 'Q' knob to its normal position.

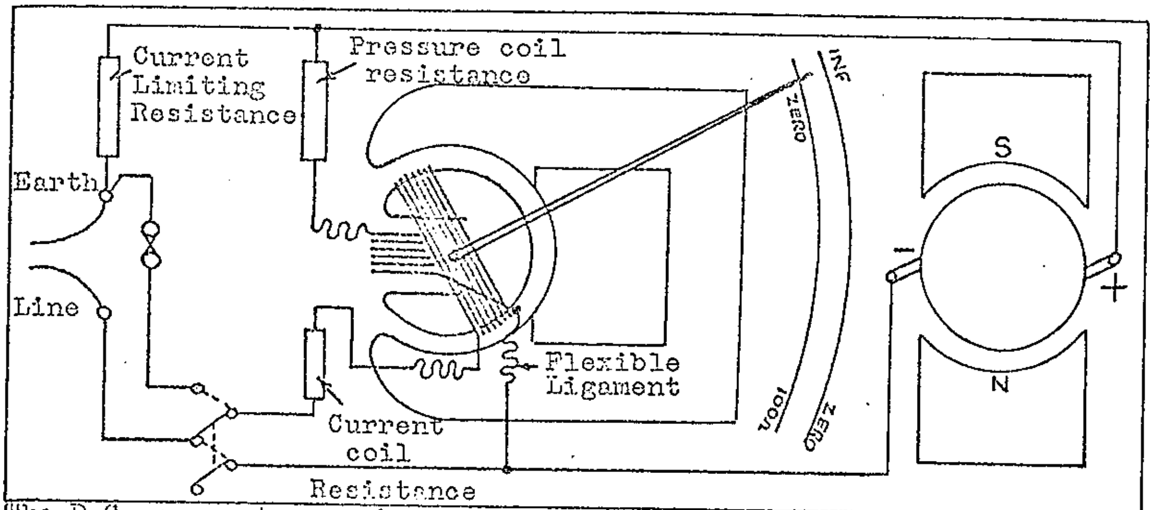
2. "Pocket" Multimeter

This type of multimeter is widely used and preferred by the electrician as it is small and compact and is easily carried in the toolbox. It does not have the wide range that the AVO has but for everyday checking it is most suitable.
Connection to AC and DC current and voltage and to the OHMS range is done by re-positioning the leads into various sockets. It is imperative that the leads be correctly connected before use.
Place the meter on a flat horizontal surface to ensure maximum accuracy.
Use the "0Ω" knob to zero the pointer when using the ohm ranges.
Observe the same precautions described in the previous section on the AVO when making current or voltage tests.
Remove the leads from the ohms sockets when not in use to prevent drain on the internal battery.

3. Megger

Insulation failure is a common occurence in electrical equipment. To check the "soundness" or otherwise of insulation, it is necessary to apply a voltage "across" it of at least twice the normal voltage.

A megger is a device which produces voltages between 250 Volts and 5000 Volts, in a series of steps. This may be done electronically or more commonly, by a generator, the construction of which is illustrated below.



The D.C. generator produces a constant voltage provided that the cranking speed is greater than that required to cause the integral clutch to slip. The voltage produced appears on the meter (reduced by the pressure coil resistance to a safe value) and is unaffected by the external resistance being measured. The current coil is in series with the generator and the resistance under test, i.e. the value of current is inversely proportional to the resistance under test.

The resultant forces from the two magnetic fields so produced cause the pointer to deflect by an amount which is proportional to the current flowing through the resistance under test.

To test the insulation of electrical equipment, follow the procedure below:-

1. Switch OFF the supply to the equipment and attach the necessary tags.
2. Connect the EARTH lead from the megger to a suitable earth connection on the equipment to be tested. TEST EARTH
3. Connect the LINE lead of the megger to the active part of the circuit.
4. Crank the handle to a speed where the clutch slips.
5. Maintain this speed for 30 secs or more.
6. Observe the readings.
7. Cease cranking and leave the megger connected for 2-3 minutes when testing long cables or inductive loads as energy may be stored within the equipment.

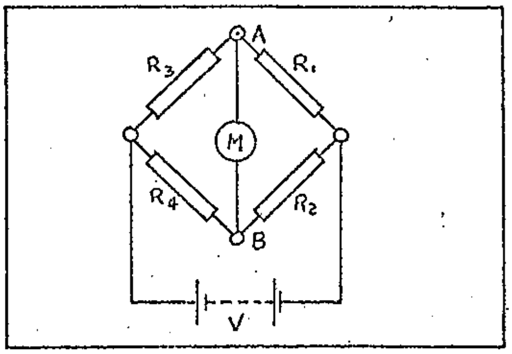
Ideally, the readings obtained should be infinity, this in many cases may not be achieved. There is no set value on the megohm scale where it can be said that the test results obtained change from good to poor. Each item tested must be assessed individually, from the results obtained. Obviously, if the tests show readings in the lower half of the scale, then steps should be taken to locate the cause of the low tests. These causes may be due to dirt, moisture, dust etc. and should be rectified as soon as possible. Remember that insulation failure may cause FIRE or SHOCK.

4. Bridge Megger

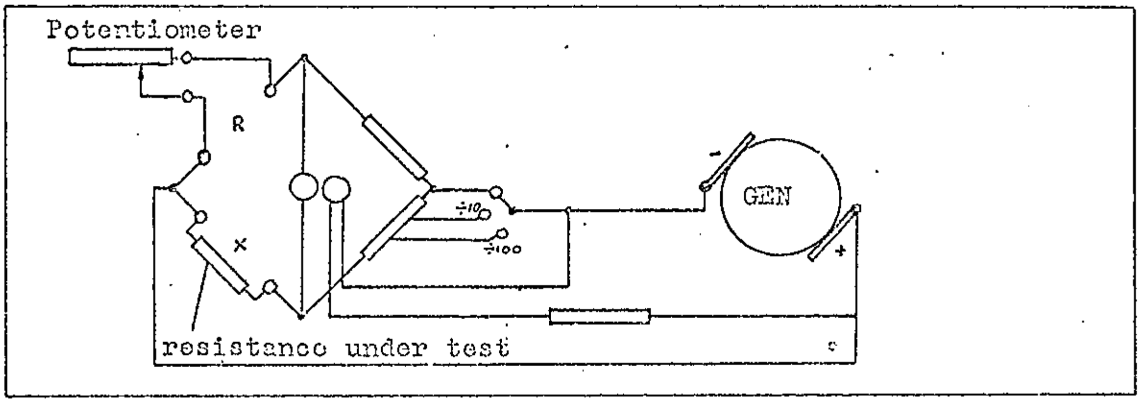
This instrument has a dual purpose. It may be used as a Megger as previously described, or it may be used as a resistance tester to measure accurately values between 0.01 ohms and 100,000 ohms using the principle of the Wheatstone Bridge.

Principle of Wheatstone Bridge

If $R1 = R2$
and $R3 = R4$
Then potential at A & B will be the same.
If one of the resistance values is changed, then the potentials at A or B change causing meter M to deflect.



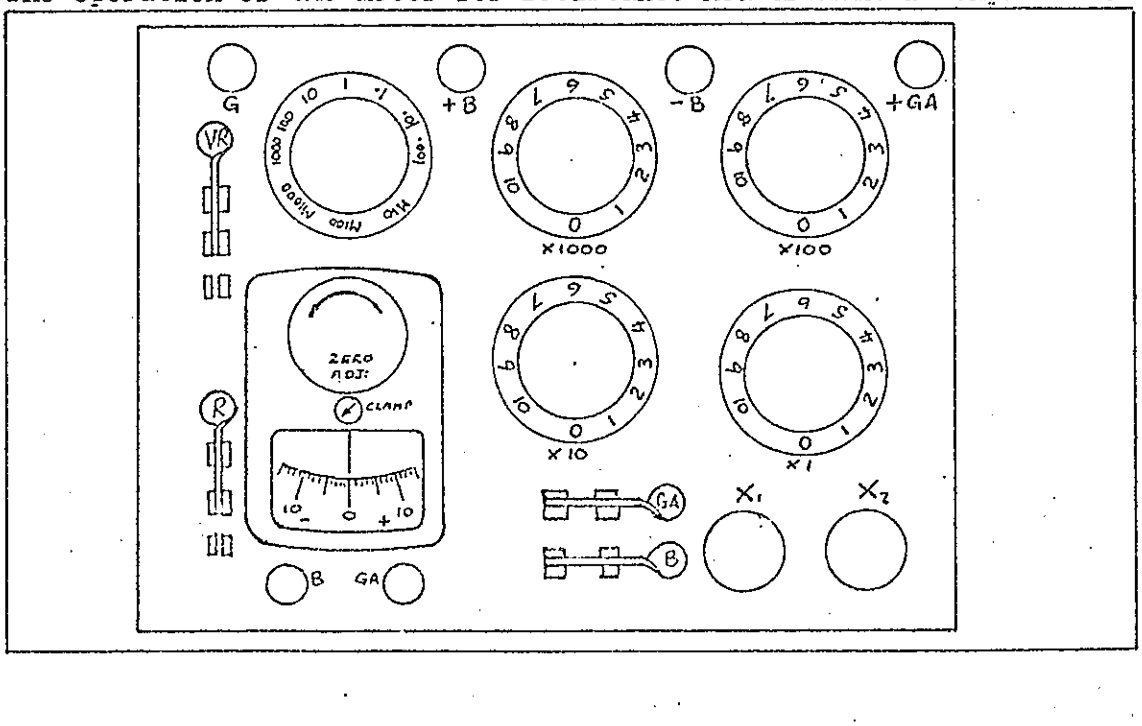
The circuit illustrated below is that of the bridge megger showing how two of the resistors in the above circuit have been replaced, one by an unknown resistor, the other by a potentiometer. The potentiometer is moved until the deflection on the meter is NIL. At this point, the potentiometer's resistance is equal to the resistance of the unknown resistor.



The actual adjustment of the potentiometer is by a series of switches which connect or disconnect fixed values of resistance. A further switch extends the range of the meter. When this switch is set to one of the values indicated (x10, x100, ÷10, ÷100) then the results of the test obtained must be multiplied or divided accordingly.

5. Wheatstone Bridge

This meter employs the principle of the Wheatstone Bridge and may be used for measuring resistance and locating faults by the VARLEY or MURRAY testing method. The carrying out of the latter two tests is explained later.
The operation of the meter for resistance measurement is explained.



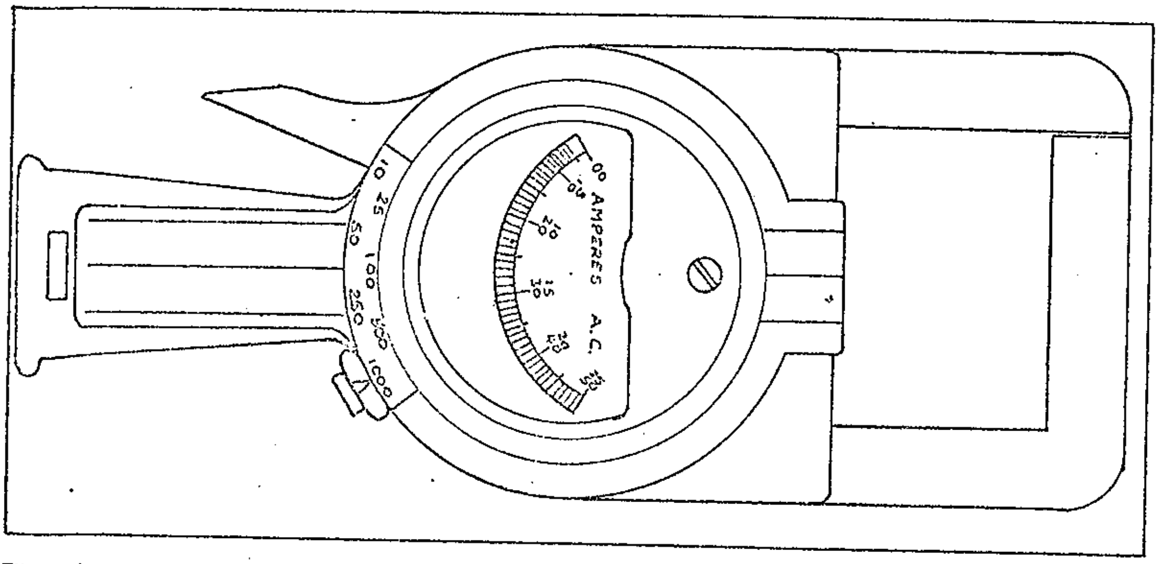
1. Close S, switch to VR side and S2 to R side.
2. Connect resistance under test to X1 and X2 terminals.
3. Unlock galvanometer movement.
4. Depress B and GA buttons.
5. Adjust MULTIPLY knob and the four resistance knobs until galvo reads zero.

The actual resistance is determined by multiplying the value obtained from the resistance control knobs by the MULTIPLY value indicated.

Extremely accurate readings may be obtained with this instrument, and care should be taken to ensure good solid connections. If connecting leads are used, the resistance of the leads should be subtracted from the total resistance calculated.

6. <u>Tong test ammeter</u>

When it is necessary to check currents flowing in a conductor without disconnecting the conductor, a Tong-test ammeter may be used. The principle of this meter is that a current carrying conductor produces a magnetic field.



The iron circuit is opened and placed around the INSULATED conductor and then closed.

The current range selector is gradually reduced from its maximum current position to a position where the meter pointer is close to centre scale.

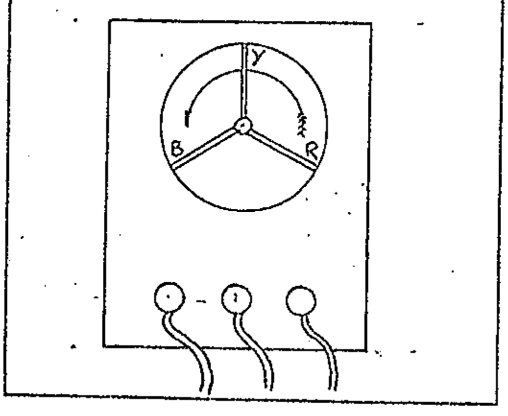
Extreme care is required when using this meter as it is used in close proximity to live equipment.

The meter will only indicate accurately when it is clamped around ONE conductor.

<u>Phase tester</u>

When a 3-phase motor has been disconnected from the supply, and it is required to re-connect it, there is a possibility of wrong connection causing the motor to turn in the wrong direction.

In most cases, this is not serious as the direction can easily be changed after the motor has been run, but in some cases, reversal of the motor may cause serious damage. To check that the polarities of the 3 phase supply are correct, a phase tester is required. This is a 3 phase synchronous motor driving a disc. The disc rotates indicating whether polarity and therefore direction of rotation is correct or not. Reversal of a 3 phase motor is achieved by interchanging any pair of leads.

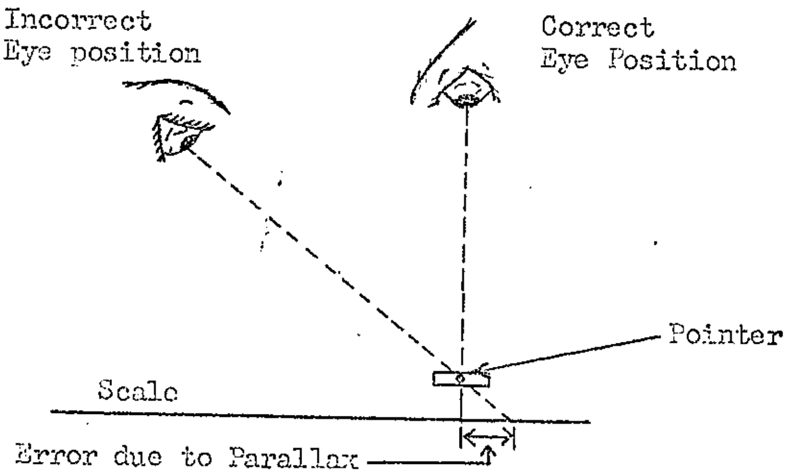


USE OF METERS

The selection of the best meter range to use depends upon two things. First, the range of the meter must be greater than the value to be measured and secondly the deflection of the meter pointer should be as large as possible. Any error due to zero correction, reading of scale, bearing friction, balance, etc., is of less importance with a large movemene of the pointer than with a small deflection. In general, meter readings should not be relied on for deflection of the lowest quarter of the scale.

Meters are expensive to repair or replace so always handle them with care. Do not drop or bump them about and place them in positions free from vibration.

Meters are of little value unless they are reading correctly. To read a meter correctly, the eye should be directly in front of the pointer, never to one side or the other. Fig. 1a, below shows how an error can be introduced by not following this rule.



A further point which must be noted is that since every line on the scale is not numbered, care must be taken in estimating the values of the unmarked intervals. The interval between two lines may be five volts on one scale and one tenth of a volt on another.

The range of the meter must also be considered. By "range" is meant the highest value which can be read on it. By the "scale" is meant the marked divisions for reading the meter. Meters may be made with a single range and scale or may be of the multi-range type. The multi-range type may be used for several ranges of measurements by the proper choice of switch settings or plug or terminal posts.

A multi-range meter may have one scale in which the true value is obtained by multiplying the scale reading by the proper number, or it may have a separate scale for each range.

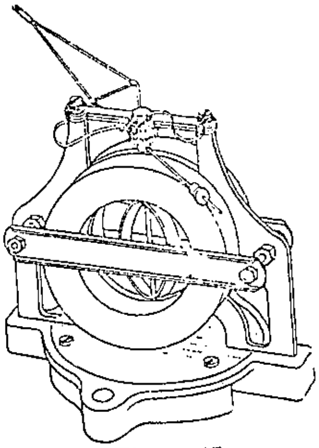


Figure 15.
Dynamometer Coils.

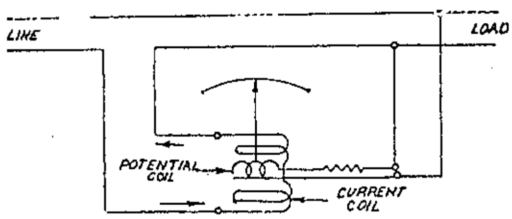


Figure 16.
Wattmeter Circuit.

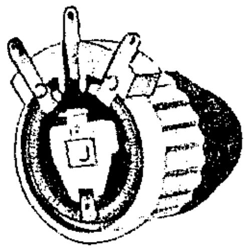


Figure 23.

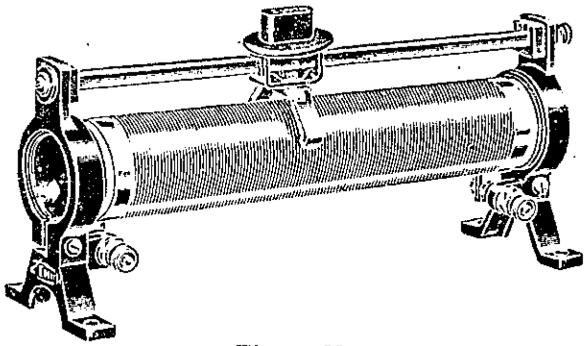


Figure 22.
Zenith Rheostat.

Figure 18.
Avometer.

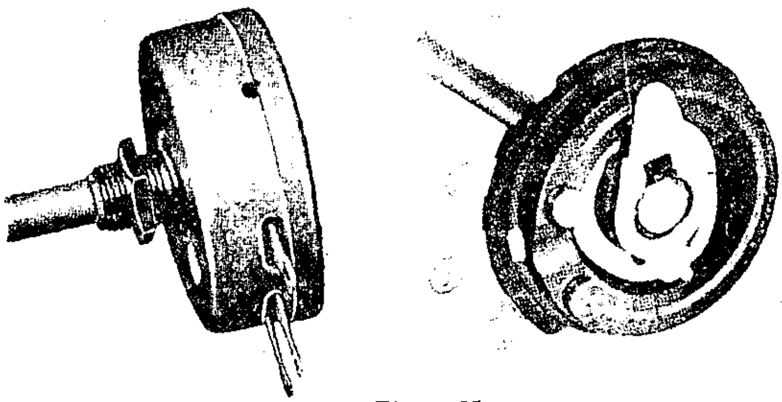


Figure 25.
Carbon Potentiometer.