Types of measuring instruments, equipments, uses and features

Objectives : At the end of this lesson you shall be able to
- **explain the principle of operation of a PMMC type movement**
- **explain D'Arsonval moving coil meter movement**
- **explain the calibration of instruments**
- **explain the functions of CRO and controls**
- **explain the parts and functions of multimeter.**

To work with electricity and to service electrical appliances, requires accurate measurements. To make electrical measurement the most popular instruments used are called Meters. Meter is a tool used to measure the basic electrical quantities such as current,potential difference(volt) and resistance. Right selection and proper use of meters can only give accurate readings.

All meters have one thing in common. They contain an internal standard to which all measured values are compared. In this respect, an electrical meter is much like a mechanical balance that compares an unknown mass to a standard mass.

Meters discussed in this lesson make use of electric current/voltage to produce a magnetic force , it then compares this force to a counter force exerted by a spring.The resultant of these forces drives a pointer which indicates the value of the electric voltage/current applied to the meter on a graduated scale found on the dial of the meter.

The D'Arsonval Movement

All meters will have some form of indicating device. Those that have a Pointer or needle that moves across a fixed scale are based on a mechanism called D' Arsonval movement.This is named after its invention by D'Arsonval Deprez. The principle of D' Arsonval movement is similar to a motor, it makes use of the force of a magnetic field exerted in a current carrying conductor. The principle of this movement is similar to that of a permanent magnet type electric motor.

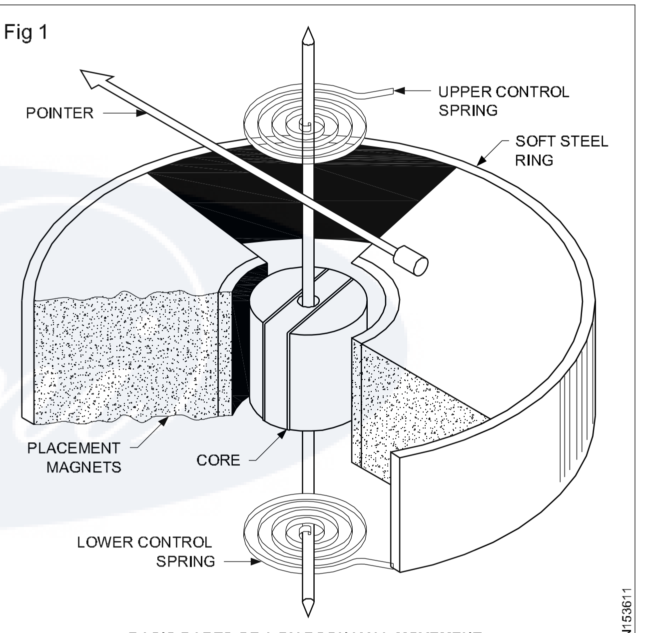
All D'Arsonval meter movements require current and a magnetic field to cause movement of the indicator. Some meters have permanent magnets that work with current to move the pointer. Such type are referred to as permanent magnet moving coil type(PMMC) meters. The other type have no permanent magnets;instead they have current carrying coils to produce the magnetic fields. These are referred to as Moving Iron type (MI) meters.

D'Arsonval meter movements consists of a permanent magnet and a moving coil, also called permenant magnet moving coil galvano meter abbreviated PMMC. The term galvanometer refers to a sensitive current-detecting device.

Fig 1 shows the essential parts of such a galvonometer.

In Fig 1, the coil is mounted on a shaft which rotates between the jewel bearings(not shown in Fig). The Soft steel core reduces the total air gap between the magnetic poles of a permanent magnet. The coil is positioned to turn against precisely made upper and lower control springs. The springs also serve as conductor to carry current to and from the coil. A light weight pointer/indicator attached to the coil indicates how far the coil has rotated. The position of the indicator on the scale tells the amount of current flowing through the coil.

Fig 1



BASIC PARTS OF A D'ARSONAVAL MOVEMENT

Principle of operation of a PMMC type meter movement

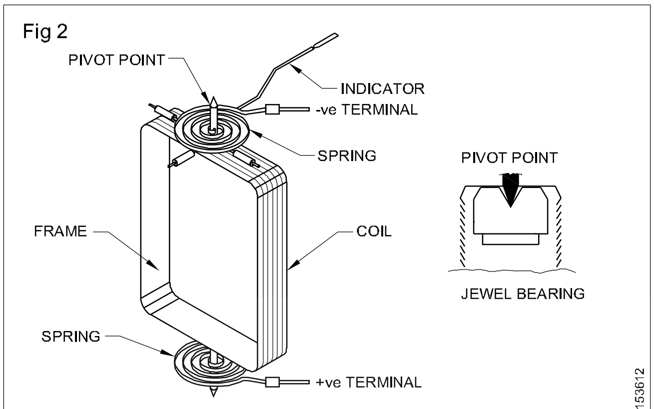
When no current flows through the coil, the control spring's tension hold the coil in a position between the pole faces. This position is defined as "Zero position".

When the coil carries current (whose value is to be measured), the force from the magnetic field due to permanent magnet exerts torque on the current carrying coil and make it rotate(like the motor principle). The indicator moves clock-wise in the direction and the springs controls/resist this motion. The magnetic field exerts a torque on the moveable coil making it to rotate.The indicator then comes to a rest at a non Zero value on the scale where the torque produced by the current and the opposition force of the spring becomes equal.

Because of the permanent magnet, the strength of the magnetic field around the coil is constant. Therefore, the deflecting force is directly proportional to the current through the moveable coil. These conditions makes it possible to calibrate the scale of the instrument to read the measurement value directly.

To allow the moving coil to deflect with bare minimum friction, the shaft of the moving coil is tapered to a point at both ends. The sharp ends rest in a highly polished jewel bearing as shown in Fig 2. The tapered ends hold the shaft precisely in position to maintain the instrument's accuracy. The bearing (usually Sapphire) reduces wear.In addition, the small area of contact keeps the torque caused by friction very low, so that the meter responds rapidly to any changes in current.

Fig 2



BEARING OF A D'ARSONVAL MOVEMENT

Damping in Moving coil type meters

Damping means to control the swing of the coil so that the pointer comes to rest quickly at its final position. Without damping, the pointer attached to the coil swings back and forth before coming to rest. In such case, it is necessary to wait till the swinging stops to take the accurate meter reading.

In permanent magnet moving coil meters, the movable coil is wound on an aluminium frame as shown in Fig 3. This frame, in addition to supporting the coil winding, the bobbin also performs the important function of damping the instrument.

Calibration of Instruments

While the tolerance figures are generally specified, this will not be true if the instrument is in use for a reasonably long time. The main reason for this could be the aging of the instrument. Therfore, to have complete confidence in the instrument used for measurement, it is necessary to "Calibrate" the instrument regularly. If an instrument is left uncalibrated, the same reading taken sometime back will be different not because of the any fault in the manufacturer's specification, but because its calibration might not have been checked within the recommended period.

Calibration is a routine procedure at stated intervals and is performed against preserved and trustworthy standards. The intervals for calibration depends on several factors such as the type of instrument, place of use, accuracy and so on. Hence, most instrument manufacturers specify the interval for calibration and suggest the procedure.

Calibration of Voltmeters and Ammeters

Among the several methods of calibration for volt meters and current meters, the two simple and popular methods are;

– Calibration by potentiometer method

– Calibration by comparison method.

Potentiometer method is the fundamental method of calibration and is necessarily used for the basic standard instrument. But this method is too slow for the general run of calibration and is more precise than needed. Hence the usual portable instruments are calibrated by comparison with a high grade standard instrument of suitable range. At present senario high precision digital instuments can be used as standard instrument while calibrating analog volt/current/ohm meters.

Advantages : The P.M.M.C. instrument

- Consumes less power
- has uniform scale and can cover an arc up to 270°
- has high torque/weight ratio.
- can be modified as voltmeter or ammeter with suitable resistors
- has efficient damping.
- is not affected by stray magnetic fields, and has no loss due to hysteresis.

Disadvantages : The P.M.M.C. instrument

- can be used only in DC
- is very delicate
- is costly when compared to a moving iron instrument
- may show errors due to loss of magnetism of the permanent magnet.

Moving iron instruments

This instrument derives its name from the fact that a piece of soft iron which is attached to the spindle and needle moves in a magnetic field produced by the current or by a current proportional to the quantity of electricity being measured.

There are two types of this instrument which are used either as voltmeter or ammeter.

They are:

– attraction type

– repulsion type.

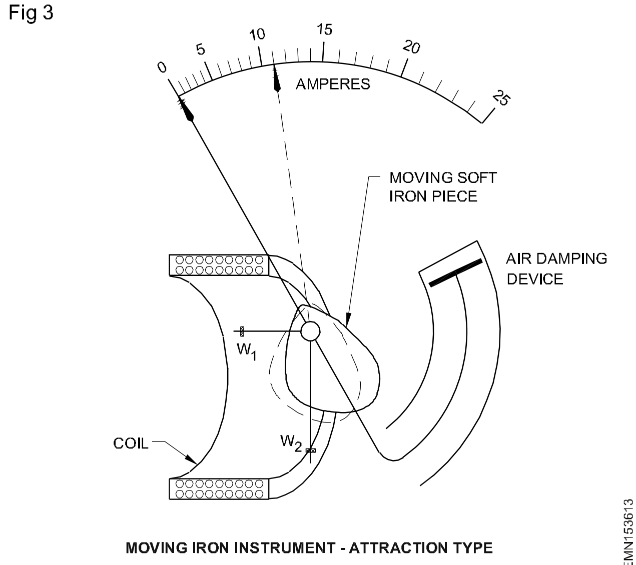
Principle of operation

The attraction type instrument works on the principle of magnetic attraction, and the repulsion type instrument works on the principle of magnetic repulsion between two adjacent pieces of soft iron, magnetised by the same magnetic field.

Construction and working of attraction type moving iron instrument

This instrument consists of an electromagnetic coil having an air core as shown in Fig 3. Just in front of the air core, an oval shaped soft iron piece eccentrically pivoted in a spindle is kept as shown in Fig 3. The spindle is free to move with the help of the jewelled bearings, and the pointer, which is attached to the spindle, could move over the graduated scale. When the electromagnetic coil is not connected to the circuit, the soft iron piece hangs vertically down due to gravitational force and the pointer shows zero reading.

Fig 3

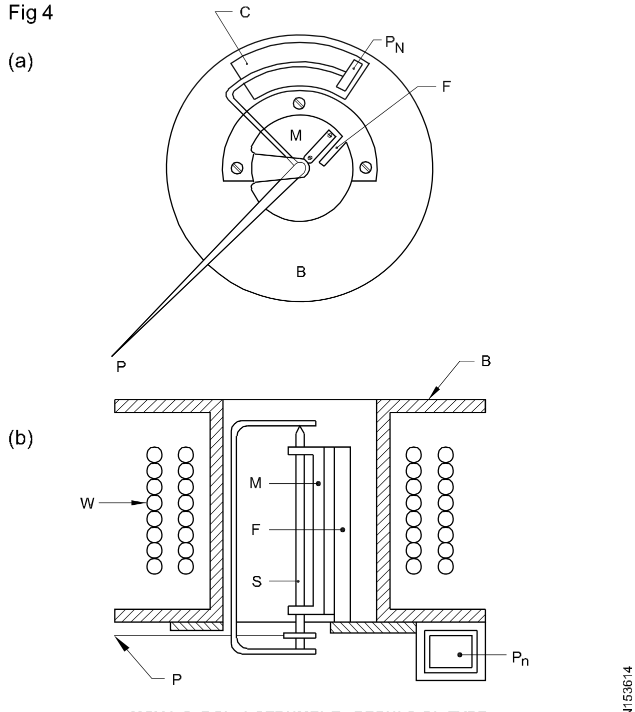


MOVING IRON INSTRUMENT - ATTRACTION TYPE

When the electromagnetic coil is connected to the supply, the magnetic field created in the coil attracts the soft iron piece. (Fig 3) Due to the eccentricity of pivoting of the iron piece, the enlarged portion of the iron piece is pulled towards the coil. This, in turn, moves the spindle and makes the pointer to deflect. The amount of deflection of the pointer will be greater when the current producing the magnetic field is greater. Further, the attraction of the soft iron piece is independent of the current direction in the coil. This characteristic enables the instrument to be used both in DC and AC.

Construction and working of repulsion type moving iron instrument

Fig 4



MOVING IRON INSTRUMENT - REPULSION TYPE

This instrument consists of a coil W wound on a brass bobbin B, inside which two strips of soft iron M and F are set axially as shown in Figs 4a & 4b. Strip F is fixed whereas the iron strip M is attached to the spindle S, which also carries the pointer P.

Spring control is used and the instrument is designed such that when no current is flowing through W, the pointer is at zero position and the soft iron strips M and F are almost touching. (Figs 4a & 4b)

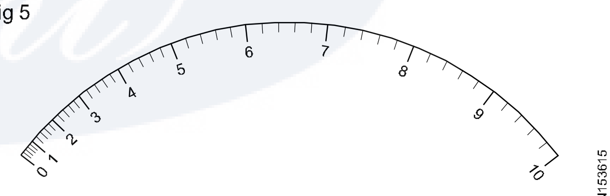
When the instrument is connected to the supply, the coil W carries current which, in turn, produces a magnetic field. This field makes the fixed and moving iron F and M respectively to produce similar poles in the ends. Therefore, the two strips repel each other. The torque set up produces a deflection of the moving system and therefore. brings into play a controlling torque due to torsion. The moving system comes to rest in such a position that the deflecting and controlling torques are equal.

In this type of instrument air damping is used commonly which is provided by the movement of piston P_N in a cylindrical air chamber C as shown in Fig 4a.

Deflecting torque and graduation of scale

However, in the moving iron instruments the deflecting torque is proportional to the square of the magnetic force which, in turn, is proportional to the square of the current passing through the coil. As such the scale of this instrument will be uneven. That is, cramped at the beginning and open at the end as shown in Fig 5.

Fig 5



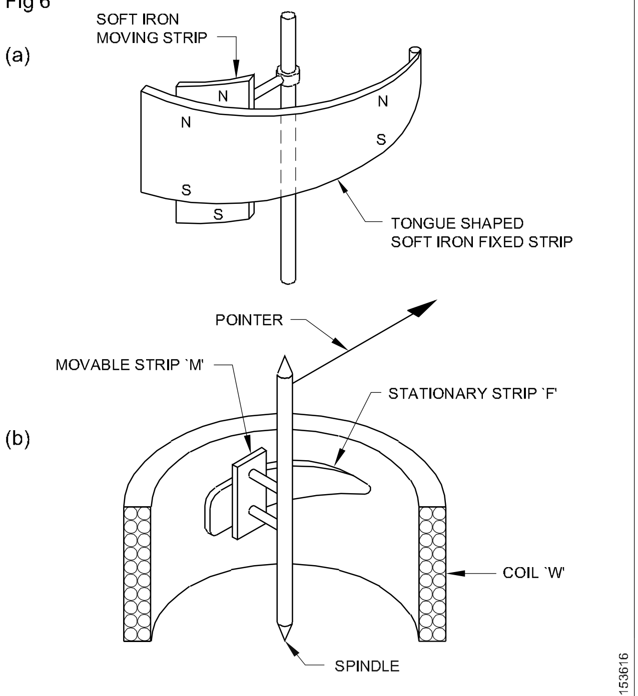
SCALE OF THE MOVING IRON INSTRUMENT (UNEVEN)

In order to achieve uniformity of scale, some manufacturers have designed tongue shaped strips as moving and fixed soft irons as shown in Fig 6a.

The fixed iron consists of a tongue-shaped soft iron sheet bent into a cylindrical form, while the moving iron is also made of another soft iron sheet and is so mounted as to move parallel to the fixed iron and towards its narrower end as shown in Fig 6b. The torque which is proportional to the square of the magnetic force/current is proportionally reduced by the narrow portion of the fixed iron resulting in more or less even torque, and, thereby, getting uniform scale.

These instruments are either gravity or spring controlled and the damping is achieved by the air friction method as shown in Fig 6a.

Fig 6



DESIGN OF THE FIXED IRON PIECE

USES, ADVANTAGES AND DISADVANTAGES

Uses

They are used as voltmeters and ammeters.

They can be used on both AC and DC and, hence, are called unpolarized instruments.

Advantages

They have a small value of friction errors as the torque/ weight ratio is high.

They are less costly when compared to the moving coil instruments.

They are robust owing to their simple construction.

They have satisfactory accuracy levels within the limits of both precision and industrial grades.

They have scales covering 240^{o}.

Disadvantages

They have errors due to hysteresis, frequency changes, wave-form and stray magnetic fields.

They have non-uniform scale usually. However, special manufacturing designs are utilized to get more or less uniform scales.

Moving iron Instrument as an ammeter

It may be constructed for full scale deflection of 1 to 30A without the use of shunts or current transformers. To obtain full scale deflection with currents less than 0.1A, it requires a coil with a large number of fine wire turns, which results in an ammeter with a high impedance.

The range of the instrument, when used as an ammeter, can be extended by using a suitable shunt across its terminals. No problem arises during operation with DC but the division of current between instrument and shunt changes with the change in applied frequency while using AC.

Multimeter

The three most commonly measured electrical quantities are current, voltage and resistance. Current is measured by an ammeter, voltage by a voltmeter and resistance by an ohmmeter.

A single instrument used for measuring all the above three quantities is known as a multimeter. It is a portable, multi range instrument.

It has a full scale deflection accuracy of ±1.5 %. The lowest sensitivity of multimeters for AC voltage range is 5 kΩ/ volts and for the DC voltage range it is 20 kΩ/ volts. The lowest range of DC is more sensitive than the other ranges.

Fig 7a

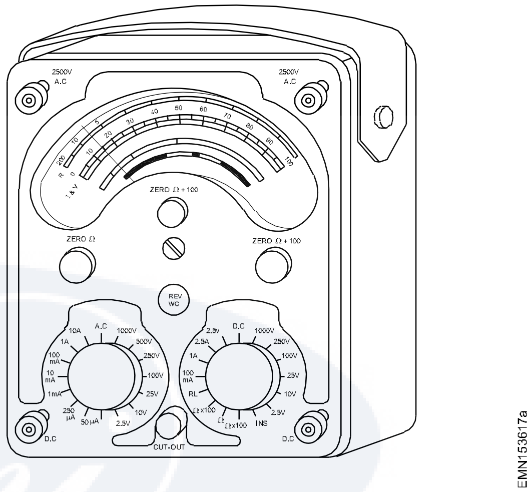
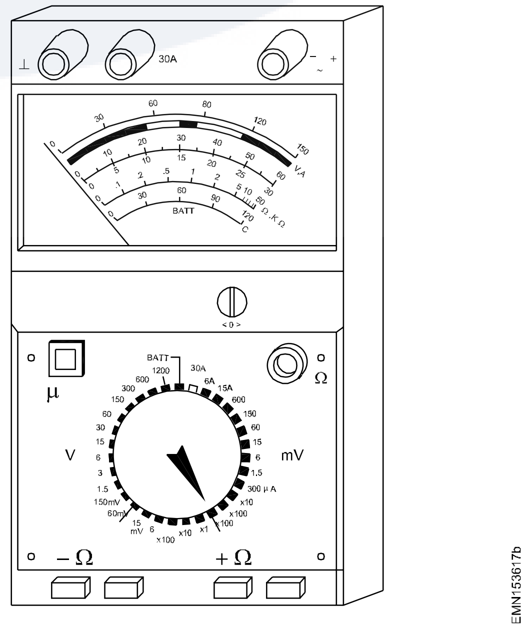


Fig 7b



Figs 7a and 7b show typical multimeters.

Construction of a multimeter

A multimeter uses a single meter movement with a scale calibrated in volts, ohms and milliamperes. The necessary multiplier resistors and shunt resistors are all contained within the case. Front panel selector switches are provided to select a particular meter function and a particular range for that function.

On some multimeters, two switches are used, one to select a function, and the other the range. Some multimeters do not have switches for this purpose; instead they have separate jacks for each function and range.

Batteries/cells fixed inside the meter case provide the power supply for the resistance measurement.

The meter movement is that of the moving coil system as used in DC ammeters and voltmeters. (Fig 8)

Rectifiers are provided inside the meter to convert AC to DC in the AC measurement circuit.

Parts of a multimeter

A standard multimeter consists of the main parts and controls, as shown in Fig 9.

Fig 8

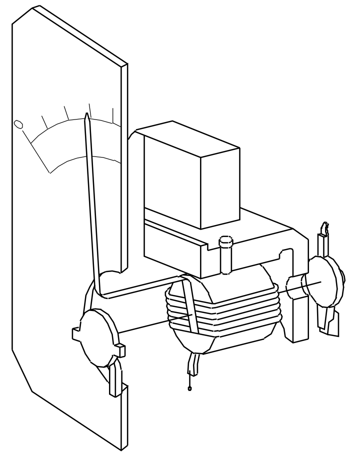
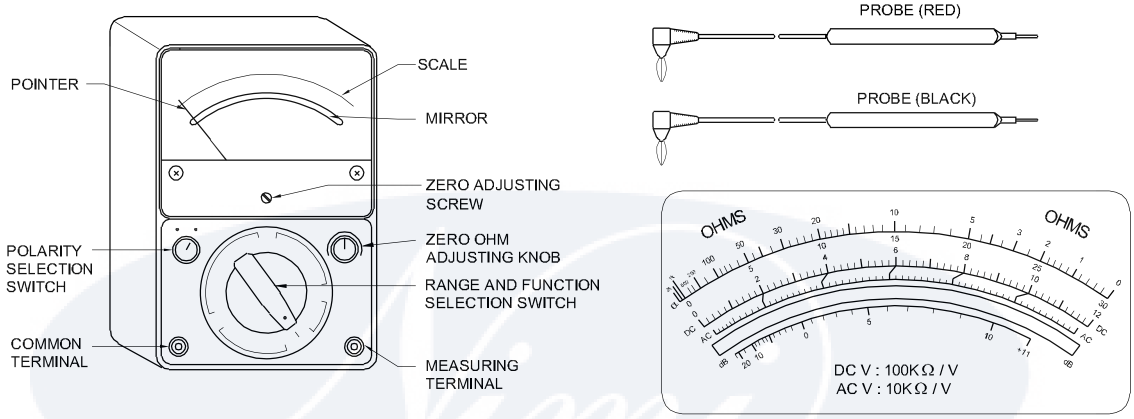


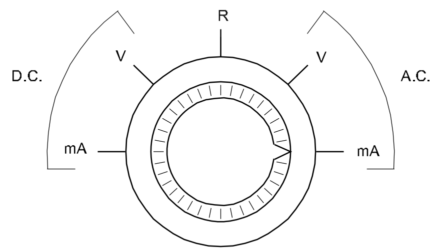
Fig 9



Controls

The meter is set to measure the current, voltage (AC and DC) or resistance by means of the FUNCTION switch. In the example given in Fig 10 the switch is set to mA, AC.

Fig 10



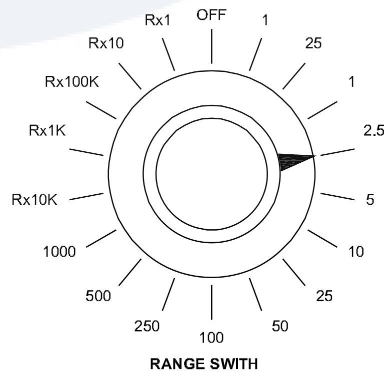
FUNCTION SWITCH

The meter is set to the required current, voltage or resistance range - by means of the RANGE switch. In Fig 11, the switch is set to 2.5 volts or mA, depending on the setting of the FUNCTION switch.

The example in Fig 12 shows the switch set to 25V DC of a meter having the function and the range selected by a single switch.

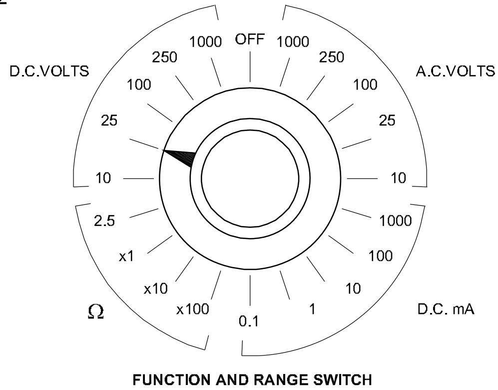
The example in Fig 13 shows the switches set to 250V AC of a meter that uses two function/range switches, one for DC ranges and the other for AC and resistance (ohms) ranges.

Fig 11



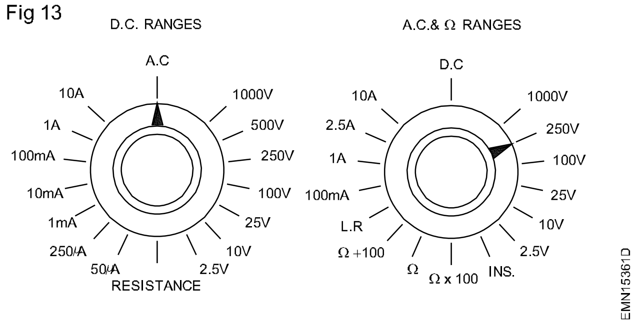
RANGE SWITH

Fig 12



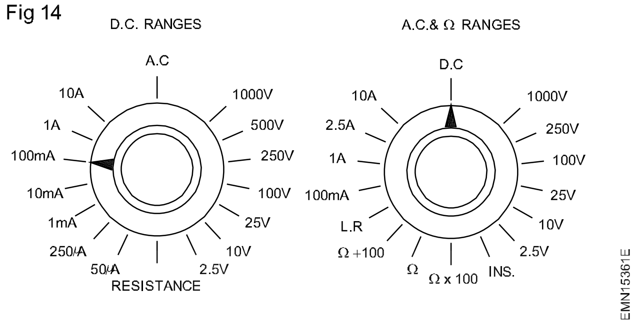
FUNCTION AND RANGE SWITCH

Fig 13



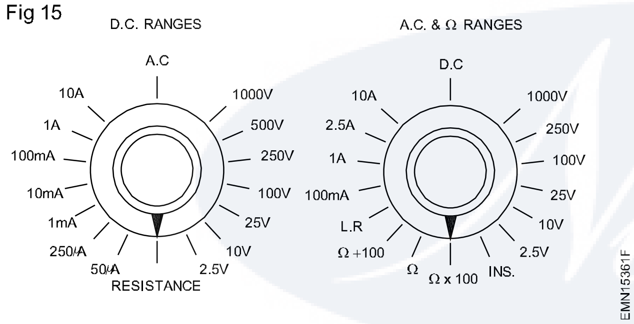
Switches set to 100 mA DC. (Fig 14)

Fig 14



Switches set to resistance, ohms x 100 range. (Fig 15)

Fig 15

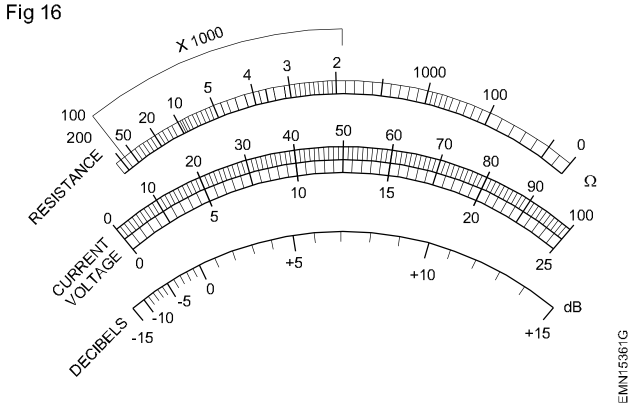


Scale of multimeter

Separate scales are provided for:

- resistance
- voltage and current.(Fig 16)

Fig 16



The scale of current and voltage is uniformly graduated.

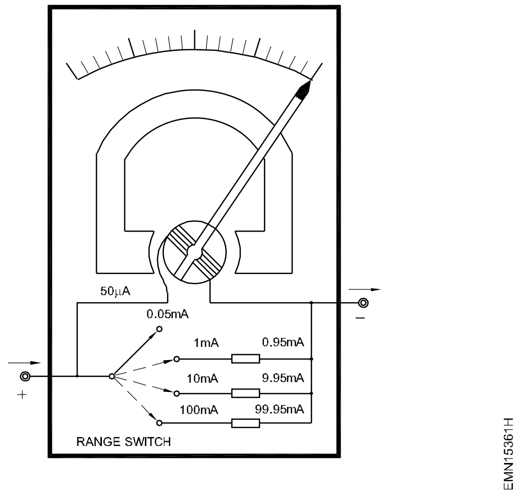
The scale of the ohmmeter is non-linear. That is, the divisions between zero and infinity (∞) are not equally spaced. As you move from zero to the left across the scale, the divisions become closer together.

The scale is usually 'backward', with zero at the right.

Principle of working

A circuitry when working as an ammeter is shown in Fig 17.

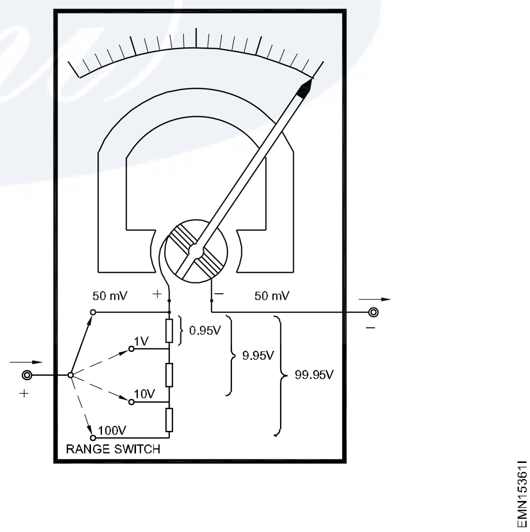
Fig 17



Shunt resistors across the meter movement bypass current in excess of 0.05 mA at FSD. A suitable value of shunt resistor is selected through the range switch for the required range of current measurement.

A circuitry when working as a voltmeter is shown in Fig 18.

Fig 18

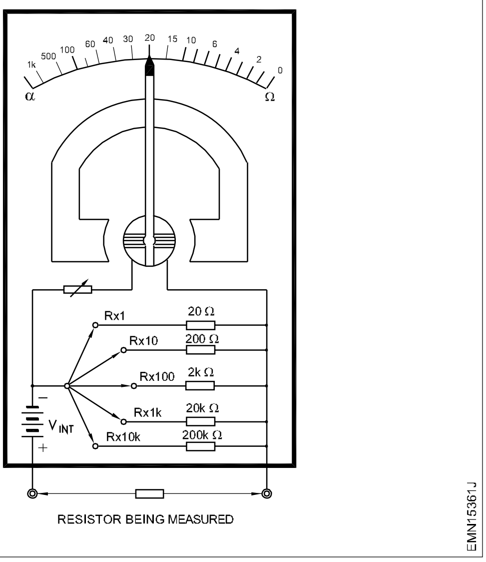


The voltage drop across the meter coil is dependent on the current and the coil resistance. To indicate voltages greater than 50 mV at FSD as per the circuit, multiplier resistances of different values are connected in series with the meter movement through the range switch for the required range of measurement.

A circuitry when working as an ohmmeter is shown in Fig 19.

To measure resistance, the leads are connected across the external resistor to be measured as shown in Fig 19. This connection completes the circuit, allowing the internal battery to produce current through the meter coil, causing deflection of the pointer, proportional to the value of the external resistance being measured.

Fig 19



Zero adjustment

When the ohmmeter leads are open, the pointer is at full left scale, indicating infinite ¥ resistance (open circuit). When the leads are shorted, the pointer is at full right scale, indicating zero resistance.

The purpose of the variable resistor is to adjust the current so that the pointer is at exactly zero when the leads are shorted. It is used to compensate for changes in the internal battery voltage due to aging.

Multiple range

Shunt (parallel) resistors are used to provide multiple ranges so that the meter can measure resistance values from very small to very large ones. For each range, a different value of shunt resistance is switched on. The shunt resistance increases for the higher ohm ranges and is always equal to the centre scale reading on any range.

Digital Multimeter (Fig 20)

Digital multimeters are high input impedance and better accuracy and resolution. It converts an input analog signal into its digital equivalent and displays it. the analog input signal might be digital voltage, an a.c. voltage, a resistance or an a.c/d.c current. The Figure 20 shows the top view of the digital multimeter

Measurement of resistance using multimeter

A moving coil meter can be used to measure unknown resistance by using a circuit configuration. With the test probes short circuited, the ohms adjust control is turned so that the current through the total circuit resistance deflects the meter to the full scale. Now by connecting the test probes across the unknown resistance, the current is decreased, and the deflection on the scale gives you the resistance value. Ohms law states the output current is proportional to the applied voltage. Unit of resistance is ohms.

Measurement of voltage

The moving coil meter has constant resistance so that the current through the meter is proportional to the voltage across it. so the current meter can be used to measure voltage. To extent, the voltage range of the meter, it is necessary to add resistance in series with the meter circuit. In order to measure a.c. voltage, rectification is required. The principle of generating a.c. is by electromagnetic induction is higher. While measuring unknowing voltage levels with multimeter, always range switch should be set to the highest available range and work down from there Unit of voltage is volts.

Measurement of current:

The moving coil meter is sensitive to the current and is therefore an ammeter. For d.c. measurement, the meter is placed in series with the circuit. So the circuit must be broken to connect the ammeter and it becomes the part of the circuit. For A.C. measurement, rectifier type meters are used which will respond to the average value of the rectified alternating current. Unit of current is amperes.

Electrical instruments may be classified based on the following.

- Manufacturing standards
- Function
- Effects of electric current on the instruments.

Manufacturing standards: The electrical instruments may, in a broad sense, be classified according to the manufacturing standards into absolute instruments and secondary instruments.

Absolute instruments: These instruments give the value of quantity to be measured in terms of deflection and instrument constants. A good example of an absolute instrument is the tangent galvanometer. In this instrument the value of current could be calculated from the tangent of the deflection produced by the current, the radius and number of turns of wire used and the horizontal component of the earth's magnetic field. No previous calibration or comparison is necessary in this type of instruments. These instruments are used only in standard laboratories.

Secondary instruments: In these instruments the value of electrical quantity (voltage, current, power, etc.) to be measured can be determined from the deflection of the instruments on the calibrated dial. These instruments should be calibrated in comparison with either an absolute instrument or with one which has already been caliberated. All the instruments used commercially are secondary instruments.

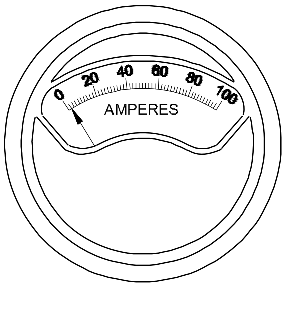
Functions

Secondary instruments are further classified according to their functions, that is, whether the instrument indicates, or records the quantity to be measured. Accordingly, we have indicating, integrating and recording instruments.

Indicating instruments: These instruments, as shown in Fig 2, indicate the value of voltage, current power etc. directly on a graduated dial. Ammeters, voltmeters and wattmeters belong to this class.

Integrating instruments: These instruments measure the total amount, either the quantity of electricity or the electrical energy, supplied to a circuit over a period of time. Ampere hour meters and energy meters belong to this class.

Fig 21



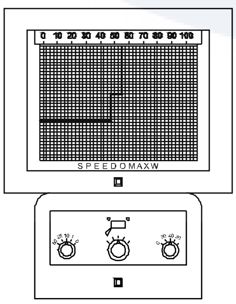
Recording instruments: These instruments register the quantity to be measured in a given time, and are provided with a pen which moves over a graph paper. With this instrument, the quantity can be checked for any particular date and time. Recording voltmeters,ammeters and power factor meters belong to this class. Fig 22 shows such a recording instrument.

Effects of electric current used on electrical instruments: Secondary instruments may also be classified according to the various effects of electricity upon which their operation depends. The effects utilised are as follows.

- Magnetic effect
- Heating effect
- Chemical effect
- Electrostatic effect
- Electromagnetic induction effect

Essential forces required for an indicating instrument:

Fig 22



The following three forces are essential requirements of an indicating instrument for its satisfactory operation. They are

- deflecting force
- controlling force
- damping force.

Deflecting force or operating force: This causes the moving system of the instrument to move from its `zero' position, when the instrument is connected to the supply. To obtain this force in an instrument, different effects of electric current, such as magnetic effect, heating effect, chemical effect etc. are employed.

Controlling force: This force is essential to control the movement of the moving system and to ensure that the magnitude of the deflction of the pointer is always the same for a given value of the quantity to be measured. As such, the controlling force always acts opposite to the deflecting force, and also brings the pointer to zero position when the instrument is disconnected from the supply.

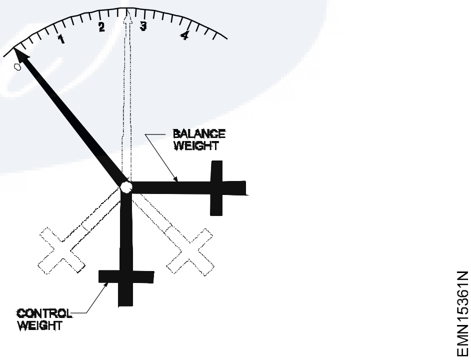
The controlling force could be produced by any one of the following ways.

- Gravity control
- Spring control

Gravity control: In this method, small adjustable weights are attached to the opposite extension of the pointer as shown in Fig 23. These weights are attracted by the earth's gravitational pull, and thereby, produce the required controlling force(torque). The instruments with gravity control are to be used in the vertical position only.

When the instrument is not connected to the supply, the control weight and the balance weight attached to the opposite end of the pointer make the pointer to be at zero position as shown in Fig 23. When the instrument is connected to the supply, the pointer moves in a clockwise direction, thereby displacing the weights as shown in dotted lines in the figure. Due to the gravitational pull, the weights will try to come to their original vertical position, thereby exerting a controlling force on the movement of the moving system.

Fig 23



Spring control: The most common arrangement of spring control utilises two phosphor-bronze or beryllium-copper spiral hair-springs A and B, the inner ends of which are attached to the spindle S as shown in Fig 24. The outer end of the spring B is fixed, whereas that of A is attached to the end of a lever `L' pivoted at P, thereby enabling the zero adjustment to be easily effected when needed.

The two springs A and B are wound in opposite directions so that when the moving system is deflected, one spring winds up while the other unwinds, and the controlling force is due to the combined torsions of the springs.

These springs are made from such alloys that they have:

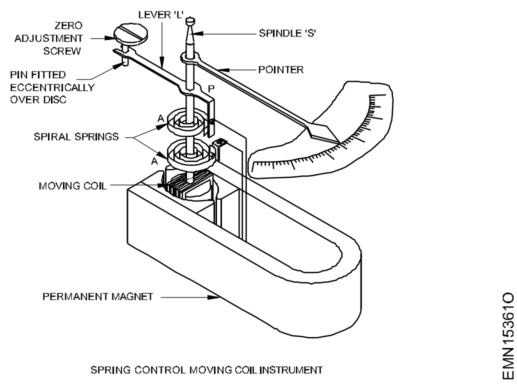
- high resistance to fatigue (can be wound or unwound several times without loosing the tension)
- non-magnetic properties (should not get affected by external magnetism)

– low temperature cofficient (do not elongate due to temperature)

– low specific resistance (can be used for leading current `in' and `out' of the moving system).

Spring controlled instruments have the following advantages over the gravity controlled instruments.

Fig 24



SPRING CONTROL MOVING COIL INSTRUMENT

Ohm meter

Resistances could be broadly classified according to their values as low, medium and high resistances.

Low resistance: All resistances of the order of 1 ohm and below, may be classified as low resistances.

***Example**:* Armature and series field resistances of large D.C. machines, ammeter shunts, cable resistance, contact resistance, etc.

Medium resistances: Resistances above 1 ohm and upto 100,000 ohms are classified as medium resistances.

***Example**:* Heater resistance, shunt field resistance, relay coil resistance etc.

High resistances: Resistances above 100000 ohms are classified as high resistances.

***Example**:* Insulation resistance of equipment, cables etc.

Medium resistances could be measured by instruments like Kelvin's bridge, Wheatstone bridge, Slide wire bridge, Post Office box and ohmmeter. Also special designs of the above instruments allow measurement of low resistances accurately.

However for measuring high resistances, instruments like megohmmeter or Megger is used.

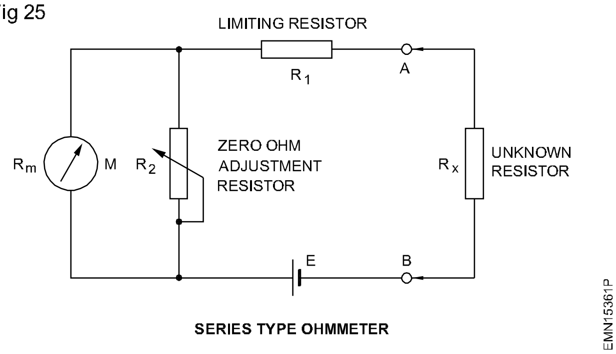
Ohmmeter: The ohmmeter is an instrument that measures resistance. There are two types of ohmmeters, the series ohmmeter, used for measuring medium resistances, and the shunt type ohmmeter, used for measuring low resistances. The ohmmeter, in it basic form, consists of an internal dry cell, a P.M.M.C. meter movement and a current limiting resistance.

Before using an ohmmeter in a circuit for resistance measurement, the current in the circuit must be turned off and also any electrolyte capacitor in the circuit should be discharged, as the ohmmeter has its own source of supply.

Series type ohmmeter

Construction: A series type ohmmeter shown in Fig 25 consists essentially of a P.M.M.C. (`D' Arsonval) movement 'M', a limiting resistance R_1 and a battery 'E' and a pair of terminals of A and B to which the unknown resistance 'R_x' is to be connected and shunt resistance R_2 is connected in parallel to meter 'M' which is used for adjusting the zero position of the pointer.

Fig 25



SERIES TYPE OHMMETER

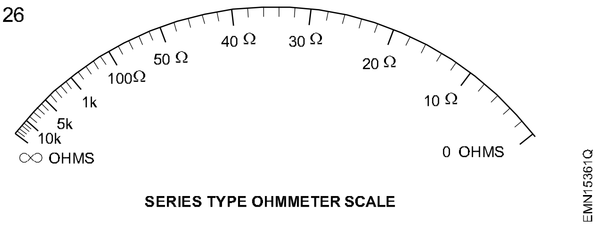
Working: When the terminals A and B are shorted (unknown resistor R_X= zero), maximum current flows in the circuit. Meter is made to read full scale current (I_{fsd})by adjusting the shunt resistance R_2. The full scale current position of the pointer is marked zero(0) ohm on the scale. When the ohmmeter leads (A & B terminals) are open, no current flows through the meter movement. Thereby the meter does not deflect and the pointer remains on the left hand side of the dial. Therefore the left side of the dial is marked infinity (∞) which means that there is infinite resistance (open circuit) between the test leads.

Intermediate marking may be placed in the dial (scale) by connecting different known values of R_x, to the instrument terminals A and B.

The accuracy of the ohmmeter greatly depends upon the condition of the battery. Voltage of the internal battery may decrease gradually due to usage or storage time. As such the full scale current drops, and the meter does not read zero when the terminals A and B are shorted. The variable shunt resistor R_2 in Fig 25 provides an adjustment to counteract the effect of reduced battery voltage within certain limits. If the battery voltage falls beyond a certain value, adjusting the zero adjusting resistance R_2 may not bring the pointer to zero position, and, hence, the battery should be replaced with a good one.

As shown in Fig 26, the meter scale will be marked zero ohms at the right end and infinite ohms at the left end.

Fig 26



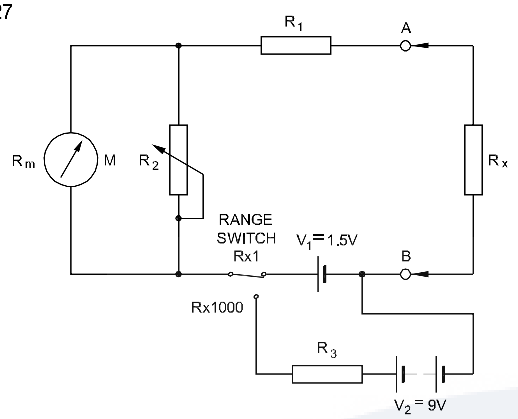
SERIES TYPE OHMMETER SCALE

This ohmmeter has a non-linear scale because of the inverse relationship between the resistance and current. This results in an expanded scale near the zero end and a crowded scale at the infinity end.

Multiple ohmmeter range: Most of the ohmmeters have a range switch to facilitate measurement of a wide range of resistors, say from 1 ohm up to 100000 ohms. The range switch acts as the multiplying factor for the ohms scale. To get the actual value of measurement,the scale reading needs to be multiplied by the R_x factor of the range switch.

The range switch arrangement is provided either through a network of resistances powered through a cell of 1.5V or through a battery of 9 or 22.5 volts. The latter arrangement is shown in Fig 27. The resistance value of R_3 is so chosen that the full scale current is passed through the meter at the enhanced source voltage.

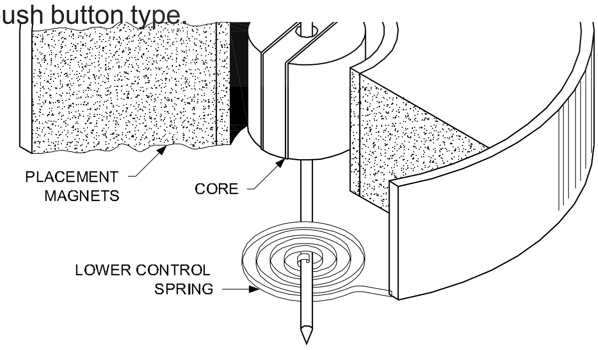
Fig 27



MULTI-RANGE SERIES TYPE OHMMETER

Use: This type of ohmmeter is used for measuring medium resistances only, and the accuracy will be poor in the case of very low and very high resistance measurements.

Shunt type ohmmeter: Fig 28 shows the circuit diagram of a shunt type ohmmeter. In this meter the battery 'E' is in series with the adjustable zero ohm adjust resistor R_1 and the PMMC meter movement. The unknown resistance R_X, which is connected across the terminals A and B, forms a parallel circuit with the meter. To avoid draining of the battery during storage, the switch S is of spring-loaded push button type.



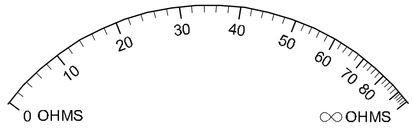
BASIC PARTS OF A D'ARSONAVAL MOVEMENT

Working: When the terminals A and B are shorted (the unknown resistance R_X= zero ohm), the meter current is zero. On the other hand, if the unknown resistance R_X = μ (A and B open) the current flows only through the meter, and by a proper selection of the value R_1, the pointer can be made to read its full scale.

The shunt type ohmmeter, therefore, has the zero mark at the left hand side of the scale (no current) and the infinite mark at the right hand side of the scale (full scale deflection current) as shown in Fig 29. When measuring resistance of intermediate values, the current flow divides in a ratio inversely proportional to the meter resistance and the unknown resistance. Accordingly the pointer takes up an intermediate position.

Use: This type of ohmmeter is particularly suitable for measuring low value resistors.

Fig 29



SHUNT TYPE OHMMETER SCALE

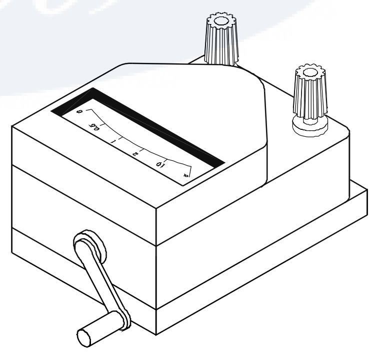
Necessity of megohmmeter: Ordinary ohmmeters and resistance bridges are not generally designed to measure extremely high values of resistance. The instrument designed for this purpose is the megohmmeter. (Fig 30) A megohmmeter is commonly known as MEGGER.

Types of insulation testers: There are two types of insulation testers as stated below.

– Magneto-generator type
– Transistorised type

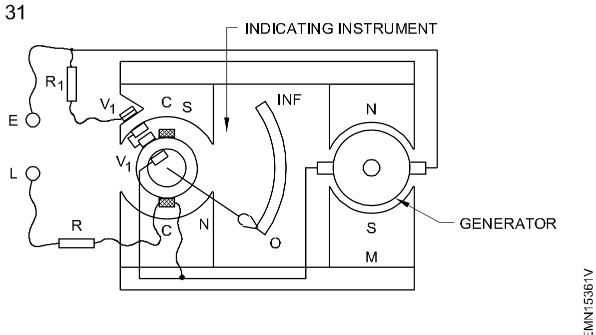
Magneto-generator type Insulation tester: In this tester, the testing voltage is produced by a magneto-generator when the handle is cranked at a speed of 160 r.p.m. approximately, whereas the transistorised insulation tester is incorporated with cells which power the tester. However a testing voltage in the order of 250V to 5000 V DC is produced by internal circuitry

Fig 30



Construction: The megohmmeter consists of (1) a small DC generator, (2) a meter calibrated to measure high resistance, and (3) a cranking system. (Fig 31)

Fig 31



A generator commonly called a magneto is often designed to produce various voltages. The output may be as low as 500 volts or as high as 1 megavolt. The current supplied by the megohmmeter is in the order of 5 to 10 milliamperes. The meter scale is calibrated: either in kilo-ohms (kW) or in megohms(MW).

Working principle: (Fig 31) The permanent magnets supply the flux for both the generator and the metering device. The voltage coils are connected in series across the generator terminals. The current coil is arranged so that it will be in series with the resistance to be measured. The unknown resistance is connected between the terminals L and E.

When the armature of the magnet is rotated, an emf is produced. This causes the current to flow through the current coil and the resistance being measured. The amount of current is determined by the value of the resistance and the output voltage of the generator. The torque exerted on the meter movement is proportional to the value of current flowing through the current coil.

The current through the current coil, which is under the influence of the permanent magnet, develops a clockwise torque. The flux produced by the voltage coils reacts with the main field flux, and the voltage coils develop a counter-clockwise torque. For a given armature speed, the current through the voltage coils is constant, and the strength of the current coil varies inversely with the value of resistance being measured. As the voltage coils deflect counter-clockwise, they move away from the iron core and produce less torque. A point is reached for each value of resistance at which the torques of the current and voltage coils balance, providing an accurate measurement of the resistance. Since the instrument does not have a controlling torque to bring the pointer to zero, when the meter is not in use, the position of the pointer may be anywhere on the scale.

The speed at which the armature rotates does not affect the accuracy of the meter, because the current through both the circuits changes to the same extent for a given change in voltage. However, it is recommended to rotate the handle at the slip speed to obtain steady voltage.

Because megohmmeters are designed to measure very high values of resistance, they are frequently used for insulation tests.

Ranges of magneto-generator type insulation tester: The instrument with the following specification is recommended for testing high tension equipment, transformers, mains etc. and apparatus having a high degree of insulation and considerable capacitance.

Ranges up to 50,000 megohms, 2500 volts.

The instrument with the following specification is recommended for contractors and inspectors for testing power circuits, motors etc. operating on 500 volts and for testing mains having moderate capacitance.

Ranges up to 2,000 megohms, 1000 volts.

The instruments with the following specification is suitable for testing house wiring, small motors etc. operating on voltages not exceeding 250 volts.

Ranges up to 50 megohms, 500 volts.

Electronic insulation tester (transistorised Megger)

This transistorised Megger converts low DC voltage (from dry cell) to high DC voltage by using an oscillator, step up transformer and a converter.

The voltage generated at the test terminals of the insulation tester is in the order of 250V or 500V or 1000 V depending upon the design which is again based on the requirement. A moving coil meter (D. Arsonval instrument) with a high resistance in series forms a series ohmmeter and has a dial graduated in megohms similar to the conventional Megger dial.

A spring loaded push-button switch in the cell circuit connects the battery only during measurement so as to increase the life of the battery. A variable resistance used in the oscillator circuit varies the oscillating amplitude of the wave-form so as to vary the DC test voltage. The instrument provides initial zero adjustment which compensates the voltage variation as the cell discharges. Initially, for every testing, the zero reading must be adjusted by shorting the terminals.

Ratings: The rated resistance in megohms and the rated voltage of the insulation resistance testers having the following ranges are recommended by I.S.2992 of 1980.

Rated voltage (DC volts)	Rated resistance (megohms)
250V	20 megohms 50 megohms
500V	20 megohms 100 megohms 1000 megohms
1000V	200 megohms 2000 megohms 20000 megohms
2500V	5000 megohms 50000 megohms
5000V	100000 megohms

The multi-range insulation testers are also available with rated voltage and rated resistance values selected from the above table. The multi-range insulation tester may be provided with a selector switch to change the range

Connection for measurement: When conducting insulation resistance test between line and earth, the terminal `E' of the insulation tester should be connected to the earth conductor.

Precautions

- A megohmmeter should not be used on a live system.
- The handle of the megohmmeter should be rotated only in a clockwise direction or as specified.
- Do not touch the terminals of a megohmmeter while conducting a test.

- Support the instrument firmly while operating.
- Rotate the handle at slip speed.

Uses of a megohmmeter

- Checking the insulation resistance
- Checking the continuity

Examples

a) Between Earth (metallic body) and winding/element/ conductor.

b) Between two windings/conductor.

Energy meter

Necessity of energy meter: The electrical energy supplied by the electricity board should be billed based on the actual amount of energy consumed. We need a device to measure the energy supplied to a consumer. Electrical energy is measured in kilowatt hours in practice. The meter used for this is an energy meter.

In AC, an induction type of energy meter is universally used for measurement of energy in domestic and industrial circuits.

Principle of a single induction type energy meter:

The opeartion of this meter depends on the induction principle. Two alternating magnetic fields produced by two coils in induce current in a disc and produce a torque to rotate it (disc). One coil (potential coil) carries current proportional to the voltage of the supply and the other (current coil) carries the load current. Torque is porportional to the power as in wattmeter. The watt-hour meter must take both power and time in to consideration. The instantaneous speed is proportional to the power passing through it. The total number of revolutions in a given time is proportional to the total energy that passes through the meter during that period of time.

Iron core: It is specially shaped to direct the magnetic flux in the desired path. It directs the magnetic lines of force, reduces leakage flux and also reduces magnetic reluctance.

Potential coil (voltage coil): The potential coil is connected across the load and is wound with many turns of fine wire. It induces eddy current in the aluminium disc.

Current coil: The current coils, connected in series with load, are wound with a few turns of thick wire, since they must carry the full load current.

Disc: The disc is the rotating element in the meter, and is mounted on a vertical spindle which has a worm gear at one end. The disc is made of aluminium and is positioned in the air gap between the potential and current coil magnets.

Spindle: The spindle ends have hardened steel pivots. The pivot is supported by a jewel bearing. There is a worm gear at one end of the spindle. As the gear turns the dials, they indicate the amount of energy passing through the meter.

Permanent magnet/brake magnet: The permanent magnet restrains the aluminium disc from racing at a high speed. It produces an opposing torque that acts against the turning torque of the aluminium disc.

Functioning of energy meters: The rotation of the aluminium disc in is accomplished by an electromagnet, which consists of a potential coil and current coils. The potential coil is connected across the load. It induces an eddy current in the aluminium disc. The eddy current produces a magnetic field which reacts with the magnetic field produced by the current coils to produce a driving torque on the disc.

The speed of rotation of the aluminium disc is proportional to the product of the amperes (in the current coils) and the volts (across the potential coil). The total electrical energy that is consumed by the load is proportional to the number of revolutions made by the disc during a given period of time.

A small copper ring(shading ring) or coil (shading coil) is placed in the air gap under the potential coil, to produce a forward torque, large enough to counteract any friction produced by the rotating aluminium disc.

This counter torque is produced when the aluminium disc rotates in the magnetic field established by the permanent magnet. The eddy currents, in turn, produce a magnetic field that reacts with the field of the permanent magnet, causing a restraining action that is proportional to the speed of the disc. The faster the disc rotates, the greater the induced eddy currents, and greater the restraining action. This restraining action is necessary to make the speed of rotation proportional to the current taken by the load and also to stop the disc from further rotation due to inertia when the supply is disconnected.

Creeping error and adjustment: In some meters the disc rotates continuously even when there is no current flow through the current coil i.e. when only the pressure coil is energised. This is called creeping. The major cause for creeping is over-compensation for friction. The other causes for creeping are excessive voltage across the pressure coil, vibrations and stray magnetic fields.

In order to prevent creeping, two diameterically opposite holes are drilled in the disc. The disc will come to rest with one of the holes under the edge of a pole of the potential coil magnet, the rotation being thus limited to a maximum of half a revolution.

Meter movement: A basic current meter movement by itself can be used to measure voltage. You know that every meter coil has a fixed resistance, and, therefore, when current flows through the coil, a voltage drop will be developed across this resistance. According to Ohm's Law, the voltage drop (E) will be proportional to the current flowing through the coil of resistance R (E = IR). For example, you have a 0-1 milliampere meter movement with a coil resistance of 1000 ohms. When 1 milliampere is flowing through the meter coil and is causing F.S.D. the voltage developed across the coil resistance will be:

$E = I_M R_M = 0.001 \times 1000 = 1$ volt.

If only half that current (0.5 milliampere) was flowing through the coil, then the voltage across the coil would be:

$E = I_M R_M = 0.0005 \times 1000 = 0.5$ volt.

It can be seen that the voltage developed across the coil is proportional to the current flowing through the coil. Also, the current that flows through the coil is proportional to the voltage applied to the coil. Therefore, by calibrating the meter scale in units of voltage instead of in units of current, the voltage in various parts of a circuit can be measured.

Although a current meter movement inherently can measure voltage, its usefulness is limited because the current that the meter coil can handle, as well as its coil resistance, are very low. For example, the maximum voltage you could measure with the 1 milliampere meter movement in the above example is 1 volt. In actual practice, voltage measurements higher than 1 volt will be required.

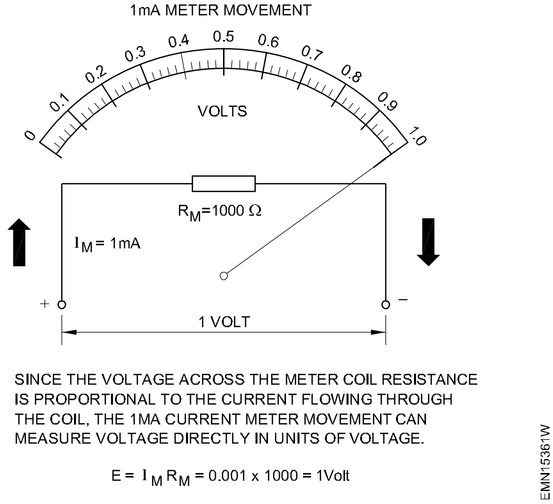
Multiplier resistors: Since a basic current meter movement can only measure very small voltages, how can it measure voltages greater than the $I_M R_M$ drop across the coil resistance? The voltage range of a meter movement can be extended by adding a resistor, in series. The value of this resistor must be such that, when added to the meter coil resistance, the total resistance limits the current to the full-scale current rating of the meter for any applied voltage.

For example, suppose one wanted to use the 1-milliampere, 1000-ohms meter movement to measure voltages up to 10 volts. From Ohm's Law, it can be seen that, if the movement is connected across a 10-volt source, 10 milliamperes would flow through the movement and would probably ruin the meter ($I = E/R = 10/1000 = 10$ milliamperes). But the meter current can be limited to 1 milliampere if a multiplier resistor (R_{MULT}) is added in series with the meter resistance (R_M). Since a maximum of only 1 milliampere can flow through the meter, the total resistance of the multiplier resistor and the meter ($R_{TOT} = R_{MULT} + R_M$) must limit the meter current to one milliampere. By Ohm's Law, the total resistance is

$R_{TOT} = E_{MAX}/I_M = 10$ volts/0.001 ampere

= 10,000 ohms.

Fig 32



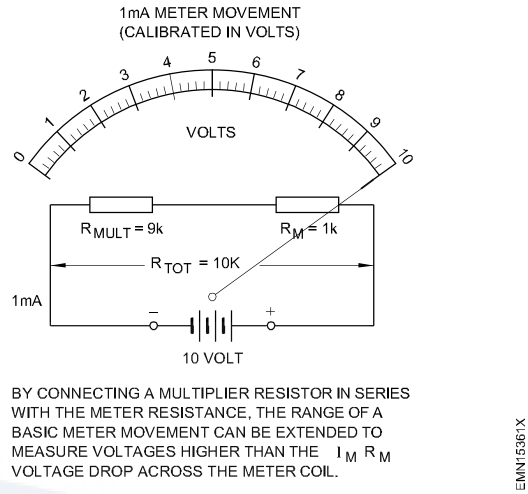
But this is the total resistance needed. Therefore, the multiplier resistance is

$$R_{MULT} = R_{TOT} - R_M = 10000 - 1000 = 9000 \text{ ohms.}$$

The basic 1-milliampere, 1000-ohms meter movement can now measure 0-10 volts, because 10 volts must be applied to cause a full-scale deflection. However, the meter scale must now be re-calibrated from 0-10 volts, or, if the previous scale is used all the reading should be multiplied by 10. (Fig 33)

Multiplying factor (M.F)

Fig 33



$$MF = \frac{\text{Proposed voltmeter range(V)}}{\text{Voltage drop across MC at FSD}} = \frac{V}{V}$$

Calculating the multiplier resistance using M F

$$R_{MULT} = (MF - 1)\, R_M$$

where

R_{MULT} = Multiplier resistance
M F = Multiplying factor
R_M = Meter resistance

A 1 mA meter has a coil resistance of 1000 ohms. What value of multiplier resistor is needed to measure 100V?

$$MF = \frac{V}{v}$$

$$v = I_M \times R_M$$

$$= 1 \times 10^{-3} \times 1000 = 1V$$

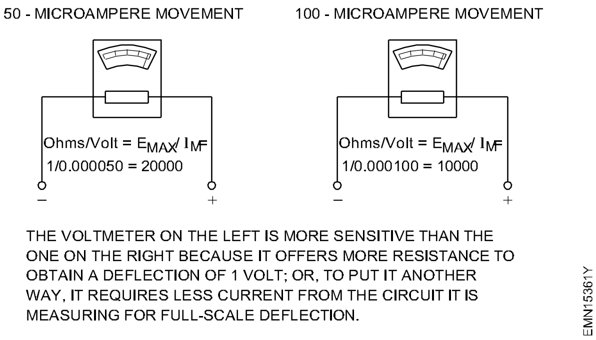
$$MF = \frac{V}{v} = \frac{100}{1} = 100$$

$$R_{MULT} = (MF - 1)R_M = (100 - 1)1000$$

$$= 99{,}000 \text{ ohms.}$$

Sensitivity of voltmeter: An important characteristic of any voltmeter is its impedance or ohms per volt (ohms/volt) rating. Ohms/volt rating is the voltmeter sensitivity. The ohms/volt rating is defined as the resistance required (R_M + R_{MULT}) for full scale deflection. For example, the 1mA 1000 ohms meter movement indicates 1 volt at full scale deflection. Therefore its `ohm/volt' rating is 1000/1 or 1000 ohms/volt (Fig 34) ohms/volt = E_{MAX}/I_M.

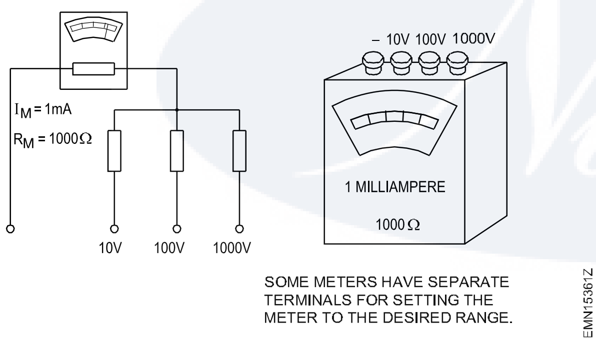
Fig 34



Multi-range voltmeters: In many types of equipment, one encounters voltages from a few tenths of a volt up to hundreds, and even thousands, of volts. To use single-range meters in these cases will be impractical, and costly. Instead, multi-range voltmeters that can measure several ranges of voltage, can be used.

A multi-range voltmeter contains several multiplier resistors that can be connected in series with the meter movement. A range switch is used to connect the proper resistor, or resistors, for the desired range. Also, in some cases, separate terminals for each range are mounted on the meter case. (Fig 35)

Fig 35

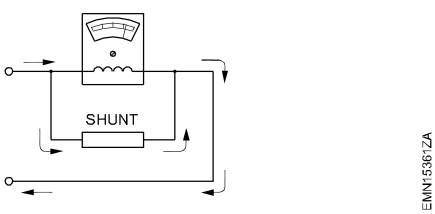


The resistance of the multiplier should not change with temperature. Therefore the material used for multipliers should have very low temperature coefficient of resistance. The temperature co-efficient of resistance of Manganin and constantan are 0.000015 and 0.00001 respectively. Therefore, Maganin and constantan as used for multipliers.

Extension of range of MC ammeters

Shunts: Moving coils of basic meters by themselves cannot carry large currents, since they are made of fine wire. To measure a current greater than that which the moving coil can carry, a low resistance, called a SHUNT, is connected across the instrument terminals as shown in Fig 36.

Fig 36



The shunt, therefore, makes it possible to measure currents much greater than that could be measured by the basic meter alone.

To understand how a shunt can be used to extend the range of a current meter, it is important to understand the behavior of current flow through two resistors connected in parallel. It has already been made clear that current will divide between two resistors in parallel.

It was also made clear that the current through each resistor is inversely proportional to its resistance; that is, if one resistor has twice the resistance of another, the current flowing through the larger resistor will be half the current through the smaller one.

Current flow divides between two resistors parallel in a ratio inversly proportional to their resistance.

Resistor R_2 is twice as large as resistor R_1. Therefore, the current through R_2 will be one-half the current through R_1.

Every meter coil has definite DC resistance. When a shunt is connected in parallel with the coil, the current will divide between the coil and the shunt, just as it does between any two resistors in parallel. By using a shunt of proper resistance, the current through the meter coil will be limited to the value that it can safely handle, and the remainder of the current will flow through the shunt.

Care and Maintenance of meters

Always start by starting the range switch at a value higher than that which you reasonably expect to measure. If not, you could damage the instrument.

Make sure your multi-tester is set in the right mode. Trying to measure voltage with the mode set on “AMPS” could destroy the meter and possibly cause harm to the operator. Also, some meters are destroyed by trying to measure voltage if meter is set to measure resistance.

If you have a choice of finding a fault in a circuit with dangerous voltages on it by either testing voltages or measuring resistance, turn off the power and use the latter.

Keep test leads in good condition-No cracked insulation, keep probes sharp, connectors tight.

Do not place the instrument in a place where it may be pulled off and onto the floor or onto other circuitry.

If using an ammeter that requires that it be inserted in series with the measured circuit, turn OFF the power, make your connections, the turn ON the power and measure. Repeat procedure when disconnecting the meter.

Clamp-on type ammeters do no require the circuit to be opened for insertion of the meter; Safer and faster to use.

When using a HI-POT tester, keep the area clear of these who are not part of the testing.

Always start tests with output control at zero, and the switch in the “OFF” condition. Make sure all equipment grounds are tight, and that the device is connected and used accroding to manufaturer’s instructions .