ELECTRICIAN

NSQF LEVEL - 5

2nd Semester

TRADE THEORY

SECTOR:Electrical

Directorate General of Training

DIRECTORATE GENERAL OF TRAINING
MINISTRY OF SKILL DEVELOPMENT & ENTREPRENEURSHIP
GOVERNMENT OF INDIA

NATIONAL INSTRUCTIONAL
MEDIA INSTITUTE, CHENNAI

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FOREWORD

The Government of India has set an ambitious target of imparting skills to 30 crores people, one out of every four Indians, by 2020 to help them secure jobs as part of the National Skills Development Policy. Industrial Training Institutes (ITIs) play a vital role in this process especially in terms of providing skilled manpower. Keeping this in mind, and for providing the current industry relevant skill training to Trainees, ITI syllabus has been recently updated with the help of Mentor Councils comprising of various stakeholder's viz. Industries, Entrepreneurs, Academicians and representatives from ITIs.

National Instructional Media Institute (NIMI), Chennai has come up with instructional material to suit the revised curriculum for **Electrician 2nd Semester Trade Theory NSQF Level - 5** in **Electrical** sector under Semester Pattern required for ITIs and related institutions imparting skill development. The NSQF Level 5 will help the trainees to get an international equivalency standard where their skill proficiency and competency will be duly recognized across the globe and this will also increase the scope of recognition of prior learning. NSQF level 5 trainees will also get the opportunities to promote life long learning and skill development. I have no doubt that with NSQF level 5 the trainers and trainees of ITIs, and all stakeholders will derive maximum benefits from these IMPs and that NIMI's effort will go a long way in improving the quality of Vocational training in the country.

The Executive Director & Staff of NIMI and members of Media Development Committee deserve appreciation for their contribution in bringing out this publication.

Jai Hind

RAJESH AGGARWAL
Director General / Addl. Secretary,
Ministry of Skill Development & Entrepreneurship,
Government of India.

New Delhi - 110 001

PREFACE

The National Instructional Media Institute (NIMI) was established in 1986 at Chennai by then Directorate General of Employment and Training (D.G.E & T), Ministry of Labour and Employment, (now under Directorate General of Training, Ministry of Skill Development and Entrepreneurship) Government of India, with technical assistance from the Govt. of the Federal Republic of Germany. The prime objective of this institute is to develop and provide instructional materials for various trades as per the prescribed syllabi NSQF (Level 5) under the Craftsman and Apprenticeship Training Schemes.

The instructional materials are created keeping in mind, the main objective of Vocational Training under NCVT/NAC in India, which is to help an individual to master skills to do a job. The instructional materials are generated in the form of Instructional Media Packages (IMPs). An IMP consists of Theory book, Practical book, Test and Assignment book, Instructor Guide, Audio Visual Aid (Wall charts and Transparencies) and other support materials.

The trade theory book provides related theoretical knowledge required to enable the trainee to do a job. The test and assignments will enable the instructor to give assignments for the evaluation of the performance of a trainee. The wall charts and transparencies are unique, as they not only help the instructor to effectively present a topic but also help him to assess the trainee's understanding. The instructor guide enables the instructor to plan his schedule of instruction, plan the raw material requirements, day to day lessons and demonstrations.

IMPs also deals with the complex skills required to be developed for effective team work. Necessary care has also been taken to include important skill areas of allied trades as prescribed in the syllabus.

The availability of a complete Instructional Media Package (IMP) in an institute helps both the trainer and management to impart effective training.

The IMPs are the outcome of collective efforts of the staff members of NIMI and the members of the Media Development Committees specially drawn from Public and Private sector industries, various training institutes under the Directorate General of Training (DGT), Government and Private ITIs.

NIMI would like to take this opportunity to convey sincere thanks to the Directors of Employment & Training of various State Governments, Training Departments of Industries both in the Public and Private sectors, Officers of DGT and DGT field institutes, proof readers, individual media developers and coordinators, but for whose active support NIMI would not have been able to bring out this materials.

R. P. DHINGRA
EXECUTIVE DIRECTOR

Chennai - 600 032

ACKNOWLEDGEMENT

National Instructional Media Institute (NIMI) sincerely acknowledges with thanks for the co-operation and contribution extended by the following Media Developers and their sponsoring organisations to bring out this instructional material **(Trade Theory)** for the trade of **Electrician (NSQF Level -5)** under **Electrical** Sector for ITI [1].

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NIMI records its appreciation for the Data Entry, CAD, DTP operators for their excellent and devoted services in the process of development of this Instructional Material.

NIMI also acknowledges with thanks the invaluable efforts rendered by all other NIMI staff who have contributed towards the development of this Instructional Material.

NIMI is also grateful to everyone who has directly or indirectly helped in developing this Instructional Material.

INTRODUCTION

This manual for trade Theory is intended for use in the ITI class rooms. It consists of a series of Theory lessons that are to be completed by the trainees during the first semester of course is the **Electrician trade under Electrical Sector. It is National Skills Qualifications Framework (NSQF) - Level 5,** supplemented and supported by instructions/information to assist the trainees in performing the exercises. The syllabus for the 2nd Semester **Electrician NSQF (Level - 5)** Trade under **Electrical Sector** Trade Theory is divided into seven modules.The allocation of time for the various modules is given below:

Module 1: Cells and Batteries	5 Exercises	50 Hrs
Module 2: Basic wiring practice	7 Exercises	100 Hrs
Module 3: Wiring Installation and Earthing	9 Exercises	100 Hrs
Module 4: Illumination	6 Exercises	50 Hrs
Module 5: Measuring Instruments	8 Exercises	75 Hrs
Module 6: Domestic appliances	6 Exercises	75 Hrs
Module 7: Transformer	9 Exercises	75 Hrs
Total	50 Exercises	525 Hrs

The syllabus and the content in the modules are interlinked. As the number of workstations available in the electrical section is limited by the machinery and equipment, it is necessary to interpolate the exercises in the modules to form a proper teaching and learning sequence. The sequence of in struction is given in the schedule of instruction which is incorporated in the Instructor's Guide. With 25 practical hours a week of 5 working days 100 hours of practical per month is available.

The procedure for working through the 50 exercises for the 2nd semester with the specific objectives to be achieved as the learning out comes at the end of each exercise is given in this book.

The symbols used in the diagrams comply with the Bureau of Indian Standards (BIS) specifications.

This manual on trade Theory forms part of the Written Instructional Material (WIM). Which includes manual on trade theory and assignment/test.

CONTENTS

LEARNING / ASSESSABLE OUTCOME

On completion of this book you shall be able to

- **Install, test and maintenance of Batteries and Solar Cell**
- **Estimate, Assemble, Install and Test Wiring System**
- **Plan and prepare Earthing Installation**
- **Plan and execute Electrical Illumination System and Test**
- **Select and perform measurements using analog / digital instruments**
- **Perform testing, verify errors and calibrate instruments**
- **Plan and carryout installation, fault detection and repairing of Domestic Appliances**
- **Execute testing, evaluate performance and maintenance of Transformer.**

SYLLABUS

Second Semester **Duration: Six Month**

Week No.	Ref. Learning Outcome	Professional Skills(Trade Practical) with Indicative hours	Professional Knowledge (Trade Theory)
27 - 37	• Install, test and maintenance of batteries and solar cell • Apply safe working practices	65. Use of various types of cells. (08 Hrs) 66. Practice on grouping of cells for specified voltage and current under different conditions and care. (12 Hrs) 67. Prepare and practice on battery charging and details of charging circuit. (12 Hrs) 68. Practice on routine, care/ maintenance and testing of batteries. (08 Hrs) 69. Determine the number of solar cells in series / parallel for given power	Chemical effect of electric current and Laws of electrolysis. Explanation of Anodes and cathodes. Types of cells, advantages / disadvantages and their applications. Lead acid cell; Principle of operation and components. Types of battery charging, Safety precautions, test equipment and maintenance. Basic principles of Electro-plating and cathodic protection Grouping of cells for specified voltage and current. Principle and operation of solar cell
29 - 30	• Estimate, Assemble, install and test wiring system	70. Identify various conduits and different electrical accessories. (8 Hrs) 71. Practice cutting, threading of different sizes & laying Installations. (17 Hrs) 72. Prepare test boards / extension boards and mount accessories like lamp holders, various switches, sockets, fuses, relays, MCB, ELCB, MCCB etc. (25 Hrs)	I.E. rules on electrical wiring. Types of domestic and industrial wirings. Study of wiring accessories e.g. switches, fuses, relays, MCB, ELCB, MCCB etc. Grading of cables and current ratings. Principle of laying out of domestic wiring. Voltage drop concept
31 - 32	• Estimate, Assemble, install and test wiring system	73. Draw layouts and practice in PVC Casing-capping, Conduit wiring with minimum to more number of points of minimum 15 mtr length. (15 Hrs) 74. Wire up PVC conduit wiring to control one lamp from two different places. (10 Hrs) 75. Wire up PVC conduit wiring to control one lamp from three different places. (10 Hrs)	PVC conduit and Casing-capping wiring system. Different types of wiring - Power, control, Communication and entertainment wiring. Wiring circuits planning, permissible load in sub-circuit and main circuit

		76. Wire up PVC conduit wiring and practice control of sockets and lamps in different combinations using switching concepts. (15 Hrs)	
33 - 35	• Estimate, Assemble, install and test wiring system	77. Wire up the consumers main board with ICDP switch and distribution fuse box. (10 Hrs) 78. Prepare and mount the energy meter board. (10 Hrs) 79. Estimate the cost/bill of material for wiring of hostel/ residential building and workshop. (10 Hrs) 80. Practice wiring of hostel and residential building as per IE rules. (15 Hrs) 81. Practice wiring of institute and workshop as per IE rules. (15 Hrs) 82. Practice testing / fault detection of domestic and industrial wiring installation and repair. (15 Hrs)	Estimation of load, cable size, bill of material and cost. Inspection and testing of wiring installations. Special wiring circuit e.g. godown, tunnel and workshop etc
36	• Plan and prepare Earthing installation	83. Prepare pipe earthing and measure earth resistance by earth tester / megger. (10 Hrs) 84. Prepare plate earthing and measure earth resistance by earth tester / megger. (10 Hrs) 85. Test earth leakage by ELCB and relay. (5 Hrs)	Importance of Earthing. Plate earthing and pipe earthing methods and IEE regulations. Earth resistance and earth leakage circuit breaker
37 - 38	• Plan and execute electrical illumination system and test	86. Install light fitting with reflectors for direct and indirect lighting. (10 Hrs) 87. Group different wattage of lamps in series for specified voltage. (5 Hrs) 88. Practice installation of various lamps e.g. fluorescent tube, HP mercury vapour, LP mercury vapour, HP sodium vapour, LP sodium vapour, metal halide etc. (18 Hrs)	Laws of Illuminations. Types of illumination system. Illumination factors, intensity of light. Type of lamps, advantages/ disadvantages and their applications. Calculations of lumens and efficiency

		89. Prepare decorative lamp circuit using drum switches. (5 Hrs) 90. Prepare decorative lamp circuit to produce rotating light effect/running light effect. (6 Hrs) 91. Install light fitting for show case lighting. (6 Hrs)	
39 - 40	• Select and perform measurements using analog / digital instruments	92. Practice on various analog and digital measuring Instruments. (5 Hrs) 93. Practice on measuring instruments in single and three phase circuits e.g. multi-meter, Wattmeter, Energy meter, Phase sequence meter and Frequency meter etc. (15 Hrs) 94. Measure power in three phase circuit using two wattmeter methods. (8 Hrs) 95. Measure power factor in three phase circuit by using power factor meter and verify the same with voltmeter, ammeter and wattmeter readings. (12 Hrs) 96. Measure electrical parameters using tong tester in three phase circuits. (10 Hrs)	Classification of electrical instruments and essential forces required in indicating instruments. PMMC and Moving iron instruments. Measurement of various electrical parameters using different analog and digital instruments. Measurement of energy in three phase circuit
41	• Perform testing, verify errors and calibrate instruments	97. Practice for range extension and calibration of various measuring instruments. (10 Hrs) 98. Determine errors in resistance measurement by voltage drop method. (8 Hrs) 99. Test single phase energy meter for its errors. (7 Hrs)	Errors and corrections in measurement. Loading effect of voltmeter and voltage drop effect of ammeter in circuits. Extension of range and calibration of measuring instruments
42 - 44	• Plan and carry out installation, fault detection and repairing of domestic appliances	100. Dismantle and assemble electrical parts of various electrical appliances e.g. cooking range, geyser, washing machine and pump set. (25 Hrs) 101. Service and repair of bell/ buzzer. (5 Hrs) 102. Service and repair of electric iron, electric kettle,	Working principles and circuits of common domestic equipment and appliances. Concept of Neutral and Earth

		cooking range and geyser. (12 Hrs) 103. Service and repair of induction heater and oven. (10 Hrs) 104. Service and repair of mixer and grinder. (10 Hrs) 105. Service and repair of washing machine. (13Hrs)	
45 - 46	• Execute testing, evaluate performance and maintenance of transformer	106. Verify terminals, identify components and calculate transformation ratio of single phase transformers. (8 Hrs) 107. Perform OC and SC test to determine and efficiency of single phasetransformer. (12 Hrs) 108. Determine voltage regulation of single phase transformer at different loads and power factors. (12 Hrs) 109. Perform series and parallel operation of two single phase transformers. (12 Hrs) 110. Verify the terminals and accessories of three phase transformer HT and LT side. (6 Hrs)	Working principle, construction and classification of transformer. Single phase and three phase transformers. Turn ratio and e.m.f. equation. Series and parallel operation of transformer. Voltage Regulation and efficiency. Auto Transformer and instrument transformers (CT & PT).
47	• Execute testing, evaluate performance and maintenance of transformer	111. Perform 3 phase operation (i) delta-delta (ii) delta-star (iii) star-star (iv) star-delta, by use of three single phase transformers. (6 Hrs) 112. Perform testing of transformer oil. (6 Hrs) 113. Practice on winding of small transformer. (8 Hrs) 114. Practice of general maintenance of transformer. (5 Hrs)	Method of connecting three single phase transformers for three phase operation. Types of Cooling, protective devices, bushings and termination etc. Testing of transformer oil. Materials used for winding and winding wires in small transformer
48 - 49		Project work / Industrial visit Broad Areas: a) Overload protection of electrical equipment b) Automatic control of street light/night lamp c) Fuse and power failure indicator using relays d) Door alarm/indicator e) Decorative light with electrical flasher	
50 - 51		Revision	
52		Examination	

Primary cells and secondary cells

Objectives: At the end of this lesson you shall be able to
- **state the chemical effect of electric current**
- **state the Laws of electrolysis**
- **state the basic principles of electroplating**
- **state the principle and construction of primary cells**
- **state the principle and construction of secondary cells (lead acid, nickel iron and nickel cadmium)**
- **compare the primary cells and secondary cells .**

Chemical effects of electric current

'There are some liquids in which a passage of electric current is accompanied by chemical changes.' This effect is known as chemical effect of electric current.

The applications of chemical effect of electric current may be observed in daily life; e.g., nickel or copper plating on metallic articles, production of E.M.F by a cell, etc. If two leads taken from the positive and negative terminals of a battery are immersed in a salted water, then the production of bubbles can be seen at the lead ends; it is all due to chemical effect of electric current.

Electrolysis

If an electric current is passed through different liquids or solutions in turn, then it is observed that the currrent passes through some of the solutions only and not through all of them. The liquid or a solution, through which an electric current can pass, is called a conductor-liquid such as ammonium chloride solution, silver nitrate solution etc.; and, through which an electric current can't pass, is called an insulator-liquid such as distilled water, alcohol, oil etc. If some salt or acid is mixed in the distilled water, then it becomes conductive.

Thus, 'the process of chemical changes due to the passage of an electric current through a liquid or a solution is called electrolysis.'

Electrolyte

'The liquid or solution which undergoes a chemical change in it on account of the passage of an electric current, is called an electrolyte'; e.g., salted water, acidic or a basic solution etc.

Electrodes (Anode and cathode)

'Two conductor plates are immersed in the liquid to form a passage of current through it, they are known as electrodes'. The electrode through which the current enters the liquid, is called a positive electrode or anode, while the other through which it leaves the liquid (electrolyte) is called a negative electrode or cathode.

Ions

During electrolysis, the molecules of the electrolyte split into their constituents whcih are called ions. When a p.d. is applied across the two electrodes, the positively charged ions (cat ions) move towards the cathode and the negatively charged ions (an ions) move towards the anode. On reaching at any electrode, an ion give up its charge and ceases to be an ion . The process of converting atoms into ions is called **Ionization.**

Electrochemical equivalent: The mass of a substance liberated or deposited during electrolysis by one coulomb of electricity is termed as electrochemical equivalent (ECE) of that substance.

The ECE of silver is 1.1182 milligram/coulomb.

Coulomb: The coulomb (C) is the unit of electric charge (Q) or the quantity of electricity.

The coulomb is the product of current in ampere and time in seconds.

Faraday's Law of Electrolysis

1. First law: The mass of the substance liberated or deposited at any electrode during electrolysis is propotional to the quantity of eletricity passed through the electrolyte. The mass of the substance liberated at any electrode will be more, if more current is passed or a current for more time is passed through the electrolyte.If the mass liberated is m then

$$m \propto I$$

$$m \propto t \qquad \text{-----(i)}$$

$$m \propto I \cdot t \qquad \text{-----(ii)}$$

$$m = Z \cdot I \cdot t$$

Where, I = current, amperes

t = time, seconds

m = mass of the substance liberated, grams

Z = constant

Here, the constant Z is known as electro-chemical equivalent (ECE).

2. Second Law - 'When the same quantity of electricity is passed through different electrolytes , then the quantites of elements liberated at the different electrodes are proportional to their electro-chemical equivalents.'

$$\text{Mass} \propto \text{E.C.E}$$

$$M \propto Z$$

Where Z = electro-chemical equivalent

According to Faraday's laws of electrolysis

$$m = Z \cdot I \cdot t$$

Where, m = mass of substance liberated in grams

z = Electro chemical equivalent of the substance in gram

I = Current in amperes

t = Time in seconds

Note. Mass deposited m = Volume x Density

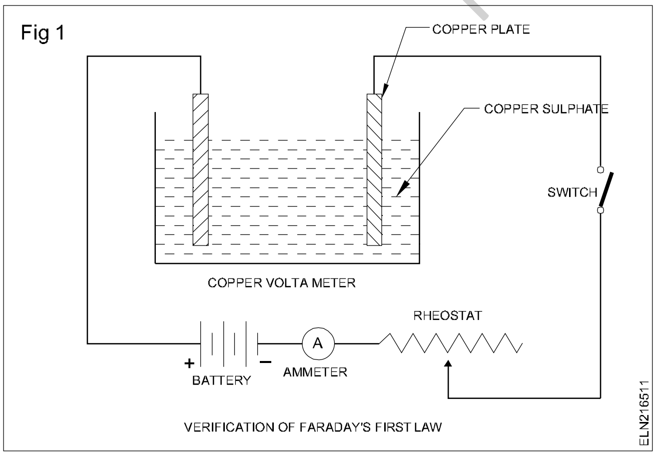
$$\text{Equivalent weight} = \frac{\text{Atomic weight}}{\text{Valency}}$$

$$\text{E.C.E. of nickel} = \frac{\text{Equivalent wt. of nickel}}{\text{Equivalent wt. of silver}} \times \text{E.C.E. of silver}$$

Verification of Faraday's laws

(1) Verification of first Law - For the verification of Faraday's first law, a copper sulphate solution is taken in a glass container (called a voltameter). Two copper plates are immersed in the solution. A battery, switch, ammeter and a rheostat are connected to the plates (Fig 1).

Fig 1



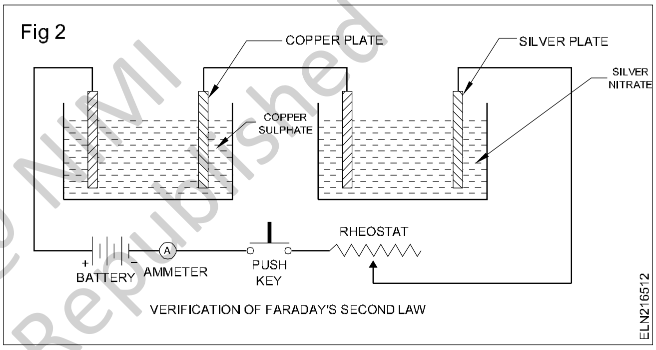
The negative elecrode is dried and weighed. After passing a definite amount of current (which can be adjusted by the rheostat) for a definite time, the cathode is weighed again, after being dried once again.

Now, the mass of copper deposited at the cathode is equal to the weight of cathode after passing the current minus the weight of cathode before passing the current.

The above experiment is repeated for twice the time of the first measurement. It is observed that the mass of copper deposited is doubled. Similarly, if the current is doubled instead of the time, then also the mass of copper deposited is doubled. These three above observations verify that the mass of copper deposited at the cathode is proportional to the product of current and time.

(2) Verification of Second Law - For the verification of Faraday's second law, two voltameters are taken, i.e., copper and silver voltameters. The copper voltameter has a solution of copper sulphate and two copper electrodes whereas the silver voltameter has a solution of silver nitrate and two silver electrodes. Both voltameters are connected in series across a battery through a switch, ammeter and a rheostat (Fig 2).

Fig 2



Now a definite current is passed for a definite time through both the voltameters. If the mass of copper deposited at the copper cathode is m_1 and the mass of silver deposited at silver cathode is m_2 and their chemical equivalents are w_1 and w_2 respectively, then it is found that -

$$m_1 : m_2 = w_1 : w_2$$

or

$$\frac{m_1}{w_1} = \frac{m_2}{w_2} \text{ or } \frac{m_1}{m_2} = \frac{w_1}{w_2}$$

$$\frac{\text{the mass of copper deposited}}{\text{the mass of silver deposited}} = \frac{31.5}{108}$$

(Since the chemical equivalents of copper and silver are 31.5 and 108 respectively)

The relation $\frac{m_1}{m_2} = \frac{w_1}{w_2}$ verifies the second law.

Table for Elecro-Chemical Equivalents of Elements

Name of Element	Atomic Weight	Valency	Electro-Chemical Equivalent mg/c	Chemical equivalent g/c
Hydrogen	1.008	1	0.01045	1.008
Aluminium	27.1	3	0.0936	9.03
Copper	63.57	2	0.3293	31.78
Silver	107.88	1	1.118	107.88
Zinc	65.38	2	0.3387	32.69
Nickel	58.68	2	0.304	29.34
Chromium	52.0	3	0.18	17.33
Iron	55.85	2	0.2894	27.925
Lead	207.21	2	1.0738	103.6
Mercury	200.6	1	2.0791	200.6
Gold	197.0	1	2.0438	197

Note. (mg/c = milli-gram per coulomb)

Application of electrolysis

The principal applications of electrolysis are as follows:

1. Electroplating
2. Electro-refining of metals
3. Electrolytic capacitor
4. Electrotyping
5. Extraction of metals.

Electroplating

The process of depositing a metal on the surface of another metal by electrolysis is known as electroplating. Electroplating is widely used in giving an attractive appearance and finish to all types of products. In this process inferior metals are coated with costly metals (such as silver, nickel, gold, chromium, etc.) to give an attractive shiny appearance and rust-proof surface.

Conditions for electroplating

The following conditions must be fulfilled before electroplating an article.

(i) The article to be electroplated must have a chemically cleaned surface, i.e. it must not have any sort of dirt, rust and greasy surface.

(ii) The article to be plated should form a cathode.

(iii) The anode must be of the metal to be deposited for maintaining the concentration of the solution constantly during electrolysis.

(iv) The metal to be coated has to be in the solution of an electrolyte.

The electrolyte is contained in a wooden reinforced cement concrete tank which is known as a "vat". The anode as well as the article to be plated are hung through the conducting wires so as to dip in the solution. The value of the current is adjusted according to the metal deposited on the surface area of the article. The time required for electroplating can be calculated if we know the mass of the metal deposited and ECE with the formula

$$M = ZIt$$

Therefore, Time $t = \frac{M}{IZ}$

we know M = ZIt ------ (1)

$$I = \frac{M}{Zt} \text{ and } Z = \frac{M}{It} \text{ mg / Coulomb}$$

We know Volume = Area x Thickness ------(2)

$$\text{Area} = \frac{\text{Volume}}{\text{Thickness}} \text{ and}$$

$$\text{Thickness} = \frac{\text{Volume}}{\text{Area}}$$

Mass = Volume x Density ----- (3)

$$\text{Volume} = \frac{\text{Mass}}{\text{Density}} \text{ cc}$$

$$\text{Density} = \frac{\text{Mass}}{\text{Volume}} \text{ gm /cc}$$

Example1: If 111.83 mg of silver is deposited on the cathode in 3 min 20 s, by a DC current of 0.5A, calculate the ECE of silver.

Solution:

t = 3 min 20 s = 200 s

M = 111.83 mg

From Faraday's law,

M = ZIt

$$Z = \frac{M}{It} = \frac{111.83}{0.5 \times 200}$$

= 1.1183 mg/ C

Example 2: It is required to be deposited copper on the both surfaces of an iron plate 200 cm^2 in area. What thickness of copper will be deposited if one ampere of current is passed through the solution for 1 1/2 hours. The density of copper is equal to 8.9 g/cc and E.C.E. of copper is 0.329 mg/C.

Solution:

Z - 0.329 mg/C = $\frac{0.329}{10^3} = 0.329 \times 10^{-3}$ g / C

I = 1A

t = 90 x 60 = 5400 s

From Faraday's law,

M = ZIt

$0.329 \times 10^{-3} \times 1 \times 5400 = 1.7766$ g (i)

Suppose the thickness of copper deposited = T cm

Area = 200 cm^2

Density = 8.9 g/cc

Volume of copper deposited

= 2 x area x thickness

= 2 x 200 x T cc

Mass of copper deposited

= Volume x density

= 400 x T x 8.9 (ii)

Equating (i) and (ii);

400 x 8.9 x T = 1.7766

or T = $\frac{1.7766}{400 \times 8.9} = 0.000499$ cm **Ans.**

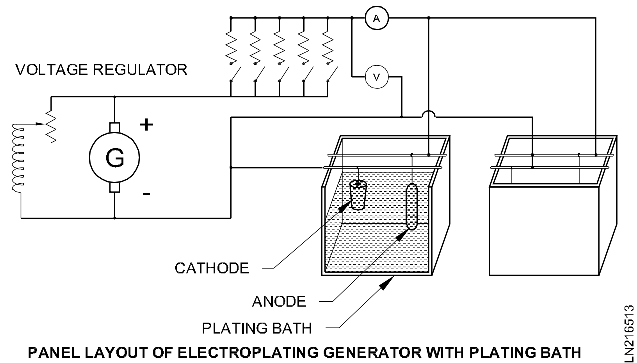
Current required for plating

Low pressure direct current (DC) supply is always used for electroplating purposes. The pressure used varies from 1 to 16 V depending upon the rate of plating and the nature of the electrolyte.

Dynamo for electroplating (Fig 3)

The shunt dynamo is generally used for electroplating. It delivers large current at low pressure and this requires a large commutator and brush gear. Such types of dynamos are run by either an AC or a DC motor or the petrol engine, etc and the current required for plating is controlled by the current regulator. The generated voltage of the dynamo is controlled by the voltage regulator (Fig 3).

Fig 3



PANEL LAYOUT OF ELECTROPLATING GENERATOR WITH PLATING BATH

Cathodic protection in Eletroplating

Cathodic protection (CP) is a technique used to control the corrossion of a metal surface by making it as the cathode of an electrochemical cell. A simple method of protection connects the metal to be protected to a more easily corroded sacrifical metal to act as the anode.

The sacrificial metal then corrodes instead of the protected metal. For the structures such as long pipe lines where passive galvanic cathodic protection is not adequate an external DC electrical power source is used to provide sufficicent current.

The CP system protects a wide range of metallic structures steel water, fuel pipe line, storage tanks water heaters, steel wire pipes, oil platform, oil well casing, wind farms etc. Another common application is in galvanised steel in which a sacrificial coating of zinc on steel parts protects them from rust. CP protection can in some cases prevents the stress corrossion cracking.

Type of cells

Cell: A cell is an electrochemical device consisting of two electrodes made of different materials and an electrolyte. The chemical reaction between the electrodes and the electrolyte produces a voltage.

Cells are classified as

- dry cells
- wet cells.

A dry cell is one that has a paste or gel electrolyte. With newer designs and manufacturing techniques, it is possible to completely (hermetically) seal a cell. With complete seals and chemical control of gas build-up, it is possible to use liquid electrolytes in dry cells. Today the term `dry cell' refers to a cell that can be operated in any position without electrolyte leakage.

Wet cells are cells that must be operated in an upright position. These cells have vents to allow the gases generated during charge or discharge to escape. The most common wet cell is the lead-acid cell.

Cells are further classified as primary and secondary cells.

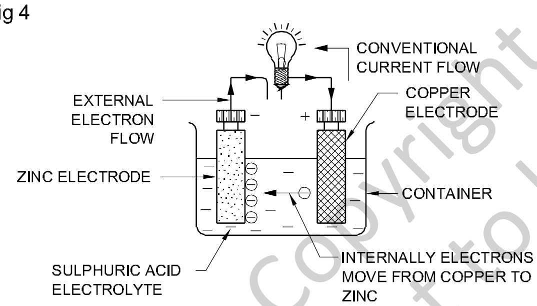
Primary cells: Primary cells are those cells that are not rechargeable. That is, the chemical reaction that occurs during discharge is not reversed. The chemicals used in the reactions are all converted when the cell is fully discharged. It must then be replaced by a new cell.

Types of primary cells:

- Voltaic cell
- Carbon-zinc cell (Leclanche cell and Dry cell)
- Alkaline cell
- Mercury cell
- Silver oxide cell
- Lithium cell

Simple voltaic cell: A voltaic cell uses copper and zinc as the two electrodes and sulphuric acid as the electrolyte. When they are placed together a chemical reaction occurs between the electrodes and the sulphuric acid. This reaction produces a negative charge on the zinc (surplus of electrons) and a positive charge on the copper (deficiency of electrons). If an external circuit is connected across the two electrodes, electrons will flow from the negative zinc electrode to the positive copper electrode (Fig 4).

Fig 4



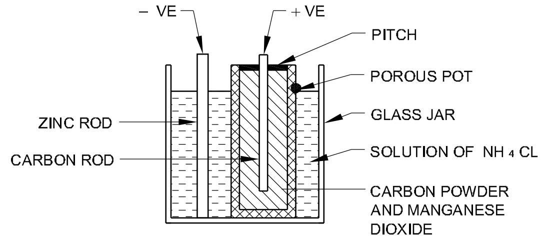
VOLTAIC CELL

ELN216514

The electric current will flow as long as the chemical action continues. In this type of cell the zinc electrode is eventually consumed as part of the chemical reaction.The voltaic cell is also known as a wet cell because it uses a liquid solution for the electrolyte.

Leclanche cell (Carbon-zinc cells) **:** The container of this cell is a glass jar. The jar contains a strong solution of ammonium chloride (NH_4Cl). This solution is an alkali and acts as the electrolyte. A porous pot is placed at the centre of the glass jar. This porous pot has in it a carbon rod surrounded by a mixture of manganese dioxide (MnO_2) and powdered carbon. The carbon rod forms the positive electrode of the cell and MnO_2 acts as the de-polarizer. A zinc rod is dipped in the solution in the jar and acts as the negative electrode (Fig 5).

Fig 5



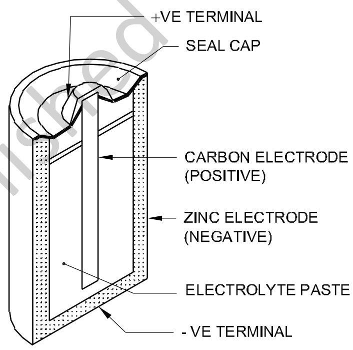
LECLANCHE CELL

ELN216515

Dry cell (Carbon-Zinc cell): The danger of spilling the liquid electrolyte from a Leclanche type of cell led to the invention of another class of cells called dry cells.

The most common and least expensive type of a dry cell is the carbon-zinc type (Fig 6). This cell consists of a zinc container which acts as the negative electrode. In the centre is a carbon rod which is the positive electrode. The electrolyte takes the form of a moist paste made up of a solution containing ammonium chloride.

Fig 6



CARBON-ZINC DRY CELL

ELN216516

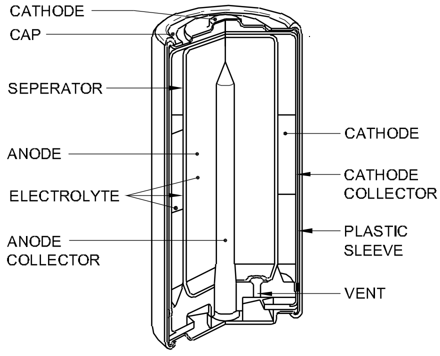
As with all primary cells, one of the electrodes becomes decomposed as part of the chemical reaction. In this cell the negative zinc container electrode is the one that is used up. As a result, cells left in equipment for long periods of time can rupture, spilling the electrolyte and causing damage to the neighbouring parts.

Carbon-zinc cells are produced in a range of common standard sizes. These include 1.5 V AA, C and D cells .(AA Pen type cell, \`C' medium size and 'D' large/economy size).

Alkaline cells: Alkaline cells use a zinc container for the negative electrode and a cylinder of manganese di-oxide for the positive electrode (Fig 7). The electrolyte is made up of a solution of potassium hydroxide or an alkaline solution.

Alkaline cells are produced in the same standard sizes as carbon-zinc cells but are more expensive. They have the advantage of being able to supply large currents for a longer period of time. For example, a standard \`D' type 1.5 V alkaline cell has a capacity of about 3.5 AH compared with about 2 AH for the carbon-zinc type. A second advantage is that the alkaline cell has a shelf life of about two and a half years as compared to about 6 to 12 months for the carbon-zinc type.

Fig 7

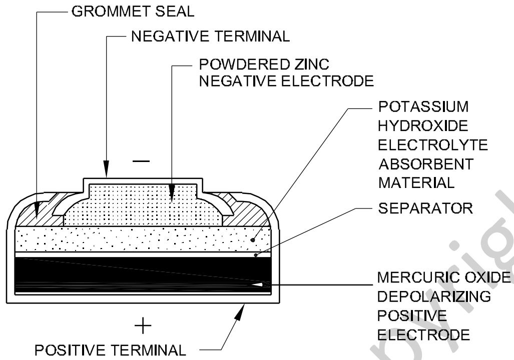


ALKALINE CELL

Mercury cells: Mercury cells are most often used in digital watches, calculators, hearing aids and other miniature electronic equipment. They are usually smaller and are shaped differently from the carbon-zinc type (Fig 8).

The electrolyte used in this cell is alkaline and the electrodes are of mercuric oxide (cathode) and zinc (anode).

Fig 8



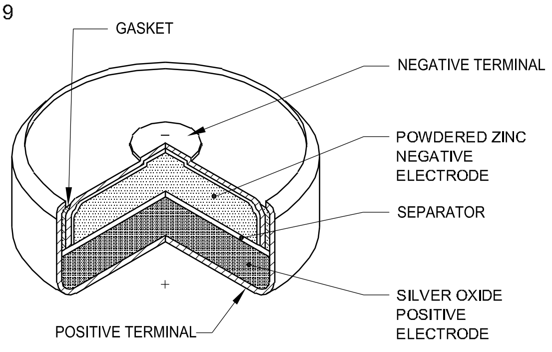
MERCURY CELL

Silver oxide cells: Silver oxide cells are much like mercury cells. However, they provide a higher voltage (1.5 V) and they are made for light loads. The loads can be continuous, such as those encountered in hearing aids and electronic watches. Like the mercury cell, the silver oxide cell has good energy-to-weight and energy-to-volume ratios, poor low-termperature response, and flat output voltage characteristics.

The structures of the mercuric and silver oxide cells are very similar. The main difference is that the positive electrode of the silver cell is silver oxide instead of mercuric oxide. Fig 9 shows the cross-section of a silver oxide cell.

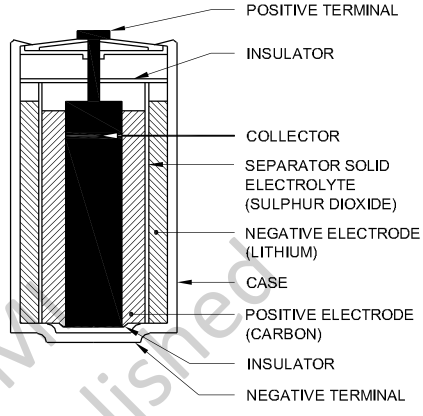
Lithium cells: The lithium cell is another type of primary cell (Fig 10). It is available in a variety of sizes and configurations. Depending on the chemicals used with lithium, the cell voltage is between 2.5 and 3.6 V. Note that this voltage is considerably higher than in other primary cells. Two of the advantages of lithium cells over other primary cells are:

Fig 9



SILVER OXIDE CELL

Fig 10



LITHIUM CELL

– longer shelf life - up to 10 years

– higher energy-to-weight ratios up to 350 WH/Kg.

Lithium cells operate at temperatures ranging from –50 to +75°C. They have a very constant output voltage during discharge.

Uses: Primary cells are used in electronic products ranging from watches, smoke alarms, cardiac pacemakers, torches, hearing aids, transistor radios etc.

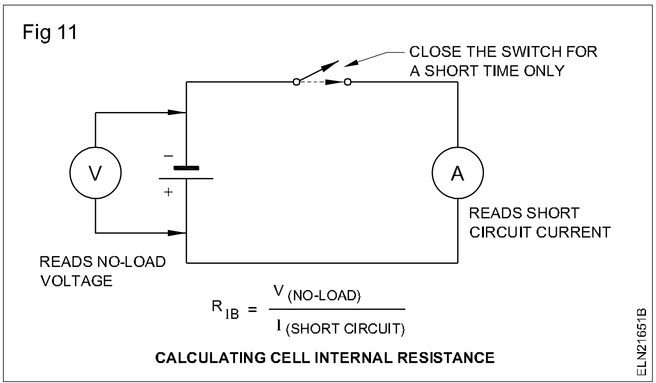
Internal resistance: The output voltage from a cell varies as the load on the cell changes. Load on a cell refers to the amount of current drawn from the cell. As the load increases, the voltage output drops. The change in output voltage is caused by the internal resistance of the cell. Since materials from which the cell is made are not perfect conductors, they have resistance. Current flowing through the external circuit also flows through the internal resistance of the cell.

According to Ohm's law, a current flowing through a resistance (either external or internal) results in a voltage drop (V = IR) . Any voltage developed across the internal resistance is not available at the terminals of the cell.

The voltage at the terminals is the voltage produced due to the chemical reactions minus the voltage dropped across the internal resistance. The terminal voltage of a cell, therefore, depends on both the internal resistance of the cell and the amount of load current.

In some applications, the changes in cell terminal voltage are so small that they make no practical difference. In other applications, the changes are very noticeable. For example, when an automobile engine is started, the battery output voltage changes from about 12.6 to 8V.

Fig 11 shows the method of calculating the internal resistance of a cell . As a cell discharges, its internal resistance increases. Therefore its output voltage decreases for a given value of load current.



Defects of a simple cell: With a simple voltaic cell, the strength of current gradually diminishes after some time. This defect is mainly due to two causes.

- Local action
- Polarisation

Local action: In a simple voltaic cell, bubbles of hydrogen are seen to evolve from the zinc plate even on open circuit. This effect is termed local action. This is due to the presence of impurities like carbon, iron, lead, etc. in the commercial zinc. This forms small local cells on the zinc plate and reduces the strength of current of the cell.

The local action is prevented by amalgamating the zinc plate with mercury. To do so, the zinc plate is immersed in dilute sulphuric acid for a short time, and afterwards, mercury is rubbed over its surface.

Polarisation: As current flows, bubbles of H_2 evolve at the copper plate on which they gradually form a thin layer. Due to this the current strength falls and finally stops altogether. This effect is called the polarization of the cell.

Polarisation can be prevented by using some chemicals which will oxidize the hydrogen to water before it can accumulate on the plate. The chemicals used to remove polarisation are called de-polarisers.

We learnt that most of the primary cell except rechargeable ones are usable once only. It does not supply current continuously. The secondary cells overcome this disadvantage.

Secondary cell: A cell that can be recharged by sending electric current in the reverse direction to that of a discharge mode is known as a secondary cell.

The secondary cell is also called a storage cell since after it is charged it stores the energy until it is used up or discharged.

In a secondary cell the charging and discharging processes are taking place according to Faraday's Laws of Electrolysis.

Comparison of primary cells

	Carbon -Zinc	**Alkaline-Manganese**	**Mercury**	**Silver oxide**
Negative, Positive, Electrolyte	Zinc Carbon Ammonium Chloride	Zinc Manganese dioxide Potassium hydroxide or alkaline	Zinc Mercuric oxide Alkaline	Zinc Silver oxide Potassium hydroxide
Nominal voltage - volts Max. rated current - amperes	1.5 2-30	1.5 0.05-20	1.35 or 1.4 0.003-3	1.5 0.1
Energy output Watt-hrs Ampere-hours	 22 2.0	 35 3.5	 46 6.0	 50 8.0
Temperature range Storage ^{0}F Operating ^{0}F	 –40 to 120 20 to 130	 –40 to 120 –5 to 160	 –40 to 140 –5 to 160	 –40 to 140 –5 to 160
Shelf life in months at 68°F to 80% initial capacity Shape of discharge curve	 6 to 12 Sloping	 30 to 36 Sloping	 30 to 36 Flat	 30 to 36 Flat

Types of secondary cells

– Lead acid cell

– Alkaline cell or nickel-iron cell

Parts of Lead acid cell (Fig 12)

1 Container

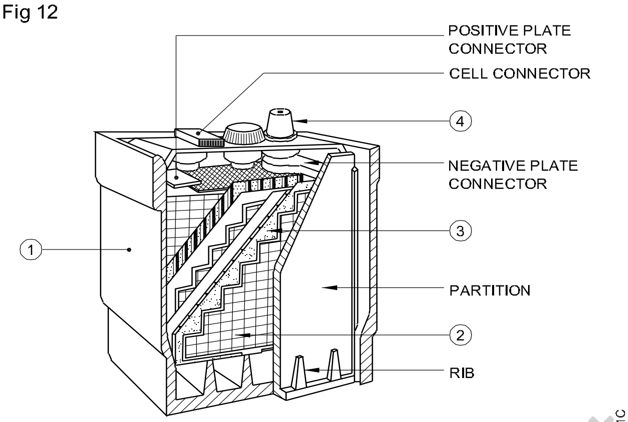
2 Plates

3 Separators

4 Post terminals

Container: The container is made of hard rubber, glass or celluloid to accommodate the active plates, separators and the electrolyte. The plates rest on ribs provided at the bottom of the container and the space between ribs is known as sediment chamber.

Fig 12



PARTS OF LEAD ACID CELL

Plates: Positive plates are of two types.

– Plante plate or formed plates

– Faure plate

Plante plates: These are prepared by the process of repeated charging and discharging. They are made of pure lead at the beginning which changes to lead peroxide after charge.

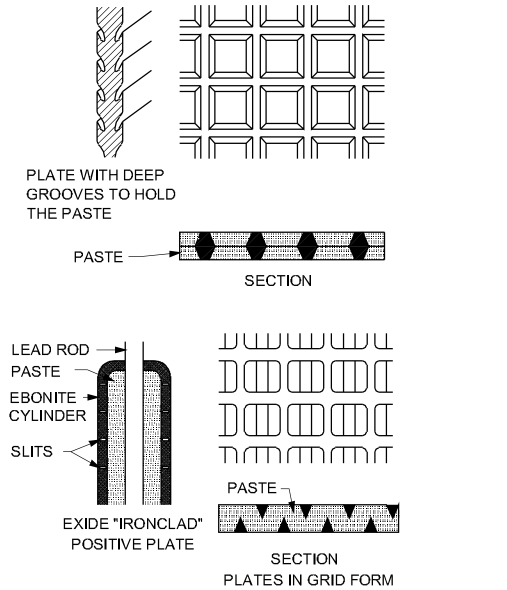
Faure plate: Pasted or Faure plates are made of rectangular lead grid into which the active material i.e. lead peroxide ($Pb\ O_2$) is filled in the form of a paste (Fig 13).

Negative plates are made of rectangular lead grid, and the active material is spongy lead (Pb) which is in the form of a paste (Fig 14).

Separators: These are made of thin sheets of chemically treated porous wood or rubber. They are used to avoid short in between the positive and negative plates (Fig 15).

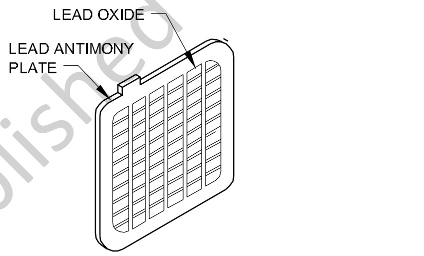
Post terminal: A small pole extended upward from each group of welded plates from the plate connecter (Fig 16) forms the post terminal.

Fig 13



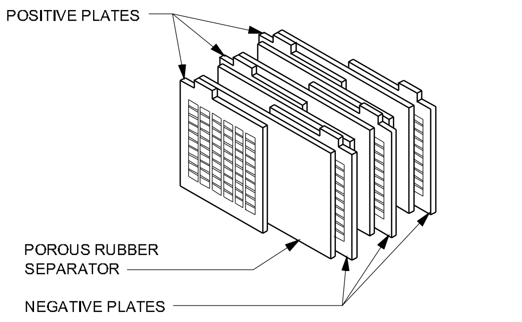
CONSTRUCTION OF PASTED-TYPE ACCUMULATOR PLATES

Fig 14



SINGLE LEAD PLATE

Fig 15



ARRANGEMENT OF PLATES AND SEPARATORS

Electrolyte: The electrolyte used in a lead acid cell is dilute sulphuric acid (H_2SO_4). The specific gravity of the electrolyte is 1.24 to 1.28. It varies according to the manufacturer's specification.

Working principle

The secondary cell has no significant electrochemical energy at the start. The energy must first be charged into secondary cell. Then the cell retains the stored energy until it is used up. That is,both cell electrodes are basically lead sulphate($Pb\ SO_4$).When the cell is charged, due to chemical reaction taking place in it, the lead sulphate eletctrode change to soft or sponge lead,(Pb - negative

Fig 16

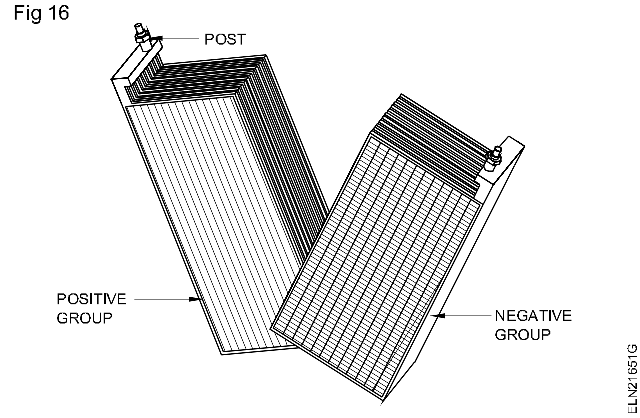
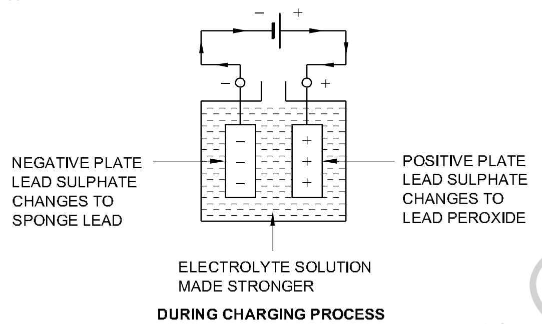


plate) and the other electrode changes to lead peroxided(Pb O_2 - positive plate).

At the same time the electrolyte solution is strengthened and becomes strong sulphuric acid (H_2SO_4) (Fig 17).

Fig 17



The general recommended specification of a storage cell(battery) is given below.

- Voltage/cell
- Ampere hour capacity
- No. of plates/cell
- Temperature
- Specific gravity of electrolyte
- No. of cells grouped

Voltage of a fully charged cell is 2.1 to 2.6V and the voltage falls to 1.8V after discharge.

Capacity: The unit of capacity of a storage cell is ampere-hour (AH). It is the product of the rated current of a cell/battery in amperes and the time in hours at which it can discharge that rated current,

Capacity = Current x Time - AH

The capacity of the cell depends on the following.

- Size of the plates
- No.of plates
- Active material used
- The strength of the electrolyte

Plates: There is always one more negative plate than the number of positive plates. That is, a negative plate at both ends of the cell gives not only more mechanical strength but also ensures that both sides of the positive plate are used. It also avoids buckling of positive plates. For example a nine plate cell is having four positive and five negative plates.

Temperature and specific gravity: The temperature of the electrolyte must be kept at 27°C and the specific gravity at 1.250 ± 0.010.

To correct the specific gravity reading to 27°C add 0.0007 to the observed hydrometer reading for each degree celsius above 27°C.

Excess temperature will cause more sulphation and buckling of the positive plate.

Defects

- Hard sulphation
- Buckling
- Partial short

Hard sulphation: Over discharging or the cell being left in a discharged condition for a long time cause sulphation on both electrodes and offers high internal resistance. The sulphation (hard) can be removed by recharging the cell for a longer period at a low rate called a trickle charge.

Buckling: The bending of electrodes due to overcharging and discharging, improper electrolyte and temperature is known as buckling.

Partial short: The sediments falling from the plates (electrodes) short- circuiting the positive and negative electrodes cause overheating of the particular cell during both charging and discharging periods. Such a cell may be replaced with a new one.

Efficiency: It is considered in two ways.

- Ampere-hour (AH) efficiency
- Watt-hour (WH) efficiency

$$\text{AH efficiency} = \frac{\text{Output in AH discharge}}{\text{Input in AH charge}}$$

The watt-hour efficiency is always less than the ampere-hour efficiency because the potential difference during discharge is less than that during charge.

Watt - hour efficiency

$$= \frac{\text{AH efficiency} \times \text{Average volts on discharge}}{\text{Average volts on charge}}$$

During discharge

positive plate

Lead peroxide + Hydrogen + Sulphuric Acid → Lead sulphate + water

$$PbO_2 + H_2 + H_2SO_4 \rightarrow PbSO_4 + 2H_2O$$

Negative plate

Pure lead + Sulphate = Lead sulphate

$$Pb + SO_4 = PbSO_4$$

During charge

positive plate

Lead sulphate + Sulphate + Water → Lead peroxide + Sulphuric acid

$$PbSO_4 + SO_4 + 2H_2O \rightarrow PbO_2 + 2H_2SO_4$$

Negative plate

Lead sulphate + Hydrogen → Lead + Sulphuric acid

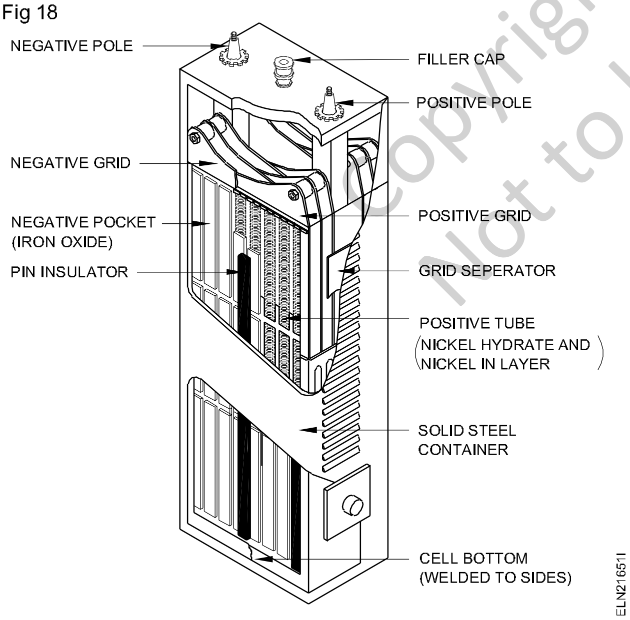
$$PbSO_4 + H_2 \rightarrow Pb + H_2SO_4$$

Nickel iron and nickel cadmium cell

In construction there is no difference between the two cells except that the negative plate of the nickel iron cell is made of iron and in the nickel cadmium cell it is of cadmium.

The nickel iron cell or Edison cell (Fig 18)

Fig 18



Parts

- Positive plate
- Negative plate
- Electrolyte
- Container
- Separators

The positive plate is made of Nickel hydroxide(Ni$(OH)_4$) tubes and perforated steel ribbon wound spirally and held together by steel ribs, and the whole lot is nickel-plated.

The negative plate is made of a nickel steel strip with fine perforation.The electrolyte is 21% solution of potassium hydroxide (KOH) along with some quantity of lithium hydrate(LiOH).

The container is made of nickel-plated steel. The separators are made of hard rubber strips and held in the nickel-plated container.

Chemical changes: On discharge, potassium hydroxide (KOH) splits up into K and (OH)ions. i.e. into potassium and hydroxide ions. OH ions travel towards the negative and oxidise the iron. K ions go to the anode and reduce Ni $(OH)_1$ to Ni $(OH)_2$. During charging, the opposite reactions take place. The chemical changes during charging and discharging can be represented by a reversible equation.

It is seen from the equation that the electrolyte acts merely as a source for transfer of OH ions from one plate to another. It does not take part in any chemical change. As a result the density does not change to the same extent as in an ordinary lead acid cell. Thus, the density of the electrolyte remains almost the same during the action.

Charactereristics: The emf of the cell when fully charged is 1.4V, and it reaches to 1.2 on discharge. If the voltage falls below 1.15, the cell is fullly discharged.

- The mechanical strength of plates is good since they are made of steel.

- The cell is portable.
- The cell can withstand heavy charge and discharge currents, and does not deteriorate even if left discharged.
- Internal resistance is large, and so the efficiency is lower than that of a lead acid cell.
- With increase in the temperature, the e.m.f. increases slightly but the capacity increases appreciably, and with a decrease in the temperature, the capacity decreases.
- It is superior to a lead acid cell in mechanical strength, durability and robustness.

Moreover, as compared to lead-acid cells, the alkaline cells operate much better at low temperatures, do not emit obnoxious fumes, have very small self-discharge and their plates do not buckle or smell.

Shelf life: Batteries are also rated for shelf life in years. Even if a cell is not being used local action takes place within the cell at all times and will eventually render the cell useless. Shelf life is defined as the time in years a stored battery will produce at least 75% of its initial capacity.

Temperature:Batteries are most often rated for a specific output capacity at room temperature or 20ºc. Operating them above and below this temperature will reduce their rated output. For example, the automobile battery output drops on cold days making it more difficult to turn the engine .

$Ni(OH)_4$	+	KOH	+	Fe	$\rightleftharpoons$	$Ni(OH)_2$	+	KOH	+	$Fe(OH)_2$
Hydrated		Potassium		Ferrous		Nickel				Ferrous

Comparison : Lead-acid cell and Edison cell

Sl.No.	Particulars	Lead-acid cell	Edison cell
1	Positive plate	PbO, lead peroxide	Nickel hydroxide $Ni(OH)_4$ or Nickel oxide (NiO_2)
2	Negative plate	Sponge lead	Iron
3	Electrolyte	Diluted H_2SO_4	KOH
4	Average emf	2.1 V/cell	1.2 V/cell
5	Internal resistance	Comparatively low	Comparatively higher resistance
6	Efficiency: Amp-hour Watt-hour	 90 - 95% 72 - 80%	 Nearly 80% About 60%
7	Cost	Comparatively less than alkaline cell	Almost twice that of Pb-acid cell (Easy maintenance)
8	Life	Gives nearly 1250 charges and discharges	Five years atleast
9	Strength	Needs much care and maintenance.Sulphation occurs often due to incomplete charge or discharge.	Robust, mechanically strong, can withstand vibration, light, unlimited rates of charge and discharge. Can be left discharged, free from corrosive liquids and fumes.

Advantages and disadvantages of nickel iron cell

(A) Advantages

(i) It can withstand heavy charge and discharge current and does not deteriorate.

(ii) It is robust in construction and thus it can be used even roughly.

(iii) It is light in weight and thus it is portable.

(iv) It can be left discharged for a long time.

(v) It can work on higher temperatures also.

(vi) It is used on higher temperatures also.

(vii) It is used in electric operated vehicles, switch-gear operations etc.

(B) Disadvantages

(i) Its EMF does not remain constant.

(ii) Its efficiency is lower than lead-acid cell.

(iii) It has a high internal resistance.

(iv) Its EMF is low in comparison to lead acid cell.

(v) If temperature is increased, its EMF will slightly reduce.

Comparison between primary and secondary cells

Primary Cell	Secondary Cell
1 It is an instant EMF producing device.	1 It is charged with electric supply first, then it produces EMF.
2 It cannot be recharged.	2 It can be recharged again and again.
3 It is light in weight.	3 It is heavy in weight.
4 It can supply a low current at a low voltage.	4 It can supply more current at comparatively more voltage.
5 It is cheap.	5 It is costly.
6 It has a short life.	6 It has a long life.
7 It transforms chemical energy into electrical energy.	7 In it, electrical energy produces certain actions in the chemicals and then chemical reactions reproduce electricity.

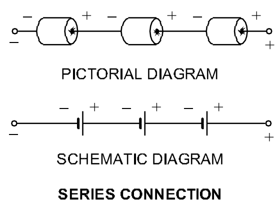
Grouping of cells

Objectives: At the end of this lesson you shall be able to
- **state the purpose of cells connected in series and parallel**
- **explain series connections, parallel connection and series-parallel connection of cells**
- **state the method of testing cells.**

Grouping of cells: Often an electric circuit requires a voltage or current that a single cell is not capable of supplying alone. In this case it is necessary to connect groups of cells in various series and parallel arrangements.

Series connections: Cells are connected in series by connecting the positive terminal of one cell to the negative terminal of the next cell (Fig 1).

Fig 1

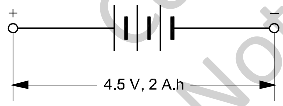


SERIES CONNECTION

Identical cells are connected in series to obtain a higher voltage than is available from a single cell. With this connection of cells, the output voltage is equal to the sum of the voltages of all the cells. However, the ampere hour (AH) rating remains equal to that of a single cell.

Example: Suppose three `D' flashlight cells are connected in series (Fig 2). Each cell has a rating of 1.5 V and 2 AH The voltage and ampere hour rating of this battery would be:

Fig 2



CIRCUIT SCHEMATIC

V Battery = V per cell x No.of cells
= (1.5V) (3)
= 4.5 V

AH Battery rating = AH rating of 1 cell
= 2 AH

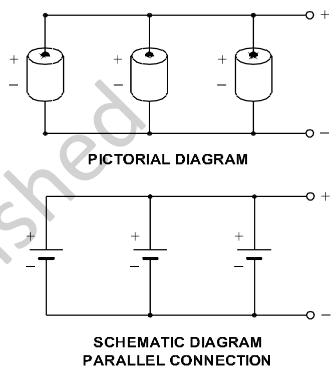
> **If, by mistake, one cell connection is reversed in a series group, its voltage will oppose that of the other cells. This will produce a lower than expected battery output voltage.**

Example: Suppose that one of the three `D' flashlight cells of the previous example is connected in reverse, the output voltage then would be:

V Battery = (1.5V)+(1.5V) − (1.5V)
= (3.V) − (1.5V)
= 1.5V.

Parallel connection: Cells are connected in parallel by connecting all the positive terminals together and all the negative terminals together (Fig 3).

Fig 3

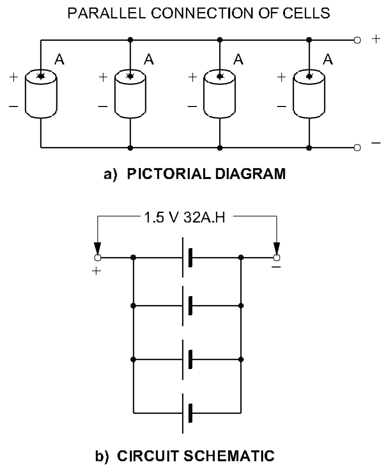


PARALLEL CONNECTION

Identical cells are connected in parallel to obtain a higher output current or ampere-hour rating. With this connection of cells, the output ampere hour rating is equal to the sum of the ampere hour ratings of all the cells. However, the output voltage remains the same as the voltage of a single cell.

Example: Suppose four cells are connected in parallel (Fig 4). Each cell has a rating of 1.5 V and 8 AH. The voltage and ampere-hour rating of this battery would be:

Fig 4

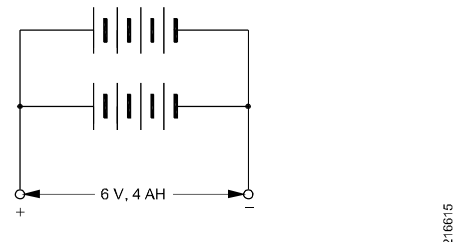


V Battery	= V rating of 1 cell
	= 1.5 V
AH Battery rating	= AH rating per cell x no. of cells
	= (8 AH) (4)
	= 32 AH

If, by mistake, a cell connection is reversed in a parallel group, it will act as a short circuit. All cells will discharge their energy through this short circuit path. Maximum current will flow through the short circuit and the cells may be permanently damaged.

Series-parallel connection: Sometimes the requirements of a piece of equipment exceed both voltage and ampere hour rating of a single cell. In this case a series-parallel grouping of cells must be used (Fig 5).

Fig 5



SERIES-PARALLEL CONNECTION

The number of cells that must be connected in series to have voltage rating is calculated first and then the number of parallel rows of series connected cells is calculated for required ampere-hour rating.

Example: Suppose a battery operated circuit requires 6 V and a capacity of 4 AH (Fig 5). Cells rated at 1.5 V and 2 A H are available to do the job. The required arrangement of cells would then be:

$$\text{No. of cells in series} = \left(\frac{\text{V required}}{\text{V per cell}}\right)$$

$$= \frac{6\text{ V}}{1.5\text{ V}} = 4 \text{ cells}$$

$$\text{No. of parallel rows} = \left(\frac{\text{AH required}}{\text{AH per cell}}\right)$$

$$= \frac{4\text{ AH}}{2\text{ AH}} = 2 \text{ rows.}$$

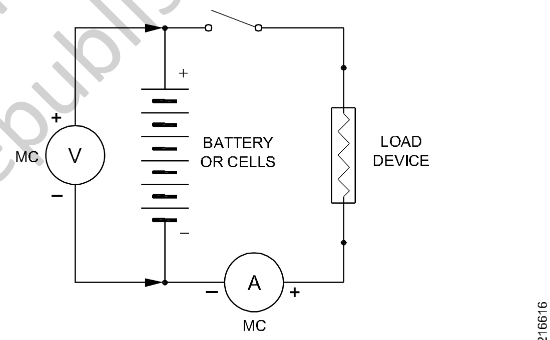
When connecting groups of cells or batteries in parallel, each group must be at the same voltage level. Paralleling two batteries of unequal voltage levels sets up a difference of potential energy between the two. As a result, the higher voltage battery will discharge its current into the other battery until both are at equal voltage value.

Testing primary cells or batteries: A visual inspection will tell you little about the useful life of a cell or battery unless it has deteriorated to the point where acid is spilling from the case.

A no-load voltage test of the cell of battery is another indication of cell or battery life. This test requires the cell or battery to deliver only a very small amount of current required to operate the voltmeter.

The best method that is used to check a cell or battery is an in-circuit test of the cell or battery voltage with the normal load connected to it (Fig 6). A substantial drop in cell or battery voltage, when normal load is applied, indicates a bad cell or battery.

Fig 6



TESTING A BATTERY UNDER LOAD

Battery charging method - Battery charger

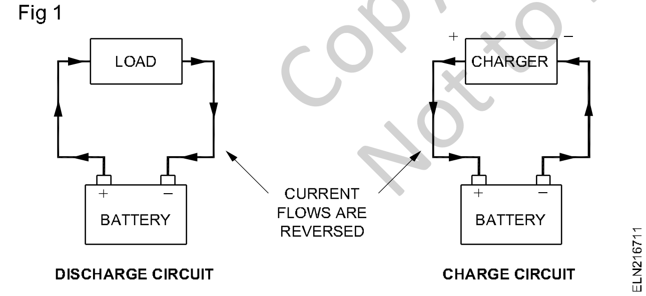
Objectives: At the end of this lesson you shall be able to
- **state the necessity of charging a battery**
- **describe the preparation of electolyte**
- **describe the use of a hydrometer and high rate discharge tester**
- **state the precautions to be followed while charging and discharging a battery**
- **describe the different types of charging methods of secondary cells**
- **explain the purpose, construction and working principle of battery charger.**

Necessity of charging: During discharge, due to chemical reaction, the active electrodes become smaller and the internal resistance becomes high causing a low output. To reverse the action, send a current (DC) through the battery or cell in the opposite direction to that of the discharge. This process is called charging. The charging can be done through a battery charger.

Battery chargers:When the chemical reaction in a rechargeable battery has ended, the battery is said to be discharged and can no longer produce the rated flow of electric current. This battery can be recharged, however, by passing direct current from an outside source to flow through it in a direction opposite to that in which it flowed out of the battery.

When charging a battery, the negative lead of the charger must connect to the negative lead of the battery and the positive lead of the charger to the positive lead of the battery (Fig 1). A reversal of these connections will produce a short circuit and may damage both the charger and the battery.

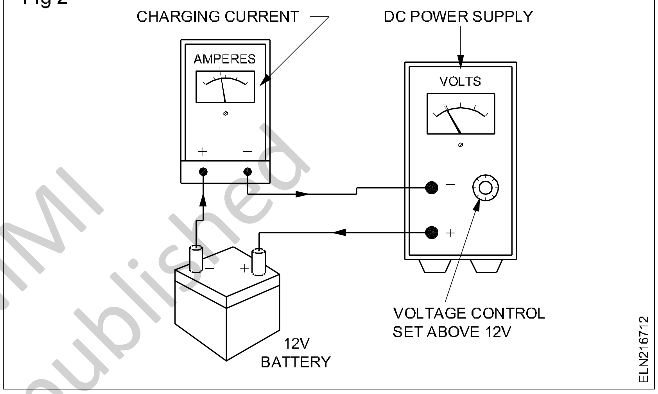
Fig 1



An automobile uses an automatic charging circuit as part of the car's electrical system, which is designed to recharge the battery as required and battery charging is also done using large commercial type battery chargers. Smaller type chargers are also available for use on the smaller nickel-cadmium cells. A simple variable-voltage DC power supply works well as a battery charger.

Charging current: When charging any battery, it is important to set the charging current to a value recommended by the manufacturer. This current is set by adjustment of the output voltage on the charger and read by an ammeter connected in series with the charger and battery (Fig 2). When the battery and charger are at the same voltage, no current flows. The charger voltage is set to a value higher than that of the battery to produce a current flow.

Fig 2



Before charging the battery or cell the following points are to be observed to ascertain the condition of the battery.

1 Specific gravity of the electrolyte
2 Voltage of each cell of the battery
3 Ampere hour capacity of each cell.

PREPARATION OF ELECTROLYTE

The electrolyte used in a cell is dilute sulphuric acid having a specific gravity between 1.21 and 1.3. The specific gravity of the acid available in the market is usually 1.835. Therefore, it is necessary to dilute the acid. Remember that for dilution, the acid is gently poured into distilled water and not the water into acid. In this way, the acid is diluted upto a specific gravity of 1.4 and stored. When, it is required to be filled up in the battery, then it is further diluted upto a specific gravity of 1.25.

Specific gravity

The ratio of the mass of a given volume of liquid to the mass of the same volume of the water at 4°C, is known as specific gravity of the liquid.

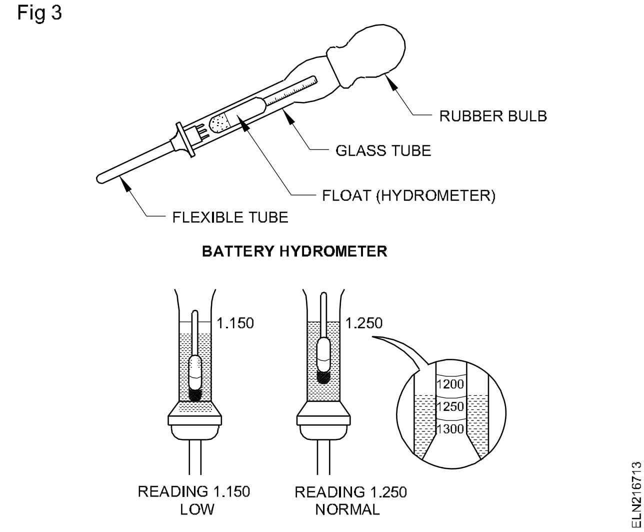
$$\text{Specific gravity} = \frac{\text{(mass of given volume of liquid)}}{\text{(Mass of the same volume of water at 4°C)}}$$

It means that the specific gravity of a liquid is a measure of comparative weights of the same volume of liquid and water at 4°C.It has no unit.

Instrument for testing the condition of cells:

Hydrometer : The specific gravity of an electrolyte is measured with a hydrometer (Fig 3).

Fig 3



The main parts

- Rubber bulb
- Glass tube
- Float
- Flexible rubber tube

The charged condition of battery can be tested by means of a battery hydrometer. This instrument measures the relative density of the battery electrolyte. Since the strength of the electrolyte varies directly with the state of charge of each cell, you need only to find what specific gravity of sulphuric acid remains in each cell electrolyte to determine how much energy is available.

Cell condition	Hydrometer reading
Full charge	1.26
50% charge	1.20
Discharged	1.15

Voltage tests of lead-acid batteries, like primary cells, should be conducted under load. To make a simple light load voltage test of a car battery, check the value of the battery output voltage with and without the headlights on. A maximum load voltage test can be made by metering the battery voltage while operating the starting motor (Fig 4). In the case of a 12V battery, a drop of battery output voltage below 7V indicates the battery is defective or not fully charged.

High rate discharge tester: The internal condition of the cell is determined by this test. A low range (0-3V) voltmeter is shunted by a low resistance (Fig 5). The two terminal prods are pressed on to the terminals of a cell for testing. A fully charged cell which is in good condition reads in the range of full charge.

A sulphated old battery will show the discharge reading. The meter is having three colours red, yellow and green - red for fully discharged, yellow for half charge, green for fully charged condition of the cell respectively.

Fig 4

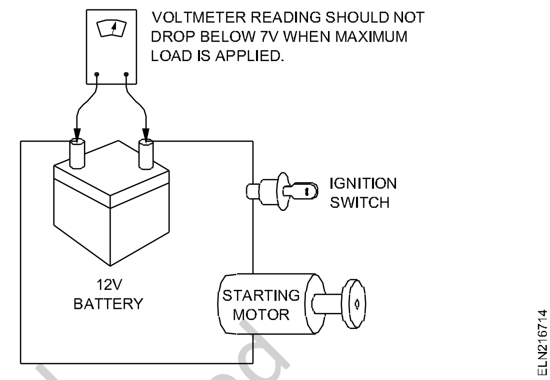
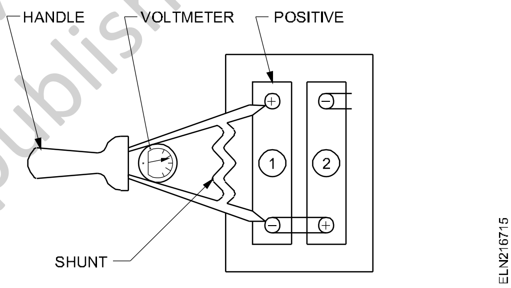


Fig 5



Voltage of each cell: The voltage of the cell is measured with a M C voltmeter. The fully charged cell will indicate 2.5 to 2.6V and a fully discharged cell will indicate 1.8V to 1.6V.

After determining the condition of the battery or cell, the charging rate, and the method of charging are to be decided. The battery should always be charged at the rates recommended by the manufacturer.

If you charge two or more batteries in series or in parallel, the potential difference between the terminals of the charging unit should not exceed the total voltage of all the batteries being charged in the case of series, and in the case of parallel the charging voltage should not exceed the voltage of a battery.

Safety precautions

Before putting the battery under charge, the following precautions are to be followed.

Topping up: If the level of the electrolyte on the surface of the plate is less than 10 to 15mm then distilled water should be added to the indicated level of the cell after removing the vent plugs.

Do not add tap water or well water for topping up.

During charge the vent plugs are to be kept open for the escape of gas produced freely.

Ventilation: The room where batteries are to be charged should be well ventilated.

Naked flame should not be brought near the battery or cell when it is under charge.

The terminal posts should be free from corrosion and they must be covered with petroleum jelly before and after charging.

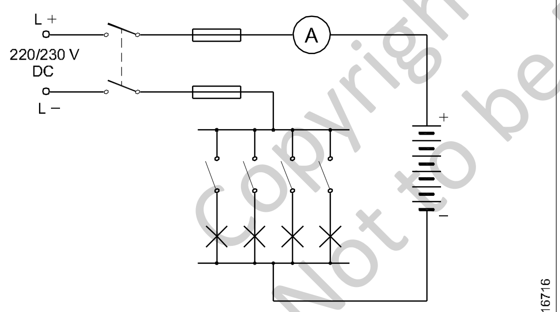
Improper electrolytes must not be used for compensating the electrolyte after it is fully charged.

The methods of charging the secondary cells are:

- constant current method
- constant potential method
- rectifier method.

Constant current method: This method is used where the supply is high voltage DC 220 V, 110 V, etc. but the battery is of low voltage 6 V, 12 V, etc. The emf of the battery is small in comparison to the supply voltage so a lamp-load or a variable resistor is connected in series with the battery (Fig 6). This causes a loss of energy, so, the method is inefficient.

Fig 6

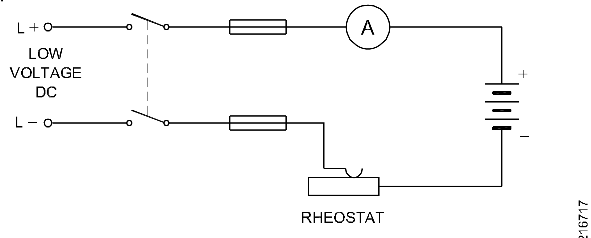


CONSTANT CURRENT METHOD

Use: For charging more number of cells at constant current rating.

Constant potential method: In this method, the voltage is maintained at a fixed value about 2.3 V per cell; the current decreases as the charging proceeds. A variable resistor is connected in series, so a voltage source of 2.5 to 2.6 V per cell is required. For a 12 V motor car battery, the charging dynamo is of about 15 V. In comparison to the constant current method less power is wasted for charging and less time is taken. Fig 7 shows the connections for a constant potential method of charging batteries.

Fig 7

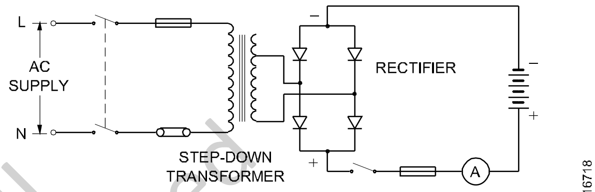


CONSTANT VOLTAGE METHOD

Use: For charging batteries of constant voltage rating.

Rectifier method: A rectifier for battery charging is generally made of diodes connected in the form of a bridge (Fig 8). A transformer is used to step down the AC voltage to that suitable for diodes. Ammeter, voltmeter, switches and fuses are also used in the rectifier set.

Fig 8



RECTIFIER METHOD

Trickle charge: When the battery is charged at a very low rate, that is 2 to 3% of the normal rate for a long period, it is said to be a trickle charge.

Use: For central or sub-station batteries and for emergency lighting systems.

Initial charge: The first charge of a new, previously uncharged battery is called the initial charge. The process that occurs inside the battery is called forming the cells.

To conduct an initial charge, fill the cells with an electrolyte of a proper specific gravity, then replace the vent plugs. Make sure the holes in the plugs are clear. The battery should also be cool before you begin the initial charge.

Freshening charge: When a new battery is put into service for the first time, it may be given a brief charge to ensure that it starts in a fully charged condition. This kind of charge is called a freshening charge. Normally all that is required is charging at the finish rate until no change in specific gravity or voltage occurs over a three hour period.

Boost charge: If a battery is in danger of becoming over-discharged during a working shift, you can give it a supplementary charge during a rest period. This boost charge is not a conventional method of charging the storage battery. It is not recommended as a standard procedure. It is generally a high rate charge of short duration, used only to ensure that the battery will last until the end of the shift.

Battery chargers

Primary batteries need to be replaced by new ones when they get exhausted. However in the recent past certain secondary cells like nickel cadmium cells which look similar to the primary cells could be recharged through low current plug-in cell chargers. On the other hand, primary cells like mercury cells should not be charged. Any attempt to charge them will make the cell to explode which will be dangerous.

Whereas in secondary or rechargeable batteries, supply power to a load till they discharge to a certain level. After this they are to be recharged with the help of battery chargers, and then they are ready for service again. Modern secondary batteries can withstand a large number of charge and discharge cycles under stipulated conditions.

Battery chargers: In general a charger is an electrical/ electronic device having provision for AC input and DC output. A battery charger is used to put energy into a cell. We know that the chemical reaction in a secondary battery is reversible. The reaction proceeds in one direction when the battery supplies power to a load. The direction of reaction is reversed during charging. This enables storage of electrical energy in the form of chemical energy inside the cell. This stored energy is again converted into electrical energy when the cell is used to supply power to a load.

A battery charger is a simple DC power supply that draws its power from the AC mains and supplies DC power at a voltage higher than that of the battery. Many chargers contain additional accessories to monitor and control the charging process. In general, a battery charger consists of the following four parts.

i) A transformer to step down the AC mains voltage to the desired AC voltage.

ii) A selector switch for voltage and current selection.

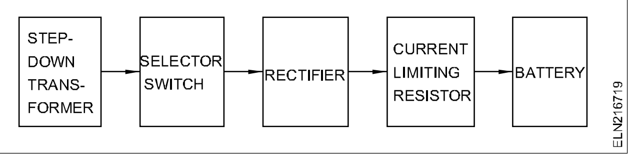
iii) A rectifier to convert AC into a uni-directional DC.

iv) A current limiting circuitry to prevent flow of excessive charging current into the battery under charge.

Construction: Fig 9 is a block diagram showing the different components that make a battery charger.

First of all, there is a step down transformer that transforms the high voltage of AC mains into a low AC voltage. The size of the transformer depends on the charging power required. Very small transformers are required for charging small Ni-Cd type batteries, while large size transformers are required to charge heavy duty automobile or emergency light batteries.

Fig 9



The transformers used for battery charging are generally provided with a number of tappings on their secondary side. In addition to stepping down the voltage, the transformer also serves another very important role. It isolates the charging circuit completely from the AC mains and thus completely eliminates the danger of electric shock from high voltage AC mains.

Most of the battery chargers are provided with two selector switches marked i) coarse and ii) fine indication.

The coarse selector switch is for the selection of output voltage according to the voltage of the battery to be charged, example 6V, 12V, 24V, 48V etc.

The fine selector switch is used for selecting either a low or a high rate charging current.

The rectifier converts the low voltage AC into uni-directional DC. There are 3 types of rectifiers which are normally used for a battery charger.

a) Tungsten rectifier

b) Metal rectifier

c) Junction diode rectifier.

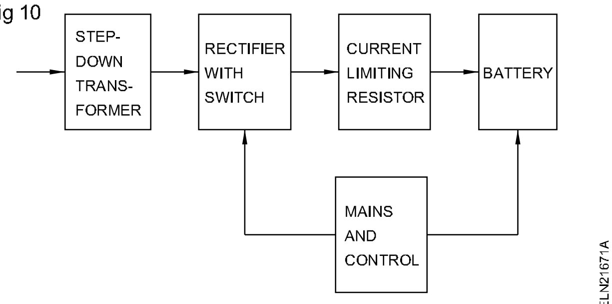
Nowadays, almost all the battery chargers are provided with junction diode which are also called as 'Solid state rectifier units'.

The rectifier unit used in a battery charger may be of half or full wave type. But in most cases full wave bridge rectifiers are used.

The size of diode depends upon the charging current requirements. A number of diode elements/metal rectifiers may be connected in series to withstand the operating voltage in the case of low voltage diodes/metal rectifier. Wherever junction diodes are used, suitable heat sinks are also provided along with the diode or bridge.

Fig 10 is a block diagram showing the different components that make a suitable battery charger for charging batteries in emergency lamp circuits.

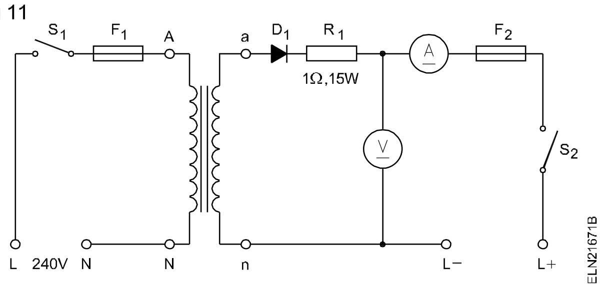
Fig 10



Working: A number of circuits are available for battery chargers. Anyhow only the 3 most commonly used circuits are explained here.

Circuit 1: The AC main supply to the primary of the step-down transformer is protected by a fuse and controlled by a toggle switch (Fig 11). Step-down secondary voltage is fed to the metal rectifier or diode and the output is passed through a current limiting resistor, an ammeter (to measure the charging current), a fuse and a switch. A voltmeter is connected in the output circuit to measure the output voltage.

Fig 11



This type of circuit is protected only through fuses and needs constant attention during the entire period of battery charging. As the output voltage is fixed, only particular rated voltage batteries or a combination of them could be charged.

Circuit 2: In the case of commercial establishments where different voltage rating batteries are required to be charged, the secondary of the transformer has different tappings and the necessary output voltage could be selected through a selector switch (Fig 12).

Further the charging current could be varied through one or more selector switches where tappings are made for lower voltage ranges. A full wave rectifier with four power diodes are used to form the bridge.

Circuit 3: The circuit (Fig 13) contains an electronic circuit that continuously monitors the condition of the battery and then regulates the charging current accordingly. This circuit also terminates the charging process when it finds that the battery has charged fully.

In many cases the charging process is not fully cut off but the charging rate is reduced to maintain a small charging current to maintain the battery in top condition. This process is called '**trickle charging**'.

Fig 13

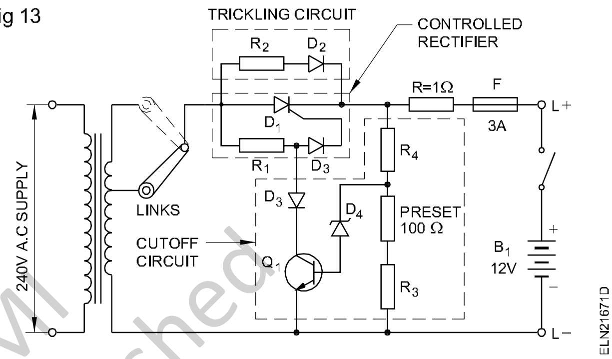
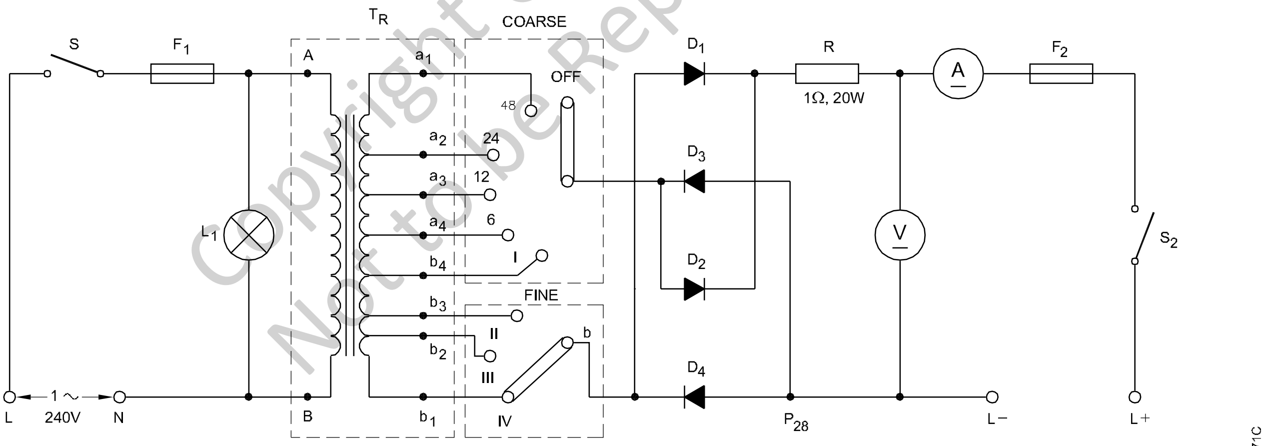


Fig 12



SCHEMATIC DIAGRAM

Installation, care and maintenance of batteries

Objectives: At the end of this lesson you shall be able to
- **list out the guidelines for installation of batteries**
- **state the guidelines for care and maintenance of batteries**
- **state the precaution to be followed while charging and discharging of battery.**

Guidlines for installation of batteries

The following guide lines to be followed during installation of batteries at residential building

- Location of battery installed should be free from heat sources and flame.
- Battery connection cables should be as short as possible to prevent excessive voltage drop.
- Before connecting the battery the positive and negative poles must be carefully checked to ensure correct installation.
- Authorised and trained person must only be allowed for installation.
- If the batteries to be installed in the accessories like remote controls first open the battery cover, insert the batteries correctly into +ve and -ve ends then close the battery cover and press it to close.
- Do not expose the batteries to heat (or) flame.
- Manufacturer's instruction must be followed when installing the batteries.
- Follow the local, state and National electricity code.
- When installing a battery bank always be careful, since shock hazard may be present.
- Always use protecting/insulating equipment such as gloves, shoes and eye protectors, wrenches and other insulated tools.
- Use proper lifting techniques when working with large batteries.
- Never lift batteries by its terminals.
- Do not allow tools (or) unconnected cables to rest on the top of batteries.
- Never use power tools that may develop more torques while making the batteries terminal connections.
- Do not use chemical cleaner on batteries,they may cause irreversible damage.
- Do not remove vent plugs and Do not add distilled water to the sealed maintanence free (SMF) batteries.
- Ensure that test equipment leads are clean, in good condition and connected with sufficient length to prevent accident.
- Ensure that all monitoring systems are operationable.
- Ensure that battery area and cabinet is properly ventilated.
- Never install batteries in an airtight enclosure.

Care and maintenance of batteries

The lead acid batteries must be operated under the right conditions if they are to function properly. Regular maintenance is necessary in order to maintain proper conditions and thus prolong the life of the battery.

The battery should not be discharged beyond the minimum value of voltage say, 1.75 V for 2V battery.

The battery should not be kept under a discharged condition for a long time.

The level of the electrolyte should always be kept to a minimum of 10 to 15 mm above the plates by adding distilled water only.

The battery should never be charged and discharged at a higher rate which weakens the plate structure. It should be done as per the manufacturer's instructions.

The battery should be recharged as early as possible after discharge.

A discharged battery should never be tested with a high rate discharge tester.

The high rate discharge tester should be used only on charged batteries and for less than ten seconds.

The specific gravity of the electrolyte should be checked regularly before and after a battery is put on charge.

The battery charging room should always be well ventilated for the gases to escape freely.

The battery terminals must be free from corrosion. The terminals must always be kept clean and petroleum jelly should be applied on them.

The spilling of the electrolyte over the battery causes corrosion and it should be cleaned with soda water or ammonia water.

If the battery has not been used for a long period then the battery should be put on a trickle charge.

The vent plugs should be kept open while charging, for free liberation of gases.

Avoid overcharging and discharging at a high rate. This causes the plates to bend from their position and buckle.

Precautions

Make sure that, while charging, the positive terminal of the charger is connected to the positive terminal of the battery, and the negative terminal of the charger to the negative terminal of the battery. Otherwise, connecting it incorrectly causes very high current which can seriously damage both the battery and the charging unit.

Make sure the cell temperature during charge does not exceed the limit specified (43°C) as per the manufacturer's instruction.

A fully charged battery stored at 100°F (38°C) will loose almost all its charge in 90 days. The same battery stored at 60°F(15°C) will loose a little of its charge in the same period of 90 days. High temperature decreases the charging rate and shortens the life.

The rate of charging at the end of the period called finish rate is most important. It must not exceed the value recommended by the manufacturer.

During recharging, the lead acid battery produces flammable gases. An accidental spark can ignite these gases, causing an explosion inside the battery. Such an explosion can break the battery case and throw acid on the people and equipment in the area.

Do not top up the cell with improper water such as tap water, well water, mineral water or acids which will cause hard sulphation and increase the internal resistance.

Avoid improper cleaning agents for terminal posts and metal parts of the battery like emery or sandpaper. Use only the recommended cleaning agents such as baking soda water(warm), ammonia water, and wipe with cotton cloth or with an old brush.

Always wear safety glasses when working with lead acid cells and batteries. If acid does come in contact with clothing or with the skin, immediately flush with clean water. Then wash with soap and water except for eyes. Wash your hands in soap and water after handling batteries.

Solar cells

Objectives: At the end of this lesson you shall be able to
- **state the necessity of tapping natural resources for energy**
- **state about the solar cell /photo voltaic cell**
- **explain the basic principle, construction and characteristics of the solar cell**
- **calculate the required series, parallel group of solar cell for given power requirement.**

Heat energy

Heat energy is the most sought energy for human being to cook the food as well as to keep warm in cold climate. However the use of wood as the fuel for fire, has ended up in deforestation and resulted in drought.

Search of fuel led the man to use coal and then oil. However these commodities are fast dwindling and after few hundred years both may completely vanish from earth. As such it is essential that human race should find alternative source of energy from nature.

Hence the use of natural resources like heat from sun thought by several scientists and one of the solutions to the energy crisis is the invention of solar cells.

Solar cell / Photovoltaic cell

A solar cell, or photovoltaic cell, is an electrical device that converts the energy of light directly into electricity by the photovoltaic effect, which is a physical and chemical phenomenon.It is a form of photoelectric cell, defined as a device whose electrical characteristics, such as current, voltage, or resistance, vary when exposed to light. Solar cells are the building blocks of photovoltaic modules, otherwise known as solar panels.

Solar cells are described as being photovoltaic irrespective of whether the source is sunlight or an artificial light. They are used as a photo-detector (for example infrared detectors), detecting light or other electromagnetic radiation near the visible range, or measuring light intensity.

The operation of a photovoltaic (PV) cell requires 3 basic attributes:

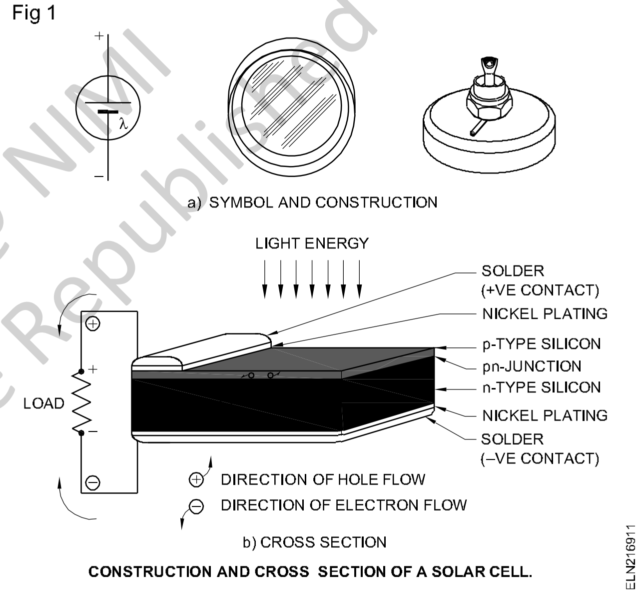
- The absorption of light, generating electron-hole pairs extraction.
- The separation of charge carriers of opposite types.
- The separate extraction of those carriers to an external circuit.

The solar cells is essentially a large photo diode designed to operate as photo voltaic device and to give as much output power as possible. When these cells are under the influence of light rays from sun, they give out about 100 mw/cm^2 power.

Fig 1 shows the construction, symbol and cross section of a typical power solar cell. The top surface consist of a extremely thin layer of P-type material through which light can penetrate to the junction.

The nickel plated ring around the P-type material is the positive output terminal, and the bottom plating is the negative output terminal. Commercially produced solar cells will be available in flat strip form for efficient coverage of available surface areas.

Fig 1



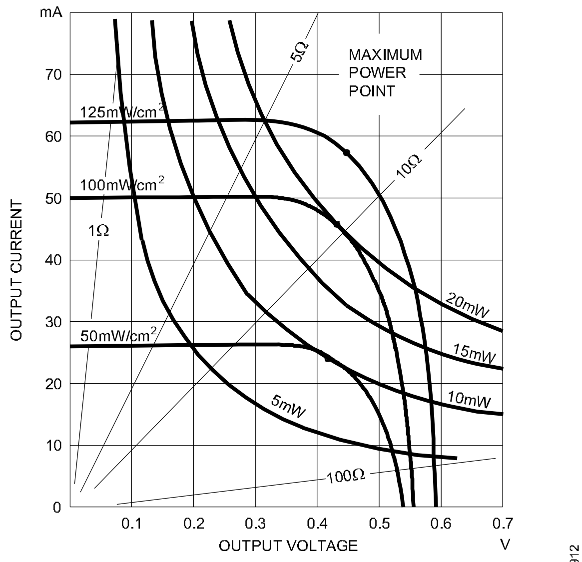
CONSTRUCTION AND CROSS SECTION OF A SOLAR CELL.

According to different manufacturing standards, the output power varies from 50mw/cm^2 to 125mw/cm^2 (Fig 2). The graph shows the characteristic of a solar cell which gives 100mw/cm^2. Considering the characteristic curve it is apparent that the cell will deliver an output current of 50mA when the output terminals are short circuited then the output voltage will be zero.

On the other hand open circuited voltage of the cell will be 0.55mv but the output current is zero. Therefore again the output power is zero. For maximum output power the device must be operated at the knee of the characteristic. In solar cells the output power decreases at high temperature.

Typical output characteristics of power photocell for use as a solar energy converter is shown in Fig 2.

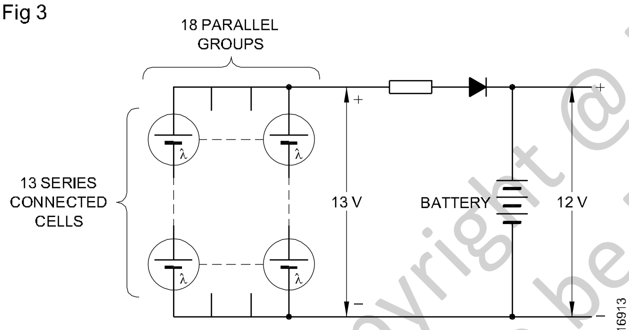
Fig 2



OUTPUT CHARACTERISTICS OF POWER PHOTOCELL FOR USE AS A SOLAR ENERGY CONVERTER

Array of solar cells is connected as a battery charger (Fig 3). Several cells must be connected in series to produce the required output voltage, and number of parallel groups to be provided as per the required output current.

Fig 3



ARRAY OF SOLAR CELLS CONNECTED AS A BATTERY CHARGER

Example

A village welfare club is having a black and white TV which operates at 24V taking a current of 3amp for four hours. Normally an array of solar cells are used for charging the 24V batteries and the light source from sun available to energise the cells for about 10hours a day.

Calculate the total number of solar cells of 125mw/cm^2 required and the series - parallel grouping of cells.

Solution

As per the graph (Fig 2) the solar cells (energy converters) should be operated at approximately 0.45V and 57mA. Assuming the charging voltage should be 10% higher than the battery voltage of 24V the solar cells should supply 26.4 volt for charging the battery circuit.

Number of series connected cells

$$= \frac{\text{Output voltage}}{\text{Cell voltage}} = \frac{26.4\text{V}}{0.45\text{V}}$$

= 58.5 = say 59 cells

The charge taken by the batteries after every day of TV programme willbe be 3 amp x 4hours = 12 ampere hours. This should be supplied by the solar cells in 10 hours. Hence the ampere requirement.

$$= \frac{\text{Ampere hours}}{\text{hours}} = \frac{12}{10}$$

= 1.2 amp

total number of groups of cells in parallel

$$= \frac{\text{output current}}{\text{cell current}} = \frac{1.2 \text{ amp}}{57 \text{ mA}}$$

= say 21 cells.

The total number of cells required

= Number of cells in series x Number of parallel groups

= **59 x 21 = 1239 cells.**

B.I.S. Symbols used for electrical accessories

Objectives: At the end of this lesson you shall be able to
- **interpret the various BIS symbols used in electrical wiring diagrams**

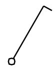
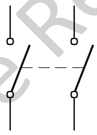
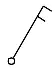
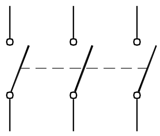
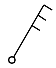
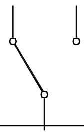
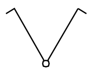
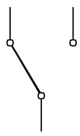
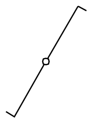
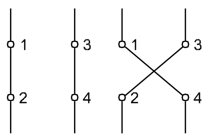
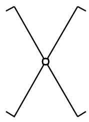
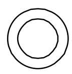
In electrotechnical engineering the symbols are used in layouts and wiring circuits to represent the electrical parts or the function of the circuit.

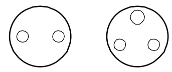
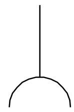
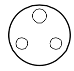
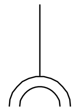
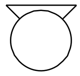
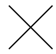
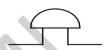
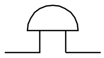
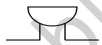
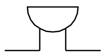
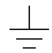
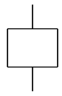
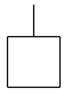
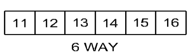
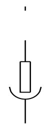
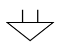
Since the drawing of the actual device is very laborious and would be drawn by each person differently, standardised symbols are used. With the help of the symbols, an electric circuit can be represented easily and can be described precisely as well.

The symbol represents only the function of a part irrespective of the structure and form.

Depending on the purpose of an application, different wiring schemes are used. For example, current flow diagram representation, plans of installation etc. the symbols of various plans of installation (layout) and the current flow diagrams (circuit diagram) differ from one another. A few examples of standard symbols recommended by B.I.S. 2032 (different parts) used for wiring are given here.

B.I.S. SYMBOLS FOR WIRING SCHEMES

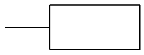
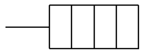
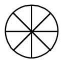
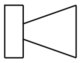
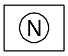
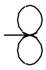
Sl.No.	Description	Symbols used in the circuit diagram	Symbols used in layout
1	One-way switch, single pole		
2	One-way switch, two poles		
3	One-way switch, three poles		
4	Multi-position switch single pole		
5	Two-way switch		
6	Intermediate switch		
7	Push-button or bell-push		

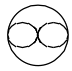
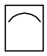
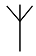
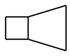
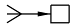
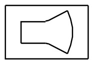
Sl.No.	Description	Symbols used in the circuit diagram	Symbols used in layout
8	Socket outlets, 6A		
9	Socket outlets, 16A		
10	Lamp or outlet for lamp		
11	Fuse		 MAIN & D.B FUSE BOARDS
12	Bell		
13	Buzzer		
14	Earth point		
15	Circuit breaker		
16	Terminal strip		N.A
17	Link (closed)		N.A
18	Plug and socket (male and female)		N.A
19	Ceiling rose		N.A
	N.A: Not applicable		

The B.I.S. Symbols used in the wiring is given here.

ITEMS	SYMBOLS
I Wiring	
1 General wiring	
2 Wiring on the surface	
3 Wiring under the surface	
4 Wiring in conduit	
a Conduit on the surface	
b Conduit concealed	
The type of conduit may be indicated, if necessary.	
5 Wiring going upwards	
6 Wiring going downwards	
7 Wiring passing vertically through a room	
II Fuse-boards	
1 Lighting circuit fuse-boards	
a Main fuse-board without switches	
b Main fuse-board with switches	
c Distribution fuse-board without switches	
d Distribution fuse-board with switches	
2 Power circuit fuse-boards	
a Main fuse-board without switches	
b Main fuse-board with switches	
c Distribution fuse-board without switches	
d Distribution fuse-board with switches	
III Switches and switch outlets	
1 Single pole pull-switch	
2 Pendent switch	
IV Socket outlets	
1 Combined switch and socket outlet, 6A	

ITEMS	SYMBOLS
2 Combined switch and socket outlet, 16A	
3 Interlocking switch and socket outlet, 6A	
4 Interlocking switch and socket outlet 16A	
V Lamps	
1 Group of three 40 W lamps	3x40 W
2 Lamp, mounted on a wall or light bracket	
3 Lamp, mounted on ceiling	
4 Counterweight lamp fixture	
5 Chain lamp fixture	
6 Pendent lamp fixture	
7 Lamp fixture with built-in switch	
8 Lamp fed from variable voltage supply	
9 Emergency lamp	
10 Panic lamp	
11 Bulk-head lamp	
12 Watertight light fitting	WT
13 Batten lamp-holder (Mounted on the wall)	BH
14 Projector	
15 Spotlight	
16 Floodlight	
17 Fluorescent lamp	
18 Group of three 40W fluorescent lamps	3x40 W

ITEMS	SYMBOLS
VI Electrical appliances	
1 General If necessary, use designation to specify.	
2 Heater	
VII Bells, buzzers and sirens	
1 Siren	
2 Horn or hooter	
3 Indicator (at `N' insert number of ways)	
VIII Fans	
1 Ceiling fan	
2 Bracket fan	

ITEMS	SYMBOLS
3 Exhaust fan	
4 Fan regulator	
IX Telecommunication apparatus	
1 Aerial	
2 Loudspeaker	
3 Radio receiving set	
4 Television receiving set	

Electrical wiring accessories

Objectives: At the end of this lesson you shall be able to
- **classify, specify, identify and state the uses of the accessories employed in domestic wiring**
- **state the IE rules related to safety and electric supply.**

Electrical accessories: An electrical domestic accessory is a basic part used in wiring either for protection and adjustment or for the control of the electrical circuits or for a combination of these functions.

Rating of accessories: The standard current ratings of the accessories are 6, 16 and 32 amps. The voltage rating is 240V AC as per B.I.S. 1293-1988.

Mounting of accessories: The accessories are designed to mount either on the surface or concealed (flush type).

Surface mounting type: Accessories are provided with a seating so that when mounted they project wholly above the surface on which they are mounted.

Flush-mounting type: These accessories are designed to mount behind or incorporated with a switch plate, the back of the plate being flush with the surface of the wall or switch box.

The electrical accessories used in wiring installation, are classified according to their uses.

- Controlling accessories
- Holding accessories
- Safety accessories
- Outlet accessories
- General accessories

Controlling accessories: The accessories which are used to control the circuits or an electrical point like switches are called `controlling accessories'. All the switches are specified in accordance with their function, place of use, type of mounting, current capacity and working voltage. For example - S.P.T. (Single pole tumbler) flush-mounted switch 6 amps 240 volts.

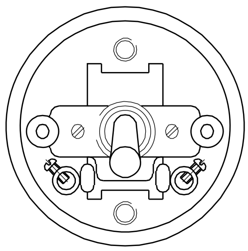
Types of switches according to their function and place of use

1 Single pole, one-way switch
2 Single pole, two-way switch
3 Intermediate switch
4 Bell-push or push-button switch
5 Pull or ceiling switch
6 Double pole switch (DP switches)
7 Iron clad double pole, (ICDP) switch.
8 Iron clad triple - pole (ICTP) switch.

Of the above 1,2,3,4 and 6 may be either surface mounting type or flush-mounting type.

Single pole, one-way switch: This is a two terminal device, capable of making and breaking a single circuit only. A knob is provided to make or break the circuit (Fig 1). It is used for controlling light or fan or 6 amps socket.

Fig 1



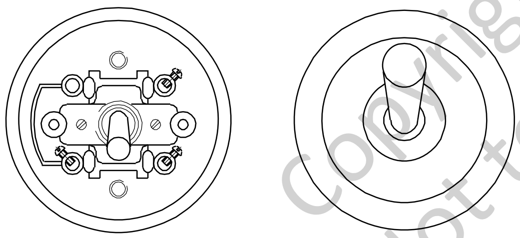
6 AMP SINGLE-WAY SURFACE MOUNTING SWITCH (COVER REMOVED)

ELN227021

Single pole, two-way switch: This is a three terminal device capable of making or breaking two connections from a single position (Fig 2). These switches are used in staircase lighting where one lamp is controlled from two different places. Though four terminals could be seen, two are short circuited and only three terminals are available for connection.

However, both single way and two-way switches with their cover look alike (Fig 2b) but can be differentiated by looking at the bottom. Single way switches will have two terminal posts whereas two-way switches will have four terminal posts.

Fig 2



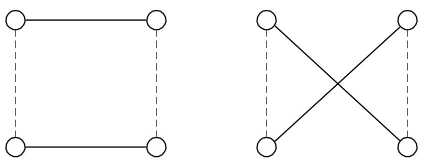
(a) 6 AMP 2-WAY SURFACE MOUNTING SWITCH (COVER REMOVED)

(b) A 2-WAY SWITCH WITH A METAL CAP

ELN227022

Intermediate switch: This is a four-terminal device capable of making or breaking two connections from two positions (Fig 3). This switch is used along with 2 way switches to control a lamp from three or more positions.

Fig 3



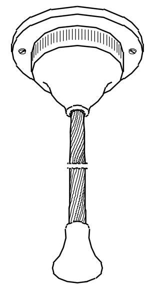
INTERMEDIATE SWITCH CONNECTIONS

ELN227023

Bell-push or push-button switch: This is a two-terminal device having a spring-loaded button. When pushed it `makes' the circuit temporarily and attains `break' position when released.

Pull or ceiling switch (Pendent switch): This switch is normally a two-terminal device functioning as a one-way switch to make or break a circuit (Fig 4).

Fig 4



PULL SWITCH

ELN227024

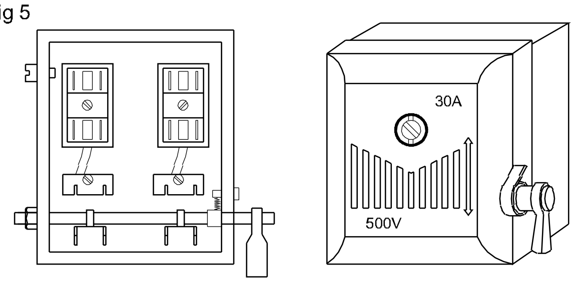
This switch is mounted on ceilings. As the user could operate the switch from a distance through the insulated cord, this could be used safely for operating water heaters in bathrooms or fan or lights in bedrooms.

Double pole switch (DP switch): This is a switch with two poles, the two poles being mechanically coupled together. It is operated with a knob. It is also provided with a fuse and a neutral link. These switches are used as main switches to control main or branch circuits in domestic installation.

Iron - Clad Double pole (ICDP) main switch : This switch is also referred to as DPIC switch and is mainly used for single phase domestic installations, to control the main supply. It controls phase and neutral of the supply simultaneously (Fig 5).

This switch consists of two fuse-carriers. The one in the phase circuit is wired with the fuse and the other in neutral is linked with a brass plate or thick copper wire. These switches should be earthed properly to safeguard the user. The current rating of the switch varies from 16 amps to 200 amperes.

Fig 5



DPIC MAIN SWITCH

ELN227025

Specification of these switches should have:

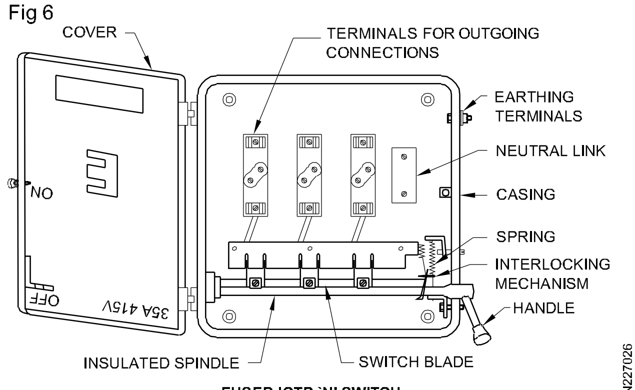
– current rating

– voltage rating

– type of enclosure (sheet steel or cast iron).

Iron - Clad Triple pole (ICTP) main switch: This is also referred to as TPIC switch and is used in large domestic installation and also in 3-phase power circuits, the switch consists of 3 fuse carriers, one for each phase. Neutral connection is also possible as some switches are provided with a neutral link inside the casing (Fig 6).

Fig 6



FUSED ICTP `N' SWITCH

These switches need to be earthed through an earth terminal or screw provided in the outer casing.

The current rating of the switch varies from 16 to 400 amps. Specification of these switches should have

- current rating
- voltage rating
- type of enclosure (sheet steel or cast iron)
- whether with neutral link or otherwise
- rewirable type fuse carriers or HRC type fuse carriers.

Holding accessories

Lamp-holders : A lamp-holder is used to hold a lamp. Earlier, brass holders were most commonly used but nowadays these have been replaced by bakelite holders. These may contain solid or hollow spring contact terminals. Four types of lamp-holders are mainly available.

- Bayonet cap lamp-holders
- Screw type holders
- Edison screw type lamp-holders
- Goliath Edison screw type lamp-holders

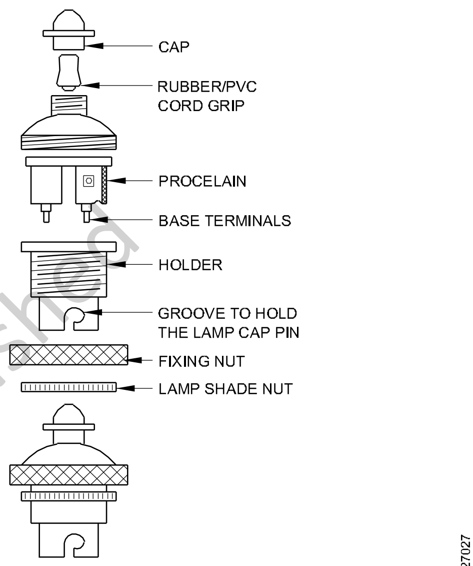
According to the Bureau of Indian Standard, 732, clause 5.8, all incandescent lamps, unless hung at a height of 2.5m (8ft), shall be provided with standard bayonet holders for lamps up to and including 200 watts. For lamp powers above 200 W and up to 300 watts Edison screw holders are to be used and for above 300 watts Goliath screw holders are to be used.

Bayonet cap (BC) lamp-holders: In this type,the bulb is fitted into the slot, and is held in position by means of two pins in the lamp cap. It has solid or hollow spring contact terminals, and the supply mains through the switch are connected to these contacts. In BC types there are two grooves on the circular construction of all types of holders.

The groove and the contact terminals are at right angle to each other. In this type of holders, the lamp is inserted, forced in, turned slightly and then left in position. These holders can be classified further as explained below.

Pendent lamp-holders: This holder (Fig 7) is used in places where the lamps are required in a hanging position. These holders are made of either brass or bakelite. An exploded view of this holder shows the parts of the holder. These holders are used along with ceiling roses for suspending the lamps from the ceiling.

Fig 7

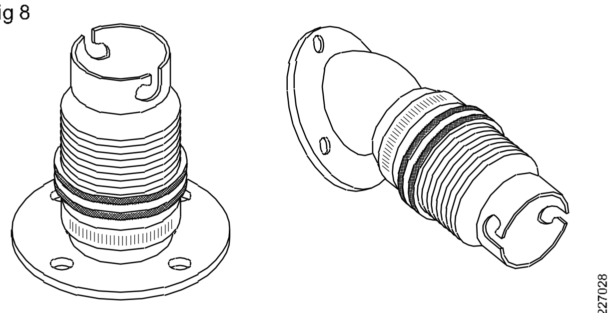


EXPLODED VIEW OF PENDENT HOLDER

Batten lamp-holders: The straight batten holder (Fig 8a) is used on a flat surface on the round block, wooden board etc. These holders are made of either brass or bakelite.

Angle holders: The angle bottom holder, (Fig 8b) is to hold the lamp in a particular angle. These are made of either brass or bakelite. These are used for advertising boards, window display, kitchens etc.

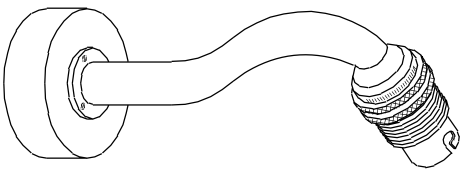
Fig 8



(a) BRASS BATTEN HOLDER (b) ANGLE HOLDER

Bracket holders: This holder (Fig 9) is used with a bracket. These are made of brass and are used to give direct light to a particular place. Brass bracket holders need to be earthed as per BIS recommendations.

Fig 9

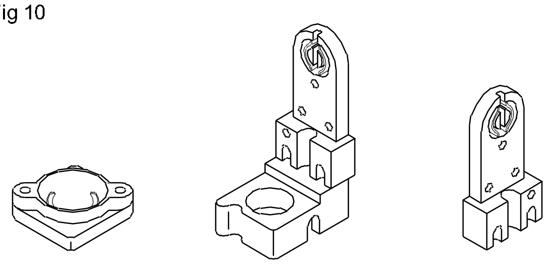


BRACKET HOLDERS

These are fixed on the bracket by the internal threading of the cap.

Tube light or fluorescent lamp-holders and starter-holders: Generally the fluorescent lamp-holders are of a bi-pin type (Fig 10).

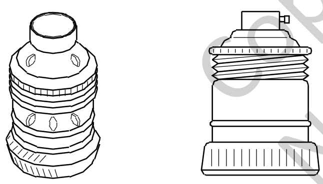
Fig 10



Edison screw-type lamp-holders: In this type, the holder is provided with inner screw threads and the lamp is fitted in it by screwing. It has a centre contact which is connected to the live wire and the screwed cap is connected to the neutral wire.

For lamps with wattage above 200W and not exceeding 300W, Edison screw-type holders are used. Edison screw (ES) lamp holders have spring-loaded central contact to ensure good contact (Fig 11).

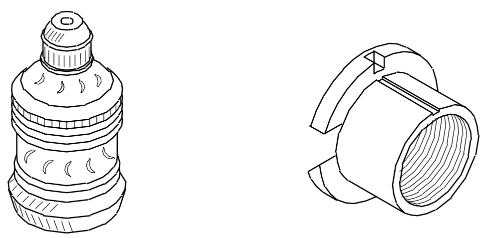
Fig 11



EDISON SCREW TYPE HOLDER

Goliath Edison screw (GES) type holders (Fig 12)**:** The cover of this type of holder is made of porcelain. Such holders are used in studios, headlights, floodlights, focussing lights etc.

Fig 12

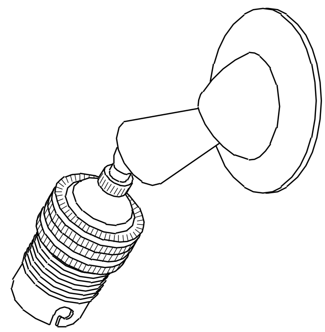


GOLIATH EDISON SCREW LAMP HOLDER

These holders are used for more than 300W lamps.

Swivel lamp-holders: The swivel lamp-holder is designed for wide angle directional lighting which is used for the lighting of shop windows, showcases, etc. It consists of a ball and socket joint fitted between a back plate and the lamp-holders. It is available in bayonet cap type, small bayonet cap type and Edison screw type. All these type of holders are also available for wall fixing patterns or ceiling pattern (Fig 13).

Fig 13



ANGLE SWIVEL LAMP-HOLDER

Specification of a lamp-holder: While specifying the lamp-holders, the type of material used for construction, type of gripping, type of mounting, working current and voltages should also be specified.

Safety accessories: A fuse is a safety accessory. It is connected in series with the circuit and protects the electrical apparatus and equipment from damage, when excess current flows.

The kit-kat type fuse is commonly used in domestic installation.

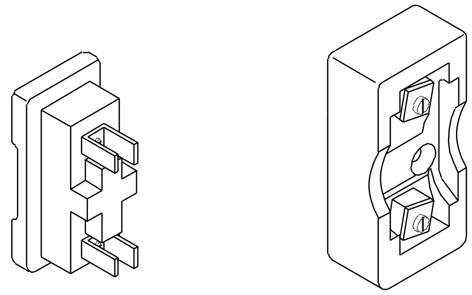
Types of fuses

- Kit-kat type (Rewirable fuse)
- Iron-clad fuse cut out

Kit -kat type fuse: This fuse consists of a porcelain base having two fixed contacts, for connecting the incoming and outgoing cables.

The line and load wires are connected in the base terminals and the carrier is provided with a fuse (Fig 14). The base is fixed but the carrier is removable.

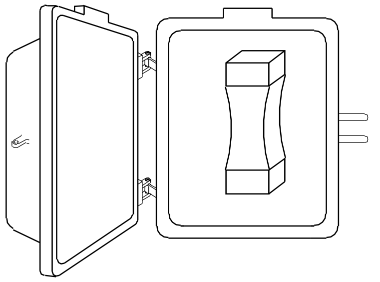
Fig 14



KIT-KAT FUSE

Iron-clad fuse cut outs (Fig 15): These are kit-kat fuses in an iron cover. The iron cover has facility to be closed and sealed with a lead seal. This is used at the incoming side of the power supply and sealed by the supply authorities to ensure the line is not loaded beyond a certain prescribed current capacity.

Fig 15



IRON CLAD CUT - OUT

Outlet accessories: These accessories are used to take the supply for the portable appliances like table fans, TV, electric irons etc.

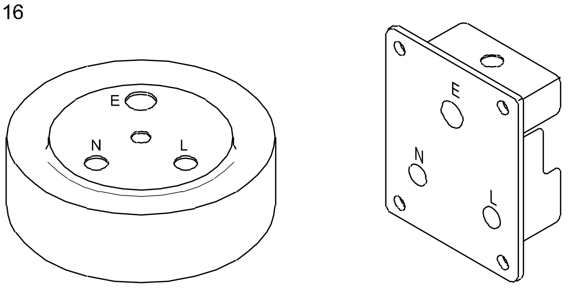
Socket outlet current rating: The standard ratings shall be 6,16 and 32 amperes and 240 volts. The following types are normally used for domestic purposes. They have to be specified according to the mounting type, number of pins, current capacity and voltage.

Two-pin socket: This socket is rated as 6A, 250V, having only two pins without earth connection. These are suitable only for double insulated appliances (having PVC or insulated body).

Two-pin plug top: It is used for taking the supply from the socket. It has got two pins of the same size.

Three-pin socket: This type of socket is suitable for light and power circuits. These sockets are rated as 6A, 250V or 16A, 250V, and are available as surface-mounting type and flush type (Fig 16). There are three terminals marked as Line (L) Neutral (N) and Earth (E). The line terminal is always on the right hand side, the neutral terminal on the left hand side, and the top is the earth terminal which is larger in diameter. In all the cases, the earth wire must be connected to the earth terminal of the socket.

Fig 16

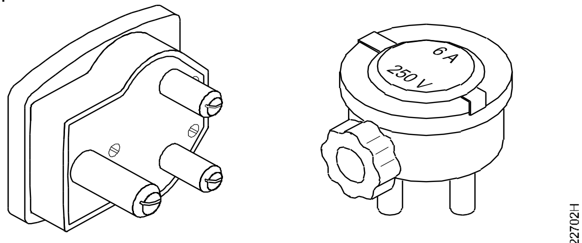


3-PIN 16 AMP SOCKET WITH TOP COVER FLUSH TYPE SOCKET

Three-pin plug top : It is used for taking the supply from the socket. It has three pins. Two are similar in size and the third one is bigger and longer which is for earth (Fig 17). These are also rated as 6A,250V or 16A, 250V. These are made of bakelite, PVC materials.

A socket which is controlled by a switch, is also available. Multi-pin sockets are also available which are suitable for 2 pins and 3 pins having 5 holes in one unit. Further multi-pin sockets for 3 pin of 6 amps and 16 amps are also available having 6 holes in one unit.

Fig 17



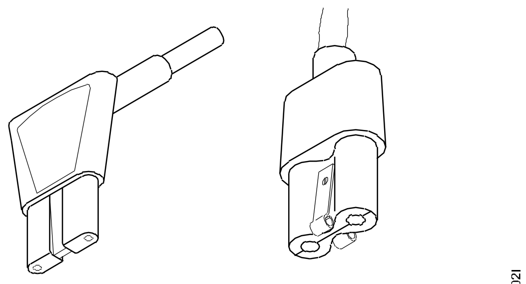
THREE-PIN PLUG TOP

General accessories : Some accessories are used for general and special purposes such as:

– appliance connectors (or) iron connectors
– adapters
– ceiling roses
  a) two-plate
  b) three-plate
– connectors
– distribution board
– neutral links.

Appliance connectors or iron connectors : These are used as female connectors to supply current to electric kettles, electric iron, hotplate, heaters etc. It is made of bakelite or porcelain. The wires are connected with two brass terminals and the earth connection is provided with a twin nickel spring. The cable entry has a rubber protection tybe. These are rated as 16A, 250V (Fig 18).

Fig 18



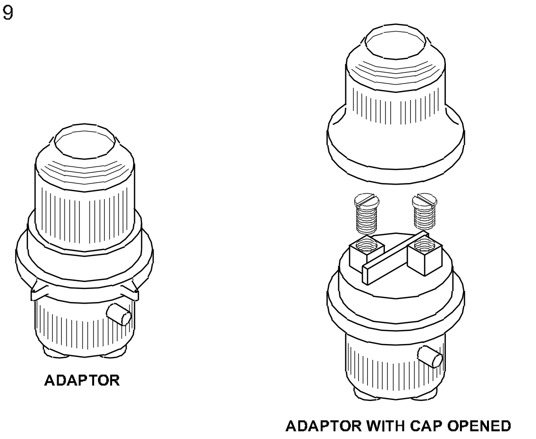
FLAT CONNECTOR WITH SIDE ENTRY IRON CONNECTOR DIRECT ENTRY

Adaptor (Fig 19)**:** They are used for taking supply from a lamp holder for small appliances. They are made out of bakelite. They are available in ratings up to 6 A 250 V.

Adaptors with multiple plugs are also available for taking supply to a number of appliances from a single point.

These adaptors should not be used in bathrooms or other damp places.

Fig 19



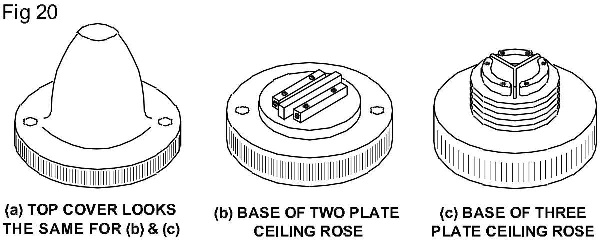
Ceiling roses: Ceiling roses are used to provide tapping points from the wiring for supplying power to fans, pendent-holders, tube lights etc. Normally flexible wires are used for tapping from the ceiling roses.

Ceiling roses have two parts, base and cover, both made of bakelite. The cover has a hole in the centre for the connecting wires to be taken out. There are threadings on the internal sides so that the cover may be fixed or tightened with the base. The base has terminals and holes for fixing on the block etc. and for wires to connect with the supply. Two types of ceiling roses are in use.

Two-plate ceiling rose (Fig 20 a & b)**:** This is made of bakelite and it has 2 terminals (phase & neutral) which are separated from each other by a bakelite bridge. Each of the terminal plates is provided with a metallic sleeve and a binding screw on one side through which the circuit wire from the back via the mounting block enters them. The other side of the terminal plate is provided with a washer and screw to tap wire connection. The two-plate ceiling rose is used for 6A, 250V current capacity. It is not used in circuits whose voltage exceeds 250V.

Three-plate ceiling rose: This type of ceiling rose has 3 terminals which are separated from each other by a bakelite bridge. It can be used for two purposes. (Fig 20 a & c)

Fig 20

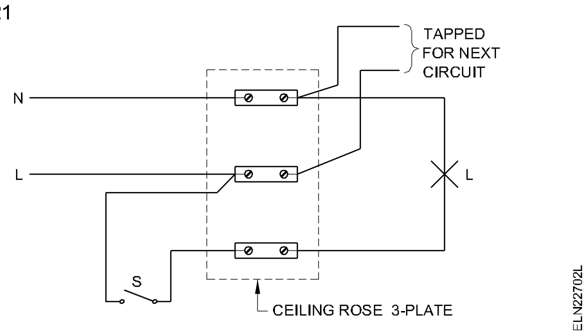


– Bunch light control

– To provide tapping for phase wire (Fig 21).

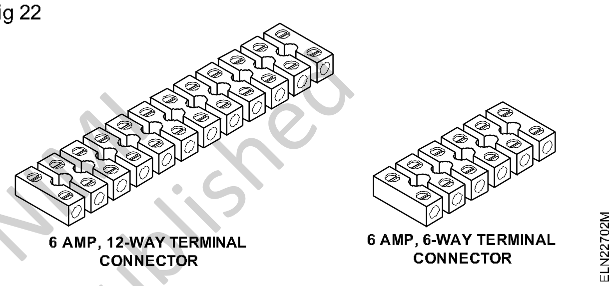
These ceiling roses are available in the rating of 6A, 250V. The covered 2 plate and 3 plate ceiling roses will look alike but could be identified by seeing the rear side.

Fig 21



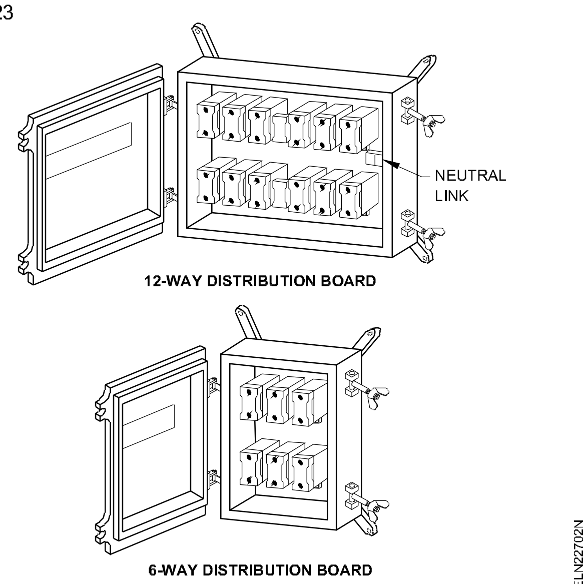
Connectors (Fig 22): Connectors are used to extend the length of the wire without joining. They are made of porcelain, bakelite or PVC based material. There is a brass sleeve with threading for small screws to tighten the wire in the sleeves. These are available in single way, two-way, three-way, six-way, 12-way types. These are rated according to the current and voltage capacity - 6A 250V, 16A 250V, 32A 250V, 16A 500V, 32A 500V etc.

Fig 22



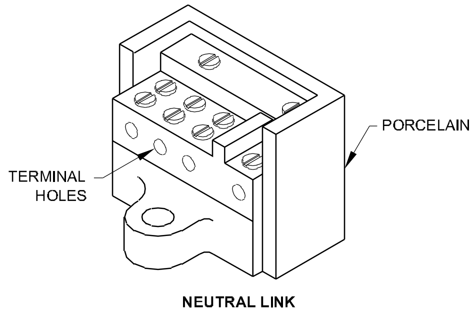
Distribution board (Fig 23): These are used where the total load is high and is to be divided into a number of circuits. These are used where the load is more than 800W. The number of fuses in the board is according to the number of circuits, and a neutral link is also provided so that the neutral wire can be taken for different circuits. All these branch fuses are enclosed in a metal box. These boards are available as two-way, three-way, 4,6,12-way types.

Fig 23



Neutral link: In a three-phase system of wiring installations, the phases are controlled through switches, and the neutral is tapped through a link called neutral link. The neutral link consists of a terminal for incoming current and a multi-way outgoing circuit. The metal terminals are mounted on high grade vitreous porcelain base (Fig 24). The ratings are 16A, 32A, 63A, 100A neutral link.

Fig 24

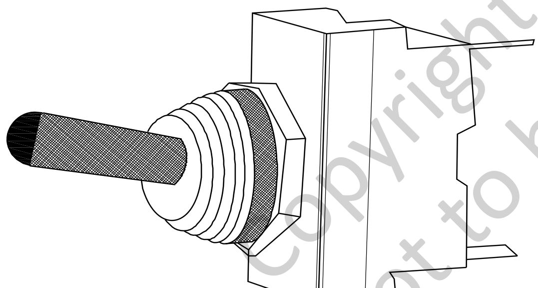


The accessories' rating shall be 240V and 6 or 16 amps from the year 1991, instead of 250V and 5 or 15 amps as per BIS 1293-1988.

Toggle switches (Fig 25)

It is an electric switch operated by means of a projecting lever that can be moved upward and downward and is also called as snap switches .

Fig 25



The toggle switches are generally specified based on

- Number of poles (single / double/ triple etc.)
- Number of throws (single / double/ double with center OFF etc.)
- Current rating (3,6,10,16,20 & 25A)
- Voltage rating (125V & 250V , AC)
- Size (8,10,12,15mm etc.)
- Knob type (Brass/ plastic and oval/ round/flat etc.)

Modular switches

The latest version of modular switch of different sizes and colours along with sockets combined and switches with indicators are available in market (Fig 26).

Fig 26

Indian Electricity Rules - Safety Requirements

The IE rules 1956 was made under sections 37 of Indian Electricity Act 1910. Now it is redefined after the enactment of the Electricity Act 2003. The Central Electricity Authority (measures relating to safety and electric supply) Regulation (CEAR) 2010 which came into effect from 20th September 2010, in place of Indian Electricity Rules 1956.

SAFETY RULES: Among safety rules, the following are important and indeed requires attention. Every rule in the Indian Electricity Rules 1956 is related either directly or indirectly to safety.

Rule 32: Switches shall be on the live conductor. No cutout, link or switch other than gang switch shall be inserted in the neutral conductor. Code of Practice of wiring shall be followed while marking the conductors.

Rule 50: Energy shall not be supplied, transformed,converted or used unless the following provisions are observed. A suitable linked switch or circuit breaker is erected at the secondary side of the transformer. Every circuit is protected by a suitable cut-out. Supply to each motor or group of motors is controlled by a linked switch or circuit breaker. Adequate precautions are taken to ensure that no live parts are exposed.

Special provisions in respect of high and extra high voltage installations

Rule 63: Approval of Inspector is necessary before energising any high voltage installations.

Rule 65: The installation must be subjected to the prescribed testing before energizing.

Rule 66: Conductors shall be enclosed in a metallic covering and suitable circuit breakers shall be provided to protect the equipment from overloading.

Rule 68: Incase of outdoor type of sub-station a metallic fencing of not less than 1.8 m height shall be erected around the transformer.

Provisions in terms of OH line

Rule 77: Clearance of lowest conductor above ground across street.

- Low and Medium Voltage lines - 5.8 m.
- High voltage Lines - 6.1 m.
- Clearance of lowest conductor above ground along a street. Low and Medium Voltage lines - 5.5 m.
- High voltage lines - 5.8 m.
- Clearance of lowest conductor above ground other than along or across the street. Low, Medium and High Voltage lines upto 11 KV if bare - 4.6m .
- Low, Medium and High upto and including 11KV, if insulated - 4.0m.
- High Voltage above 11 KV - 5.2 m.

Rule 79: Clearance of low and medium voltage lines from building,

- Vertical Clearance - 2.5 m.
- Horizontal clearance - 1.2 m.

Rule 80: Clearance from building of high and extra high voltage. Vertical Clearance High Voltage upto 33KV - 3.7m.

- Extra High Voltage above 33KV - 3.7 m, plus 0.3 m for every 33KV part there of.
- Clearance from building of high and extra high voltage - Pitched Roof . Vertical Clearance upto 11KV - 1.2m.
- Above 11KV upto 33KV - 2.2 m.
- Above 33KV - 2m. plus 0.3m for every 33KV part there of.

Rule 85: Maximum interval between supports. It shall not exceed 65 m except by prior approval of inspector.

Indian electricity rules regarding to internal wiring:

1 The minimum size of conductor used in domestic wiring must not be of size less than 1/1.12mm in copper or 1/1.40mm (1.5mm) in aluminium wire.

2 For flexible wires the minimum size is 14/0.193mm.

3 The height at which meter board, Main switch board are to be fitted 1.5 meters from ground level.

4 The casing will be run at a height of 3.0 meters from the ground level.

5 The light brackets should be fixed at a height of 2 to 2.5 meters from ground level.

6 The maximum number of points in a sub circuit is 10.

7 The maximum load in a sub circuit is 800W.

I.E. Rules regarding - Voltage drop concept:

1 **I.E. Rule 48:** The insulation resistance between the wiring of an installation and earth should be of such a value that the leakage current may not exceed 1/50000 the part or 0.02 percent of the F.L. current.

2 The permissible voltage drop in a lighting circuit is 2% of the supply voltage plus one volt.

3 The maximum permissible voltage drop in a power industrial circuit should not be more than 5% of the declared supply voltage.

4 The insulation resistance of any wiring installation should not be less than 1MΩ .

5 The earth resistance should not exceed the value of one ohm.

I.E. Rules regarding to power wiring:

1 In a power sub circuit the load is normally restricted to 3000 watts and number of outlets to two in each sub circuit.

2 All equipment used in power wiring shall be iron clad construction and wiring shall be of the armoured cable or conduit type.

3 The length of flexible conduit used for connections between the terminal boxes of motors and starters, switches and motors shall not exceed 1.25 meters

4 Every motor, regardless of its size shall be provided with a switch fuse placed near it.

5 The minimum cross-sectional area of conductor, that can be used for power mining of 1.25 mm for copper conductor cables and 1.50 mm for Aluminium conductor cables (refer ISI recommendations). Hence VIR or PVC cables of size lower than 3/0.915 mm copper or 1/1.80 mm Aluminium can not be used for motor wiring.

Circuit Breaker (CB) - Miniature Circuit Breaker (MCB)- Moulded Case Circuit Breaker (MCCB)

Objectives: At the end of this lesson you shall be able to
- **explain the types, working principle and parts of a miniature circuit breaker.**
- **state the advantages and disadvantages of MCB**
- **explain the working of combination circuit breaker (ELCB + MCB)**
- **state the categories and applications of MCBs**
- **state the application, advantage and disadvantage of MCCBs.**

Circuit Breaker

A circuit breaker is a mechanical switching device capable of making, carrying and breaking the currents under normal condition and breaking the currents under abnormal conditions like a short circuit.

Miniature circuit breaker (MCB)

A miniature circuit breaker is a compact mechanical device for making and breaking a circuit both in normal condition and in abnormal conditions such as those of over current and short circuit.

Types of MCB's

MCBs are manufactured with three different principles of operation namely

a Thermal Magnetic

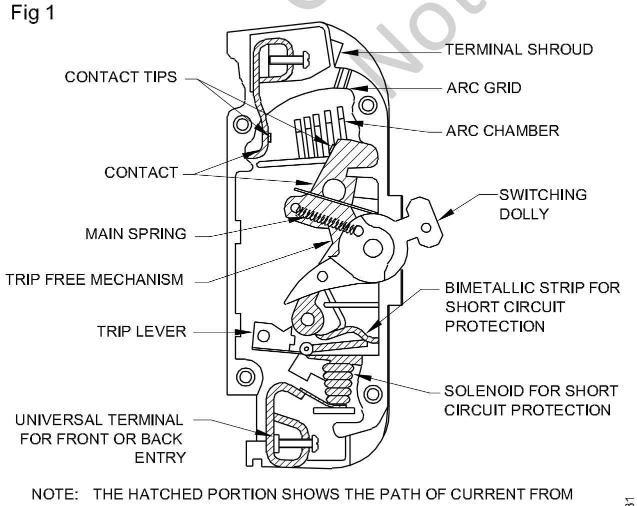
b Magnetic hydraulic and

c Assisted bimetallic

Thermal magnetic MCB

The switching mechanism is housed in a moulded housing with phenolic moulded high mechanically strong switching dolly. This type of MCB is also provided with bimetallic overload release (Fig 1).

Fig 1



NOTE: THE HATCHED PORTION SHOWS THE PATH OF CURRENT FROM TOP TERMINAL TO BOTTOM

THERMAL MAGNETIC TYPE MCB

The electric current gets through two contact tips one each on moving and fixed contact of silver graphite.

An arcing chamber incorporating de-ionising arc chutes for control and quick suppression of the arc is provided in the gap between two contacts. It has a ribbed opening closed by metal grid which allows ventilation and escape of gases.

For protection against over-load and short circuit, MCB's have thermal magnetic release unit. The overload is taken care of by bimetallic strip, short circuit currents and over loads of more than 100% are taken care by solenoid.

Working

The bimetallic strip when flexing due to temperature rise caused by increasing normal rated current beyond 130% rotates a trip lever carrying an armature to which it is to brought into field of a solenoid. The solenoid is designed to attract the armature to full position at about 700% overload or instantaneous short circuit current.

For initial portion of current wise (130% to 400%) tripping of circuit breaker is due to thermal action, between 400 to 700% tripping is due to combined thermal and magnetic action and beyond 700% due to fully magnetic action.

Magnetic hydraulic MCB

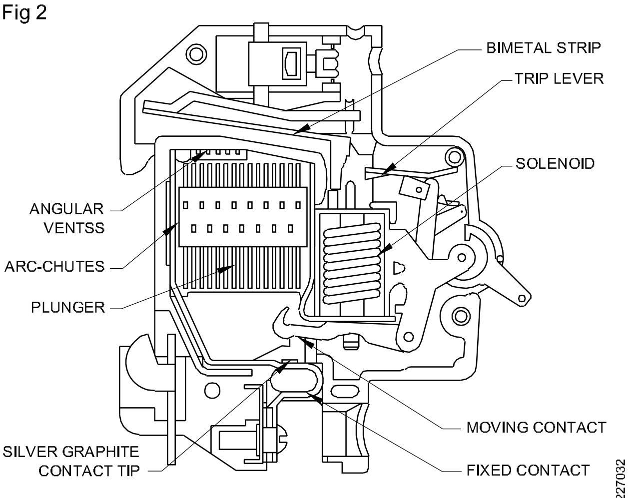
Magnetic hydraulic circuit breaker operates on the principle of a solenoid and hydraulically damped plunger.

Construction and working

A movable ferrous plunger is held against a non-ferrous tube containing polysiloxane liquid which have flat temperature viscosity characteristic in temperature range of 20 to 60°C. The solenoid is a series coil in the circuit of MCB. As the plunger moves towards a pole piece, the reluctance of magnetic path.

Containing the armature is cumulatively reduced leading to some magneto motive force producing a progressively increasing flux. The armature is then attracted causing the mechanism to trip and open the controls on overload or short circuit (Fig 2). Instantaneous tripping occurs on very large currents 7 to 8 times the full load current. The construction of magnetic hydraulic tripping mechanism is in Fig 2.

Fig 2

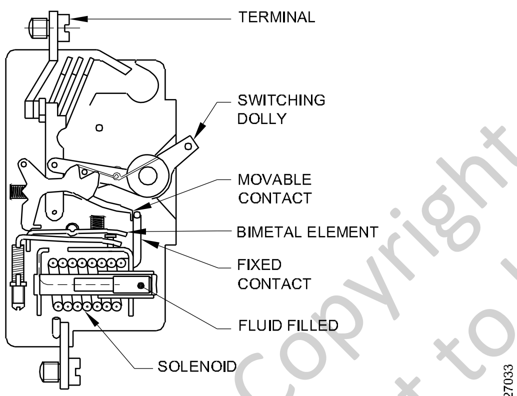


MAGNETIC HYDRAULIC MCB

Assisted Bimetal Tripping MCB (Fig 3)

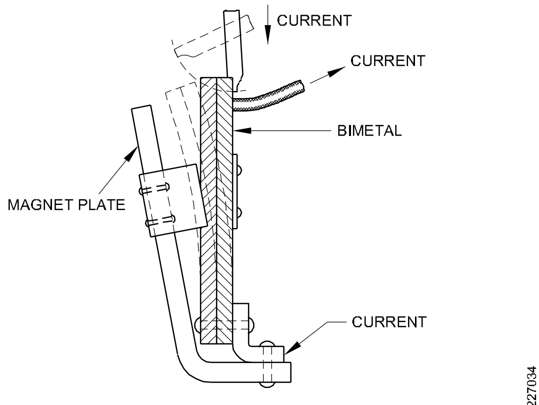
In the assisted bimetal form of construction, the time delay characteristic is provided by a thermally operated bimetal element which may be either directly or indirectly heated. Instantaneous tripping in short circuit condition is achieved by arranging a powerful magnetic pull to deflect the bimetal (Fig 4).

Fig 3



ASSISTED BIMETAL TRIPPING MCB

Fig 4



ASSISTED BIMETAL TRIPPING

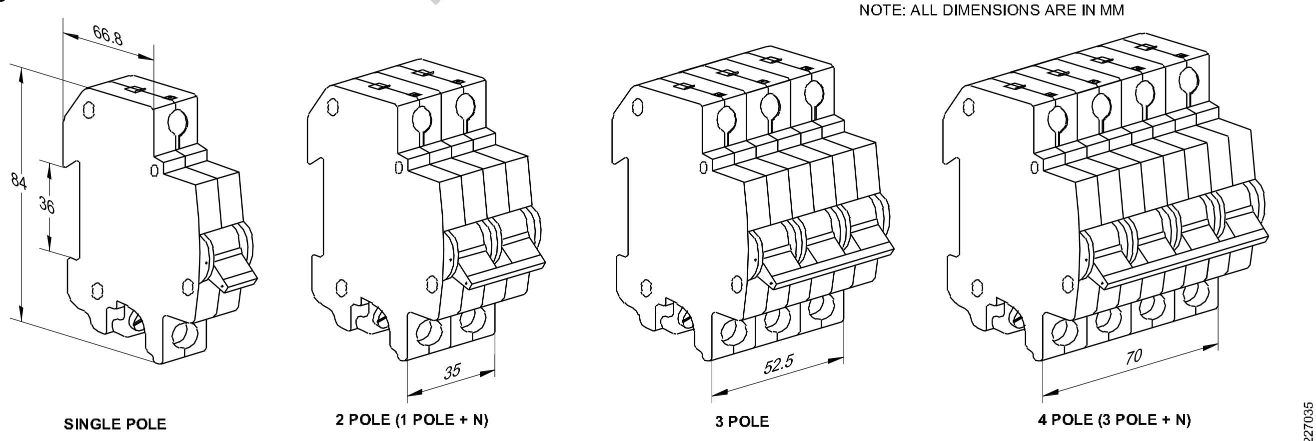
This method utilises the magnetic field which is produced when a current flows through the conductor. By locating the bimetal near to a substantial section of ferrous material, the magnetic field associated with current flowing in the bimetal will cause a sideways pull to be applied to the bimetal element, attracting the bimetal towards the ferrous material.

This sideways pull is arranged to coincide in direction with the normal direction of movement of the bimetal, which is powerful enough to deflect the bimetal (in heavy over load or short circuit condition) sufficiently to trip the breaker.

Design and rating of MCBs

MCBs are normally rated for 25°C ambient temperature and are available in the following various combination of poles and current ratings (Fig 5).

Fig 5



DIFFERENT TYPES OF MCB'S

Sl.No.	No. of poles	Current
1	Single pole MCB	0.5 to 60A
2	Double pole MCB (ie. 2 MCBs with common trip bar)	5 to 60A
3	Triple pole MCB	5 to 60A
4	Four pole MCB	5 to 60A

Isolators

An isolator is a switch. These cannot be used for automatic tripping. Isolators are not meant for either closing or breaking the circuit on load or short circuit. Isolators have the same physical dimensions of MCBs and are available in the following configurations and ratings.

No. of poles	Current rating
Single pole	30, 60, and 100A
Single pole with Neutral	30, 60, and 100A
Triple pole	60, and 100A
Four pole	60 and 100A

ELCB + MCB combination circuit breaker

Now a days some manufacturers have introduced an ELCB + MCB combination circuit breaker which can be used instead of using separate MCB and ELCB (earth leakage circuit breaker). This combination not only allows reduction in costs, but also ensures

- over current
- short circuit
- earth leakage
- earth fault.

Earth leakage circuit breakers are now generally called Residual Current circuit breakers (RCCB).

The rated load currents of the RCCB + MCB combination are 6A, 10A, 16A, 20A, 25A, 32A and 35A. The bimetal trip is so adjusted that no tripping will occur upto 1.3 times the rated current.

Categories of MCBs

Certain manufacturers like Indo Kopp manufacture the MCBs in three different categories namely 'L' series, 'G' series, and 'DC' series.

'L' series MCBs

'L' series MCBs are designed to protect circuits with resistive loads. They are ideal for protection of equipment like Geysers, ovens and general lighting systems.

'G' series MCBs

'G' series MCBs are designed to protect circuits with inductive loads. G series MCBs are suitable for protection of motors, air conditioners, hand tools, halogen lamps etc.,

'DC' series MCBs

'DC' series MCBs are suitable for voltage upto 220V DC and have a breaking capacity up to 6kA.

The tripping characteristics are similar to 'L' an 'G' series. They find extensive application in DC controls, locomotives, diesel generator sets etc.,

Advantages of MCB

1 Tripping characteristic setting can be done during manufacture and it cannot be altered.

2 They will trip for a sustained overload but not for transient overload.

3 Faulty circuit is easily identified.

4 Supply can be quickly restored.

5 Tamper proof.

6 Multiple units are available.

Disadvantages

1 Expensive.

2 More mechanically moving parts.

3 They require regular testing to ensure satisfactory operation.

4 Their characteristics are affected by the ambient temperature.

Application of (RCCB + MCB) combination circuit breakers

1 All residential premises can have incoming protection after energy meter instead of fixing fuse and main switch.

2 All domestic equipments like water heaters, washing machines, electric iron, pump sets etc.,

3 All construction and outdoor electrical equipments such as lifts, hosts, vibrators, polishing machines etc.,

4 All industrial distribution and equipments

5 All agriculture pump sets.

6 Operation theatres and electrically operated medical equipment such as X-ray machines.

7 All neon sign installations

8 All low and medium voltage electrical distributions.

Technical specification of MCBs

Related voltage	240/ 415V AC 50Hz
	Up to 220V DC
Current rating	0.5, 1, 1.6, 2, 2.5, 3, 4, 5, 6, 7.5, 10, 16, 20, 25, 32, 35, 40 and 63A.
No. of poles	1,2,3
Types	'L' 'G' and 'DC' series
Breaking capacity	UP to 9kA
Mechanical life	1,00, 000 operations
Electrical life	50,000 operations
Overload capacity	15% over load
Housing	Glass fiber reinforced polyester
Fixing	Snap fixing on 35 mm DIN channel
Types of terminals	25mm² box type terminal at the incoming and outgoing.

Definition of Breaking capacity of MCB

The short circuit breaking capacity of the circuit breaker is the current more than the prospective fault current at the point of installation of circuit breaker. Prospective fault current is the maximum fault current which may have to be interrupted by the circuit breaker.

Moulded Case Circuit Breakers (MCCB)

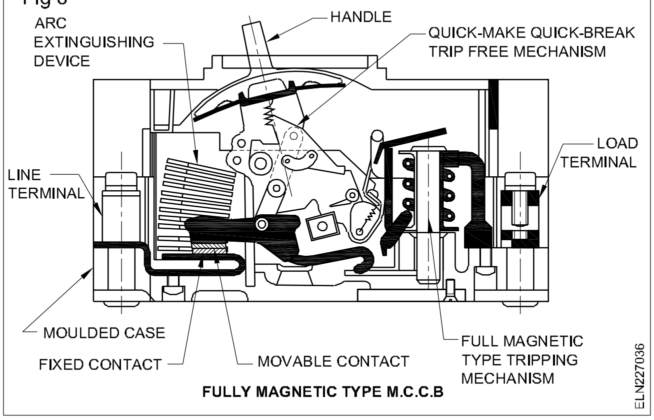
Moulded case circuit breakers are similar to thermo magnetic type MCBs except that these are available in higher ratings of 100 to 800amp at 500V 3-phase.

In MCCB, thermal and magnetic releases are adjustable. A shunt release is also incorporated for remote tripping and interlocking at MCCB. MCCBs are provided with under voltages release. There are two types of MCCB.

1 Thermal magnetic type.

2 Fully magnetic type (Fig 6).

Fig 6



FULLY MAGNETIC TYPE M.C.C.B

Advantages of MCCB

1 MCCBs occupy much less space in comparison to fuse switch units.

2 MCCBs provide equal amount of protection against high faults as switch gears having HRC fuses.

Disadvantages

1 MCCBs are much costlier.

2 Leak proof situation required.

3 Sensitivity to insulation resistance low.

ELCB - types - working principle - specification

Objectives : At the end of this exercise you shall be able to
- **explain the working principle, different types and construction of an earth leakage circuit breaker (ELCB)**
- **explain the technical specifications of ELCB's.**

Introduction

The sensation of electric shock is caused by the flow of electric current through the human body to earth. When a person comes in contact with electrically live objects like water heaters, washing machines electric iron etc., the extent of damages caused by this current depends on its magnitude and duration.

This kind of current is called the leakage current which comes in milli-amps. These leakage current being very small in magnitude, hence undetected by the fuses/MCBs are the major cause for the fires due to electricity.

The leakage current to earth also results in the wastage of energy and excessive billing for electricity not actually used.

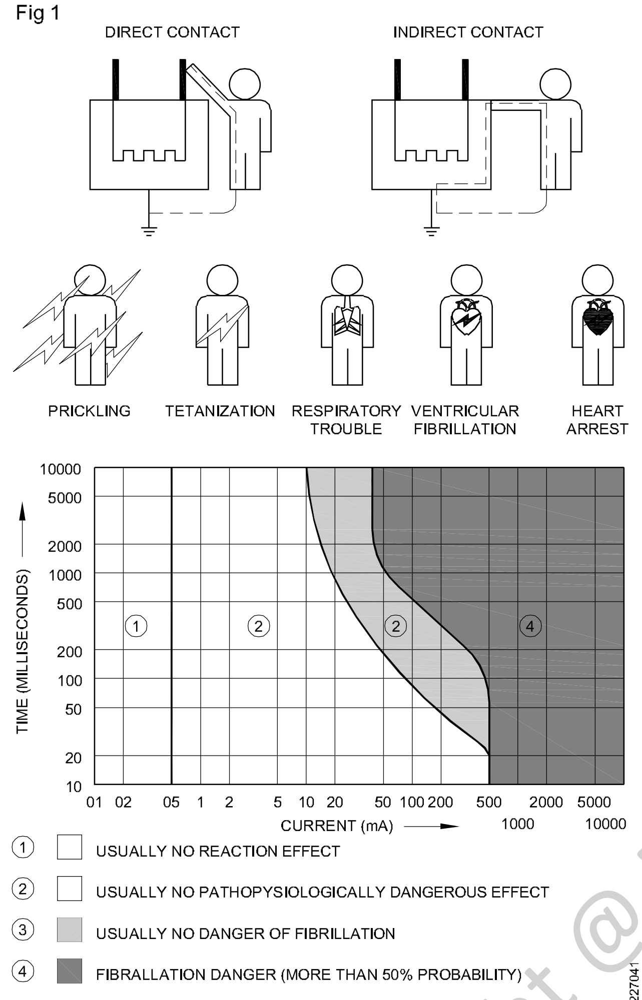
Residual current operated circuit breakers are inter-nationally accepted means of providing maximum protection from electric shocks and fires caused due to earth leakage current and also prevents the waste of electrical energy. These residual current circuit breakers (RCCB) are popularly called as Earth leakage circuit breakers (ELCB). The effect of electric current on human body in various levels represented in graph (Fig 1).

Basically ELCBs are of two types namely voltage operated ELCBs and the current operated ELCBs.

Voltage operated ELCB

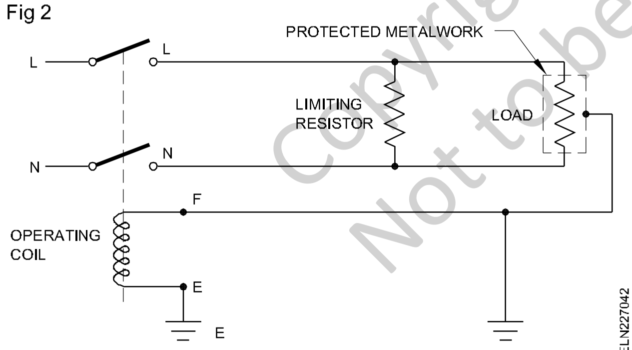
This device is used for making and breaking a circuit. It automatically trips or breaks the circuit when the potential difference between the protected metal work of the installation and the general mass of earth exceeds 24V. This voltage signal will cause the relay to operate (Fig 2).

Fig 1



EFFECT OF ELECTRIC CURRENT ON HUMAN BODY

Fig 2



Voltage operated ELCBs are meant to be used where it is not practicable to meet the requirements of IEE wiring regulation by direct earthing or where additional protection is desirable.

Current operated ELCB

This device is used for making and breaking a circuit and for breaking a circuit automatically when the vector sum of current in all conductors differs from zero by a predetermined amount. Current operated ELCBs are much more reliable in operation, easier to install and maintain.

Construction of current operated ELCB

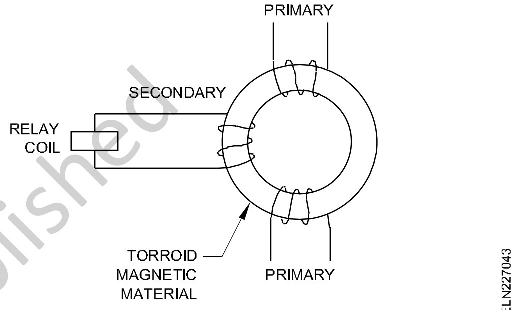
It consists of a Torroid ring made of high permeability magnetic material. It has two primary windings each carrying the current flowing through phase and neutral of the installation. The secondary winding is connected to a highly sensitive electro - magnetic trip relay which operates the trip mechanism.

Working principle

The residual current device (RCD) is a circuit breaker which continuously compares the current in the phase with that in the neutral. The difference between the two is called as the residual current which is flowing to earth.

The purpose of the residual current device is to monitor the residual current and to switch off the circuit if it rises from a preset level (Fig 3).

Fig 3



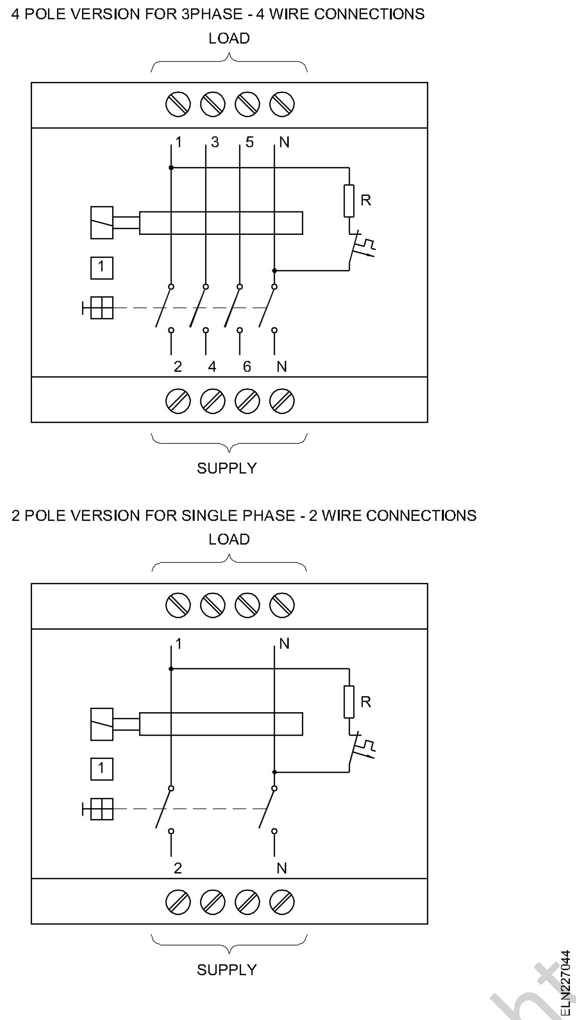
The main contacts are closed against the pressure of a spring which, provides the energy to open them when the device trips. Phase and neutral current pass through identical coils wound in opposing direction on a magnetic circuit, so that each coil will provide equal but opposing numbers of ampere turns when there is no residual current. The opposing ampere turns will cancel and no magnetic flux will be set up in the magnetic circuit.

In a healthy circuit the sum of the current in phases is equal to the current in the neutral and vector sum of all the current is equal to zero. If there is any insulation fault in the circuit then leakage current flows to earth. This residual current passes to the circuit through the phase coil but returns through the earth path and avoids the neutral coil, which will therefore carry less current.

So the phase ampere turns exceeds neutral ampere turns and an alternating magnetic flux results in the core. The flux links with the secondary coil wound on the same magnetic circuit inducing an emf into it. The value of this emf depends on the residual current, so it drives a current to the tripping system which depends on the difference between them and neutral current.

When tripping current reaches a predetermined level the circuit breaker trips and open the main contacts and thus interrupts the circuit. A 3 - phase 4 wire electric system can also be protected by providing a 4 pole RCCB (Fig 4).

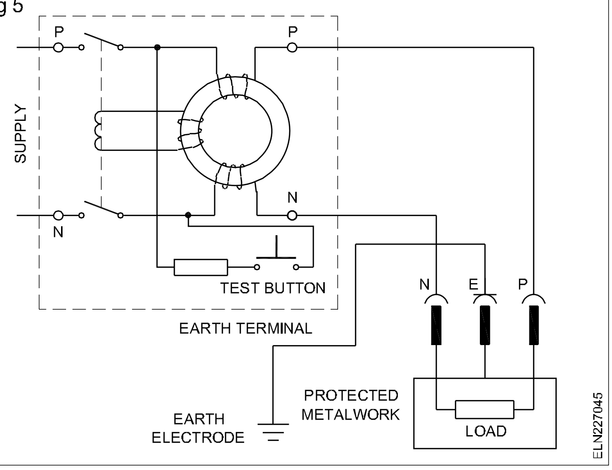
Fig 4



Test Switch

A test switch is a requirement as per BS842 (Fig 5). It is used to test the functioning of ELCB. When the test button is pressed it circulates additional current through neutral coil which is determined by the value of current limiting resistor R. As a result there exists a difference in current flowing through phase and neutral coils and hence the ELCB trips OFF.

Fig 5



Technical specification

The current ratings of ELCB are 25A, 40A and 63A.

No. of poles - 2 and 4

Nominal voltage - 240/415V 50Hz.

Sensitivities: ELCBs are designed to trip at leakage currents of 30mA, 100mA, and 300mA.

Electrical life: More then 10,000 operations.

Mechanical life:

20000 to 100000 operations.

Tripping time - < 30ms.

Time delayed RCCB

There are cases, where more than one RCCB is used in an installation, for example a complete installation may be protected by an RCCB rated at 100mA, while a socket intended for equipment may be protected by 30mA device.

Discrimination of the two devices then becomes important. For example an earth fault occurs in the equipment giving an earth fault current of 250mA. Since the fault current is higher, than the operating current of both devices, both will trip.

It does not follow, that the device with smaller operating current will trip first. This is a lack of discrimination between the two devices. To ensure proper discrimination, the device with a larger operating current, has a deliberate time delay built into its operation. It is called time-delayed RCCB. Images of 2 pole and 4 pole ELCB are given below (Fig 6).

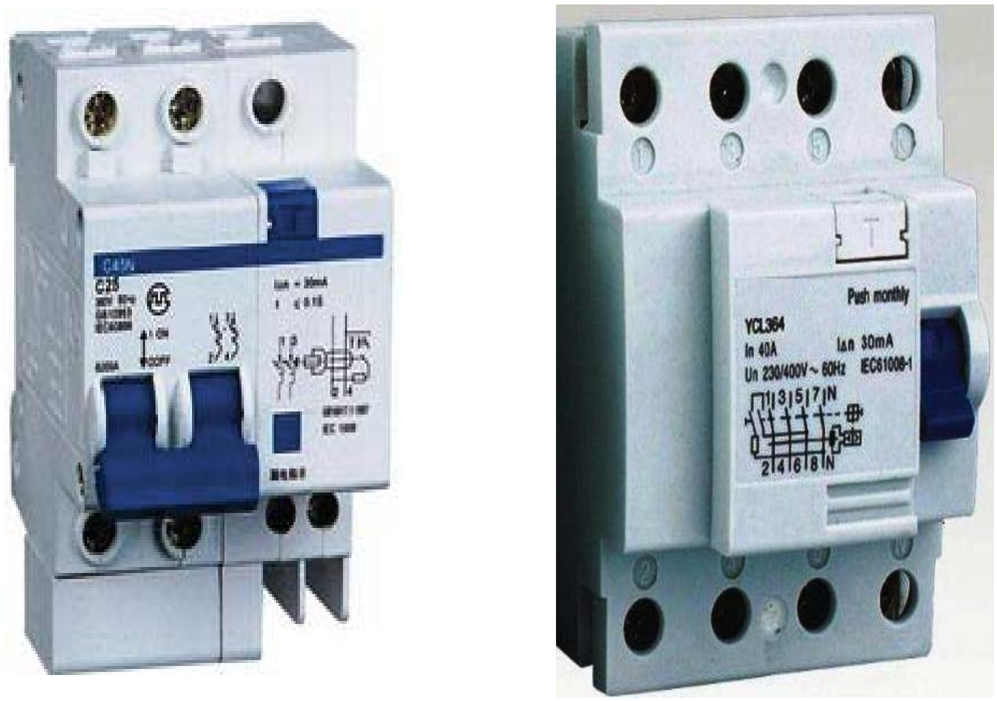
Earth fault loop impedance

Earth wire from an equipment to the earth electrode is called earth loop. Earth fault loop impedance (Z_E) is the impedance of the fault current path. It must be low enough to ensure that the productive devices like ELCB will operate within the specified time.

In any case, the multiplication value of earth fault loop impedance in Ohms and the rated tripping current (I_t)in ampere of ELCB should not exceed 50V .

$Z_E \times I_t < 50V$.

Fig 6



a) 2-POLE ELCB

b) 4-POLE ELCB

Fuses

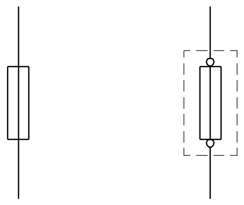
Objectives: At the end of this lesson you shall be able to
- **explain the purpose of the fuse in a circuit**
- **classify the different types of fuses and their uses.**

Purpose of fuses: A fuse is a safety device used for the purpose of protecting a circuit against excess current. In the event of excessive current, the fuse element melts and opens up the circuit thereby protecting it from damage.

Symbols: These are the graphical symbols used to illustrate an electrical fuse in electro-technical diagrams.

- General symbols of a fuse (Fig 1a)
- Fuse with terminals and protective housing (Fig 1b)

Fig 1

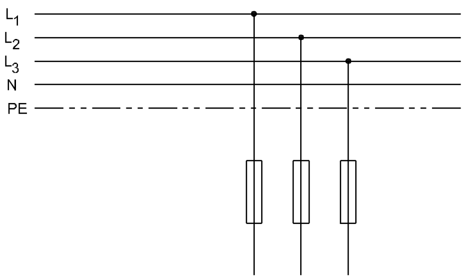


Placement of fuses: In electrical installations, the fuses are always connected into the live wires (Fig 2) and never into the neutral N or the protective earth line PE.

Terminology

Fuse element: The part of the fuse which is designed to melt and open up a circuit.

Fig 2



Fuse-carrier: The removable portion for carrying the fuse element.

Fuse base: The fixed part of the fuse provided with terminals for connection to the circuit which is suitable for the reception of the fuse- carrier.

Current rating: Safe maximum current that can pass continuously without overheating.

Fusing current: The current at which the fuse element melts.

Cut-off factor: Time (period) taken by a fuse to interrupt the circuit in the event of a fault.

Fusing factor: Ratio between minimum fusing current and current rating.

$$\text{Fusing factor} = \frac{\text{Minimum fusing current}}{\text{Rated current}}$$

The fusing factor for a re-wirable fuse varies between 1.4 to 1.7 and may go up to 2.0, but for a HRC fuse it is 1.1

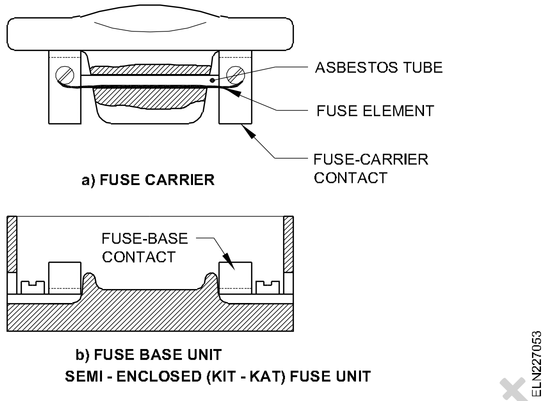
However, a fuse selected for over-current protection should not have a fusing factor of more than 1.4.

Types of fuses used in domestic wiring:

- Re-wirable type (up to 200A)
- Cartridge type (up to 1250A)

Rewirable type fuse (Fig 3): The fuse element in this type of fuse consists of a wire which may be replaced when necessary. These fuses are simple in construction and the initial cost as well as the renewal cost is very low.

Fig 3



The fuse elements used in this type are tinned copper wire, lead and tin alloy or aluminium wire (Table 1).

The fuse element will melt after approximately 2 minutes when carrying a current equal to twice the current rating. However, the cut-off time factor varies in rewirable fuses due to:

- the construction of the carrier (design of fuse-carrier/ base)
- the manner in which the fuse wire has been fitted
- the length of time the fuse was in service
- ambient temperature
- the amount of current etc.

Small fuse wires in parallel in a carrier to carry a large current should be avoided, as far as possible. The actual rating becomes less than the sum of the ratings of the individual strands. A paralleling factor of 0.7 to 0.8 is used to multiply the sum of the rating of individual strands to get the actual current rating.

Example: 35 SWG - copper wire has a fuse rating of 5 amps, and 3 strands in parallel together will a have current rating equal to 5x3x0.8=12 amps when 0.8 is taken as the paralleling factor.

Table 1

Current rating for	Approximate fusing current Amp	Tinned copper wire		Aluminium wire dia. in mm
		S.W.G.	Diameter in mm	
1.5	3	40	.12192	--
2.5	4	39	.13208	–
3.0	5	38	.1524	.195
4.0	6	37	.17272	–
5.0	8	35	.21336	–
5.5	9	34	.23368	–
6.0	10	33	.254	.307
7.0	11	32	.27432	–
8.0	12	31	.29464	–
8.5	13	30	.31496	–
9.5	15	–	—	.400
10.0	16	29	.34544	–
12.0	18	28	.37592	–
13.0	20	–	—	.475
13.5	25	–	—	.560
14.0	28	26	.4572	–
15.0	30	25	.508	.630
17.0	33	24	.5588	–
18.0	35	–	—	.710
20.0	38	23	.6096	--
21.0	40	–	—	–
22.0	45	–	—	.750
24.0	48	22	.7112	.850
25.0	50	–	—	.90
29.0	58	21	.8128	–
30.0	60	–	—	1.00
34.0	70	20	.9144	1.22
37.5	80	–	—	1.25
38.0	81	19	1.016	--
40.0	90	–	—	1.32
43.0	98	–	1.1176	–
43.5	100	–	—	1.40
45.0	106	18	1.2192	–
55.0	120	–	—	1.60
62.0	130	–	—	1.70
65.0	135	17	1.4224	–
66.0	140	–	—	1.80
69.0	150	–	—	1.85
73.0	166	16	1.6256	–
75.0	175	–	---	2.06
78.0	197	15	1.8288	–
80.0	200	–	—	2.24
102.0	230	14	2.032	–

Disadvantages of rewirable type fuse:

- Deterioration of the fuse element by oxidation due to heating.
- Lack of discrimination.
- Effected by the fluctuation of the ambient temperature.
- Premature failure due to deterioration under normal load.
- Low speed operation (poor cut - OFF factor).
- External flash or arc on blowing.
- Poor rupturing capacity (under short-circuit condition).
- Wrong rating possible by human error.

Rewirable-type fuses up to 16A rated current should not be used in locations where short circuit level exceeds 2 KA, (I.S. 2086-963).

Cartridge fuses: Cartridge fuses are developed to overcome the disadvantages of the rewirable fuses. As cartridge fuse elements are enclosed in an air tight chamber, deterioration does not take place. Further the rating of a cartridge fuse could be accurately determined from its marking. However, the cost of replacement of cartridge fuses is more than that of rewirable fuses.

Cartridge fuses can be grouped as those with a:

- low rupturing capacity (Say rupturing capacity up to 50 KA.)
- high rupturing capacity. (Say rupturing capacity above 80 KA.)

Rupturing capacity is the ability of a fuse to open the faulty circuit without much arcing or damage to itself. For domestic installations, low rupturing capacity fuses are used whereas for power installations, high rupturing capacity (HRC) fuses are used.

Low rupturing capacity cartridge fuses can be further divided into:

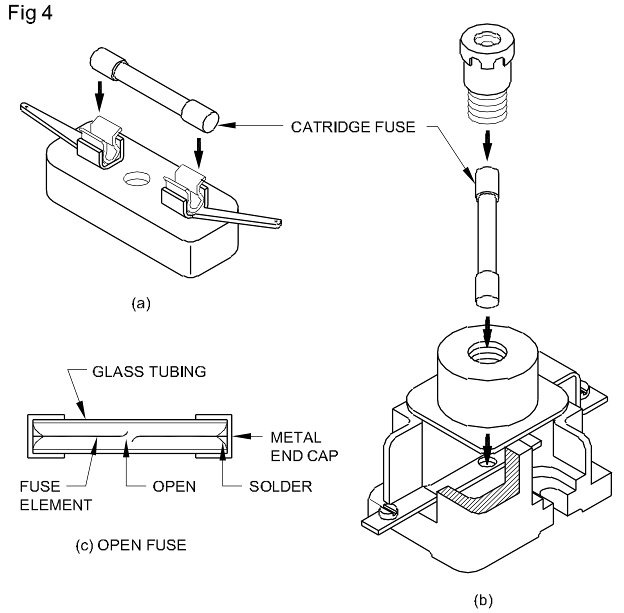
- Ferrule-contact cartridge fuses (Fig 4).
- diazed screw-type cartridge fuses (Fig 5).

Ferrule-contact cartridge fuses: This type, is used for protecting electrical and electronic circuits. These are available in 25, 50, 100, 200, 250, 500 milliamperes, and also in 1,2,5,6,10,16 & 32 amperes capacity.

Normally the current rating is written on one side of the cap, and while replacing, the same capacity fuse should be used. Its body is made of glass and the fuse wire is connected between two metallic caps.

This fuse can be plugged into the fuse socket (Fig 4a) or it can be fitted into a fuse base with a screw, type fuse- holder (Fig 4b).

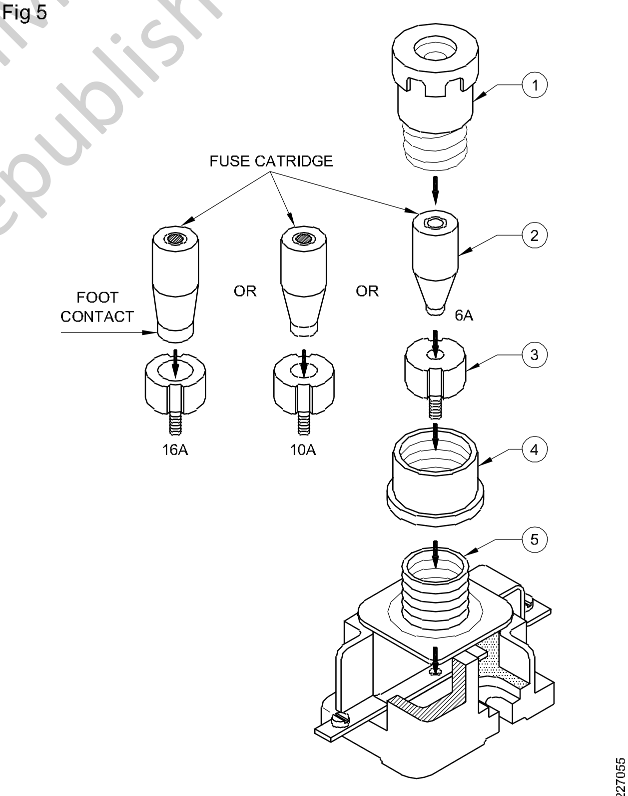
Fig 4



FERRULE - CONTACT CATRIDGE FUSE UNIT

Diazed screw-type cartridge fuses: This type of fuse is commonly used in domestic and industrial electrical installations . It consists of the following parts Fig 5.

Fig 5



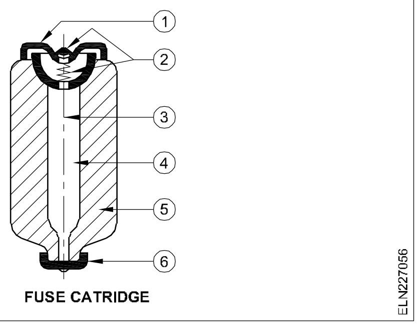
DIAZED SCREW TYPE CATRIDGE FUSE UNIT

- Screw cap or fuse cartridge-holder(1)
- Fuse cartridge(2)
- Fitting screw or contact screw(3)
- Protective plastic or ceramic ring(4)
- Fuse base or fuse socket(5)

Fuse cartridges are available for rated electric currents of: 2-4-6-10-16-20-25-32-50 and 63 amperes. To prevent the insertion of a fuse cartridge having a larger current rating than intended, the foot contacts of the fuse cartridges have different diameters for each rated current(the smaller the current the smaller the diameter of the foot contact). As there is also a separate fitting screw for each type of cartridge, it is not possible to insert, let's say, a 32 amp. fuse cartridge into the fitting screw of a 25 amp fuse cartridge.

The fuse cartridges has ceramic body of the cartridge with its foot and head contacts. The two contacts are linked by a fuse wire which is embedded in sand. Each cartridge has a break indicator which will be ejected from the cartridge if the fuse wire is burnt out (Fig 6).

Fig 6

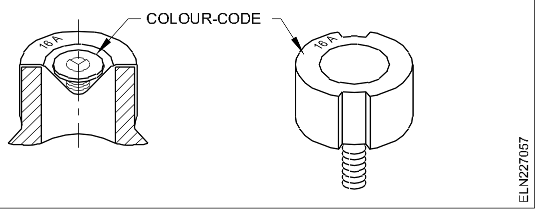


The parts of this fuse cartridge are

- head contact (1)
- break indicator (2)
- fuse wire (3)
- sand filling(4)
- ceramic fuse body (5)
- foot contact (6).

For easy identification of the fuse cartridges and the corresponding fitting screws, they are marked with various colours at the places (Fig 7). For each current rating, a different colour is used.

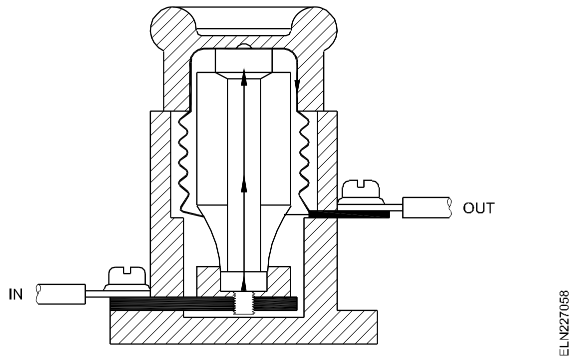
Fig 7



Pink	- 2 amperes	Blue	- 20 amperes
Brown	- 4 amperes	Yellow	- 25 amperes
Green	- 6 amperes	Black	- 32 amperes
Red	- 10 amperes	White	- 50 amperes
Grey	- 16 amperes	Copper	- 63 amperes

The flow of the electric current through the fuse base and the fuse is as shown in Fig 8. In order to prevent the accidental touching of a live line, the electrical supply must be connected to the terminal which is connected to the fixing screw at the bottom of the base.

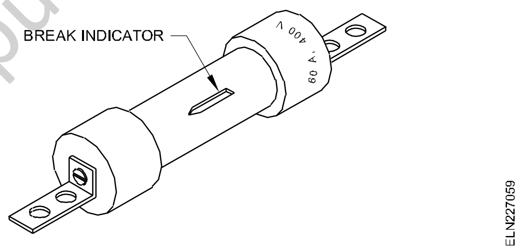
Fig 8



Diazed type fuses are available in two categories, a)quick-response type and b) delayed-action type. The quick-response type is used for heating circuits and normal loads whereas the delayed- action type is used for motor circuits and highly inductive circuits.

High rupturing capacity (HRC) fuses (Fig 9): They are cylindrical in shape and are made of a ceramic body filled in with a chemically treated filling powder or silica to quench the arcing quickly without any fire hazard.

Fig 9



Normally a silver alloy is used as the fusing element and when it melts due to the excessive current, it combines with the surrounded sand/powder, and forms small glob-ules without making an arc, spark or gas. HRC fuses can open a short-circuited circuit within 0.013 second. It has an indicator to show the fuse has blown. The rupturing capacity of the fuse could be calculated from the following formula.

$$\text{Rupturing capacityin MVA} = \frac{\text{Fault current in amperes} \times \text{Circuit voltage}}{10^6}$$

As HRC fuses are capable of opening circuits having very high faulty currents, these are preferred in high power circuits even though the replacement cost is high.

Comparison between HRC & Rewirable fuses

Factor	Rewirable	HRC fuse
Rupturing capacity	Not recommended for currents exceeding 200 A or for more than 600V or where there is a possibility of S.C. fault of more than 5 MVA.	Normal types cater to fault loads up to 2500 KVA. For certain appli-tions, fuses up to 50 MVA are obtainable.
Rupturing speed(Cut-off factor)	Rating and cut-off are not absolutely reliable.	Very rapid. Usually AC supply current is cut off within the first half cycle.
Discrimi-nation	Poor.	Accurate.
Safety in operation	Risk of flash-over under heavy fault condition.	No external flame.
Deterio-ration	Oxidation and conse-quent scaling causes reduction in the cross-sectional area, thus increasing resistance, and leading to over-heating and premature rupturing.	No oxidation. The element is completely sealed.
Fusing factor	Copper wire upto 20A -1.7. Over 20A- 2.0.	As low as 1.1.

Relays - types - symbols

Objectives: At the end of this lesson you shall be able to
- **define a relay and classify the relays**
- **classify relays according to the operating force and function**
- **state the common codes used for specifying contacts and poles**
- **specify a relay**
- **explain the function of the shading coil in an AC relay**
- **state the causes of the failure of the relay**
- **identify the symbols used in relay as per I.S.2032 (Part XXVII).**

Relay: A relay is a device which opens or closes an auxiliary circuit under predetermined conditions in the main circuit.

Relays are extensively used in electronics, electrical engineering and many other fields.

There are relays that are sensitive to conditions of voltage, current, temperature, frequency or some combination of these conditions.

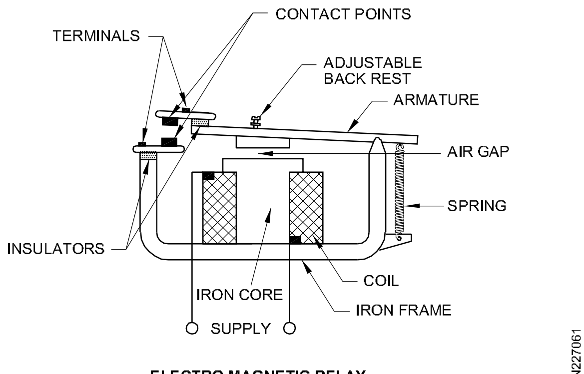
Relays are also classified according to their main operating force as stated under.

- Electromagnetic relays
- Thermal relays

Electromagnetic relay: A relay switch assembly is a combination of movable and fixed low-resistance contacts that open or close a circuit. The fixed contacts are mounted on springs or brackets, which have some flexibility. The movable contacts are mounted on a spring or a hinged arm that is moved by the electromagnet in the relay (Fig 1).

The other types of relays coming under this group are as follows.

Fig 1



ELECTRO MAGNETIC RELAY

Current sensing relay: A current sensing relay functions whenever the current in the coil reaches an upper limit. The difference between the current specified for pick up (must operate) and non-pick up (must not operate) is usually closely controlled. The difference in current may also be closely controlled for drop out (must release) and non-drop out (must not release).

Under-current relay: Under-current relay is an alarm or protective relay. It is specifically designed to operate when the current falls below a predetermined value.

Voltage sensing relay: A voltage sensing relay is used where a condition of under-voltage or over-voltage may cause a damage to the equipment. For example, these types of relays are used in voltage stabilizers. Either a proportional AC voltage derived from a transformer or a proportional DC derived from a transformer and rectifier used for this purpose.

Latching relays

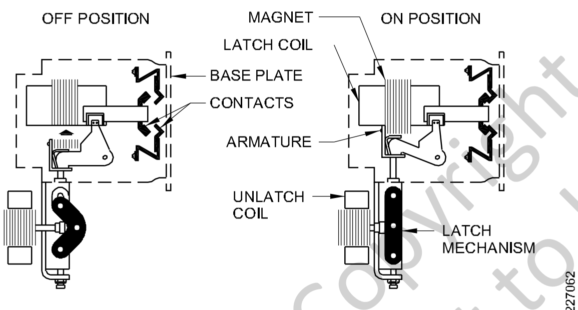
Latching relays are capable of maintaining their contacts in the last assumed position without the maintained current in the coil. These relays hold their contacts in position after power is cut off.

There are two basic kinds of latching relays called mechanical reset and electrical reset.

Mechanical re-set relays: Mechanical re-set relays have a coil, an armature mechanism, and a mechanical latching device that locks the armature in the operated position after the coil has been de-energised. Manual tripping of the locking mechanism, re-sets the relay.

Electrical reset relays: An electrical re-set relay (Fig 2) has the same operating mechanism, but it includes a second coil and armature to trip the latching mechanism. This system allows remote re-setting of the relays to their original position.

Fig 2



LATCH RELAY ELECTRICAL RE-SET TYPE

Reed relays

Reed relays physically look different than other kinds of relays. They consist of essentially magnetically actuated reed switches, with actuating solenoids or coils.

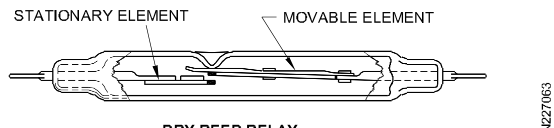
In the reed relay, freedom from contamination and the limited number of moving parts, avoid many disadvantages of the conventional electromechanical relays. In addition to the above, the contact resistance is kept to minimum due to the fact the contact points are made either with gold or rhodium. Further, these relays need very low power to operate and can handle a 250 watt solenoid load on their contacts.

There are three types of reed relays namely

- dry-reed relay
- ferreed relay
- mercury wetted contact relay

Dry reed relay: Two opposing reeds are sealed in to a narrow glass tube (Fig 3). The reeds overlap at their free ends. At the contact area, they are usually plated with gold or rhodium to produce a low contact resistance. They may have multipole multicontact designs.

Fig 3

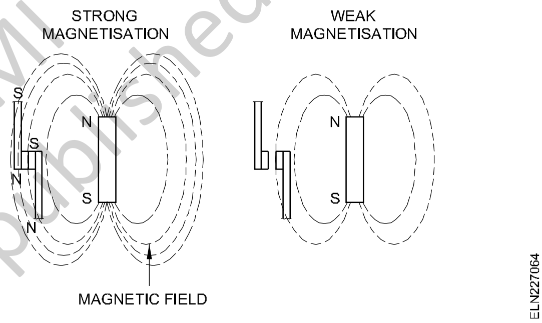


DRY REED RELAY

Ferreed relay: The word ferreed denotes a reed relay in which the dry-reed switch is contained with one or more magnetic members. The magnetisation can be changed by current pulses in associated coils.

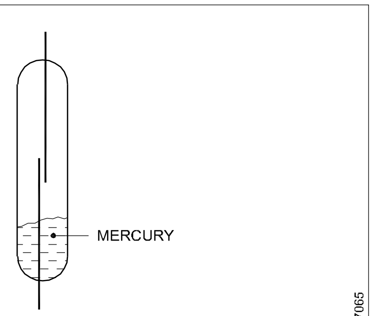
In the magnetised state the magnetic members supply a field strong enough to close the contacts. In the other magnetised state, the field is too weak to hold the contacts closed (Fig 4). An operating pulse through the coil produces the first state. A release pulse produces the second state. The contacts can break or make within 5 micro-seconds duration.

Fig 4



Mercury wetted contact relay: This relay consists of a glass enclosed reed with its base immersed in a pool of mercury (Fig 5). When the coil surrounding the capsule is activated, mercury makes the contact between fixed and movable contacts.

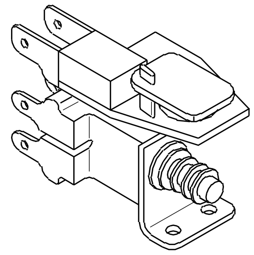
Fig 5



MERCURY-WETTED REED RELAY

Impulse relay: The impulse relay (Fig 6) is a special single-coil relay. It has an armature-driven mechanism that alternatively assumes one of two positions as the coil is pulsed. This mechanism moves the contact from one position to the other and back again as electrical pulses are received. The relay can operate on AC or DC power.

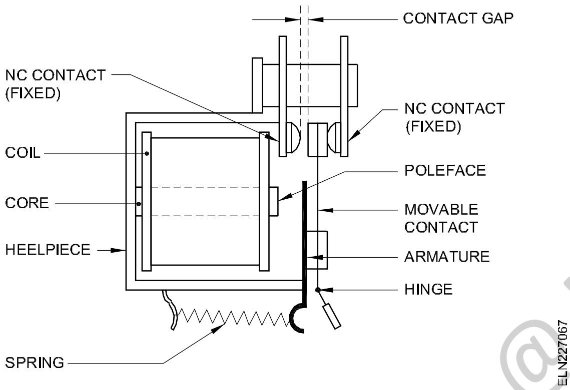
Fig 6



IMPULSE RELAY

Clapper-type armature relay: The simplest contact arrangement used in armature relays is the break-make or transfer-contact combination. A clapper-type armature, (Fig 7) opens or closes the contacts. A movable contact is attached directly to the armature by means of a flexible strip of metal. When the electromagnet operates, the armature moves this contact, opening and closing the two sets of contacts.

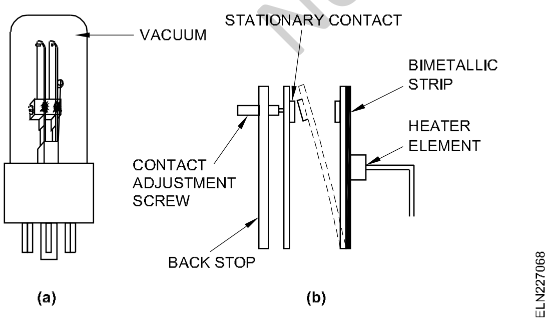
Fig 7



Thermal relay: A thermal relay (Fig 8) is one that operates by changes in temperature. Most of the bimetallic relays where the bimetallic element changes its shape, in response to changes in temperature comes under this group.

It takes time for the heating element to reach the necessary temperature and more time to raise the temperature of the bimetallic element. Therefore, thermal relays are often used as time-delay relays.

Fig 8



Poles and contacts: Relays may operate single or as multi-poles and may open or close specified contacts. In writing specifications certain abbreviations as stated below are commonly used.

SP - Single pole

SB - Single break

ST - Single throw

DB - Double break

DP - Double pole

DM - Double make

DT - Double throw

NO - Normally open

3P - Three pole

NC - Normally closed

4P - Four pole

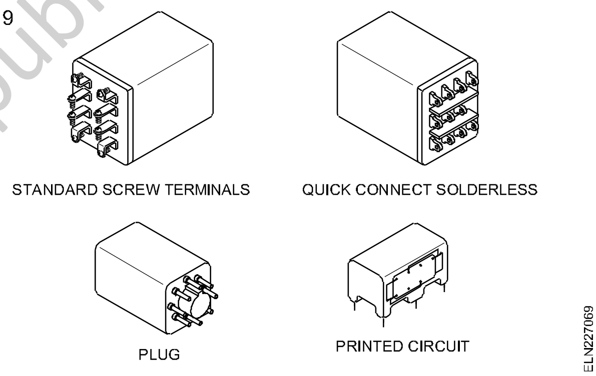
For example a 4PDT has a four-pole, double throw contact arrangement.

NO indicates the contacts are open in the unoperated position of the relay and they are called as normally open (NO) contacts.

NC indicates the contacts are closed in the unoperated position of the relay and they are called normally closed (NC) contacts.

Enclosures and mounts: Relays are normally enclosed in plastic or metal caps to protect the operating parts against dust and environment. Relays can be mounted to the circuit direct by plug-in system, PCB mounting or may be wired separately using screws terminals (Fig 9).

Fig 9



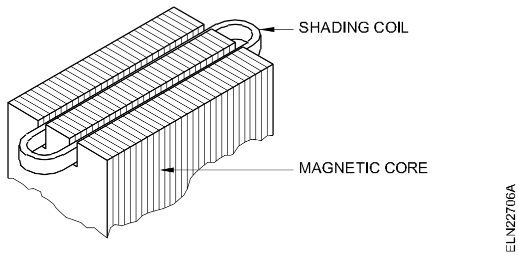
AC relay: In an AC relay magnet, the magnetic field continually changes direction. With a 50 Hz supply the magnetic field passes through zero 100 times per second. At the time of zero field, the armature starts to release. Although the field quickly builds up in the reverse direction, a noisy chatter can result.

To eliminate chatter, a shading coil (Fig 10) is placed near the tip of the magnet pole face. This shading coil establishes a magnetic field that lags the main magnetic field slightly and aids in keeping the magnet sealed when the main field passes through zero.

An AC relay should not be used in DC supply.

The AC relay when connected to DC supply, will draw more current in the absence of inductive reactance and result in burning out the coil.

Fig 10



Causes of relay failures: Relay failures are usually caused by the gradual deterioration of the parts. This deterioration can be electrical, mechanical or chemical in nature.

The environmental shirks that contribute to physical breakdown include large temperature changes, shock, vibration and voltage or current changes. Therefore, it is important that these factors are taken into consideration to ensure reliable performance of relays.

In general, when a relay fails, look for the following.

1 Improper control voltage.

2 Dirt, grease or gum on contacts or moving parts.

3 Excessive heating of parts: discolouration or charred insulation on coil or base.

4 Bending of moving parts.

5 Corrosion or deposits on metal parts.

6 Excessive wear on moving parts.

7 Loose connections.

8 Improper spring tension.

9 Improper control pressure.

10 Improper functioning of the time delay device.

While specifying relays the following particulars are necessary.

Type of operating voltage

AC or DC

Sequence of operation ______________________

Operating voltage ______________________ volts

Current rating ______________________ amps

Coil resistance ______________________ ohms

Number of contacts ________ NO ________ NC

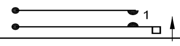
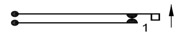
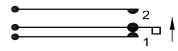
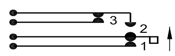
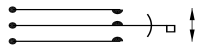
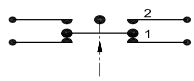
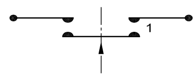
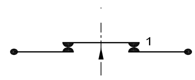
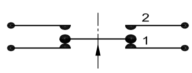
Number of poles ______________________

Type of mount ______________________

Type of enclosure ______________________

Table 1 given below lists some of the relay contact combinations.

Table 1

Design	Sequence	Symbol
1 SPST-NO	Make 1	
2 SPST-NC	Break 1	
3 SPDT	Break1 before make 2	
4 SPDT	Make 1 before break 2	
5 SPDT (B-M-B)	Break 1 before make 2 before break 3	
6 SPDT-NO	Center OFF	
7 SPDT-NC-NO (DB-DM)	Double break 1 double make 2	
8 SPST-NO (DM)	Double make 1	
9 SPST-NC (DB)	Double break 1	
10 SPDT-NC (DB-DM)	Double break 1 double make 2	

NE code Mounting accessories - specification of wooden boards and blocks

Objectives: At the end of this lesson you shall be able to
- **state the National Electrical Code of Practice with respect to mounting accessories and boards**
- **specify the wooden round blocks and boards for mounting electrical accessories.**

Recommendations of the National Electrical Code for mounting the accessories on the boards

When electrical accessories are to be mounted on the boards, the following National Electrical Code recommendations should be adopted.

– All ceiling roses, brackets, pendents and accessories shall be mounted on substantial wooden blocks, having a depth of not less than 4 cm.

– Where teak or hardwood boards are used for mounting switches, regulators etc., these boards shall be well varnished with pure shellac on all sides (both inside and outside), irrespective of being painted, to match the surroundings. The size of such boards shall depend on the number of accessories that could be conveniently and neatly arranged.

– No mounting of accessories shall be done within 2.5 cm of any edge of the panel of the board, and no hole other than the holes by means of which the panel is fixed shall be drilled closer than 1.3 cm from any edge of the panel.

– A switchboard shall not be installed with its bottom within 1.25 m above the floor unless the switchboard is enclosed in a box with locking arrangement.

– If the switchboards are recessed in the wall, the front shall be fitted with a hinged panel of teakwood or other suitable material, such as bakelite, or fitted with an unbreakable glass door in teakwood frame.

– Open type switchboards shall not be placed in the vicinity of storage batteries or exposed to chemical fumes.

– Switchboards shall not be erected above gas stoves or sinks, or within 2.5 m of any washing unit in the washing room.

– Unnecessary crossing of connections should be avoided between apparatus and terminals, within the board.

– In a hinged type board, the incoming and outgoing cables shall be fixed at one or more points according to the number of cables on the back of the board, leaving suitable space in between the cables, which shall also, if possible, be fixed at the corresponding points on the switchboard panel. The cables between these points shall be of such length as to allow the switchboard panel to swing through an angle of not less than 90°.

Specification of commercially available boards, round blocks for mounting electrical accessories

The boards which are used for wiring installation are available in different sizes, made up of teak wood, P.V.C. or metal. When selecting the boards, the following points are to be considered.

Size of the board: The number and type of accessories to be mounted on the board decide the size of the board. After selecting the accessories to be mounted on the board, the layout may be formed on a cardboard template, and then the size of the board may be determined.

System of wiring: This decides whether boards should be placed on the surface of the wall or flush-mounted. Accordingly, a single or hinged board could be selected. However, depending upon the system like batten or metal conduit or PVC conduit, the board may be made of wood, metal or PVC respectively.

Place of wiring : This is another deciding factor to choose the material of the board. For indoors we may use board of any material depending upon the system of wiring.

Specification for blocks and boards

While specifying the boards for wiring installation, the following particulars shall be given.

– Material of the board - wood, PVC or metal.

– Size - length, breadth and height in mm.

– Thickness of the material in mm.

– Single or double (double-hinged or non-hinged type).

– Additional information like type of finish on wooden boards, colour of PVC or metal boards, surface or flush mounting etc.

T.W. round blocks: For specifying the round blocks, its overall diameter and thickness have to be given. Single and double (with base block) round blocks are available. Nowadays, P.V.C. blocks are also in use. The following sizes are available commercially. The first dimension denotes the overall diameter, and the second dimension denotes the thickness of the block.

Round blocks - single	Round blocks - double
75 mm x 25 mm	75 mm x 35 mm
75 mm x 40 mm	75 mm x 40 mm
90 mm x 25 mm	90 mm x 35 mm
90 mm x 40 mm	100 mm x 35 mm
100 mm x 25 mm	100 mm x 40 mm
100 mm x 40 mm	

Instead of round blocks, square blocks are also available. For certain special purposes hexagonal shape blocks are also used. According to the code of practice, the minimum thickness of round blocks should be 40 mm.

T.W. boards

For fixing two or more accessories on one board or for fixing accessories like fan regulators, D.P. switches etc. T.W. boards are used. Generally, the following sizes of boards are available commercially, in teak wood, PVC or metal.

> **The minimum thickness of non-hinged boards should be 40 mm whereas for hinged boards the thickness varies from 65 to 80 mm.**

Specification: Metric System

Length x Breadth	Length x Breadth
100 mm x 100 mm	300 mm x 250 mm
150 mm x 100 mm	380 mm x 450 mm
150 mm x 150 mm	450 mm x 250 mm
200 mm x 150 mm	450 mm x 300 mm
200 mm x 200 mm	600 mm x 300 mm
250 mm x 200 mm	600 mm x 300 mm
300 mm x 200 mm	750 mm x 600 mm

Through and pilot holes - wood-machine screw specifications

Objectives: At the end of this lesson you shall be able to
- **determine the size of through holes, with respect to the cable size and the number of cables**
- **state the method of making pilot holes using a bradawl or gimlet or by undersized drills**
- **specify wood screws and machine screws.**

Determining the through hole size according to the cable size and number of cables

While drilling holes in the boards for cable entry, the overall diameter of the cable has to be known. The overall dia. of the cable may vary according to the type of insulation used, and also from one manufacturer to another. Further the size depends upon the voltage grading. Hence the best practice is to take a piece of the cable, measure the overall size and select a suitable drill so that the cable enters the hole freely. When the number of cables to be inserted is more than one, the drill size may be selected accordingly.

The overall dia. and the overall sizes of the cables are indicated in Table 1.

TABLE 1
Sizes of conductors

Conductor of cables		Approximate overall dia . of cables	
Normal area in mm²	Number and dia of wire in mm	250V grade in mm	660 V grade in mm
1.5	1/1.40	4.20	5.40
2.5	1/1.80	4.60	6.00
4.0	1/2.24	5.25	6.80
6.0	1/2.24	6.00	7.35
10.0	1/3.55	7.10	8.10
16.0	7/1.70	8.85	9.65
25.0	7/2.24	10.80	11.50
35.0	7/2.50	11.75	12.25
50.0	7/3.00	13.40	13.90
70.0	19/2.24	---	16.70
95.0	19/2.50	---	19.10

Example: Referring to Table 1 it is found that for a 2.5 sq.mm. size conductor of the cable, the diameter of the cable (including insulation) is 4.6 mm. Hence, the hole size can be determined as 5 mm dia. and the drill required is of 5 mm dia.

The method of making pilot holes in wood using bradawl and gimlet

Pilot holes should always be made in the wood, when using wood screw for fixings so that the screw can be driven securely into the wood without damaging the wood, and is fixed with less effort.

First, position the accessories to be fitted on the board according to the layout and also to meet the aesthetic requirements. Open the cover and identify the placeswhere the pilot holes are to be made. The usual practice is to identify the cable entry 'through holes' and the screw fixing 'pilot holes' with different distinct markings.

Use a bradawl for making the pilot holes in softwood. If a gimlet is chosen, it should not be bigger than the wood screw proposed to be fitted. Pilot holes can be made in softwoods for screws up to size 6. For larger sized screws and for harder woods, pilot holes can be made best by a gimlet, or a second choice is by drilling undersized holes.

Select the correct size of drill for pilot holes: Drill sizes should be about 2 mm smaller in diameter than the diameter of the screw shank.

Drill hole to correct depth: In softwoods - hole depth equals 1/2 screw length.

In hardwoods - hole depth equals screw length.

> **For secure fixings it is important not to drill holes too deep.**

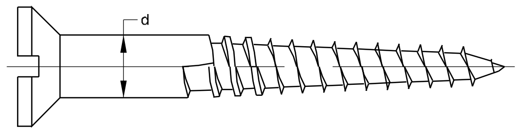
Wood screws: These screws have a single spiral of thread running from the point, clockwise for about two thirds of the length. The unthreaded part is called the shank, and gives the 'screw number' (Designation number).

Types of wood screws

Wood screws are classified with respect to the shape of the heads. Accordingly 3 types of wood screws are used for wiring installation.

Slotted countersunk head wood screws (Fig 1): This type of screws is used for general wood work for fitting miscellaneous hardware.

Fig 1

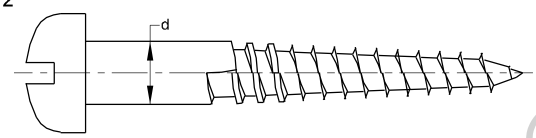


SLOTTED COUNTERSUNK HEAD WOOD SCREW

In electrical wiring for fixing wooden blocks, boards, battens and electrical accessories, countersunk holes should be used. The screw shall be driven until the head is flush with the work or slightly below surface.

Slotted round head wood screws (Fig 2): This type of wood screws is used for surface work, for installing electrical fittings and accessories where fitting holes are not countersunk.

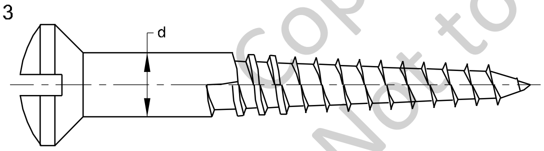
Fig 2



SLOTTED ROUND HEAD WOOD SCREW

Slotted raised countersunk head wood screws (Fig 3): Raised countersunk wood screws are used for fixing decorative electrical fittings. Even for fixing flush type electrical accessories on T.W. board or box, raised countersunk wood screws are used.

Fig 3



SLOTTED RAISED COUNTERSUNK HEAD WOOD SCREW

Of the three types of screws listed above, countersunk (flat head) screws are commonly used for electrical wiring installations.

Designation of wood screws: Wood screws shall be designated by the screw number, length, type of head and material. Table 2 gives the designation number, shank diameter available and length for slotted countersunk wood screws.

Example 1: A slotted countersunk head wood screw of shank 4.17 mm dia. length 20 mm, made of steel shall be designated as

Wood screw No. 8 x 20 countersunk steel (or)

Wood screw No. 8 x 20 I.S. 6760 steel.

The preferred length and screw number of countersunk wood screws are given in Table 2.

Example 2: A slotted round head wood screw of shank, 3.45 mm dia. length 30 mm, made of steel shall be designated as

Wood screw No.6 x 30 round head steel or
Wood screw No.6 x 30 I.S. 6739 steel.

Example 3: A slotted raised countersunk head wood screw of 2.08 mm dia. length 12 mm, made of steel shall be designated as

Wood screw No.2 x 12 raised countersunk steel, or
Wood screw No.2 x 12 I.S. 6736 steel.

Selection of the correct type, size and length of screws: Note the surface finish on the fixture at the fixing point, where a recess is provided. Select a countersunk screw; if not, select a round head screw.

Check the size of the hole in the fixture, then select a screw with a screw shank diameter equal to the hole size.

Decide on the length of the screw from the thickness of the fixture, and the thickness of the wood that the fixture is to be fixed in.

Screwing methods

In softwood: Locate the fixture and screw over the hole and tighten the screw.

In hardwood: Locate the screw in the hole and drive the screw for atleast 5 turns. Withdraw the screw, then locate the fixture and screw over the hole and tighten the screw. When the fixture has more than one fixing hole prepare the uppermost hole, and allow the fixture to hang from its fixing screw while the other fixing screws are located and then tightened.

Precautions to be adopted while fixing wood screws

- Before fixing the wood screws, the tip of the screws must be coated with rust-preventing material such as soap, wax etc.

Screws should never be hammered.

- Use a proper screwdriver which fits as closely as possible in the slots of the screws.
- Do not use a high-leverage screwdriver for fixing small screws.
- Pilot holes should be made, before fixing the wood screws.

Advantages of screws over nails

Screws provide for a more secure fixing than is possible with nails, and have the further advantage that they may be loosened or tightened as required. Screws can be made from rust-proof and corrosion-resistant materials, like brass, stainless steel, aluminium alloy, bronze etc.

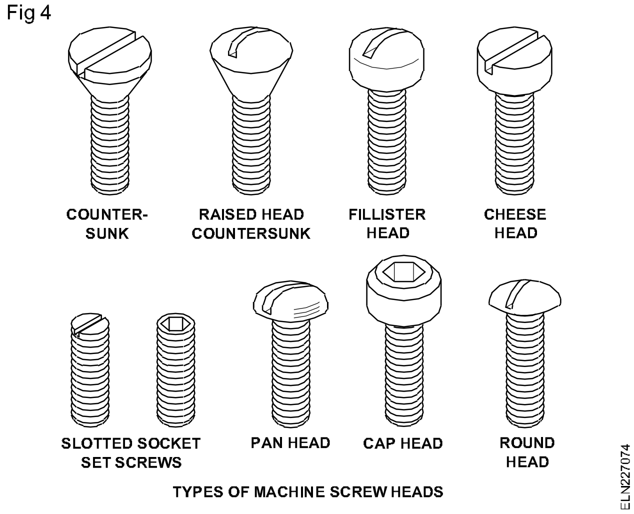
Machine screws: Machine screws are used for securing component and assembly work.

These screws should normally be screwed into tapped holes or used with nuts.

Types of machine screw head

Machine screws are mainly classified with respect to the shape of heads.The different types of screw heads in general use is given below (Fig 4).

Fig 4



TYPES OF MACHINE SCREW HEADS

Application: The cheese head type of screws is used for general assembly work.

Flush fitting screws are used when there is little clearance between assemblies or where protruding heads are not desirable.

The semi-flush type is used mainly for panel assembly or where a pleasing appearance is required.

Types of threads

Various types of thread screws are available.

Metric threaded screws: These screws are normally specified with alphabet `M'. M4, where `4' denotes the diameter of the screw in mm, and M denotes the type of thread in metric. Hence `M4 x 20' is a machine screw of metric thread having 4 mm dia. and 20 mm length.

BA (British Association) threaded screws: These screws are specified with the letters `BA'.

Unified national threaded screws (UNF): These screws are specified as `UNF' i.e. `Unified National Fine' or `UNC' i.e. `Unified National Coarse'.

Self-tapping screws: These are also called `Thread forming tapping screws'. They are specified in screw size and number, similar to the wood screws.

Specification: While specifying a machine screw, it is essential to mention the head type, screw length and the thread type.

Table 2

Screw No.	Nominal diameter of un- threaded shank in mm.	Preferred length in mm													
		8	10	12	15	20	25	30	35	40	45	50	55	60	65	70	75
0	1.52	✓	✓	✓													
1	1.78	✓	✓	✓													
2	2.08	✓	✓	✓													
3	2.39	✓	✓	✓													
4	2.74			✓	✓	✓	✓										
5	3.10			✓	✓	✓	✓	✓									
6	3.45			✓	✓	✓	✓	✓	✓	✓							
7	3.81			✓	✓	✓	✓	✓	✓	✓							
8	4.17			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
9	4.52				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
10	4.88				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Types of wiring : Domestic and Industrial - selection of cable size

Objectives: At the end of this lesson you shall be able to
- **state the types wiring used in domestic installations**
- **state the use of cord grip and underwriter's knot.**

Introduction

The type of wiring to be adopted is dependent on various factors viz. location durability, safety, appearance, cost and consumer's budget etc.

Types of wiring

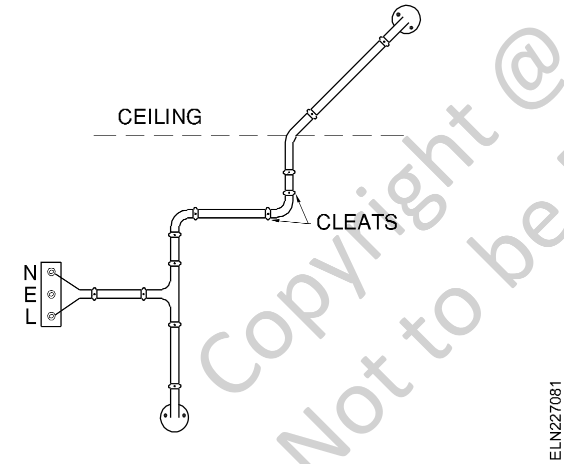
The following are the types of internal wiring used in domestic installations.

- Cleat wiring (for temporary wiring only)
- CTS/TRS (batten) wiring
- Metal/PVC conduit wiring, either on surface or concealed in the wall.
- PVC casing & capping wiring

Cleat wiring

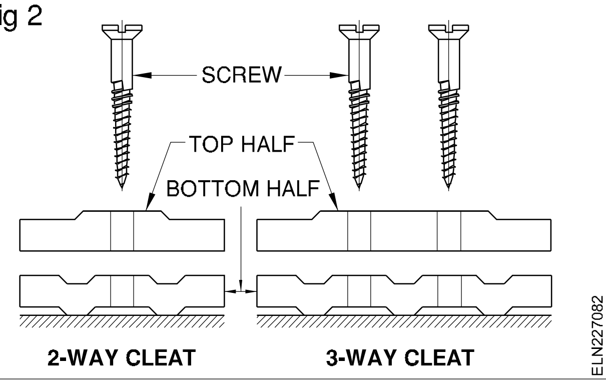
This system uses insulated cables supported in porcelain cleats (Fig 1).

Fig 1



Cleat wiring is recommended only for temporary installations. These cleats are made in pairs having bottom and top halves (Fig 2). Bottom half is grooved to receive the wire and the top half is for cable grip.

Fig 2



Initially the bottom and top cleats are fixed on the wall loosely according to the layout. Then the cable is drawn through the cleat grooves, and it is tensioned by pulling and the cleats are tightened by the screw.

The cleats are of three types, having one, two or three grooves, so as to receive one, two or three wires.

Cleat wiring is one of the cheapest wirings considering the initial cost and labour, and is most suitable for temporary wiring. This wiring can be quickly installed, easily inspected and altered. When not required this wiring could be dismantled without damage to the cables, cleats and accessories. This type of wiring may be done by semi-skilled persons.

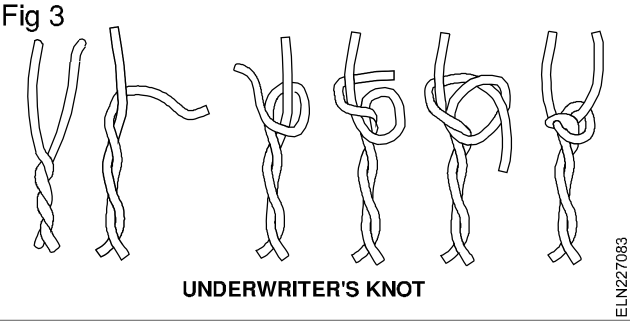
Cord grip and underwriter's knot

When a lamp or lamp with its shade is hung from the ceiling, the flexible cable connected to the lamp-holder is subjected to mechanical stress due to the weight of the lamp-shade and the lamp.

If the stress is not removed, the cable connection may come out of the terminals and result in shock hazards. To relieve the strain from the terminals of pendants, lamp-holders and ceiling roses, a cord grip or an underwriter's knot is used. A cord grip or underwriter's knot is also used in pull switches and other portable appliance connectors.

Underwriter's knot (Fig 3)

Fig 3

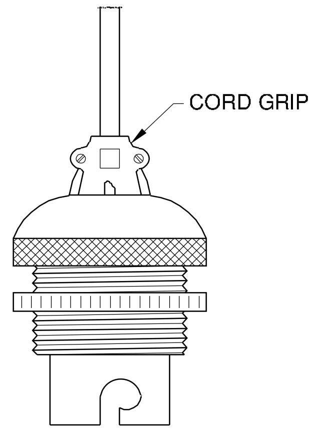


A knot is made on twin-twisted or twin-core flexible cable inside the accessories' cap cover.

Cord grip (Fig 4)

In some of the electrical accessories like lamp-holders, appliance connectors, plug pin tops etc. a cord grip arrangement is provided. These are an effective means of relieving the terminals from strain due to pulling or twisting of the cord.

Fig 4



LAMP-HOLDER WITH CORD GRIP

Types of electrical wiring

Objectives: At the end of this lesson you shall be able to
- **explain the types of electrical wiring and their application**
- **state the advantages and disadvantages of each types.**

Many wiring systems are developed to meet the safety requirements, economy of cost, easy maintenance and trouble shooting. A particular system can be chosen according to technical requirements but the system needs to be approved by the local electricity authorities. The following are the fundamental requirements for any wiring system. They are:

i For safety, switches should control the live phase wire. The second terminal of the switch called as half wire should be connected to the appliance or socket through the wire. The neutral can be connected directly to the appliance, socket or lamp. This enables the workman to rectify the defects of the particular lamp or appliance by switching off the particular circuit only and the main supply need not be switched 'off'.

ii For safety, fuses should be placed in the live/phase wire only. The lamp should not get supply when the fuse is blown.

iii To supply the rated voltage, parallel connections should be given to all lamps and appliances.

Types of wiring system: There are three types of wiring systems used for tapping supply from mains to the different branches. They are as follows.

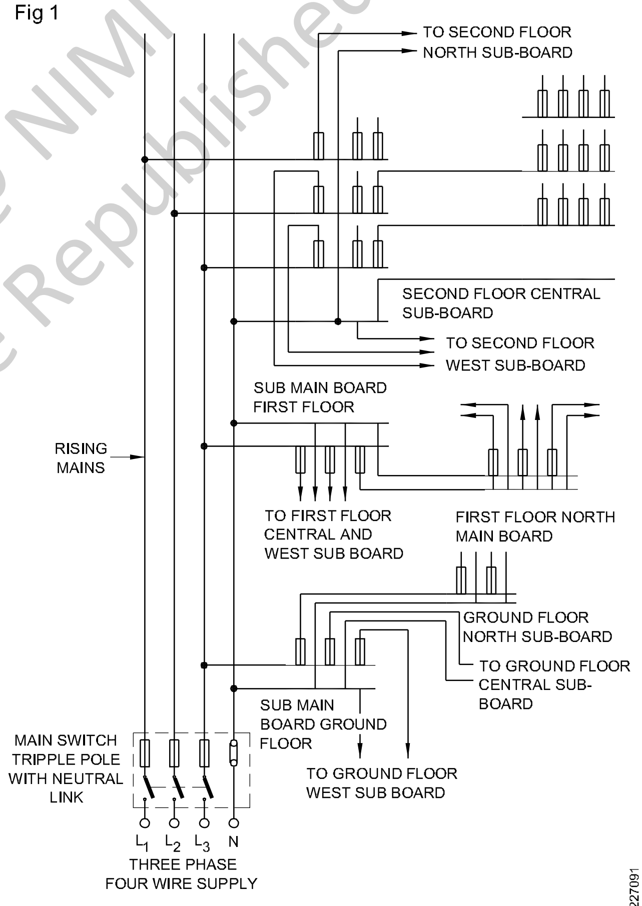
1 Tree system

2 Ring main system

3 Distribution board system

Tree system: In this system, copper or aluminium strips in the form of bus bars are used to connect the main supply to the raising mains (Fig1). This system is suitable for multi-story buildings and the bus bar trunking space is provided in the building at a convenient location and at load centres for the purpose of economy.

Fig 1



WIRING OF BUILDING BY TREE SYSTEM

At each floor the running main is connected to the sub-main board through proper cable terminations. If there are more than one flat in each floor the individual main switches for the flat get their supply from the sub-main board through a distribution network which may include an energy meter for each flat.

However the system adopted within the flat will be the distribution board system.

Advantages

1 The length of the cables required for installation will become less. Hence, the cost is less.

2 This system is suitable for high rise buildings.

Disadvantages

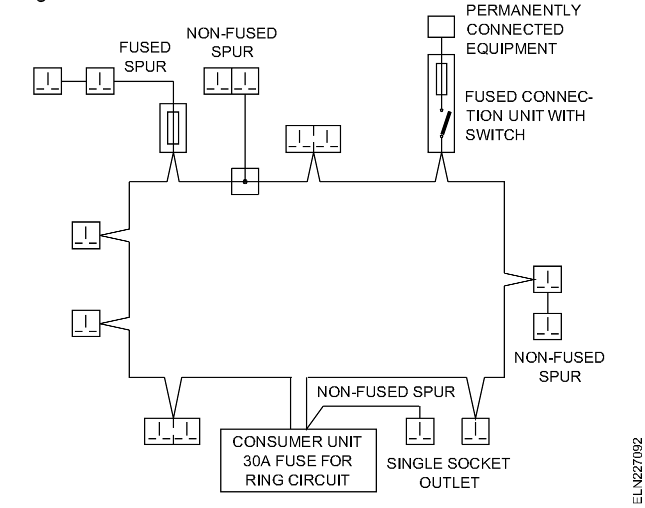
1 The voltage across the appliances which are at the farthest end of the tree system may be less when compared to the one connected to the nearest end if the bus bars size is not of sufficient size.

2 As fuses are located at different places, fault location becomes troublesome.

3 When aluminium bus bars are used for economic considerations, the tappings can become loose and interrupt power supply.

Ring main system: This system consists of two pairs of cables of size 4 or 6sq.mm which run through the rooms and are brought back to the main or sub-board (Fig 2 and 3). Tappings are taken for sockets or ceiling roses from the pair of cables through fuses and controlling switches. There may be saving of copper used because the current can be fed from both sides. As this system requires special sockets or plugs with fuses it becomes costly; and hence rarely used in India.

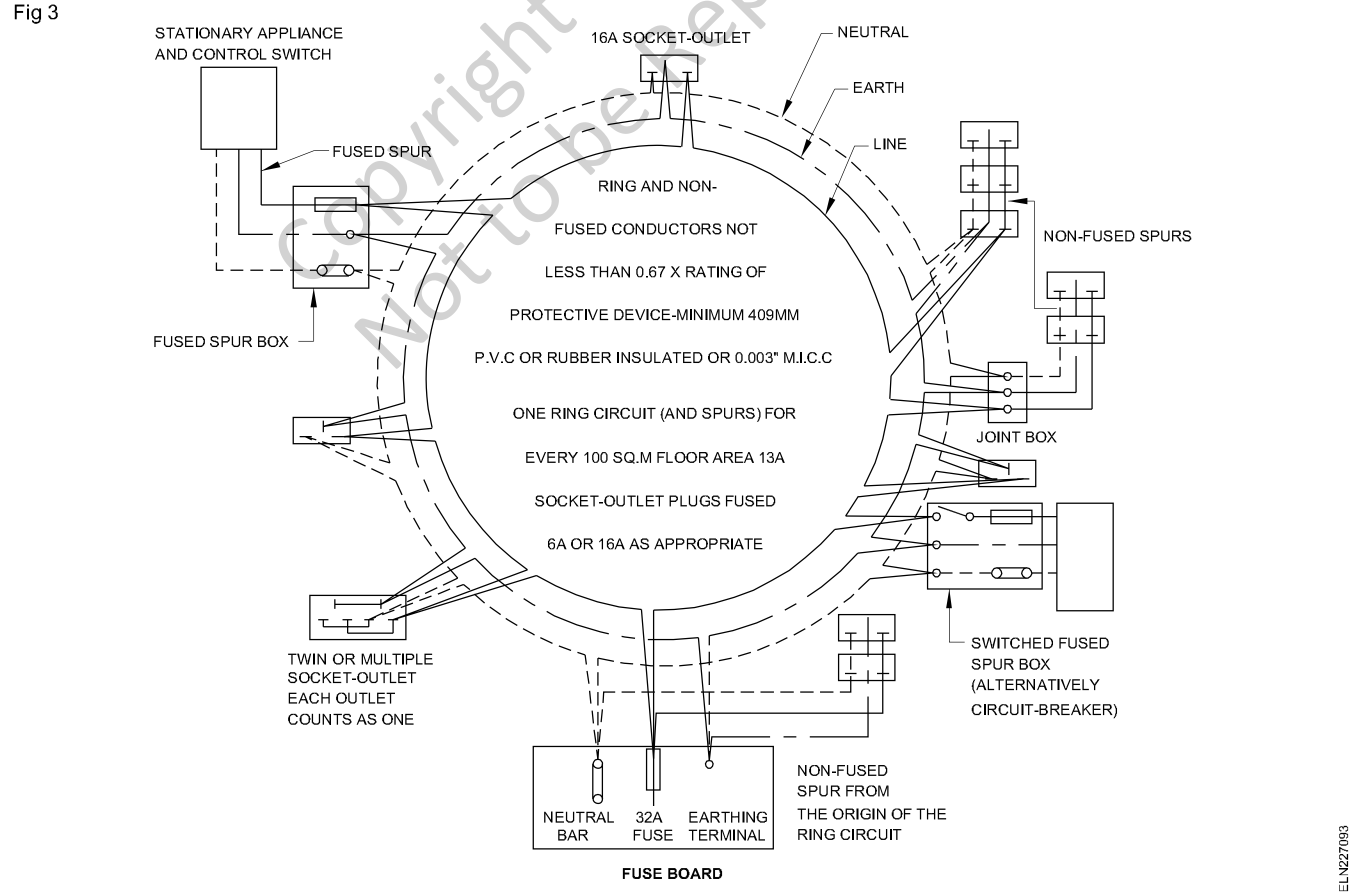
Fig 2



As per IEE regulations one ring circuit has to be there for every 100 sq metres of the floor area or part thereof. The number of power plugs fed from branch lines (spurs) should not exceed two and the total current should not exceed 30 amps. Protection for individual power plug can be provided by having built-in-fuses with the individual power plugs or by having MCB type switch and socket arrangement.

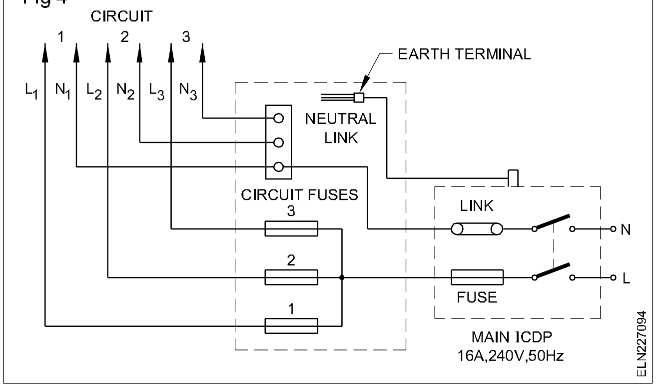
Distribution board system: This is the most commonly used system. This system enables the appliances connected to the system to have the same voltage. The main switch is connected to the distribution board through

Fig 3



suitable cables. The distribution board has a number of fuses depending upon the number of circuits required in the installation, and the phase and neutral cable of each phase are taken from the distribution board (Fig 4).

Fig 4

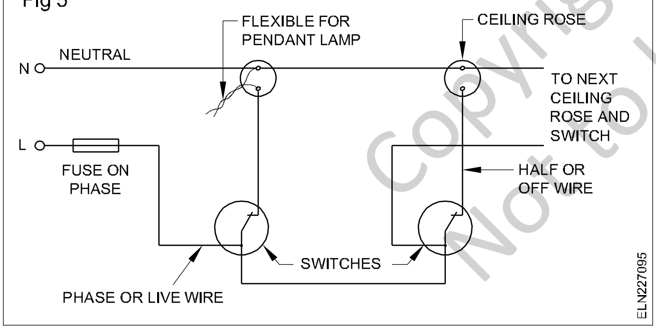


As each circuit can have power up to 800 watt, the phase wire which is taken from the circuit fuse of the distribution board is looped to the other light switches or fan switches of the same circuit by any one of the following ways.

No joint is allowed in the cable route except in switches, ceiling roses and joint boxes.

a Looping out from switch and ceiling rose: Fig 5 shows the simple looping in method which is commonly employed. The phase wire which is connected to the terminals of the switch is looped out to the next switch and so on, whereas the neutral wires are looped together from ceiling roses (Fig 5). Cable consumed in this system is very high.

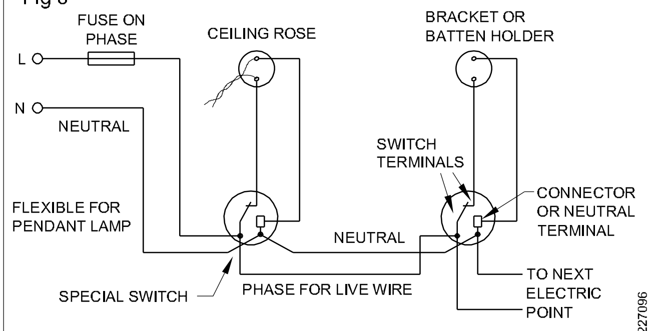
Fig 5



b Looping out from switch: This system employs special switches having two terminals and one connector (Fig 6). Both the phase and neutral cables are taken to the switch for looping the cables. As these accessories are not commonly manufactured in India such a system is not used.

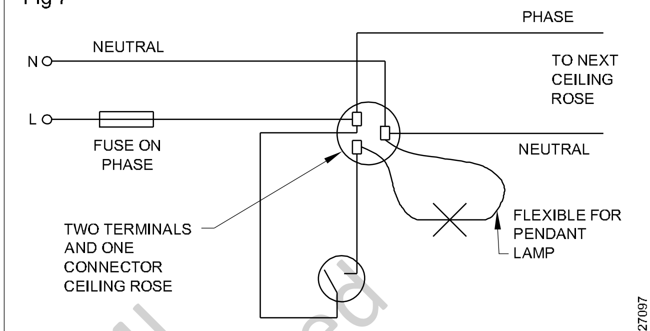
c Looping out from 3-plate Ceiling roses: In this type of system, three terminal ceiling roses need to be used (Fig 7). As this system uses less cables when compared to (a), this system is in use in some parts of India.

Fig 6



WIRING WITH TWO TERMINALS AND ONE CONNECTOR SWITCH

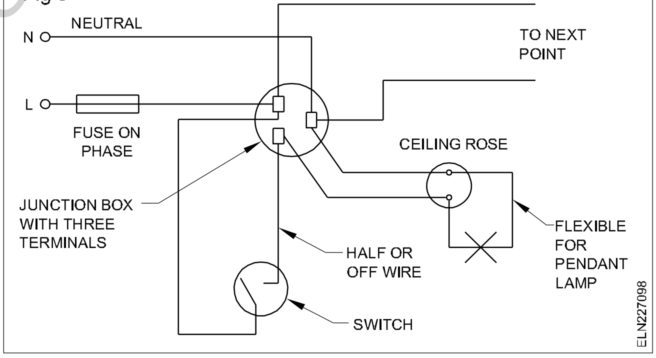
Fig 7



WIRING WITH THREE TERMINALS CEILING ROSE

d Looping out with junction box: In this system a pair of conductors from the distribution board is brought to the junction box and tappings are taken to switches, two plate ceiling roses as well as other points from the junction box are shown in Fig 8. This method may be economical for lodges where a row of rooms are constructed on either side of a common corridor.

Fig 8



Distribution board system

Advantages:

1 All loads are connected across the same voltage

2 Fault location is easy.

Disadvantages:

1 Requires skilled labour

2 Costlier than other systems.

Comparison of different types of wiring at a glance is given in the following table.

Different types of wiring at a glance

Sl. No.	Particulars	Casing & Capping	Batten wiring		Conduit wiring	
		PVC (Poly Vinyl Chloride)	TRS (Tough Rubber Sheathed)	LCC (Lead Covered Cable)	Metal	PVC
1	Material	PVC casing and capping PVC wires wooden gutties screws, blocks and boards.	T.W.Batten TRS/CTS wires gutties, screws, nails, clips, board & blocks.	Batten lead covered wire gutties, screw clips, board and blocks.	Metal conduit pipe, saddles hooks, wooden gutties, bend and socket and other accessories screws, block and board.	PVC conduit pipe, saddles, hooks, wooden gutties, bend and socket and other accessories screws block and board.
2	Cost	Fairly cheap	Cheap	Expensive	Expensive	Cheap
3	Life	Fairly long	Long	Long	Very long	Long
4	Mechanical Protection	Fair	Fair	Good	Very good	Good
5	Protection	Bad	Fair	Fair	Very good	Bad
6	Safety	Fair	Good	Good	Very good	Fair
7	Labour	Skilled	Skilled	Skilled	Highly skilled	Skilled
8	Extension and removal	Easy	Easy	Difficult	Not so easy and costly.	Easy
9	Time	Fairly short	Short	Fairly long	Very much longer	Fairly long
10	General reliability	Good	Fairly good	Fairly good	Very good	Good
11	Appearance	Good	Good	Good	Very good	Very good
12	Nature of application	Office only for Computer wiring.	Domestic & Office building	Domestic & Office building	Workshop	Domestic

Types of domestic wiring

Objectives: At the end of this lesson you shall be able to
- **explain the layout, installation plan, circuit -diagram, wiring diagram and state their uses**
- **state the B.I.S. regulation pertaining to wiring installation.**

In electrical wiring work, the electrician is supplied with a layout of wiring installation and an installation plan initially.

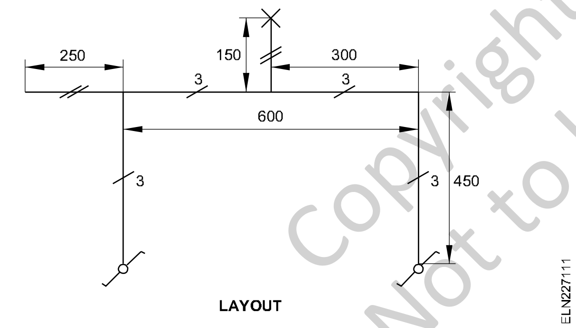
On the basis of the layout and installation plan, the electrician should draw the circuit and wiring diagrams before the commencement of work for systematic execution of the work.

The terms used in wiring installation drawings are explained here.

Layout diagram: Some customers give their requirements in writing. But a few can give them in the form of a layout diagram to the electrician. In the case of a written requirement, the electrician will prepare a layout diagram and then get the approval of the consumer.

The layout diagram (Fig 1) is a simplified version of the wiring diagram. Its purpose is to inform the reader quickly and exactly, what the circuit is designed for without giving any information on the circuit itself.

Fig 1



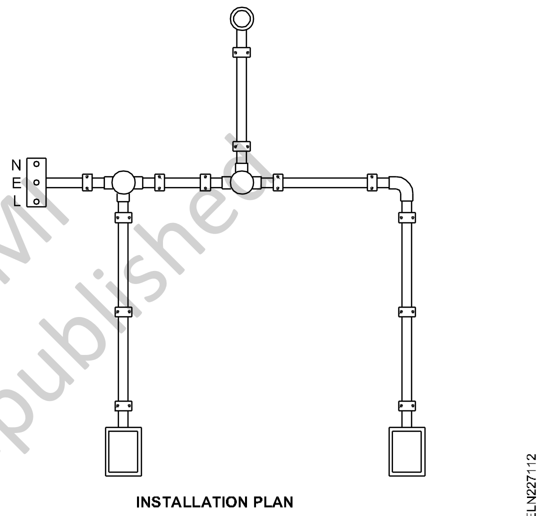
This type of layout diagram is used for preparing architectural diagrams, plans, etc. of a building.

In a layout diagram, it is necessary to indicate with symbols details like whether the wiring is on the surface or concealed, and the run `up' or `down', the number of wires in run, dimensions, and accessories with appropriate I.S. symbols.

Normally the layout plan is drawn and then the wiring diagram. After completion of the wiring diagram, the number of cables to be run in each cable run and the size of conduit or batten are estimated. With the help of the distance marking in the layout plan, the estimation of cables, could be made.

Installation plan (Fig 2): This plan shows the physical position of accessories in an installation, and also gives the final appearance of the installation. It may not be possible to draw the installation plan for the entire layout diagram. But it can be restricted to a small part of the installation to highlight the type of conduit, accessories, spacing of gutties, clamps etc.

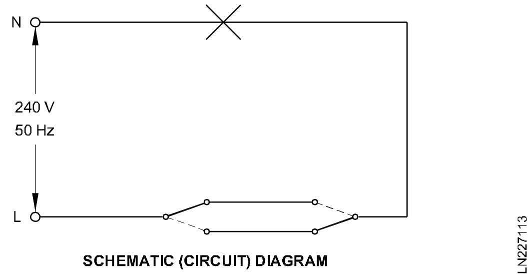
Fig 2



Circuit diagram (Fig 3): This shows the schematic connections of the circuit for a specific task in the simplest form, incorporating the graphical symbols.

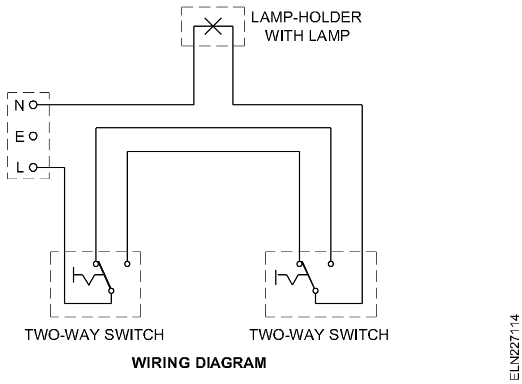
The purpose of a circuit diagram is to explain the function of the various accessories in the circuit. Fig 3 is an example of a circuit diagram for controlling a lamp from two different places.

Fig 3



Wiring diagram (Fig 4): This is the diagram in which the position of the components in the diagram bears a resemblance to their actual physical position.

Fig 4



The wiring diagram may not have distance marking. Use of the wiring diagram along with the layout diagram enables the technician in the initial stages of the planning to specify/estimate the required type, size and length of the cables, and also to decide on the vertical, horizontal and ceiling runs of the cable. The wiring diagram is of great use to test and rectify faults in the installation during maintenance work. Fig 4 also shows the wiring plan for controlling a lamp from two different places with their actual locations.

For his own good and to facilitate quick location of faults at a later stage, the customer should insist on the electrician giving him a copy of the wiring diagram soon after the completion of wiring. The electrician should make it a point to do so.

B.I.S. Regulations and the N .E. code pertaining to wiring installations

The wiring installation shall generally be carried out in conformity with the requirements of the Indian Electricity Act 1910, as updated from time to time and the Indian Electricity Rules 1956, framed thereunder, and also the relevant regulations of the electric supply authority of the concerned area (State Government).

To govern the installation of electrical wirings in buildings, with particular reference to safety and good engineering practice, the Indian Standard is published.

The following are some of the extracts of B.I.S. (Bureau of Indian Standards) regulations pertaining to wiring installations. All the B.I.S. regulations are recommended by the National Electrical Code (NEC).

B.I.S. regulations pertaining to wiring installations

Wiring: Any one of the following types of wiring may be used in a residential building.

- Tough rubber-sheathed or PVC-sheathed or batten wiring.
- Metal-sheathed wiring system
- Conduit wiring system:
  a rigid steel conduit wiring
  b rigid non-metallic conduit wiring
- Wood casing wiring

Fittings and accessories: All fittings, accessories and appliances used in wiring installations shall conform to Indian Standards. (I.S. mark)

The system should provide easy access to fittings for maintenance and repair, and for any possible modification to the system. Modifications to the system shall be done only by licensed electrical contractors, licensed under the Indian Electricity Rules.

Sub-circuits - different types: The sub-circuits may be divided into the following two groups:

- Light and fan sub-circuit
- Power sub-circuit.

After the main switch, the supply shall be brought to a distribution board. Separate distribution boards shall be used for light and power circuits.

Light and fan sub-circuits: Lights and fans may be wired on a common circuit. Each sub-circuit shall have not more than a total of ten points of lights, fans and 6A socket-outlets. The load on each sub-circuit shall be restricted to 800 watts. If a separate circuit is installed for fans, the number of fans in that circuit shall not exceed ten.

Power sub-circuits: The load on each power sub-circuit should normally be restricted to 3000 watts. In no case shall there be more than two outlets on each sub-circuit.

If the load on any power sub-circuit exceeds 3000 watts, the wiring for that sub-circuit shall be done in consultation with the supply authority.

A switch shall be provided adjacent to the normal entrance to any area for controlling the general lighting in that area. The switches should be fixed on a usable wall space and should not be obstructed by a door or window in its fully open position. They may be installed at any height up to 1.3m above the floor level.

Two-way switching is recommended for halls and staircases.

Switches and bell pushes should preferably be self-illuminating where they are often operated in dark.

Deep, dark cupboards and larders may be fitted with a lighting outlet, preferably with a door switch.

The light fittings in kitchens should be so placed that all working surfaces are well illuminated and no shadow falls on them when in normal use.

In living and dining rooms, if a cover or valance is provided, a lighting outlet should be provided, and it should have a separate switch.

In bedrooms it is recommended that some lighting be controlled from the bed location.

For bathrooms, it is recommended to use ceiling lighting with the switch located outside the bathroom. Alternatively an insulated cord-operated switch may be used. However, if the light switch is installed inside the bathroom, it should be out of reach of a person in a bath-tub or under the shower. Touching a switch with wet hand is highly dangerous.

It is recommended that lighting facilities be provided for lighting of all steps, walkways, driveways, porch, carport, terrace, etc, with switches for each provided inside the house at a convenient place. If the switches are installed outdoors, they should be weatherproof.

Waterproof lighting fittings should be used for outdoor lighting.

Socket-outlets: All plugs and socket-outlets shall be of 3-pin type, the appropriate pin of the socket being connected permanently to the earthing system.

An adequate number of socket-outlets shall be placed suitably in all rooms so as to avoid the use of long lengths of flexible cords.

Only 3-pin, 6A socket-outlets shall be used in all light and fan sub-circuits. 3 pin, 16A socket-outlets shall be controlled by individual switches which shall be located immediately adjacent to it. For 6A socket-outlets, if installed at a height of 130 cm above the floor level, in situations where a socket-outlet is accessible to children, it is recommended to use shuttered or interlocked socket-outlets.

In case an appliance requiring the use of a socket-outlet of a rating higher than 16A is to be used, it should be connected through a double-pole switch of appropriate rating.

Socket outlets shall not be located centrally behind the appliances with which they are used. Socket-outlets shall be installed either 25 or 130 cm above the floor as desired.

It is recommended that 3-pin, 6A socket-outlets may be provided near the shelves, bookcases, clock positions, probable bed positions etc.

Depending on the size of the kitchen, one or two 3-pin, 16A socket-outlets shall be provided to plug in hot plates and other appliances. Dining rooms, bedrooms, living rooms, and study rooms, if required, shall each be provided with atleast one 3-pin, 16A socket outlet.

No socket-outlet shall be provided in the bathroom at a height less than 130 cm.

A recommended schedule of socket-outlets is given below.

Location	6A Outlets	16A Outlets
Bedroom	2 to 3 Nos.	1 No.
Living room	2 to 3 Nos.	2 Nos.
Kitchen	1 No	2 Nos.
Dining room	2 Nos	1 No.
Garage	1 No	1 No.
Refrigerator	-	1 No.
Air-conditioners	-	1 No.
Verandah	1 No.	1 No.
Bathroom	1 No.	1 No.

Multi-plug adaptors for connecting more than one appliance to one socket outlet should not be used.

Fans: Ceiling fans shall be wired to ceiling roses or to special connector boxes. All ceiling fans shall be provided with a switch besides its regulator.

Fans shall be suspended from hooks or shackles with insulators between the hooks or shackles and also with insulators between the hooks and suspension rods.

Unless otherwise specified, all ceiling fans shall be hung not less than 2.75 m above the floor.

Flexible cords: Flexible cords shall be used only for the following purposes.

- For pendents
- For wiring of fixtures
- For connection of transportable and hand-held appliances

Flexible cords shall not be used in the following cases.

- As a substitute for the fixed wiring.
- Where cables may have to run into holes through the ceiling, walls, floors, windows, etc.
- For concealed wiring.
- If attached permanently to the walls, ceilings, etc.

Mounting levels of the accessories and cables as recommended in B.I.S. and N.E.C.

Height of main and branch distribution boards should be not more than 2m from the floor level. A front clearance of 1 m should also be provided.

All the lighting fittings shall be at a height of not less than 2.25 m from the floor.

A switch shall be installed at any height 1.3 m above the floor level.

Socket-outlets shall be installed either 0.25 or 1.3 m above the floor as desired.

The clearance between the bottom point of the ceiling fan and the floor shall be not less than 2.4 m. The minimum clearance between the ceiling and the plane of the blades of the fan shall not be less than 300 mm.

The cables shall be run at any desired height from the ground level, and while passing through the floors in the case of wood casing and capping and T.R.S. wiring, it shall be carried in heavy gauge conduit 1.5 m above floor level.

References

I.S. 732-1963
I.S. 4648-1968
N.E. Code

Method of marking the layout for wiring

Objective: At the end of this lesson you shall be able to
- **list the tools required for layout marking and state the method of marking the layout for wiring.**

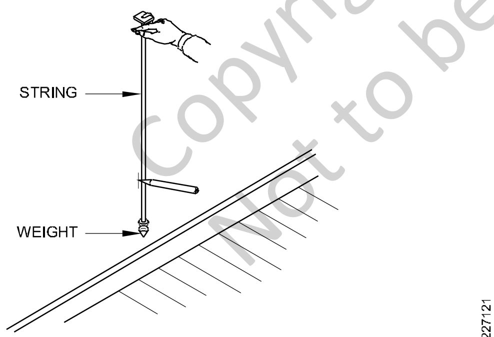
When installing electrical wiring in a building, it is necessary to mark the layout on the ceiling and walls to indicate the position of the various fittings and appliances to be installed and the routing of the cable runs.

To assist in the marking of the layout on the walls and ceilings, the following tools are used.

- Plumb bob or plummet
- Spirit-level
- Water-level

Plumb bob: A plumb bob consists of a block and a weight attached to each other by a string through their centres. When the plumb bob is placed on the wall, the weight is made to hang vertically through the string and the plumb line (string) indicates the true vertical (Fig 1).

Fig 1

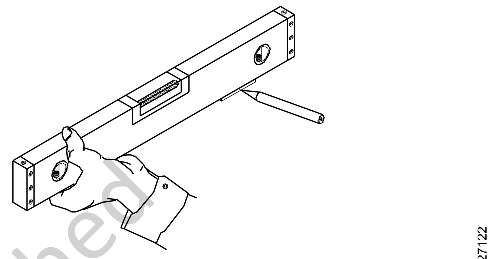


PLUMB BOB

Spirit-level: This consists of a level tube set in a straight edge. When the air bubble in the level tube locates centrally between the markings on the tube, the surface on which the straight edge is kept, it is deemed to be in a horizontal position. Spirit-levels are usually available in sizes from 150 mm to 1 m long (Fig 2).

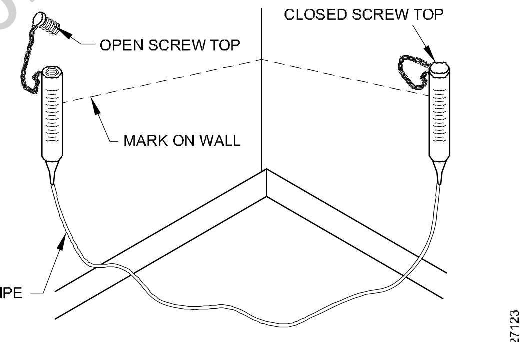
Water-level: A water-level consists of two calibrated glass tubes which are connected together by a flexible rubber tube. The tube is filled with water until the level is halfway up in both the glass tubes. The glass tubes shall be sealed when not in use. Instead of glass tubes on either side of a non-transparent tube, we can use an ordinary transparent PVC tube as water level(Fig 3) .

Fig 2



USE OF SPIRIT LEVEL

Fig 3



WATER LEVEL

Marking of layout: For marking of layout on walls and ceilings of an installation, chalking lines are used. Fine chalk powder is dusted on to a twine thread. When the twine thread dusted with chalk powder is held taut against a wall and `plucked', it marks the wall with a fine line of chalk dust.

Marking of true vertical runs: For marking the vertical lines, a `plumb bob' also known as plumb line, is generally used. A `plumb line' is used in the following manner.

Determine the position of the vertical line to be marked.

Hold the string(line) between the finger and the thumb at an appropriate distance from the weight to correspond with the height of the vertical line position marked.

Suspend the weight just clear of the floor or other obstructions, such as skirting boards, and rest the thumb against the wall and hold it steady until the string and the plumb bob are at rest, just clear of the wall's surface, at the location required as in Fig 1.

Make two pencil or chalk marks on the wall atleast 1 metre apart to correspond with the line of the string.

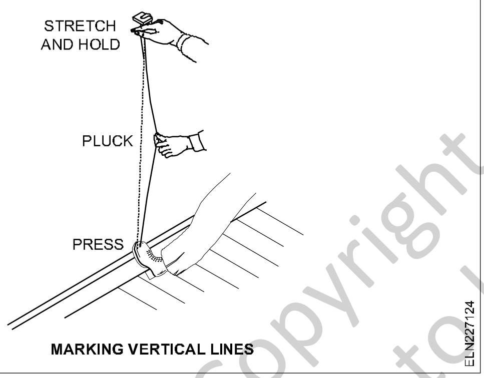
Draw a line joining the two marks using a straight edge and extend the lines as necessary.

For marking chalking twine (string) lines, stretch out the chalking twine, pull out a sufficient length for the height of the line required.

Hold the lower end with one foot and pull the string taut, adjusting the foot and hand as necessary until the line is directly over the two pencil marks on the wall. (Instead of holding the string with your foot, another person may be asked to assist.)

Use the free hand to lift the tautly held string about 20-30 mm away from the wall and release it. The string springs back to deposit a line of chalk dust on the surface of the wall (Fig 4).

Fig 4



MARKING VERTICAL LINES

A chalking line is usually used to mark long lines.

Marking `true' horizontal runs: The horizontal run is marked either by using a spirit-level or a water-level. Generally for electrical works, a spirit-level is used.

Mark the horizontal lines as outlined below.

Determine where you want the horizontal line to be drawn, using dimensions from the drawings and measuring off the fixed features such as the floor or ceiling. Make a single mark on the wall at the required height.

Hold the spirit-level with both hands and line it up with the mark on the wall.

Check the position of the air bubble in relation to the markings on the tube. Adjust the spirit-level until the bubble comes to rest exactly in the centre of the two markings.

Finally hold the level in position with one hand, and with the free hand draw a pencil line along the straight end of the level (Fig 2).

Use the straight edge of the level and line it up with the line already made and extend the pencil mark to the left and right of the original line.

Where long lines are required, repeat the above steps in the desired direction of the wall.

Measuring of horizontal and vertical runs: Horizontal lines can also be drawn by measuring off from a common base. For drawing horizontal lines on the walls, the common base could either be the floor, top of the skirting board or ceiling surface, provided the floor or the ceiling is reasonably level and even.

This method of measuring is used in many situations where installations are made parallel to existing features such as door frames, and skirting boards.

Marking cable runs on the ceiling: For marking on the ceiling, choose two adjoining walls which are at right angles to each other. Taking these walls as the base, take the measurement of the cable run route centres.

Keep the chalk-powdered string on the marking jointly by holding the edges of the string with the help of assistants and pull the strings hard to make the chalk marking on the ceiling.

Methods of connections in domestic wiring installations

Objectives: At the end of this lesson you shall be able to
- **explain the looping-back (loop-in) method**
- **explain the joint-box method**.

Introduction

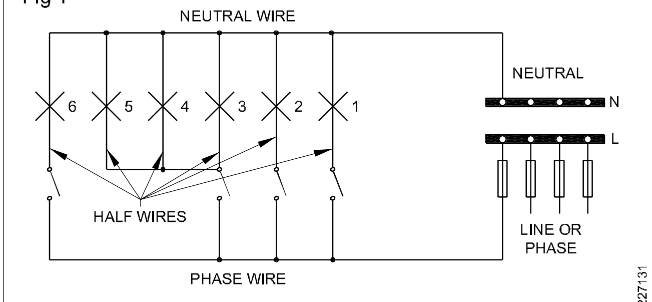
The circuit diagram of a sub-circuit of six lamps, three controlled separately by one-way switches, and three controlled as a group by a one-way switch (Fig 1). If the circuit were wired exactly as in the circuit diagram, a large number of joints would be necessary which are to be done in joint boxes only resulting in an increase in cost and labour. Two methods are adopted to execute the wiring economically. They are 1) the looping-back method and 2) the joint-box method.

Looping-back (loop-in) method

In this method, no separate joints are used. Instead twisted joints are used at the terminals of the accessories themselves. (In switches and ceiling roses)

Where the looping-back system of wiring is specified, the wiring shall be done without any junction or connector boxes on their line.

Fig 1



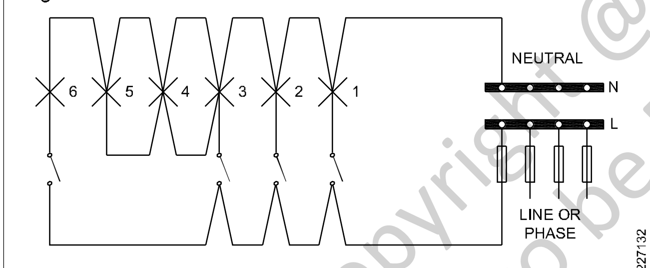
SCHEMATIC DIAGRAM

In domestic wiring installation, the looping-back system should be preferred.

The loop-back system can be adopted with two variations.

Loop-in method using 2-plate ceiling roses and switches: Fig 2 shows the schematic diagram of the circuit (Fig 1) as wired by the looping-in system. No separate joints are required in joint boxes. Twisted joints in the terminals of the two-plate ceiling roses and of the switches are, however, required. The schematic diagram (Fig 2) is not practicable and cannot be acceptable in any of the wiring systems like conduit, wooden batten or casing and capping system as it is generally necessary to run the cables close together in the same conduit, batten or casing.

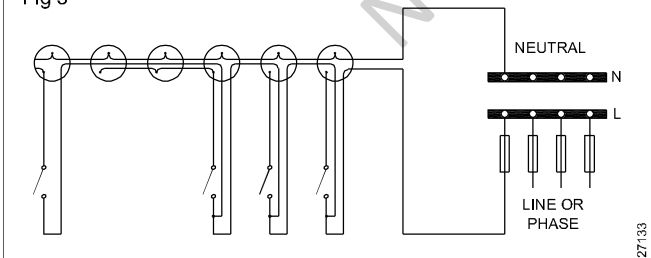
Fig 2



SCHEMATIC DIAGRAM OF LOOP-IN METHOD

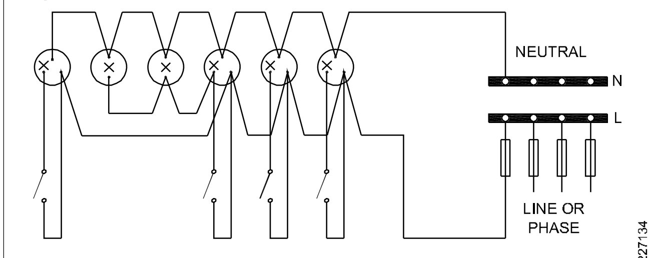
Fig 3 shows the same circuit suitable for practical work.

Fig 3



PRACTICAL WAY OF LOOP-IN METHOD

Fig 4



PRACTICAL WAY OF LOOP-IN METHOD

Loop-in method by 3-plate ceiling rose: We can also use 3-plate ceiling roses (Fig 4). Considerable cable length could be saved by using the third terminal of the ceiling rose as a looping-in terminal for the switch drop, so that two cables only are required from the ceiling rose to the switch.

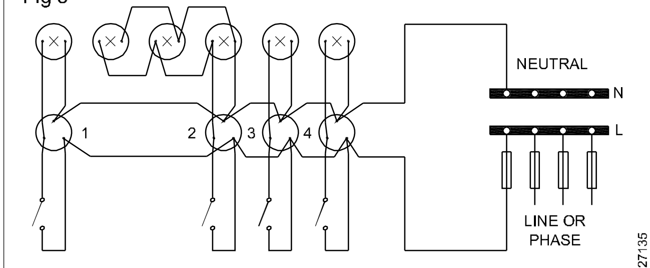
Joint-box method

In the joint-box method, wherever tapping has to be taken from the cable, joints are made. All joints in cable conductors shall be made by means of porcelain connectors or connector-boxes, and housed in suitable joint-boxes.

In any wiring system no bare or twist joints shall be made at intermittent points in the cable run of the main circuit or sub-circuit. If joining is unavoidable, such joints shall be made through proper cut outs or drawn through proper junction-boxes open for easy inspection.

The joint-box method of wiring system a pair of cables from the switches and ceiling roses will terminate in the junction box. The junction-box is kept in between the light points and switches for economy in the cable length (Fig 5).

Fig 5



1,2,3 AND 4 JOINT BOXES

Selection of the type and size of cable for a given wiring installation

Objectives: At the end of this lesson you will be able to
- **state the factors to be considered for selecting the cable for a circuit**
- **apply the factors and select the cable.**

In order to determine the type and size of the cable for a given circuit, the following points should be taken into account.

- Suitability of the type of cable for the location of the circuit and the type of wiring.

- Size of the cable depending upon the current carrying capacity of the cable.
- Size of the cable depending upon the length of the wiring and permissible voltage drop in the cable.
- Minimum size of the cable based on the economy.

Location of the circuit and the type of wiring decide the type of cable.

It is necessary to consider whether the installation is for industry or domestic use and whether the atmosphere is damp or corrosive. Accordingly the type of cable has to be chosen.

Further the type of wiring determines the type of cable suitable for the installations.

The current carrying capacity of the cable decides the size of the cable.

In this, the first step is to find out the current expected to flow in the circuit when the total connected load is fully switched on. This current is the maximum current that would flow through the circuit in case all the loads are working at the same time. But this is not the case in actual situations.

Diversity factor

In the case of lighting installation all the lamps in a domestic installation may not be switched 'on' at the same time. Hence, it is assumed only two thirds of the lights (say 66%) only will be 'on' at a given time. This introduces a factor called 'diversity factor'.

When the connected load is multiplied by the diversity factor you get a load value which can be said as normal working load. Use of this diversity factor enables the technician to use a lesser size cable than the one calculated, based on the connected load. The suggested diversity factor according to IEE rules is given in Table 2.

Based on the working load the current in each circuit is to be calculated and the size of the cable suitable to carry the current has to be chosen from Tables 3, 4 and 5.

Voltage drop in the cable

In any current carrying conductor, voltage drop takes place due to its internal resistance. This voltage drop in a premises as per BIS 732 should not be more than 3 percent of the standard supply voltage when measured between the consumer supply point and any point of the installation when the conductors are carrying the maximum current under the normal conditions of service.

Tables 3 and 4 for aluminium cable and 5 for copper cable give the relation between voltage drop and length of the cable run for various cables. In case the voltage drop found in the cable exceeds the stipulated limit of 3% voltage drop, the technician has to choose the next bigger sized cable to maintain the voltage drop within limits.

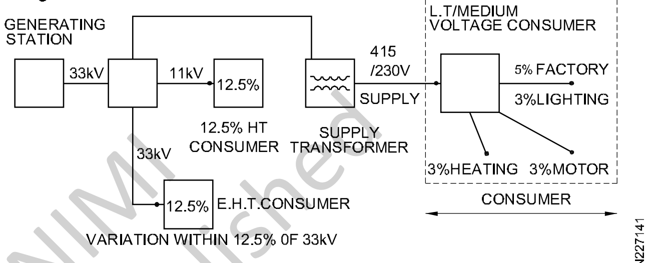
If the cable size is increased to avoid voltage drop in the circuit, the rating of the cable shall be the current which the circuit is designed to carry. In each circuit or sub-circuit the fuse shall be selected to match the load or the cable rating whichever is minimum, to ensure the desired protection (BIS 732).

Declared voltage of supply to consumer

On the other hand according to IE Rule No.54, the voltage at the point of commencement of supply at the consumer should not vary from the declared voltage by more than 5 percent in the case of low or medium voltage or by more than 12 percent in the case of high or extra high voltage (Fig 1).

At this stage it is better to remember that when current

Fig 1



PERMISSIBLE VOLTAGE DROP-DIAGRAM

flows through a conductor, the resistance offered by the conductor produces heat. The increase in heat is proportional to the cable resistance which in turn depends upon the cross-sectional area of the cable. Since overheating damages the insulation, the conductor size must be adequate to prevent this from occurring.

While choosing the cable size, voltage drop is a more severe limitation than any other criterion. Hence, it is advisable to select the cable size only after ascertaining the permissible voltage drop. Excessive voltage drop impairs the performance of heating appliances, lights and the electric motors.

Calculation of voltage drop

In DC and single phase AC two-wire circuits

Voltage drop = Current x Total resistance of cables

= 2 IR

where I is the current and

R is the resistance of one conductor only

Wherever voltage drop is given as 1 volt drop per metre run of cable, we have to assume that both (lead and return) cables are taken into account and the cable carries its rated current. In such cases the voltage drop for X metre length of cable for a current of Y amps is calculated as given.

$$\left\{\begin{matrix}\text{Voltage}\\ \text{drop}\end{matrix}\right\} = \frac{\left\{\begin{matrix}\text{Length of}\\ \text{the cable}\end{matrix}\right\} \times \left\{\begin{matrix}\text{Actual current}\\ \text{of the load}\end{matrix}\right\}}{\left\{\begin{matrix}\text{Metre length of}\\ \text{the cable per one}\\ \text{volt drop}\end{matrix}\right\} \times \left\{\begin{matrix}\text{Rated current}\\ \text{of the cable}\end{matrix}\right\}}$$

$$= \frac{XY}{\left\{\begin{matrix}\text{Metre length of}\\ \text{the cable per one}\\ \text{volt drop}\end{matrix}\right\} \times \left\{\begin{matrix}\text{Rated current}\\ \text{of the cable}\end{matrix}\right\}}$$

3-phase circuits

$$\text{Voltage drop} = 1.73 \text{ x } I\,R = \sqrt{3}\,IR$$

where I is the line current

R is the resistance of one core only.

The above points could be explained through the following set of examples.

Example 1

A guest house installation has the following loads connected to the three phase 415 V supply with neutral. Select a proper size of cable for this installation.

Lighting - 3 circuits of tungsten lighting total 2860 watts

Power from 3 x 30A ring circuits to 16A socket outlets for

1 x 7 KW Water heater (Instant)
2 x 3 KW Immersion heater (Thermostatically controlled)
Cooking appliances: 1 x 3 KW cooker
1 x 10.7 KW cooker

Current demand in amperes in each of the circuit is calculated by referring the Table 1. Calculation of current taking account into the diversity factor from Table 2.

Assuming the declared voltage as 240 volts and the length of the longest run in a circuit as 50 metres

Permissible voltage drop at the rate of 3%

$$= \frac{3 \text{ x } 240}{100} = 7.2 \text{ Volts}$$

Referring to Table 3, if the size of the conductor selected is 35.0 sq.mm which can carry 69 amps, the voltage drop at 69 amperes rating will be 1 volt for every 7.2 metres cable run.

For 50 metres cable run the voltage drop at 69 amps current rating = 50 / 7.2 volts.

Voltage drop for 65 amps

$$= \frac{50 \text{ x } 65}{7.2 \text{ x } 69} = 6.54 \text{ Volts}$$

As the actual voltage drop in the circuit, that is 6.54 volts, is well within the permissible value, of 7.2 volts, the cable selected is suitable for the installation.

Table 1

Sl. No	Demand description	Current Demand (Ampere)	Diversity Factor (Table 2)	Current allowing for Diversity (Ampere)
1	Lighting	11.9	75%	9.00
2	Power i	30	100%	30
	ii	30	80%	24 } 72.00
	iii	30	60%	18
3	Water heaters (inst)	29.2	100%	29.2
4	Water heaters (thermo)	25.00	100%	25.00
5	Cooker i	12.5	80%	10.00
	ii	44.5	100%	44.5
Total current		= 213.1		189.7

Total current demand (allowing diversity) = 189.7 amps
Load spread over 3 phases = 189.7/3 = 63.23 amps, say 65 amps per phase.

Example 2

A three-phase 3-wire connection is to be given to a premises in which an electric motor of 50 H.P. is to be installed. 40 metres of cable run from the main switch is required for this purpose. Determine the size of the 3-core cable to be used, if the available voltage is 400 V 50 Hz (Assuming PF is 0.8).

$$\{\text{Current drawn by the motor}\} = \frac{50 \times 746}{\sqrt{3} \times 400 \times 0.8} = 67.3$$

As a 3-core cable is used, referring to Table 4 it will be seen that 35 sq.mm. (7/2.5) PVC cable will be in a position to carry the motor current safely.

$$\left\{\begin{matrix}\text{The Permissible}\\ \text{Voltage drop}\end{matrix}\right\} = \frac{400 \text{ x } 3}{100} = 12 \text{ Volts}$$

But as per Table 4, the selected cable will have 1 volt drop for every 7.1 m cable run.

Hence, for 40 metres the voltage drop is = 40 / 7.1 volts = 5.63 volts.

Referring to Table 4 we have voltage drop at 69 amps = 5.63 volts.

Hence the voltage drop at 67.3 amp is

$$= \frac{40 \text{ x } 67.3}{7.1 \text{ x } 69} = 5.49 \text{ Volts}$$

As the drop is within permissible limits, of 12V ,the 3-core PVC cable size 35 sq.mm (7/2.5) is suitable.

TABLE 2

Allowances for diversity

Purpose of final circuit fed from conductors or switchgear to which diversity applies		Individual household installations, including individual dwellings of a block	Small shops, stores, offices and business premises.	Small hotels, boarding houses
1	Lighting	66% of total current demand	90% of total current demand	75% of total current demand
2	Heating and power (but see 3 to 8 below)	100% of total current demand up to 10 amperes + 50% of any current demand in excess of 10 amperes.	100% FLC of largest appliance + 75% FLC of remaining appliances.	100% of FLC of largest appliance + 80% FLC of 2nd largest appliance + 60% FLC of remaining appliances
3	Cooking appliances	10 amperes = 30% FLC of connected cooking appliances in excess of 10 amperes + 5 amperes if socket outlet incorporated in unit.	100% FLC of largest appliance + 80% FLC of 2nd largest appliance + 60% FLC of remaining appliances	100% FLC of largest appliance + 80% FLC of 2nd largest appliance + 60% FLC of remaining appliances
4	Motors (other than lift motors which are subject to special consideration)	100% FLC of largest motor + 80% FLC of 2nd largest motor + 60% FLC of remaining motors.		100% FLC of largest motor + 50% FLC of remaining motors.
5	Water heaters (instantaneous type)*	100% FLC of largest appliance + 100% FLC of 2nd largest appliance + 25% FLC of remaining appliances.	100% FLC of largest appliance +100% FLC of 2nd largest appliance + 25% FLC of remaining appliances	100% FLC of largest appliance + 100% FLC of 2nd largest + 25% FLC of remaining appliances.
6	Water heaters (thermostatically controlled)	No diversity allowable.		
7	Floor warming installations	No diversity allowable.		
8	Thermal storage space heating installations	No diversity allowable.		
9	Standard arrangements of final circuits in accordance with Appendix 5	100% of current demand of largest circuit + 40% of current demand of every other circuit.	100% of current demand of largest circuit + 50% of current demand of every other circuit.	
10	Socket outlets other than those included in 9 above	100% of current demand of largest point of utilisation + 40% of current demand of every other point of utilisation.	100% of current demand of largest point of utilisation + 75% of current demand of every other point of utilisation.	100% of current demand of largest point of utilisation + 75% of current demand of every point in main rooms (dining rooms etc.) + 40% of current demand of every other point of utilisation.

*** For the purpose of this table an instantaneous water heater is deemed to be a water heater of any loading which heats water only while the tap is turned on and, therefore, uses electricity intermittently.**

It is important to ensure that the distribution boards are of sufficient rating to take the total load connected to them without the application of any diversity.

Table 3

Current ratings and voltage drop for vulcanised rubber PVC or polythene insulated or tough rubber PVC lead sheathed, single core, aluminium wires or cables

Size of conductor		2 cable DC or single phase AC		3 or 4 cables balance 3 phase		4 cables DC	
Nominal area sq.mm	No. and diameter of wire in metres	Current rating in amperes	Approx. length of run for 1 volt drop in metres	Current rating in amperes	Approx. length of run for 1 volt drop/ metre	Current rating in amperes	Approx. length of run for 1 volt drop in metres
1.5	1/1.40	10	2.3	9	2.9	9	2.5
2.5	1/1.80	15	2.5	12	3.6	11	3.4
4.0	1/2.24	20	2.9	17	3.9	15	4.1
6.0	1/2.80	27	3.4	24	4.3	21	4.3
10.0	1/3.55	34	4.3	31	5.4	27	5.4
16.0	7/1.70	43	5.4	38	7.0	35	6.8
25.0	7/2.24	59	6.8	54	8.5	48	8.5
35.0	7/2.50	69	7.2	62	9.3	55	9.0
50.0	7/3.0 19/1.80	91	7.9	82	10.1	69	10.0

TABLE 4

Current ratings and voltage drop for vulcanised rubber, PVC or polythene insulated or tough rubber, PVC lead sheathed, twin, three or four cores aluminium wires or cables

Nominal area sq. mm.	No. and diameter of wire in metres	Current rating in amperes	Approx.length of run for 1 voltage drop/ metre	Current rating in amperes	Approx. length of run for 1 volt drop in metres
1.5	1/1.40	10	2.3	7	3.7
2.5	1/1.80	15	2.5	11	1.9
4.0	1/2.24	20	2.9	14	4.8
6.0	1/2.80	27	3.4	19	5.5
10.0	1/3.55	34	4.2	24	6.8
16.0	7/1.70	43	5.3	30	8.7
25.0	7/2.24	59	6.6	42	10.8
35.0	7/2.50	69	7.1	48	11.7
50.0	7/3.00 19/1.80	91	7.7	62	13.1
70.0	19/2.24	118	8.8	82	14.7
95.0	19/2.50	135	9.5	94	15.7
120.0	37/2.06	162	10.3	114	16.8

TABLE 5

Wattage loading of small VR Insulated copper conductor cables

Maximum permissible loading in watts at unity power factor for two single core cables in one conduit based on IEE current ratings subject to voltage drop

Cable Size			Current rating	Circuit Voltage		Approximate voltage drop per 10 metres run with current in Col 4. volts
mm	inch	approx. area in mm	amp	230V watts	250 V watts	
1	2	3	4	5	6	7
1/1.11	1/.044	1	5	1150	1250	1.97
3/0.74	3/.029	1.2	10	2300	2500	3.09
3/0.91	3/.036	2	15	3450	3750	2.98
7/0.74	7/.029	3	20	4600	5000	2.64
7/0.91	7/.036	4.5	28	6440	7000	2.37
7/1.11	7/.044	6.75	36	8280	9000	2.04
7/1.32	7/.052	9.5	43	9890	10750	1.75
7/1.62	7/.064	15	53	12190	13250	1.42
19/1.11	19/.044	18	62	14260	15500	1.30
19/1.32	19/.052	25	74	17020	18500	1.11
19/1.62	19/.064	38.75	97	22310	24250	0.96

Metal conduit pipe - methods of cutting, threading and bending

Objectives: At the end of this lesson you shall be able to
- **state the methods of cutting a metal conduit pipe**
- **state the purpose and process of threading and list out the precautions of conduit pipes**
- **list the different accessories used in conduit installation**
- **state the purpose and methods of bending the conduit pipes and list out the precautions.**

Cutting: Rigid and intermediate conduits may be cut with a hacksaw (Fig 1) or a pipe cutter (Fig 2). With either method, the conduit must be locked in a pipe vice before making the cut. Fix the conduit in the vice so that the vice grips the conduit 50 or 75 mm from the point where the cut has to be made. This prevents the grip of the pipe vice from damaging the surface of the conduit that must be threaded.

If a hacksaw is used, use 24 teeth per 25 mm blade. Be sure to install the blade so that the cut is made on the forward stroke.

After cutting (Figs 1 and 2) the inside edge of the conduit must be smoothed with a half round file (Fig 3) or a pipe reamer mounted in a brace.

Be particularly careful while cutting the conduit with a pipe cutting tool. This tool tends to leave a sharp ridge on the inner edge of the cut. Be sure this ridge is removed and the conduit is smooth before installing a coupling or any fitting, to avoid damage to the insulation of conductors.

Fig 1

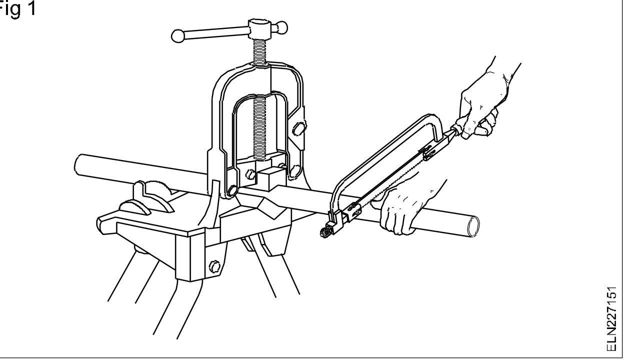
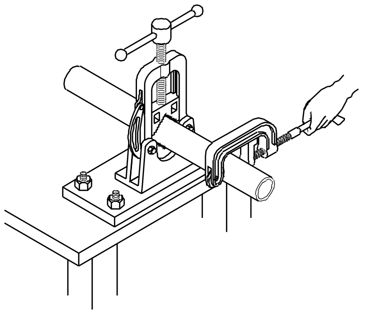


Fig 2



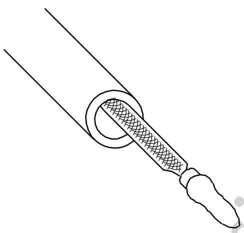
CUTTING A PIPE USING A PIPE CUTTER

ELN227152

Purpose of threading: When short lengths of conduits are to be used for switch or lamp drops, the cut end of the pipe needs to be threaded to enable fixing of the conduit to accessories. Threads on conduit pipes in all cases shall be between 11 mm to 27 mm long, sufficient to accommodate pipes to the full-threaded portion of couplers or accessories.

Threading: Conduit is threaded by using dies and a die stock. Apply cutting oil to the end of the conduit before starting to cut threads. Cutting the threads longer than necessary will leave the exposed threads subject to corrosion.

Fig 3



DEBURRING PROCESS

ELN227153

Do not use any lubricant which is an electrical insulator, as this may increase the resistance of the conduit assembly and affect its use as the circuit protective earthing conductor.

Precautions to be observed while threading conduit pipes

1 Chamfer the end of the conduit to be threaded. Make the depth of the chamfer equal to the pitch of the thread (1.5 mm for conduit).

2 Apply a lubricant frequently while threading the conduit pipe. It helps the die to cut more easily and the die to stay sharp.

3 Check whether stock is at right angles to the pipe axis.

4 Reverse turnings of the die stock are necessary to break off cut chips and to clear the cutting edges of the die.

5 Use only a brush to remove the metal burrs from the die. Do not use your hand.

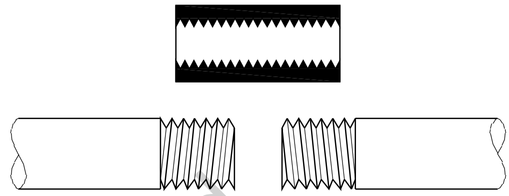
Conduit accessories

Conduit coupling: As conduits are commercially available in specific lengths only, it has become necessary to join two or more lengths to obtain the required runs. Joining of conduits is done by means of couplers.

There are two types of couplers used for rigid metal conduits as explained below.

Screwed couplers: They are also called running couplers and are made of cast iron, having female threads inside (Fig 4). The conduits to be joined should be threaded to a length sufficiently long to fit half way into the coupling such that no threaded portion is visible outside (Fig 5) to avoid corrosion.

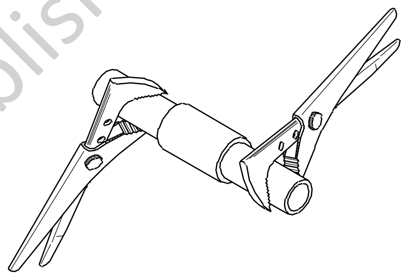
Fig 4



CONDUIT COUPLER ASSEMBLY

ELN227154

Fig 5



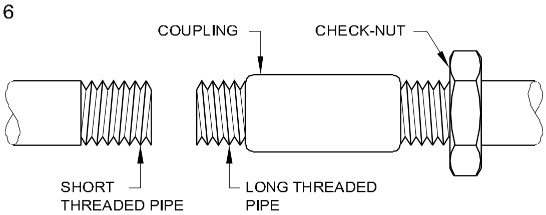
FIXING A CONDUIT COUPLER

ELN227155

This type of running couplers makes the joint mechanically weaker and electrically non-continuous. Hence the second type of coupler uses a check (jam) nut along with the running coupler which is a much better choice than the running coupler.

Check-nut and running coupler: For using this coupler, one of the conduits should have longer threads to accommodate fully the coupler, and the other conduit should have threads to a length equal to half the length of the coupler (Fig 6).

Fig 6



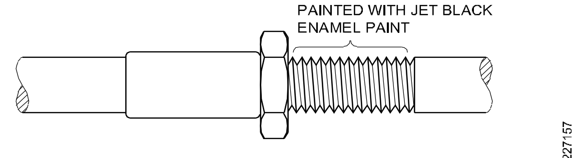
COUPLER AND CHECK-NUT ASSEMBLY

ELN227156

First the check-nut and then the coupler should be screwed inside the long threaded conduit. Then the short threaded conduit is butted with the long threaded conduit and the coupler is screwed on the short threaded conduit tightly.

Then the check-nut is screwed and tightened along the coupler (Fig 7).

Fig 7

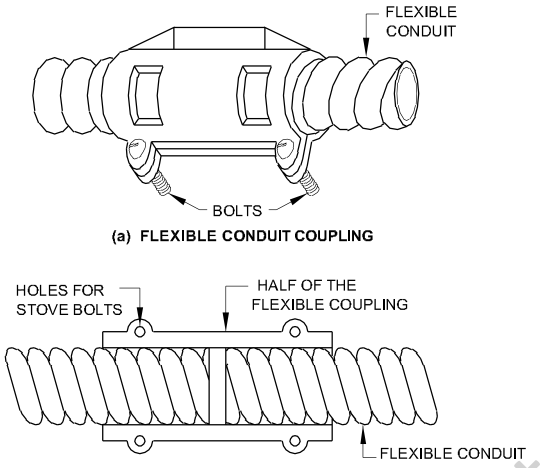


COUPLE AND CHECK-NUT ASSEMBLY.

The exposed threaded portion of the long threaded conduit is painted with jet black enamel paint to prevent rust.

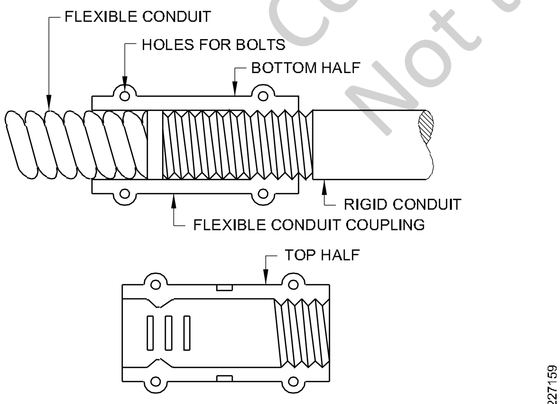
Coupling for flexible conduits: For flexible conduits, split couplings are used (Fig 8).

Fig 8



Special type of split couplings (Fig 9) is to be used when the flexible conduit is to be connected to a rigid conduit at places where high flexibility is required. This coupling has threading on one side with the other side made suitable to grip the flexible conduit.

Fig 9



Metal conduit boxes: Termination of rigid conduits is done at metal conduit boxes of either cast iron or sheet metal. Various shapes and sizes of boxes are commercially available in the market. Junction boxes of round, square, rectangular and hexagonal shapes are manufactured for one-way, 2-way, 3-way and 4-way outlets.

These outlets may be straight, angular or tangential as required for the situation. When ordering, the specification should contain the material with which the box is to be made, the size of the conduit to be fitted, the number of ways, shape and the position of outlets.

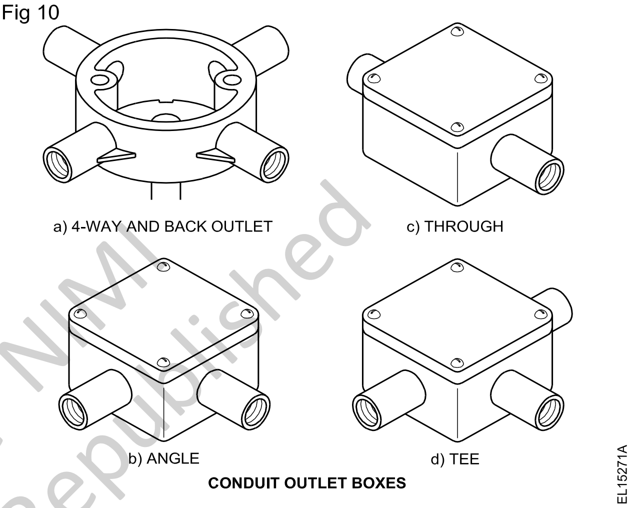
Example: Cast iron 20 mm, 3-way, round tee.

Fig 10 shows some of the popular types of outlet boxes. Cast iron 20 mm, 3-way, round tee.

Fig 11 shows various types of circular (round) boxes in a single line diagram.

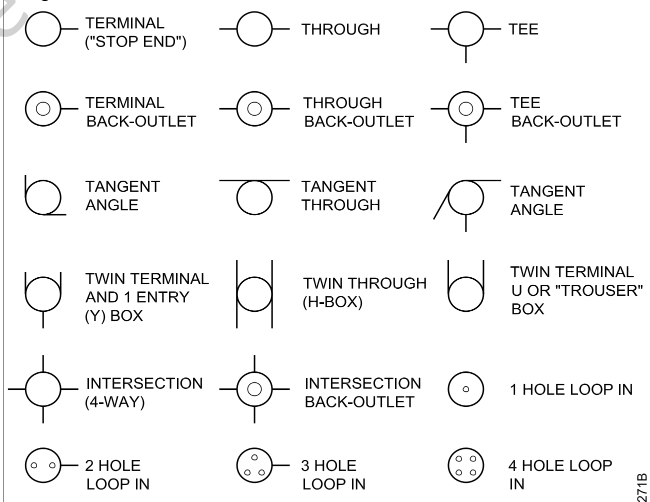
Fig 12 shows typical ceiling boxes, and Fig 13 shows wall boxes whereas Fig 14 shows switch boxes.

Fig 10



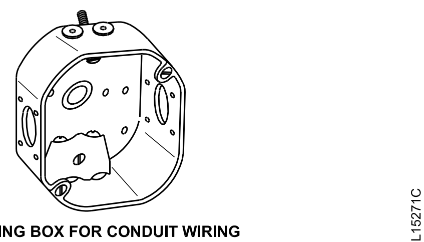
CONDUIT OUTLET BOXES

Fig 11



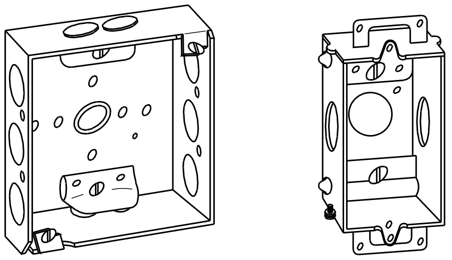
SMALL CIRCULAR BOXES

Fig 12



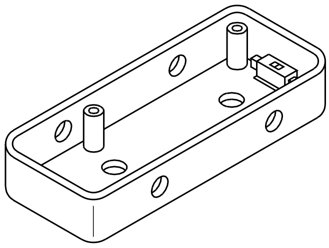
CEILING BOX FOR CONDUIT WIRING

Fig 13



WALL BOXES FOR CONDUIT WIRING

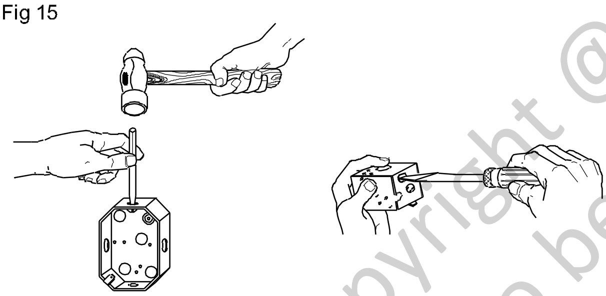
Fig 14



SWITCH BOXES FOR CONDUIT WIRING

The ceiling, wall and switch boxes are normally provided with knock-out openings which can be removed when required by using punches or chisels with a stroke from a hammer. In some cases the knock-out openings could be made by the pry out-method with a screwdriver (Fig 15).

Fig 15



METHOD OF REMOVING THE KNOCK OUTS

After removing the knock-outs, the conduit is to be fitted in the opening by any one of the methods shown in Fig 16.

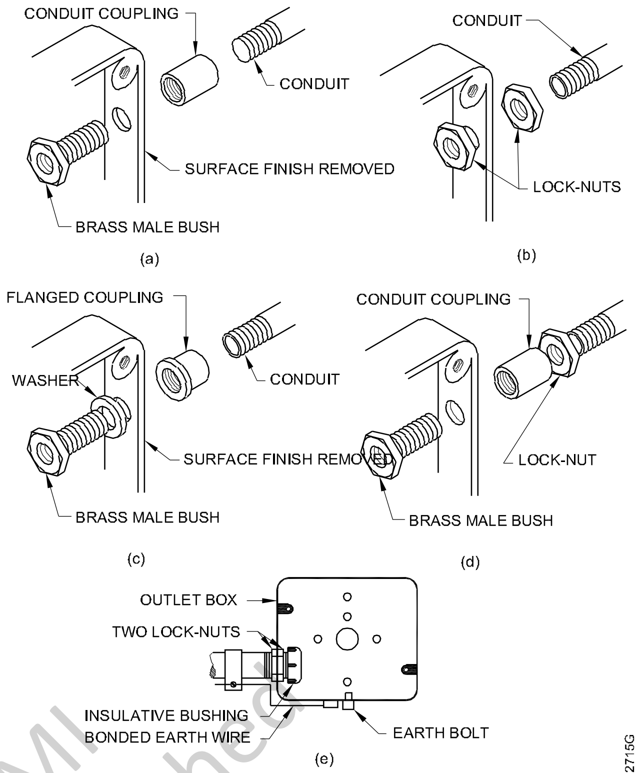
However, when brass bushes are not used in the terminating end of the conduits, it is necessary to use PVC bushes at the conduit ends to facilitate easy drawing of the cables and to avoid damage to the cable insulation.

Lock nuts: Hexagonal lock nuts are used at the conduit terminations (Fig 17) to make the terminations mechanically strong and electrically continuous. Remember that the paint at the box entries should be scraped out, before fitting the lock nut in position to facilitate electrical continuity.

Conduit bushings: These are made from brass or malleable iron or PVC and have a smooth large radius edge (Fig 18). This should be used at conduit terminations for dual purposes.

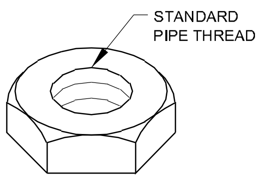
The first purpose is to protect the cable insulation from getting damaged during drawing of the cables, and the second purpose is to give a proper grip mechanically and make the conduit electrically continuous in the installation.

Fig 16



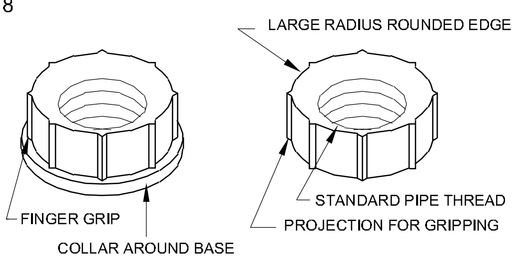
CONDUIT BOX ASSEMBLY

Fig 17



LOCK-NUT

Fig 18



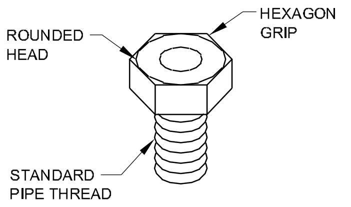
CONDUIT BUSHINGS

Conduit nipples (Fig 19) are provided in conduit termination along with couplers and they serve the same purpose as conduit bushes.

Conduit fittings like elbows, bends and Tees: All these fittings are available in two categories.

- Normal
- Inspection type

Fig 19

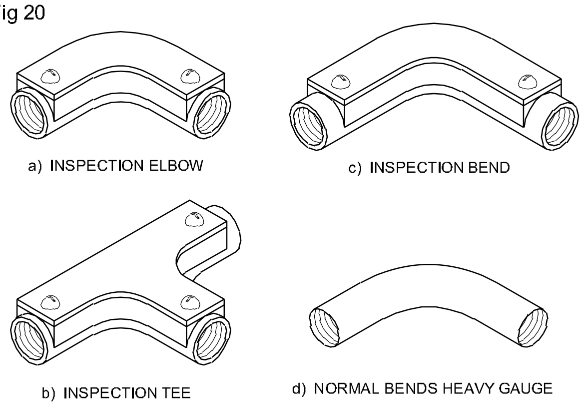


They are made from cast iron.

Elbows are suitable for short bends whereas bends are suitable for long bends. In general where a conduit runs between the wall and the ceiling, elbows are used.

Tees are used in switch-drops and diversions. Various types of these accessories (Fig 20).

Fig 20



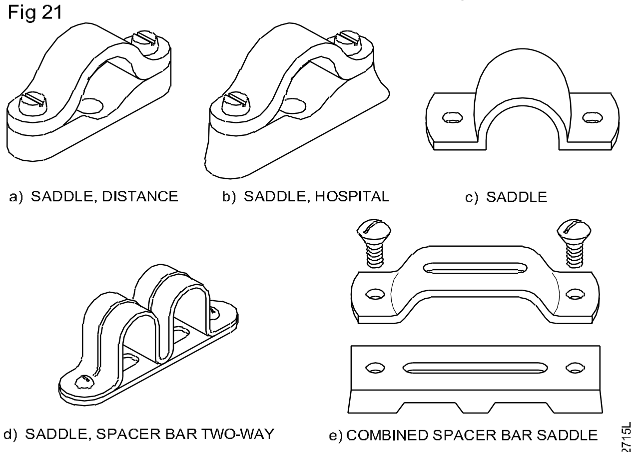
CONDUIT ACCESSORIES

Conduit saddles are used to fasten the conduit on the surface of the walls. These saddles could be used along with any one of the following bases. They are:

- spacers made from sheet metal
- distance piece made from wood or PVC
- hospital piece made from wood or PVC.

Various types of these base fittings along with the saddles are shown in Fig 21.

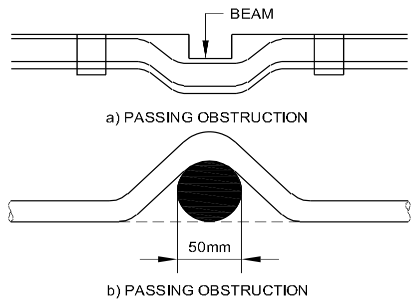
Fig 21



CONDUIT SADDLE ASSEMBLY

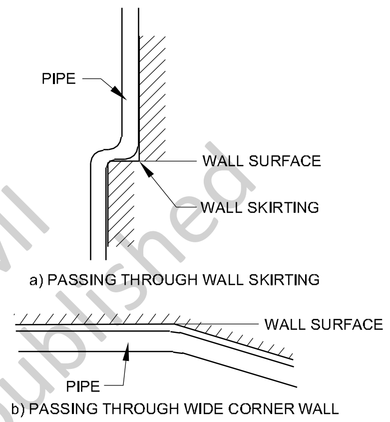
Conduit pipe bending: It is often necessary to set or bend the conduit to enable it to pass over an obstruction (Fig 22) or to turn a corner which is less or more than 90^0 (Fig 23). The bending may be a little offset to the line of conduit installation. This can be manipulated by proper bending as required.

Fig 22



OFFSETTING THE CONDUIT RUN

Fig 23

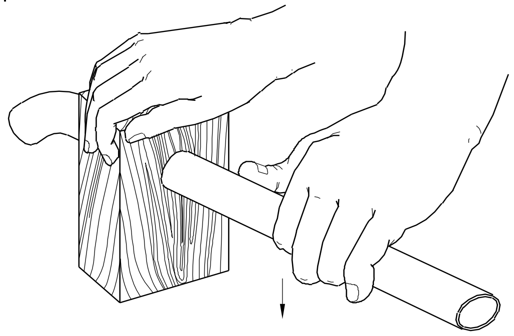


CONDUIT RUN THROUGH OFFSET WALL SURFACE

The bending may be done by using a simple bending block or by a hickey or with the help of a bending machine. Further, in concealed conduit wiring, the B.I.S. recommends bending of conduit pipes in preference to the use of bends and elbows.

Using bending block for bending conduit: The bending block (Fig 24) is made preferably with teak wood or strong country wood, and should have holes suitable for the conduit to be bent. Edges are chamferred to avoid kinks in the bent portion of the conduit. Light gauge conduits need to be filled with sand and heated before bending to have smooth bends.

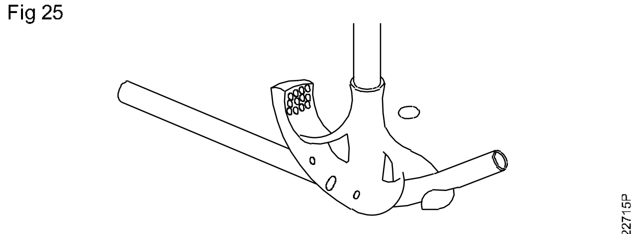
Fig 24



BENDING CONDUIT WITH THE BENDING BLOCK

Using hickey for bending conduits: A hickey is a special bending tool (Fig 25) and is made of forged steel or alloy steel. A particular size of pipe requires that size of hickey. Bending of pipes could be performed cold or hot by using a hickey.

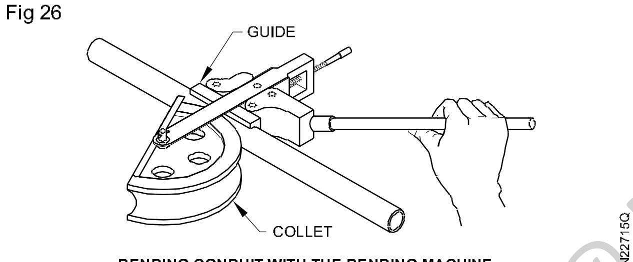
Fig 25



BENDING CONDUIT WITH THE HICKEY

Using bending machine for bending conduit: Various types of bending machines are available in the market. They can either be operated by hand (Fig 26) or by hydraulic pressure. For each size of conduit, the guide and collet need to be changed.

Fig 26



BENDING CONDUIT WITH THE BENDING MACHINE

Precautions to be observed while bending

- The pipe used should be mechanically strong to withstand the pressure while bending.
- Poorly seam-welded pipes are not suitable for bending as they may split while bending.
- One of the easy methods of bending is to draw the bending curve on the floor and bend the pipe accordingly.
- When a wooden block is used for bending, chamfer both sides of the hole opening in the block.
- Ensure that the conduit does not twist while bending.
- Use a proper size of hickey according to the dia. of the pipe to be bent.
- While doing manual hot bending do not use wet sand as the steam generated during heating may cause an explosion.

Test board, Extension board and colour code of cables

Objectives: At the end of this lesson you shall be able to
- **explain the method of using a test board**
- **state the general colour codes used in cables.**

Test board: A test board is an electric switch board, used for conducting the following tests.

- **Continuity test** (Load connected in series with a lamp)

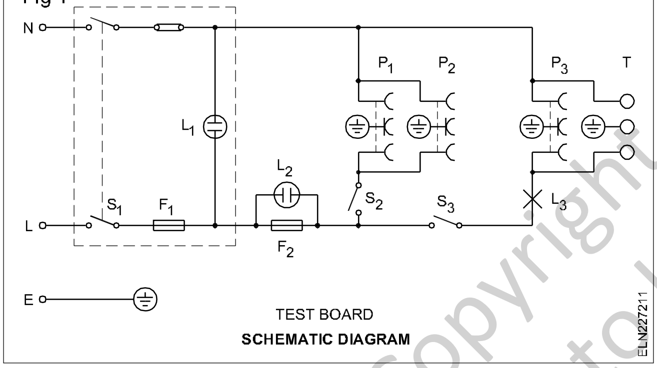
  Example: Testing of fan winding, condition of choke and tube light starter etc.

- **Direct test**

  Example : Testing electrical appliances of 1000 watts or lower rating for proper functioning.

Fig 1 source the schematic diagram of a test board with all the outlets and controls. Sockets P_1 and P_2 provide direct, single-phase supply whereas socket P_3 and terminal block T provide a single-phase supply in series with the lamp L_3.

Fig 1



Continuity test: While performing a continuity test, the appliance to be tested is connected to the socket P_3 or to the terminal T which are in series with the lamp L_3 and are controlled by switch S_3. Normally this test is conducted by the electrician to ascertain whether the appliance is open-circuited or short-circuited. A low wattage, appliance when connected, will make the lamp L_3 to burn dim, and a high wattage appliance will make the lamp to burn bright.

According to the brightness of the lamp, the behaviour of the appliance, as well as the wattage of the appliance and the lamp and the condition of the appliance could be judged. `No light' indicates either open circuit or high resistance in the appliance. In the same way, a choke coil and a starter of a tube light can be checked. (The flickering of the lamp L_3 with the starter indicates that the starter is good.)

Thus the testing board also works as a continuity tester.

Direct testing: By connecting the appliance direct to the socket P_1 or P_2, the performance of the appliance can be verified after repair.

Fuses: If the indicator lamp L_1 does not burn, it indicates no supply. On the other hand, in normal conditions, the indicator lamp L_2 will not burn, and it burns only when the fuse F_2 is open.

Thus the test board is a cheap and handy test set which is easy to use by an electrician to carry out his routine checks in the course of his work.

Colour identification of cables: The colour of the cables indicates their function. Table 1 gives the colour code and the alpha-numeric notation as recommended by N.E.Code.

The rules apply for marking conductors in equipment/ apparatus/installation.

TABLE 1

Alpha-numeric notation and colours

Designation of		**Identification by** alpha	colour
Supply AC system	Phase 1	L1	Red
	Phase 2	L2	Yellow
	Phase 3	L3	Blue
	Neutral	N	Black
Apparatus AC system	Phase 1	U	Red
	Phase 2	V	Yellow
	Phase 3	W	Blue
	Neutral	N	Black
Supply DC system	Positive	L+	Red
	Negative	L-	Blue
	Mid-wire	M	Black
Supply AC system (Single phase)	Phase	L	Red
	Neutral	N	Black
Protective Earth conductor		PE	Green and yellow
Earth		E	Colour of the bare conductor.

Extension board (Fig 2)

Extension boards are used to operate portable electrical appliances/ machines. It is also used where more number of sockets are required at a time.

Extension boards are available in different shapes with PVC (or) plastic boxes provided with 2 core (or) 3 core cables and moulded plugs. Extension boards are available in 6A and 16A ratings.

Fig 2

EXTENSION BOARDS

ELN227212

Conduit wiring - types of conduits - non-metallic conduits (PVC)

Objectives: At the end of this lesson you shall be able to
- **distinguish between the different types of conduits used in wiring**
- **compare metal and PVC conduit wiring**
- **state the different types of accessories used in non-metallic conduits wiring.**

In general, conduit is defined as a tube or channel, which is the most commonly used in electrical installations. When cables are drawn through the conduit and terminated at the outlet or switch points, the system of wiring is called conduit wiring.

Types of conduits

There are four types of conduits used for wiring.

- Rigid steel conduits
- Rigid non-metallic conduits
- Flexible conduits
- Flexible non-metallic conduits.

Non-metallic conduits

These are made of fibres, asbestos, polyvinyl chloride (PVC), high density polyethylene (HDP) or poly vinyl (PV). Of the above, PVC conduits are popular owing to their high resistance to moisture and chemical atmosphere, high dielectric strength, low weight and low cost. These conduits may be buried in lime, concrete or plaster without harmful effects.

However, light gauge (lower than 1.5 mm wall thickness) PVC pipes are not as strong as metal conduits against mechanical impact. Special PVC pipes which are heavy gauge and high impact resistance are available in the market which can withstand heavy mechanical impact as the thickness of the pipe is more than 2 mm.

There are some PVC heavy gauge conduits having special base material made to withstand temperatures up to 85^{o}C. These PVC conduits are available in 3 m length.

Flexible conduits

Apart from rigid conduits, flexible conduits are also used for protecting cable ends connected to a vibrating machine inter connection between switchgear and distribution boards. In the case of metal flexible conduits, steel strips are spirally wound to form a tube. However, these flexible conduits of any type cannot be relied on as the sole means of earthing due to the manufacturing method as well as material. Hence, earthing conductors should run either externally or internally to the flexible conduit to form the earth connection. Flexible conduit accessories should be of threaded type.

Variation in conduit wiring systems

There are two types of conduit wiring systems as stated below, for either metallic or non-metallic types.

- Surface conduit wiring system done on wall surfaces.
- Concealed (recessed) conduit wiring system done inside the concrete, plaster or wall.

Selection of the type of conduit

Metallic or PVC conduits are equally popular in electrical installations. Selection of the type of conduit depends upon the following criteria.

- Type of location, outdoor or indoor
- Type of atmosphere, dry or damp or explosive or corrosive
- Expected working temperature
- Exposure to physical damage due to mechanical impact
- Allowable weight of conduit runs
- Estimated cost.

A comparison between metal and PVC conduit wirings given in Table 1 will help in choosing the right type of conduit for a specific installation.

Table 1

Comparison between metal and PVC wirings

Metal conduit	PVC conduit
1 Provides good physical protection to cables.	Comparatively poor.
2 Weighs more for a given length.	Lighter.
3 Needs skill and time for installation.	Needs less skill and time.
4 Risk of electric shock due to leakage.	No risk as PVC is an insulator.
5 Good earth continuity available through the pipe itself.	Not possible. Separate earth wire required.
6 Can be used in gas-light and explosive-proof installations.	Not suitable.
7 Not resistant to corrosion, needs protective coating.	Resistant to corrosion.
8 Large ambient temperature range	Suitable for limited temperature range. At temperature above 60^{0}C, the conduit starts melting. At very low temperature the conduit cracks.
9 Fire resistant.	Non-fire-resistant.
10 More costly.	Less costly.

Special precautions with non- metallic conduits

1 If the conduits are liable to mechanical damages they should be adequately protected.

2 Non-metallic conduits shall not be used for the following applications.

- In concealed/inaccessible places of combustible construction where the ambient temperature exceeds 60^{o}C.
- In places where the ambient temperature is less than 5^{o}C.
- For suspension of fluorescent fittings and other fixtures
- In areas exposed to sunlight.

Non-metallic conduit accessories

Non-metallic conduit fittings and accessories shall be fabricated or moulded to the required shape. They shall be so designed and constructed so that they can be fitted with the corresponding conduit sizes without any adjustment, ensuring ready mechanical protection to the cables.

These fittings and accessories are used for conduit extension, and tappings or to assist pulling conductors. Rigid conduit accessories are normally of grip type only.

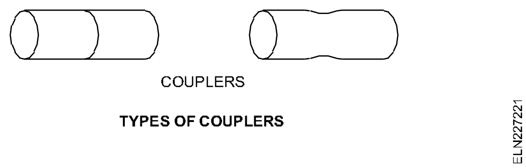
Inspection type, non-metallic fittings and accessories are permitted to be used only with surface mounting type wiring. Inspection fittings shall be so constructed that the screws used for fixing the cover do not deform the conduits or damage the insulation of the cables enclosed.

PVC fittings and accessories

Couplers (Fig 1)

Normally push type couplers are used and the conduit shall be pushed right through to the interior of the fittings. Inspection type couplers are used in straight conduit runs to assist in the inspection of the cables.

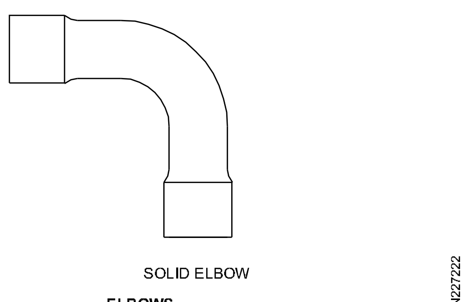
Fig 1



TYPES OF COUPLERS

Elbow (Fig 2)

Fig 2

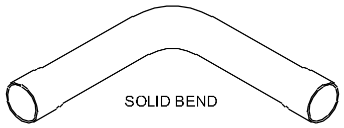


ELBOWS

The axis of any elbow shall be a quadrant of a circle plus a straight portion of each end. Elbows are used at sharp ends of nearby walls or roof and wall.

Bends (Fig 3)

Fig 3

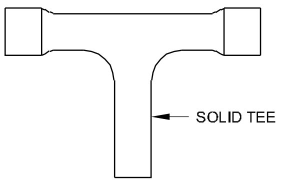


BENDS

A bend gives a diversion of 90ºC in the turn of a conduit, and a normal bend shall be a large sweep. Inspection type bends are used to assist in the inspection at the corners and for drawing cables.

Tees (Fig 4)

Fig 4



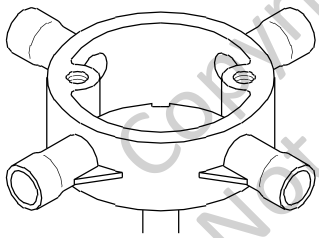
TEE

Tees are used to take diversion from the main line either to the switch points or the light points. It may be either an ordinary type or an inspection type. Inspection type tees are used to assist in the inspection in case there is a need.

Boxes

Circular boxes (Fig 5)

Fig 5



CIRCULAR BOXES

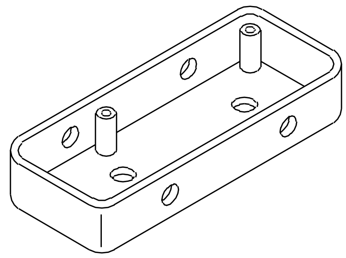
Small circular boxes shall be provided with two machine screws of a diameter not less than 2.8 mm for fixing the covers. Large circular boxes have four machine screws of not less than 4 mm diameter having not less than 10mm threaded portion for fixing the cover.

They are available in a single-way, two-way, three-way and four-way as well as back outlet types which can be used as per necessity in wiring. The minimum depth of junction boxes used in roof slabs shall be 65 mm. The cover of the circular box shall be made of the same material as that of the the box, and have a minimum thickness of 1.6 mm.

Rectangular boxes (Fig 6)

These boxes shall be provided with two machine screws of a diameter not less than 2.8 mm for fixing the cover. They can be used as a junction box or switch box, for fixing flush type switches. These boxes shall be free from burrs, fins and internal roughness. The minimum thickness of the wall and base of the PVC box should be 2 mm and clear depth of 60 mm.

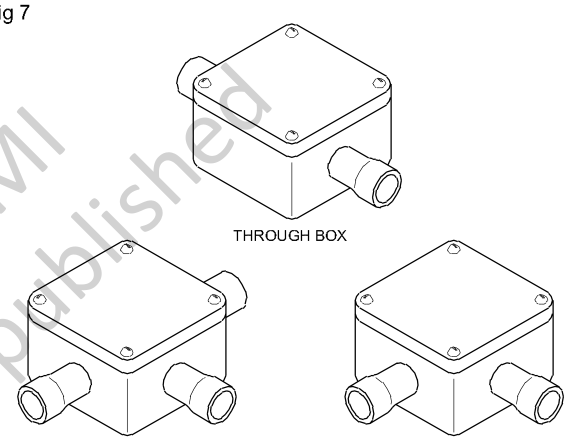
Fig 6



RECTANGULAR BOX

Apart from the above types, various other types are used as junction boxes (Fig 7).

Fig 7



TYPES OF BOXES (JUNCTION BOXES)

Method of cutting, joining and bending PVC conduit pipes

While doing the conduit wiring, it becomes essential, that the length has to be increased or decreased. Further the conduit is to be bent according to the required situation.

Cutting PVC conduit

A PVC conduit is easily cut by holding at the corner of a bench and using a hacksaw. Any roughness of cut and burrs should be removed with the aid of a knife blade/emery sheet, or sometimes by using a reamer. Before installing the PVC conduit pipe great care should be taken to remove the burrs inside the pipes to avoid damage to the cables during the cable drawing process.

Joining conduit with fittings

The most common jointing procedure uses a PVC solvent adhesive. Before applying the adhesive the inner surface of the accessory and the outer surface of the PVC pipe shall be cleaned with emery sheet to have a better grip. The adhesive should be applied to the receiving portion of the conduit fitting, and the conduit twisted into it to ensure a total coverage.

Generally, the joint is solid enough for use after two minutes although complete adhesion takes several hours. In order to ensure a sound joint, the tube and fittings must be clean and free from dust and oil.

Where expansion is likely and adjustments become necessary a mastic adhesive should be used. This is a flexible adhesive which makes a weatherproof joint, ideal for surface installations and in conditions of wide temperature variation. It is also advisable to use the mastic adhesive where there are straight runs on the surface exceeding 8 metres in length.

Conduit fittings should be best avoided, as far as possible, on outdoor systems.

Bends in conduit

All bends in the non-metallic system shall be formed either by bending the pipes by proper heating or by inserting suitable accessories such as bends elbows or similar fittings. Solid type fittings shall be used for recessed wiring. Solid type/inspection type of fittings shall be used for surface conduit wiring.

The minimum bending radius of conduits shall be 7.5 cm. Care should be taken while bending the pipes to ensure that conduit pipes are not damaged or cracked and the internal diameter is not effectively reduced.

In recessed conduit wiring, conduit bending, other than at the ends, shall be made by bending the pipes to the required angle and clamping at short intervals. In the case of conduits laid in the roof slab, it can be clamped or tied to steel reinforcement bars with suitable metallic clamps.

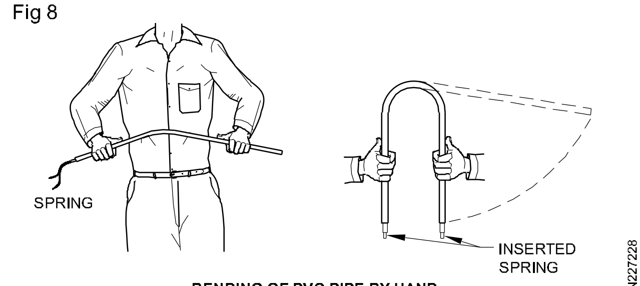
In the case of conduits recessed on walls, the chasis shall be made in the required shape and conduit fixed in the groove with suitable clamps. In the case of bending for surface conduit system, bending can be done either at cold state or by proper heating.

Cold bending PVC conduit pipes

PVC conduits not exceeding 25 mm diameter can be bent cold by using a spring. The bend is then made either with the hands or across the knee (Fig 8). In order to achieve the angle required the original bend should be made at twice the angle required and the tube allowed to return to the correct angle.

Under no circumstances should an attempt be made to force the bend back with the spring if it is twisted in an anticlockwise direction. This reduces the diameter of the spring, making it for easy withdrawal.

Fig 8



BENDING OF PVC PIPE BY HAND

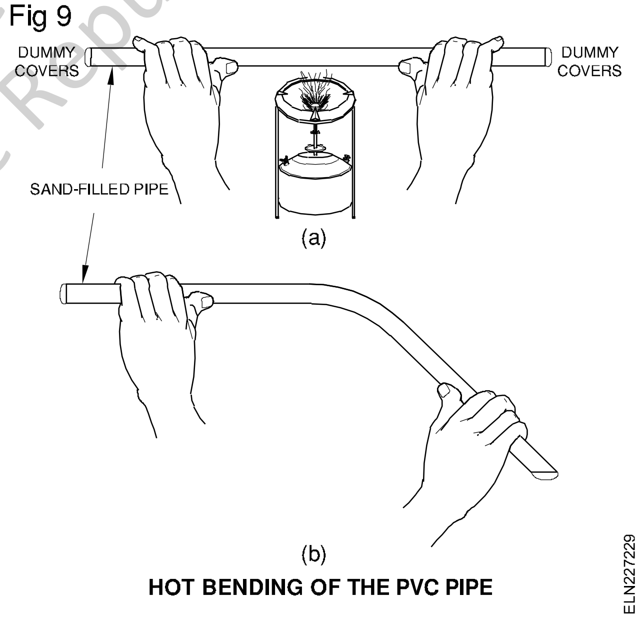
Bending PVC conduit in cold weather

In cold weather it may become necessary to warm the conduit slightly at the point where the bend is required. One of the simplest ways to do this is to rub the conduit with the hand or a cloth. The PVC will retain the heat created long enough for the bend to be made. In order that the bend is maintained at the correct angle, the conduit should be saddled as quickly as possible.

Bending of conduit by heating

The piece of conduit to be bent is first cut and inspected for any sharp edges or burrs left out. In such cases it shall be made smooth by using suitable emery sheet. The conduit is then filled with river sand. The ends are sealed with suitable dummy covers. The portion where the bend is to be made shall be heated uniformly (Fig 9a) to a temperature below its melting point.

Fig 9



HOT BENDING OF THE PVC PIPE

Then bend the required angle is made by holding both sides, with sufficient gap from the heated portion to avoid burning of hands, and applying uniform pressure (Fig 9b). Care shall be taken to avoid kinks on the conduits while bending.

Selection of conduit sizes and general regulations

Objectives: At the end of this lesson you shall be able to

- **state the method of selection of a suitable size of conduit for a specific number and size of cables.**

In PVC conduit wiring the first step is to select the correct size of conduit. The conduit size is determined by the size of cables and the number of cables to be drawn in a particular section. This information can be obtained from the wiring layout and the wiring diagram.

Selection of conduit size

A non-metallic conduit pipe, used in wiring, should have a minimum size of 20 mm in diameter. Where a large number of conductors are to be drawn, the size of the diameter depends on the size of the conductor and the number of conductors. Table 1 gives details of the numbers and the sizes of conductors that can be drawn in each size of a non-metallic conduit.

Example

For selection of a PVC conduit

When 2.5 sq mm 650 V grade single core cables of six numbers are to be drawn in a single run, we can use 25 mm non-metallic conduit as per the table.

When 6 sq mm. 650 V single core 6 cables are to be drawn in a single pipe we can use 32 mm PVC pipe. The following are the maximum permissible number of 650/1100V volts grade single core cables that may be drawn into rigid non-metallic conduits (Table 1).

TABLE 1

Maximum number of PVC insulated 650 V/1100 V grade aluminium/copper conductor cable drawing through conduits conforming to IS: 694-1990.

Nominal Cross- sectional area of condutor in sq.mm	20 mm		25 mm		32 mm		38 mm		51 mm		70 mm	
	S*	B*	S	B	S	B	S	B	S	B	S	B
1.50	5	4	10	8	18	12	–	–	–	–	–	–
2.50	5	3	8	6	12	10	–	–	–	–	–	–
4	3	2	6	5	10	8	–	–	–	–	–	–
6	2	–	5	4	8	7	–	–	–	–	–	–
10	2	–	4	3	6	5	8	6	–	–	–	–
16	–	–	2	2	3	3	6	5	10	7	12	8
25	–	–	–	–	3	2	5	3	8	6	9	7
35	–	–	–	–	–	–	3	2	6	5	8	6
50	–	–	–	–	–	–	–	–	5	3	6	5
70	–	–	–	–	–	–	–	–	4	3	5	4

- **The above table shows the maximum capacity of conduits for a simultaneous drawing in of cables.**
- **The columns headed 'S' apply to runs of conduits which have a distance not exceeding 4.25 m between draw in boxes and which do not deflect from the straight by an angle of more than 15 degrees. The columns headed 'B' apply to runs of conduit which deflect from the straight by an angle of more than 15 degrees.**
- **Conduit sizes are the nominal external diameters.**

PVC Channel (casing and capping) wiring

Objectives: At the end of this lesson you shall be able to
- **state the use limitation and rules of channel wiring system**
- **select the channel size according to size and number of cables from the chart**
- **explain the method of fabricating neutral, bend, and junction in PVC channel .**

Introduction : Channel (Casing and Capping) wiring is a system of wiring in which PVC/metallic channels with covers are used for drawing wires. This system of wiring is suitable for indoor surface wiring works. This system is adopted to give a good appearance and for extension of existing wiring installation. PVC insulated cables are generally used for wiring in casing and capping system. This is otherwise called 'wireways'.

The channel and top cover shall be of the same material either PVC or anodised aluminium. The casing is square or rectangular in shape. The capping shall be slide in type with double grooving in the case of PVC wire ways. Plain type capping are used for metallic wireways.

The only disadvantage in a channel wiring is that it is inflammable and risk of fire.

Channel (casing & capping) wireways should not be used.

In residential buildings or such buildings were there is a risk of tampering where ambient temperature exceeds 60°C or less than 5°C in areas exposed to sunlight.

Dimensions : The sizes of channel, the maximum number of wires which can be drawn in each size are given in the table 1 below.

The thickness of channel should be 1.2mm ± 0.1mm.

TABLE 1

Nominal cross sectional area of conductor in sq.mm	**10/15mm x 10mm size channel**	**20mm x 10mm size channel**	**25mm x 10mm size channel**	**30mm x 10mm size channel**	**40mm x 20mm size channel**	**50mm x 20mm size channel**
	No. of wires	**No. of wires**	**No. of wires**	**No. of wires**	**No. of wires**	**No. of wires**
1.5	3	5	6	8	12	18
2.5	2	4	5	6	9	15
4	2	3	4	5	8	12
6	-	2	3	4	6	9
10	-	1	2	3	5	8
16	-	-	1	2	4	6
25	-	-	-	1	3	5
35	-	-	-	-	2	4
50	-	-	-	-	1	3
70	-	-	-	-	1	2

Precautions

1 Neutral (Negative) cables should be carried in top channel and phase (Positive) in the bottom channel.

2 Crossing of cables between phase (Positive) and neutral (Negative) should be avoided.

3 Porcelain or PVC pipe should be used for crossing the cables through the walls.

Installation of PVC channel : The channel should be fixed to wall/ceiling with flat headed screws and rawlplugs. These screws shall be fixed at an interval of 60cm. On either side of joints this distance shall not exceed 15cm from the end point. Channel under steel joints shall be fixed with MS clips of not less than 1.2mm (18SWG) thickness and width not less than 19mm.

Floor/Wall crossings : When conductor pass through floors/wall the same should be carried in a steel conduit/ PVC conduits properly bushed at both ends. The conduits shall be carried 20cm above floor level and 2.5cm below ceiling level and properly terminated into the channel.

Joints in PVC/Metal channel : As far as possible wireways in straight runs should be single piece. All joints shall be scarfed or cut diagonally in longitudinal section. The section ends shall be filed smoothly but joined without any gap. Care shall be taken to see that the joints in PVC cover does not overlap those channel.

Joints shall also be done using standard accessories like elbows, tees, 3 ways/4 ways junction box etc of high grade PVC/Aluminium alloy. In PVC channel separate channel cover for joint, elbows, tees, cross etc are available. These can be fixed after fixing the channel to give a good appearance. The radius of curvature of the cables inside a bend should be more than 6 times its over all diameter.

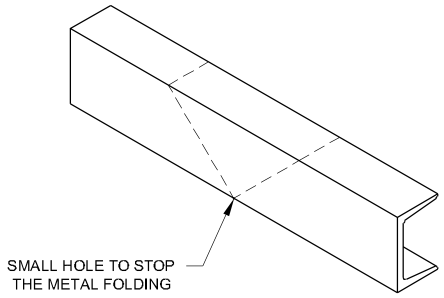
In the case of PVC channel, making joints is comparatively easy. Mark the joints by placing the two pieces in required angle. Identify the position to be cut and remove on each pieces. Cut through the lines and file the edges to get gapless joint.

Fabricating a right-angled vertical bend

1 Mark out the position of bend of all sides as shown in Fig 1. the width 'Y' must be made equal to the diagonal length 'Y' to be cut.

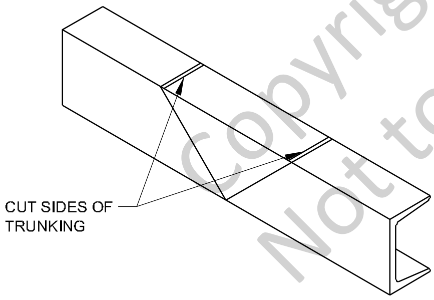
2 Drill small holes in corners at point of bend to stop channel folding (Fig 1).

Fig 1



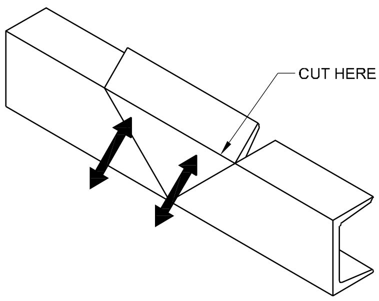
3 Place wood blocks inside trunking for support. Cut sides of trunking (Fig 2).

Fig 2



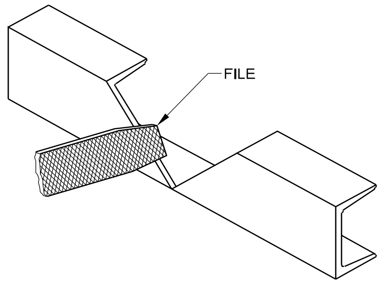
4 Cut, file and break-off waste (Fig 3).

Fig 3



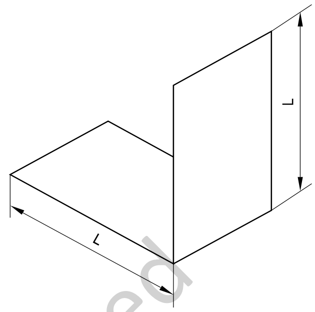
5 File all the edges smooth in order to bend to shape (Fig 4).

Fig 4



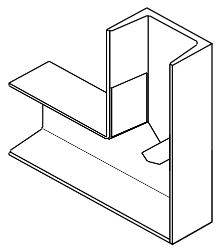
6 Make 'L' plates out of PVC scrap (Fig 5).

Fig 5



7 Make and secure assembly with 'L' plates and paste it with suitable adhesive (Fig 6).

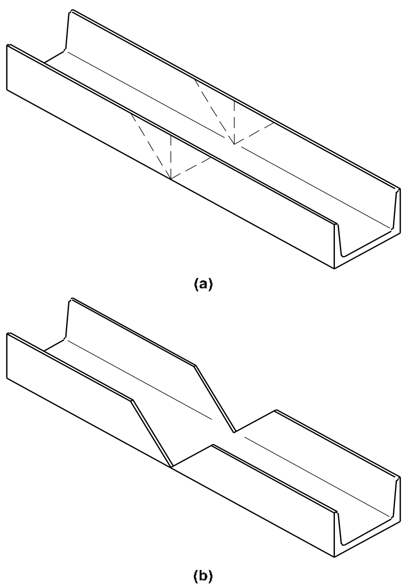
Fig 6



Fabricating 90° bend

1 Mark out the position of bend (Fig 7a & b).

Fig 7



2 Place wood blocks in trunking for support and make cuts with hacksaw.

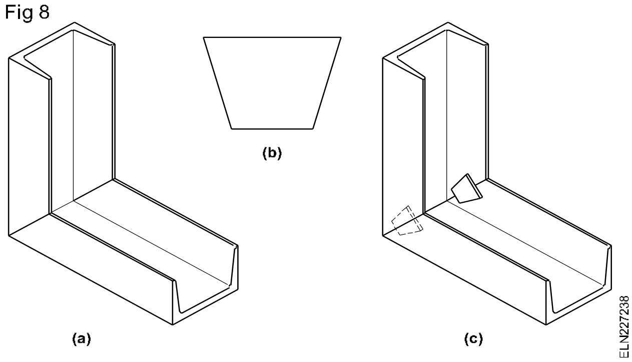
3 Remove sections and file smoothly.

4 Bend shape and adjust the fit as required (Fig 8a, b & c).

5 Make fish plates from PVC scrap (Fig 8b).

6 Make and secure the assembly with fish plate (Fig 8).

Fig 8



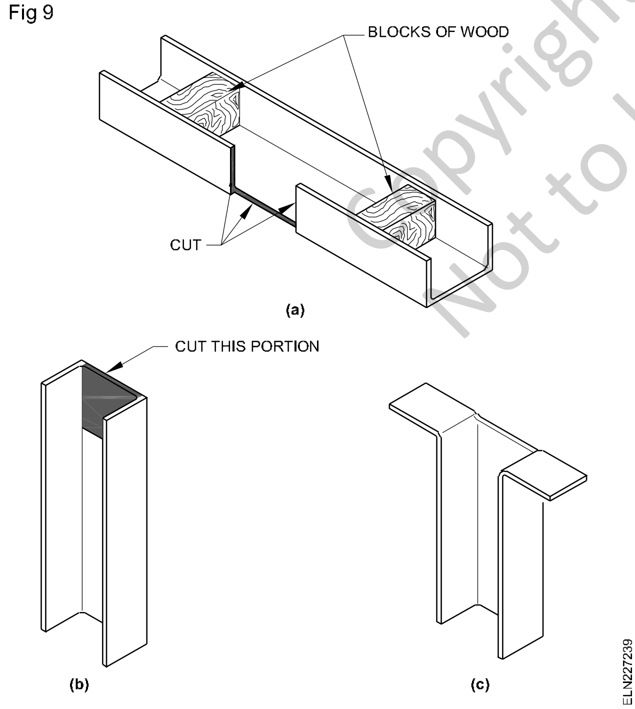
Fabricating a Tee junction

1 Mark out the position of tee using another piece of trunking to gauge width

2 Cut out the space for the tee (Fig 9a). Blocks of wood should be used to support section being cut.

3 In another piece cut away the section (Fig 9b) to form two legs (Fig 9c).

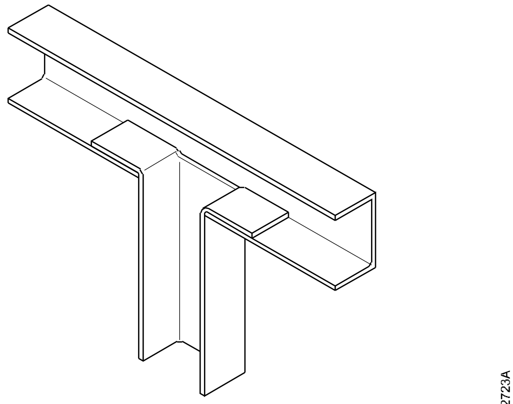
Fig 9



4 File edges smooth and remove burrs. Check fit and adjust as necessary.

5 Make, assemble and secure the Tee junction using suitable adhesive (Fig 10).

Fig 10



ASSEMBLEDTEE JUNCTION

Fabricating a cross junction

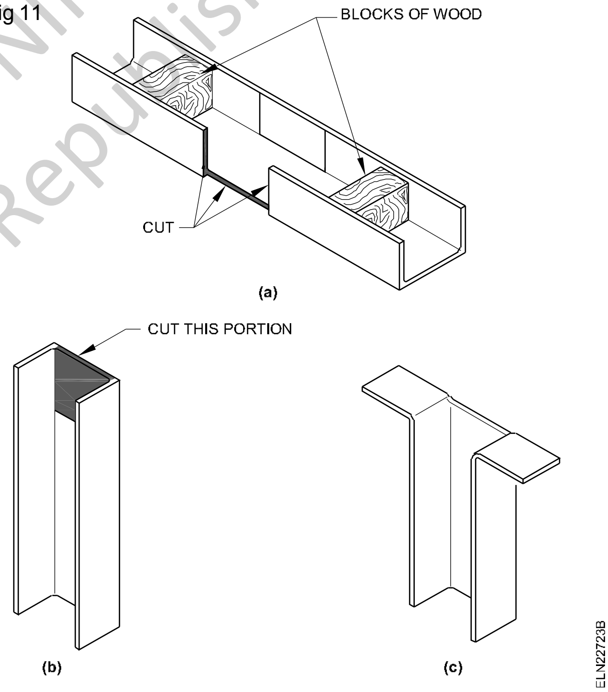
1 Mark the position of first set (Fig 11a).

2 Place blocks of wood in trunking for support and make cuts with hacksaw.

3 Remove section of trunking and file the edges.

4 Take another two pieces and cut away the section (Fig 11b) to from two legs (11c).

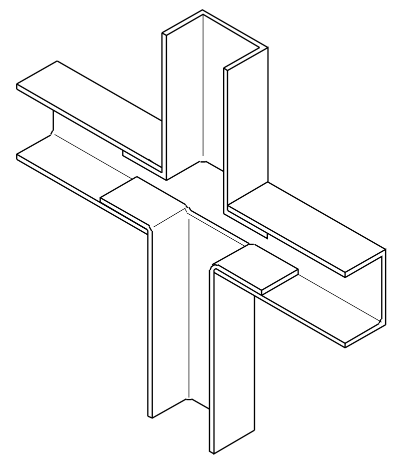
Fig 11



5 Make, assemble and secure the cross junction using suitable adhesive (Fig 12).

Installation of cables : Cables carrying the direct current or alternate current shall always be bunched seperately so that the outgoing and return cables are drawn in the same channel. Clamps shall be provided to hold the wires inside the channel at suitable intervals, so at the time of opening of the cover of channel, the wires do not fall out.

Fig 12



ASSEMBLED CROSS JUNCTION

Attachment of cover : Cover should be attached to channel in individual sections after drawing all wires inside. No screws or nails shall be used for fixing PVC capping (cover) to the casing (channel). The capping (cover) should be slided in through the grooves. Metallic capping (cover) shall be fixed by using cadmium plated screws in a staggered manner with axial spacing not exceeding 30cm.

Earth continuity conductor : Earth continuity conductor shall be drawn inside the casing and capping (channel) for earthing of all metallic boxes of the installation as well as for connecting to earthpin of the socket.

In case of metallic casing and capping channel, there shall be a metallic link between adjacent casing with screw connections, and also connections from end channel (casing) to earth terminal of metallic boxes/outlets.

Power wiring

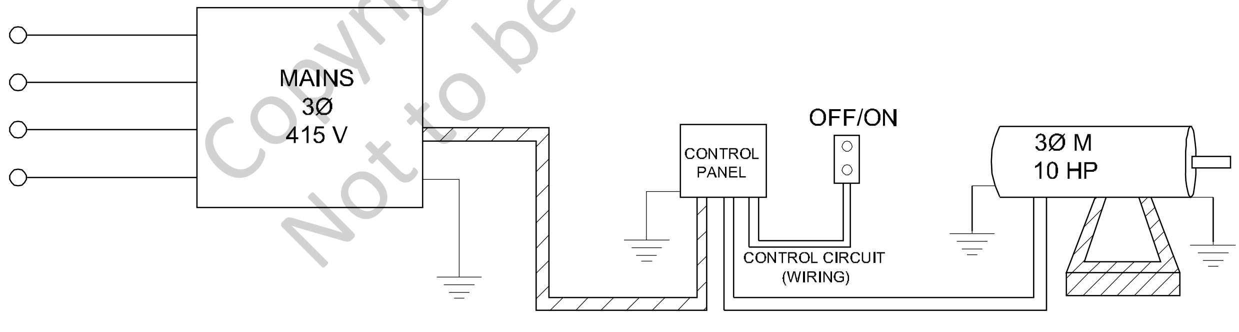
Objectives: At the end of this lesson you shall be able to
- **state the power, control, communication and entertainment wiring**
- **state the necessity of various wiring.**

A panel wiring diagram usually gives information about the relative position and arrangement of devices and terminals of the devices to help in installing or servicing the device.

Generally all the control panel / commercial / industrial wiring invariably consists of two sections viz control wiring and power wiring.

Fig 1 shows the typical layout diagram of a motor wiring. The control panel consisting of all the control and protective devices installed near to the power source and the load like, furnace, compressor etc, are installed away from the power source / panel boards.

Fig 1



POWER CIRCUIT (WIRING)

Power wiring is a high current carrying circuit which is wired to connect / disconnect the load like motors/ furnace through the protective devices like OLR and fuses etc..

Power wiring has to be done as per the guideline and rules specified in IE rules. The cable size depends on the load current and it varies according to the load.

The power and control cable should not be run into single conduit. As the current radiation influences the control cable, a seperate conduit to be provided for control and power cables.

Control wiring

Control wiring is a circuit which is wired to communicate the commands and other information between control devices and lighting.

Control wiring enables the control circuit for various control purpose. In a motor control unit the control circuit is wired and kept near to motor. In other system such as fire alarm, fire detector etc. The control circuit is wired seperately with low current carrying condutors and drawn seperately for easy maintenance.

Fire alarm

The purpose of fire alarm system is to provide an immediate alarm in case of any fire and to prevent loss of life, also to secure the immediate attention of fire fighting staff.

Fire detectors

The three principal fire detection method involve sensing the heat, presence of flame or smoke. The third method identifies the pre - fire condition that is a flammable gas detector, which is techniclaly not a fire detector and its use is limited to places where flammable gases are likely to be present.

I Heat detector

The three basic operating principles for heat detection are:

a Fusion detector (melting of a metal)

b Thermal expansion detector

c Electrical sensing

II Smoke detectors

There are three types of smoke detectors namely

1 Ionisation detector
2 Light - scattering smoke detector
3 Obscuration smoke detector.

III Flammable gas detector

A flammable gas detector is designed to measure the amount of flammable gas in the atmosphere. The gas mixture is drawn over a catalytic surface where oxidation i.e. combustion takes place. The combustion causes a rise in temperature of the surface which is measured by a decrease in its electrical resistance. The instruments are calibrated by considering pentane or heptane as reference gas. The readings are displayed in terms of percentage of lower explosive limit.

Control panel for fire alarm system

The control panel is the heart of the system through which the fire alarm system is monitored and alarm is initiated if any indication/signal is conveyed to the panel.

The working of the fire alarm system should be checked once in a month regularly.

The features of the control panel are the power supply, battery charging unit and control card.

Communication wiring

It is type of wiring which is used to transmit the voice, data, images and video etc to the desired places.

Some of examples are

- Telephone wiring
- Internet / LAN network wiring
- Cable TV and other entertainment wiring
- Data and security services wiring
- Telex/ Fax machines wiring

Faster and more reliable than ordinary phone wiring, low-cost, high-tech copper wiring should serve every room in the modern home. Its is required to carry voice, data and other services from where they enter the house to every room, and from any one room to any other.

Necessity of communication wiring

Unshielded twisted pair (UTP) copper information wiring often called structured wiring is used today for offices, schools and factories to provide local area networks (LANs), which allow computers to talk to one another and to receive and send Internet and high-speed computer data outside the facility.

Educated homebuyers-and homebuilders realize it is better to use the most advanced wiring technology up front, when installation is economical.

It's better to anticipate the homeowner's future needs by wiring the house with a state-of-the-art system while it is being built, and at the same time equip yourself with a powerful marketing tool.

The phone wiring of the past, often referred to as quad wiring because it has four copper wires, is now obsolete. Cat 5 or higher speed wiring has four twisted wire pairs, or eight wires.

Copper UTP Wiring

Copper UTP wiring contains eight color-coded conductors (four twisted pairs of copper wires). It offers greatly increased bandwidth compared with old-fashioned quad wiring.

The cable is small (roughly 3/16 inch in diameter), inexpensive and easy to pull, although it must be handled with care.

Advantages

Modern copper UTP wiring offers the following advantages:

Diversity

The Internet and computer communications, as well as ordinary phone signals, can be carried throughout the home on modern, inexpensive, high-speed, UTP cables. (To service a large number of TV channels, it is recommended to also run high-quality coaxial cable, such as quad-shielded RG-6.)

More phone numbers

Several phone numbers can be made available throughout the house. Actually, voice service requires very little bandwidth, and the addition of separate numbers is almost trivial.

Bandwidth

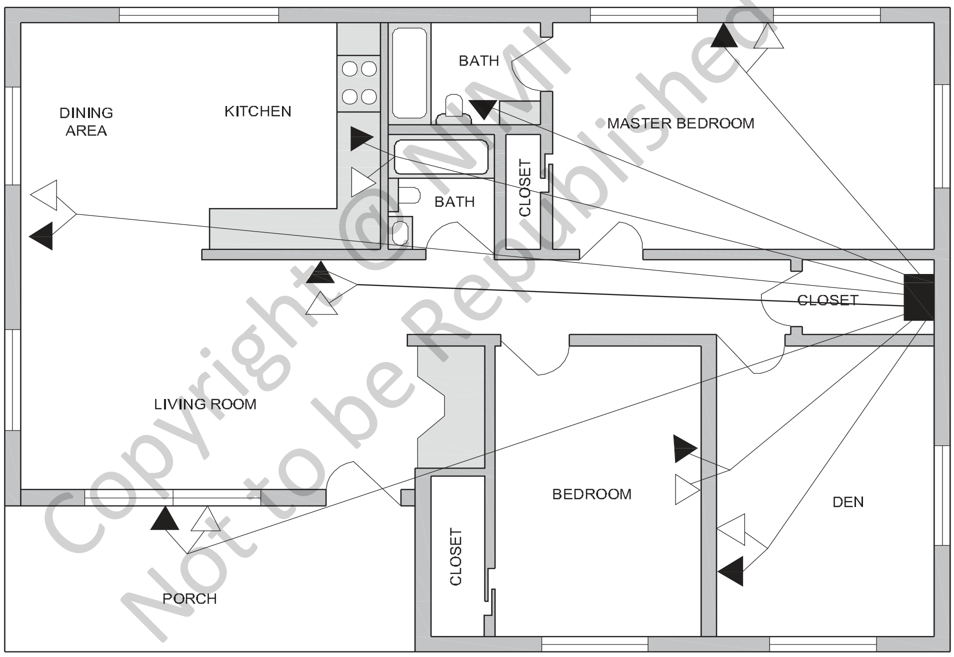
Bandwidth correlates with speed, and these bandwidths are many orders of magnitude greater than the bandwidth required for a "modern" 56 kbps (kilobits per second) modem.

New Services

The Internet is now available at high speed to many homes, but homebuyers are not able to take full advantage of it, if their wiring is inadequate. One high-capacity technology now being offered by local phone companies is DSL (digital subscriber line). And cable modems are being offered by cable TV companies that bring in the Internet on the same coaxial cable carrying the TV signals.

Fig 1 is a simplified plan of a small, two-bedroom, single-story house. Note that all the wiring radiates from a single distribution device the star pattern and there are multiple outlets in each major room, including the kitchen and the porch.

Fig 1



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Use 8-Pin Modular (RJ-45) Jacks (Fig 2)

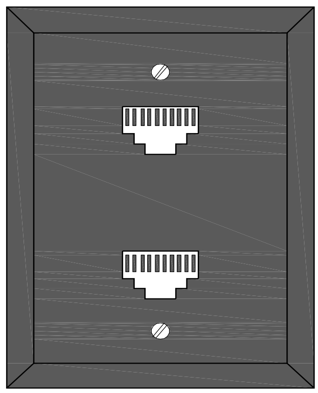
These devices provide connection points for all eight of the wires contained in the four twisted pairs.

Fig 2 (below) shows a wall outlet with two such jacks.

All connecting devices, central distribution device, plugs on the ends of cables, outlets, etc.-should be rated for the cable used.

Finally, the finished installation should be thoroughly tested.

Fig 2



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Video Cables

Although the industry is working toward an all-UTP solution for wiring residences, at this time it is prudent to also include conventional coaxial cable for video distribution, particularly cable TV. This is because it is difficult to predict whether many channels well over 100, for example-may become a reality in the near future, some channels of which will be the more bandwidth-consuming high-definition television (HDTV).

If coax is installed, quad-shielded RG-6 coax, with an all-copper center conductor, should be used for superior performance. (Copper-plated steel center conductors are also available, providing additional stiffness, but are unable to handle low-frequency currents used to power some devices.) A lesser grade, RG-59, should not be used.

Entertainment wiring

It is a type of wiring which is mainly used for entertainment or relaxation purpose.Example Home theatre wiring.

The nature and quality of wiring will not only determine the level of safety in home theatre room, but equally important, will have a noticeable impact on the video and sound quality of your system components.

Home Theatre Wiring Basics: Safety, planning, budgeting

When it comes to home theatre wiring, the guiding principle is...

- Do it safe
- Do it once
- Do it right

Safety: This is a most important aspect in any installation. Do not save on the wiring by using sub-standard cables.

With in-wall installations, Specially certified wires (UL-rated CL3 wires) should be used that comply with national standards for resistance to fire, chemicals, abrasion, and temperature extremes.

Planning: Planning is the key to future proofing the installation while avoiding costly alterations later on.

AV (Audio Video) equipment and speaker placement the room lighting requirements, networking, possible future additions, etc. are to be taken care of these will determine the quantity and placement of the various audio/video points in the room as well as the electrical needs for home theatre installation.

Finally, when it comes to estimating the required cable lengths, do not just calculate the linear lengths to complete your cable runs; allow for at least 20% extra to cover for possible errors and slack for terminations.

Budgeting: The wiring requirements during planning stage will determine the budget necessary for your home theater wiring project.

Home Theatre Speaker Wiring

Many fail to realize that home theatre wiring can have a noticeable impact on speaker performance. The greatest speakers will not sound their best with the use of inappropriate speaker wires or an incorrect wiring installation. In particular, selecting the correct speaker wire thickness is essential for the best speaker performance.

At the same time, keep in mind that some speaker manufacturers use non-standard connectors with their speakers; in these circumstances, use of optional third-part speaker wire and connectors may not always be an option unless you take the extreme route of splice your wiring.

Speaker Wire Size

Selecting the correct thickness for your home theater wiring is important as it affects the speakers' performance; it will impact the speakers' ability to deliver the explosive effects in home theatre sound.

The thickness of a wire conductive copper part is identified by its Wire Gauge, normally expressed either in AWG (American Wire Gauge) or SWG (British Standard Wire Gauge)

Single Room Installation

The thicker wire will help bring out fine musical detail in quality music systems, as well as deliver the explosive effects of surround sound.

In those situations where long speaker wire runs cannot be avoided, thicker wire helps reduce the overall resistance, and therefore amplifier load - leading to lower operating temperatures. This will result in improved sound quality and long-term stability.

After setting up a modestly priced home-theatre-in-a-box package, do not go for the more expensive thicker wire unless you plan an upgrade sometime in the future; using of gauge 16 speaker wire should suffice in this case.

Multi-Room Wiring

In a multi-room installation, long home theatre wire runs are inevitable; The suggested wire gauge to use in home theatre wiring is given below:

Distance between speaker and amplifier	Speaker Wire Gauge
Less than 50 feet	16
50 to 100 feet	14
100 to 150 feet	12
more than 150 feet	10

The 'length factor' is not the only issue to consider when determining the wire gauge to use. The speaker impedance should also be taken into account.

Connection Basics

Speakers and amplifiers/receivers normally come equipped with one of two types of connectors - spring terminals or binding post connectors.

Each speaker connection have two such terminals marked (+) and (-) to help you distinguish the two leads. Maintaining correct polarity all along your home theater wiring is important. For this reason, speaker wire and terminals are normally color coded black for the -ve terminal and red for +ve side.

Spring terminals will only accept pin connectors or tinned base wire ends. Instead, binding posts accept many types of connection, including pin, banana plug or spade.

Guidelines for Home theatre wiring & installation

- Do not run home theatre cables in close proximity or parallel to other electrical lines, nor run your wiring around power supplies as these can lead to interference issues with both your audio and video system components.

- Avoid splicing wiring at all cost, as it leads to a lowering in performance. In addition, always use direct speaker wire runs straight from amplifier to each speaker. This is the normal way of wiring the sound in the home theatre but in the case of a multi-room audio installation, some may simply skip on this and splice the speaker cable along the way. Doing so, may not only lead to a detrimental effect but equally important, makes fault tracing even more difficult later should problems arise.

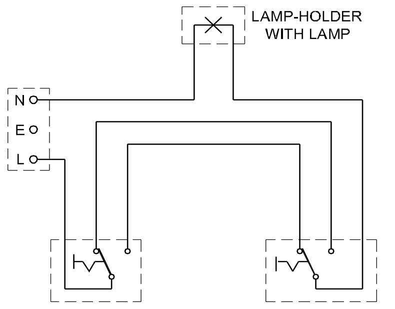
- Leave extra length at each end of the cable runs. And if home theatre wiring is part of a renovation project, it is also advisable to cover the extra cable lengths and termination/junction boxes. The plastering/painting process that follows can be really messy..

Special wiring circuits - Tunnel, corridor, godown and hostel wiring

Objectives: At the end of this lesson you shall be able to
- **state the difference between godown, tunnel and corridor, bank/hostel wirings**
- **draw the tunnel lighting / corridor / bank / hostel circuits**
- **prepare the mode chart for the above circuits.**

Staircase wiring: In wiring one lamp controlled with one switch in a simple wiring circuit to begin with. However,one lamp controlled with two switches from two different places, known an staircase wiring in the very basic wiring. Fig 1 shows such a wiring where two double pole switches are used to control one lamp individually.

Fig 1



STAIRCASE–WIRING DIAGRAM

In the case of godown wiring we have seen that as you move inside the godown, you can switch on a lamp ahead of you while the light behind you is put off. The same process in the reverse order takes place while moving out of the godown.

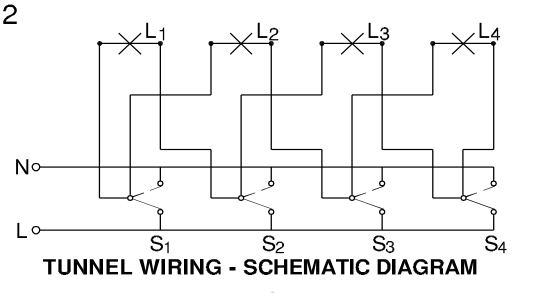
But one light will not be sufficient to give enough illumination in the case of tunnels where darkness is more. Hence, the wiring circuit for a tunnel needs at least two lights to be 'ON' at a time while a person moves inside a tunnel and goes out.

Whereas in the case of corridor wiring the corridor may have a number of rooms occupied by different persons. When one moves toward his room, he needs a forward light to do so. The moment he finds the room and opens it, he may not need the corridor light. Then there should be an arrangement to switch off the light left behind the forward moving person and at the same time there should be a provision to switch off the light in front of his room. Such an arrangement is incorporated in corridor wiring.

On the other hand in bank/jail/hostel, there may be a number of lights having individual controls. There should be a provision for the security staff/warden to switch ON all the lights where they are all OFF. Such a provision is incorporated in the bank / jail / hostel wiring.

Tunnel lighting circuit (Fig 2)

Fig 2



TUNNEL WIRING - SCHEMATIC DIAGRAM

In tunnel wiring a person walking along the tunnel can successively light behind two lamps ahead and put off a lamp behind with one switch.

All switches are two-way switches.

Caution: This circuit is not in accordance with IE rules as the phase and neutral come in the same switch. So care should be taken while connecting the wires.

The mode of operation of the switches and the consequent lighting position are shown below.

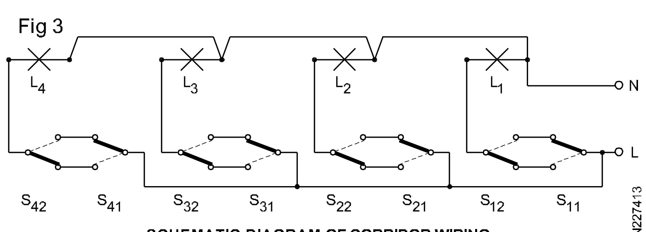
Mode chart for tunnel wiring

SWITCHES				LIGHTS			
S_1	S_2	S_3	S_4	L_1	L_2	L_3	L_4
✓	✗	✗	✗	✓	✓	✗	✗
✓	✓	✗	✗	✗	✓	✓	✗
✓	✓	✓	✗	✗	✗	✓	✓
✓	✓	✓	✓	✗	✗	✗	✗

MODE CHART FOR TUNNEL WIRING

Corridor wiring (Fig 3)

In this circuit, operating the first switch in one set makes the first light to switch on while operating the 2nd switch in the first set switches off the first light. This sequence goes on as explained in the mode chart.



SCHEMATIC DIAGRAM OF CORRIDOR WIRING

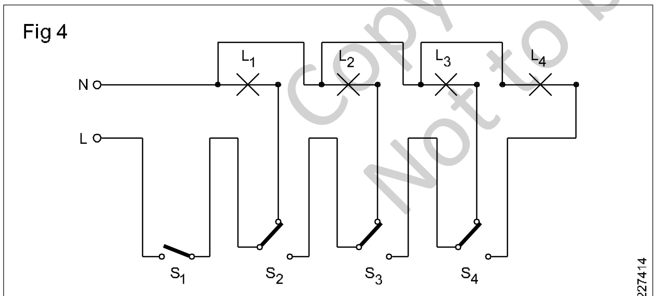
Switch lamps chart

SWITCHES								LAMPS			
Ist SET		2nd SET		3rd SET		4th SET		L_1	L_2	L_3	L_4
S_{11}	S_{12}	S_{21}	S_{22}	S_{31}	S_{32}	S_{41}	S_{42}				
ON	–	–	–	–	–	–	–	✓	✗	✗	✗
ON	OFF	–	–	–	–	–	–	✗	✗	✗	✗
ON	OFF	ON	–	–	–	–	–	✗	✓	✗	✗
ON	OFF	ON	OFF	–	–	–	–	✗	✗	✗	✗
ON	OFF	ON	OFF	ON	–	–	–	✗	✗	✓	✗
ON	OFF	ON	OFF	ON	OFF	–	–	✗	✗	✗	✗
ON	OFF	ON	OFF	ON	OFF	ON	–	✗	✗	✗	✓
ON	OFF	ON	OFF	ON	OFF	ON	OFF	✗	✗	✗	✗

MODE CHART FOR CORRIDOR WIRING

Godown lighting circuit

Let us consider a godown lighting circuit (Fig 4) having three lamps L_1, L_2, L_3 and L_4 which are to be controlled such that if one moves in a godown in either direction he can switch ON one light after the other in the forward direction while the lamp which was lighted earlier gets switched OFF. In an arrangement. S_1 is a one way switch, S_2, S_3 and S_4 are two-way switches.



CIRCUIT DIAGRAM

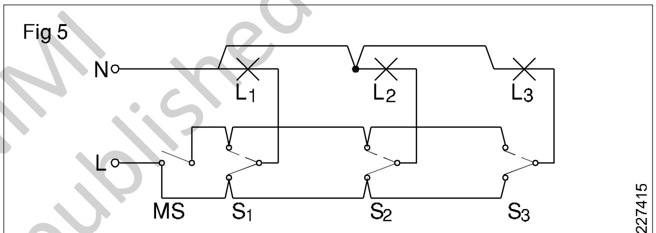
While coming back from the godown when the person switches off the light 4, then the light 3 will be on and give light for his return movement. When he leaves the godown all the lights could be switched 'off' by operating switch S_1.

The following chart gives the mode of operation of the switches and lights. Trainees are advised to make the return mode chart.

Mode chart for godown wiring

Switches				Lights			
S_1	S_2	S_3	S_4	L_1	L_2	L_3	L_4
ON	OFF	OFF	OFF	ON	-	-	-
ON	ON	OFF	OFF	-	ON	-	-
ON	ON	ON	OFF	-	-	ON	-
ON	ON	ON	ON	-	-	-	ON

Bank / jail / hostel wiring (Fig 5)



SCHEMATIC DIAGRAM OF JAIL WIRING

The master switch (MS) could be operated by the warden to make all the lights ON when they are all OFF.

Intermediate switch - specification and application in lighting circuit

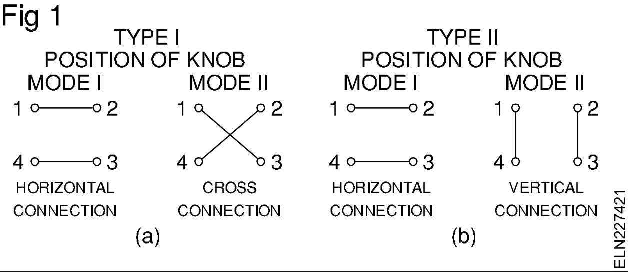
Objectives: At the end of this lesson you shall be able to
- **identify the features and specify an intermediate switch**
- **draw diagrams of a lighting circuit using intermediate switches.**

An intermediate switch is a special type of switch having four terminals for connection. This switch is commonly used to control a lamp or load from three or more positions as encountered in the lighting of staircases, corridors, bedrooms.

Specifications of an intermediate switch

These switches are available in the market with two possible change over types of connections Figs 1a and 1b.

Fig 1



Accordingly the specification should contain the following information.

- Type of mounting
- Voltage rating
- Current rating
- Type of connection

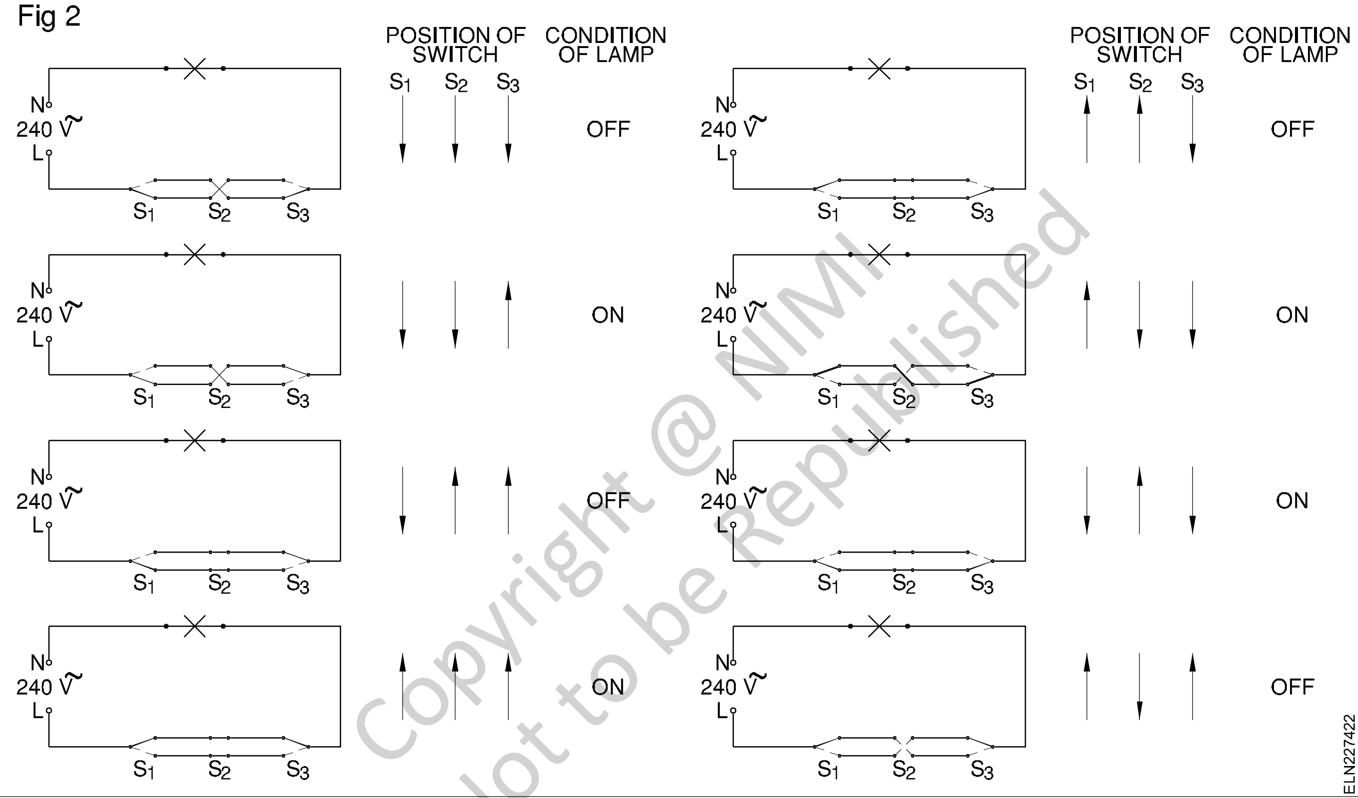
Example

Flush mounting intermediate switch 250 V 6 A horizontal and cross connection.

Circuit connections

For controlling a lamp from three locations, one intermediate switch and 2 two-way switches could be used (Fig 2). Knob positions of the switches and the conditions of the lamp are also given along with Figure 2 for easy understanding.

Fig 2



To control a lamp from three locations, three intermediate switches instead of a two two-way switches can also be used. (But, in practice, they are not used since it is very expensive).

Schematic diagrams (Figs 3 and 4) shows the method of controlling a lamp from three locations using three intermediate switches having horizontal and cross/ vertical connection respectively.

Fig 3

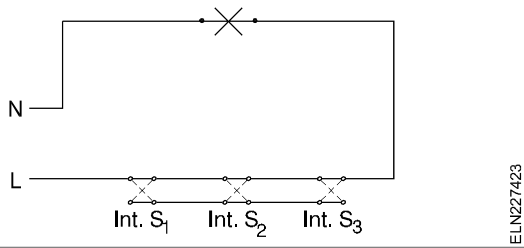
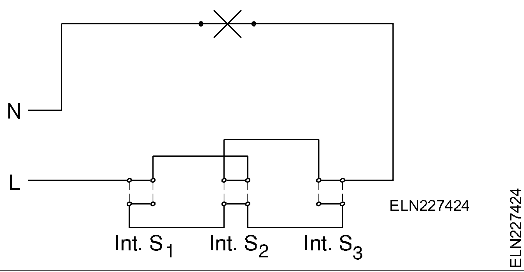


Fig 4



The schematic diagram (Fig 5) is for controlling one lamp from five locations using two two-way switches and three intermediate switches is given below.

In the schematic diagram (Fig 6) is for controlling one lamp from 3 positions with a master control as a security control switch. The lamp is controlled independently from three places by switches S_1, S_2 and S_3. When the master switch

'M' is 'ON' the lamp is permanently 'ON'and cannot be controlled by switches S_1, S_2 and S_3.

Fig 5

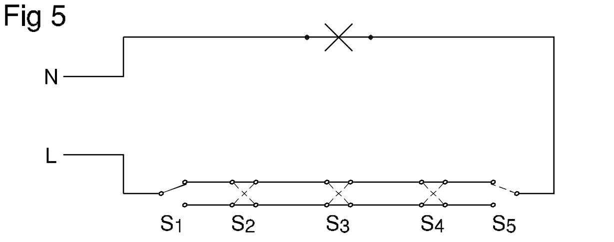
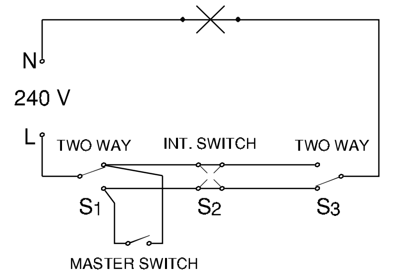
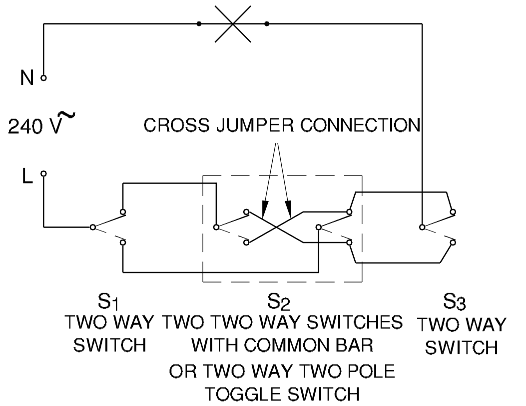


Fig 6



As intermediate switches are costly two numbers of two-way switches can be linked through a common bar and can be used as an intermediate switch (Fig 7). This circuit controls one lamp from 3 places.

Fig 7



IE Regulation for main switch and distribution board

Objectives: At the end of this lesson you will be able to
- **state the I E regulations/ B I S recommendations/ NE Code of practice with regard to the main switch and distribution fuse box.**

Reception and distribution of main supply

There shall be a circuit breaker or a linked switch with fuse in each live conductor of the supply mains at the point of entry.

The neutral wire should not have any break in the form of switch or fuse unit. In the main switch, the neutral conductor should be marked clearly.

The main switchgear shall be located in a place where it is accessible and should be near to the terminating point of the service line.

Main switches and switchboards

Reference BIS 732-1963 and NE code.

All main switches shall be either of metal-clad enclosed pattern or of any insulated enclosed pattern which shall be fixed at close proximity to the point of entry of supply.

Location

Switchboards shall not be erected above gas stoves or sinks, or within 2.5 m of any washing unit in the washing rooms or laundries, or in bathrooms, lavatories, toilets, or kitchens.

In the case of switchboards unavoidably fixed in places likely to be exposed to atmospheric weather, the outer casing shall be weatherproof and shall be provided with glands or bushings or adapted to receive screwed conduit, according to the manner in which the cables are run.

Metal-clad switchgears shall preferably be mounted on any of the following types of boards.

Hinged type metal boards

These shall consist of a box made of sheet metal not less than 2 mm thick and shall be provided with a hinged cover to enable the board to swing open for examination of the wiring at the back.

The joints shall be welded. The board shall be securely fixed to the wall by means of rag bolts, plugs, or wooden gutties and shall be provided with a locking arrangement and an earthing stud. All wires passing through the metal board shall be bushed. Alternatively, hinged type metal boards shall be made of sheet covering mounted on channel or angle iron frames.

Such types of boards are particularly suitable for small switchboards for mounting metal-clad switchgears connected to supply at low voltages.

Fixed type metal boards

These shall consist of an angle or channel iron frame fixed on the wall or on the floor and supported on the wall at the top, if necessary. There shall be a clear distance of one metre in front of the switchboard.

Such types of boards are particularly suitable for large switchboards for mounting large number of switchgears or higher capacity metal-clad switchgear or both.

Teak wood boards

For small installations connected to a single phase 240 volts supply, teak wood boards may be used as main boards or sub-boards. These shall be of seasoned teak or other durable wood with solid back impregnated with varnish of approved quality with all joints dovetailed.

Thoroughly protected both inside and outside with good insulating varnish conforming to IS:347-1952 and of not less than 6.5 mm thickness, shall be provided at the back for attachment of incoming and outgoing cables. There shall be a clear distance of not less than 2.5 cm between the teak wood board and the cover,

Recessing of boards

Where so specified, the switchboards shall be recessed in the wall. The front shall be fitted with a hinged panel of teak wood or other suitable materials, such as Bakelite, or with unbreakable glass doors in teak wood frames with locking arrangement, the other surface of the doors being flush with the walls. Ample room shall be provided at the back for connection and at the front between the switchgear mountings.

Arrangement of apparatus

Equipment which is on the front of a switchboard shall be so arranged that inadvertent personal contact with live parts is unlikely during the manipulation of switches, changing of fuses or like operation.

No apparatus shall project beyond any edge of the panel. No fuse body shall be mounted into 2.5 cm of any edge of the panel and no hole other than the holes by means of which the panel is fixed shall be drilled closer than 1.3 cm from any edge of the panel.

In every case in which switches and fuses are fitted on the same pole, these fuses shall be so arranged that the fuses are not live when their respective switches are in the 'off' position.

No fuses other than the fuses in the instrument circuit shall be fixed on the back of or behind a switchboard panel or frame.

Marking of apparatus

Where a board is connected to a voltage higher than 250 volts, all the apparatus mounted on it shall be marked in the following colours to indicate the different poles or phases to which the apparatus or its different terminals may have been connected.

Alternating current

Three phases	– red, yellow and blue.
Neutral	– black.

Where three-phase, 4-wire wiring is done, the neutral shall be in one colour and the other three wires in another colour.

Where a board has more than one switch, each such switch shall be marked to indicate which section of the installation it controls. The main switch shall be marked as such and where there is more than one main switch in the building, each such switch shall be marked to indicate which section of the installation it controls.

Main and branch distribution boards

The main and branch distribution boards shall be of any type mentioned here.

The main distribution board shall be provided with a switch or circuit-breaker on each pole of each circuit, a fuse on the phase or live conductor and a link on the neutral or earthed conductor of each circuit. The switches shall always be linked.

Branch distribution boards shall be provided with a fuse on the live conductor of each circuit and the earthed neutral conductor shall be connected to a common link and be capable of being disconnected individually for testing purposes. One spare circuit of the same capacity shall be provided on each branch distribution board. Lights and fans may be wired on a common circuit. Such sub-circuit shall not have more than a total of ten points of lights, fans and socket outlets. The load of such circuit shall be restricted to **800 watts**. If a separate fan circuit is adopted, the number of fans in the circuit shall not exceed ten.

Power sub-circuits

The outlet shall be provided according to the load design for these circuits but in no case shall there be more than two outlets on each circuit. The load on each power sub-circuit should be restricted to **3000 watts.**

Installation of distribution boards

- The distribution fuse-boards shall be located as near as possible to the centre of the load they are intended to control.
- Distribution boards shall be fixed at a height not more than 2 metres from the floor level.
- These shall be fixed on suitable stanchion or wall and shall be accessible for replacement of fuses.
- These shall be of either metal-clad type or all-insulated type. But, if exposed to weather or damp situations, they shall be of weatherproof type and, if installed where exposed to explosive dust, vapour or gas, they shall be of flame proof type.
- Where there are two or more distribution fuse-boards in feeding low voltage circuits and fed from a supply at medium voltage, these distribution boards shall be:
  – fixed not less than 2 m apart; or
  – arranged so that it is not possible to open two at a time, namely, they are interlocked and the metal case is marked 'Danger 415 Volts'; or
  – installed in a room or enclosure accessible to only authorized persons.
- All distribution boards shall be marked 'Lighting' or 'Power' as the case may be and also marked with the voltage and number of phases of the supply. Each shall be provided with a circuit list giving details of each circuit with controls, the current rating and its size of fuse-element.

Wiring of distribution boards

In wiring branch distribution board, the total load of the consuming devices shall be divided, as far as possible evenly between branch circuits.

Cables shall be connected to a terminal only by soldered or welded or crimped lugs using suitable sleeve or lugs or ferrules unless the terminal is of such a form that it is possible to securely clamp them without cutting away cable strands.

Fuses

a A fuse carrier shall not be fitted with a fuse element of higher rating than that for which the carrier is designed.

b The current rating of a fuse shall not exceed the current rating of the smallest cable in the circuit protected by the fuse.

c Every fuse shall have in its own case or cover, or in an adjacent conspicuous position, an indelible indication of its appropriate current rating for the protection of the circuit which it controls.

Selection of size of conductor

The size of conductors of circuits shall be so selected that the drop in voltage from the consumer's terminals in a public supply (or from the bus-bars of the main switch-board controlling the various circuits in a private generation plant) to any point on the installation does not exceed 3 per cent of the voltage at the consumer's terminals.

In each circuit or sub-circuit the fuse shall be selected to match the cable rating to ensure the desired production.

All conductors shall be of copper or aluminium. The conductor for final sub-circuit for fan and light wiring shall have a nominal cross-sectional area of not less than 1.00 mm^2 copper and 1.50 mm^2 aluminium. The cross-sectional areas of conductors for power wiring shall be not less than 2.5 mm^2 copper, 4.00 mm^2 aluminium. The minimum cross-sectional area of conductors of flexible cords shall be 0.50 mm^2 copper.

Branch switches

Where the supply is derived from a three-wire or four-wire source and distribution is done on the two wire system, all the branch switches shall be placed in the outer or live conductor of the circuit and no single phase switch or fuse shall be inserted in the middle wire, earth or earthed neutral conductor of the circuit.

Passing through walls and floors

Where conductors pass through walls the conductor shall be carried either in a rigid steel conduit or a rigid non-metallic conduit or in a porcelain tube of such a size which permits easy drawing in. The end of the conduit shall be neatly bushed with porcelain, wood or other suitable material.This steel conduit shall be earthed andsecurely bushed.

Where a wall tube passes outside a building so as to be exposed to the weather, the outer end shall be bell mouthed and turned downwards and properly bushed on the open end.

Fixing to walls and ceilings

Plugs for ordinary walls or ceilings shall be of well seasoned teak or other suitable hardwood not less than 5 cm long and 2.5 cm square on the inner end and 2 cm square on the outer end. They shall be cemented into walls to within 6.5 cm of the surface, the remainder being finished according to the nature of the surface with plaster .

In the case of new buildings, wherever possible, teak wood plugs shall be fixed in the walls before they are plastered. To achieve neatness, plugging of walls or ceilings may be done by a suitable type of asbestos, metallic or fibre fixing plug.

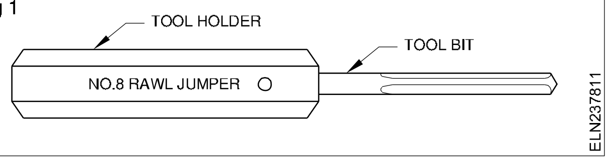
Energy meter board installation

Objectives: At the end of this lesson, you shall be able to
- **state the purpose and method of use of a rawl jumper**
- **state the type of filler materials used for rawl jumper holes**
- **state the shape and use of wooden gutties**
- **describe the method of preparing pipe jumpers**
- **state the precautions while making through holes in the wall.**

Purpose of Rawl jumper

The purpose of the rawl jumper is to make holes in the brick and concrete walls or ceiling for fixing the batten or round blocks. It consists of two parts. Tool bit and tool holder as shown in Fig 1. The tool bit is made of carbon steel whereas the holder is made of mild steel.

Fig 1

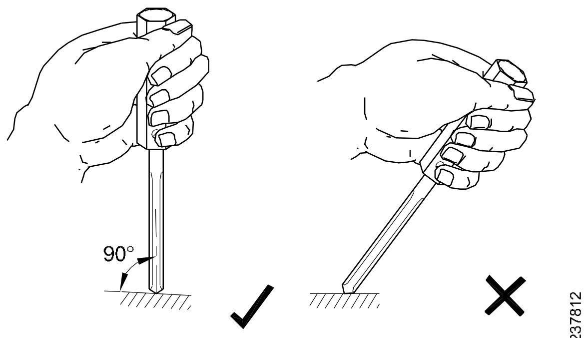


The tool bit is fluted to allow maximum debris clearance and ensure fast penetration. The shank of the tool bit is tapered to fit into the tool holder.

There are different sizes available. Numbers 8, 10, 12, and 14 are used in electrical work. As the number increases the size of the bit as well as the size of the holder decreases

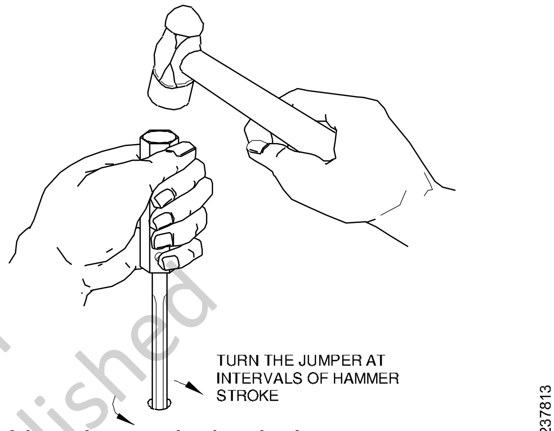
While making holes, the rawl jumper is held at right angles to the wall surface and hit by a hammer. The rawl jumper is turned clockwise and anticlockwise by 90^o between hits as shown in Fig 3 to enable removal of debris and to avoid breakage of the tool bit. Care should be taken to see that the mushroom is removed from the tool holder head after every use. (Fig 2)

Fig 2



RAWL BIT SHOULD BE KEPT AT RIGHT ANGLE TO THE WALL SURFACE

Fig 3



CORRECT METHOD OF USING RAWL JUMPER

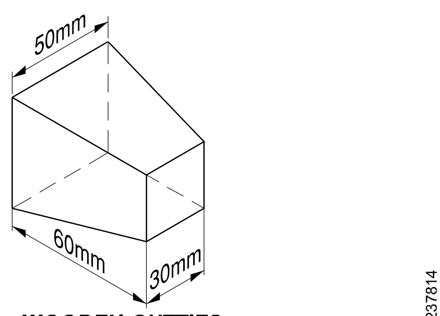
Types of filler materials

Saw dust, fibre, plastic, asbestos, and some times nylon plugs are inserted into the holes. The batten or round block etc are fixed by the screws penetrated into the plug which expands and grips the wall firmly.Rawl plugs are only suitable for rigid walls. But for non-rigid walls, wooden gutties are used.

Shape of the wooden guttie

A wooden guttie is made up of teak wood. The shape of the guttie : Normally, it is 50 mm sq. on one side and gradually tapered to 30 mm sq. at the other side. The length on the side will be 60 mm. The size of the guttie depends upon the load it has to carry. After fixing wooden gutties the cement requires atleast 24 hours of curing before screws could be used on them.(Fig 4)

Fig 4



WOODEN GUTTIES

Method of fixing

A recess hole of a size larger than the size of guttie is made in the wall with a cold chisel and hammer. Then water is sprinkled inside the hole and a small quantity of cement mortar is inserted into the hole. Then the larger area side of the guttie is inserted into the hole and positioned such that the smaller area side is flush with the wall. Fill the hole with cement mortar.

Allow it to set for a day. After 4 hours of fixing, water is sprinkled on the cemented area after every one hour duration for curing. After 24 hours of curing, fix the board or batten or round block with a screw driven into the guttie.

Pipe jumper

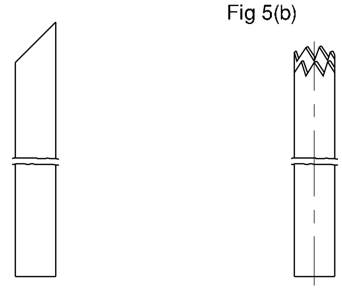
A pipe jumper is used along with a hammer to make through holes in walls during wiring. The diameter of the pipe jumper depends upon the diameter of the pipe to be accommodated in the wall and the length depends upon the wall thickness.

Preparing the pipe jumper

One method of making a pipe jumper is to use a GI pipe of suitable size and to have a slant cut by a hacksaw. (Fig 5 a).

The second method of preparing a pipe jumper is to cut the teeth on one end of the pipe Fig 5(b) in the form of a crown.

Fig 5(a) Fig 5(b)



PIPE JUMPERS

ELN237815

While making through holes in the walls, the following precautions should be observed.

From time to time, between hammer blows, rotate as well as pull out the pipe jumper from the hole to remove the broken masonry pieces. This enables free movement of the pipe jumper.

Slow down the hammer strokes when the pipe jumper reaches nearer to the other end of the wall. Otherwise it causes larger sized plaster to fall down from the other side of the wall.

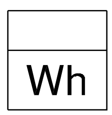
While making a hole on a wall in which concealed wiring exists, ascertain the lay out of the existing wiring on the wall and then make a hole. Otherwise switch off the mains to avoid electrocution.

NE code of practice and IE Rules for energy meter installation

Objectives: At the end of the lesson you shall be able to
- **interpret BIS symbols for single and 3-phase energy meters**
- **state the BIS recommendations pertaining to the mounting of the energy meters.**

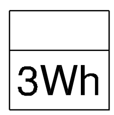
The BIS symbols for energy meters are given in Figs 1a and 1b

Fig 1a



SINGLE PHASE ENERGY METER

Fig 1b



THREE PHASE ENERGY METER

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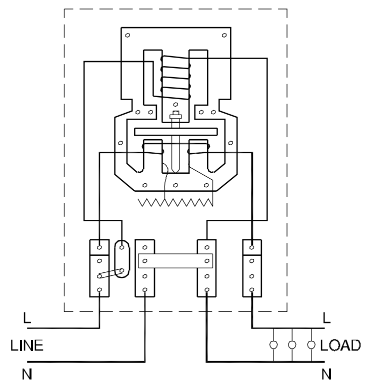
Internal circuit diagrams of single phase and three phase meters are Fig 2 and 3 respectively.

In earlier domestic installations the service mains were brought inside the consumer premises and first connected to the IC cutouts, then to the energy meter and to the consumer main switch (Fig 4a and 4b)

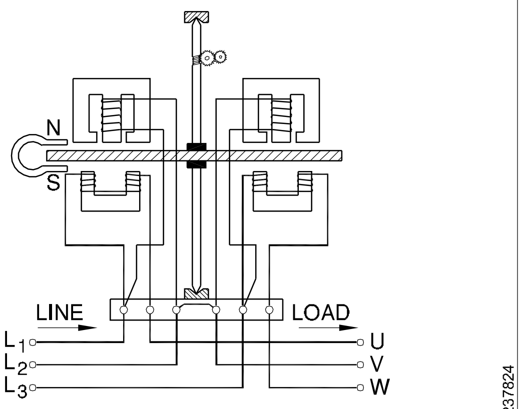
Fig 2



INTERNAL CONNECTION OF SINGLE PHASE ENERGY METER

ELN237822

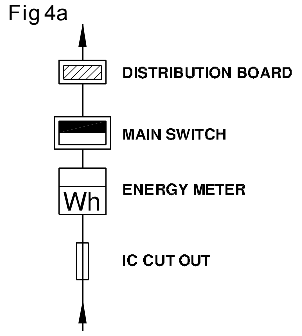
Fig 3



INTERNAL CONNECTIONS OF THREE PHASE ENERGY METER

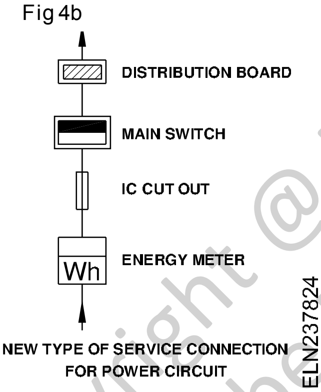
However, to avoid pilferage of electricity, certain electricity boards insist that the service connections should first be connected to the energy meter, then to the I C cutout and then to the consumer main switch. In all the cases the neutral should be directly connected from the outgoing terminals of the energy meter to the consumer main switch.(Fig 4b)

Fig 4a



OLD TYPE OF SERVICE CONNECTION FOR POWER CIRCUIT

Fig 4b



NEW TYPE OF SERVICE CONNECTION FOR POWER CIRCUIT

Precautions while installing energy meters

- Energy meters which are tested and approved by the local electricity board authorities only should be used.
- Energy meters should be used in vertical position only.
- Connections for incoming and outgoing supply should be made according to the manufacturer's instructions/ connection diagram which will be available on the inner side of the terminal plate of the energy meters.

NE code of practice and IE rules for energy meter installation

Energy meters shall be installed at such a place which is readily accessible to both the owner of the building and the authorised representatives of the supply authority.

It should be installed at a height where it is convenient to note the meter reading; it should preferably be not installed below 1 m from the ground. The energy meters should either be provided with a protective covering, enclosing them completely, except the glass window through which the readings are noted or should be mounted inside a completely enclosed panel provided with hinged or sliding doors with arrangement for locking it.

Any meter placed upon the consumer's premises shall be of appropriate capacity and shall be deemed to be correct if its limits of error do not exceed 3% above or below absolute accuracy at all loads in excess of one tenth of full loads and up to full load.

No meter shall register at no load.

General instructions

The body of the energy meter should be earthed to the general mass of earth using a proper size of earth continuity conductor depending upon the current capacity of the installation.

For multi-storeyed buildings which consist of a number of offices or commercial centres or flats occupying various areas, the electrical load for each of them is metered separately. In such cases, all the energy meters are located in a meter room which is normally situated on the ground floor.

Estimation and cost of material for wiring installation

Objectives: At the end of this lesson, you will be able to
- **state the points to be considered before taking up domestic wiring**
- **calculate the load(s) and select the number of sub(branch) circuits**
- **estimate the load in a circuit**
- **select proper cable size for branch main circuits and the supply system**
- **estimate and list out the accessories for given wiring installation.**

Points to be considered before taking up domestic wiring

The following points shall be noted particularly in respect of domestic dwellings.

Before starting the wiring installation, information should be exchanged between the owner of the building or architect and the local supply authority in respect of tariffs applicable, types of apparatus that may be connected under each tariff, requirement of space for installing meters, switches, service lines etc. and for the total load requirement of lights, fans and power.

While planning an installation, consideration should be given to the anticipated increase in the use of electricity for lighting, general purpose socket-outlet, kitchen, heating etc. Otherwise, the householder may be tempted to carry out extension of the installation himself or to rely upon the use of multiplug adaptors and long flexible cords, both of which are against the electric supply rules. Fundamentally safe installation may be rendered dangerous, if extended in this way.

Hence the National Electricity Code suggests the following schedule.

Number of points in branch circuits: The recommended yardstick for dwelling units for determining the number of points is given in Table 1.

Table 1

Number of points for dwelling units

Sl.No.	Description	Area of the main dwelling unit (m^2)				
		35	45	55	85	140
1	Light points	7	8	10	12	17
2	Ceiling fans (See NOTE below.)	2-2	3-2	4-3	5-4	7-5
3	5 A socket outlets	2	3	4	5	7
4	15 A socket outlets	–	1	2	3	4
5	Call bell (buzzer)	–	–	1	1	1

NOTE: **The figures in the table against Sl.No.2 indicate the recommended number of points and the number of fans. Example: For the main dwelling unit of 55m^2, 4 points with 3 fans are recommended.**

Number of socket outlets

The recommended schedule of socket outlets for the various sub-units of a domestic dwelling are given in Table 2.

Table 2

Description	Number of socket outlets	
	6A	16A
Bedroom	2 to 3	1
Living room	2 to 3	2
Kitchen	1	2
Dining room	2	1
Garage	1	1
For refrigerator	–	1
For air-conditioner	–	1 (for each)
Verandah	1 per 10 m^2	1
Bathroom	1	1

Note that the BIS has changed the ampere specification of socket and plugs as 6 amps and 16 amps,whereas the earlier BIS references is for 5 amps and 15 amps. Further the manufacturers are yet to change their product specification from 5 A/15 A to 6 A/16 A. Hence the trainees are advised to use the new reference with due care for old reference also.

Electrical installation in a new building should normally begin immediately on the completion of the main structural building work. For conduit wiring system, the work should start before finishing work like plastering has begun. For surface wiring system, however, work should begin before final finishing work like white washing, painting etc.

Usually, no installation work should start until the building is reasonably weatherproof, but where electric wiring is to be concealed within the structures, the necessary conduits and ducts should be positioned after the shuttering is in place and before the concrete is poured, provision being made to protect conduits from damage. For this purpose, sufficient coordination shall be ensured amongst the concerned parties.

Sub(branch) circuits

Stated below are some of the important points from the above information sheet.

Sub-circuits may be divided into two groups

a Light and fan sub-circuits.

b Power sub-circuit.

Separate distribution boards shall be provided for light and power.

Each circuit shall be provided with a fuse in the phase wire and the neutral conductor shall be connected to a common link with disconnecting arrangement for testing.

The load on the light and fan sub- circuits should be restricted to 800 watts or ten points considering each light, fan and 6 amps sockets as points.

A minimum of two lighting sub-circuits shall be provided in each house so that in case of fault in one sub-circuit, the whole house is not plunged in total darkness.

The load on power circuits should be restricted to 3000 watts having not more than two socket outlets.

Estimation of load requirements

Electrical installation in domestic dwellings is basically designed to cater to light and fan loads and for electrical appliances and gadgets. In estimating the current to be carried by any branch circuit, unless the actual values are known, these shall be calculated based on the following recommended ratings.

Item	Recommended rating (in watts)
Incandescent lamps	60
Ceiling fans	60
Table fans	60
6 A, 3-pin socket-outlet points	100
Fluorescent tubes	
Length 600 mm	25
1200 mm	50
1500 mm	90
Power socket outlets (16 A)	1000

Example

Estimate the cost of material for wiring PVC channel for an office room having 2 lamps 1 fan one 6A socket outlet.

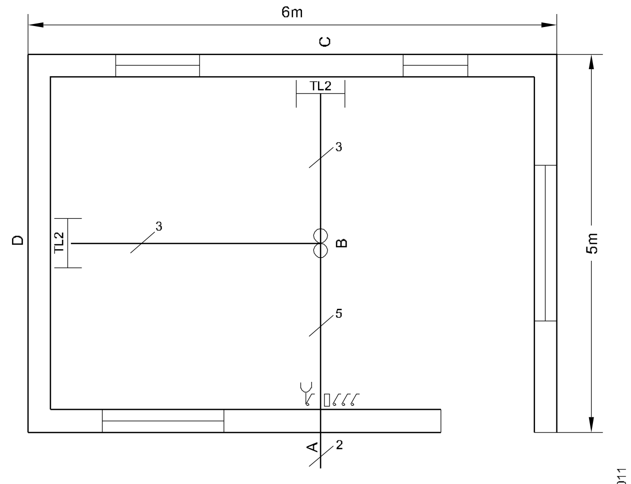
To estimate the cost of material the electrician has to follow these steps:

Type of wiring to be decided- PVC channel (casing and capping - given).

Position of the electrical points/Loads has to be decided as per the requirment.

Layout of the office has to be prepared (Fig 1).

Fig 1



LAYOUT DIAGRAM OF AN OFFICE ROOM

Total load to be calculated, In the given example

i) Tube 2nos x 50 W	= 100 W	
ii) Fan1no x 60 W	= 60 W	
iii) 6A socket 1 no	= 100 W	
	260 W	

circuit/connection diagram for the room has to be developed.

Based on the layout and circuit diagram calculate the length of PVC channel required.

1) Length of PVC channel

in Roof	= 5 +3 = 8m	
2) Vertical drops	= 0.5 +0.5 +2.0 = 3.0m	
Total	= 8+ 3.0	= 11.0 m
3) Add 10% tolerance	= 1.1 m	
	12.1 m	

7 Calculate the length of wire and size of wire based on layout, circuit diagram and load. In the given example,the total load is 260W the current taken by the total load are

$$I = \frac{p}{v \text{ x } \cos\theta} = \frac{260}{240 \text{ x } 0.8} = 1.35A$$

Hence PVC copper flexible 1sqmm wire is enough to this circuit/room. However since this wiring come in the catagory of commercial wiring, for safe-side, we can choose 1.5sq mm PVC insulated copper flexible wire.

Assume vertical drop is 0.5 m for tube lights and 2m for switch board then the length of wire required is

From A to B and vertical drop	= (2.5 +2)m x 5	= 22.5 m
From B to C and vertical drop	= (2.5 +0.5) m x 3	= 9m
From B to D vertical drop	= (3 +0.5)m x 3	=10.5m
total length	= 22.5 + 9 +10.5	= 42m
add 10% telerance	= 42 + 4.2	= 46 m

The maximum number of wire runs in a PVC channel is 5 hence 19 mm x 10mm PVC channel may be used.

List of electrical accessories required with complete specification has to be prepared. Also calculate the cost of materials as per the present market rate.

SI No	Accessories	Length	unit price	price
1	PVC channel 19 mm x10mm	12m		
2	1.5 sq mm PVC insulated copper flexible 650V	46 m		
3	Flush type SPT switch 6 A 250 V	4 No		
4	Flush type socket 6 A 250V	1No		
5	Wooden switch board 250mm x 150mm	1No		
6	Tube light fitting complete set 250V 4 feet 40W	2No		
7	Ceiling fan 250V, 1200 mm sweep	1 No		
8	electrcial fan regulator 250V , 60W	1No		
9	Wood screws 15 x 4mm, 25 x 5mm, 30 x6mm	25 Nos each		
10	PVC insulation tape 19mm width 9m length	1No		
11	Ceiling rose 3 plate 250 V , 6 A	3No		
Total	Cost of the material required			

In the same way trainees can be instructed to calculate the cost of materials required to wire up the following wiring in the PVC conduit.

1) godown wiring

2) Corridor wiring

3) hostel wiring

4) Tunnel wiring

Estimation for 3 phase domestic and commercial wiring

Objectives: At the end of this lesson you shall be able to
- **state specific rules related to 3-phase wiring installations**
- **estimate the wiring by load calculation, load distribution, layout diagram, wiring diagram, selection of cables, selection of conduit, calculation of conduit length, cable length, accessories required and the cost of wiring.**

3-phase wiring installation : The following provisions must be maintained for electrical installation:

1 Separate and distinct circuits for lighting, fan, heating and power wiring shall be kept.

2 All the wiring conductors shall be run at a height of 2.5 metres along the wall or on ceiling.

3 Proper distribution of load should be done at the main distribution load and also at the branch distribution board.

4 The load should be arranged in such a way that it is balanced on all the phases in case of 3-phase 4 wire system or poly phase system.

5 Distribution boards should be located at convenient points, preferably at the load centre.

6 The third pin of all the wall sockets must be earthed with minimum size of earth conductor of GI 14SWG or Aluminium 1.4mm^2

7 All the metal boards must be double earthed for medium and high voltage installation.

8 The phase, neutral and earth wire shall be distinctly marked at the main and branch distributed loads as per Indian Electricity Rule 32 of 1956.

Estimation of wiring

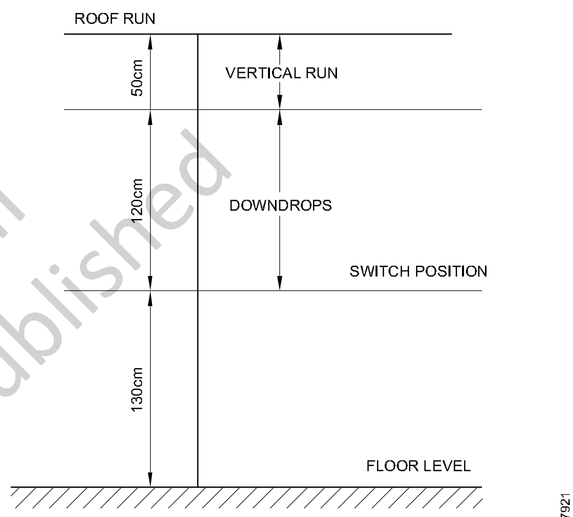
Fig 1 shows the vertical and down drops and switch position measurement from the ground level.

Study the consumer's requirement of light, fan and power points in each room (Fig 2).

Divide the load equally in 3-phases while doing so, as a requirement, the light and fan circuits of one room should be from the same phase.

In other words a single room should not get supply from two phases as this will pose a great danger to maintenance electrician and also separate line for individual phase is to be taken through the separate conduits. Clubbing of two or three phases through single conduit should be avoided.

Fig 1



VERTICAL RUN AND DOWN DROPS

Calculate the wattage of light, fan and power circuits in individual branch circuits of each phase. Then calculate the total connected load of the installation as well as current in each branch circuit.

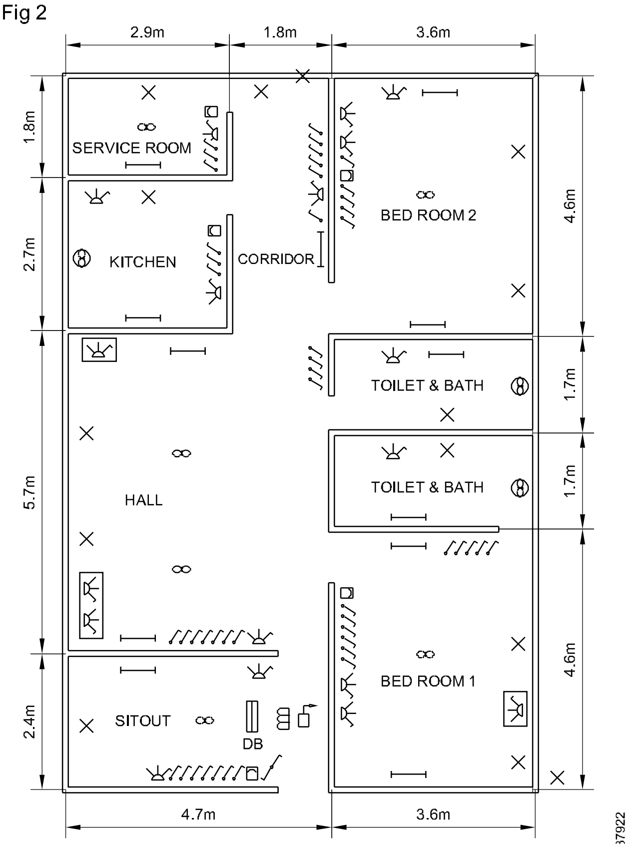
Refer to the position of accessories diagram and also the load division, then draw the layout diagram showing individual phase lines feeding to various rooms and exterior of the building. Fig 3 shows the layout diagram of phase L_1.

After finalizing the layout, the wiring diagram to be drawn.

Check the current capacity of each branch and select the size of the cable. After selecting the size of the cable and number of cables in each conduit run refer the PVC conduit table and select the size of the conduit (In the govt. installation CPWD has prescribed 19mm conduit as the minimum size to be used).

Required conduit length has to be calculated as per given method.

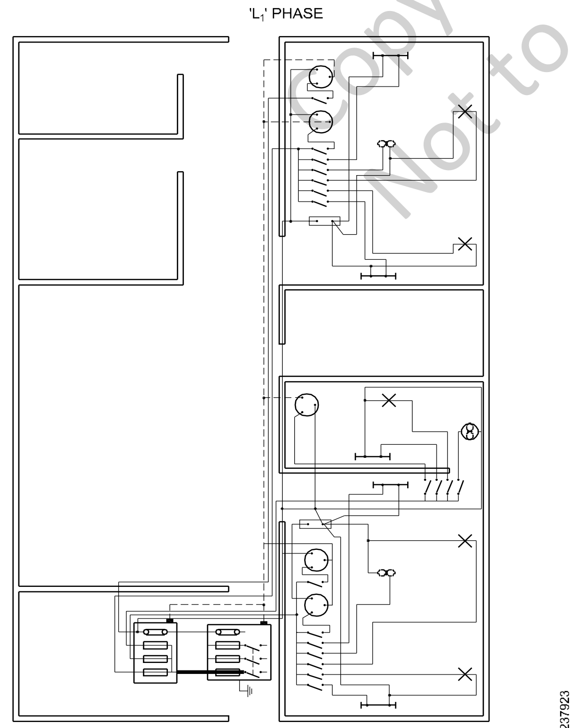
Fig 2



ACCESSORIES POSITION DIAGRAM

NE code recommends the horizontal run of cables should be at a height of 2.5m (250cm) and the height of switches from floor level should be 130cm. The example taken here for the roof height is 3m (300cm) from floor level. In all cases the dimension of the rooms should be available for estimating.

Fig 3



LAYOUT DIAGRAM OF PHASE L_1

Vertical run : As such all vertical runs can be calculated as under (Refer Fig 4) for L_2 phase.

Length of selected conduit =

Roof height - (down drop + switch height) x No. of vertical runs

= 3m - (1.20m + 1.30m) x No. of vertical heights

= (3m- 2.5m) x No. of vertical heights

= 0.5m x No. of vertical heights (Eqn. 1)

The value 0.5m will change if there is difference in roof height and height of horizontal run of conduit changes.

Length of conduit required for down drops

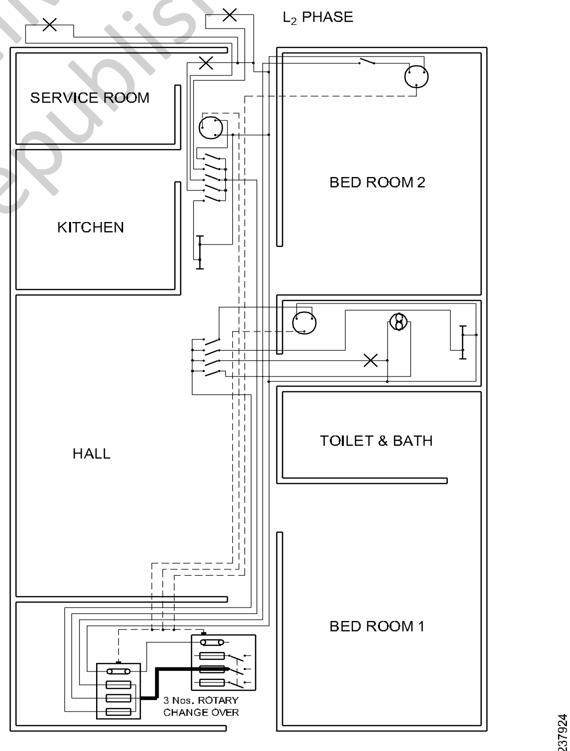
This could be calculated as under:

Length of selected conduit = Height of conduit in horizontal run - Switch position height x No. of down drops for switches

= (2.5m - 1.3m) x No. of down drops for switches

= 1.2m x No. of down drops to switches

Fig 4



LAYOUT DIAGRAM OF PHASE L_2

Length of conduit required for roof runs

This could be calculated as under

Length of selected conduit = Sum of the actual length of roof run taken in each case.

For each size the total requirement is to be calculated.

Length of conduit required for horizontal run

Length of selected conduit = sum of the actual length of horizontal run taken in each case.

Length of conduit required for the distance between main switch and DB is to be calculated. In most of the cases wall is thickness has to be taken into account.

Example

(Refer the layout and wiring diagram with respect to phase L_1) In all cases except for main switch and DB the cable used is 1/1.12 copper cable and maximum number of cable it can accommodate in 19mm conduit is 7 cables. Hence PVC conduit of 19mm is chosen.

1 Length of conduit required for vertical run

Length for vertical run = 0.5m x No. of vertical height

A careful study of layout indicates there are 8 vertical height runs

= 0.5m x 8 = 4m of 19mm PVC conduit

2 Length of conduit required for down drops

Length of down drops = 1.2m x No. of down drops

A careful study of layout indicates there are 9 down drops = 1.2m x 9 = 10.8m

3 Length of conduit required for roof runs

Length of conduit = 2.35m + 2.35m + 2.35m + 2.35m + 1.45m + 0.9m = 9.75m

4 Length of conduit required for horizontal runs

Length of conduit = 4.7m + 3.6m + 1m + 1m + 1.2m + 4.7m + 2.4m + 1.35m + 1.2m + 2m + 2.35m + 5.7m + 2.9m + 2.9m + 1.35m + 2.7m + 2.5m + 1.45m + 1.8m + 1.45m = 48.25m

5 Length of conduit required for main switch and DB

If individual phase line is to be drawn through 19mm PVC conduit will be sufficient on the other hand if all three phase cables to be drawn through single pipe, the requirement to be calculated separately.

Assuming individual phases will be drawn through individual conduits the 19mm PVC conduit will be sufficient to draw two cables of sizes upto 1/2.8 or 7/1.06 aluminium and copper cables respectively.

Length of conduit required for the distance between main switch and DB : Length of conduit = wall thickness + allowance for connection = 0.36m + 0.5m + 0.5m = 1.36m

Total length of PVC conduit 19mm for wiring phase L_1 as per layout and wiring diagram

= Vertical run + down drops + roof runs + horizontal runs + switch DB
= 4m + 10.8m + 9.75m + 48.25m + 1.36m = 74.16 m

Assuming 10% wastage, the total required length of 19mm PVC conduit will be 73.81m + 7.3m = 81.11m or say 80m

Calculation of length of cable required for wiring phase L_1: For calculating the length of cable accurately the layout and wiring diagrams should be referred. Selected cable in this case is 1 sq.mm copper cable.

Cable required = For outside runs ((L_1 + L_2 + L_3 + L_4) down drop + Horizontal run + switch board to outside wall (thickness of wall)
+ DB to switch board (DD + HR + DD)
+ Switch board to L_5 + (DD + HR)
+ L_5 to F_1 (VR + RR)
+ L_5 to L_6 L_7 (HR + HR)
+ DB to SB_2 (DD + HR + DD)
+ SB_2 to L_9 (DD + HR)
+ L_9 to F_2 (VR + RR)
+ SB_2 to S_3, S_4 (DD + HR + DD)
+ L_9 to L_{10} (HR)
+ L_{10} junction to F_3 (VR + RR)
+ L_{10} junction to L_{11} (HR)
+ S_3, S_4 to S_5 (DD + HR + DD)
+ From DB to S_6 (DD + HR +DD)
+ From S_6 to L_{12} (DD + HR)
+ L_{12} to F_5 (HR)
+ S_6 to F_4 (DD + HR + DD)
+ S_6 to L_{13} (DD + HR)
+ S_6 to S_8 (DD + HR + DD)
+ S_6 to S_7 (DD + HR + DD)
+ S_8 to F_6 (DD + RR)
+ F_6 to L_{15}
+ F_6 to L_{14}

= +	(3.6m + 1m)2 + (4.7m + 1m)3	26.3m
+	(0.36M+ 0.5m) x 5 + (1.2m + 3m + 1.2m)2	15.1m
+	(1.2m + 3m + 1.2m)2	10.8m
+	(1.2m + 4m + 1.2m)5	32.0m
+	(0.5m + 2.35m)2	5.7m
+	(1.2m + 2.35m)3 + 2.35m x 2	15.35m
+	(1.2m + m2 + 1.2m)2	8.8m
+	(1.2m + 4m + 2m)6	43.2m
+	(0.5m + 2.35m)2	5.7m
+	(1.2m + 1.5m)2	5.4m
+	(1.2m + 4m + 2m + 1.2m)2	14.8m
+	2m x 4	8.0m
+	(0.5m + 2.35m)2	5.7m
+	(2m + 2.5m)2	9.0m
+	(1.2m + 5m + 1.2m)2	14.8m

+	(1.2m + 4m + 5.7m + 2.9m + 2m + 1.2m)2	34.0m
+	(1.2m + 1.4m + 1.5m)3	12.3m
+	(1.5m + 1.35m)2	5.7m
+	(1.35m x 3m) + (1.35m x 2m)	6.75m
+	(1.35m + 1.45m + 1.2m)2	8.00m
+	(1.2m + 1.4m + 0.9m + 1.2m)2	9.4m
+	(1.2m + 1.45m + 1.2m)2	7.7m
+	(1.2m + 1.45m)3	7.95m
+	0.9m x 2m	1.8m
+	0.9m x 2m	1.8m
		325.95m
	Add 10%	32.59m
	Say 360m of 1 sq.mm copper	358.54m

The length of the cable required for power circuit in phase L_1. The cable chosen is 4 sq.mm copper cable which can carry 24 amps

Total length of cable = (1.2m + 0.36m + 2.4m + 3.6m + 2.4m + 1.2m)2
= 11.16m x 2
= 22.32m

Add 10% for wastage = 2.2m

24.52m

Say 25m of 4 sq.mm copper cable is required.

In the same way for the circuits in L_2 and L_3 phases should be calculated. After the list of accessories for entire wiring is prepared the cost of the accessories could be obtained from any local electrical dealer.

Instructor is requested to discuss with the trainees about the mandays required to complete the job alongwith the cost of labour.

Total cost of wiring comprisis of following components.

Total cost of wiring = cost of the accessories
+ cost of cable
+ cost of conduit
+ cost of hardware items
+ labour cost

Estimation of cost for workshop wiring

Objectives: At the end of this lesson you shall be able to
- **calculate the full load current and size of cables**
- **estimate the cost for workshop wiring**
- **tabulate the material required.**

The trainees can be instructed to estimate the cost of materials for the workshop wiring. Some of the guidance are given below for the trainees and instructor referance.

A sample requirement is given below for trainee's reference

1 One 5HP, 415V 3 phase motor

2 One 3HP, 415V 3 phase motor

3 One ½ HP, 240V 1 phase motor

4 One 1HP, 415V 3 phase motor

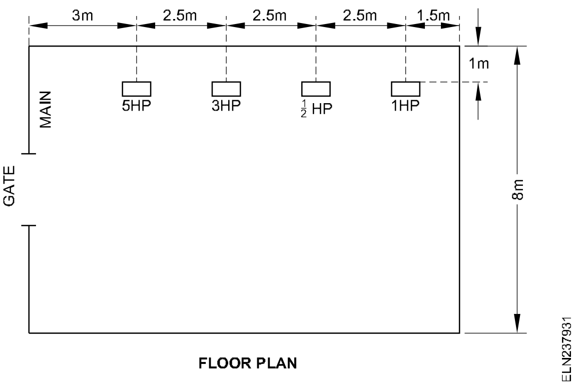
The motors are to be arranged in row (Fig 1).

The main switch, motor switch and starters are to be mounted at a height of not more than 1.5m from the ground level and the height of horizontal run from ground level will be 2.5 m.

Calculation for the size of cable:

Assuming the motor efficiency to be 85% and the power factor to be 0.8 for all the motors and the supply voltage is 400V.

Fig 1



$$\text{FL current of 5HP motor} = \frac{5 \times 735.5}{\sqrt{3} \times 400 \times 0.85 \times 0.8} = 7.8\text{A}$$

$$\text{FL current of 3HP motor} = \frac{3 \times 735.5}{\sqrt{3} \times 400 \times 0.85 \times 0.8} = 4.68\text{A}$$

$$\text{FL current of ½ HP motor} = \frac{0.5 \times 735.5}{240 \times 0.85 \times 0.8} = 2.25\text{ A}$$

$$\text{FL current of 1HP motor} = \frac{1 \times 735.5}{\sqrt{3} \times 400 \times 0.85 \times 0.8} = 1.56\text{ A}$$

The main switch and the cable from meter to main switch should be capable of handling starting current of one motor of high rating plus full load current of the all other motors.

i.e, 15.6+4.68+2.35+1.56 = 24.19A

Assuming the starting current of each motor will be two times of their full load current Table 1 gives cable size of each motors to be installed for guidance.

Table - 1

Sl. No.	Motor	FL current I_L in Amp	Starting current $I_S = 2I_L$ in Amp	Recommended cable size
1	5HP motor	7.5	15.6	2.0mm² coppere conductor cable (17A) or 2.5mm² aluminium conductor cable (16A)
2	3HP motor	4.68	9.36	2.0mm² copper conductor cable (17A)
3	1/2 HP motor	2.25	4.5	1.0mm² copper conductor cable (11A) minimum recommended cable
4	1HP motor	1.56	3.12	1.0mm² copper conductor cable (11A) minimum recommended cable

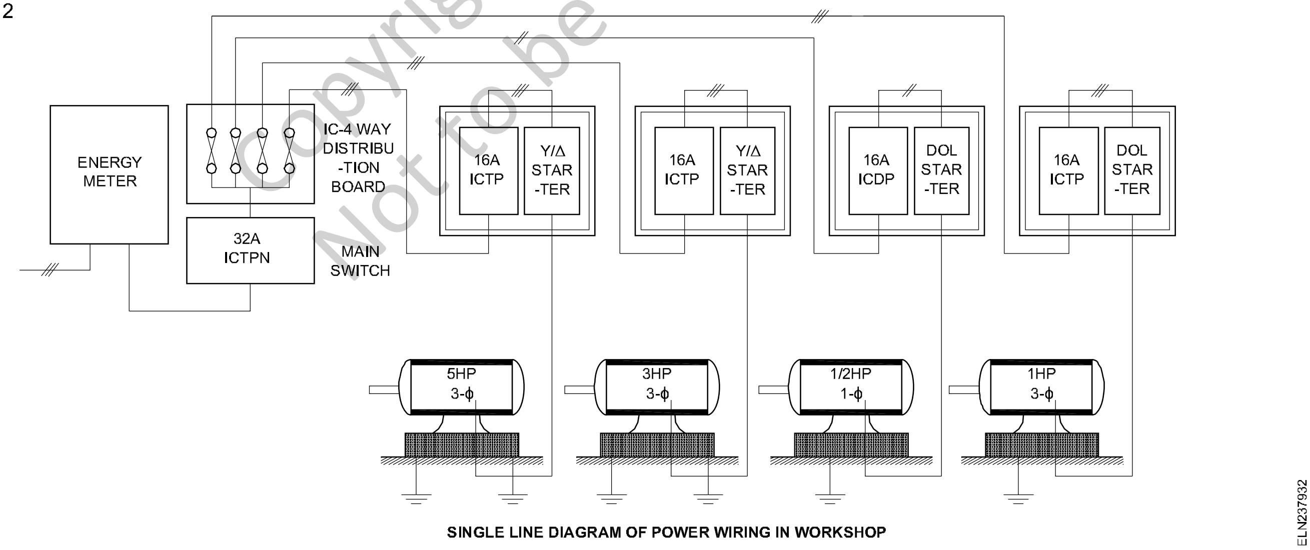
The type and gauge of cable shall be selected by referring the table - 1

Some guidance are given bleow to select the suitable switches and distribution board for trainees reference.

- A 32A, 415V ICTP switch with fuses can be used as main switch.
- 16A, 415V, ICTP switches with fuses can be used for 5HP, 3HP, & 1HP motors.
- 16A, 240V, ICDP switch with fuses can be used for ½ HP motor.
- 415V, 4 way, 16A per way IC distribution board with neutral link can be used for power distribution.

The single typical line diagram of power wirings (Fig.2)

Fig 2



SINGLE LINE DIAGRAM OF POWER WIRING IN WORKSHOP

Calculation for the sizes and length of conduit:

19mm heavy gauge conduit should be used for 3 cable runs and 24.4 mm heavy gauge conduits should be used for 6 cable runs.

- 19 mm heavy gauge conduit

Length from main board to 5HP motor starter = 1+1+3+1 = 6.0m

Length from main board to 3HP motor starter = 1+1+5.5+1 = 8.5m

Length from main board to ½ HP motor base = 1+1+8+1+1.5+1.5 = 14.0m

Length from main board to 1HP motor base = 1+1+10.5+1+1.5+1.5 = 16.5m

Total = 45.0 m

10% wastages = 4.5m

Total length = 49.5m, say 50.0m

- 25.4 mm heavy gauge conduit.

Length from meter to main switch = 0.75 m

Length from 5HP motor starter to 5HP motor base (1.5 +1.5) 3.0 m

Length from 3HP motor starter to motor base = 3.0 m

Total = 6.75 m

10% wastage = 0.67 m

Total = 7.42m, Say 8.0m

- 25.4 mm flexible conduit for 5HP & 3 HP motor (0.75+0.75) = 1.5, Say 2.0m
- 19mm flexible conduit for 1/2 HP & 1 HP motor (0.75+0.7) = 1.5, Say 2.0m

Calculation for the length of cables:

2.0mm^2 copper conductor from main board to 5HP motor terminals = 3(1+1+3+1) + 6(1.5+1.5+0.75) = 40.5m

15% wastages & end connections = 7.2 m

Total = 55.2m , Say = 56.0m

1.0mm^2 copper conductor from main board to 1/2 HP motor terminals = 2(1+1+8+1+1.5+1.5+0.75) = 29.5 m

15% wastages & end connections = 7.76m

Total = 59.51m, Say 60.0m

Trainees may be instructed to tabulate the list of materials.

Testing a domestic wiring installation - location of faults - Remedies

Objectives: At the end of this lesson you shall be able to
- **state the type of test to be carried out in wiring installations and explain the procedure of conducting them**
- **Determine the condition of installation and the method of improving the condition.**

General requirement of inspection and tests (Ref: B.I.S.732-(Part III) 1982.)

Before a completed installation or an addition to the existing installation is put into service, inspection and testing shall be carried out in accordance with the Indian Electricity Rules, 1956. In the event of defects being found, these shall be rectified as soon as practicable, and the installation re-tested.

Periodic inspection and testing shall be carried out in order to maintain the installation in a sound condition after putting it into service.

Items to be inspected in a lighting circuit

Lighting circuits: The lighting circuits shall be checked for ensuring the following.

- Wooden boxes and panels are avoided in factories for mounting the lighting boards and switch controls etc.
- Neutral links are provided in double pole switch-fuses which are used for lighting control, and no fuse is provided in the neutral.
- The plug points in the lighting circuit are all of 3-pin type, the third pin being suitably earthed.
- Tamper-proof interlocked switch sockets and plugs are used for locations easily accessible.
- Lighting wiring in the factory area is taken in enclosed conduits, and conduits are properly earthed, or alternatively, armoured cable wiring is used.
- A separate earth wire is run in the lighting installation to provide earthing for plug points, fixtures and equipment.
- Proper connectors and junction boxes are used wherever joints are to be made in conductors or when cross-over of conductors takes place.
- Cartridge fuse units are fitted with cartridge fuses only.
- Clear and permanent identification marks are painted in all distribution boards, switchboards, sub-main boards and switches as necessary.
- The polarity having been checked, all fuses and single pole switches are connected on the phase conductor only and wiring is correctly connected to the socket-outlets.
- The spare knock-outs provided in distribution boards and switch-fuses are blocked.
- The ends of the conduits enclosing the wiring leads are provided with ebonite or other suitable bushes.
- The fittings and fixtures used for outdoor use are all of weatherproof construction, and similarly, fixtures, fittings and switchgears used in the hazardous area are of flame-proof application.
- Proper terminal connectors are used for termination of wires (conductors and earth leads) and all strands are inserted in the terminals.
- Flat-ended screws are used for fixing conductors to the accessories.
- Use of flat washers backed up by spring washers for making end connections is desirable.
- The number of wires in a conduit conforms to the provisions of Part II of BIS 732.

Testing of installation: After inspection, the following tests shall be carried out, before an installation or an addition to the existing installation is put into service. Any testing of the electrical installation shall commence after obtaining a permit to work from the engineer in-charge and after ensuring the safety provisions.

1 Continuity or open circuit test
2 Polarity test
3 Earth and ground test
4 Insulation and leakage test:
   - between conductors
   - between conductors and earth.

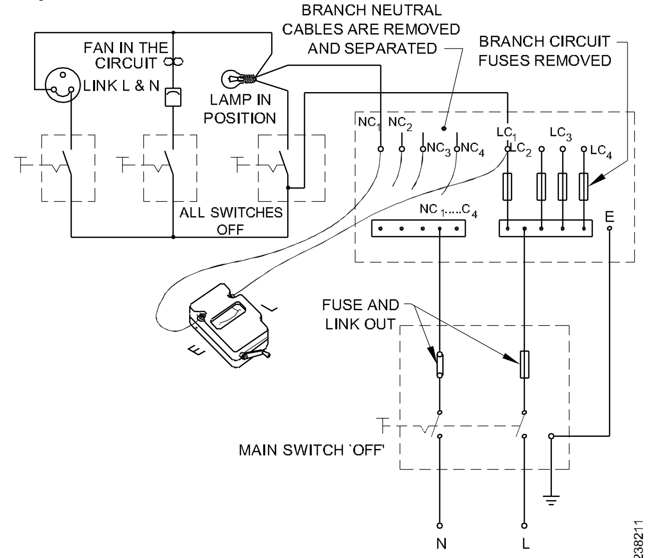
Continuity or open circuit test: This test is carried out to check the continuity of cables in the individual sub-circuits. Before conducting this test, the main and all the distribution circuit fuses should be removed.

The phase and the neutral of the individual circuits should be identified from the distribution board and segregated.

Place all bulbs in position, connect fans to respective ceiling roses, regulators and switches, short all socket outlets by linking the phase and neutral.

Connect the Megger terminals E and L to the individual circuit phase and neutral (Fig 1) and rotate the Megger.

Fig 1



CONTINUITY OR OPEN CIRCUIT TEST

By switching the switches ON and OFF one by one, the Megger should show zero reading and infinity alternatively. The two-way switches may have to be operated alternatively to ensure the correct test results.

If the Megger shows no continuity in the `ON' condition of the switch, then the particular circuit is deemed to be open. On the other hand, if the Megger shows continuity in both the `ON' and `OFF' positions of the switch, this indicates short in the particular circuit.

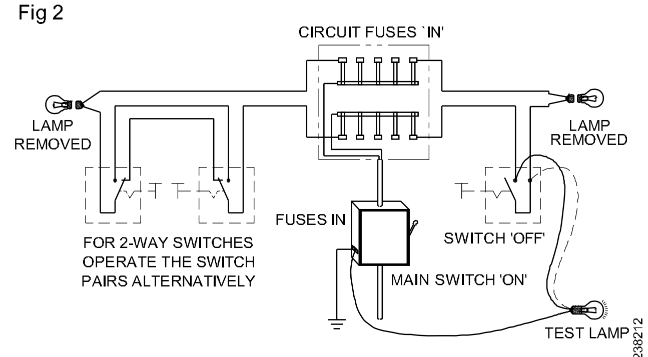
Remember to remove all the shorting links at socket points and to connect the phase to the fuse, and neutral to the link, before switching `ON' the supply.

Polarity test: This test is conducted to check whether switches are connected in phase/live cable or not.

For conducting this test, the lamps are removed from the lamp-holders, the fan regulators are kept in the `OFF' position and the fuses inserted in the main and distribution boards.

Remove the switch covers and switch `ON' the supply. Connect one end of the test lamp to the earth continuity conductor and the other end of the test lamp to the switch terminals alternatively (Fig 2).

Fig 2



POLARITY TEST

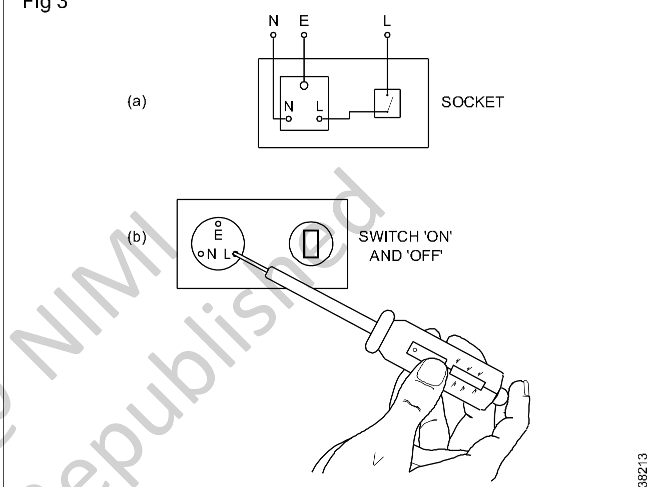
Lighting of the test lamp indicates that the phase or live cable is controlled by the switch.

A further polarity test should be done on the sockets to verify whether

- The phase wire is connected to the right side hole of the socket (Fig 3a).
- The switch controls the phase wire.

  For this test, a neon tester could be inserted in the right side hole of the socket as shown in Fig 3b and the control switch is switched `ON'. Lighting of the neon tester when the switch is `ON' and no light when the switch is `OFF' indicate correct polarity. This test is a must, in all old or new wiring installations as a safety measure.

Fig 3



POLARITY TEST ON SOCKETS

Testing the effectiveness of earth connection: For checking the efficiency of earthing, the following tests are done.

- Testing the continuity of earth continuity conductor (ECC) and measuring its resistance.
- The earth resistance of the electrode shall be measured.

The value of earth electrode resistance should not exceed 5 ohms or to a value such that the protective devices in the circuit operate efficiently in case of earth faults in the circuit.

Insulation tests in wiring installation (BIS 732 (Part II) - 1982.)

The following tests shall be done:

1 The insulation resistance shall be measured by applying the test between the earth and the whole system of the conductor or any section thereof, with all the fuses in place and all the switches closed, and except in earthed concentric wiring, all lamps in position or both poles of installation, otherwise electrically connected together, a DC voltage of not less than twice the working voltage, provided that it does not exceed 500 volts for medium voltage circuits.

2 Where the supply is derived from a three-wire AC or DC or poly-phase system, the neutral pole of which is

connected to earth either direct or through added resistance, the working voltage shall be deemed to be that which is maintained between the outer or phase conductor and the neutral.

3 The insulation resistance in megohms of an installation measured shall not be less than 50 divided by the number of points on the circuit, provided that the whole installation need not be required to have an insulation resistance greater than one megohm.

4 Control- rheostats, heating and power appliances and electric signs, may, if desired, be disconnected from the circuit during the test, but in that event the insulation resistance between the case or framework, and all the live parts of each rheostat, appliance and sign shall be not less than that specified in the relevant Indian Standard Specification, or where there is no such specification, shall be not less than half a megohm.

5 The insulation resistance shall also be measured between all conductors connected to one pole or phase conductor of the supply and all the conductors connected to the middle wire or to the middle wire or to the neutral on to the other pole of the phase conductors of the supply.

6 Such a test shall be made after removing all metallic connections between the two poles of the installation, and in these circumstances the insulation resistance between the conductors of the installation shall be not less than that specified.

On completion of an electrical installation (or an extension to an installation) a certificate shall be furnished by the contractor, countersigned by the certified supervisor under whose direct supervision the installation was carried out. This certificate shall be in the prescribed form as required by the local electric supply authority.

Insulation resistance between conductors and earth:

For this test, put `OFF' the main switch and remove the main fuse-carrier. All distribution fuses should be `IN'; the lamps should be in their holders and all switches for fans and lights should be in the `IN' position. Unplug all the appliances from the sockets, and short the phase and neutral of the sockets with a jumper wire.

Connect the phase and neutral cables at the outgoing terminals of the main switch together, and connect the lead of the Megger terminal to the shorted cables. (Fig 4) Connect the other lead of the Megger to the earth connection and rotate the Megger at its rated speed.

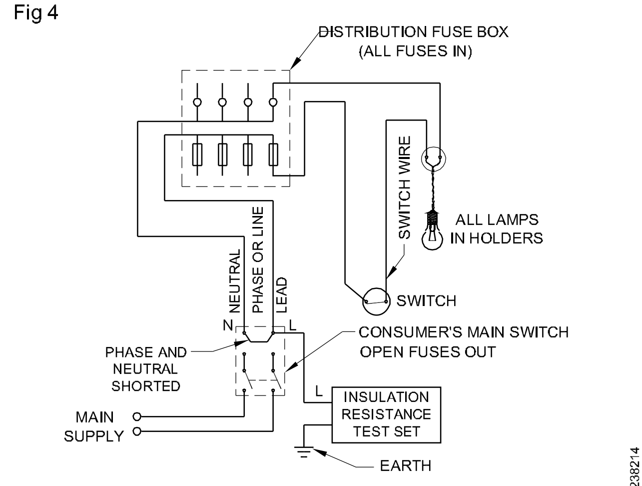
The reading thus obtained should not be lower than the lowest of the values obtained in these three methods.

Method 1 - **Standard value as per B.I.S.**

Standard value of insulation resistance

$$= \frac{50}{\text{No.of points in the circuit}} \text{Mega ohms}$$

Fig 4



INSULATION RESISTANCE TEST BETWEEN CONDUCTORS AND EARTH

where the switch, the lamp-holder and the socket are taken as individual points.

In case, the wiring is done in PVC insulated cables, 50 should be replaced by 12.5.

Method 2 - **I.E. rules state that the leakage current in an installation should not exceed 1/5000th part of the full load current of the installation.**

Applying this, the value of insulation resistance

$$= \frac{\text{Supply voltage in volts}}{\text{Leakage current}} \text{ohms}$$

$$= \frac{\text{Supply voltage in volts x 5000}}{\text{Full load current of the insatallation}}$$

Where leakage current

$$= \text{Full load current of the installation x } \frac{1}{5000}$$

Hence the insulation resistance

$$= \frac{\text{Supply voltage in volts x 5000 x } 10^{-6}}{\text{Full load current of the installation}} \text{Megaohms}$$

Method 3 - **Thumb rule**

The measured insulation resistance of an installation should not be less than one megohm.

Insulation resistance between conductors: For this test, switch off the mains and remove the fuse-carriers.

Remove all lamps from their holders, disconnect all appliances and keep all switches in the ON position.

Keep all the distribution fuses in position.

Connect one test prod of the Megger to the phase cable and the other to the neutral (Fig 5).

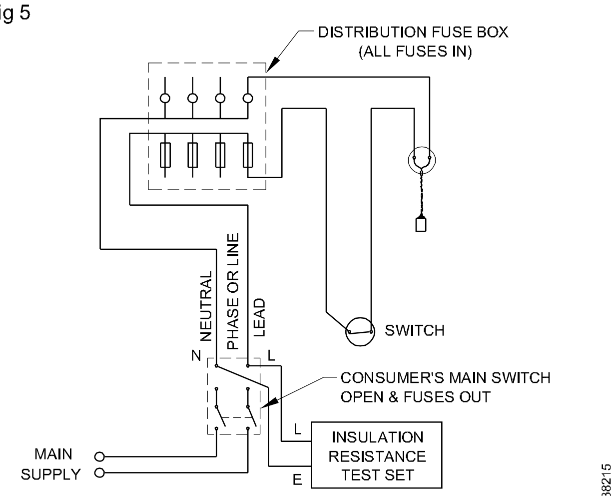
Rotate the Megger and measure the insulation resistance in megohms.

The reading in megohms should not be less than the lowest of the readings obtained in any one of the three methods, stated under `Insulation resistance between conductors and earth.

Inspection, testing and improving the condition of wiring installations

The table given below shows the test results, and the methods to improve the conditions of the wiring installations.

Fig 5



INSULATION RESISTANCE TEST BETWEEN CONDUCTORS

Test Results and Methods for Improving the conditions

S. No.	Test Conducted	Test results	Method of Improvement
1	Continuity or open circuit test	a) Zero reading b) Higher reading in terms of kiloohms or megohms	a) Ok. b) Operate each individual switch in the circuit.Where the reading jumps to a higher value, there will be an open circuit, either by fused bulbs or loose connections at the terminals or break in the wire. After identifying the subcircuit, check the continuity of cables in the smaller zones till the defect is detected and rectified. Where 2-way switches are encountered,operate the switches one by one to detect the fault.
2	Polarity test	a) Polarity was found wrong throughout the installation. b) Polarity found wrong in one or two sockets.	a) Switch off the mains. Remove the fuse-carrier.Interchange the output terminals at ICDP switch or at DB. b) See that the phase is connected to the right side terminal of the socket.
3	Effectiveness of earth connection	a) Discontinuity between earth electrode and one earth pin of the 3- pin socket. b) Indicates voltage drop between phase & the metallic body when tested by test lamp method.	a) Check up the connections and reconnect or replace the earth continuity conductor. b) The earth electrode resistance may be high. ECC may have high resistance. Prepare one more earth electrode and connect the electrodes in parallel. Remove rust and rectify loose connections in ECC connections at all earth terminals including the one at the earth electrode.

S. No.	Test Conducted	Test results	Method of Improvement
4	Insulation test between conductors and earth (or) between the phase and neutral	a) 1 megohm or above	a) Ok. Check the value of the insulation resistance by the formula Megohms = $\frac{50}{\text{No.of outlets}}$ For PVC wired installation replace 50 by 12.5. In case the measured value of insulation resistance is equal to or more than the calculated value, the insulation is OK.
		b) Less than 1 megohm	b) Otherwise locate the fault by sectionalising the zone and replacing the defective cable with a good one. If, however, the values obtained are not sufficiently high, withdraw all the fuses of the distribution fuse-board and test again. This test will include only that portion of the installation between the main switch and the distribution fuse-board. If the fault does not lie in this section,proceed to the distribution fuse-board, and test each branch circuit in turn till the faulty circuit or circuits are discovered.

Testing the industrial wiring installation for faults and their remedies - Flow chart

Objectives: At the end of this lesson you shall be able to
- **explain the different types of faults occur in the industrial**
- **trace and interpret the flow chart for locating the fault.**

Any fault can be found and rectified. It is necessary for the electrician to adopt a method or system based on a sound knowledge of circuitry and electrical theory on experience. The electrician detects to repair a faulty circuit in many ways like a doctor who makes his diagnosis or test using the correct instrument.

The investigation must always be based on an intelligent assessment of the fault and its probable causes, judged from its effects. In many instances, faults arise from installations or circuits. The following are some common installation defects which eventually lead to faults.

1 Fuse protection not matched to the current rating of cables to be protected. This is very often happening due to fitting the fuse-carries with a fuse element of maximum rating than the fuse unit in the protection system.

2 Indiscriminate bunching of too many cables with inadequate connections.

3 Insufficient protection provided for sheathed wiring (e.g.) to switch positions and on joints in roof voids.

4 Incorrect use of materials, not resistant to corrosion, in damp situation (e.g. enameled conduit and accessories)

5 Insufficient attention given to cleaning ends of conduit and/or . Omission of bushings .

6 Incorrect use of PVC insulated and/or sheathed cables and flexible cords instead of heat resistance type, for connections to immersion heating, thermal storage block heaters etc.,

7 Incorrect use of braided and twisted flexible cords for bathroom pendant fittings and similar situations subject to dampness or condensation.

8 Installation of cable of insufficient capacity to carry the starting current of motors, causing excessive voltage drops.

9 Incorrect rating of fuse-element to give protection to the cables connecting the motor.

Segregation of fault

Open circuit fault

Usually the effect of this fault is that the apparatus or lamp in the circuit will not operate. This fault can be located by using the continuity Tester. The fault is of a

a) break in a wire

b) very loose or disconnected terminal or joint connections

c) blown fuse

d) faulty switch contacts.

The fuse should always be checked first for fault finding. Their wirable type can be easily inspected. The cartridge type must be tested for continuity of the fuse element. If it is found not correct replace it. A broken wire or a disconnection will show high resistance in the kiloohm or Megohm ranges in continuity Tester. Before each wire in faulty circuit is tested in turn (live wire, switch-wire, and neutral) all mechanical connections should be inspected like plug, switch, lamp holders, junction box and appliance terminals etc). Make sure that the original connections are restored, once the fault has been found.

Earth Fault

An earth fault between earthed metal work and a live conductor will have the same effect as a direct short-circuit. For this situation the circuit fuse will blow off. To trace the fault, first isolate the live conductor from the neutral by removing all lamps etc.

Keeping all switches in ON position by using insulation resistance Tester, faults are traced. The reading obtained on the instrument will be in low ohms range. It is important to rectify any such fault found, other wise it may cause a shock and fire hazards.

Short circuit fault

Short circuit can occur as the result of damaged insulation, bare wire in junction boxes and fittings or loose terminals contact with a conductor of opposite polarity. The result of a short circuit is a blown fuse. The result will be over heating of the conductors and sparking or arcing at the point of contact. Open all switches, lamps and appliances from the faulty circuit and carry out an insulation resistance test between the live and neutral conductors.

If reading is obtained is satisfactory, close each circuit switch in turn until the fault is located.

High-value series resistance fault

This type of fault is most difficult to trace; it occurs in joint or terminator where it has become loose. Due to this effect the lights will be 'dim or motor will run very slow thereby heating up'. In new wiring wrong connection in a junction box resulting in two or more lamps being connected in series.

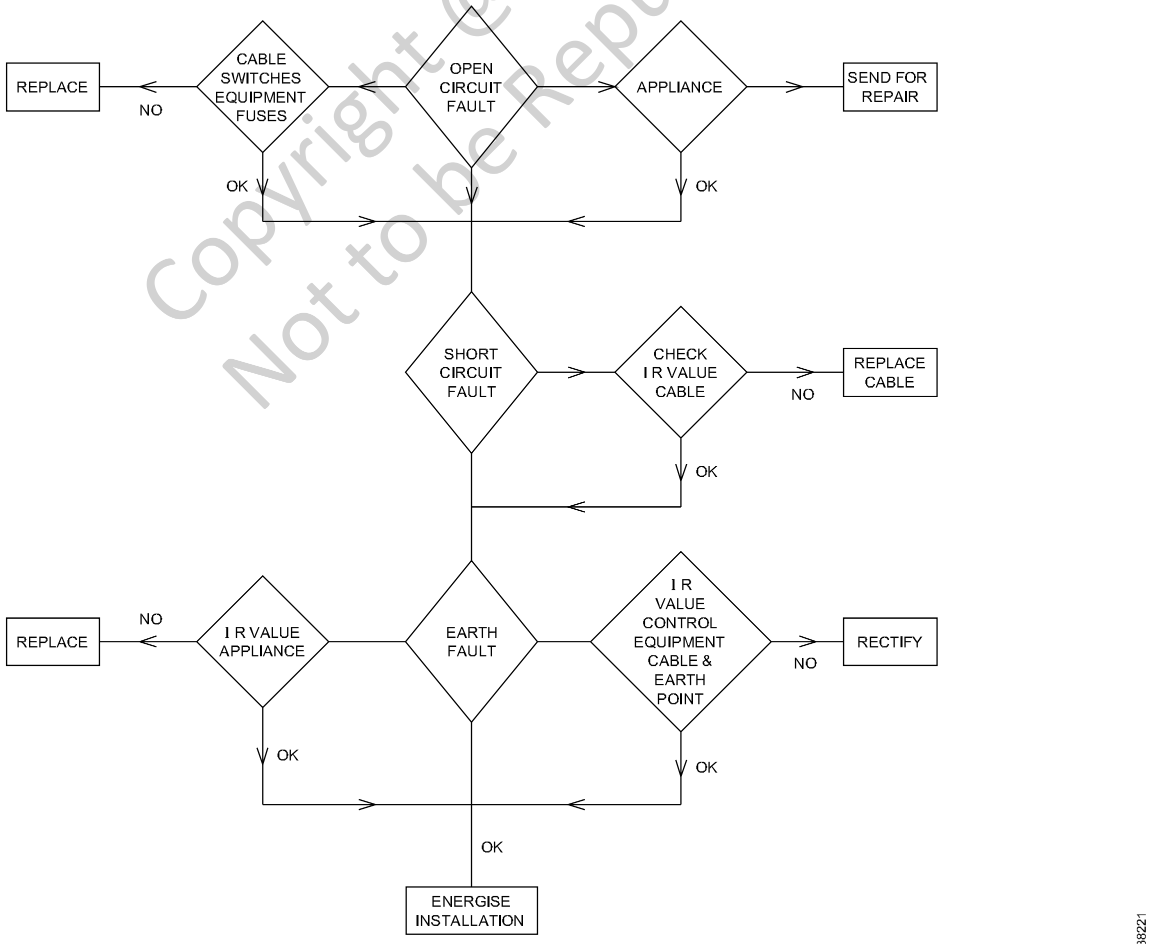
Main faults in new wiring

Wrong connections will either blow a fuse or cause lamps to operate dimly or not at all work. Works only when another circuit switch is switched ON, this indicates wrong connections in looping of wires.

Flow chart of faults

Figure 1 shows the flow chart of each fault kept in chart form.

Fig 1



FLOW CHART FOR LOCATING FAULT IN DOMESTIC WIRING INSTALLATION

Earthing - Types - Terms - Megger - Earth resistance Tester

Objectives: At the end of this lesson you shall be able to
- **explain the reasons for system and equipment earthing**
- **define the terminalogy related to earthing**
- **state and explain the methods of preparing pipe earthing and plate earthing, according to B.I.S. recommendations**
- **explain the procedure for reducing the resistance of earth electrodes to an acceptable value.**

Earthing:

Connecting the non-condutive metal body/parts of an electrical equipment and system to the earth through a low resistance condutor is called as **earthing**.

Earthing of an electrical installation can be brought under two major categories.

- System earthing
- Equipment earthing

System earthing: Earthing associated with current-carrying conductors is normally essential to the security of the system, and is generally known as system earthing.

System earthing is done at generating stations and sub-stations.

The purpose of system earthing is to:

- maintain the ground at zero reference potential, thereby ensuring that the voltage on each live conductor is restricted to such a value with respect to the potential of the general mass of the earth as is consistent with the level of the insulation applied
- protect the system when any fault occurs against which earthing is designed to give protection, by making the protective gear to operate and make the faulty portion of the plant harmless.

In most cases such operation involves isolation of the faulty main or plant by circuit breakers or fuses. Earthing may not give protection against faults which are not essentially earth faults.

Equipment earthing: Earthing of non-current carrying metal work and conductor which is essential for the safety of human life, animals and property is generally known as equipment earthing.

Terminology

> **Trainees can be instructed to refer the international electro technical commission (IEC 60364-5-54) website for the standard safety rules related with earthing installation for the further details.**

Dead: Dead' means at or about earth potential and disconnected from any live system.

Earth: A connection to the general mass of earth by means of an earth electrode. An object is said to be `earthed' when it is electrically connected to an earth electrode; and a conductor is said to be `solidly earthed' when it is electrically connected to an earth electrode.

Earth-continuity conductor (ECC): The conductor which connect the non-conductive metal part/body of an electrical system/equipment to the earth electrode is called as earth contained conductor.

Earth electrode: A metal plate, pipe or other conductor electrically connected to the general mass of the earth.

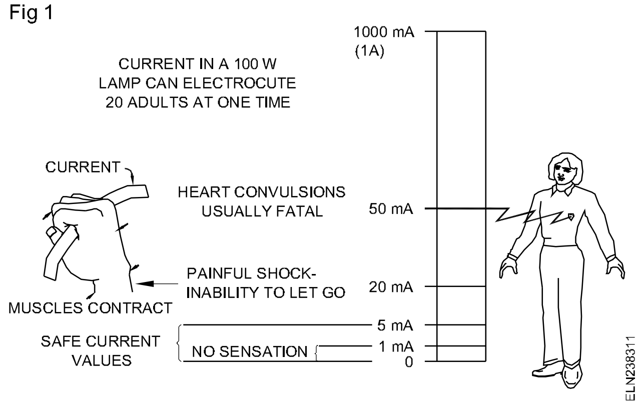
Earth fault: Live portion of an electrical system getting accidentally connected to earth.

Leakage current: A current of relatively small value, which passes through the insulation of conductive parts/ wire.

Step potential: The maximum value of the potential difference possible of being shunted by a human body between two accessible points on the ground separated by the distance of one step, which may be assumed to be one metre.

Touch potential: The maximum value of potential difference between a point on the ground and a point touched by a person.

Fig 1



Reasons for earthing: The basic reason for earthing is to prevent or minimize the risk of shock to human beings and livestock. The reason for having a properly earthed metal part in an electrical installation is to provide a low resistance discharge path for earth leakage currents which would otherwise prove injurious or fatal to a person or animal touching the metal part.

An electric shock is dangerous only when the current through the body exceeds beyond a certain milliampere value. In general, any current flow through the body beyond 5 milliamperes is considered dangerous. Fig 1 shows the magnitude of current and its effect.

However, the degree of danger is also dependent on the time during which it flows, and resistance of the body. In human beings, the resistance between hand and hand or between hand and foot can easily be as low as 400 ohms under certain conditions. Table 1 shows the body resistance at specified areas of contact.

Table 1

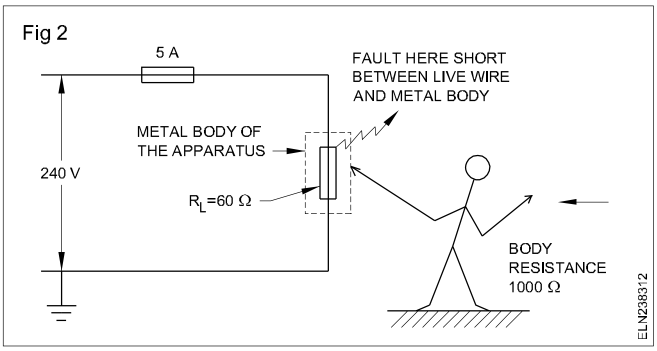
Skin conditon or area	Resistance value
Dry skin	100,000 to 600,000 ohms
Wet skin	1,000 ohms
Internal body-hand	400 to 600 ohms to foot
Ear to ear	about 100 ohms

CASE 1: **Metal body of apparatus when it is not earthed**

Let us consider a 240V AC circuit connected to an apparatus having a load resistance of 60 ohms. Assume that the defective insulation of cable makes the metal body live and the metal body is not earthed.

When a person, whose body resistance is 1000 ohms, comes in contact with the metal body of the apparatus which is at 240V, a leakage current may pass through the body of the person (Fig 2).

Fig 2



The value of current through the body = $\frac{V}{R_{Body}}$

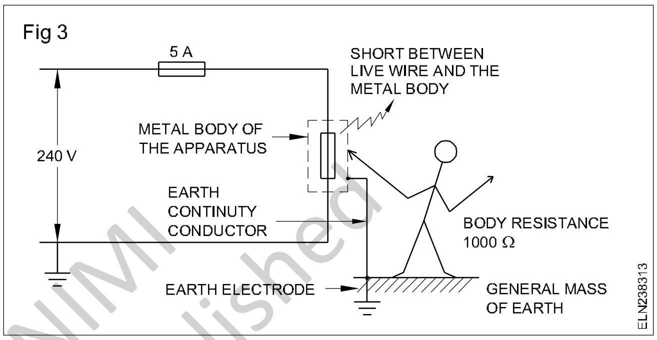
$$= \frac{240}{1000} = 0.24 \text{ amps or 240 milliamps.}$$

This current, as can be judged from Table 1, is highly dangerous, and might prove to be fatal. On the other hand, the 5 amps fuse in the circuit will not blow for this additional leakage current of 240 milliamperes. As such the metal body will have 240V supply and may electrocute any person touching it.

CASE 2: **Metal body of apparatus when earthed.**

In case the metal body of the apparatus is earthed (Fig 3), the moment the metal body comes in contact with the live wire, a higher amount of leakage current will flow through the metal body to earth.

Fig 3



Assuming that the sum of the resistace of the main cable, metal body, earth continuity conductor and the general mass of earth is to the tune of 10 ohms

$$\text{the leakage current} = \frac{V}{R_{Total}} = 240/10 = 24 \text{ amps.}$$

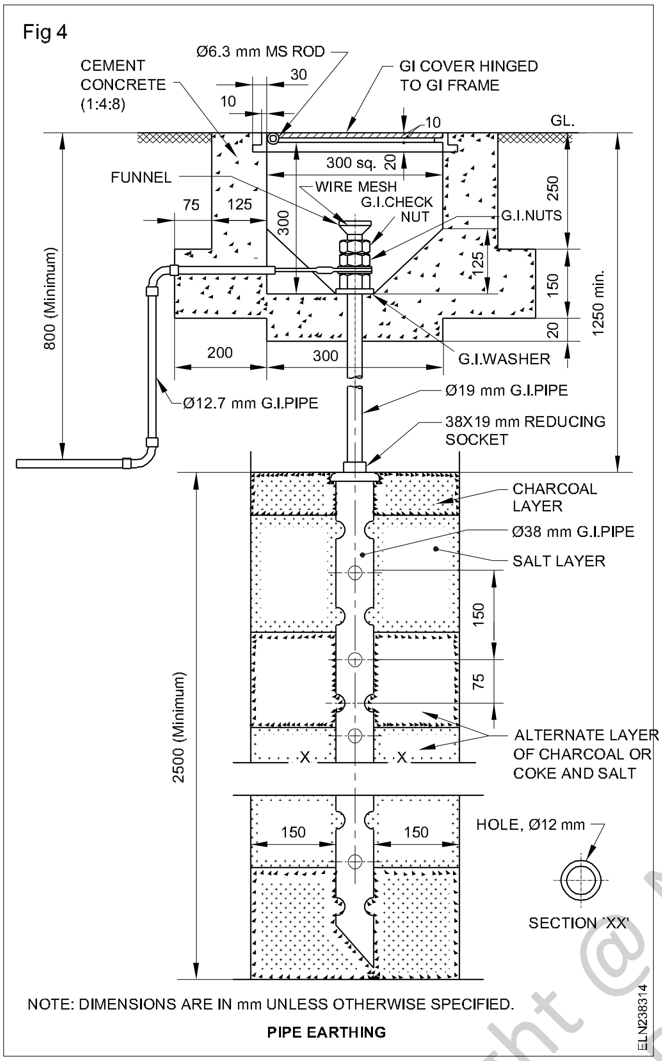
This leakage current is 4.8 times higher than the fuse rating, and, hence, the fuse will blow and disconnect the supply from the mains. The person will not get a shock due to two reasons. Before the fuse operates, the metal body and earth are in the same zero potential, and across the person, there is no difference of potential. Within a short (milli-seconds) time the fuse blows to open the defective circuit, provided the earth circuit resistance is sufficiently low.

By studying the above two cases, it is clear that a properly earthed metal body eliminates the shock hazards to persons and also avoids fire hazards in the system by blowing the fuse quickly in case of ground faults.

Types of earth electrodes

Rod and pipe electrodes (Fig 4): These electrodes shall be made of metal rod or pipe having a clean surface not covered by paint, enamel or other poorly conducting material.

Rod electrodes of steel or galvanised iron shall be at least 16 mm in diameter, and those of copper shall be at least 12.5 mm in diameter.



Pipe electrodes shall not be smaller than 38 mm internal diameter, if made of galvanised iron or steel, and 100 mm internal diameter if made of cast iron.

Electrodes shall, as far as practicable, be embedded in earth below the permanent moisture level.

The length of the rod and pipe electrodes shall not be less than 2.5 m.

Except where rock is encountered, pipes and rods shall be driven to a depth of atleast 2.5 m. Where rock is encountered at a depth of less than 2.5 m, the electrodes may be buried, inclined to the vertical. In this case too, the length of the electrodes shall be atleast 2.5 m, and the inclination not more than 30^0 from the vertical.

Deeply driven pipes and rods are, however, effective where the soil resistivity decreases with depth or where a sub-stratum of low resistivity occurs at a depth greater than those to which rods and pipes are normally driven.

Pipes or rods, as far as possible, shall be of one piece.

For deeply driven rods, joints between sections shall be made by means of a screwed coupling,which should not be of a greater diameter than that of the rods which it connects together.

Plate electrodes (Fig 5): Plate electrodes,when made of galvanised iron or steel,shall not be less than 6.3 mm in thickness. Plate electrodes of copper shall be not less than 3.15 mm in thickness. Plate electrodes shall be of a size, at least 60 cm by 60 cm.

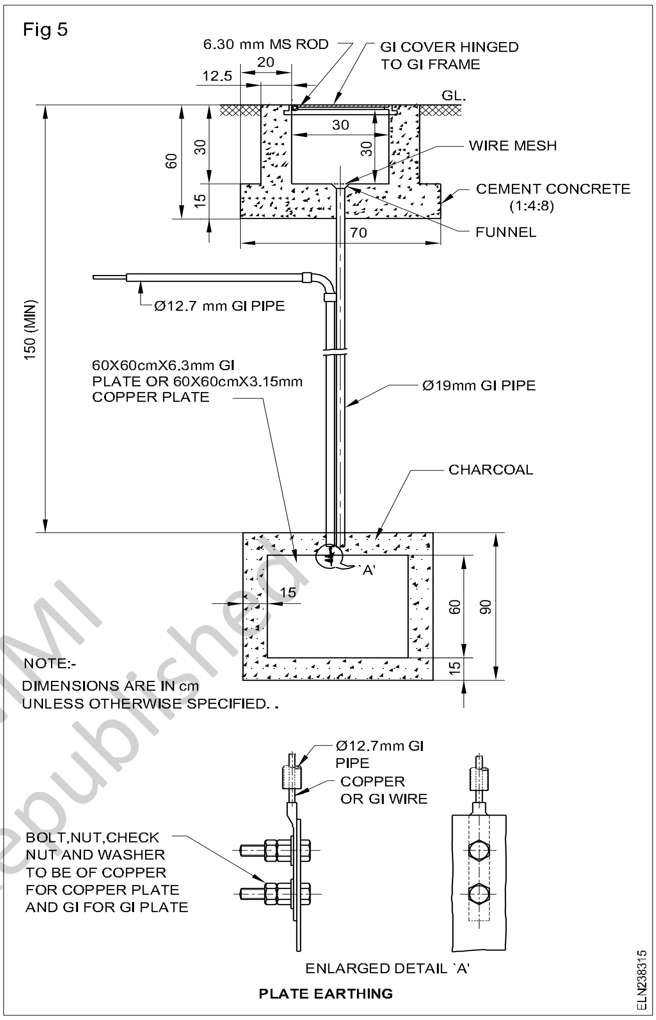


Plate electrodes shall be buried such that the top edge is at a depth not less than 1.5 m from the surface of the ground.

Where the resistance of one plate electrode is higher than the required value, two or more plates shall be used in parallel. In such a case, the two plates shall be separated from each other by not less than 8.0 m.

Plates shall preferably be set vertically.

Use of plate electrodes is recommended only where the current-carrying capacity is the prime consideration; for example, in generating stations and substations.

If necessary, plate electrodes shall have a galvanized iron water pipe buried vertically and adjacent to the electrode. One end of the pipe shall be atleast 5 cm above the surface of the ground, and it need not be more than 10 cm. The internal diameter of the pipe shall be atleast 5 cm and need not be more than 10 cm. The length of pipe, if under the earth's surface, shall be such that it should be able to reach the centre of the plate. In no case, however, shall it be more than the depth of the bottom edge of the plate.

Methods of reducing the resistance of an earth electrode to an acceptable value:

To achieve efficient operation of the protective devices, under fault condition the earth electrode resistance should be lower than an acceptable value which could be calculated from circuit details.

However, the earth electrode resistance is found higher in rocky or sandy areas where moisture is very low.

The following methods are suggested to bring down the earth electrode resistance to an acceptable value.

1 After installing the rod or pipe or plate in earth, the earth pit (the area surrounding the rod / pipe / plate) should be treated with layers of coke and common salt to get a lower value of earth resistance.

2 Pouring water in the earth pit at repeated intervals lowers the earth electrode resistance.

3 Connecting a number of earth electrodes in parallel reduces the earth electrode resistance. (Distance between two adjacent electrodes shall be not less than twice the length of the electrodes.)

4 Soldering the earth connections or using non-ferrous clamps lowers the earth electrode resistance.

5 Avoiding rust in the earth electrode connections lowers the earth electrode resistance.

Insulation resistance tester (Megger)

Objectives: At the end of this lesson you shall be able to
- **define megger**
- **state the working principle of an insulation tester (Megger)**
- **explain the construction and working of megger**
- **state the uses of an insulation tester like insulation test, continuity test etc.**
- **state the safety precautions to be observed while using an insulation tester.**

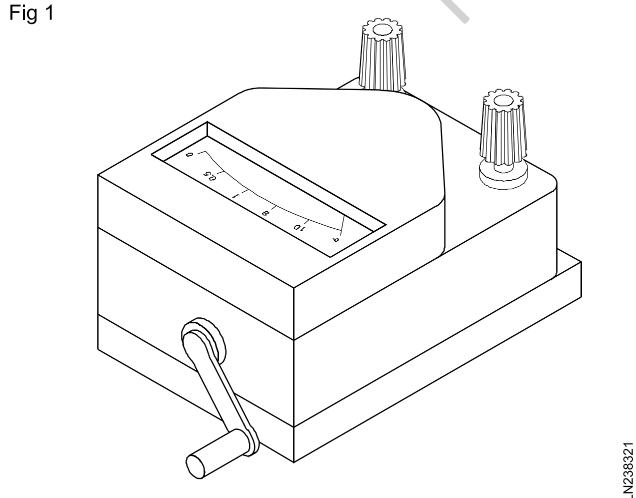
Megger

It is an electrical measuring instrument generally used to measure the insulation resistance of an installation/ equipment etc in terms of Megaohms.

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 1) A megohmmeter is commonly known as MEGGER.

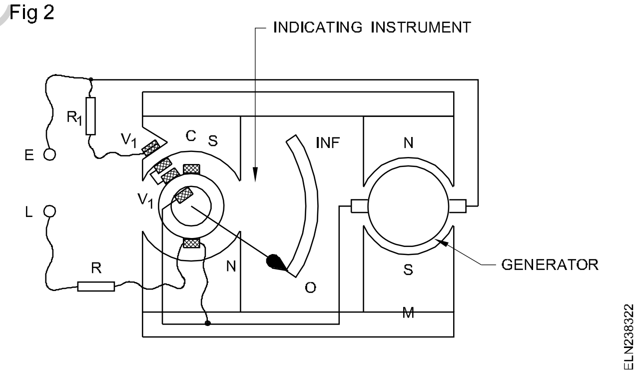
Fig 1



Construction

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

Fig 2



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: kilo-ohms (K Ω) and megohms(MΩ).

Working principle

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 rotate 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.

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.

Specification of Megger :

Nowadays electronically operated, Meggers are available, called as push button type for general application and for industrial application motorised megger are also available. Hence a megger is basically specified based on the voltage generated by it .

example: 250 V, 500V, 1KV, 2.5KV, 5KV.

Earth resistance tester

Objectives: At the end of this lesson you shall be able to
- **state the necessity of earthing**
- **state the precautions to be followed while selecting a site for the earth electrode**
- **define earth resistance tester**
- **explain the principle constructon and working of an earth resistance tester**
- **explain the method of measuring the earth resistance**
- **state the IE rules pertaining to earthing.**

Necessity of earthing

Earthing the metal frames/casing of the electrical equipment is done to ensure that the surface of the equipment under faulty conditions does not hold dangerous potential which may lead to shock hazards. However, earthing the electrical equipment needs further consideration as to ensure that the earth electrode resistance is reasonably low to activate the safety devices like earth circuit leakage breaker, fuses and circuit breakers to open the faulty circuit and thereby protect men and material.

Precautions to be followed while selecting the site for earth electrode: However, even the earth electrode, either rod or plate type, implanted properly in the earth according to the specified recommendations is found to have high resistance resulting in failure of safety. This defect is mainly due to the soil and moisture condition. The explanation given below is to guide an electrician to select a proper site for providing an earth electrode so that the earth electrode resistance could be kept at a reasonable level.

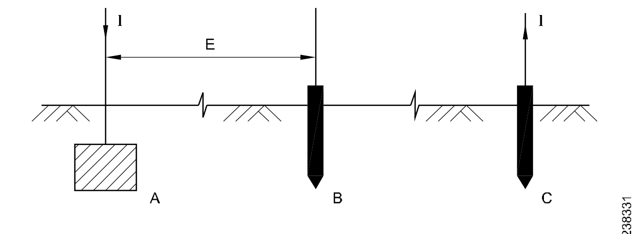
Necessity of measuring of earth electrode resistance: Physically an earth electrode may look alright, but its resistance may be high enough to damage the safety requirement. The only way to ensure the acceptable value of earth electrode resistance is to measure the resistance with the use of an earth resistance tester.

Earth resistance tester: It is an electrical measuring instrument used to measure the resistance between any two points of the earth. It is also called as earth tester. Even varieties of earth testers are available in market, the hand operated earth tester is explained below.

Principle: The earth tester works on the principle of the fall of potential method.

In this method the two auxiliary electrodes B and C are placed at a straight line (Fig 1).

Fig 1



FALL OF POTENTIAL METHOD

An alternating current of I_{amps} magnitude is passed through the electrode A to the electrode C via the earth and the potential across electrodes A and B is measured.

The resistance of electrodes B and C does not influence the measurement result.

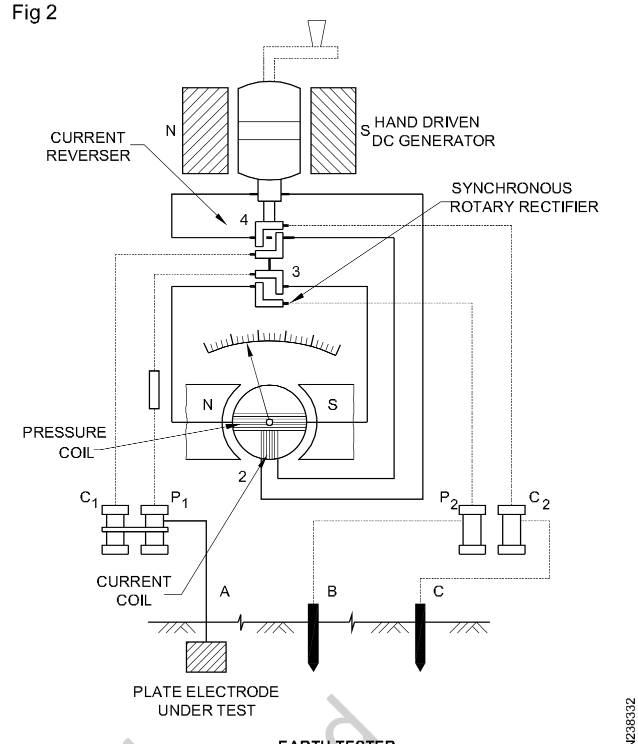
This is achieved by placing the electrode C at a sufficient distance from A so that the resistance areas of A and C are quite independent. A distance of above 15 metres between electrode A and C is regarded as sufficient distance.

Construction and working of earth tester : The earth tester essentially consists of a hand drive generator which supplies the testing current and a direct reading ohmmeter (Fig 2).

The ohmmeter section of this instrument consists of two coils (potential and current coils) kept at 90° to each other and mounted on the same spindle. The pointer is attached to the spindle. The current coil carries a current proportional to the current in the test circuit whereas the potential coil carries a current proportional to the potential across the resistance under test.

Thus the current coil of the instrument acts as an ammeter in the fall of potential method and the pressure coil acts as the voltmeter. Since the deflection of the ohmmeter needle is proportional to the ratio of the current in the two coils, the meter gives resistance readings directly.

Fig 2



EARTH TESTER

When DC is used in electrode resistance measurement the effect of electrolytic emf interferes with the measurement and the reading may go wrong. To avoid this, the supply to the electrodes should be AC.

To facilitate this the DC produced by the the hand generator is changed to AC through a current reverser. After the alternating current passes through the electrodes, the measurement should be done by an ohmmeter which requires DC supply.

To change the alternating voltage drop outside the instrument to direct voltage drop inside, a synchronous rotary rectifier is used (Fig 2)

Sometimes the meter needle vibrates during measurement due to the fact that strong alternating currents of the same frequency as the generated frequency enters the measuring circuit.

In such cases the handle rotating speed of the instrument may be either increased or decreased. In general these instruments are designed such that the readings are not affected by strong currents or by electrolytic emfs.

Method of earth resistance measurement: To measure the earth electrode resistance, the earth electrode is preferably disconnected from the installation. Then two spikes (the current and pressure spikes) are to be driven into the ground at a straight line at a distance of 25 metres and 12.5 metres respectively from the main electrode under test. The pressure and current spikes and the main electrode need to be connected to the instrument (Fig 1)

The earth tester has to be placed horizontally and is rotated at a rated speed (normally 160 r.p.m.). The resistance of the electrode under test is directly read on the calibrated dial. To ensure correct measurement, the spikes are placed at a different position around the electrode under test, keeping the distance the same as in the first reading. The average of these readings is the earth resistance of the electrode.

I.E. Rules pertaining to earthing

Earthing shall generally be carried out in accordance with the requirements of Indian Electricity Rules 1956, as amended from time to time, and the relevant regulations of the electricity supply authority concerned. The following Indian Electricity Rules are particularly applicable to both system and equipment earthing: 32,51,61,62,67,69,88(2) and 90.

Extracts from Indian Electricity Rules, 1956

Rule no. 32: **Identification of earthed and earthed neutral conductors and position of switches and cut-outs therein.**

Where the conductors include an earthed conductor of a two-wire system or an earthed neutral conductor of a multi-wire system or a conductor which is to be connected thereto, the following conditions shall be compiled with.

1 An indication of a permanent nature shall be provided by the owner of the earthed or earthed neutral conductor, or the conductor which is to be connected thereto, to enable such a conductor to be distinguished from any live conductor. Such indication shall be provided:

   a) where the earthed or earthed neutral conductor is the property of the supplier, at or near the point of commencement of supply

   b) where a conductor forming part of a consumer's system is to be connected to the supplier's earthed or earthed neutral conductor at the point where such connection is to be made.

2 No cut-out, link or switch other than a linked-switch arranged to operate simultaneously on the earthed or earthed neutral conductor and live conductors shall be inserted or remain inserted in any earthed or earthed neutral conductor of a two-wire system or in any earthed or earthed neutral conductor of a multi-wire system or in any conductor connected thereto with the following exceptions:

   a) a link for testing purposes or

   b) a switch for use in controlling a generator or trans former.

Rule no.51: **Provisions applicable to medium, high or extra high voltage installations**

All metal work enclosing, supporting or associated with the installation, other than that designed to serve as ta conductor, shall, if considered necessary by the Inspector, be connected with earth.

Rule no.61: **Connection with earth**

1 The following provisions shall apply to the connection with earth of systems at low voltage in cases where the voltage between phases or outers normally exceeds 125 volts and of systems at medium voltage.

   a) The neutral conductor of a three-phase four-wire system, and the middle conductor of a two-phase three-wire system shall be earthed by not less than two separate and distinct connections with earth both at the generating station and at the substation. It may also be earthed at one or more points along the distribution system or service line in addition to any connection with earth which may be at the consumer's premises.

   b) In the case of a system comprising electric sypply lines having concentric cables, the external conductor of such cables shall be earthed by two separate and distinct connections with earth.

   c) The connection with earth may include a link by means of which the connection may be temporarily interrupted for the purpose of testing or for locating a fault.

   d) In the case of an alternating current system, there shall not be inserted in the connection with earth any impedance (other than that required solely for the operation of switchgear or instrumets), cut-out or circuit-breaker, and the result of a test made to ascertain whether the current (if any) passing through the connection with earth is normal, shall be duly recorded by the supplier.

   e) No person shall make connection with earth by the aid of, nor shall keep it in contact with, any water main not belonging to him except with the consent of the owner thereof and of the inspector.

   f) Alternating current systems which are connected with earth as aforesaid may be electrically interconnected. Provided that each connection with earth is bonded to the metal sheathing and metallic armouring (if any) of the electric supply lines concerned.

2) The frame of every generator, stationary motor, and so far as is practicable, portable motor, and the metallic parts (not intended as conductors) of all transformers and any other apparatus used for regulation or controlling energy and all medium voltage energy consuming apparatus shall be earthed by the owner by two separate and distinct connections with earth.

3) All metal casings or metallic coverings contained or protecting any electric supply-line or apparatus shall be connected with earth and shall be so joined and connected across all junction-boxes and other openings as to make good mechanical and electrical connection throughout their whole length:

Provided that where the supply is at low voltage, this sub-rule shall not apply to isolated wall tubes or to brackets, electroliers, switches, ceiling fans or other fittings (other than portable hand lamps and portable and transportable apparatus) unless provided with earth terminal.

Provided further that where the supply is at low voltage and where the installations are either new or renovated, all plug sockets shall be of the three-pin type and the third pin shall be permanently and efficiently earthed.

4) All earthing systems shall, before electric supply lines or apparatus are energised, be tested for electrical resistance to ensure efficient earthing.

5) All earthing systems belonging to the supplier shall, in addition, be tested for resistance on a dry day during the dry season not less than once every two years.

6) A record of every earth test made and the result thereof shall be kept by the supplier for a period of not less than two years after the day of testing and shall be available to the Inspector when required.

Rule no.62: **Systems at medium voltage**

Where a medium voltage supply system is employed, the voltage between earth and any conductor forming part of the same system shall not, under normal conditions, exceed low voltage.

Rule no.67: **Connection with earth**

1) The following provisions shall apply to the connection with earth of three-phase systems for use at high or extra-high voltages:-

In the case of star-connected with earthed neutrals or delta-connected systems with earthed artificial neutral point

a) The neutral point shall be earthed by not less than two separate and distinct connections with earth, each having its own electrode at the generating station and at the sub-station and may be earthed at any other point, provided that no interference of any description is caused by such earthing;

b) in the event of an appreciable harmonic current flowing in the neutral connections so as to cause interference with communication circuits, the generator or transformer neutral shall be earthed through a suitable impedance.

2) In the case of a system comprising electric supply lines having concentric cables, the external conductor shall be the one to be connected with earth.

3) Where the earthing lead and earth connection are used only in connection with earthing guards erected under high or extra-high voltage overhead lines where they cross a telecommunication line or a railway line, and where such lines are equipped with earth leakage relays of a type and setting approved by the Inspector, the resistance shall not exceed 25 ohms.

Rule no.69: **Pole type substations**

1) Where platform type construction is used for a pole type substation and sufficient space for a person to stand on the platform is provided, a substantial hand rail shall be built around the said platform, and if the hand rail is of metal, it shall be connected with earth:

Provided that in the case of pole type substation on wooden support and wooden platform the metal hand-rail shall not be connected with earth.

Rule no.88: **Guarding**

1) Every guard-wire shall be connected with earth at each point at which its electrical continuity is broken.

Rule no.90: **Earthing**

1) All metal support of overhead line and metallic fittings attached thereto, shall be permanently and efficiently earthed. For this purpose a continuous earth wire shall be provided and securely fastened to each pole and connected ordinarily at four points in every mile or 1.601 km, the spacing between the points being as nearly equidistant as possible. Alternatively, each support and metallic fitting attached thereto shall be efficiently earthed.

2) Each stay-wire shall be similarly earthed unless an insulator has been placed in at a height not less than 10 ft. from the ground.

The details of ELCB and relay are already discussed in the lession 2.2.70.

Illumination terms - Laws

Objectives: At the end of this lesson you shall be able to
- **explain the nature of light**
- **state and explain different terms used in illumination**
- **state properties and advantages of good illumination**
- **state and explain laws of illumination.**

The nature of light

Light is a form of electromagnetic radiation. It is basically the same thing as the radiations used in radio, television, X-rays, gamma rays etc. Visible light is the radiation in that part of the spectrum between 380 and 760 (nm) nanometre (10^{-9}M) to which the human eye is sensitive. A nanometre (nm) is a wavelength of one millionth (10^{-6} mm) of a millimetre.

Within these limits, differences in the wavelength produce the effect of colour, blue light being at the short-wave and red at the long-wave ends of the visible spectrum. Because the human eye is more sensitive to the yellow and green light in the middle of the spectrum, more power must be expended to produce the same effect from colours at the end of the spectrum.

Standared safety norms:

Trainees may be instructed to refer the Internation Electrotechnic Commission (IEC - 60598 part 2 section 3) web site for standard safety norms related with electrical illumination system for further details

Definitions

A few principle terms in connection with illumination are defined below.

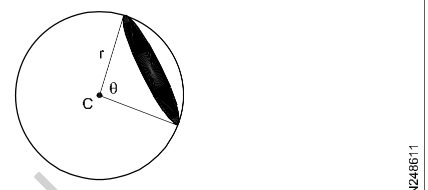
Luminous flux (F or Φ)**:** The flux of light emitted from a luminous body is the energy radiated per second in the form of light waves. The unit of luminous flux is `lumen'(lm).

Luminous intensity(I): The luminous intensity of a light source in a given direction is the luminous flux given out by the light source per unit solid angle. The angle subtended by an area r^2 on the surface of sphere of radius r, at the centre of sphere is unit solid angle. In SI, the unit of luminous intensity is the candela.

Candela: This is the amount of light emitted in a given direction by a source of one candle power. SI base unit is candela (cd). 1 candela = 0.982 international candles.

Lumen (lm)**:** It is the unit of luminous flux. This is defined as the amount of light contained in one steradian from a source of one candela at its focus. (Fig 1)

Fig 1



If the shaded area = r^2 and a source of one candela is at the centre C, the light contained within the solid angle is one lumen.

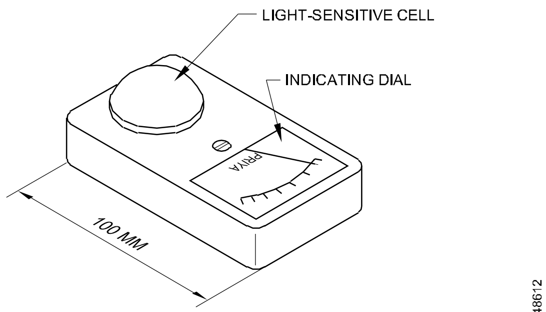
The light output of electric lamp is measured in lumens and their luminous efficiency (efficacy) is expressed in lumens per watt (lm/w).

Illuminance or Illumination (E): Illuminance of a surface is defined as the luminous flux reaching it perpendicularly per unit area. The metric unit is the lumen / m^2 or lux (lx).

Lux: This is the total output of light. Lumen per square meter (1m/m^2) or lux is the intensity of illumination produced in the inner surface of a hollow sphere of radius one meter by a standard candle at the centre. Sometimes this is also known as metre-candle.

Lighting engineers use a pocket-size instrument called a `lightmeter' to measure illuminance; and the reading in lux is read off the scale (Fig 2). This is not the same sort of instrument as a photographic exposure meter, which measures brightness, not illuminance.

Fig 2



TYPICAL POCKET-SIZE LIGHT-METER FOR MEASURING ILLUMINANCE.

Measured brightness is termed `luminance', and it should not be confused with `illuminance'. Luminance is the lumens emitted by a luminous surface of one square metre.

Two other terms that are easily confused with each other are `luminance' and `luminosity'. The first is measured brightness expressed in apostlibs or candelas per square metre, the second the apparent brightness as seen by the eye.

A simple example is the appearance of a motor car head lamps by day and by night. Their luminance is the same in both conditions but their luminosity is far greater at night than when it is seen in daylight.

Factors to be viewed for correct illumination

The following are the important factors which should be considered while planning correct and a good illumination:

Nature of work : Considering the nature of work , sufficient and suitable lighting sould be maintained. For example, a delicate work like radio and TV assembling, etc. requires good illumination to increase the production of work where as for rough work like storage, garages, etc needs very small illumination.

Design of Apartment : The design of apartment must be kept in view while planning scheme for illumination. It means that the light emitted by the illumination source should not strike the eyes of the occupants or workers.

Cost : It is an important factor which should be considered while designing an illumination scheme for particular purpose.

Maintenance Factor : While planning illumination, it should also be kept in view the amount of reduction of light due to accumulation of dust or smoke on the source of light and after how much period cleanliness is required. Where there is a possibility of heavy loss of light due to the adherence of smoke, arrangement for the extra light is to be made from the very beginning.

Properties of good illumination

An illumination source should, have the following properties.

i It should have sufficient light.

ii It should not strike the eyes.

iii It should not produce glareness in the eyes.

iv It should be installed at such a place that it gives uniform light.

v It should be of correct type as needed.

vi It should have suitable shades and refelectors.

Advantages of good illumination

i It increases production in the workshop.

ii It reduces the chances of accidents.

iii It does not strain the eyes.

iv It reduces the wastage or loss of material.

v It increases the interior decoration of the building.

vi It gives smoothing effect to mind.

Laws of illumination

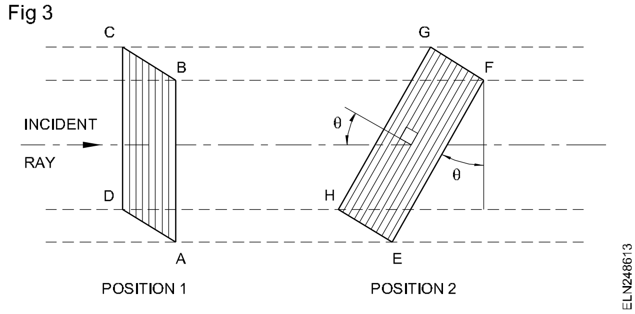
Inverse square law: If the internal radius of a sphere is increased from 1 metre to r metres, the surface area of it is increased from 4π to $4\pi r^2$ square metres. With a uniform point source of light of one candela at the centre, the number of lumen per square metre on the sphere of radius r metres.

$$= \frac{4\pi}{4\pi r^2} = \frac{1}{r^2}$$

Hence the illumination of a surface is inversely proportional to the square of its distance from the source. This is called the **Inverse Square Law of Illumination.**

Lambert's cosine law: According to this law, illumination (E) is directly proportional to the cosine of the angle made by the normal to illuminated surface with the direction of the incident flux. (Fig 3) Let Φ be the flux incident on the surface of area ABCD when in position 1. When this surface is so placed that the angle between the incident ray and the perpendicular to the surface EFGH is θ. The luminous flux falling on area EFGH is Φ.

Fig 3



Hence the illumination on the surface in position 1 is

$$E_1 = \frac{\Phi}{\text{Area ABCD}}$$

But in position 2, the illumination is

$$E_2 = \frac{\Phi}{\text{Area EFGH}}$$

(Area ABCD = AB x BC,

Area EFGH = EF x GF

$$= \frac{AB}{\cos\theta} \times BC$$

because, $\cos\theta = \frac{AB}{EF}$

Therefore, $E_2 = \frac{\Phi \times \cos\theta}{\text{Area ABCD}} = E_1 \cos\theta$

So illumination on EFGH

$$= \frac{1}{d^2} \times \cos\theta$$

where `d' is the distance of the surface from a source having a luminous intensity of one candela.

Filament lamps

Objectives : At the end of this lesson you shall be able to
- **list out the types of lamps**
- **explain the different types of lamps**
- **explain the construction and working of tungsten filament lamp.**

Types of lamps

There are many types of electric lamps now available. They differ in construction and in the principle of operation. The lamps can be grouped on the principle of operation as follows.

Filament lamps fall into a group of light producing devices called `incandescents'. They give light as a result of heating the filament to a very high temperature. The definitions of the terms are given below.

Electric lamps
- Filament lamps
  - Carbon
  - Metal
- Arc lamps
- Discharge lamps
  - Cold cathode
  - Hot cathode

Filament lamp: A lamp in which a metal, carbon or other filament is rendered incandescent by the passage of electric current.

Vacuum lamp: A filament lamp in which the filament operates in a vacuum.

Gas-filled lamp: A filament lamp in which the filament operates in an inert gas.

Halogen lamp: A tungsten filament lamp in which the tungsten filament operates in a relatively small space filled with an inert gas and halogen of iodine or bromine.

Arc lamp: An electric lamp in which the light is emitted by an arc.

Discharge lamp: An electric lamp in which the light is obtained by a discharge of electricity between two electrodes in gas or vapour.

Carbon filament lamp: The carbon filaments made today have limited application as resistance lamps (battery charging) and radiant heat apparatus. This lamp gives a reddish light and operates at a temperature about 2000°C. Above this limit, the carbon evaporates rapidly and blackens the glass bulb or envelope. The output from a carbon filament lamp is abot 3 lm/W (lumens per watt).

Tungsten filament lamp: This lamp consists essentially of a fine wire of the metal, tungsten (the filament) supported in a glass envelope and the air evacuated from the glass bulb - hence called a **vacuum lamp**.

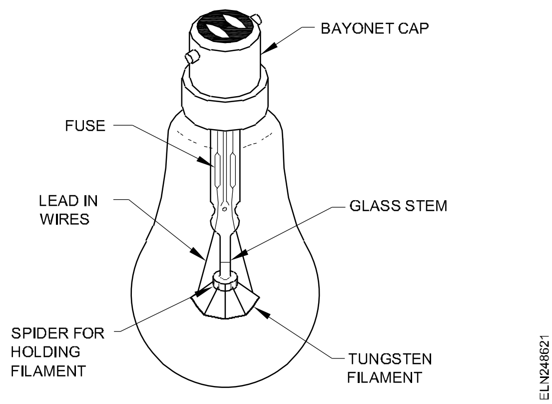
Filaments are now constructed of tungsten due to its exceptionally high melting point. It operates at a temperature of 2300° C and has an output of about 8 lm/W.

At temperatures above 2000°C, whilst the filament does not melt, it begins to break up and particles fly to the side of the lamp. This causes the glass bulb to become blackened. (Frequently observable in torch light bulbs.) The evaporation causes weak spots in the filament resulting in uneven resistance, which sets up hot spots and the filament burns out and breaks, i.e. fuses.

Filling up the bulb with an inert gas reduces the rate of evaporation. Argon and nitrogen are inert gases which do not support combustion. The operating temperature of a gas-filled lamp is about 2700°C. The output is in the region of 12 lm/W.

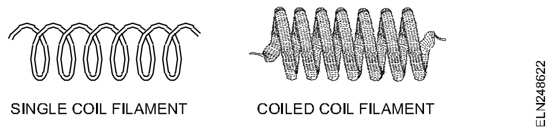
Fig 1 shows the parts of tungsten filament lamp

Fig 1



The two types of filaments (Fig 2) are

Fig 2



- single coil filament
- coiled coil filament.

The main advantage of a coiled coil lamp is the higher light output.

Most general lighting service (GLS) filament lamps used in homes have a bayonet cap (BC). Some small lamps used in special fittings have a `small' bayonet cap (SBC). Some GLS lamps have an Edison screw (ES) cap. There are also `small' Edison screw (SES) and `giant' Edison screw (GES) caps.

ES Caps are favoured for spot lights in which the lamp must be accurately positioned. Each type of lamp can be used only in an appropriate design of a lamp holder.

The rated life of GLS lamps is 1000 hours. This means that in any batch of lamps, 50 percent will have failed after 1000 hours of use. The life of an individual lamp in any batch may be greater or less than this average. The rated life is achieved in `normal conditions of use'. The normal conditions of use are

- operated cap up
- free from vibration
- not subjected to a voltage in excess of the rated voltage
- suitable light fittings.

Operating a filament lamp at a voltage higher than its rated voltage will reduce its life. Lower operating voltage will extend its life. At higher voltage, the filament gives a whiter and a more bluish light and operates at brighter and higher efficiency.

Lights and light fittings

Objectives: At the end of this lesson you shall be able to
- **name the types of bulbs for illumination**
- **explain direct and indirect lighting.**

Types of lamps used for illumination: The lamps used are:

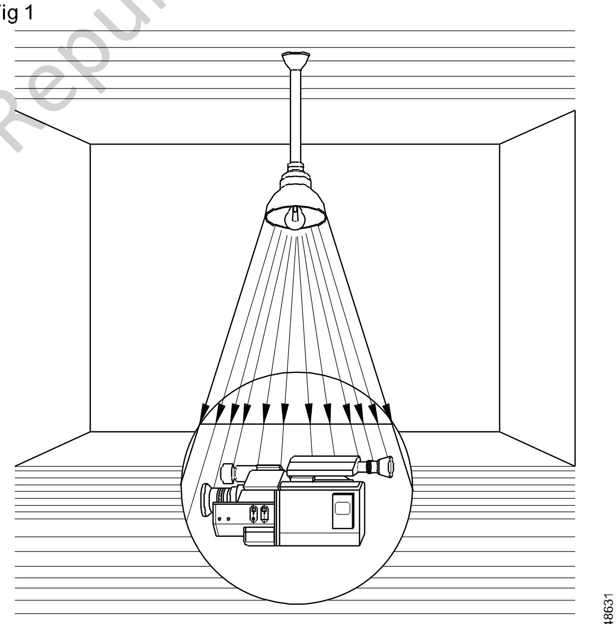
- incandescent lamps
- tube lights

Types of bulbs/incandescent lamps

- Glow lamps
- Moonlight lamps
- Luminous lamps
- Daylight lamps
- Tree light lamps
- Photo flood lamps
- Movie flood lamps
- Photo flash lamps
- Silvered bowl lamps
- Projector lamps
- Reflector lamps
- Halogen lamps.

Points to remember while designing illumination direct lighting and indirect lighting: Lighting for commercial purposes is divided into many parts such as built in direct lighting (Fig 1), indirect lighting (Fig 2), core lighting, spot lighting etc.

Fig 1



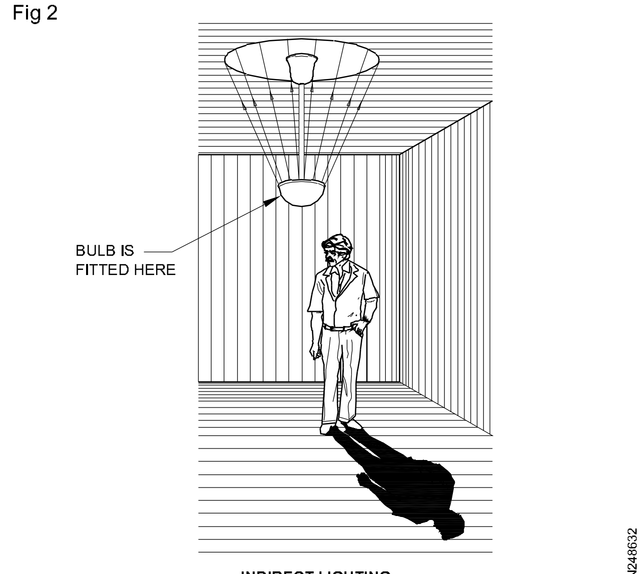
DIRECT LIGHTING

To achieve the above lighting there are ceiling fixtures, side wall fixtures, portable fixtures and other luminaries available.

The number of lumens required for the working place is 150 lumens/m^2. The lumens provided by the lamp must however be greater than this figure to allow for depreciation of the installation owing to dust and dirt on the lamps and their fittings.

Atleast 150 lumens per square metre should be provided for

Fig 2



INDIRECT LIGHTING

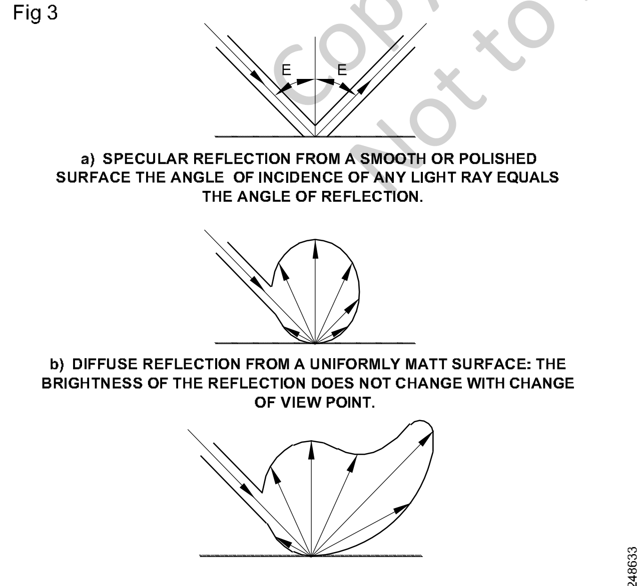
adequate visual performance on rough or unskilled work. Up to 1500 lumens per square metre should be provided for difficult or fine works.

Most sources radiate light in all direction and are too bright to be viewed comfortably. The light must therefore be controlled to direct it where it is required and to soften its brilliance.

Reflection of light may be of three kinds.

- Specular reflection Fig 3(a)
- Diffuse reflection Fig 3(b)
- Spread reflection Fig 3(c)

Fig 3



a) SPECULAR REFLECTION FROM A SMOOTH OR POLISHED SURFACE THE ANGLE OF INCIDENCE OF ANY LIGHT RAY EQUALS THE ANGLE OF REFLECTION.

b) DIFFUSE REFLECTION FROM A UNIFORMLY MATT SURFACE: THE BRIGHTNESS OF THE REFLECTION DOES NOT CHANGE WITH CHANGE OF VIEW POINT.

c) SPREAD REFLECTION FROM A SEMI-GLOSSY SURFACE (EGG-SHELL) FINISH

Specular reflection: When light strikes a mirror like surface it is reflected at the same angle and in the same plane as it strikes, for example a car lamp.

Diffuse reflection: Diffuse reflection is useless for the precise control of light, but it can be used to reflect light in a general direction.

Spread reflection: Unpolished metals and satin-finish mirrored surfaces have reflection characteristics between specular and diffuse. Vitreous and synthetic enamels are widely used for reflecting surfaces of light fittings. Vitreous enamels is the more hard working.

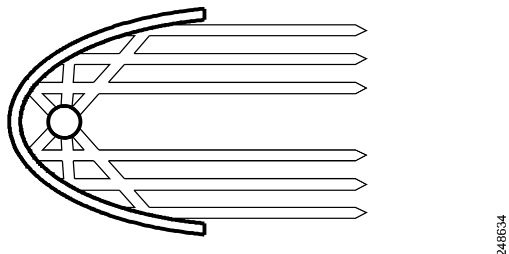
Types of reflectors: A lamp without any kind of reflector will radiate light in every direction. By placing the lamp within a reflector, you can control the light and direct it where you want it.

Dispersive type: The reflecting surface is either white enamelled or vitreous enamelled. The Viterous enamelled type is more expensive and less efficient optically but are more suitable for use in damp and corrosive atmosphere.

Mirror type reflector: These have highly polished surface for specular reflection. Silvered glass, Chromium plated; copper sheet anodized aluminium shades are typical example of this. This type is used in yard lighting

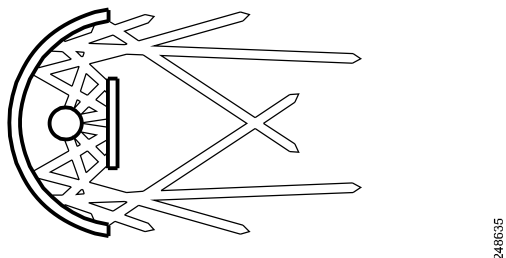
Parabolic and softlight reflector (Fig 4 & Fig 5): A parabolic reflector produces a hard light and is most commonly used with tungsten lamps. A softlight reflector has shield in front of the bulb and so produces a diffused light. A spotlight enables you to vary the light beam. In each case, the light will be softer if the reflector surface is matted or dimpled rather than highly polished.

Fig 4



PARABOLIC REFLECTOR

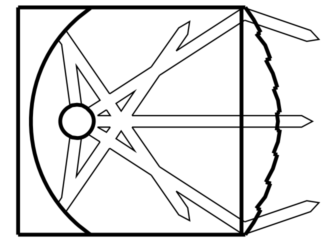
Fig 5



SOFTLIGHT REFLECTOR

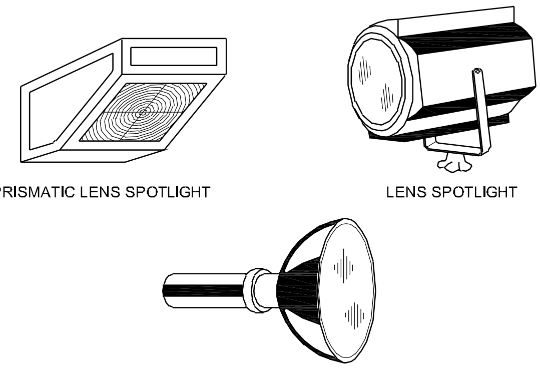
Spotlighting (Figs 6 & 7)**:** Spotlighting is one way lighting, usually employed projectors with lenses but sometimes with reflectors only, and is used to give special illumination to a limited area as in theatre practice. The spotlights must be so located as to be out of the direct line of vision and produce no troublesome reflections or glare.

Fig 6



SPOTLIGHT

Fig 7



TYPE OF SPOTLIGHT FIXTURES

Supplementary lighting: Supplementary lighting as the name implies, should be employed in conjunction with a general lighting system, when necessary or desirable.

Light fitting, types and performance (Fig 8)

Direct lighting type has largest efficiency from energy utilization point of view but glare is always present. Such systems are used for flood and Industrial lighting.(Fig 8a)

Indirect lighting type designed to avoid glare and recommended for specific purposes.(Fig 8b)

Semi direct type designed to avoid glare and recommended for offices and other specific purposes. (Fig 8c)

Semi indirect type designed to avoid glare and recommended for specific purposes.(Fig 8d)

General diffusing type system has got low efficiency but are free from glare and has got uniform distribution of light.

Details of reflector's and their %age of light distribution is given in Table 1 for your reference.

Fig 8

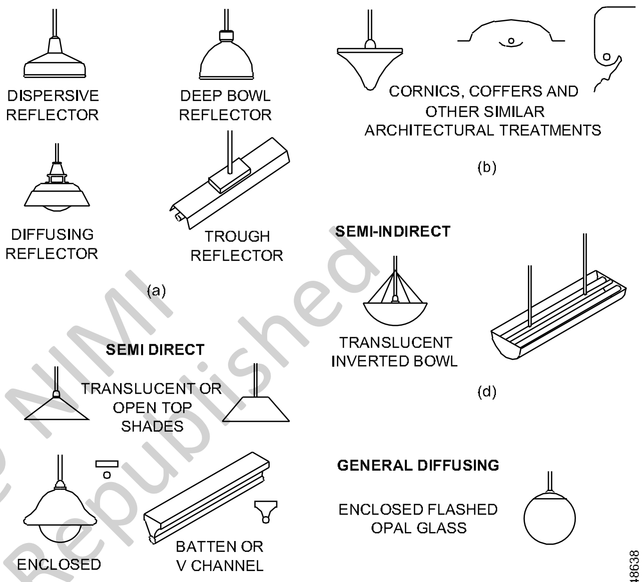


Table 1

Lighting systems

Types of system	Amount of emergent light	
	Downward	**Upward**
Shaded or reflector system		
1 Direct	90 to 100%	0 to 10%
2 Semi direct	60 to 90%	10 to 40%
3 Semi indirect	10 to 40%	60 to 90%
4 Indirect	0 to 10%	90 to 100%
Diffused system		
1 General diffused	50%	50%

Above table is in line with CIE classification of general indoor lighting luminaries

Low voltage lamps - different wattage lamps in series

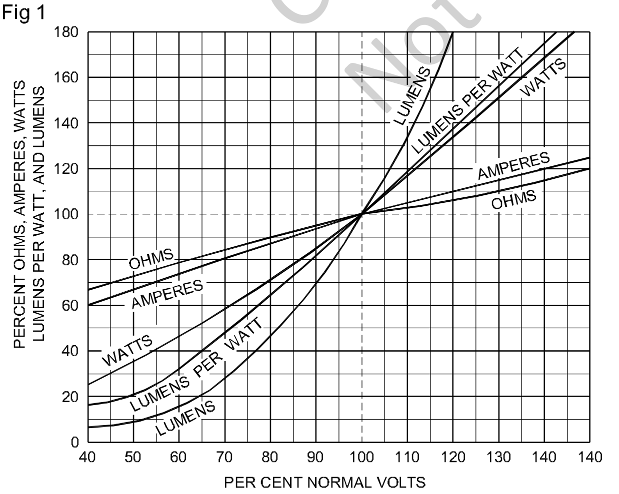
Objectives: At the end of this lesson you shall be able to
- **state the purpose of diffirtent voltage lamps**
- **calculate and compare the hot resistance of the same voltage but of different wattage/current lamps**
- **describe the method of measuring and calculating the 'hot resistance'**
- **state the effects of different wattage lamps in series.**

Purpose: In quite a few places we use low voltage supply i.e. 6V, 12V or 24V, such as in automobile vehicles. Automobile vehicles are equipped with many lights to provide an efficient lighting system for both day and night driving conditions. The various lights require the use of different wattage and types of light lamps to provide the amount of illumination desired.

Glow conditions of low wattage lamps with current flow through it: An electric lamp changes electrical energy into heat and light, when current flows through its filament and causes it to become incandescent. The filament is made of tungsten wire. The low voltage lamps are generally of low wattage because at a low voltage, the current taken by the filament for a given wattage is much more as compared to the domestic light.

The performance characteristics of tungsten-filament lamp is affected by voltage. The effect of operating a lamp at other than its rated voltage is shown in Fig 1. The decrease in voltage across the lamp lowers the current flow thus lowering the filament temperature. At 50% of the rated voltage, current decreases to about 68% and the resistance of the filament to 75%. The temperature of the filament lowers to an extent to give a light out of less than 10% lumens.

Fig 1



CHARACTERISTIC CURVES FOR INCANDESCENT LAMPS SHOWING THE EFFECT OF OPERATING A LAMP AT OTHER THAN ITS RATED VOLTAGE. THESE CHARACTERISTICS ARE AVERAGES OF MANY LAMPS.

Calculating the hot resistance: The lamp filament operates at a very high temperature, 1800°C to 2200°C. Therefore, there is a very big difference between 'cold resistance' and 'hot resistance'. Hot resistance (when the lamp is ON) is nearly 12 times more than the cold resistance (when the lamp is OFF).

Hot resistance

a Wattage = 12W

Voltage = 12V

$$\text{Current} = \frac{W}{V} = \frac{12}{12} = 1 \text{ amp.}$$

$$\text{Resistance} = \frac{V}{I} = \frac{12}{1} = 12 \text{ ohm(hot)}$$

b Wattage = 40W

Voltage = 24V

$$\text{Current} = \frac{W}{V} = \frac{40}{24} = 1.667 \text{ amps.}$$

$$\text{Resistance} = \frac{V}{I} = \frac{24}{1.667} = 14.4 \text{ ohm (hot)}$$

c

(i) Voltage = 6V

Current = 0.1 ampere

$$\text{Resistance} = \frac{V}{I} = \frac{6}{0.1} = 60 \text{ ohm (hot)}$$

(ii) Voltage = 6V

Current = 0.15 ampere

$$\text{Resistance} = \frac{V}{I} = \frac{6}{0.15} = 40 \text{ ohm (hot)}$$

(iii) Voltage = 6V

Current = 1 ampere

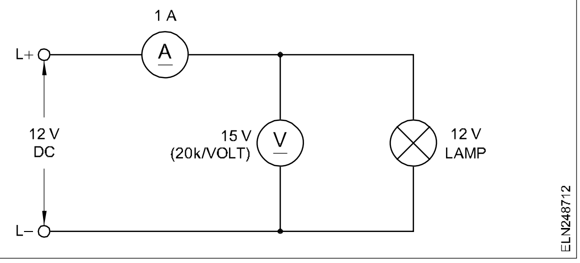
$$\text{Resistance} = \frac{V}{I} = \frac{6}{1} = 6 \text{ ohm (hot)}$$

The resistances calculated above are always hot resistance. To find out the cold resistance, it is measured with the ohmmeter when the lamp is OFF and at room temperature.

Measuring 'hot resistance': The hot resistance of a low voltage lamp could be measured by connecting the lamp as per the circuit given, Fig 2. The lamp must operate at its rated voltage. A voltmeter of high sensitivity not less than 20 k ohms per volt is used such that the current taken by the voltmeter is negligible. The reading of the ammeter and voltmeter must be taken accurately.

$$\text{Hot resistance} = \frac{\text{Voltmeter reading}}{\text{Ammeter reading}}$$

Fig 2



Different wattage lamps in series: If the two lamps of different wattage in parallel across in A.C. circuit, it should be same voltage for proper operation. But, if they are connected in series they should have the same current ratings.

All the bulbs in house are probably connected in parallel and they will draw the current it requires, and all the lamps will glow bright.

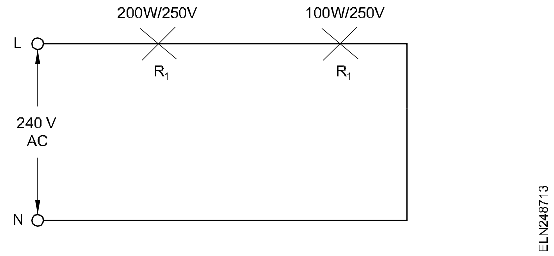
If two lamps with unequal wattages and same voltage ratings are connected in series they will divide up the available voltage between them.

Low wattage lamp will glow bright, due to high resistance and high voltage drop. High voltage lamp will glow dim, due to low resistance and low voltage drop.

Example

In a circuit the two lamps rated as 200W/ 250V, and 100W/250V are connected in series across 240 volt A.C. supply. (Fig 3)

Fig 3



200W (higher wattage) lamp will glow dim and

100W (low wattage) lamp will glow bright.

because,

The resistance of 200W/ 250V lamp,

$$R_1 = \frac{V^2}{W_1} = \frac{250 \times 250}{200} = 312.5\ \Omega$$

The resistance of 100W/250V lamp,

$$R_2 = \frac{V^2}{W_2} = \frac{250 \times 250}{100} = 625\ \Omega$$

Total resistance $R_T = 312.5 + 625 = 937.5\ \Omega$

$$\text{current } I = \frac{V}{R_T} = \frac{240}{937.5} = 0.256\text{A}$$

voltage drop in 200W lamp, $= IR_1 = 0.256 \times 312.5 = 80V$

Voltage drop in 100W lamp, $= IR_2 = 0.256 \times 625 = 160V$

Power V X I = 240 X 0.256 = 61.4 W

Hence,

The 100W lamp having high voltage drop due to high resistance it will glow bright than high wattge lamp 200W which is having low voltage drop and low resistance.

Various types of Lamps - Carbon arc lamps

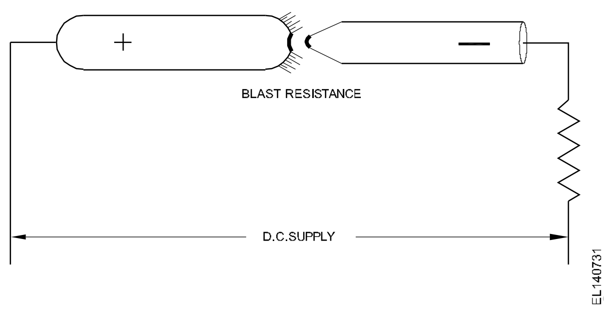
Objective: At the end of this lesson you shall be able to
- **Explain the construction and working of carbon arc lamp.**

Carbon arc lamp

Construction

Two carbon electrodes placed in contact end to end, in which direct current is flowing, and on separating by about 0.6 cm., apart gives out a luminous arc . (Fig 1)

Fig 1



The arc gives path to the flow of current and the separated ends of the carbon emits light rays. The major portion of the light is due to the electrodes and only 5 per cent is given out by the arc. About 85 per cent of light is given out by the positive electrode which has a temperature of 3500°C to 4000°C and only 10 per cent light is emitted by the negative electrode which has temperature of nearly 2500°C. In the Fig 1, a ballast resistance is also shown because of the negative resistance charcteristic of the carbon arc.

Working

The production of heat due to the arc is explained as:

When the carbon electrodes are separated, the electrons flow from negative electrode to positive electrode through the air. When passing through the air they collide with neutral air atom and set the air in ionised (charged) condition. The positive ions move towards the negative electrode colliding with the carbon, there they produce a good amount of heat, which raises the temperature of the negative electrode. Similarly the negative ion will move towards the positive electrode and collide with the electrode producing enough heat to raise the temperature of the electrode about 3500°C to 4000°C.

The heat developed at the positive electrode is greater because the negative ions have less weight than positive ions and so they move with higher velocity after collision.

Due to higher operating temperature, the rate of consumption of positive electrode is nearly double than the negative electrode. Due to this reason the positive electrode is made of twice the cross sectional area to that of the negative electrode. When using arc lamp on ac supply, both electrodes burn away at equal rates and therfore they are made of equal cross-sectional area. The efficiency of the arc lamp is higher than incandescent lamp and is about 0.5 to 0.3W per candle power or 20 lumens per watt.

Advantages and disadvantages

As the rate of consumption is high due to high operating temperature, it is essential to maintain the air gap between the electrodes to obtain constant and continuous light. For this purpose an electrical and mechanical arrangement is provided in arc lamps. When the carbon becomes short in length, they are replaced.

As this lamp needs frequent adjustment and replacement of the carbon rod, it is not used in general purposes. They are only used in cinemas projectors, search lights. The operating voltage of these lamps varies between 40 to 60 V.

Neon sign lamp

Objectives: At the end of this lesson you shall be able to
- **explain the construction and working of neon sign tubes**
- **explain the colour mechanism of neon signs**
- **state the regulation for the use of neon sign lamps.**

Gas discharge lamp

A gas discharge lamp is one in which some inert gas is filled in a glass tube having two electrodes sealed into each end, which on heating allows the flow of electron through it. To obtain a continuous flow of electron, gas is first charged but as the supply is disconnected from the bulb, the gas is discharged. Such a lamp is known as electric Gas Discharge Lamp. Electric gas discharge lamps are of two main types:

(i) Cold cathode lamp

(ii) Hot cathode lamp

In first type no filament is used to heat the electrode for starting but in the second type a filament is provided for heating the main electrode at the time of starting.

The function of both the lamps depend upon the fact that when a current is passed through the gas, it emits light rays. When a voltage is applied across the two ends of the filament contained in a gas filled glass tube, electrons start flowing from one electrode to the other. On the way they strike with neutral gas atoms separating an electron temporarily which when returns gives out light rays. The following are the different types of gas discharge lamps:

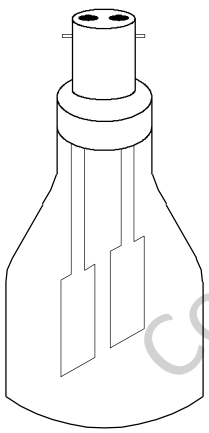
Cold Cathode Lamps (i) Neon lamp, (ii) neon sign tubes, (iii) sodium vapour lamp.

Hot Cathode Lamps (i) mercury vapour lamp (medium pressure), and (ii) fluroscent tube (low pressure mercury vapour lamp)

Types of gas discharge lamps

Neon Lamp This is a cold cathode lamp as shown in Fig 1 Neon gas at low pressure is used in it.

Fig 1



Construction

In this lamp, two flat or spiral electrodes are kept close together in a glass bulb so that the lamp can be operated at low voltage such as 150 V dc or 110 V ac. On giving supply to the electrodes, the gas becomes ionised and emits light which is reddish in colour. In usual practice a 2000Ω resistance is also connected in series with the electrodes which is placed in the cap of the lamp. This minimizes the fluctuation of current due to large variation of potential difference.

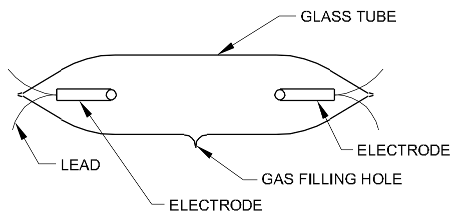
Uses

A neon lamp is generally used as an indicator lamp to indicate the presence of supply. It gives a small quantity of light and can also be used as a night lamp. A neon lamp of this type is also used in the testing pencil which is of 0.5 W.

Neon sign tube

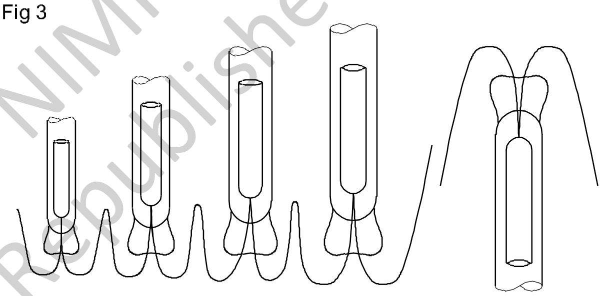
Construction of neon sign tube: Neon sign tube lamps are used mostly for advertising purposes. Fig 2 shows the construction details of a neon sign tube. A neon sign tube is made of glass.

Fig 2



The length of the tube varies from 1 metre to 5 metres, and the diameter varies from 10 mm to 20 mm. The tubes are joined with electrodes which are operated at high voltage. The electrodes are connected with nickel wires for more length or to different letters. (Fig 3)

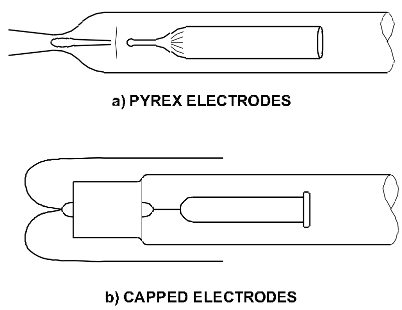
Fig 3



There are two types of electrodes.

- Pyrex electrode
- Capped electrodes (Figs 4a and 4b)

Fig 4



The shape of the electrode is cylindrical. The electrodes are made of nickel, iron or copper. The electrode consists of:

- a glass shell
- a lead in wires
- a glass jacket seal
- a ceramic collar. (heat resisting material)

The electrodes are fitted at the end of the tubes and fused. A vacuum is created in the tube before filling it up with an inert gas, such as neon or helium. After that it will be sealed. The neon sign tube will operate at 2000V to 15000V depend upon the length of the tube, and the current flow depends on the diameter of the tube. (Table 1)

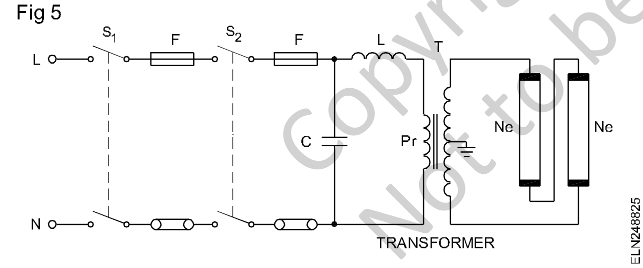
Table 1

Type	10SC	12SC	D4C	19MC	D stud
Size of electrode	10mm dia	12mm dia	15mm dia	19mm dia	15mm dia
Current	10mA	20mA	50mA	60mA	50mA

Working of neon sign tube: The neon sign tube requires a high voltage to operate. (Fig 5) This is obtained by a leakage field transformer (T) which simuntanously limits the current. The colour and the temperature of a neon tube depend on the gas inside, and we can also get various colours by using different fluorescent materials.

When high voltage is applied between the electrodes, the positive ions and the electrons drift towards the cathode and anode respectively. The movement of electrons increases with the potential and attain a very high velocity. The movement of electrons results in collision with the netural atoms, and may detach electrons from them. The high velocity of electrons is responsible for luminous discharge (light). The striking voltage of a neon sign lamp is about 1.5 times higher than the operating voltage, which is controlled by the R.F. choke)'L'.(Fig 5)

Fig 5



Circuit description and operation

Step-up transformer: The step up transformer is used to obtain a high voltage. The centre tap is earthed. The secondary output voltage is connected to the neon lamp.

R.F. choke L is connected in series with the primary of the leakage transformer to limit the surge current of the neon lamp. (Fig 5)

The capacitor C It is connected across the primary of the transformer to improve the power factor.

The fireman switch S2 It is connected alongwith the main switch and is used as an emergency switch. (Fig 5)

Main switches normally 15A 250V ICDP are used to control the circuits.

H.T. cables are used to connect the secondary of the transformer to the neon sign lamp as per IE rule No 71.

Colour mechanism of neon sign lamp: When electric current is conducted by a gas or vapour it produces luminous light. The elements most commonly used in this process of producing light by gaseous discharge are neon or mercury. The neon discharge yields orange-red light which is very popular in making advertising signs. The pressure of neon in the tubes is usually from 3 to 20 mm of the Hg. (millimeter of mercury)

Table 2

	Basic powder	Colour
1	Calcium tungstate	Blue
2	Magnesium tungstate	Blue-white
3	Calcium silicate	Pink
4	Zinc silicate	Green
5	Zinc beryllium silicate, depending upon the activating agent	Yellow, white, pink
6	Cadmium silicate	Yellow, pink
7	Cadmium borate	Pink

The ultimate colour produced by using fluorescent powders depends not only on the chemical composition of the powders but also on the gas, the pressure at which the gas was filled, the diameter of the tubing and the operating current.

Neon lighting - regulations: Maximum voltage 5000V to earth. Thus a 10KV display unit could be used provided its supply transformer is centre-tapped to earth.

H.V.Transformers: Where the input exceeds 500W, an automatic disconnection of the supply is to be provided in the event of a short-circuit or earth-leakage of current which exceeds 20% of the normal steady current.

Installation: All equipment to be housed in an earthed metal or substantial containers suitable for high voltage. A notice `Danger-High Voltage' in the type of lettering as stated in 1.E regulation No.71, to be permanently fixed near to the equipment.

For connection to high voltage cables, the insulation which is exposed by removing the metal sheath or braid must be protected from the effects of the sun's ultra-vilot rays.

Armouring may be required + cables may only be drawn through short- earthed lengths of metal tubing where they are passing through walls or ceilings. Unless easily identifiable, high voltage cables require, red on white background `DANGER' notices, at intervals not greater than 1.5 m; the minimum height of the letters to be 8 mm.

Separation and isolation: High-voltage discharge lamps to be supplied via a double-wound transformer. However auto-transformers may be used on 2-wire circuits which do not exceed 1.5KV, one pole to be connected to earth and the control switch to be of the double-pole type. Isolation of live conductors may be made by any one of the following methods.

- An interlock on self-contained fitting to be provided in addition to the switch normally used for controlling the circuit.
- Local isolation by plug and socket or similar method in addition to the normal control switch.
- Switch should be with a removable handle. Alternatively, a switch or distribution board of a type that can be locked may be fitted, if the keys are held by authorised persons. Where there are more than one switch or distribution board all removable handles and keys are to be non-interchangeable.

Fireman's switch: These emergency switches, which are required for neon lighting installations, must be provided for all exterior H.V. installations including closed markets and arcades. Internally, their use is confined to circuits that are run unattended, such as in window-display signs. The fireman's switch must also conform to the following requirements.

- The switch must be able to isolate the live conductors. One switch only should be fitted to control the whole of an exterior installation, and another for the interior.
- The switch should be coloured red with an adjoining name-plate marked `FIREMAN'S SWITCH' with regulation lettering.
- The ON and OFF positions to be clearly indicated by lettering legible to a person standing on the ground; the switch `OFF' to be positioned on the top, and the construction must be such as to prevent accidental movement of the switch to the ON position.
- The fireman's switch should be in a conspicuous position, as may be agreed to with the local fire brigade authority, at not more than 2.75 m from the ground. It is desirable that the switch be adjacent to the discharge lamps for an exterior installation and at the main entrance to the building for an interior installation.

Sodium vapour lamp

Objectives: At the end of this lesson you shall be able to
- **state the sodium vapour lamp and its types**
- **describe the construction of low and high pressure sodium vapour lamp**
- **state the functions of the parts in the circuit**
- **specify the standard sizes of sodium vapour lamps available**

Sodium vapour lamp and its types: Sodium vapour lamp is a cold cathode gas discharge lamp, which gives a yellow colour light. Sodium lamps are not suitable for locations where colour rendition is important, but due to their higher efficiency (110 lumens/watt), they are used for the lighting of streets, railways, storage yards etc. where human traffic is less and colour rendition unimportant. Sodium lamps are particularly suitable in fog as their yellow light can penetrate fog better.

The average life of a sodium vapour lamp is well over 6000 hours. There are two types of Sodium Vapour lamps as given below:

- low pressure SV lamp
- high pressure SV lamp.

Construction

Low pressure sodium vapour lamp: In the sodium vapour lamps efficiency decreases rapidly as the current density is increased above a certain value. Consequently the lamp has to be operated at a low current density and this necessitates a large surface area of the tube.

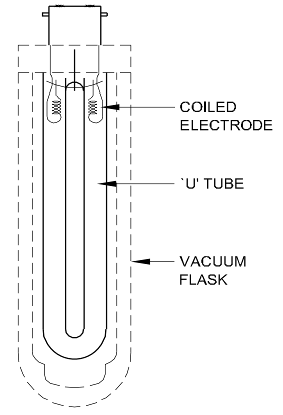
This lamp possesses a brightness of 7.5 candle per sq.cm. Because of these points the length of this tube has to be very long. Moreover its efficiency is very sensitive to the change in tube temperature. For maximum efficiency the temperature of the lamp has to be maintained at about 220^{0}C. So the whole tube is placed in a detachable double walled vacuum jacket.

As stated above low pressure Sodium Vapour lamps require a long tube, but as there is limit to the practicable size of such a jacket of the vacuum flask type, the long lamp tube is bent to a `U' shape to suit the jacket.

The low pressure Sodium Vapour lamp possesses a `U' shaped glass tube internally coated with fluorescent powder, consisting of Sodium together with Neon and one percent of Argon, the function of the Argon being used to reduce the initializing voltage.

In a cold lamp the Sodium is in the form of solidified drops on the inner walls. The tube contains two Barium and Strontium coated, coiled Tungsten electrodes at both ends. The two ends of the electrodes are fixed to the bayonet cap. (Fig 1) Connection diagram is Fig 3.

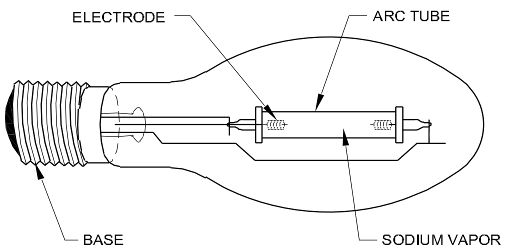
Fig 1



SODIUM DISCHARGE LAMP

High pressure sodium vapour lamp: A high pressure Sodium vapour lamp (Fig 2) operates at a much higher current which flows through a much shorter arc tube (discharge tube).

Fig 2



HPSV LAMP

This discharge tube is made of sintered aluminium ceramic discharge arc tube which is resistant to the hot ionised Sodium Vapour up to a temperature of about 1600^0C which transmits over 90% of visible radiation.

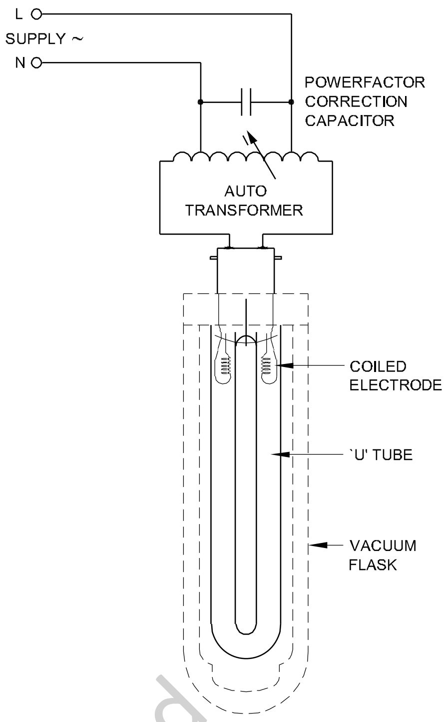
The discharge tube operates at a pressure of about half an atmosphere, and is enclosed in an evacuated hard glass envelope of elliptical shape to maintain the tube at the correct temperature. (Fig 3) The lamp gives a rich Golden light which enables colours to be easily distinguished. This discharge tube contains Sodium and Mercury, with Argon or xenon added at a low pressure for starting purposes at low pressure.

A voltage pulse of about 2.5 KV is required to initiate the discharge (Fig 4) in higher pressure Sodium Vapour lamp. This high voltage pulse is generated by high external ignitor or by built in thermal starter.

Leak transformer: The ignition voltage of sodium lamps varies from 400 to 600V. A `leak transformer' performs the dual role of providing the ignition voltage initially, and acting as a choke for limiting the current subsequently when the lamp starts conducting. The diagram of a leak transformer is shown in Fig 5.

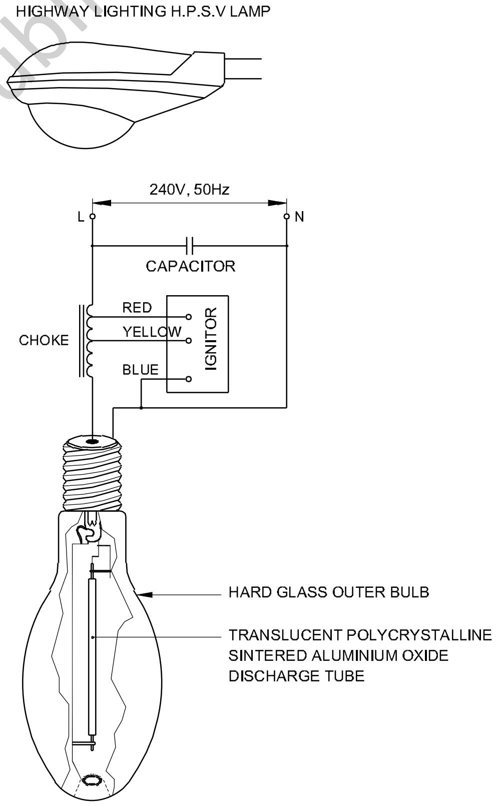
The primary and the secondary windings are connected in series and placed around the centre limb of a 3-core yoke. Between the coils, a loose iron core is clamped in

Fig 3



SODIUM DISCHARGE LAMP

Fig 4

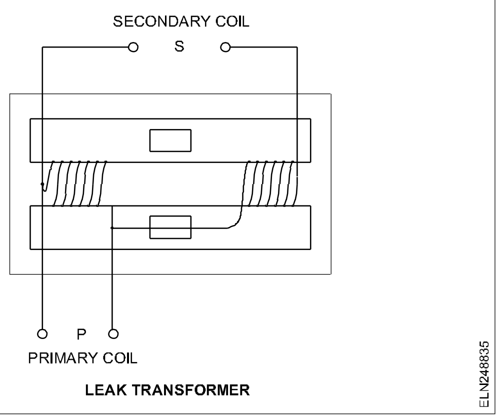


HIGH PRESSURE SODIUM VAPOUR LAMP

the yoke on either side, which acts as a shunt for the magnetic field.

Under no-load conditions, the resistance of the shunt is large due to air gaps, with the result the magnetic field moves through the limbs of the yoke, and the device acts as an auto-transformer. But when the lamp ignites and consumes current, a part of the magnetic field leaks away through the shunt due to the counter-acting field of the secondary.

Fig 5



LEAK TRANSFORMER

The device now acts as a choke coil reducing the voltage across the lamp electrodes to the required value.

Function of Sodium vapour lamp

Before the lamp starts, the sodium is usually in the form of a solid deposited on the sides of the tube walls. So in the initial stage when the potential is applied to the lamp it operates as a low pressure Neon lamp with pink colour (characteristics of the neon gas); but as the lamp warms up it vaporizes the sodium, and slowly it radiates out yellow light ,and after about ten minutes the lamp starts giving its full output.

Now the resistance of the lamp decreases and the current increases but the voltage drop across the high leakage transformer controls the current to safe values.

The lamp works at low voltage, and the working temperature is about 300^0C.

Operating position of sodium lamps: Sodium lamps of 45W and 60W may be operated in horizontal or any other position. The cap of the lamp should always be higher than the lamp itself, so that the Sodium does not settle behind the electrodes.

For Sodium lamps of should not exceed 20°; otherwise, the distribution of the sodium will be altered, affecting the life and performance of the lamp.

Life of sodium lamps: The average life of a sodium lamp is well over 6000 hours for three or more burning hours per switching operation. At the end of this period the light output will be less by about 15% due to ageing.

Tin-oxide sodium lamps (SOX Lamps): This lamp is an improvement over the ordinary sodium lamp the light output in its case is of the order of 150 lumens/watt.

Details of sodium vapour lamps (Std sizes)

Data on sodium lamps

Watts	Lamp voltage V	Minimum starting voltage V	Current A	Light output (lumens)	Dimensions mm
45	80	340	0.6	3500	257 x 51
60	105	340	0.6	5000	300 x 51
85	160	400	0.6	8000	414 x 51
140	160	410	0.9	13000	525 x 10
200	260	600	0.9	22000	785 x 60

Data on tin-oxide sodium lamps

Watts	Voltage	Current	Light output (lumens)	Dimensions
40	75	0.5	4400	310 x 51
60	115	0.7	7800	425 x 51
100	125	0.95	12500	528 x 64.5
150	185	0.94	20500	775 x 64.5
200	265	0.90	30000	1120 x 61.5

High pressure mercury vapour lamp (H.P.M.V)

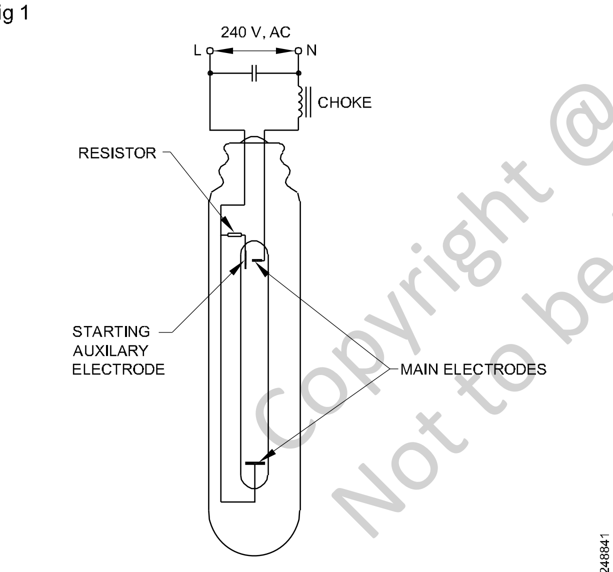
Objectives: At the end of this lesson you shall be able to
- **state the principle of discharge lamps**
- **describe the working of a `high pressure' mercury vapour lamp**
- **explain the different types of mercury vapour lamps**
- **identify the circuit elements in a mercury vapour lamp**
- **compare a sodium vapour lamp with a mercury vapour lamp.**

Discharge lamps: When an arc is struck in gas or metallic vapour, it radiates energy in characteristic wave-bonds. For example, neon gives red light, sodium yellow and mercury vapour four distinct lines in the visible, and two in the ultraviolet region of the spectrum.

All modern discharge lamps operate in a translucent enclosure. The initial discharge is usually struck in argon or neon.

The discharge occurs in an inner tube enclosed in an outer evacuated tube. (Fig 1) The inner tube of glass or quartz contains mercury and a small amount of argon to assist in the starting of the discharge. The electrodes are rich in electron-emittting materials in order to permit ease in the release of electrons.

Fig 1



MA TYPE HPMV LAMP CIRCUIT

Working of HPMV lamps

The lamp operates at high pressure. To start the discharge, an auxiliary electrode is positioned quite close to the main electrode. The auxiliary electrode is connected to the lamp terminal through a high resistor.

The high resistor limits the current. When switched on, the normal mains voltage is not sufficient to start the discharge between the main electrodes but it can start over the very short distance between the main and auxiliary electrodes.

At the beginning, the discharge current passing through the high resistance causes a potential difference to develop between the starting electrode and one of the main electrode through the argon gas. The discharge now spreads rapidly until it takes place between the main electrodes.

The argon discharge then warms up the tube and vaporises the mercury. Soon the gas content is mainly mercury vapour and the argon has less and less effect. The discharge then takes place in the mercury vapour.

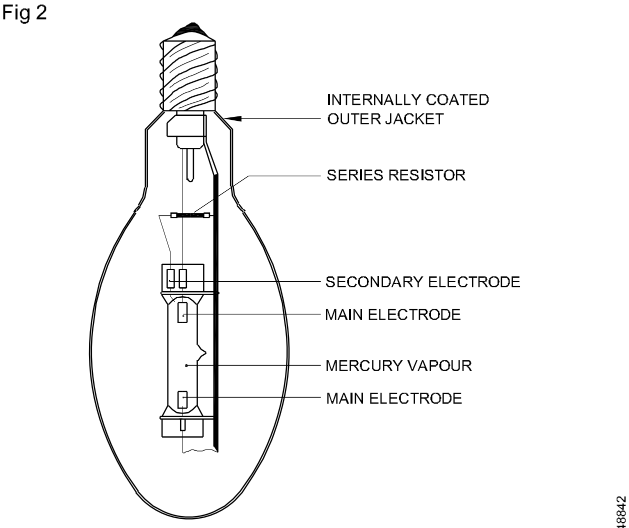
Types of HPMV lamps

Three different types of high pressure mercury vapour lamps are:

- MA type (MV lamp with auxiliary electrode)
- MAT type (MV lamp with tungsten filament)
- MB type. (MV lamp with auxiliary electrode and Bayonet cap)

MA type HPMV lamp: The discharge tube is made of borosilicate which is quite hard. The tube consisting of the main and auxiliary electrodes is sealed with an inside pressure of one and a half atmospheres. The lamp has a screw cap and is connected to the mains through the choke. (Fig 2) The lamp takes about 5 minutes to start giving full output.

Fig 2



MA TYPE HPMV LAMP

This lamp, once switched off, will not restart again until the pressure developed inside the tube falls back. It takes about 7 minutes to start again. There is no harm in keeping the switch on. The lamp should always be hung vertically, otherwise the inner tube will be damaged.

The efficiency is 45 lm/watt for 400 watts lamp.

MAT type lamp: This type of lamp is almost similar to the MA type, but the outer glass envelope, instead of being empty, consists of a tungsten filament. The tungsten filament, similar to the one in an ordinary lamp, is in series with the discharge tube. It acts as a ballast. This lamp requires no external choke (or ballast) and capacitor.

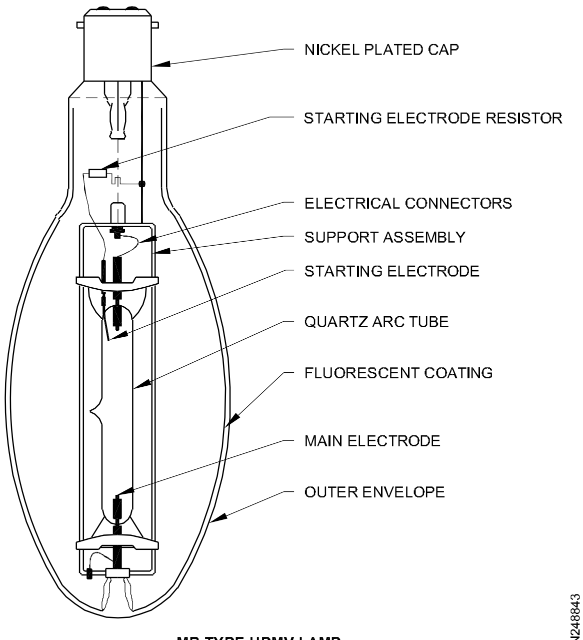
When the lamp is switched on, it works as a filament lamp does and its full output is given by the outer tube. At the same time, the discharge tube starts warming up, and when a particular temperature is attained, a thermal switch operates. The thermal switch cuts off a part of the filament so that the voltage across the discharge tube increases.

The light output is a mixture of light produced by a filament lamp and a discharge lamp.

MB type lamp: This lamp operates at an extra high pressure of 5 to 10 atmospheres. The discharge tube of this type is of quartz, about 5 cm long and has three electrodes, two main and one auxiliary. This lamp has a 3-pin bayonet cap and it cannot be put into an ordinary holder as it requires a choke and capacitor. (Fig 3)

The functioning of the tube is similar to that of a MA type lamp. Since a quartz tube can withstand high temeperature, it can be used in any position.

Fig 3



MB TYPE HPMV LAMP

The wattages available are 80 watts 125 W, 250 W, 400 W, 700 W and 1000 watts operating in 230V/250V, 50 Hz main supply.

The efficiency is about 50 lm/W.

Comparison of Sodium vapour lamp with Mercury vapour lamp

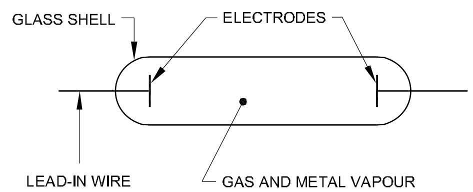
Sl.No.	Sodium vapour lamp	Mercury vapour lamp
1	It is provided with a high leakage reactance transformer.	It is provided a with choke. (Ballast)
2	Higher light efficiency: 160 lm/w.	Lower light efficiency: 50 lm/w.
3	Ignition voltage of Sodium Vapour lamp varies from 400 to 600V.	Ignition voltage of mercury vapour lamp is less.
4	Burning position critical.	Burning position not critical.
5	Yellowish light.	Greenish blue light.
6	It posses only two main electrodes.	It posses two main electrodes and one auxiliary electrode.

Fluorescent lamp

Objectives : At the end of this lesson you shall be able to
- **state the principle of discharge lamps**
- **describe the construction of single tube fluorescent lamp with its components**
- **state the function of each component in the circuit**
- **state probable causes for different problems in the circuit malfunctioning.**

Principle of a discharge lamp : The basic principle of a gas-discharge lamp is explained in Fig 1. Gases are normally poor conductors, especially at atmospheric and higher pressures, but application of suitable voltage (known as ignition voltage) between two electrodes in a sealed envelope containing gas at low pressure ionises the gas, and current passes from one electrode to the other through the gas medium.

Fig 1



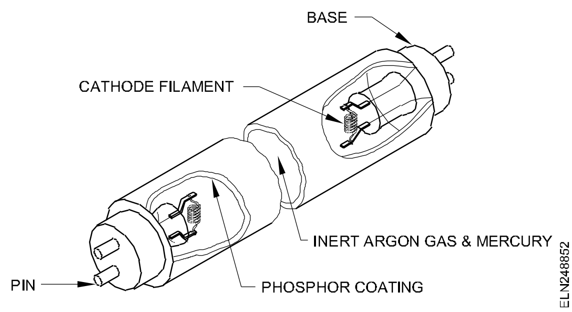
GAS-DISCHARGE LAMP

A glass shell with two electrodes apart is connected through lead in wires to the voltage source. The space within the shell is filled with low pressure vapour. When the voltage applied to the electrodes is increased to a certain value, the gas inside gets ionised and starts conducting.

The current flow through the low pressure gas is called discharge. This causes the gas/vapour to emit radiation in the ultraviolet region. The UV radiation cannot be perceived by the human eye. Certain phosphors have the property of emitting light in the visible spectrum when it is exposed to UV rays.

Construction of fluorescent tubes: A fluorescent light bulb is basically a glass tube capped by two bases. (Fig 2) These bases are fitted with pins to carry current to internal components called cathodes. Contained inside the tube are minute droplets of mercury and an inert gas.

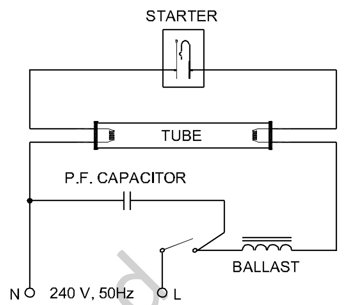
Fig 2



The inner surface of the tube is coated with a fluorescent powder or phoshphor. This phosphor emits light when exposed to ultra-violet rays. Cathodes or electrodes are made up of coiled tungsten filaments coated with a mixture of barium and strontium oxides.

Circuit diagram: The method of connecting the starter, ballast and the tube's electrodes at its either end is as in (Fig 3)

Fig 3

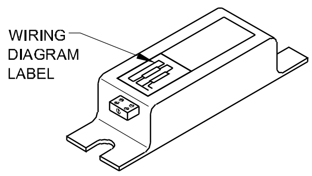


CIRCUIT DIAGRAM

Function of the various parts in a fluorescent light circuit

Ballast (Choke)**:** The ballast is basically a coil of many turns wound on a laminated iron core (Fig 4). It steps up the supply voltage to start the fluorescent tube conducting. Once the tube is conducting, it regulates the flow of heavy current to the tube cathodes to keep them from burning out.

Fig 4



BALLAST

Starters: A starter in the fluorescent tube circuit performs two functions.

- It completes the circuit at first for preheating the electrodes.
- It opens the circuit to provide voltage kick for ignition.

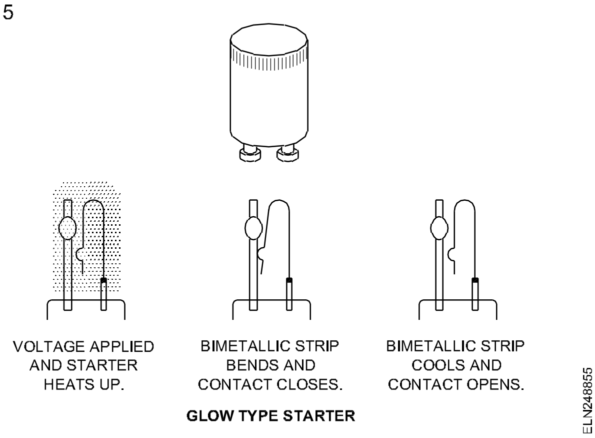
There are two types of starters.

- Glow-type
- Thermal type

Glow type starters: A glow-type starter switch (Fig 5) is the one most widely used. It consists of a gas-filled glass tube containing two electrodes, one of which is a bimetallic strip. When voltage is applied to the starter, a glow discharge occurs between the two contacts. The heat thus developed causes the bimetallic strip to deflect and close the circuit.

Current for preheating the electrodes starts flowing. At the same time the glow discharge ceases resulting in the cooling of the bimetallic strip. The contacts reopen and the voltage induced in the choke coil provides the ignition voltage.

Fig 5

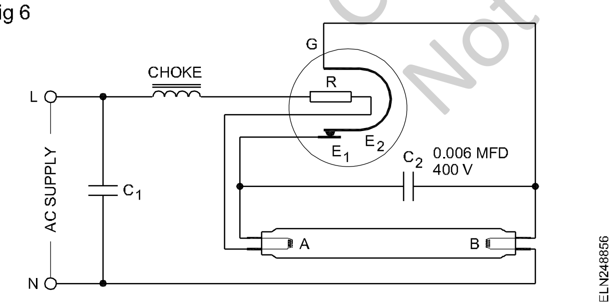


Thermal type starter: The switch has a bimetalic strip close to the resistance R which produces heat.

Thermal type starters are generally enclosed in a hydrogen - filled glass bulb G. The two switch electrodes E_1 and E_2 are normally closed when the lamp is not in operation. When normal supply is switched on, the lamp filament electrodes A and B are connected together through the thermal switch and a large current passes through them.

Consequently, they are heated to incandescence. Meanwhile the heat produced in resistance R causes the bimetallic strip E_2 to break contact. The inductive surge of about 1000V produced by the choke is sufficient to start discharge through mercury vapours as explained. The heat produced in R keeps the swtich contacts E_1 and E_2 open during the time as shown in Fig 6.

Fig 6



A 0.006 MFD capacitor (C_2) is connected across the electrodes of the starter contacts (bimetals) in the case of both thermal and glow type starters, to eliminate any radio interference effects that may be caused by the opening and closing of the bimetallic contacts.

Fluorescent tube: When the circuit in Fig 3 is energised, a small current passes through the series reactor, the two tube filaments, and the glow-tube. At the instant when the circuit is energised, the current is very small because of the high resistance of the glow-tube.

Because of the high resistance of the glow-tube, the current is small, and there is little voltage drop across the series reactor. Therefore, there is sufficient voltage at the glow-tube to produce a glow discharge between the U-shaped bimetallic strip to expand and close the contacts. Preheating takes place at both cathodes.

The current through the two filaments is relatively high but the series reactor limits the current to a safe value. In the period that the contacts of the glow-tube are closed, the temperature of the fluorescent tube electrodes increases rapidly.

However, when the contacts close in the glow-tube, the glow discharge is stopped, the bimetallic U-strip cools and the contacts open. At the instant these contacts open, an inductive voltage-kick generated by the series reactor coil starts conduction of current between the main electrodes of the fluorescent tube.

A stream of electrons flows between the filament electrodes. These electrons collide with the electrons of the argon and mercury vapour in the tube. The two gases radiate ultraviolet light. These rays bombard the phosphor coating on the tube wall. The phosphor-coating radiates visible light.

The fluorescent lamp continues to operate as long as the circuit is energised. The usual operating voltage for satisfactory operation is 110 to 125 volts AC. Once the circuit is in operation, the reactor limits the current to the rated value so that the fluorescent tube fluoresces at the proper light intensity.

Power factor correction capacitor: The reactor or voltage ballast in series with the fluorescent tube causes the power factor of fluorescent units to range between 50 and 60 percent lag. The power companies, therefore, have requested the various fluorescent lamp manufacturers to install capacitors in fluorescent lighting units. So that the operating power factor of most fluorescent lamp units is near 100 percent or unity.

Standard sizes of fluorescent lamps available in the market: The light output of a fluorescent lamp amounts to about 70 lumens per watt. The usual sizes are 10, 20, 40 and 80 watts; 1 foot (30 cm), 2 feet (60 cm), 4 feet (120 cm) and 5 feet (150 cm) respectively at 240 volts.

Comparison of a fluorescent lamp with incandescent lamps: Fluorescent lamps or tubes have several advantages over standard incadescent lamps. Their main advantage is that they can produce light at a much lower cost. Fluorescent tubes produce about four times as much light per watt of power than do incandescent lamps. This makes them much cheaper to operate. Glare level is low.

Fluorescent tubes produce less heat than incandescent lamps due to their higher light efficiency. If you touch a fluorescent tube after it has been `ON' for some time, you will note that it is cool to touch. Large incandescent bulbs will cause burns to anyone trying to remove them after they have been in operation for some time.

Under ordinary operating conditions, fluorescent lamps last five to fifteen times longer than standard incandescent lamps. However, the more often a fluorescent lamp is turned on and off, the shorter its life span. The major disadvantage of fluorescent lighting is the higher initial

cost of the fixture. This extra cost is due to the auxiliary hardware required to operate the fluorescent lamp circuit.

The disadvantage is the small wattage of these lamps require a large number of fittings.

Life of fluorescent lamps: Their normal life span is 7500 hours. They are affected by both high and low voltage, frequency of switching. The average life is for three burning hours per switching operation. The actual life may vary from 5000 to 10000 hours, depending upon the operating conditions. Light output is reduced by 15 to 20% after 4000 hours operation, and it is, therefore, a good practice to replace the fluorescent lamps after 4000 - 5000 hours of burning, on economic grounds.

Fluorescent light - Trouble shooting

Fluorescent light - troubleshooting chart

Problem	Possible causes	Solution
The tube fails to start	Bulb burnt out.	Replace bulb.
	Defective starter.	Replace starter.
	Broken lamp-holder.	Replace lamp-holder.
	Incorrect bulb for ballast	Check ballast label for correct bulb.
	Fixture wired incorrectly.	Check wiring diagram on ballast label.
	Line voltage too low.	Contact electricity board.
	Air temperature too low.	Install special low-temperature,ballast.
	Defective ballast.	Replace ballast.
Ends of the bulb glow but centre does not	Defective starter.	Replace starter.
	Fixture wired incorrectly.	Rewire according to ballast wiring diagram.
	Fixture not adequately grounded	Check ground connection on fixture.
Ends of bulb are black.	Bulb nearly burnt out.	Replace bulb.
Bulb flickers or blinks.	Tube pins making poor contact.	Clean the prongs and tighten the tube in the lamp-holder.
	Bulb nearly burnt out.	Replace bulb.
	Defective or incorrect starter.	Replace starter.
	Air temperature too low.	Warm room; if necessary install special low temperature ballast.

Instant start fluorescent lamp

Objectives: At the end of this lesson you shall be able to
- **describe the construction and working of an instant start fluorescent lamp**
- **state the purpose of instant start ballast**
- **explain the advantages of instant start fluorescent lamps.**

Instant start flouresent lamp

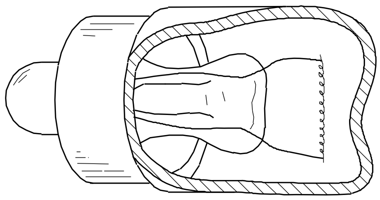
The instant start or quick start method of starting fluorescent lamps consists of an auto-transformer connected across the tube. When the electrodes become hot (usually in a fraction of a second), the tube strikes.

Construction and working

The fluorescent lamp, designed for instant starting, has only one terminal at each end. It has a filament type of cathode and operates as a hot-cathode lamp. The current passing between the two electrodes heat the segments of the small wire filaments to red-hot temperature in a fraction of a second. Therefore the need for separate starters is eliminated.

Fig 1 illustrates the construction of the filament type cathode and single terminal pin used on instant start fluorescent lamps.

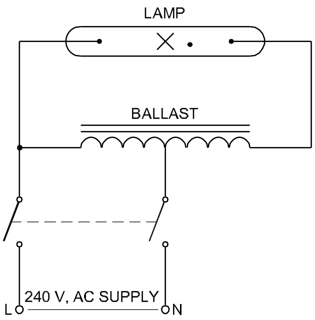
Fig 1



This type of construction results in lower electrode losses. The other details of construction for instant start fluorescent tubes are the same as for preheat fluorescent tubes with the exception that the diameter of the instant start tubes is slightly smaller than that of the pre-heat fluorescent tubes.

Fig 2 illustrates the connections for a circuit used to operate instant start fluorescent lamps.

Fig 2



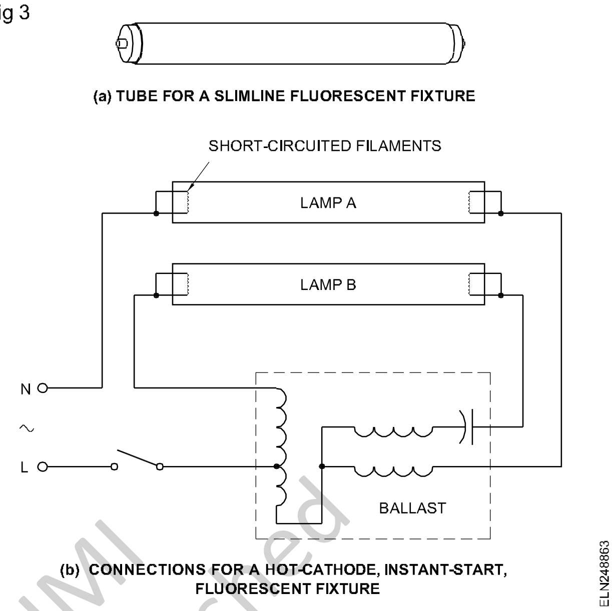
Purpose of ballst

The ballast used with the circuit is designed to:

- deliver a high starting voltage at the instant the circuit is energised to start the lamp without preheating
- deliver a normal operating voltage after the lamps are in operation.

Earlier two-lamp slimline circuit tubes were connected in parallel with lead-lag configuration. Modern circuitry has the two lamps in series, (Fig 3) and the ballast is designed to start the lamps in very rapid sequence. It requires a smaller ballast, and leads to reduced cost, and lower sound level.

Fig 3



The use of instant circuit has the following advantages.

- The resultant power factor for the two lamp unit is 95 percent or higher.
- The phase displacement between the currents in the two lamps circuit reduces any stroboscopic effect.
- This type of lighting unit starts the instant the circuit is energised.

Rapid start fluorescent lamp

Objectives: At the end of this lesson you shall be able to
- **describe the working of a rapid start fluorescent lamp**
- **explain the connection circuit of a rapid start fluorescent lamp and its ballast in the circuit**
- **state the advantages of a rapid start circuit.**

Rapid start fluorescent lamp

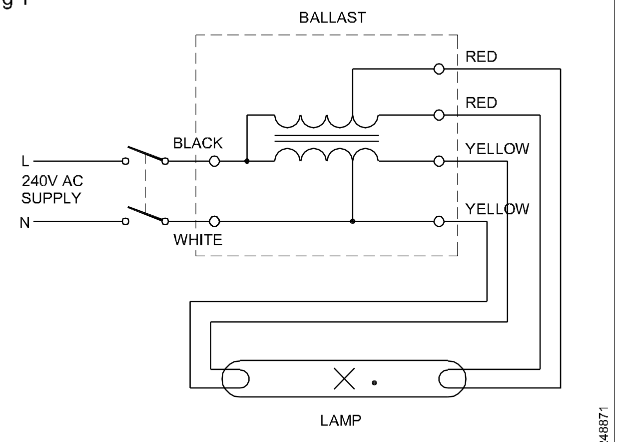
The rapid start lamps are widely used in modern installations. The cathodes are heated continuously and the lamp gets illuminated very quickly after the circuit is energised.

Fig 1 illustrates a rapid start circuit. The ballast has separate windings to heat the cathodes continuously. Therefore, when the lighting switch is placed in the ON position, the lamps light very quickly, and no flicker occurs.

This lamp requires a special ballast and a metal starting aid, which is at ground potential. One popular arragnement for metal starting is to provide 1 or 2 mm strip of metal coating over the tube between the caps, which is grounded.

Proper polarity is very important when connecting a rapid start fixture. The black wire from the ballast must be connected to the ungrounded (hot/phase) wire from the supply.

Fig 1

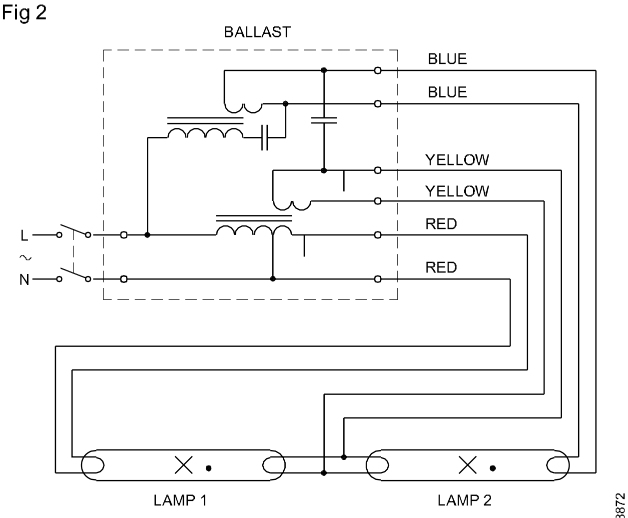


RAPID START FLUORESCENT LAMP CIRCUIT

Since the cathodes are already heated, the amount of voltage required to cause the lamp to fluorescent is smaller than the voltage required for the instant start lamp. As a result, the rapid start system is very efficient particularly because of the small amount of loss in the ballast.

Fig 2 illustrates the connections for 'two rapid start lamps' fixture. It is a series circuit and is commonly used. Once lamp 1 is on, the voltage across it drops to a low value and nearly all of the ballast voltage appears across lamp 2, which is the starting voltage required to start one lamp. The result is that the size of the ballast can be small.

Fig 2



RAPID START TWIN FLUORESCENT LAMPS CIRCUIT

Advantages:

1 The rapid start lamp can be used in dimming and flashing circuits.

2 Certain types of rapid start lamps work very well in the preheat system.

3 A rapid start lamp can be obtained for almost any type of weather conditions.

4 It has longer life than the instant start lamp, yet requires minimal starting time.

5 In the rapid start system, as in the instant start system, there is no need for a separate starter and starter socket as is required in the preheat system.

Fluorescent lamp - Twin-tube

Objectives: At the end of this lesson you shall be able to
- **state the necessity of twin-tube connections**
- **explain the methods to prevent stroboscopic effect**
- **compare with a neon sign lamp with a fluorescent lamp.**

Necessity of twin-tube connections: If a suitable wattage choke (ballast) is not available, then two tubes of half wattage rating of choke can be connected in series to get the correct performance of the two tubes.

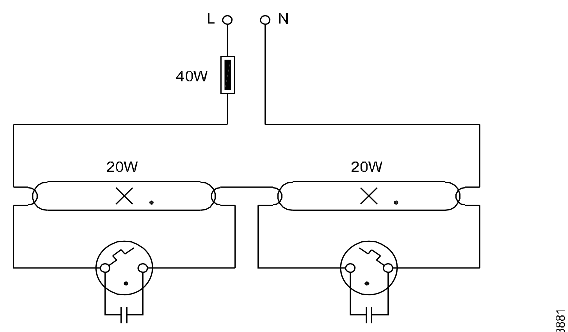
Example: If a 40 watt choke and two 20 watts tubes are available, then the twin tubes may be connected in series Fig 1.

Unlike incandescent lamps which emit light due to heat, a fluorescent lamp extinguishes itself every time the voltage wave passes through zero, i.e. 100 times in a second. This results in a feeling of discomfort if rapidly moving objects are viewed in this light.

To prevent this discomfort (stroboscopic effect), connect the twin-tube lights in parallel as lag-lead circuit.

Stroboscopic effect: In an AC cycle, zero value occurs twice per cycle, and theoretically lamps should go out twice per cycle or every hundredth part of a second on a standard 50Hz supply. In tungsten lamps, the heating of the filament results in a `carrying over' of this null period, which, therefore, prevents lamps from being extinguished or even flicker.

Fig 1



TWIN-TUBE LIGHT SERIES (TANDEM) CONNECTION

In discharge lights although the flickering may not be noticeable a peculiar dangers referred to as the stroboscopic effect, can arise where moving machinery is present. Spokes of a wheel, when rotating at the same speed as that of the supply, appear to be stand still.

If the interval of time between the zero points is exactly equal to the time taken for one revolution of the wheel, the object will appear to be stationary because the same spoke will be illuminated while in the same position each time.

The wheel will appear to be revolving backwards if the intervals of time are slightly shorter. If the intervals are longer the wheel will appear to be moving slowly forwards.

Methods adopted to prevent the stroboscopic effect: The stroboscopic effect is reduced to a minimum in fluorescent lamps by utilizing fluorescent powder having a slight afterglow. They can be further eliminated in a large three-phase installation by connecting adjacent lighting points to different phases of the supply, so that minima occur on different lamps at different times. Where only a single phase supply is available, lamps may be operated in pairs.

Types of twin-tube connections

Mainly these are of two types.

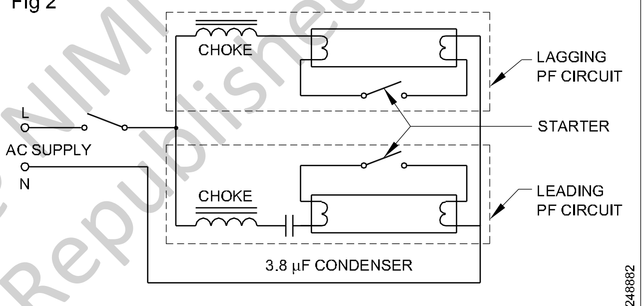
- Twin-tube light series connections
- Twin-tube light parallel connections

Twin-tube light series connection: For each fluorescent lamp, the right type of choke has to be used. For example a 40 watt choke must be used with a 40 watt lamp, a 60 watt choke with a 60 watt lamp and so on. It is, however, possible to operate two 20 watt lamps with one 40 watt choke, and two 40 watt lamps with one 80 watt choke. Each lamp must, however, have its own starter. Fluorescent lamps which are connected in this way are connected in TANDEM. (Fig 1)

Twin-tube light-parallel connections: The stroboscopic effects in flurescent lamps can be avoided by wiring twin lamp fixtures with one lamp wired inductively and the other with a leading current by the use of a capacitor. (Fig 2) The recommended capacitor rating is 3.8 mfd, 380V.

The normal P.F. capacitor is omitted but another is connected in series with one of the lamps and the choke windings are dissimilar. The lagging current in one lamp is balanced by the leading current in the capacitor circuit, thus the currents, and, therefore, the light outputs differ in phase by approximately 120 degrees and the total P.F. is nearly unity.

Fig 2



TWIN-TUBE LIGHT PARALLEL CONECTIONS

Differences between fluorescent lamp and neon sign lamps

Issue	Neon sign lamp	Fluorescent lamp
Construction	1 Two ends of the tube are fitted with electrode.	The two ends are fitted with filament.
	2 Maximum length of the tube - 1 metre.	Maximum length of the tube - 1.5 metres (5 feet)
	3 Diameter of the tube 10 mm to 20 mm.	Diameter of the tube 20 mm to 40 mm.
	4 The tubes are to be matched with high voltage transformer	It can operate on medium voltage,ie. 250 V.
	5 We can set any design or shape.	Only straight or circular tube.
	6 Electrode is cylindrical-shaped and is made of nickel, iron or copper.	Electrode is of a spiral form and is made of tungsten, coated with an electrode emitting material.
Colour	1 Colour can be obtained by using different gases and chemicals.	Colour can be obtained by using chemical coating on the tube walls.
	2 Only gas such as neon or helium. and a small quantity of argon gas.	The tube contains a small amount of mercury
Application	1 These tubes are used for advertising purposes as neon signs and letters.	These tubes are used for domestic/industrial lighting purposes.
	2 These tubes are not readily available as per requirements.	Readily available.

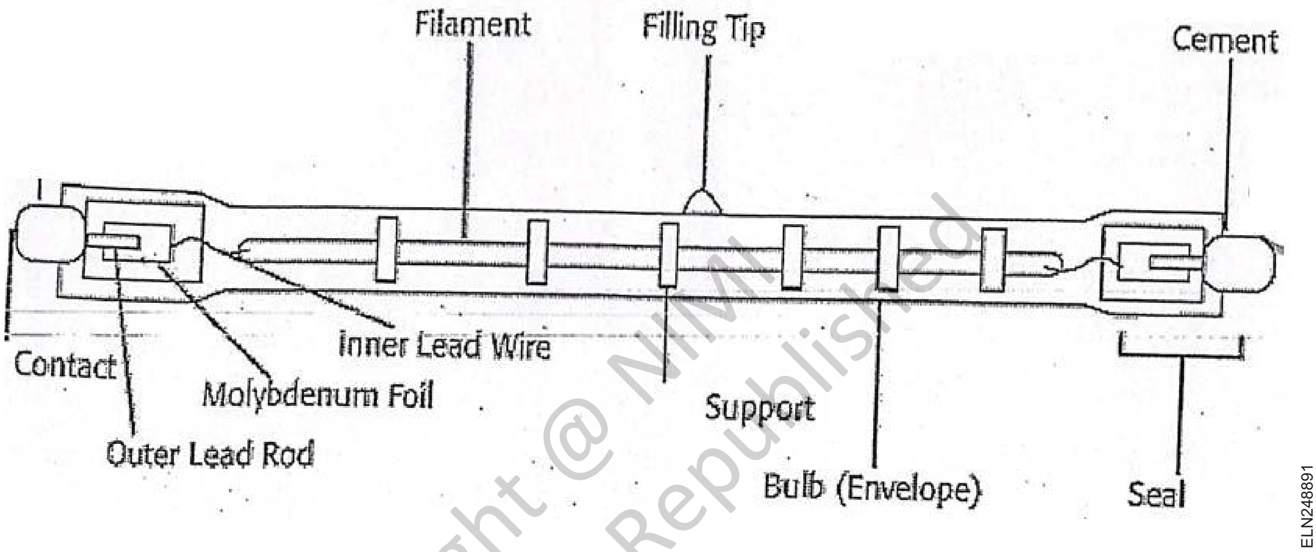
Halogen lamp

Objectives: At the end of this lesson you shall be able to
- **explain Halogen lamp construction**
- **describe the principle of tangsten halogen regenerative cycle process**

Construction

Halogen lamps are the most advanced and multi-purpose incandescent lamps. Although they belong to the incandescent family of lamps, they are designed to provide a superior quality of crisp white light, long life, high efficiency and constant lumen maintenance. Due to their reduced size, the halogen lamps allow for the most compact and stylish fixture designs. Halogen lamps operate on the tungsten halogen regenerative principle which eliminates filament evaporation and bulb blackening. As a result, the initial lumens and color temperature are maintained throughout the lamp life. The use of bromine, which is a transparent gas, increases efficiency by 28 -33 lumens/watt as compared with iodine because there is less absorption of light by the filled gas (Fig 1).

Fig 1



Principle of tungsten halogen regenerative cycle process

1 If the lamp is turned on, tungsten particles evaporate from filament and attach on to bulb wall. At the same time, halogen is decomposed and becomes atomic halogen.

2 Atomic halogen is diffused on the bulb wall and combines with free tungsten particle to become transparent and volatile tungsten halide.

3 Due to the high temperature (over 500°F) on the bulb wall, tungsten halide is volatilized and circulated back to filament.

4 After tungsten halide is decomposed around the filament at a high temperature, halogen gas is released, ready to combine again, and tungsten is re-deposited on the filament, whereby the process is ready to begin again.

The halogen lamp's envelope is made of quartz glass because of the high operating temperature and pressure required to permit the halogen regenerative cycle process. Quartz also renders the lamp extremely resistant to heat impact. The small dimensions of halogen lamps allow accurate control over the light beam for a better focused and precise light.

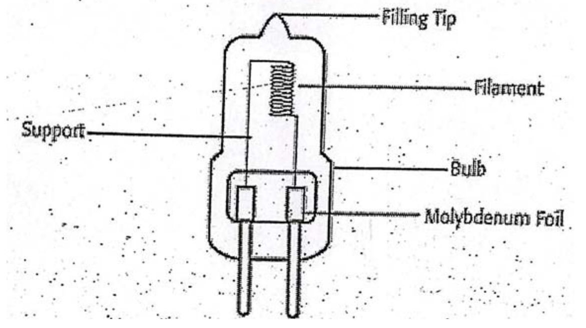
Tungsten Halogen Lamp

Halogen is the name given to group of gaseous elements like flourine, chlorine, bromine and Iodine.In incandescent lamp the life of filament is affected by evaporation of tungsten.

To prevent this a small amount of halogen gas (say iodine) is added to the argon gas filling of the lamp. Evaporated tungsten iodine is very volatile and suffers thermal diffusion in direction of filament and gets decomposed into tungsten and halogen.

Tungsten so relesed is deposited back on filament restoring its strength. Thus addition of halogen results in formation of a regenerative cycle and evaporation of tungsten is prevented. This also results in increased efficiency as tungsten filament can now be heated to much more temperature (Fig 2).

Fig 2



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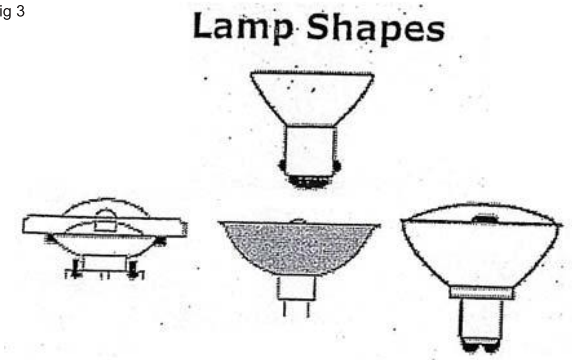
To maintain this regenerative cycle, it is necessary that the wall temperature is maintained high to 2500^{0}C. The lamp envelope is therefore made of quartz due to which it is possible to miniaturise, as filling gas can now be filled at high gas pressure.

The efficacy of this lamp is 50% more as compared to GLS for equal watage and life is just double. These lamps have better colour rendition. These are available in sizes of 500 W to 5kW. Halogen lamp with much better efficiency and lesser sizes but having very less life are manufactured for TV photography and film camera purpose.

The Fig 3 shows the different shapes of halogen lamps.

Fig 3



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Compact Fluorescent Lamp (CFL)

Objectives: At the end of this lesson you shall be able to
- **explain the construction of CFL**
- **describe the working principle of CFL**
- **state the types of CFL's and tubes.**

CFL Lamp

Construction: A compact fluorescent lamp (CFL), also called compact fluorescent light, energy-saving light, and compact fluorescent tube, is a fluorescent lamp designed to replace an incandescent lamp; some types fit into light fixtures formerly used for incandescent lamps. The lamps use a tube which is curved or folded to fit into the space of an incandescent bulb, and a compact electronic ballast in the base of the lamp (Fig 1)

Fig 1

Fig 2.3.12.01

A CFL has a higher purchase price than an incandescent lamp, but can save over five times its purchase price in electricity costs over the lamp's lifetime.

Working principle : The principle of operation in a CFL bulb remains the same as in other fluorescent lighting: electrons that are bound to mercury atoms are excited to states where they will radiate ultraviolet light as they return to a lower energy level; this emitted ultraviolet light is converted into visible light as it strikes the fluorescent coating on the bulb (as well as into heat when absorbed by other materials such as glass).

CFLs radiate a spectral power distribution that is different from that of incandescent lamps. Improved phosphor formulations have improved the perceived color of the light emitted by CFLs, such that some sources rate the best "soft white" CFLs as subjectively similar in color to standard incandescent lamps.

Types of CFL

There are two types of CFLs:

1 Integrated lamps

2 Non-integrated lamps.

Integrated lamps: Integrated lamps combine the tube and ballast in a single unit. These lamps allow consumers to replace incandescent lamps easily with CFLs. Integrated CFLs work well in many standard incandescent light fixtures, reducing the cost of converting to fluorescent.

Non-integrated lamps: Non-integrated CFLs have the ballast permanently installed in the luminaire, and only the lamp bulb is usually changed at its end of life. Since the ballasts are placed in the light fixture, they are larger and last longer compared to the integrated ones, and they don't need to be replaced when the bulb reaches its end-of-life. Non-integrated CFL housings can be both more expensive and sophisticated.

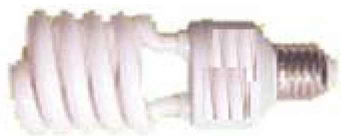
Types of tubes

There are two types of tubes (i) a bi-pin tube designed for conventional ballast, and a (ii) quad-pin tube designed for an electronic ballast or a conventional ballast with an external starter. A bi-pin tube contains an integrated starter, which obviates the need for external heating pins but causes incompatibility with electronic ballasts (Fig 1).

CFLs have two main components: a CFLs have two main components: a magnetic or electronic ballast and a gas-filled tube (also called bulb or burner). Replacement of magnetic ballasts with electronic ballasts has removed most of the flickering and slow starting traditionally associated with fluorescent lighting, and has allowed the development of smaller lamps directly interchangeable with more sizes of incandescent bulb.

CFL light output is roughly proportional to phosphor surface area, and high output CFLs are often larger than their incandescent equivalents. This means that the CFL may not fit well in existing light fixtures. To fit enough phosphor coated area within the approximate overall dimensions of an incandescent lamp, standard shapes of CFL tube are a helix with one or more turns, multiple parallel tubes, circular arc, or a butterfly.(Fig 2)

Fig 2



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CFLs typically have a rated service life of 6,000–15,000 hours, whereas standard incandescent lamps have a service life of 750 or 1,000 hours.

The life of a CFL is significantly shorter if it is turned on and off frequently. In the case of a 5-minute on/off cycle the lifespan of some CFLs may be reduced to that of incandescent light bulbs.

Light Emitting Diodes (LEDs)

Objectives: At the end of this lesson you shall be able to
- **define the LED**
- **state the advantages of LEDs over-conventional bulbs**
- **explain the principle of working of LED**
- **state the popular types of LED**
- **explain the method of testing of LED**
- **calculate the resistor value to be used with LED for a given application**
- **state how to protect LEDs from high reverse voltage.**

Light emitting diodes (LED)

In recent years, the use of filament lamps/bulbs which consume quite an amount of power, has less life became absolute as indicators of electric systems. One of the most common and popular of new devices in the optical electronics is the **Light Emitting Diode** abbreviated as **LED**. These LEDs are now used as indicators in almost all electrical and electronic circuits and equipments.

The advantages of LEDs over incandescent bulbs are listed below:

1 LEDs have no filaments to heat and so require less current to glow.

2 LEDs require lower voltage level (typically 1.2 to 2.5 V) than the conventional bulbs.

3 LEDs last much longer - upto several years.

4 Because there is no filament to heat up, LEDs are always cool.

5 LEDs can be switched ON and OFF at a much faster rate compared with conventional lamps.

Principle of working of LEDs

Although LED is also a type of diode, it cannot and should not be used for the purpose of rectifying AC to DC.A LED is a semi conductor device which emits visible ligt when it is property connected with the electric supply.

Recall that a general purpose diode or a rectifier diode conducts when energy is supplied to the electrons (Si=0.7V, Ge=0.3V) to cross the barrier junction. Each electron, after acquiring the supplied extra energy, crosses the junction and falls into the hole on the P side of the junction while the electron recombines with a hole, the electron gives up the extra energy by it. This extra energy is dissipated in the form of heat and light.

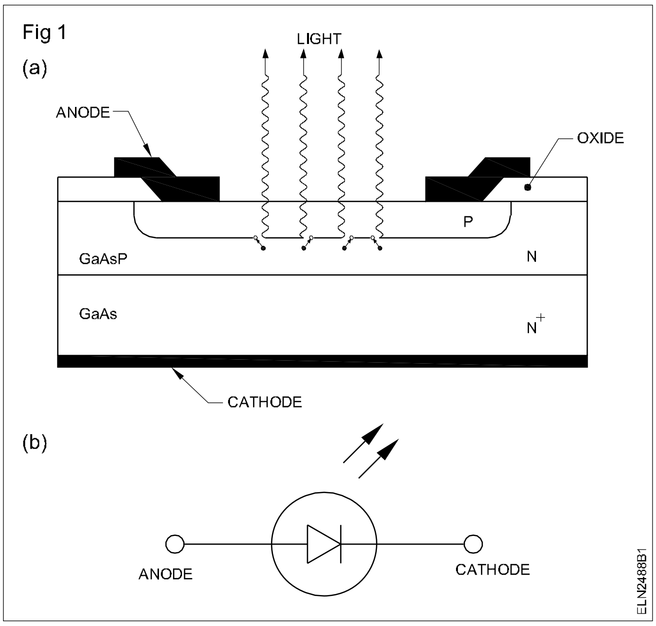
In general purpose diodes because the silicon material is not transparent(opaque), the light produced by the electrons does not escape to the outer environment. Hence, it is not visible. But LEDs are made using semi-transparent materials instead of silicon.

Because the material used in making LEDs is semi-transparent, some of the light produced by the electrons escapes to the surface of the diode, and, hence, is visible. (Fig 1a)

LEDs are typically doped with gallium arsenic, gallium phosphate or gallium arseno-phosphate. Different dopes cause the LED to emit light of different colours (wave-lengths) such as red, yellow, green, amber, or even invisible infrared light.

The schematic symbol of LED Non-integrated lamps is as shown in (Fig 1b). The arrows are used to indicate that light is radiated from the device.

Fig 1



Types of LEDs

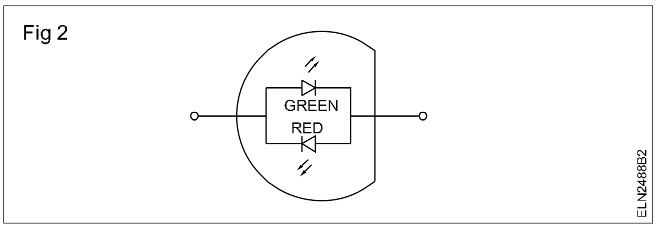
Single colour LEDs: Most of the commercially available and commonly used LEDs are single colour LEDs. These LEDs radiate one of the colours such as red, green, yellow or orange. Different coloured LEDs will have different forward voltages as given in the table below:

Colour of LED	Red	Orange	Yellow	Green
Typical Forward voltage drop	1.8V	2V	2.1V	2.2V

These typical forward voltage drops are at a typical LED forward current I_f = 20 mA

Two colour LEDs: These LEDs can give two colours. Actually, these are two LEDs put in a single package and connected . (Fig 2)

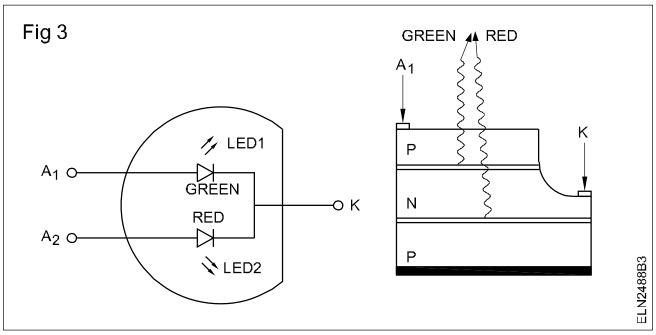
Fig 2



In a two-colour LED, two LEDs are connected in inverse parallel, so that one of the colour is emitted when the LED is biased in one direction and the other colour is emitted when the LED is biased in the other direction. These LEDs are more expensive than the single colour LEDs. These LEDs are useful to indicate +ve, –ve polarities, GO-NOGO indication, null detection etc.

Multicolour LEDs: These are special types of LEDs which can emit more than two colours. These LEDs comprises of a green and a red LED mounted in a three-pin common cathode package. (Fig 3)

Fig 3

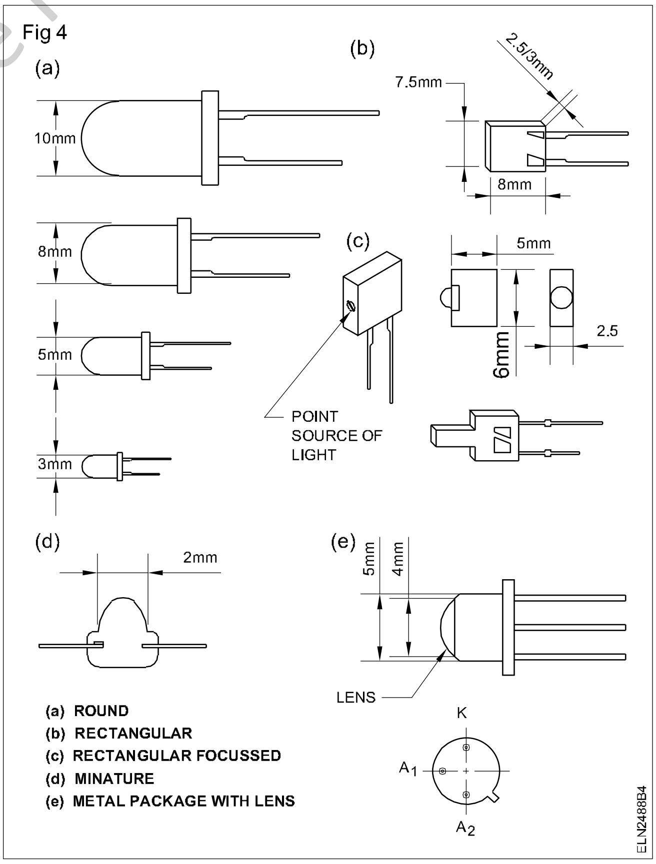


Output colour	Red	Orange	Yellow	Green
LED-1 current	0	5mA	10mA	15mA
LED-2 current	15mA	3mA	2mA	0

This LED will emit green or red colour by turning ON only one LED at a time. This LED will emit orange or yellow by turning on the two LEDs with different current ratios as shown in the table given.

Sizes and shapes of LEDs (Fig 4)

Fig 4



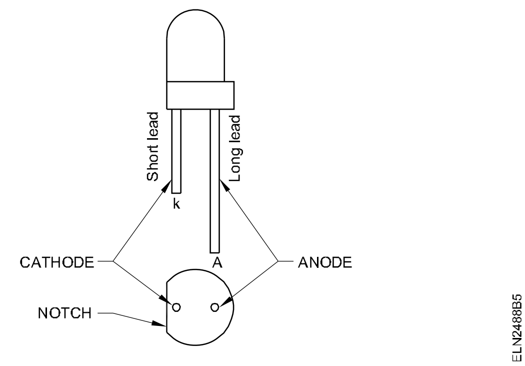
LEDs are available commercially in different shapes and sizes to suit varied commercial applications. Fig 4 shows some of the most popular shapes and sizes of LEDs.

The light output of LED may be guided as point-source or diffused. The point-source LED provides a small point of light while the diffused type has a lens which diffuses the light into a wide angle viewing area.

Terminals of LEDs

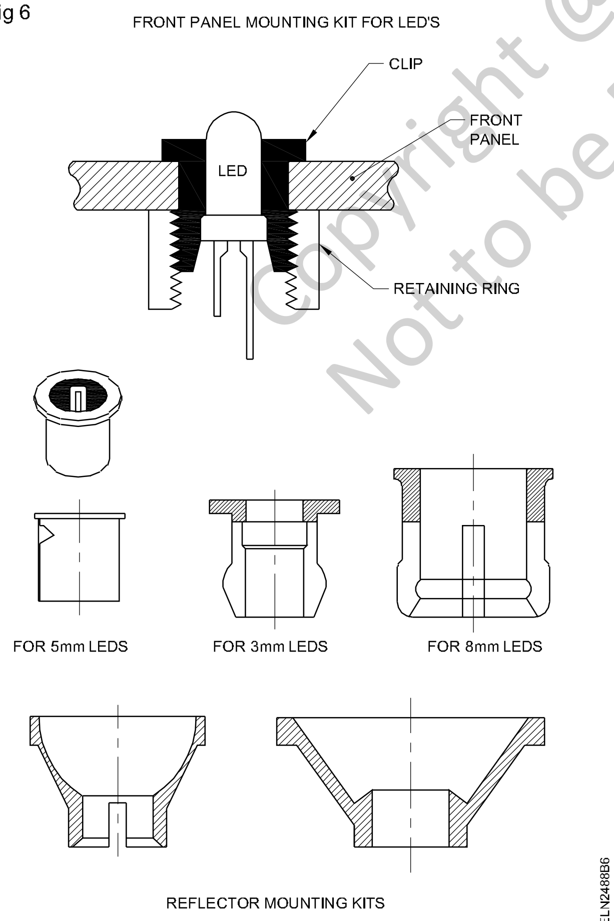
Since LEDs are basically diodes, they have anode and cathode terminals/leads as in any general purpose diode. Fig 5 shows the methods to identify the terminals of a LED.

Fig 5



Mounting kits for LEDs (Fig 6)

Fig 6



Special mounting kits Fig 6, are available for fixing the LEDs on to the printed circuit boards and monitoring panels. These kits not only extend the life of the LED by way of protecting it from mechanical stress but also make the output of the LED clearly visible.

Testing of LEDs

The anode and cathode terminals of a general purpose diode can be checked easily using an ohmmeter. But, in the case of LEDs, unlike general purpose diodes, the forward voltage of LED ranges from 1.5 to 3 volts (in some cases it is higher than 3 V), and a typical forward current ranges from 2 mA to more than 50mA. Because of this large forward voltage and current requirement of the LEDs, it is not always possible to test the LEDs using an ohmmeter.

Hence, when an LED is tested using an ohmmeter, the glow of the LED may be very dim or the LED may not glow at all depending on the condition of the battery inside the meter. Hence, the condition of an LED cannot be confidently confirmed using a meter. However, since meter testing is the quickest, this can be used while purchasing an LED from the vendor where other equipments may not be available for testing.

Characteristics	Min.	Typical	Max.
Forward current, I_f		2 mA	50 mA
Forward voltage, V_f		1.7V	3V
Reverse voltage, V_R		8V	
Axial luminous intensity	0.8 mcd	2 mcd	
Angle of half intensity		±20°	
Peak wave-length		665 nm	

Specifications of LEDs

Specifications sheet of a typical LED is given in the table above:

A Typical LED-specification sheet
(For: FairChild, FLV117 Red LED)

From the specifications of a typical LED given above, the following important points are to be noted;

- The forward voltage drop of the LED is much higher (1.7V to 3V) than that of general purpose diodes.
- The reverse voltage that can be applied to the LED is much lower than in general purpose diodes.

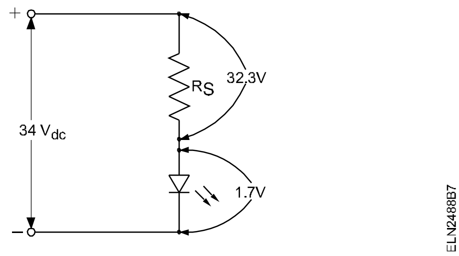
The above two important points confirm that, LEDs do not have the same characteristics as general purpose diodes.

In the typical LED specification, for instance, if 8 V or more is applied across the LED in the reverse biased polarity, the LED will be damaged.

Example: What value of R_S is required, if a red colour LED is to be used in a circuit with a source of 34V dc.

Using the specifications of the red LED given in the table, it is clear beyond doubt that the LED cannot be connected across 34 volts supply directly (maximum Vf = 3V). Hence,a resistor is to be used in series with the LED (Fig 7) which must drop to 32.3 volts if the voltage across LED should be 1.7 V.

Fig 7

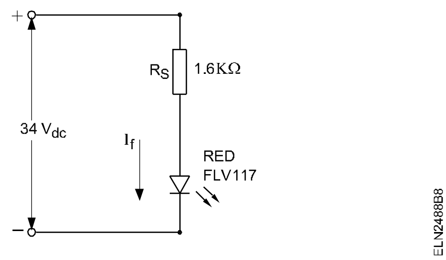


For the LED to give reasonably good light, the current through the LED has to be 20 mA, as indicated in the specifications sheet. So, the value of R_S must be,

$$R_S = \frac{V}{I} = \frac{32.3\ V}{0.02\ A} = 1615\ \Omega$$

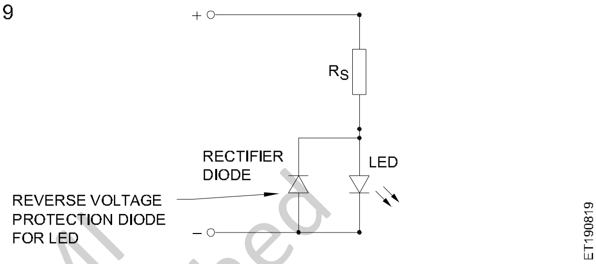
Since the maximum permissible current through the LED is given as 50 mA, it is possible to use a standard 1.6KΩ resistor. This will make a current of 20.2 mA to flow through the LED which is well within the permitted maximum current rating. The LED can now be safely connected across a source voltage of 34 V. (Fig 8)

Fig 8



Note that, the maximum reverse voltage that can be applied for the chosen LED is only 8 volts. If accidentally a reverse voltage greater than 8 volts is applied, the LED will get damaged permanently. One way to protect the LED is by connecting a rectifier diode in parallel to the LED Fig 9.

Fig 9



In Fig 9, when a reverse voltage across the LED becomes more than 0.7 V, the rectifier diode conducts with a forward voltage of 0.7 V. Thus the reverse voltage across the LED is restricted to 0.7 V which is much less than the maximum reverse voltage of 8 V of the LED, and hence the LED is safe.

Solar lamps

Objectives: At the end of this lesson you shall be able to
- **state the features of solar lamps**
- **state the components of solar street lights.**

Solar lamp

A solar lamp is a light fixture composed of an LED lamp, a photovoltaic solar panel, and a rechargeable battery. Outdoor lamps may have a lamp, solar panel and battery integrated in one unit.

Indoor solar lamps, also referred to as shaftless skylights or tubeless skylights, have separately-mounted solar panels and are used for general illumination where centrally generated power is not conveniently or economically available.

Solar-powered household lighting may displace light sources such as kerosene lamps, saving money for the user, and reducing fire and pollution hazards.

Solar lamps recharge during the day. Automatic outdoor lamps turn on at dusk and remain illuminated overnight, depending on how much sunlight they receive during the day. Indoor solar lamps may or may not store power.

Solar garden lights are used for wide decoration. They are frequently used to mark footpaths or the areas around swimming pools. Some solar lights do not provide as much light as a line-powered lighting system, but they are easily installed and maintained, and provide a cheaper alternative to wired lamps.

Solar street light

Solar street lights provide public lighting without use of an electrical grid; they may have individual panels for each lamp of a system, or may have a large central solar panel and battery bank to power street lights.

To reduce the overall cost of a solar lighting system, energy saving lamps of either the fluorescent or LED lamp type are used, since incandescent bulbs consume more energy for a given quantity of light.

Solar-powered lighting consists of a solar panel or photovoltaic cell that collects the sun's energy during the day and stores it in a rechargeable gel cell battery. The intelligent controller senses when there is no longer any energy from the sun and automatically turns the LED light on using a portion of the stored energy in the rechargeable battery.

High pressure metal halide lamps

Objectives: At the end of this lesson you shall be able to
- **describe the working principle of metal halide lamp (M.H.L)**
- **explain the starting of M.H lamp**
- **state the parts of MH lamp and its starting methods**
- **explain the features of MH lamps and state its advantages.**

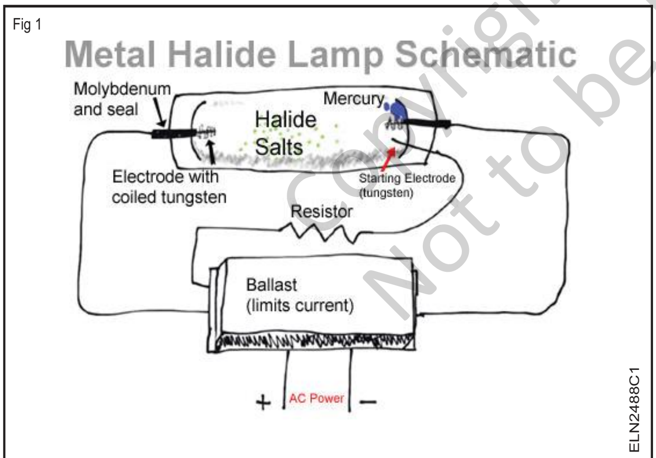
Metal halide lamps

This type of lamp is also known as an `MH' lamp. It is an HID lamp (High intensity Discharge), which means it provides most of its light from the electric arc within a small discharge tube. It is becoming increasingly popular due to its good quality white light and good efficiency. The most prominent use of the MH lamp is in stadiums and sports fields. It is also used widely for parking lots and street lighting in urban areas. Its competitors include the HPS lamp, mercury vapor lamp, LPS lamp, halogen lamps, and LEDs. MH lamps have advantages over the rest which make it more useful for certain applications.

Working Principle

Fig 1 shows the schematic connection diagram of a metal Halogen lamp in to the AC supply. A resistor is connected to limit the current so as to increase the life of ballast?

Fig 1



When the lamp is cold the halides and mercury are condensed on the fused quartz tube. When the lamp is turned on current passed through the starting electrode and jumps the short distance to the main electrode (Fig 1), this is aided by argon gas. The argon strikes an arc at low temperatures.

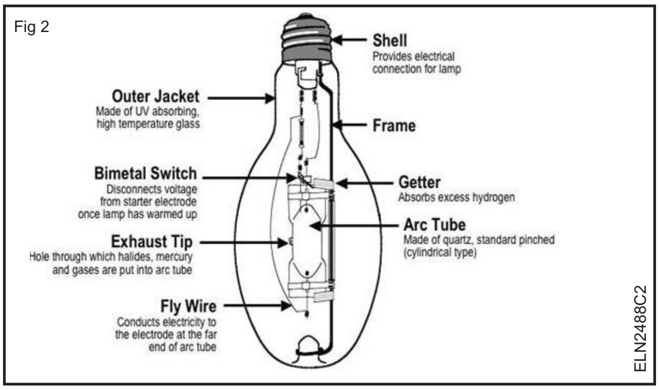
After the initial small arc the tube heats up and the mercury is vaporized. Electric arcs fight to works through the distance of a gas, but over time more molecules of the gas become ionized. This makes it even easier for more electric current to pass through, so the arc gets wider and hotter.

In the lamp as the first arc heats up, it begins to turn the solid mercury into a vapor, soon the arc is able to travel through the mercury vapor to reach the other main electrode on the opposite side of the discharge tube. There is less resistance on this path now and current stops flowing through the starting electrode, just as a river changes course to a path of least resistance, drying out the previous channel.

Parts of Metal Halide lamps.

Fig.2 shows the inner parts and its various function of a metal halide lamp. The inner tube contains the electrodes and various metal halides, along with mercury and inert gases that make up the mix. The typical halides used are some combination of Sodium, Thallium, and Scandium and Dysprosium Iodides. These iodides control the lamp's spectral power distribution and provide color balance by combining the spectra of the various iodides used.

Fig 2



Light is generated by creating an arc between the two electrodes located inside the inner arc tube. The inner arc tube is typically made of quartz, and this is a very harsh environment, with high temperatures approaching 1000°C and pressure of 3 or 4 atmospheres.

To start a metal halide lamp, a high starting voltage is applied to the lamp's electrodes to ionize the gas before current can flow and start the lamp. The outer jacket is usually made of Borosilicate glass to reduce the amount of UV radiation emitted from the lamp.

It also provides a stable thermal environment for the arc tube and contains an inert atmosphere that keeps the arc tube's components from oxidizing at high temperatures.

Starting Metal Halide Lamps

A metal halide lamp's starting requirements are important because they impact the type of ballast that the lamp requires. Two methods are used to start MH lamps: probe start (standard start) and pulse start.

Probe start refers to the method used to ignite the arc in the tube. A traditional or probe start metal halide lamp has three electrodes - two for maintaining the arc and a third internal starting electrode, or probe.

A high open circuit voltage from the ballast initiates an arc between the starting electrode and the operating electrode at one end of the arc tube. Once the lamp reaches full output, a bi-metallic switch closes to short out the probe, thereby discontinuing the starting arc.

Pulse-start MH lamps do not have a starting probe electrode. An igniter in the pulse start system delivers a high voltage pulse (typically 3 to 5 kilovolts) directly across the lamp's operating electrodes to start the lamp, eliminating the probe and bi-metallic switch needed in probe start lamps.

Without the probe electrode, the amount of pinch (or seal) area at the end of the arc tube is reduced, which allows for increased full pressure and reduced heat loss. Furthermore, using an ignitor with a lamp reduces tungsten sputtering by heating up the electrodes faster during starting, reducing the lamp's warm-up time.

Advantages of MH Lamps

- **Excellent Color Rendering**

Metal halide offers excellent color rendering, with a 65-90 CRI (color rendering index).

- **Compact Size**

Metal halide generates high light levels from a compact light source. This allows for smaller, more controllable luminaires.

- **Versatility**

Metal halide lamps are relatively unaffected by ambient temperature, equally suited for indoor or outdoor use. Extensive style and wattage options allow for many application.

- **High Efficiency**

Metal halide lamps generate 65-115 lumens per watt, more than incandescent, fluorescent or mercury vapor lamps.

- **Positive Environmental Impact**

Since metal halide lamps deliver light more efficiently than incandescent, lower electrical power generating requirements means less air pollution. Efficient long-life system means less landfill waste.

- **Long Life**

Metal halide lamps have an average life of 15,000-20,000+hours, more than ten times that of incandescent.

- **Better Light Quality**

The output of metal halide lamps is closer to natural sunlight than most other light sources.

- **Designable Color**

Metal halide lamps can be designed to produce almost any color including blue, green, aqua and pink.

- **The Most Advanced Technology**

A mojor advancement in metal halide lighting was the introduction of Venture's revolutionary Unit-Form pulse start system. Unit-Form pulse start systems offer up to 50% more lumens per system watt than do traditional metal halide lamps and ballasts.

Decorative lamp circuits with drum switches - serial set design - Flasher

Objectives: At the end of this lesson you shall be able to
- **state the functions of a drum switch**
- **explain the designing of a lighting sequence with the drum switch.**

Drum switch

It is the usual practice to illuminate houses, workshops marriage halls, temples etc. during festivals with flash lights, flickering lights and running lights with the help of rotating drum switches.

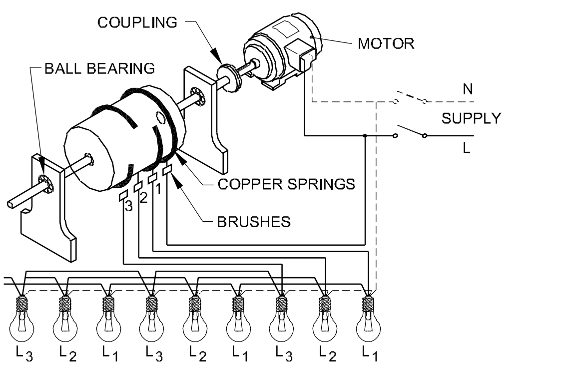
A drum switch is used for decorative lamp circuits. This switch can be used for sequential switching `on' of the decorative lamps. It is coupled with a slow speed motor so that the lamp will glow at proper intervals.

Preparation of decorative lights

The decorative effect of lights is usually obtained by means of a flasher, which consists of a wooden cylinder which rotates into the two ball bearings at the two ends. The wooden cylinder is connected to the motor through a belt or a coupling. The speed of the motor and the selection of pulley should be so made such that the wooden cylinder rotates at low r.p.m. On the wooden cylinder a copper ring is provided (to which the live wire is connected through a brush), and 3 copper segments 120° apart from each other, and each end of these segments is permanently connected to the copper ring.

As the cylinder rotates, the three segments make contact in turn with the brushes 1,2 and 3 in turn. The brush No.1 is connected to lamps L_1, the brushes No.2 and 3 are connected to lamps L_2 and L_3 respectively. Fig 1 shows the instant when the copper segment No.1 makes contact through 1/3rd of the revolution, the circuit No.1 goes off, and just at the same instant circuit No.2 becomes live and lights the lamps L_2, and after a further 1/3rd of the revolution the circuit No.3 becomes live and lights the lamps L_3. This process is repeated to make it appear that the lights move from the right to the left.

Fig 1

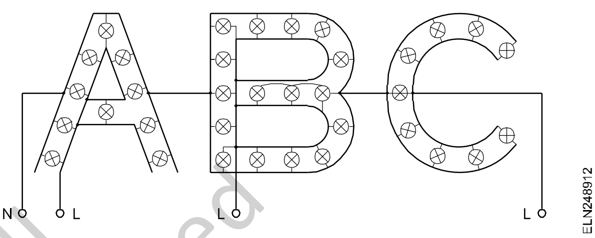


CIRCUIT FOR MOVING LIGHTS WITH A FLASHER

Waving, flickering or lightning effects can be achieved by such a system of lights.

Design of display: Draw the layout of the required display, for example ABC, on the board. (Fig 2)

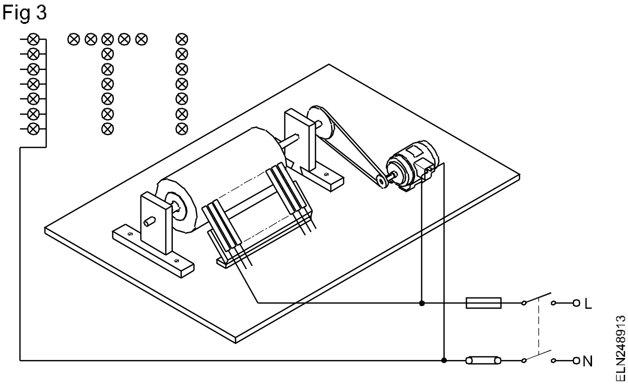
Fig 2



Mark the lamp position on the layout, connect all the lamps in parallel of letters A, B and C as shown in Fig 2, and then test the lamps for each letter by effecting supply. The neutral is run to all the lamps commonly.

Construction of a drum switch: The cylindrical drum is made of dry, soft wood, having low weight. (Fig 3)

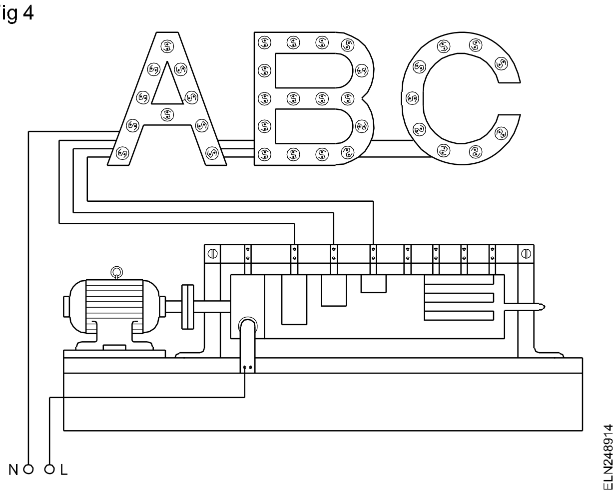
Fig 3



The length of the drum is determined by the number of finger-strips, and the diameter of the drum depends on the number of circuits to be incorporated. The speed of the drum must be as low as possible which is obtained by using two pulleys of different sizes to create a high ratio. (Fig 3) The drum-plates are usually made of brass/ copper, and are nailed. The contact strips are fixed by screws or wire nails. (Fig 4)

The drum-plate is designed keeping in view the time required to make and break the contact in one revolution. The strip should be fixed in such a way as to establish good contact through. To avoid sparking, conductive grease should be applied over the drum-plate.

Fig 4



Electrical motor: A single phase, low speed motor usually the shaded pole motor with sufficient power to drive the drum, is used for this purpose.

Lighting for decoration

Objectives: At the end of this lesson you shall be able to
- **state the methods used for decoration**
- **state the names of flasher and their function.**

Use of decoration lights

Electric light decoration for special occasions like wedding parties, festivals and fairs is a common feature nowadays. Special electric light sign circuits add much colour, fun and pleasure on the occasion. Electric signs, particularly neon signs, are extensively used in advertisements which have tremendous eye catching effects. Decoration with electric signs improves the appearance of a building and makes the place more attractive.

Two methods are mainly used for decoration.

- Signs employing miniature low voltage incandescent lights which can be switched on and off in sequence to produce the desired effect.
- Neon signs employing tubes shaped to produce designs in various colours, the colour being determined by the type of gas used in the tube.

Miniature incandescent lamps: Miniature incandescent lamps are normally available with 6V, 9V, 12V & 16V ratings with different colours which may be grouped in series or series parallel combinations for operation in available 240V supply.

For getting different messages and decoration effects the following types of flasher signs are used.

Speller type flashers are used for spelling out signs letter by letter or word by word for building up or down, plain on-off flashing, with changing colour.

Speed type flashers are used for operating spectacular signs such as lighting waving-flags, - flame, revolving wheels etc.

Script type flashers as the name implies are used when the effect of handwriting in script letters is desired.

An example of a speed type flasher for revolving is shown in Fig 1. The speed of running light/ rotating light can be adjusted. In this three-point running light (the sign flasher) there are three groups of lamps, each group switched on and off, in sequence, for running effect (Fig 2) with the help of a small induction motor which is running on eddy current principle and is connected to 240V/115V 50 Hz. Cans or drums are mounted on a shaft which is rotated by the motor.

Fig 1

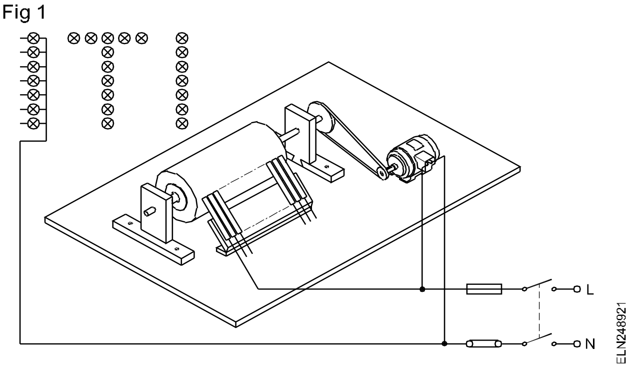
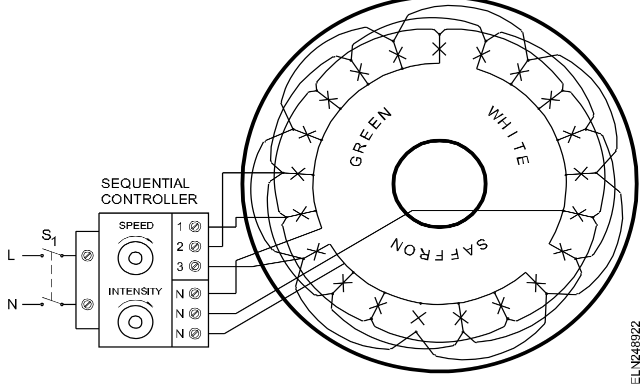


Fig 2



The circumference of the cans or the drums are so cut that the brushes will make contact only during the fixed portion of the revolution, thus completing the circuit. We can make three independent circuits by the 3-point sign flashers which are switched 'ON' and 'OFF' successively.

Designing a decorative serial lamp for a given supply voltage

Objectives: At the end of this lesson you shall be able to
- **calculate the number of bulbs to be connected in series for a given supply voltage**
- **state the condition of glow of all the lamps in series and precaution to design serial set.**

Serial set design

We have to design a row of 6 or 9 volts lamps. If these lamps are connected directly to the 240V supply, the lamps will get fused immediately. Therefore the lamps are to be connected in series. The calculation as shown will be -

1 For 6 volts lamps

Total No. of lamps required = $\frac{240}{6} = 40$ lamps.

Taking 5% allowance for fluctuations in the supply voltage

Total No. of lamps = 40 + (5% of 40)
= 40 + 2 = 42 lamps.

2 For 9 volts lamps

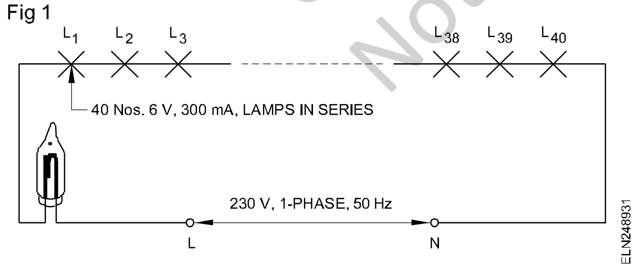
Total No. of lamps required= $\frac{240}{9} = 26.6$ or 27 lamps

Taking 5% allowance for fluctuations in the supply voltage

Total No. of lamps = 27 + (5% of 27)
= 27 + 2 = 29 lamps.

The circuit for a series lamp connection of 6V lamp and supply voltage 240V. (Fig 1)

Fig 1



Precautions

- Never connect the low volt lamps directly to the mains.
- Never touch the exposed wires.

In the above case we discussed for 6V and 9V lamps. In the market we get for 6 volts different current ratings viz. 100mA, 150mA, 300mA, 500mA. The shape of the lamp for the above current ratings however remains the same.

For the series lamps to work satisfactorily the current rating of all the lamps should be the same.

We can prepare serial lamps with different voltages but of the same current rating.

Example

You have 25 lamps of 6V, 300mA rating and 20 numbers of 9V,300mA lamps. How will you design a 'serial lamp' circuit for 240V supply mains

a using all the available 6V lamps and for the rest of 9V lamps.

b using all the available 9V lamps and for the remaining 6V lamps.

The important factor is that the sum of the voltages of the lamps in series should be equal to or slightly greater than the supply voltage.

Calculation

a Voltage drop across 25 lamps of 6 volts rating in series = 25 x 6 = 150V

Supply voltage : 240V

Voltage to be dropped by 9 volts lamps
= 240 –150 = 90 volts

Number of 9V lamps in series

$= \frac{90}{9} = 10$

25 Nos. of 6V lamps and 10 Nos. of 9V lamp in series.

b Voltage drop across 20 Nos. of 9 volt lamps

20 x 9 = 180

Voltage to be dropped by 6V lamps in series
= 240 – 180 = 60V

Number of 6 volt lamps in series $\frac{60}{6} = 10$

20 Nos. of 9 volt lamps and 10 Nos. of 6 volt lamps in series.

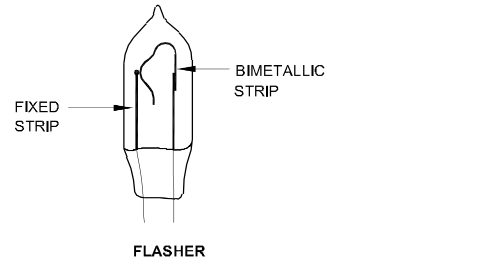
The number of bulbs in series is always kept more than the calculated value. The purpose is to reduce the current through each lamp slightly. The reduced current makes the fusing of the lamps rather remote.

Flasher

Objectives: At the end of this lesson you shall be able to
- **state the purpose of the flasher in the series lamp circuit**
- **explain the constructional details and working by rejecting and accepting bad and good flashers.**

Flasher: In the row of lamps of low voltage, a small lamp (flasher) of filament type is connected in series with the other lamps. This lamp (flasher) does not give light but acts as a switch for the other lamps. This lamp contains a bimetal strip, which is in contact with a fixed strip (Fig 1).

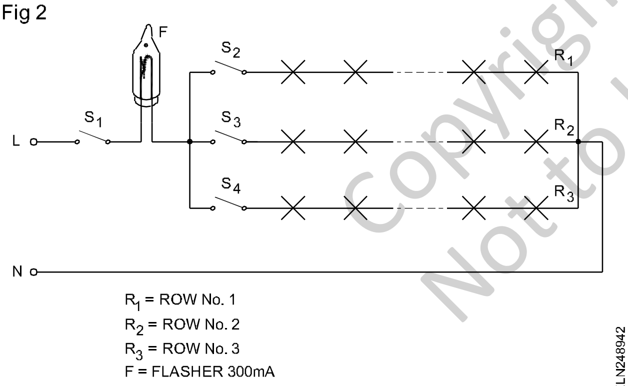
Fig 1



When the row of lamps is connected across the supply and switched ON, the bimetal strip gets heated up, this breaks the contacts and disconnects supply to the other lamps, making the lamps OFF.

After a few seconds, the bimetal strip cools down and makes contact. The supply to the other lamps is ON and the lamps light up. This is a twinkling type row of lamps used for decoration (Fig 2).

Fig 2



The rating of the flasher in each row of (small) low voltage lamps must be the same as that of the other lamps in that series circuit. If the lamps are of different ratings, then the flasher should be of the lowest current capacity in that circuit.

Though the flasher can be connected anywhere in the series circuit, it should be connected at the supply (phase) considering it as a switch.

The operating condition of the flasher can be decided by observation. If the bimetal strip is found welded to a fixed strip, then the flasher is not useful and if it is in an unserviceable condition. It can also be found out by connecting in circuit and tested for its condition, i.e. whether it is operating or not.

When a number of series lamp rows are connected in parallel the flasher should be connected at the input of supply as shown in Fig 2.

Example

Each row 100mA, 3 rows in parallel

The current-carrying capacity of such a flasher in the parallel circuit should be equal to the total current drawn by the parallel circuit say 300 mA.

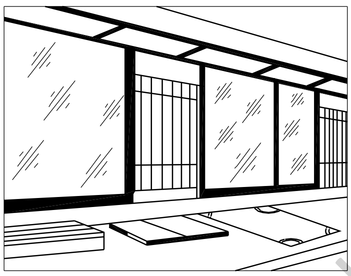
Show case lights and fittings - calculation of lumens efficiency

Objectives: At the end of this lesson you shall be able to
- **state the types of bulbs for illumination**
- **explain direct and indirect lighting and showcase lighting**
- **explain the luminous efficiency calculation.**

Show case lighting: A number of commercial establishments use visual representation to their products, using a lighting system called show case lights. Some of them are discussed below.

Counters and dealing shelves: In bank cages and ticket offices supplementary trough lighting equipment is usually located at the top of the cages to produce a band of light lengthwise on the counter. Troughs may be covered with diffusing glass or fitted with longitudinal louvers to shield the lamps. Sixty watt lamps on 15 to 18 inch centres will generally be adequate. (Fig 1)

Fig 1



Small metal bracket type reflectors luminary or regular 25 or 40 watt tubular lamps effectively illuminate small vertical display racks, stands and cabinets. (Fig 2)

Fig 2

Small compact lens posts available in both 250 and 400 watt size, mounted on columns or ceiling brackets, give sales emphasis to small counter or table displays. Adjustable in spot size for 12 to 48 inches diameter spot at 10 ft. a 250 watt unit at 10 ft. will deliver 200 to 250 feet candles, with a 12 to 15 inches spot size: the 400 watt unit will give 350 to 400 foot candles. (Fig 3)

Louversed concentrating reflector spotlights available in 200 to 500 watt sizes give a less sharply defined beam than lens units. The spot size cannot be adjusted except by changing the projection distances. A 200 watt unit at 10 ft. will produce about 90 foot candles. (Fig 4)

Fig 3

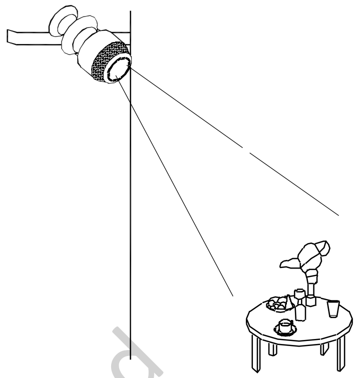
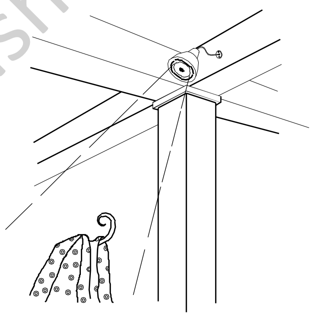
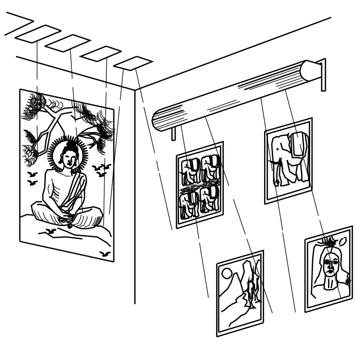


Fig 4



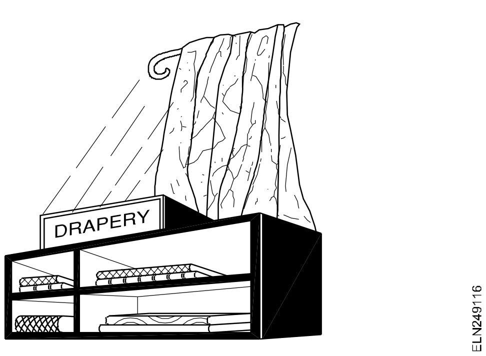
For extended vertical surface displays - rungs, tapestries, draperies, paintings - a series of 150 or 200 watt lens plate units at the ceiling is suitable for fixed display locations. Bracket type parabolic, polished metal troughs produce equivalent results and have some advantage in greater mobility. (Fig 5)

Fig 5



Footlight type trough lighting for counter and shelf displays ranges from single lumiline reflectors for counter cards and small displays to extended shelf troughs as illustrated. Trough footlights with changeable, luminous sign panels transform waste space into valuable display. (Fig 6)

Fig 6



For necessity and impulse items such as groceries, where attention rather than critical seeing is the requirement, less engineering refinement is needed in shelf lighting equipment. Concentrating trough reflectors which incorporate luminous panels for changeable advertising copy are satisfactory. Sockets 30 cms apart may be fitted with 40 to 100 watt lamps, as conditions dictate. (Fig 7)

Fig 7

For lighting displays on columns or built-in shelving a metal nosing along the front edge of each shelf effectively conceals small 25 watt tubular lamps as shown in the sketch. Lamps should be spaced not more than 30 cms apart. Lumiline lamps are, of course, equally suitable in many cases.

Displays of glassware and bottled goods are highly attractive and colourful if lighted by transmitted light as shown in Fig 8. An opal glass panel, illuminated uniformly from behind the lamps spaced not more than 1½ times their distance at the back of the glass will provide a suitable luminous background.

Circline tubes used for window show case: For circline tubes the ballasts are specially designed and are easily adaptable to assembly on the stem of portable lamps and in shallow wall and ceiling fixtures, and in some designs they can be mounted within the circle of the tube.

Ballast equipments designed for use with the 8¼ inch 22 watt, 12-inch 32 watts. circle line include two single lamp ballasts, one with uncorrected power factor. The other with high power factor. Many of the portable lighting equipments - dressing table, desk lamp, vanity mirror, tie rack, display unit and boudoir lamps such as Fig 9 and 10 - in which the 8¼ inch circline will be used which have small thin bases and slender stems.

Fig 8

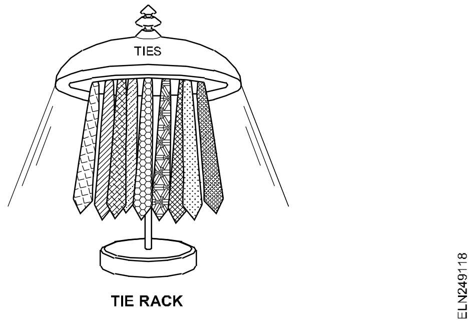
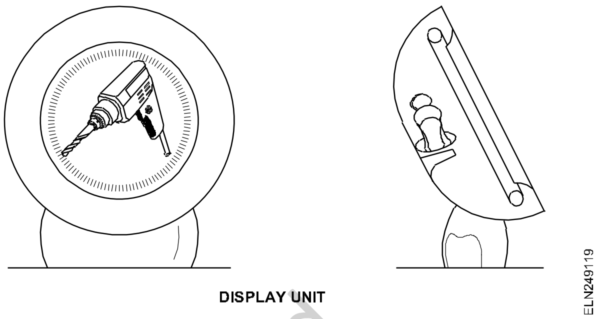


Fig 9



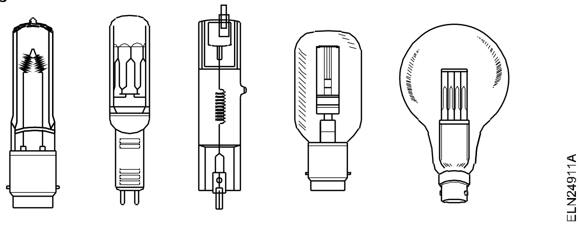
There are varieties of goods which are being displayed in showcases of different colours, size, shape, fineness etc. Hence Different shades and colour layers will be used to get the proper colour of goods or fineness of detail or both by proper illumination.

Merchandise will change from time to time and for this type, illumination will change from time to time. Hence there is a necessity to have a larger number of electrical points than normally required .

Precaution should be taken while putting the merchandise in showcases so that wiring will not be damaged. Also the wiring and merchandise should not get damaged due to the excessive heat of lamps.

Quartz lights (Halogen lamps) (Fig 10)**:** Also known as tungsten-halogen or quartz-iodine, lamps. Now they are smaller, lighter and more efficient than tungsten lights. This consist of a metal tungsten filament inside a small quartz glass tube filled with a halogen gas - usually iodine. The presence of the iodine guarantees that the bulb does not darken and that the light output and colour temperature remain constant.

Fig 10

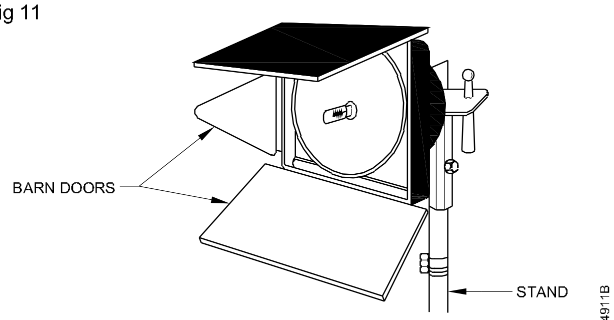


Most quartz lamps last as long as 250 hours and have a colour temperature rating of 3,200°K. Outputs vary from 150 to 350 watts for battery lights and from 200 to 10,000 watts for main power supply use. The quartz bulb itself should never be touched with a bare hand, even when unlit, as acid from the skin can cause premature failure of the bulb. Always handle the bulb with a small piece of tissue paper.

Quartz bulbs set in open reflectors are probably the most common quartz lights. They are available in a wide range of wattages, usually from 200 to 2,000 but also as high as 10,000 watts. On many models the light may be focused by moving the quartz bulb to and fro. Nowadays, many of the better lamps are made with fiberglass housings to reduce transmission of the bulbs' heat.

Basic quartz lighting kits usually consists of three lights, each of which might be 1,000 watts. They are often equipped with "barndoors" and stands. (Fig 11)

Fig 11



QUARTZ REFLECTOR LANE

Luminous Efficiency Calculation

Luminous Efficiency: Luminous efficiency is a measure of how will a light source produces a visible light. It is a quantity of measurement for light source and it is defined as the ratio of luminous flux to power of the lamp in watts. It's unit is **lumen/watt** in SI unit.

$$\text{Luminous efficiency} = \frac{\text{Luminous flux in lumen}}{\text{Power in watt}}$$

This is important, it describes how much light is being given compare to the amount of electricity is used.

Purpose of calculating luminous efficiency

Typical house hold spends 30% of the electricity bill in lighting. Money can be saved by bringing the most cost efficient lighting option in home needs.

For example : A 60w light bulb usually produces 860 lumens. Calculate the luminous efficiency.

$$\text{So, efficiency} = \frac{\text{Luminous flux in lumen}}{\text{Power in watt}}$$

$$= \frac{860}{60} = 14.3 \text{ lumen/watt}.$$

This calculation can be taken for any light source as long as the data pertaining to its power and luminous flux are available. The higher efficiency lamps will save more money.

> **It is usefull when you are shopping for light bulbs/lamps most of its box will have the bulb voltage and luminous produced . Use this calculation method to see, how the cost efficient a bulb will be for your home needs.**

The luminousity function or luminous efficiency function describes the average special sensitivity of human visual preception of brightness.

By comparing LED's to compact fluorescent lamp (CFL) with 55 - 70 lumens per watt and incandescent lamp bulbs with 13 -18 lumen per watt.

The LED bulbs require much less wattage than the CFL (or) incandescent light bulbs. CFL are 4 times more efficient and 10 times longer than incandescent lamps.

The most popular energy saving bulbs available are:

- halogen incandescent bulbs
- Compact fluorescent lamps (CFLs)
- Light emitting diodes (LED)

Their initial cost is 5 to 10 times more than traditional incandescent lamps, but they save the money due to lesser energy.

Instruments - Scales - Classfication - Forces - MC and MI meter

Objectives: At the end of this lesson you shall be able to
- **state the instrument, range, position, types, error from the data and symbols**
- **state the terminal markings in instrument**
- **classify the instruments based on measuring accuracy**
- **state the indication error, when measuring**
- **state the instrument scales type .**

Electrical Measuring Instrument

Electrical measuring instruments (meters) is an apparatus, used for measuring the electrical quantities like current, voltage, resistance power and energy etc.

Identification of instrument

Identification of the instrument for any particular measurement is very important. By wrong identification not only the instrument may be damaged but also we may not get the result that we want.

The instrument should be identified for the quantity to be measured, the range, suitability for a particular type of supply etc. by carefully going through the data available on the dial.

Data contained on the measuring instrument dial: The important application data needed for use of the measuring instrument are in the form of symbols on the dial/scale of the instrument. In addition to the `symbols' the manufacturer's name, the instrument type and the Serial or Production numbers are also indicated on the dial.

Measuring range and measuring units: Instruments are identified by the appropriate letter markings(symbols) on the dial. For example V for voltmeter, mv for millivoltmeter, KV for Kilo Voltmeter etc.

The measuring range is indicated by the series of numbers under the divisions of the scale.

V	Volt	(mV, mV, kV ...)	Voltage
A	Ampere	(mA, mA, kA ...)	Current
W	Watt	(mW, kW, MW ...)	Power
Ω	Ohm	(mΩ, KΩ, MΩ)	Resistance
Hz	Hertz	(kHz, MHz ...)	Frequency

Types of current: The types of supply on which the instrument is suitable for measurement is indicated by symbols as follows.

—	Direct current
~	Alternating current
≂	Direct and alternating current
≈ (one of three waves bold)	One phase measured multiphase (alternating) current
≋	Three phase measured multiphase (alternating) current.

Testing potential (voltage): The star mark on the dial indicates the voltage to which the instrument is subjected for test.

☆	Testing potential 500V
☆ 2	Testing potential over 500V eg, 2000V(2KV)
☆ 0	No testing potential

Using position: Instruments must be used as per the specified position mentioned on the dial.

⊥	Vertical using position.
⊓	Horizontal using position.
∠60°	Angle of usage eg. 60^0 tilt angle.
⊥ ±2°	Departure from the permissible position eg. $\pm 2^0$ vertical.
±10° ⊓	Departure from the permissible position eg. $\pm 10^0$ horizontal.

Instruments used in any position other than the one specified may cause error in reading.

Accuracy class: This is specified in two ways. The % of the full scale deflection and the % of the actual reading. This is indicated as follows.

2.5	Class determined by the measuring range end value.
2.5	Class determined by the length of the scale.

Measuring instrument types

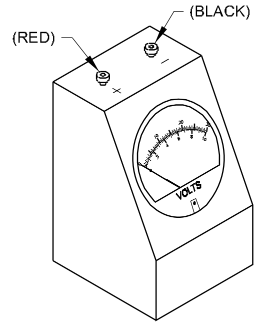
	Moving coil instrument
	Moving iron instrument
	Electrodynamic quotient instrument
	Enclosed electrodynamic quotient instrument
	Moving coil instrument with rectifier
	Device with built-in measuring rectifier
	Separated series and shunt resistance
	Observe instructions for use.

Indication error: Instruments are manufactured to read within certain accuracy. This is indicated on the dial by a number close to the other symbols.

1	Indication error ± 1%
2.5	Indication error ± 2.5%
3.5	Indication error ± 3.5%

Terminal markings: In a moving coil type of instrument, the terminals are marked with + and − . The positive (+) terminal is red in colour and the negative(−) terminal is black in colour (Fig 1). This type of instrument must be connected in the circuit with correct polarity. i.e. the +ve of supply to the +ve of instrument and the −ve of supply to the −ve of the instrument.

Fig 1

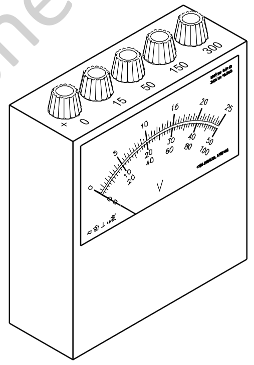


In the moving iron type there is no polarity marking on the terminals. Both the terminals are of the same colour. The instrument can be connected in the circuit without identifying the line and neutral of the supply.

In ohmmeters the terminals are marked in the same way as in the case of the moving coil meters.

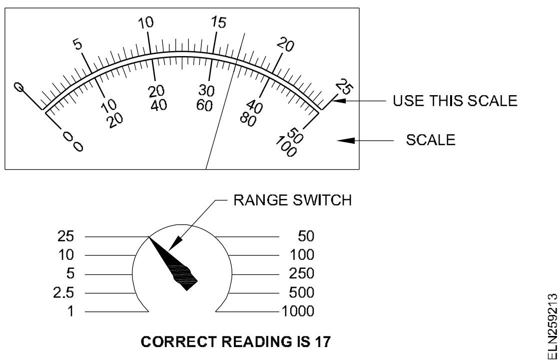
In multi-range meters, one of the terminals is marked as + or zero and the other terminal is marked with the range of measurement value (Fig 2).

Fig 2



A range selector switch is used in some meters (Fig 3). While reading such meters, care should be taken to keep in mind the position of the range selector switch, and read the scale reading corresponding to that selected range.

Fig 3



Reading instrument scales

Objectives: At the end of this lesson you shall be able to
- **distinguish the class of instruments based on measuring accuracy**
- **state the different types of scale graduations**
- **state the sources of error when measuring**
- **state the precautions to be used while using instruments.**

All measurements must be as accurate as possible and must have the smallest possible influence on the system. To ensure that the influence on the system is reduced as much as possible, particular care must be taken in selecting the correct measuring instrument and in employing the correct method of making measurements.

When selecting a measuring device, care should be taken that the measured value is indicated on the scale above 60% of the full scale value. This reduces the measuring error as much as possible.

Classification of instrument as per accuracy: The classification of measuring devices is based on the measuring accuracy and is dependent on the quality and the application. Measuring instruments are divided into quality classes as follows.

Class	Application
0.1 0.2 0.3	Precision and laboratory measuring devices
0.5	Portable measuring devices and laboratory devices
1.0 1.5 2.5	Industrial and panel measuring devices

The indicated number under the column `class' represents the relative error.

Example: Quality class 1.5 refers to a relative measuring error of ±1.5% which means that the indicated error may be ±1.5% of the rated value.

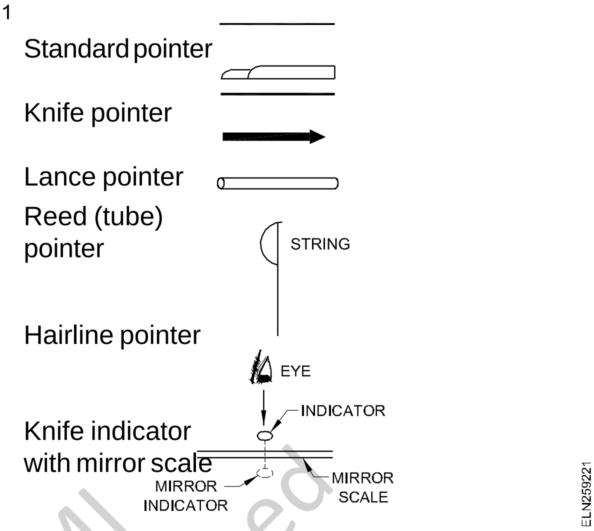
Reading accuracy: The reading accuracy of a measuring device must always be greater than the measuring accuracy. By the application of the correct indicator arrangement, the reading accuracy may be increased.

The indicator arrangement, that is discussed is for an indicator (pointer) with a scale.

Indicators (Pointers): Indication of readings is obtained by the mechanical movement of a pointer which moves parallel to the divisions of the scale.

Following are the different types of pointers used in instruments (Fig 1).

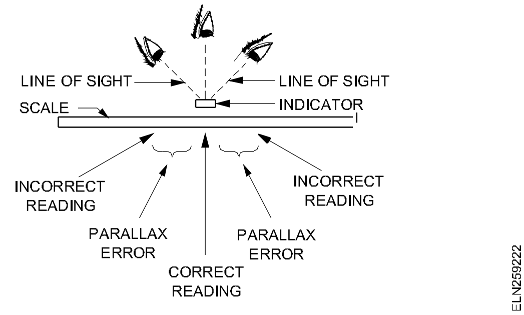
Fig 1



Due to the gap between the pointer and the scale, while reading an instrument, a slanting view may be obtained. Depending on the eye angle, a reading error may exist. This error is known as parallax error.

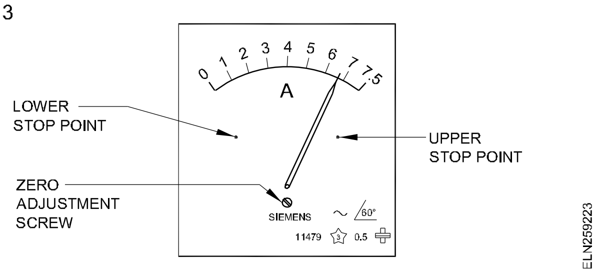
Mirror scales: Mirror scales are used in precision devices and Industrial devices of higher quality class. When reading, the indicator must cover its image (picture) in the mirror, so as to avoid reading errors caused by reading the scale from an angle (parallax error) (Fig 2).

Fig 2



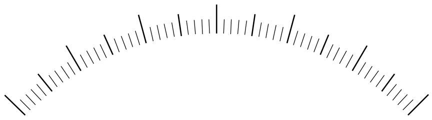
Zero adjustment: The mechanical zero of the pointer may be adjusted by an external screw adjustment (Fig 3).

Fig 3

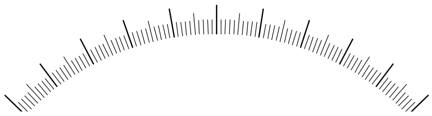


Types of scales

1 **Coarse and coarse-fine scale:** Coarse scales and coarse-fine scales are used primarily in panel instruments with a quality class from 1 to 2.5.



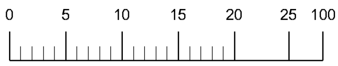
COARSE-FINE DIVISION



2 **Fine scale**: Performance for precision and laboratory devices with a quality class from 0.1 to 0.3 are used mostly in conjunction with a mirror scale.

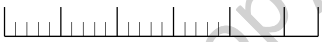
STANDARD WORKS DIVISION
FINE DIVISION

3 **Extended scale**: Used primarily for current measurements with short overload time i.e. starting current of motors.



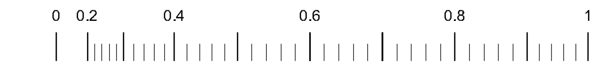
EXTENDED SCALE

4 **Linear scales**: Linear scales are used primarily in moving coil measuring devices. The graduations are uniform throughout the span.



EXTENDED SCALE

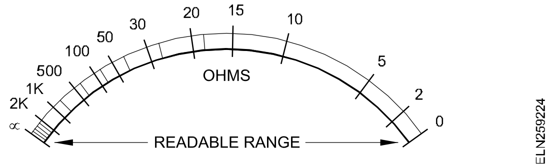
5 **Non-linear scales:** Non-linear scales are used primarily in moving iron measuring devices. The graduations on the scale are not uniform. They are crowded in the begining of the scale



Non-linear scales, coarse: The dot under the division mark indicates the start and end of the measuring range. This instrument should not be used for measurement of value below the start range.

The ohmmeter scale is also non-linear. It may be noted that the zero on the scale is on the right hand side. (Fig 4)

Fig 4



Sources of errors when measuring

1 **Device errors**: This error will occur as a result of careless assembly, damage, false adjustment or when used in a false position. While using the instrument it must be used in the position as specified on the dial.

2 **Influence errors**: These are errors caused by the effect of environment, such as humidity (dampness), temperature, vibrations, electrical or magnetic fields.

3 **Switching errors**: These errors are caused by the influence of the electrical quantity being measured, through incorrect method of connection before measurement or false selection of the proper measuring device.

4 **Human errors:** Reading errors caused by looking at the indicator (pointer) from an angle (parallax error) or false reading of middle value of subdivision graduation.

Reading the scales: When using a multi-range ammeter or voltmeter, it is important to know the function of the range switch. The range switch selects the amount of current or voltage that causes full-scale deflection (FSD) of the meter. When measuring an unknown quantity, it is wise to start out on the highest range and reduce to a lower range until you get a deflection somewhere between mid and full scale if possible.

To avoid placing as many scales on the meter as there are ranges, some scales are used for many different ranges simply by multiplying or dividing the scale numbers by 10 or 100. For instance, to read a multi-range meter, find the range being used on the range switch and determine which scale has a full-scale deflection most closely corresponding to the range. Then read off the number from the scale where the pointer has come to rest.

The following examples illustrate the method.

Example 1 (Fig 5)

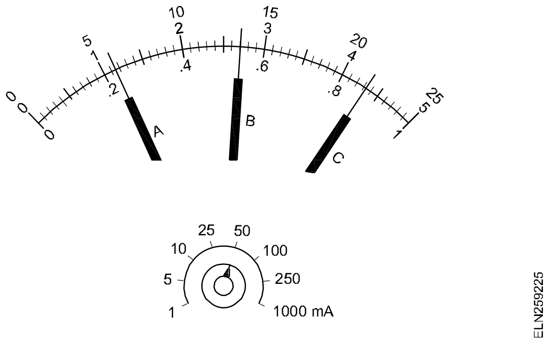
Multi-range DC milliammeter scale with range switch on 50mA.

At A: Reading is between 10 and 20 i.e. = 11.5mA.

At B: Reading is between 20 and 30 i.e. = 27mA.

At C: Reading is between 40 and 50 i.e. = 43.5mA.

Fig 5



Multi-range AC/DC voltmeter scales with range and function switches set to 5V DC.

Example 2 (Fig 6): With the range switch on 5V DC, the FSD must be 5V on the AC/DC scale. Therefore, we must use the 0-50 scale with each number divided by 10.

At A: Reading is between 0.5 and 1.0 i.e. = 0.72V.

At B: Reading is between 2.0 and 2.5 i.e. = 2.37V.

At C: Reading is between 4.0 and 4.5 i.e. = 4.30V

Example 3 (Fig 6): With the range switch on 150V AC, the FSD must be 150V on the AC/DC scale. Therefore, we must use the 0-15 scale with each number multiplied by 10.

At A: Reading is between 20 and 30 i.e. = 23V.

At B: Reading is between 70 and 80 i.e. = 75V.

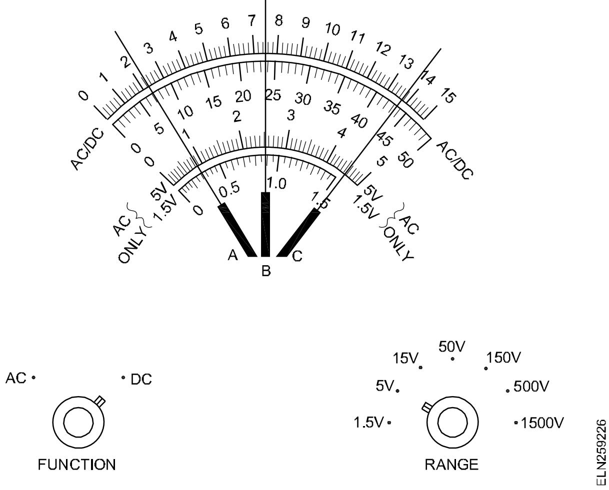
At C: Reading is between 130 and 140 i.e. = 136V.

Precautions to be observed while using an instrument

1 Select the meter for the electrical quantity to be measured, eg. voltage, current, resistance.

2 Choose the correct range for the quantity being measured, eg. for measuring 10V the correct range is 0-15V.

Fig 6



3 Identify the correct instrument suitable for AC/DC measurements.

4 Use the instrument in the correct position as specified.

5 Ensure correct polarity while connecting MC type instrument.

6 Errors are caused by the effect of the environment, such as humidity (dampness), temperature, vibrations, electrical or magnetic fields. Care should be taken to avoid such environmental factors.

7 Read the instrument looking straight at the pointer to avoid parallax error.

8 In mirror back scale read such that the pointer coincides with its image in the mirror.

9 If there is any zero error this must be corrected before using the instrument by the zero adjustment screw.

Classification of electrical instruments - Essential forces, MC and MI meter

Objectives: At the end of this lesson you shall be able to

- **classify electrical instruments with respect to standard, function and operation by the effect of electric current**
- **explain the type of forces required for the proper functioning of an electrical indicating instrument.**

Electrical instruments may be classified based on the following.

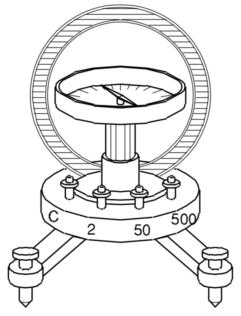
- Manufacturing standards
- Function
- Effects of electric current on the instruments.

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 (Fig 1).

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.

Fig 1



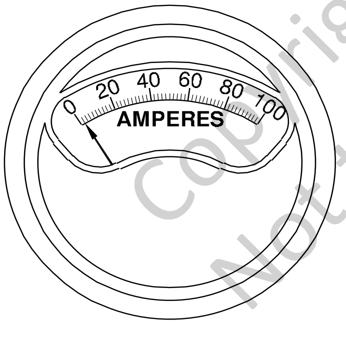
Secondary instruments: In these instruments the value of electrical quantity (voltage, current, power, etc.) to be measured can be determined from the deflection of the instruments on the calibrated dial. These instruments should be calibrated in comparision with either an absolute instrument or with 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 (Figs 2) indicate the value of voltage, current power etc., directly on a graduated dial. Ammeters, voltmeters and wattmeters belong to this class.

Fig 2

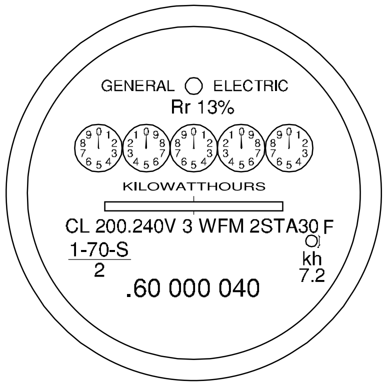


Integrating instruments: These instruments measure the total amount, either the quantity of electricity or the electrical energy, supplied to a circuit over a period of time. Ampere hour meters and energy meters belong to this class. Fig 3 shows the Kilowatt hour/energy meter.

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 4 shows such a recording instrument.

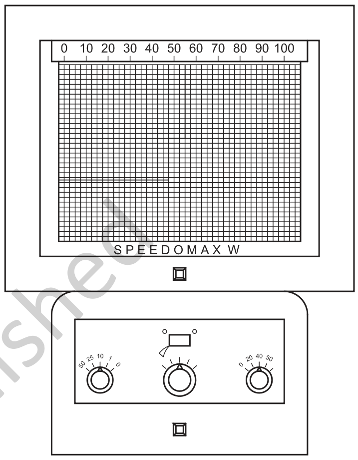
Effects of electric current used on electrical instruments: Secondary instruments may also be classified

Fig 3



ENERGY METER

Fig 4



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: 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.

How this deflecting force is developed in an instrument will be explained later while explaining the individual type of instruments.

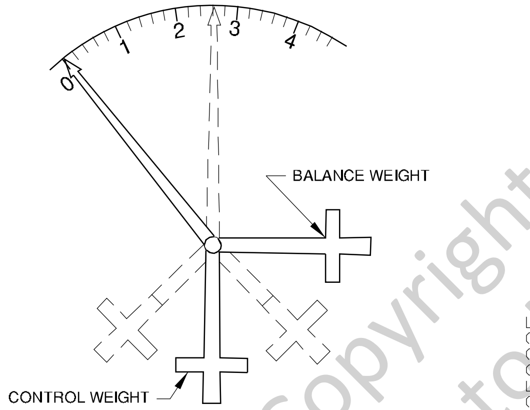
Controlling force: This force is essential to control the movement of the moving system and to ensure that the magnitude of the deflction of the pointer is always the same for a given value of the quantity to be measured. As such, the controlling force always acts opposite to the deflecting force, and 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 (Fig 5). 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.

Fig 5



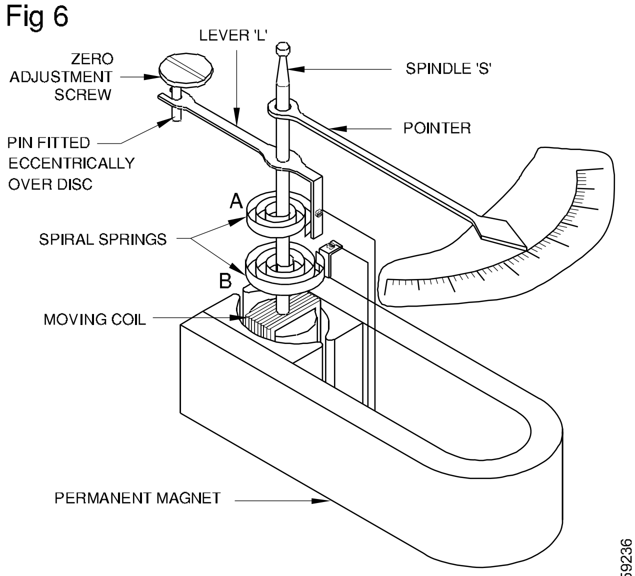
GRAVITY CONTROL

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 (Fig 5). When the instrument is connected to the supply, the pointer moves in a clockwise direction, thereby displacing the weights (Fig 5). 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.

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 (Fig 6). 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.

Fig 6



SPRING CONTROLLED MOVING COIL INSTRUMENT

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.

They are:

- the instruments can be used in any position
- the control springs help in leading in and out the current to the moving coil of the instruments.

Damping force: This force is necessary to bring the moving system to rest in its final deflected position quickly.Without such damping, the combination of the inertia of the moving system and the controlling force makes the pointer (moving system) to oscillate about its final deflected position for some time before coming to rest, resulting in a waste of time in taking the reading.

Critical/under/over damping: If the pointer moves quickly to its final deflected position without any sort of oscillation, the damping is called as 'critical damping' and the instrument is the 'dead beat'.

On the other hand in the under-damped instrument, the pointer will oscillate before coming to the final deflected position, and in the case of an over-damped instrument, the pointer comes slowly to the final deflected position.

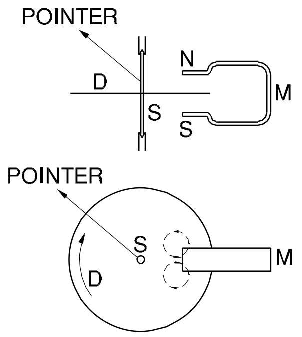
The two methods of damping, commonly employed are:

- eddy current damping
- air friction damping.

Eddy current damping: Fig 7 shows one form of eddy current damping. A copper or aluminium disc D,is attached tothe spindle 'S'. When the pointer moves, the disc also moves.

The disc is made to move in the air gap between the poles of a permanent magnet M. The moving disc cuts the flux, thereby inducing eddy currents in the disc. According to Lenz's law, the flux produced by the eddy current opposes the movement of the disc, thereby effecting the damping force.

Fig 7

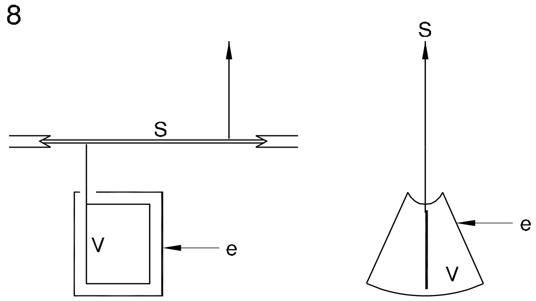


EDDY CURRENT DAMPING

In the case of moving coil instruments, the moving coil is wound on a thin aluminium former. The eddy currents induced in the former produces the damping force.

Air friction damping: Fig 8 shows the method of obtaining air friction damping. Accordingly a thin metal vane V is attached to the spindle S, and the vane is made to move inside a sector shaped box 'e' while the pointer moves on the graduated scale.

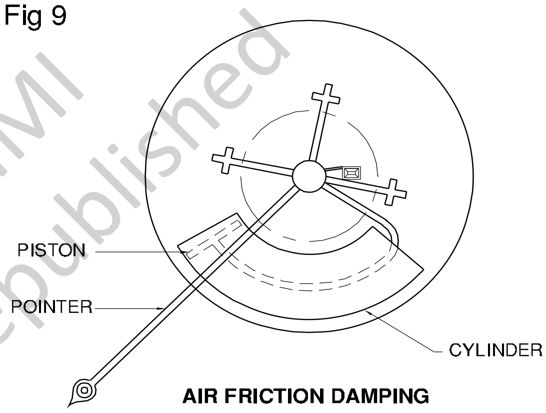
Fig 8



AIR FRICTION DAMPING

Alternatively, the vane in the form of a piston could be arranged to move inside an air chamber (cylinder) as shown in Fig 9. In the above two cases, the air inside the air chamber opposes the movement of the vane/piston, and, thereby, the damping force is created.

Fig 9



AIR FRICTION DAMPING

Permanent magnet moving coil (PMMC) instruments

Objectives: At the end of this lesson you shall be able to

- **state the principle of a permanent magnet moving coil (P.M.M.C) instrument**
- **describe the construction and operation of a P.M.M.C instrument**
- **state the uses, advantages and disadvantages of a P.M.M.C instrument.**

Moving Coil and Moving Iron Instruments :

Instruments are classified based on their moving system They are :

(i) Moving Coil Instruments (MC)

Permanent Magnet Moving Coil Instrument (PMMC)
Dynamo meter type instruments

(ii) Moving Iron Instruments (MI)

Attraction type
Repulsion type

Permanent magnet moving coil (PMMC) instruments

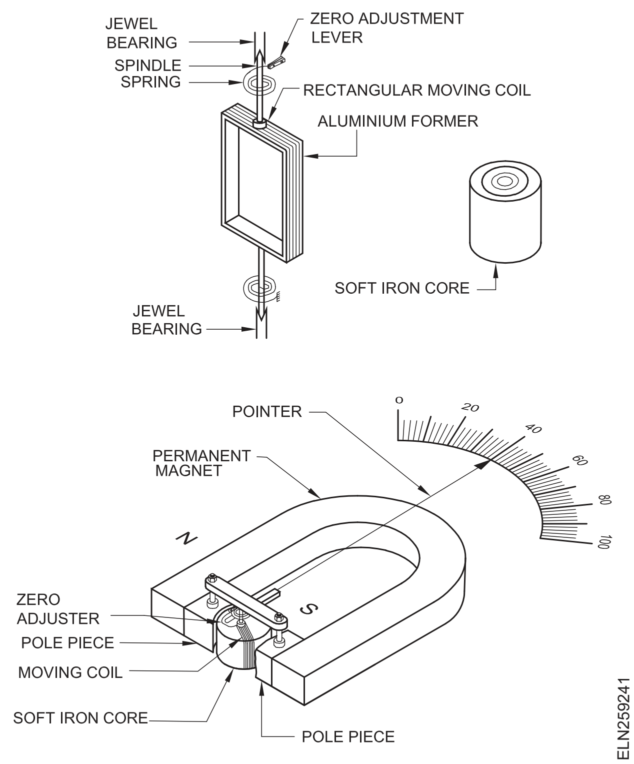
The most commonly used instrument to measure DC quantities like voltage and current, is the permanent magnet moving coil (PMMC) instrument.

Principle: The working of the PMMC instrument is based on the principle that when a current-carrying conductor is placed in a magnetic field, it is acted upon by a force which tends to move the conductor. The DC motor also works on this principle.

Construction: The PMMC instrument consists of a permanent magnet and a rectangular coil wound with a very fine gauge insulated copper wire on a thin light aluminium former.

The aluminium former not only supports the coil, but also produces eddy current for damping. The coil and the former are attached with spindles on either side, and supported by jewelled bearings so as to make the assembly move freely in the air gap (Fig 1).

Fig 1



The two ends of the coil are connected to two phosphor-bronze springs, fixed one on each spindle to lead in and lead out the current. The springs are spiralled in the opposite direction in order to neutralize the effect of temperature changes.

The horseshoe shaped permanent magnet is made of an alloy called 'Alnico' and it has soft iron pole pieces which are shaped to distribute uniform flux in the air gap.

A soft iron core is fixed in such a way that the moving coil can move within the gap, between the soft iron core and the pole pieces. The function of the soft iron core is (i) to decrease the reluctance of the magnetic path between the poles and thereby increase the magnetic flux and (ii) to make the flux uniformly distributed in the air gap.

The pointer is attached to one of the spindles, and it moves on a graduated scale when the coil is deflected by the quantity to be measured.

Operation: When the current is passed through the coil, the coil experiences a force due to the interaction of the magnetic fluxes, produced by the permanent magnet and the current in the moving coil.

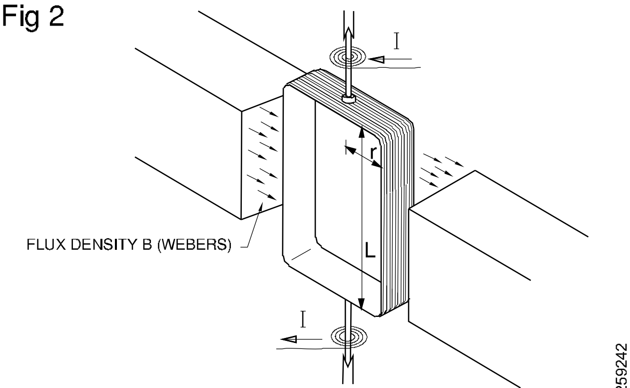
We have the force 'F' in the coil equal to BLIN Newtons Fig 2

where

B - The flux density in the air gap in Webers/ square metre,

L - The active length of one conductor in the air gap in metres

Fig 2



PRINCIPLE OF THE MOVING COIL INSTRUMENT

I - The current in amperes passing through the coil and N is the number of turns.

Torque produced in the coil

= force X perpendicular distance between the centre of the conductor to the centre of the spindle in metres.

Let us assume the distance as 'r'metres.

Hence we have

T = Fr Newton metres

T = BLINr Newton metres.

(F = BLIN Newton)

But B,L,N and r are constants for a particular instrument and can be denoted by a letter 'K'. As such

Torque = KI

Torque proportional to I

From the above equation we can infer that the deflecting torque of a PMMC instrument is directly proportional to the current, and, therefore, the scale of the PMMC instrument is uniform that is the scale in which the space between numbers are equal.

Full scale deflection current: This is the maximum current flowing through the moving coil to give full scale deflection of an instrument.

Meter sensitivity: It is an important characteristic of any meter. The amount of current necessary to cause full scale deflection of the meter pointer is the meter sensitivity. The typical current meter sensitivity varies from about 5 microamperes to 75 milliamperes.

However, the direction of deflection of the moving coil depends upon the direction of the current flowing through the coil. As such, if the instrument is connected with reverse polarity, the deflection of the coil will be reversed, and the pointer will try to move in an anticlockwise direction and read below zero.

Hence, while connecting the instrument in DC the polarity should be correctly observed. Further the instrument will not deflect when connected to an AC supply.

Uses/advantages/disadvantages: As a PMMC instrument is a polarized instrument, it could be used only in DC.

The PMMC instrument could be directly used to measure milli or micro amperes as the moving coil can carry a low current only. With proper shunts, this instrument could be used to measure large currents, and with proper series resistors, called multipliers, it could be converted into a voltmeter. (The procedure of extending the range of an ammeter or converting it into a voltmeter will be dealt with in another lesson.)

Advantages: The PMMC 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 PMMC 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.

Uses :

It can be used as volt meter and Ammeter

Moving-iron instruments

Objectives: At the end of this lesson you shall be able to
- **state the principle of moving-iron instruments - attraction and repulsion type**
- **describe the construction and working of a moving-iron Instrument**
- **state the use, advantages and disadvantages of moving-iron instruments.**

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:

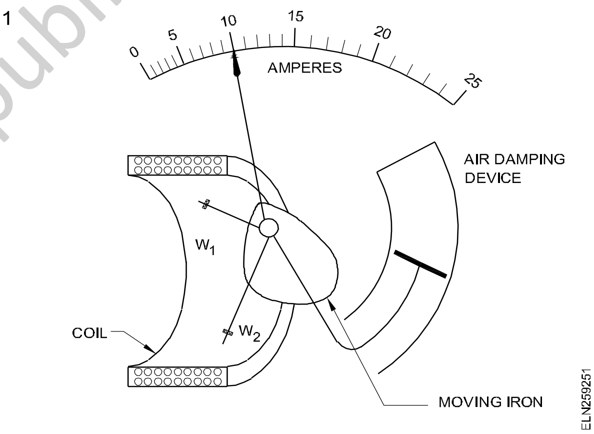
- attraction type
- repulsion type.

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 (Fig 1). Just in front of the air core, an oval shaped soft iron piece is eccentrically pivoted in a spindle (Fig 1).

The spindle is free to move with the help of the jewelled bearings, and the pointer, which is attached to the spindle, could thus 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 1

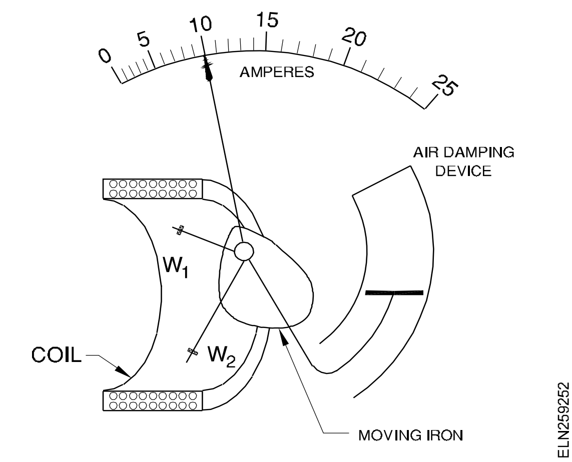


When the electromagnetic coil is connected to the supply, the magnetic field created in the coil attracts the soft iron piece (Fig 2). Due to the eccentricity of pivoting of the iron piece, the enlarged portion of the iron piece is pulled towards the coil. This in turn moves the spindle and makes the 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 on 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: This instrument consists of a coil wound on a brass bobbin B, inside which two strips of soft iron M and F are set axially (Fig 3a). Strip F is fixed whereas the iron strip M is attached to the spindle S, which also carries the pointer P.

Fig 2



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. (Fig 3a & 3b)

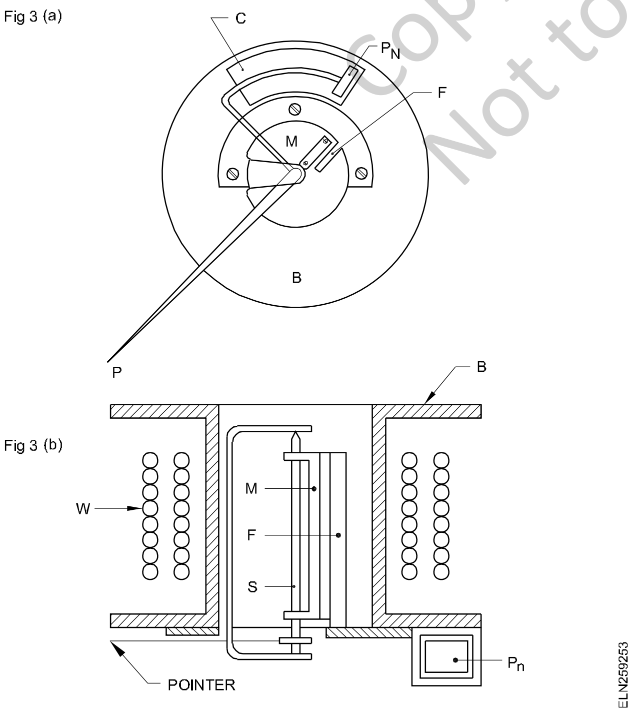
When the instrument is connected to the supply, the coil W carries current which in turn produces a magnetic field. This field makes the fixed and moving-iron F and M respectively to produce similar poles in the ends. Therefore, the two strips repel each other.

The torque set up produces a deflection of the moving system end. Therefore it brings into play a controling torque due to torsion of the control springs or weights. 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 a piston P_N in a cylindrical air chamber C (Fig 3a).

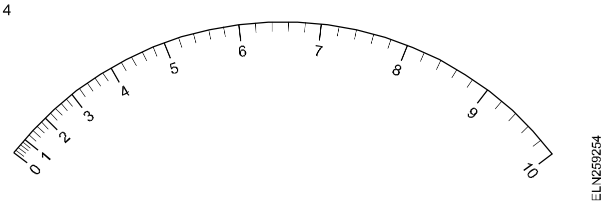
Fig 3 (a)

Fig 3 (b)



Deflecting torque and graduation of scale: However, in the moving-iron instruments, the deflecting torque is proportional to the square of the current passing through the coil. As such the scale of this instrument will be uneven. It is cramped at the beginning and open at the end (Fig 4).

Fig 4

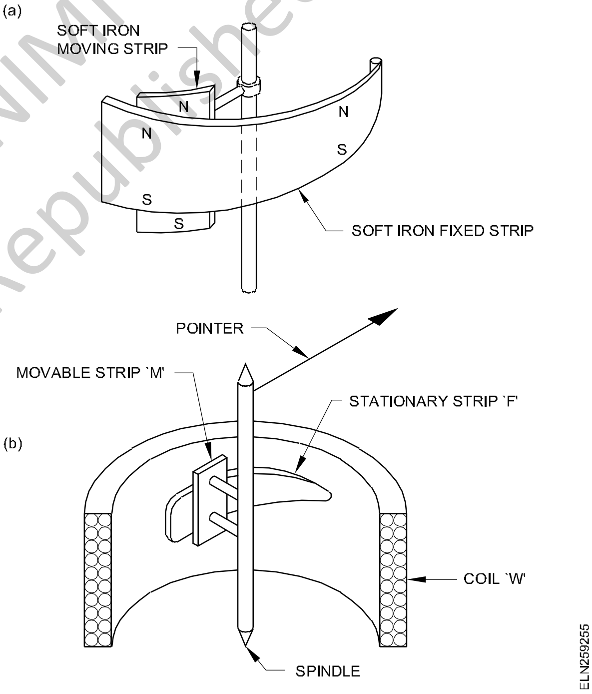


In order to achieve uniformity of scale, some manufacturers have designed tongue shaped strip as fixed soft iron (Fig 5a).

The fixed iron consists of a tongue-shaped soft iron sheet bent into a cylindrical form, while the moving iron is made of another soft iron sheet, and is so mounted as to move parallel to the fixed iron and towards its narrower end (Fig 5b).

Fig 5 (a)

Fig 5 (b)



The torque, which is proportional to the square of the current, is proportionally reduced by the narrow portion of the fixed iron, resulting in more or less even torque and thereby uniform scale.

These instruments are either gravity or spring controlled, and the damping is achieved by the air friction method

Uses, advantages and disadvantages of Moving-iron instruments

Uses: They are used as voltmeters and ammeters.

The coil W is wound with thick conductor of less number of turns for ammeters and is wound with thin conductors of large number of turns for voltmeter.

Advantages

- They can be used for both AC and DC, and are hence called unpolorized instruments.
- 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°.

Disadvantages

- They have errors due to hysteresis, frequency changes, wave-form and stray magnetic fields.
- They have non-uniform scales commonly. However, special manufacturing designs are utilized to get more or less uniform scales.

Dynamometer type instrument

Objectives: At the end of this lesson you shall be able to
- **state the principle of dynamometer type instrument**
- **describe the construction, and working of the dynamometer type instruments**
- **explain the internal connections of a dynamometer instrument when used as a voltmeter, ammeter and wattmeter**
- **state the advantages and disadvantages of using the dynamometer instruments.**

Electro-dynamic or Dynamo-meter type Instruments

Working principle: This Instrument works on the principle of DC motor. That is, whenever a current-carrying conductor is kept in a magnetic field, a force is created and it tends to move the conductor away from the magnetic field. In a dynamo- meter instrument, the magnetic field is produced by an electromagnet named as fixed coils.

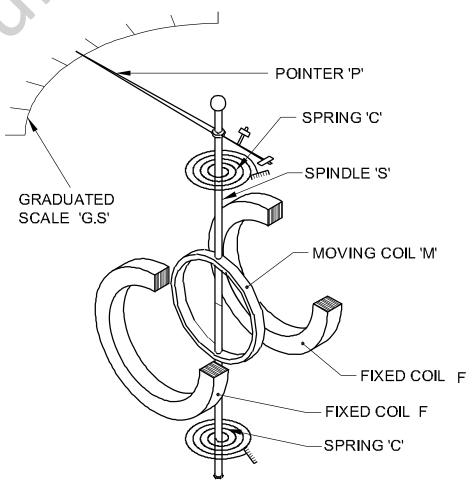
The moving coil, either connected in series or parallel with the fixed coil, carries a proportionate current. Operation of this instrument in both AC and DC is possible due to the fact that when ever the current reverses in AC, the direction of flux in the fixed coils as well as the direction of flux produced by moving coil, reverses at the same time resulting in the same direction of torque.

Construction: A general arrangement of the instrument is shown in Fig 1. The main magnetic field is produced by the fixed/stationary coil. This coil is divided into two sections to give a uniform field in the centre and also to allow the moving coil mechanism to be placed in between them.

The fixed coils F and F are placed close together and parallel to each other (Fig 2). The air core section removes hysteresis effects when used in AC circuits. The moving coil `M' is mounted on a spindle `S' and the spindle is free to move in the air gap with the help of jewelled bearings.

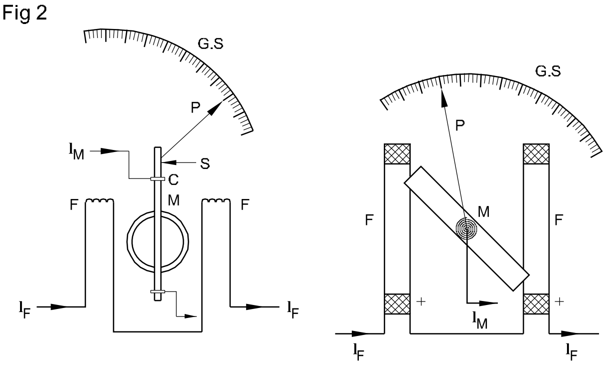
The pointer `P' is attached to one end of the spindle and the spindle end made to move on a graduated scale `G S'. The controlling torque is provided by two phosphor-bronze springs `C' attached to the spindle. Further the springs are used to allow the current `in' and `out' from the moving coil.

Fig 1



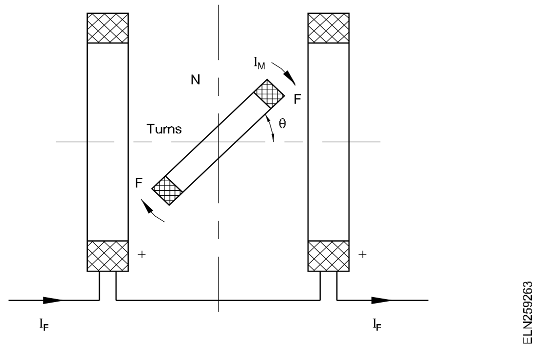
DYNAMOMETER INSTRUMENT

Fig 2



Working: As shown in Fig 3,let the current passing through the fixed coils be I_F, and the current passing through the moving coil be I_M. The field strength will be proportional to the current I_F.

Fig 3



The deflecting torque is produced due to the interactions of the magnetic fields produced by the fixed and moving coils and will be proportional to the current carried by them.

The deflecting torque T_d is proportional to I_F and I_M where I_F is the current in the fixed coil and I_M is the current in the moving coil.

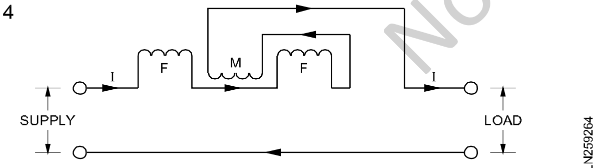
From the above torque equation, it is clear that the instrument when used as voltmeter or ammeter will have ununiform scale due to the square law response.

However, when used as a wattmeter, the instrument will have uniform scale.

Connection of this instrument requires modification depending up on the usage viz, ammeter, voltmeter or wattmeter as explained below.

Dynamometer instrument as an ammeter: This instrument could be used as milli or micro ammeter by connecting the fixed and moving coils in series (Fig 4).

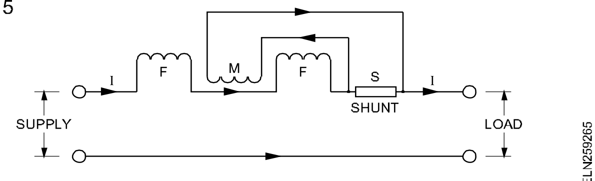
Fig 4



As the moving coil is made by winding small gauge (thin) wire, the above connection is unsuitable for measuring heavy currents.

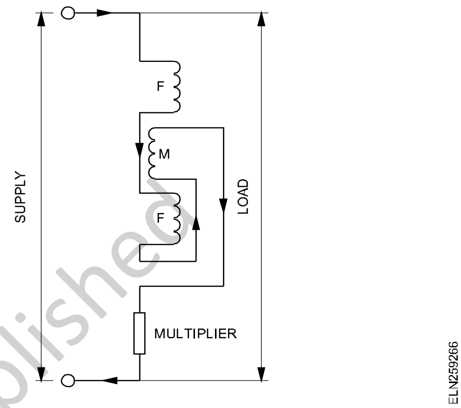
When the instrument is to be converted as an ammeter to measure large currents, the moving coil is connected across a shunt (Fig 5). Both AC and DC, measurements are possible.

Fig 5



Dynamometer instrument as a voltmeter: When this instrument is used as voltmeter, the fixed and moving coils are joined in series along with a high resistance (multiplier) (Fig 6). This voltmeter could be used both in AC and DC.

Fig 6



Dynanometer used as a Wattmeter: The dynamometer is commonly used as a wattmeter to measure power in both AC and DC circuits and will have uniform scale.

Advantages :

- This instrument can be used both in AC and DC.
- As this is an air cored instrument, the hysteresis and eddy current losses are eliminated.
- This instrument has better accuracy.
- When used as wattmeter, the scale is uniform.

Disadvantages :

- It is more expensive than PMMC and moving iron instruments.
- When used as voltmeter or ammeter the scale will not be uniform.
- It has a low torque/weight ratio-as such has low sensitivity.
- Sensitive for over loads and mechanical impact. Hence careful handling is necessary.
- It consumes more power than PMMC meters.

Digital Ammeter

Objectives: At the end of this lesson you shall be able to
- **state the features of digital ammeter**
- **state the movements, special operation and standard.**

Digital Ammeter

Digital Ammeters are instruments that measure the current in ampere and display it in digital. These instruments provide information about current drawn and current continuty to help users troubleshoot electric loads.

They have both positive and negative leads and low internal resistance. Digital ammeters are connected in series with a circuit so that current flow passes through the meter.

High current flow may indicate short circuit (or) defective component. Low current flow may indicate high resistance. It can be used to measure the A.C and D.C. Many digital ammeters include a current sensor built in the meter or that is clamped around the wire.

Features:

Different types of digital ammeters can measure different ranges of A.C current and D.C current and also A.C frequency.

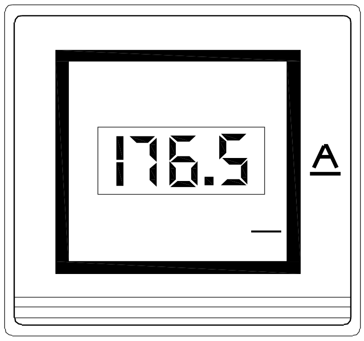
Batteries are provided in it to operate without plug-in-power and suitable for cutdoor use Fig 1 shows a typical digital ammeter.

Special measurements and advanced option:

In some of advanced option, digital ammeters can

- Adjust sampling rates automatically

Fig 1



TYPICAL DIGITAL AMMETER

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- Display status information as bar graph
- Measure decibel readings

Standards :

Digital ammeters must have a certain standards and specifications to ensure proper design and functionality refer IEC 600 51 - 2.

Digital Volt Meter (DVM)

Objectives: At the end of this lesson you shall be able to
- **distinguish between analogue and digital voltmeter**
- **list out the advantage of DVM**
- **explain the working principle of DVM.**

Digital Volt Meter (DVM) :

The Digital Volt Meter(DVM) is an electrical measureing instrument which is used to measure line potential difference (P.D) between two points. The voltage to be measured may be AC or DC. Two types of voltmeters are available for the purpose of voltage measurement i.e. analog and digital. Analog voltmeters generally contain a dial with a needle moving over it according to the measure and hence displaying the value of the same.

Digital voltmeters display the value of AC or DC voltage being measured directly as discrete numerical instead of a pointer deflection on a continuous scale as in analog instruments.

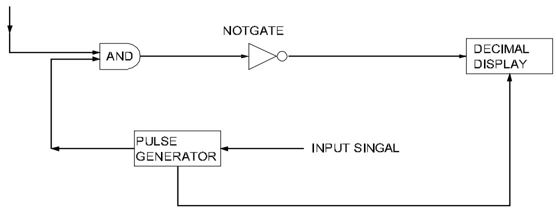
Advantages of Digital Voltmeters:

- Read out of DVMs is easy as it eliminates observational errors in measurement
- Parallax error is eliminated
- Reading can be taken very fast
- Output can be fed to memory devices for storage and future computations
- More versatile and accurate
- Compact portable and cheap
- Requires low power

Working Principle of Digital Voltmeter:

The block diagram of a simple digital voltmeter is shown in the Fig 1 It consists the following blocks

Fig 1



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Input signal: It is basically the signal of voltage to be measured.

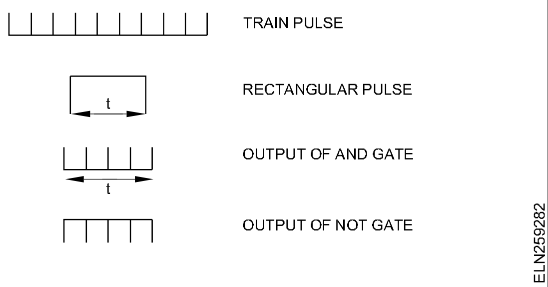
Pulse generator: Actually it is a voltage source. It uses digital, analog or both techniques to generate a rectangular pulse. the width and frequency of the rectangular pulse is controlled by the digital circuit inside the generator while amplitude with rise and fall time is controlled by analog circuitry

AND gate: It gives high output only when both the input are high, when a train pulse is fed to it along with rectangular pulse, it provides output having train time duration as same and the rectangular pulse from the pulse generator.

Decimal Display: It counts the numbers of impulses and display the value of voltage on LED or LCD display after calibrating it.

Working (Fig 2)

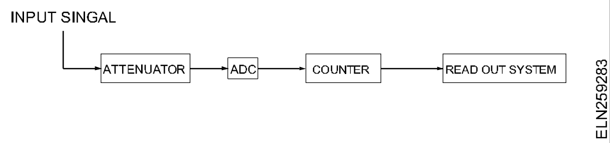
Fig 2



- Unknown voltage signal is fed to the pulse generator which generates a pulse whose width is proportional to the input signal.
- Output of pulse generator is fed to one leg of the AND gate.
- The input signal to the other leg of the AND gate is a train of pulses.
- Output of AND gate is positive triggered train of duration same as the width of the pulse generated by the pulse generator.
- This postitive triggered train is fed to the inverter which converts it into a negative triggered train.
- Output of the inverter is fed to a counter which counts the number of triggers in the duration which is proportional to the input signal i.e. voltage under measurement

This counter can be calibrated to indicate voltage in volts converts an analog signal into a train of pulses, the number is proportional to the input signal. So a digital voltmeter can be made by using any one of the A/D conversion methods (Fig 3)

Fig 3



On the basis of A/D conversion method used digital voltmeters can be classified as:

- Ramp type digital voltmeter.
- Intergrating type voltmete.
- Potentiometric type digital voltmeter.
- Succesive approximation type digital voltmeter.
- Continuous balance type digital voltmeter.

Now-a- days digital voltmeters are also replaced by digital multi meters due to its multitasking feature.

Wattmeters

Objectives: At the end of this lesson you shall be able to
- **state the advantages of measuring power directly**
- **state the types of single phase wattmeters**
- **explain the construction and working of the induction type single phase wattmeter**

Advantages of measuring power supply

Power in a single phase AC circuit can be calculated by using an ammeter, a voltmeter and a power factor meter with the help of the formula

Power in a single phase circuit = $EI \cos \phi$ watts.

In the same way power in a 3-phase balanced circuit can be measured by using one ammeter, one voltmeter and one power factor meter with the help of the formula

Power in a balanced 3 - phase circuit = $3E_P I_P \cos\phi$

$$\text{or } \sqrt{3}\, E_L I_L \cos\phi$$

where $E_P I_P$ are the phase values and

$E_L I_L$ are the line values

This indirect method of measuring power in an AC circuit has the following disadvantages.

- Low accuracy due to a number of meters.
- Reading errors due to a number of meter readings.
- Involves calculation every time the load changes and hence not suitable for changing loads.

To get an on the spot true power reading, a wattmeter is used. The power dissipated in the circuit can be read directly from the scale of the meter. The wattmeter takes the power factor of the circuit into account and always indicates the true power.

Types of wattmeters

There are three types of wattmeters in use as stated below.

- Dynamometer wattmeter
- Induction wattmeter
- Electrostatic wattmeter

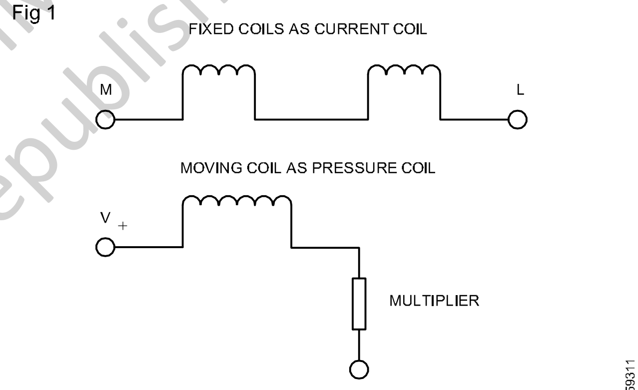
Among the three, the electrostatic type is very rarely used. Information given here is for the other two types only.

Dynamometer type, single phase wattmeter: This type is commonly used as a wattmeter. Construction details and the working of this type of meter have already been discussed . Hence the trainees are advised to read the information before proceeding further.

Dynanometer used as a Wattmeter: The dynamometer is commonly used as a wattmeter to measure power in both AC and DC circuits and will have uniform scale.

When this instrument is used as a wattmeter, the fixed coils are treated as current coil, and the moving coil is made as pressure coil with necessary multiplier resistance (Fig 1).

Fig 1



DYNAMOMETER INSTRUMENT AS A WATT METER

Advantages

- This instrument can be used both in AC and DC.
- As this is an air cored instrument, the hysteresis and eddy current losses are eliminated.
- This instrument has better accuracy.
- When used as wattmeter, the scale is uniform.

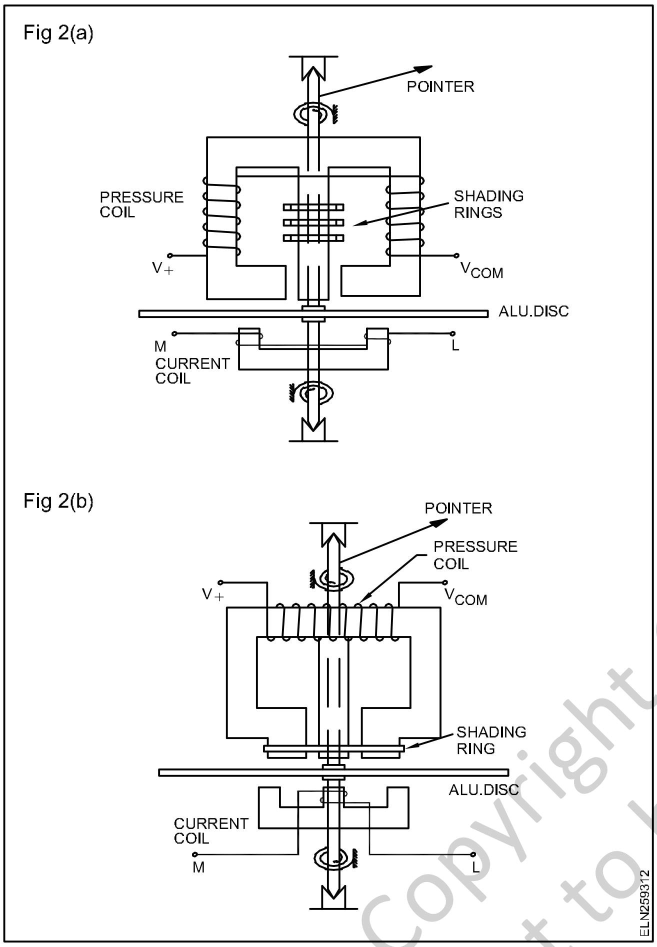
DIsadvantages

- It is more expensive than PMMC and moving iron instruments.
- When used as voltmeter or ammeter the scale will not be uniform.
- It has a low torque/weight ratio-as such has low sensitivity.
- Sensitive for over loads and mechanical impact. Hence careful handling is necessary.
- It consumes more power than PMMC meters.

Induction type single phase wattmeter: This type of wattmeters could be used only in AC circuits whereas a dynamometer type wattmeter could be used in both AC and DC circuits.

Induction type wattmeters are useful only when the supply voltage and frequency are almost constant.

Construction: Induction wattmeters having two different types of magnetic cores (Figs 2a and 2b).



Both the types have one pressure coil magnet and one current coil magnet. The pressure coil carries a current proportional to the voltage whereas the current coil carries the load current.

A thin aluminium disc is mounted on a spindle in between the space of the magnets and its movement is controlled by springs. The spindle carries a weightless pointer at one end.

Working: The alternating magnetic fluxes produced by the pressure and current coils cut the aluminium disc and produce eddy currents in the disc. Due to the interaction between the fluxes and the eddy currents a deflecting torque is produced in the disc and the disc tries to move. Control springs attached to the two ends of the spindle control the deflection and the pointer shows the power in watts on a graduated scale.

Shaded rings provided in the pressure coil (shunt) magnet could be adjusted in order to cause the resultant flux in the magnet to lag in phase by exactly 90° behind the applied voltage.

Method of connecting wattmeter in single phase circuits - pressure coil connection to reduce erroneous measurement.

There are two ways of connecting the pressure coil of the wattmeter (Fig 3).

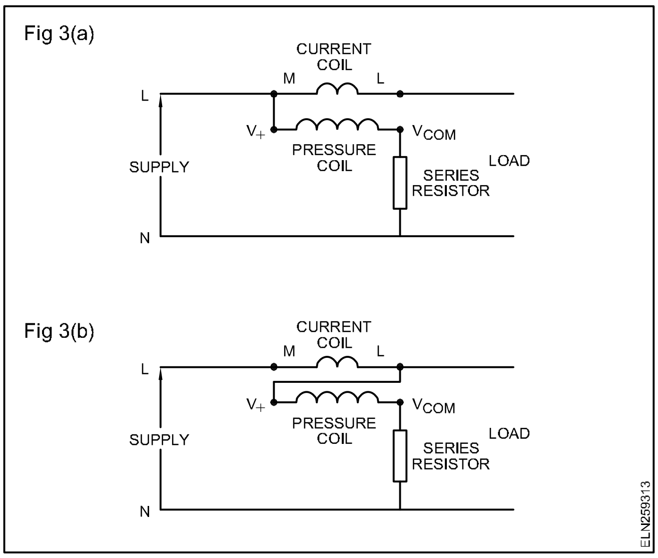
Both the methods shown in Figs 3a & b need correction in power measurement due to the reasons stated below.

In the method of connection shown in Fig 3a, the pressure coil is connected on the 'supply' side of the current coil, and hence, the error in power measurement is due to the fact that the voltage applied to the voltage coil is higher than that of the load on account of the voltage drop in the current coil. As such the wattmeter measures the load power in addition to the power lost in the current coil.

On the other hand, in the method of connection shown in Fig 3b, the current coil carries the small current taken by the voltage coil, in addition to the load current, thereby introducing errors in power measurement. As such the wattmeter measures the load power in addition to the power lost in the pressure coil.

If the load current is small, the voltage drops in the current coill will be small, so that the method of connection, shown in Fig 3a, introduces a very small error and, hence, preferable.

On the other hand, if the load current is large the power lost in the pressure coil will be negligible when compared to the load power in the method of connection shown in Fig 3b, and, hence, a very small error is introduced resulting in the preference of this connection.



3-phase Wattmeter

Objectives: At the end of this lesson you shall be able to
- **describe the various types of 3-phase wattmeters, their connections**
- **state how to connect different types of 3 phase watt meter.**

In single-phase wattmeters there will be one set of pressure and current coils driving a single aluminium disc, whereas in 2-element, three phase wattmeters there will be two sets of pressure and current coils driving a single aluminium disc (Fig 1a) or driving two aluminium discs mounted on the same shaft (Fig 1b) thereby providing a torque proportional to the 3-phase power.

Fig 1(a)

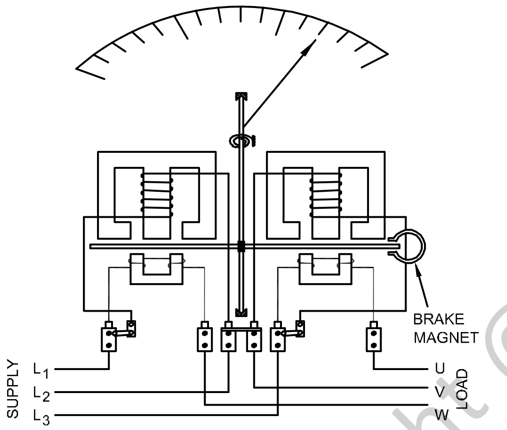
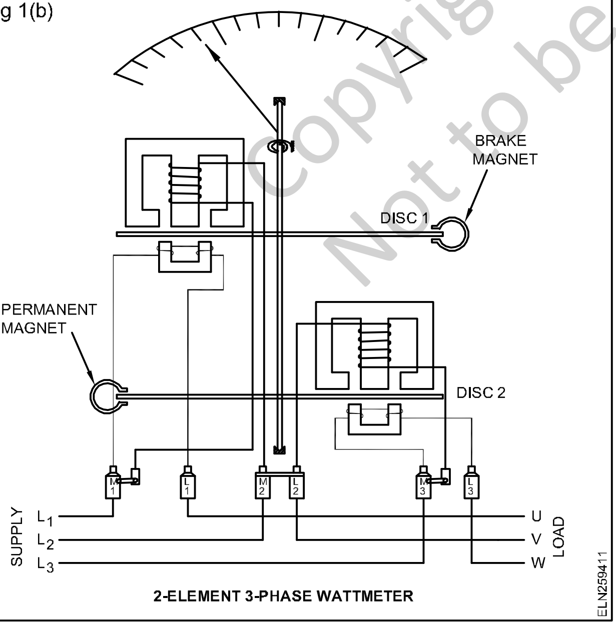


Fig 1(b)



2-ELEMENT 3-PHASE WATTMETER

On the other hand a 3-element, 3-phase wattmeter will have three sets of pressure and current coils kept at 120° to each other but driving a single aluminium disc (Fig 2) or alternatively 3 sets of pressure and current coils driving three discs one over the other but mounted on the same single spindle (Fig 3).

Fig 2

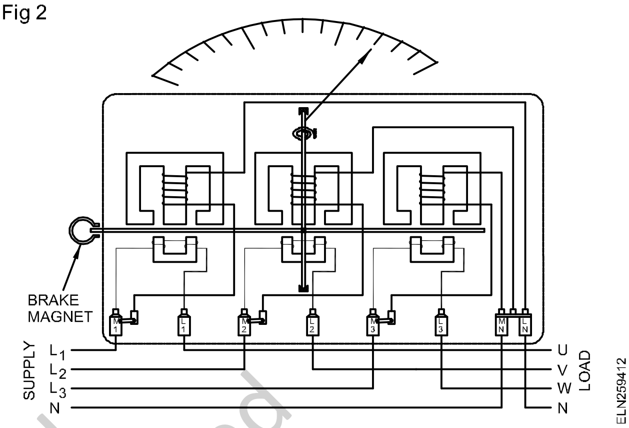
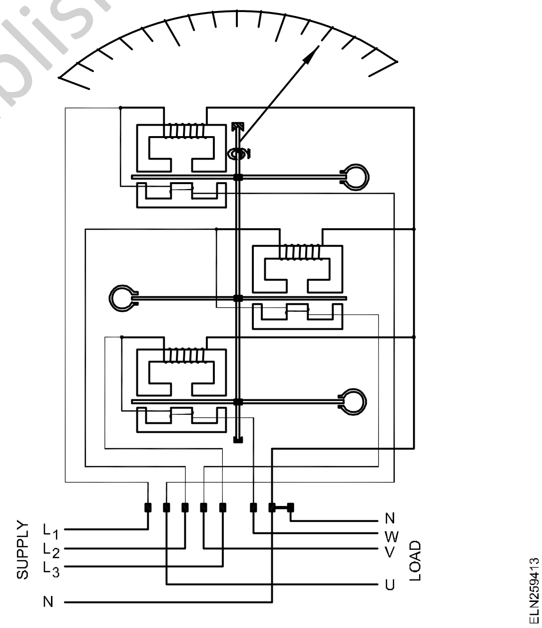


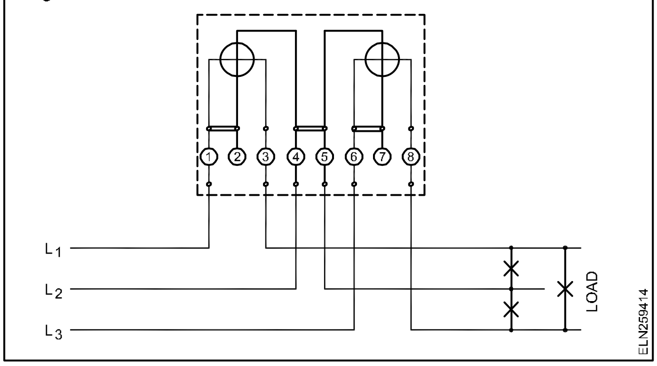
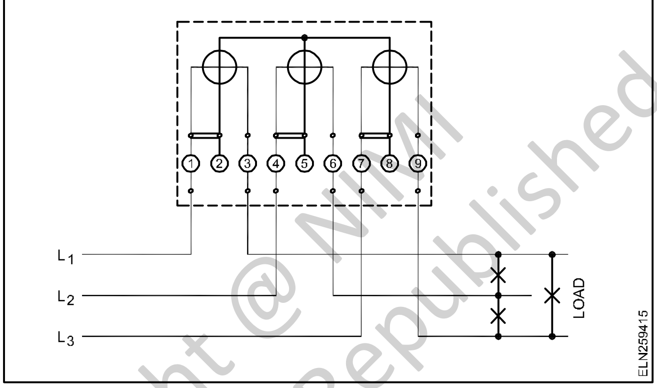
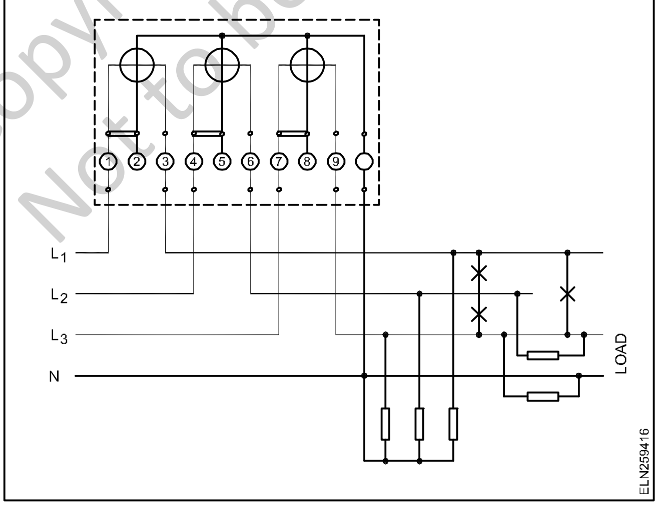
Fig 3



The principle and working of an induction type wattmeter are similar to the induction type energy meter. The only difference in construction between the energy meter and wattmeter is that the spindle of the wattmeter is spring-controlled, has a pointer but no train of gears.

However to summarise what has been learnt earlier the following table 1 is provided with connection diagram of 3-phase wattmeter Fig 4, Fig 5 & Fig 6

Table 1

Sl.No.	Types of 3-phase wattmeter	Circuit diagram	Application
1	2-element 3-wire type	Fig 4 	Balanced and unbalanced loads.
2	3-element 3-wire type	Fig 5 	Balanced loads.
3	3-element 4-wire type	Fig 6 	Un balanced loads.

Digital Wattmeter

Objectives: At the end of this lesson you shall be able to
- **describe the block diagram**
- **compare between analog and digital wattmeter**

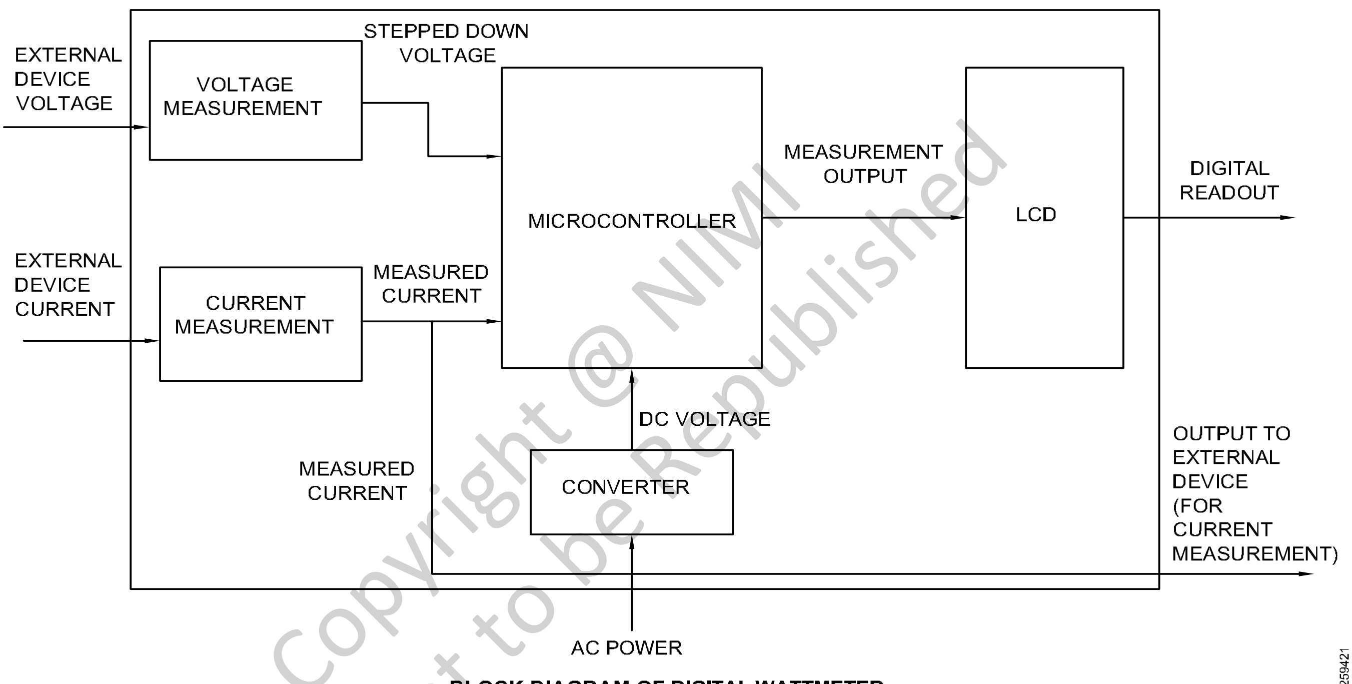
Digital wattmeter

The wattmeter is an instrument for measuring the electric power in watts of any given circuit. Electromagnetic wattmeters are used for measurment of utility frequency and audio frequency and audio frequency power; other types are required for radio frequency.

Fig 1 shows the block diagram of digital wattmeter.

Digital wattmeters measure current and voltage electronically thousands of times a second, multiplying the results in a computer microcontroller chip to determine watts. The computer can also perform statistics such as peak, average, low watts consumed. They can monitor the power line for voltage surges and outages. Digital electronic wattmeter, have become popular for conveniently measuring power consumption in household appliances with saving energy and money.

Fig 1



BLOCK DIAGRAM OF DIGITAL WATTMETER

Comparison between analog wattmeter and digital wattmeter

Analog wattmeter	Digital wattmeter
Due to moving parts there are losses and bearings.	As there are no moving parts,friction at mechanical losses are reduced .
Accuracy is less compared to digital wattmeters.	Accuracy is high as compared to analog.
Error may take place at the time of reading due to its non linearity.	Digital display facilitates to read the scale due power in fraction and in correct fashion.
It does not require any auxillary supply.	It requires auxillary DC supply to work.
More reliable as no complications in design and avoidance of electric components	Reliability is less as compared to analog to work
No effect of supply transients on performance of meter.	Any supply transients may damage the wattmeters.
More stable to vibration and temperature variations.	Considerable effect of vibration and temperature on performance of electric components.

Energy meter (analog and digital)

Objectives: At the end of this lesson you shall be able to
- **describe the construction and working principle of single phase energy meters**
- **state and explain creeping error in 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 phase induction type energy meter: The operation of this meter depends on the induction principle. Two alternating magnetic fields produced by two coils 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. (Fig 1) Torque is proportional to the power as in wattmeter.

Fig 1

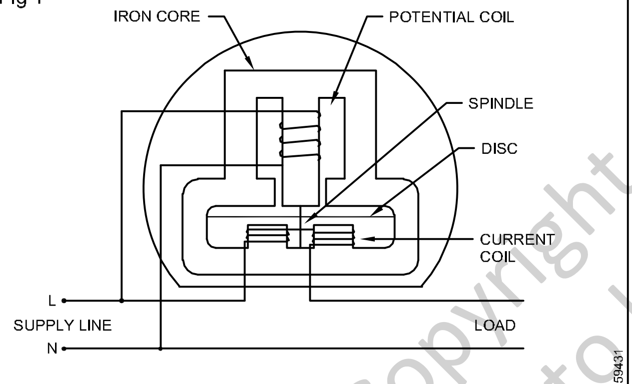


DIAGRAM OF AN INDUCTION TYPE WATT-HOUR METER

The watt-hour meter must take both power and time into 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.

Parts and functions of an energy meter: The parts of the induction type single phase energy meter are (Fig 1).

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.

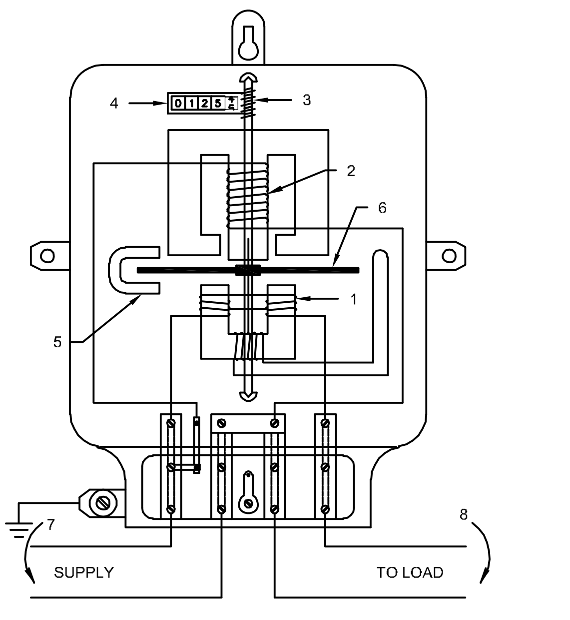
Disc: The disc is the rotating element in the meter, and is mounted on a vertical spindle which has a worm gear at one end. The disc is made of aluminium and is positioned in the air gap between the potential and current coil magnets.

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 (Fig 2) 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.

Fig 2



1. CURRENT COIL
2. VOLTAGE COIL
3. WORM GEAR
4. REGISTERING MECHANISM
5. PERMANENT MAGNET
6. ALUMINIUM DISC
7. SUPPLY TERMINALS
8. LOAD TERMINALS

INDUCTION TYPE ENERGY METER

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.

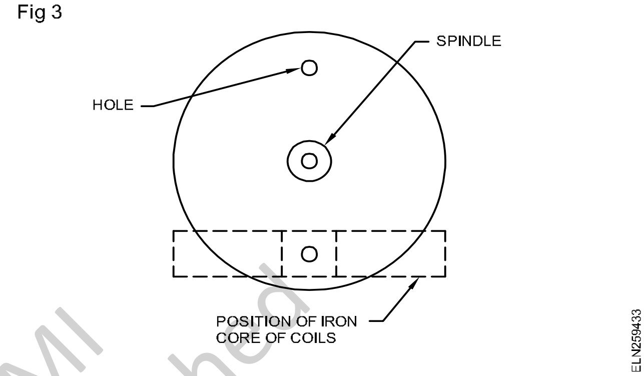
This counter torque is produced when the aluminium disc rotates in the magnetic field established by the permanent magnet. The eddy currents, in turn, produce a magnetic field that reacts with the field of the permanent magnet, causing a restraining action that is proportional to the speed of the disc.

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 (Fig 3). 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.

Fig 3



Digital Energy meters

Objectives: At the end of this lesson you shall be able to
- **distinguish the merits of digital type over electromechanical type energy meter**
- **describe the functional operation of digital type energymeter from block diagram.**

Energy meter

An electric meter or energy meter is an essential device enables systematic pricing of energy consumed by individual consumer as it measures the amount of electrical energy consumed by a residence, business or equipment.

Generally, energy meters operate by continuously measuring the instantaneous voltage and current and finding the product of these to give instantaneously electrical power (watts) which is then integrated against time to give energy is used in joules, kWh

The energy meters are classified into two basic categories. They are

- Electromechanical type
- Electronic (digital) type

Electro mechanical type Energy meter

This meter has spinning disc and a mechanical counter display. It operates by counting the revolutions of a metal disc that rotates at a speed proportional to the power drawn through the main switch. Nearby coils spin the disc by inducing eddy currents and a force proportional to the instantaneous current and voltage

A permanent magnet exerts a damping force on the disc, stopping its spin after power has been removed

This type meter has these limitations

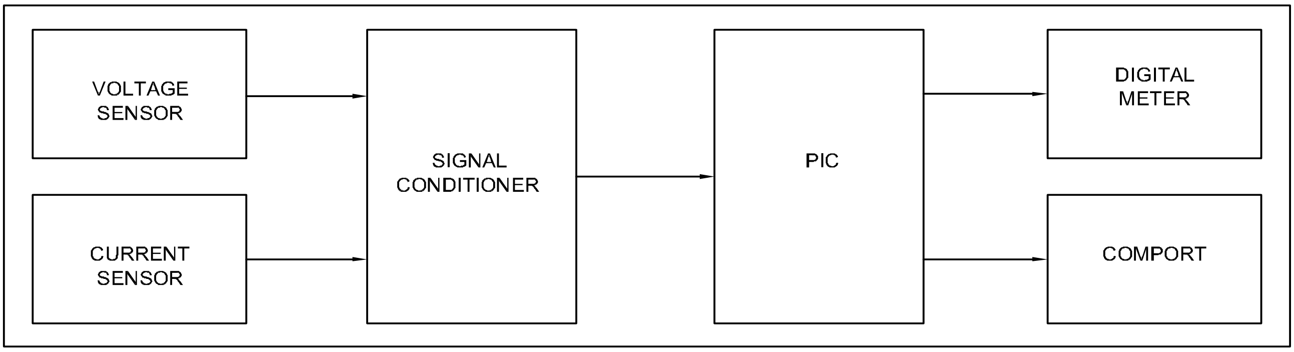
- Less accuracy
- Many methods for error correction
- Percentage error is more
- Installation is difficult
- No interface capability to external devices

The above mentioned disadvantages are overcome in digital meter, such as more accuracy, error correction method is only by A/D converters, percentage of error is 0 (Zero), installation is more easier. The display makes energy reducing from time to time can be obtained.

Electronic (Digital energy meter)

This meters measure the energy using highly integrated components and it digitizs the instantaneous voltage and current in a high-resolution sigma-delta analogue to digital converter (ADC), gives the instantaneous power in watts. Integration over time gives energy used, measured in kilo-Watt hour. The block diagram for a digital meter is shown in Fig 1. The two sensors, voltage and current sensors are employed.

Fig 1



The voltage sensor built around a step down element and potential divider network sensors both the phase voltage and load voltage.

The second sensor is a current sensor, which senses the current drawn by the load at any point in time .

It's inbuilt around a current transformer and other active devices (voltage comparator), which converts the sensed current to voltage for processing. The output from both sensors is then fed into a signal (voltage) conditioner which ensures matched voltage (or) signal level to the control circuit containing multiplexer. It enables sequential switching of both signal to the analogue input of the Peripheral Interface Controller (PIC).

The control circuit centred on a PIC integrated circuit. It contains ten bit analogue to digital converter (ADC), flexible to program and good for peripheral interfacing.

The ADC converts the analogue signals to its digital equivalent, both signals from the voltage and current sensors are then multiplied by the means of embedded software in the PIC.

The error correction is taken as the offset correction by determining the value of the input quality in the short circuited input and storing this value in the memory for use as the correction value device calibration.

The PIC is programmed in 'C' language. It stimulates to use the received data to calculate power consumption per hour, as well as the expected charges. These are displayed on the liquid crystal display (LCD) attached to the circuit.

Fig 2 shows the image of a digital energy meter.

Fig 2

DIGITAL TYPE

ELN259442

Advantages

DIGITAL electronic meters are much more accurate than electromechanical meters. There are no moving parts and , hence, mechanical defects like friction are absent.

In addition, electronic energy meters come with indicating LEDs for phase/ neutral ok, earth/leakage loss, kilowatt-hour pulse etc.

3-phase energy meter

Objectives: At the end of this lesson you shall be able to
- **list the various types of 3-phase energy meters**
- **describe the construction and working of a 3-phase 3-wire induction type energy meter**
- **describe the construction and working of a 3-phase 4-wire induction type energy meter**
- **state the application of a 3-phase 3-wire and 3-phase 4-wire energy meter.**

3-phase energy meters: Even though different types of energy meters are available, the induction type energy meter is most commonly used because it is simple in construction, less in cost and requires less maintenance. The function of a 3-phase energy meter is similar to that of a single phase energy meter

The three phase energy meter is required to measure the energy consumed in 3-phase loads whether balanced or unbalanced. The three phase energy can be measured by three separate single phase energy meters or by 3-phase energy meters.

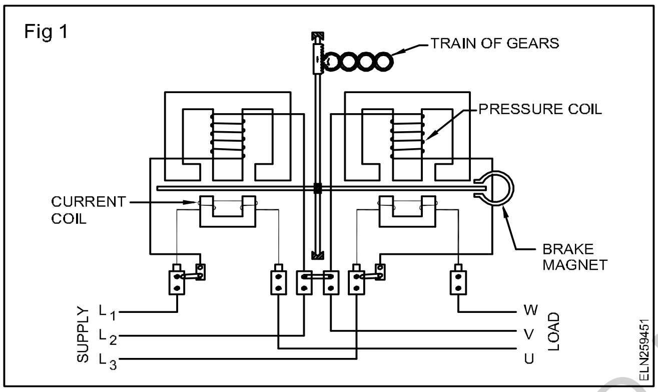
Types of 3-phase energy meters

There are two types of 3-phase energy meters mainly.

- Three phase 3-wire energy meters (3-phase 2- element energy meter)
- Three phase 4-wire energy meters (3-phase 3- element energy meter)

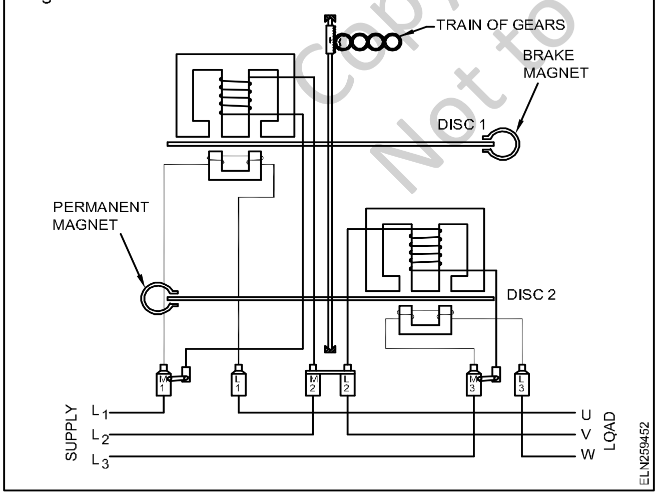
Two element 3-phase energy meters: This energy meter works on the principle of measurement of power by the two wattmeter method. Two elements of a current coil and two elements of a potential coil are used in this energy meter. These assemblies can be arranged on the different sectors in a horizontal position (Fig 1) with a single aluminium disc which rotates between the poles of a single braking magnet.

Fig 1



The two elements can also have individual driving discs on a common spindle. In this case they will have individual braking magnets (Fig 2). The second type usually preferred by the manufacturers due to the construction simplicity.

Fig 2

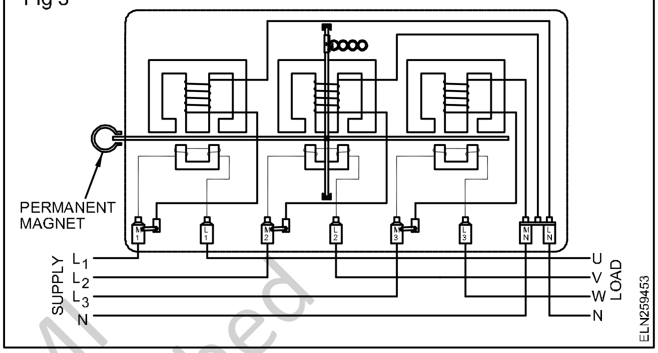


In both the cases the driving torque produced by individual elements are summed up. The recording mechanism which is attached to the train of gears i.e., cyclometer or counter type dial shows the sum of the energies that has passed through the elements. The two element energy meter is only suitable for a 3-phase 3-wire system but can be used for both balanced and unbalanced loads.

3-element 3-phase energy meter: This works on the same principle as that of the 3 wattmeter method of power measurement with a 3-phase load. Here 3 units, each with a current coil and a potential coil, are used. The potential coils of the 3 elements are connected in star to the supply lines with their common point connected to the neutral line of power supply.

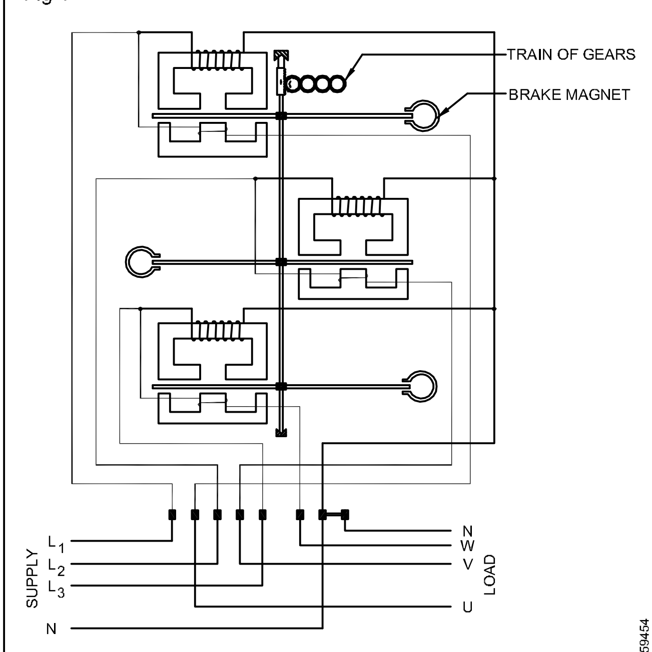
The current coils are connected in series to the individual lines. As is the case with the two element energy meter, these three elements can be arranged in the different sectors of a common single aluminium disc which serves as a rotating part connected to driving dial (Fig 3).

Fig 3



The three elements can also have a common spindle with three individual discs and braking magnets (Fig 4). Here also the 2nd type is usually preferred by manufacturers due to the easiness in construction. The driving torque produced by the three individual elements are summed up and the recording mechanism shows the sum of energies that has passed through the individual elements. This energy meter is suitable for the 3-phase 4-wire system.

Fig 4



3-ELEMENT 3-PHASE ENERGY METER

Application of 3-phase energy meter: A two element 3-phase energy meter is used with three phase loads in which a neutral is not used such as for an industry or irrigation pumpset motors etc. having three phase loads only or with an 11kV 3-phase 3-wire supply to an industry.

A 3-phase 4-wire element energy meter is used with three phase load in which balanced or unbalanced loads are connected with individual phases and neutral such as for a large domestic consumer or for an industry having lighting loads also.

Errors in energy meter

Objectives: At the end of this lesson you shall be able to
- **explain the errors caused by the driving system and the braking system in energy meters**
- **explain the different adjustments provided for correcting the errors in energy meters**
- **explain the method of determining the percentage error in the single phase energy meter**
- **state the recommendations of IS regarding percentage errors, load percentage and the power factor.**

Errors caused by the driving system.

Incorrect magnitude of fluxes: This may be due to abnormal values of current or voltage. The shunt magnet flux may be in error due to changes in resistance of coil or due to abnormal frequencies.

Incorrect phase angles: There may not be a proper relationship between the various phasors. This may be due to improper lag adjustment, abnormal frequencies, change in resistance with temperature etc.

Lack of symmetry in magnetic circuit: If the magnetic circuit is not symmetrical, a driving torque is produced which makes the meter creep.

Error caused by the braking system

They are:

- changes in the strength of the brake magnet
- changes in the disc resistance
- self-braking effect of series magnet flux
- abnormal friction of the moving parts.

Adjustments are provided for correcting the errors in the energy meters so that they read correctly and their errors are within acceptable limits.

Preliminary light load adjustment: The rated voltage is applied to the potential coil with no current through the current coil and the light load device is adjusted until the disc just fails to start. The electromagnet is slightly adjusted to make the holes in the disc to take a position in between the poles of the electromagnets.

Full load unity power factor adjustment: The pressure coil is connected across the rated supply voltage and the rated full load current at unity power factor is passed through the current coils. The position of the brake magnet is adjusted to vary the braking torque so that the meter revolves at the correct speed within the required limits of error.

LAG adjustments (Low power factor adjustments): The pressure coil is connected across the rated supply voltage and the rated full load current is passed through the current coil at 0.5 P.F. lagging. The lag device is adjusted till the meter runs at the correct speed.

Rated supply voltage: By adjusting the rated supply voltage, with the rated full load current and unity power factor, the speed of the meter is checked and the full load unity power factor and low power factor adjustments are repeated until the desired accuracy limits are reached for both the conditions.

Light load adjustment: The rated supply voltage is applied across the pressure coil and a very low current (about 5% of full load current) is passed through the meter at unity power factor. Light load adjustment is done so that the meter runs at the correct speed.

Full load unity power factor: Light load adjustments are again done until the speed is correct for both loads i.e. full load as well as light loads.

The performance: This is rechecked at 0.5 P.F. lagging.

Creep adjustment: As a final check on the light load adjustment, the pressure coil is excited by 110 percent of the rated voltage with zero load current. If the light load adjustment is correct, the meter should not creep under these conditions.

Methods of determining the percentage error in the energy meters.: There are two methods to determine percentage error in energy meters.

- One is the percentage by which the recorded energy differs from the true energy. From the number of revolutions and the constant given on the meter cover the recorded energy is calculated. The meter constant (K) is generally given as a certain number of revolutions per KWH at the rated voltage.

  Hence Recorded energy (KWH)

$$= \frac{\text{Revolutions}}{\text{Meter constant}}$$

True energy is calculated from the ammeter, voltmeter, power factor meter and time.

$$\text{Hence True energy} = \frac{EI\cos\phi \times t\,(sec)}{1000 \times 3600}$$

where 't' is in seconds.

The true energy can also be obtained from the reading of the substandard energy meter connected in the circuit instead of the ammeter, voltmeter and power factor meter and the

$$\%\ \text{error} = \frac{\text{Recorded energy - True energy}}{\text{True energy}} \times 100$$

In the second method the constant of the meter is compared with the constant calculated from the standard meter readings and time (test constant). When the error is calculated by this method it is usual to express the constant in watt secs. per revolution, instead of revolutions per KWH.

$$\text{Meter constant (Watt secs/rev.)} = \frac{3600 \times 1000}{\text{Rev./KWH}}$$

$$\text{Test constant} = \frac{E \times I \times T\,(sec)}{\text{Rev.}}$$

$$\text{and } \%\ \text{error} = \frac{\text{Meter constant (T) - Test constant } (T_1)}{\text{Test constant } (T_1)} \times 100$$

By comparing time for certain revolutions of the rotor

$$\%\ \text{error} = \frac{T - T_1}{T_1} \times 100$$

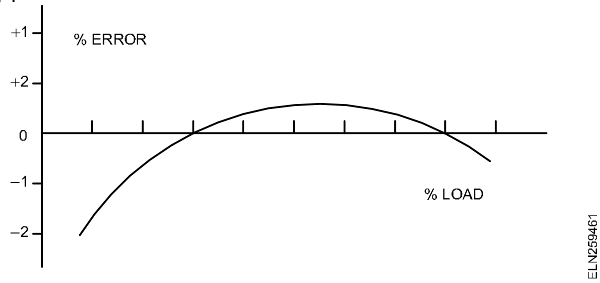
Where T= correct time for a given number of revolutions

$$= \frac{3600 \times 1000}{\text{Rev./KWH}} \times \frac{\text{Rev.}}{\text{Watts}}$$

T_1 = actual time for the same number of revolutions as found by a stopwatch.

From the readings a curve is plotted for percentage error Vs. percentage load on the meter. If the meter records more than the true energy (i.e. runs fast) the error is +ve and if it reads less error is –ve. (Fig 1)

Fig 1



Recommendations as per BIS 722: As per Bureau of Indian Standards IS 722 (Part II 1977), a single phase energy meter should have the following ratings and accuracies.

- Standard basic current (I_b) 2.5, 5, 10, 20 and 30A.
- Rated maximum current (I_{max}) 200% of the rated basic current.
- Starting current at unity power factor shall be 0.5 of basic current.
- Limits of error shall be as follows.

Values of current	Power factor	%error limit
5% I_b	1	± 2.5
10% I_b to I_{max}	1	± 2
10% I_b	0.5 lagging	± 2.5
20% I_b to I_{max}	0.5 lagging	± 2

Multimeters

Objectives: At the end of this lesson you shall be able to
- **state what is a multimeter**
- **explain the construction of multimeter**
- **explain the working priniciple of analog multimeter**
- **explain the method of measuring direct / alternating voltages and current with a multimeter**
- **explain the method of measuring resistance by a multimeter**
- **explain the precautions to be observed while measuring voltage, current and resistance in the circuit.**

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 K ohms/ volts and for the DC voltage range it is 20 K ohms/volts. The lowest range of DC is more sensitive than the other ranges.

Figs 1a and 1b show typical multimeters.

Construction of a multimeter

Fig 1

(a)

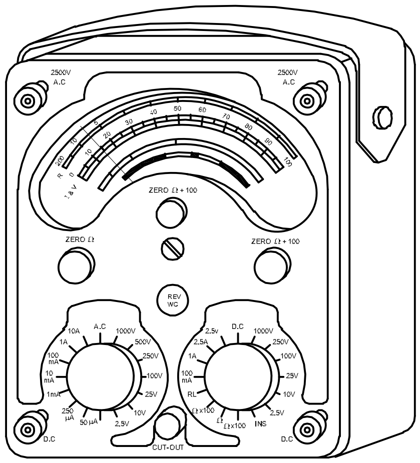


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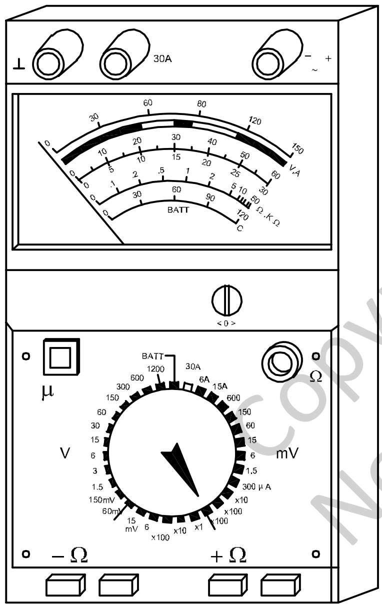
Fig 1

(b)



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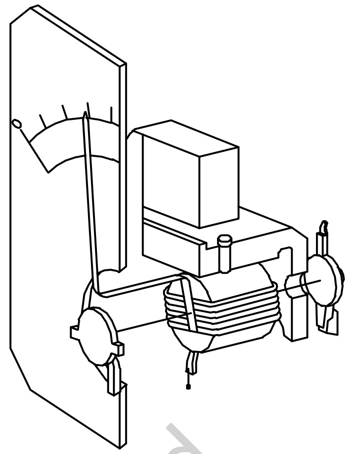
A multimeter uses a single meter movement (Fig 2), with a scale calibrated in volts, ohms and milliamperes. The necessary multiplier resistors and shunt resistors are all contained within the case. Front panel selector switches are provided to select a particular meter function and a particular range for that function.

On some multimeters, two switches are used, one to

Fig 2



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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 2)

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

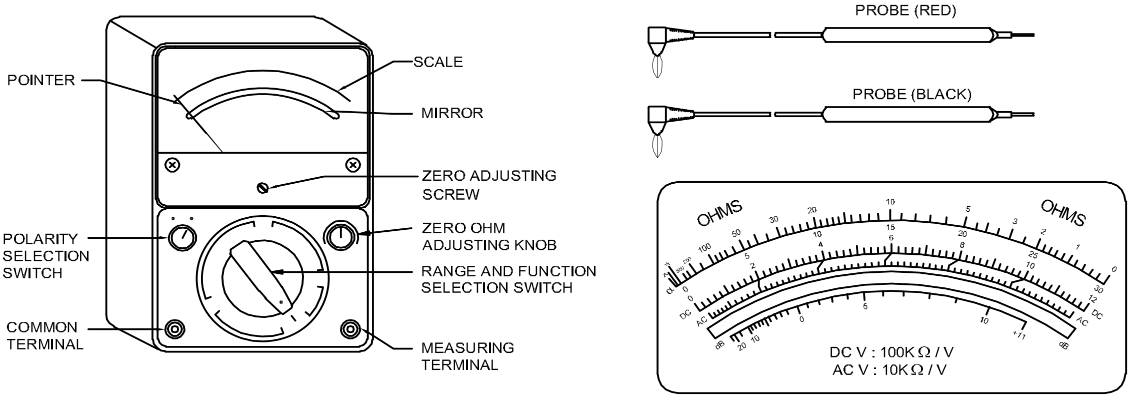
Parts of a multimeter

A standard multimeter consists of the main parts and controls (Fig 3).

Controls

The meter is set to measure the current, voltage (AC and

Fig 3



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DC) or resistance by means of the FUNCTION switch. In the example given in Fig 4 the switch is set to mA, AC.

The meter is set to the required current, voltage or resistance range - by means of the RANGE switch. In

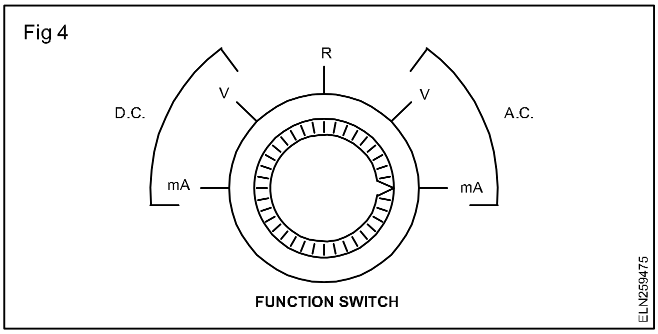


Fig 4

Fig 5, the switch is set to 2.5 volts or mA, depending on the setting of the FUNCTION switch.

The example in Fig 6 shows the switch set to 25V DC of

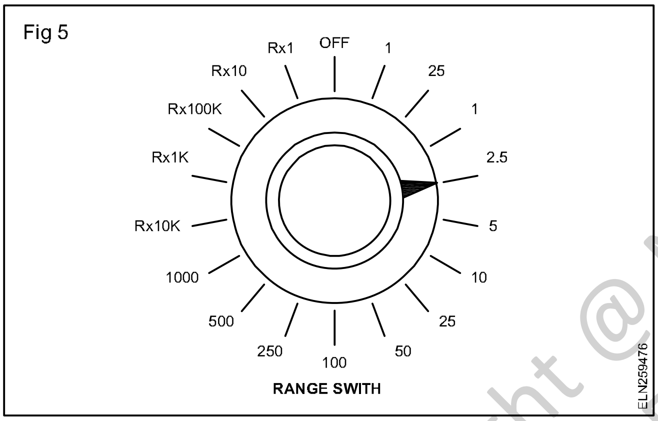


Fig 5

a meter having the function and the range selected by a single switch.

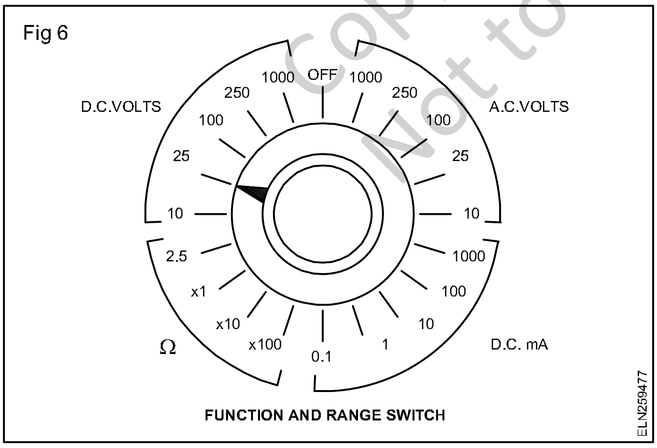


Fig 6

The example in Fig 7 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.

Switches set to 100 mA DC. (Fig 8)

Switches set to resistance, ohms x 100 range. (Fig 9)

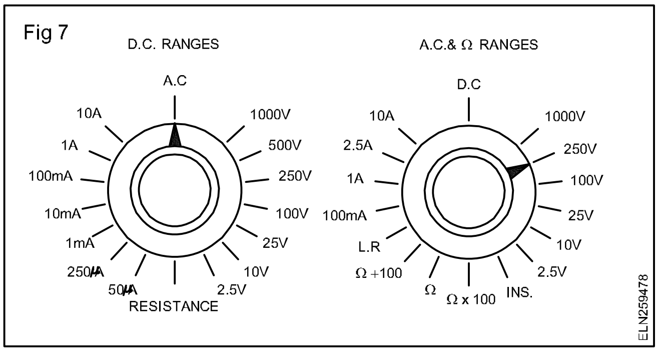


Fig 7

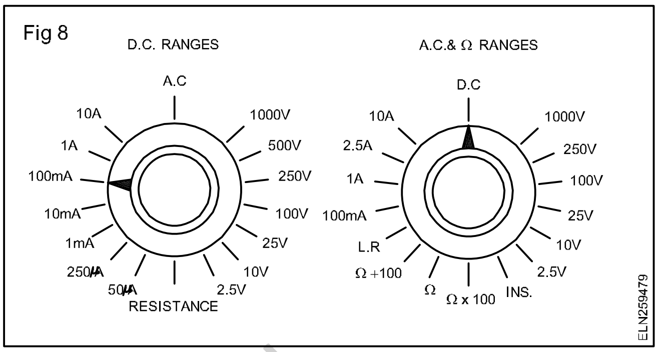


Fig 8

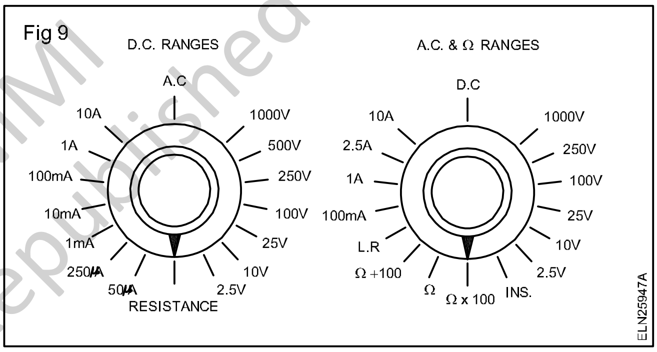


Fig 9

Scale of multimeter

Separate scales are provided for:

- resistance
- voltage and current.(Fig 10)

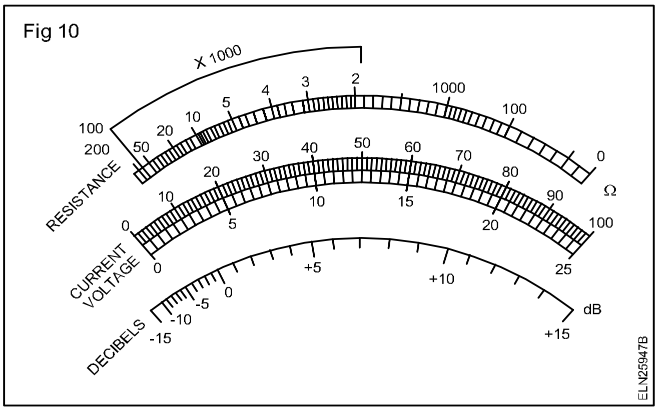


Fig 10

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 11.

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 12.

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 13.

To measure resistance, the leads are connected across the external resistor to be measured (Fig 13). 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.

Zero adjustment

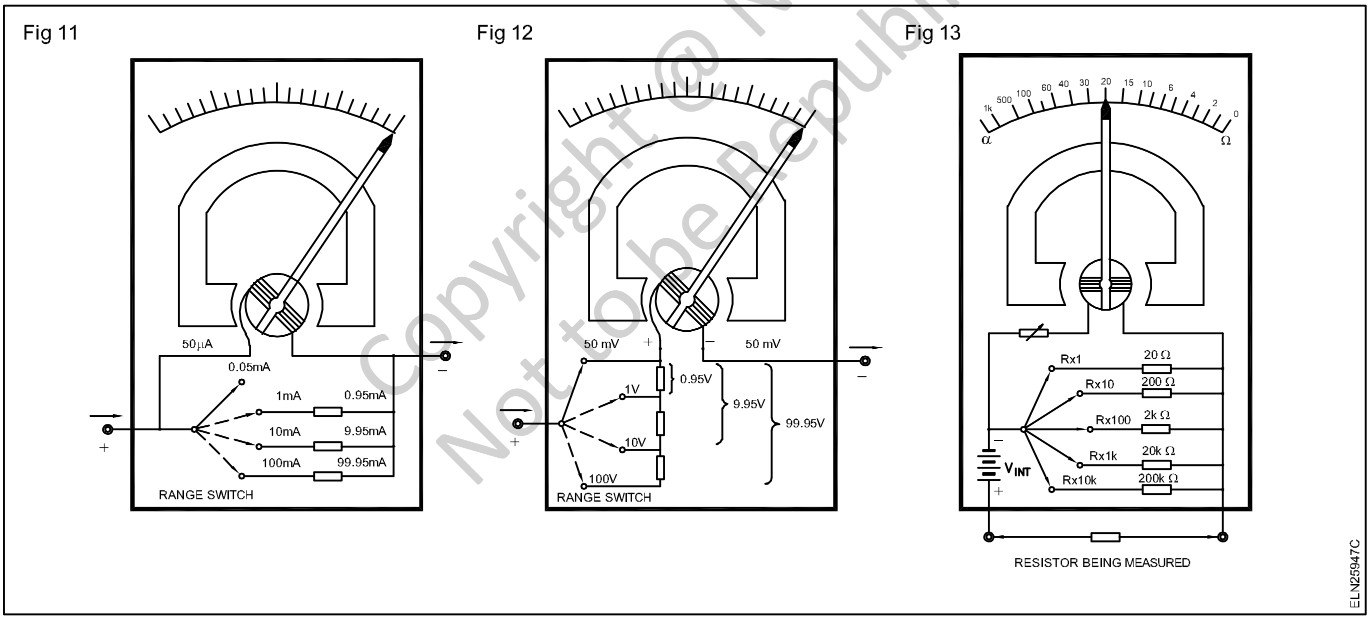
When the ohmmeter leads are open, the pointer is at full left scale, indicating infinite (¥) resistance (open circuit). When the leads are shorted, the pointer is at full right scale, indicating zero resistance.

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. These range settings are interpreted differently from those of the ammeter or voltmeter. The reading on the ohmmeter scale is multiplied by the factor indicated by the range setting.

Remember, an ohmmeter must not be connected to a circuit when the circuit’s power is on. Always turn the power off before connecting the ohmmeter.



Digital multimeters

Objectives: At the end of this lesson you shall be able to
- **distinguish between the analog and digital multimeter**
- **explain the method of measurement of voltage by using digital multimeter**
- **list and explain the types of digital multimeter**
- **state the application of digital multimeters**

Types of multimeters

Analogue types

- Selector switch type
- Multi-plug type

Digital types

- Selector switch type
- Auto-ranging type
- LCD display

Analogue type multimeters

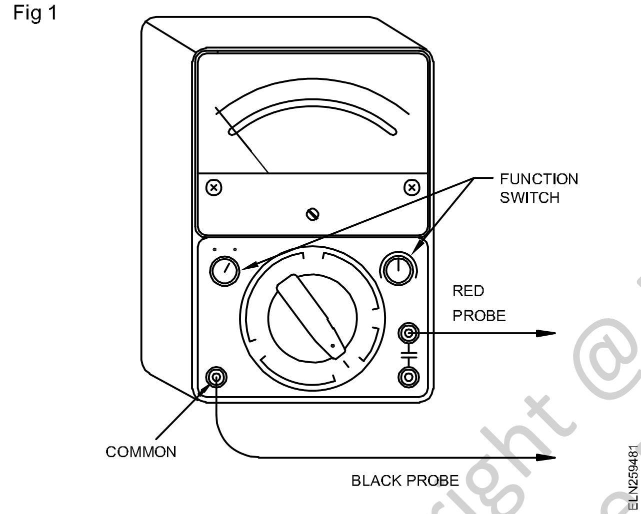
They have a meter movement mechanism, a calibrated scale and a pointer. Reading is obtained by looking at the position of the pointer on the scale.

The multimeter explained earlier is an analog type. (Fig 1)

In a digital multimeter the meter movement is replaced by a digital read out (Fig 2 and 3). This readout is similar to that used in electronic calculators. The internal circuitry of the digital multimeter is made up of digital, integrated circuits. Like the analog-type multimeter, the digital multimeter has a front panel switching arrangement.

The quantity measured is displayed in the form of a four digit number, with a properly placed decimal point. When DC quantities are measured, the polarity is identified by means of a + or sign displayed to the left of the number.

Fig 1



The quantity measured is displayed in the form of a four digit number with a properly placed decimal point. When DC quantities are measured the polarity is identified by '+ve' or '-ve' sign displayed to the left of the number indicating the probes are connected correctly by +ve sign and probes are reversely connected by -ve sign.

Fig 2

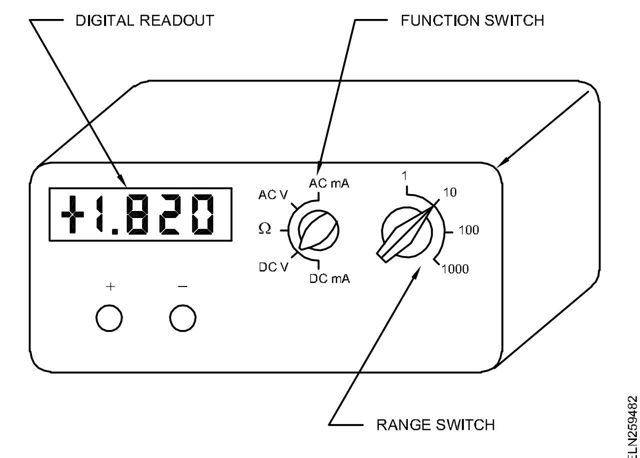
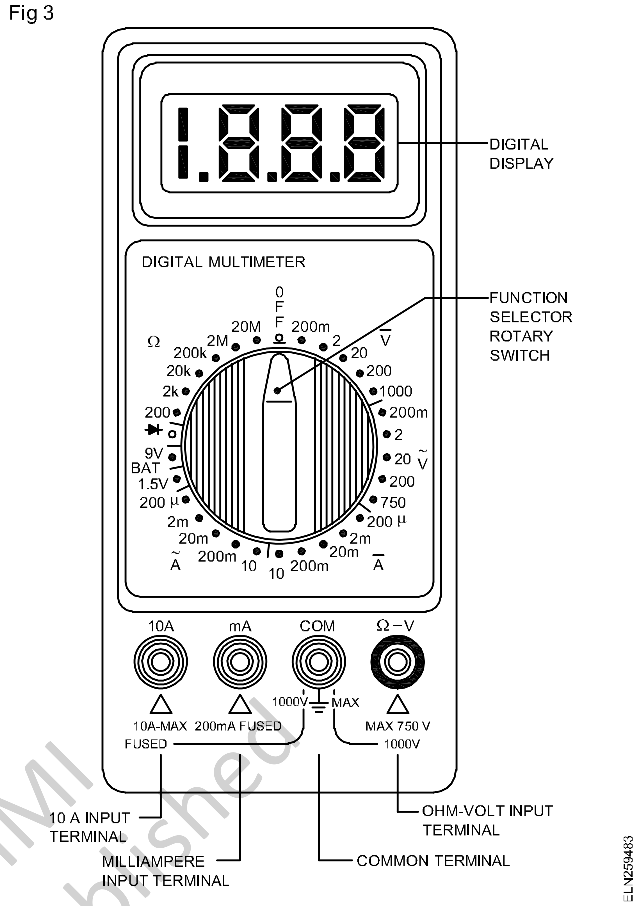


Fig 3



DMM functions: The basic functions found on most DMMs are the same as those on analouge multimeters. That is it can measure:-

- ohms
- DC voltage and current
- AC voltage and current

Some DMMs provide special functions such as transistor or diode test, power measurement, and decibel measurement for audio amplifier tests.

DMM displays: DMMs are available with either LCD (liquid -crystal display) or LED (light-emitting diode) read-outs. The LCD is the most commonly used read-out in battery-powered instruments due to the fact that it draws very small amount of current.

A typical battery-powered DMM with an LCD read-out operates on a 9V battery that will last from a few hundred hours to 2000 hours and more. The disadvantages of LCD read-outs are that (a) they are difficult or impossible to see in poor light conditions, and (b) they are relatively slow response to measurement changes.

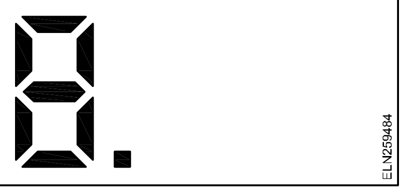
LEDs, on the other hand, can be seen in the dark, and respond quickly to changes in measured values. LED displays require much more current than LCDs, and, therefore, battery life is shortened when they are used in portable equipment.

Both LCD and LED-DMM displays are in a seven segment format (Fig 4).

Many meters have 3 1/2 digit in their display. For example a 3 1/2 digit multimeter has three digit positions that can indicate from 0 through 9 and one digit position that can indicate only a value of 1. This latter digit, called the half-digit, is always the most significant digit in the display.

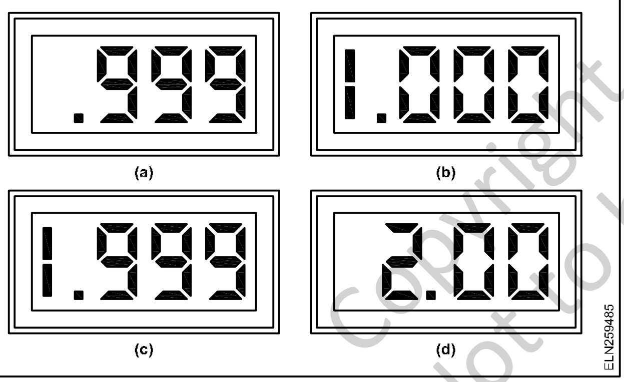
For example, suppose a DMM is reading 0.999 volt (Fig 5a), if the voltage increases by 0.001V to 1V, the display correctly 1.000V (Fig 5b). The 1 is the half-digit. Thus, with 3 1/2 digits, a variation of 0.001V, can be observed.

Fig 4



Now, suppose the voltage increases to 1.999V, this value is indicated on the meter (Fig 5c). If the voltage increases by 0.001V to 2V, the half-digit cannot display the '2', so the display shows 2.00. The half-digit is blanked and only three digits are active, as indicated in Fig 5d. DMMs with displays of 4 1/2 through 8 1/2 digits are also available.

Fig 5



Multimeter: Safety precautions: While using a multimeter safety is an important technical skill. When measuring electricity, you are dealing with an invisible and often a lethal force. Voltage levels above 30V can kill. The following safety precautions should always be taken.

- Never use the ohmmeter section on a live circuit.
- Never connect the ammeter section in parallel with a voltage source.
- Never overload the ammeter or voltmeter sections by attempting to measure currents or voltages far in excess of the range switch setting.
- Check the meter test leads for frayed or broken insulation before working with them. If damaged insulation is found the test leads should be replaced.
- Avoid touching the bare metal clips or tips of the test probes.
- Whenever possible, remove the supply before connecting the meter test leads into the circuit.
- When connecting the meter test leads to live circuits, work with one hand hanging at your side to lessen the danger of accidental shock.
- To lessen the danger of accidental shock, disconnect the red meter test leads first and then the common test lead (black) after the test is completed.

Applications of Digital multimeter: A multimeter is used for testing and fault finding in electrical/electronic circuits, electrical appliances and machines. A multimeter is a portable handy instrument used for

- checking continuity of circuit, appliances and devices.
- measuring/checking the supply presence at the source
- for testing components like capacitors, diodes, and transistors for checking their condition.
- measuring the current drawn by the circuit to infer its condition
- measuring resistance of the electrical appliances and devices for checking their condition.

Note: Some meters have provision also for temperature measurement with suitable sensing probes.

Comparison of Analog and Digital multimeters

Analog type	Digital Type
Instrument has moving parts. Care should be exercised in handling the meter.	There are no moving parts
Position of use is fixed and should not be altered.	Can be used in any position
Reading error due to parallax is possible.	No reading error as they have numerical display.
Actual value of indication is obtained by computation.	No need to compute as the value is directly indicated.
Manual zero setting for resistance measurement is required.	Zero setting is automatic for resistance measurement.
Auto range setting is not possible.	Auto-ranging instruments are available.
It can track short term variations and trends in measured quantity.	Not possible. The response is slow.
Indication of measured quantity by the movement of pointer over the graduated scale.	Digital numerical read out.
Loads the measuring circuit.	Practically no loading.

Calibration of analog multimeter

Objectives: At the end of this lesson you shall be able to
- **state briefly the function of analog and digital multimeter**
- **state the function of the parts of analog multimeter**
- **state the procedure to calibrate the analog multimeter.**

Analog multimeter

A multimeter is an instrument for measuring resistance (ohmmeter), voltage (voltmeter) and current (ammeter). All these meters (ohmmeter, voltmeter, and ammeter) are combined to a single meter called as multimeter as short for multiple meter. Others also call it VOM meter. Fig 1

Fig 1

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The primary types of multimeters are analog and digital multimeter. Digital multimeter converts the measured variables into a digital signal and displays numerical value on screen. while a analog multimeter, uses a needle which deflects to show the value it can be a bit difficult to use because of its multiple function and its scale is non-linear.

Multimeter parts

Multimeter Scale

- A scale with set of numerical values used to read the measured variables. The upper scale is for measuring resistance and the lower scale for measuring voltage and current

Pointer

- It indicates the value of electrical quantity being measured

Selector knob

- A selector switch that allows to choose functions to use.

Test probe

- The input part of the multimeter. Red probe for positive and black probe for common.

Zero ohm adjuster

- A part of the multimeter where it is adjusted when it's pointer will not point to zero.

Calibration

- Set the multimeter to its ohmmeter function it is located at lower right portion of selector knob.

Multipliers are used to increase or change the scaling of Ohm meter for better resolution

- Select the selector knob to multiplier.
- Shunt the test probes of the multimeter. the pointer must point to zero scale because there is nothing to measure.
- If it is not pointing to zero, calibrate it to set to zero. Locate the zero ohm adjuster and rotate the knob until it points to zero.
- Now, pointer is pointing at zero scale. It means it is ready to use.

For other multiplier like x10 (or) x100, repeat the procedure to calibrate again

Phase-sequence indicator (Meter)

Objectives: At the end of this lesson you shall be able to

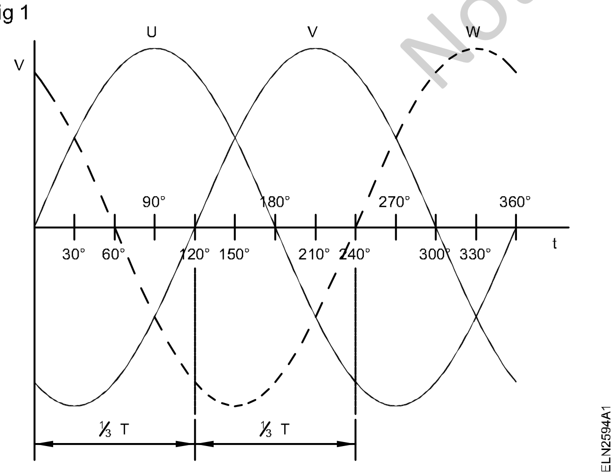
- **describe the method of finding the phase sequence of a 3-phase supply using a phase-sequence indicator**
- **state the method of using phase sequence indicator with choke & lamp and capacitor & lamp.**

Review

A three-phase alternator contains three sets of coils positioned 120° apart and its output is a three-phase voltage as shown in Fig 1. A three-phase voltage consists of three voltage waves, 120 electrical degrees apart.

At a time 0, phase U is passing through zero volts with positively increasing voltage. (Fig 1) V follows with its zero crossing $\frac{1}{3}$ of the period later and the same applies to W with respect to V. The order in which the three-phases attain their maximum or minimum values is called the phase sequence. In the illustration given here the phase sequence is U,V,W.

Fig 1



Importance of correct phase sequence: Correct phase sequence is important in the construction and connection of various three-phase systems. For example, correct phase sequence is important when the outputs of three-phase alternators must be paralleled into a common voltage system. The phase `U' of one alternator must be connected to phase `U' of another alternator. The phase `V' to phase `V' and phase `W' to phase `W' must be similarly connected to each other.

In the case of an induction motor, reversal of the sequence results in the reversal of the direction of motor rotation which will drive the machinery the wrong way.

Phase-sequence indicator(meter)**:** A phase-sequence indicator (meter) provides a means of ensuring the correct phase-sequence of a three-phase system. The phase-sequence indicator consists of 3 terminals `UVW' to which three-phases of the supply are connected. When the supply is fed to the indicator a disc in the indicator moves either in the clockwise direction or in the anticlockwise direction.

The direction of the disc movement is marked with an arrowhead on the indicator. Below the arrowhead the correct sequence is marked (Fig 2). The phase sequence of the three-phase system may be reversed by interchanging the connections of any two of the three phases.

Phase-sequence indicator using choke and lamps: The phase-sequence indicator consists of four lamps and an inductor connected in a star formation (Y). A test lead is connected to each leg of the `Y'. One lamp is labelled U-V-W, and the other is labelled U-W-V. When the three leads are connected to a three-phase line, the brighter lamp indicates the phase sequence (Fig 3).

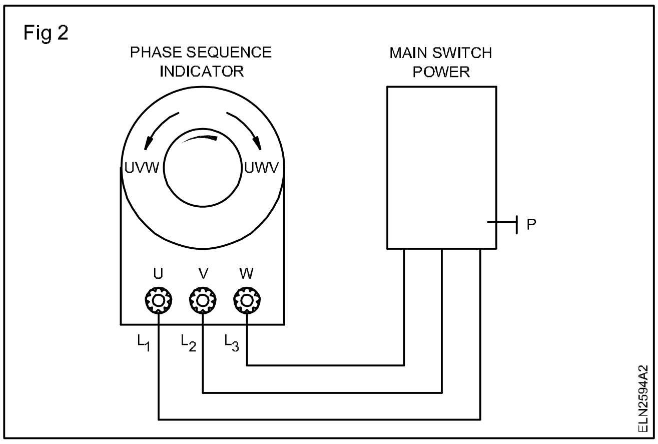


Fig 2

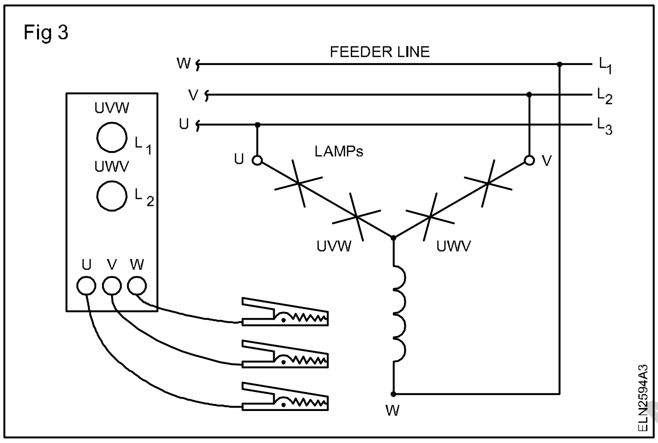


Fig 3

Phase-sequence indicator using capacitor & lamps: The phase-sequence indicator consists of four lamps and a capacitor connected in a star formation (Y). A test lead is connected to each leg of the `Y'. One pair of lamps are labelled U-V-W,and the other pair are labelled U-W-V. When the three leads are connected to a 3-phase line, the brighter lamp indicates the phase sequence. (Fig 4)

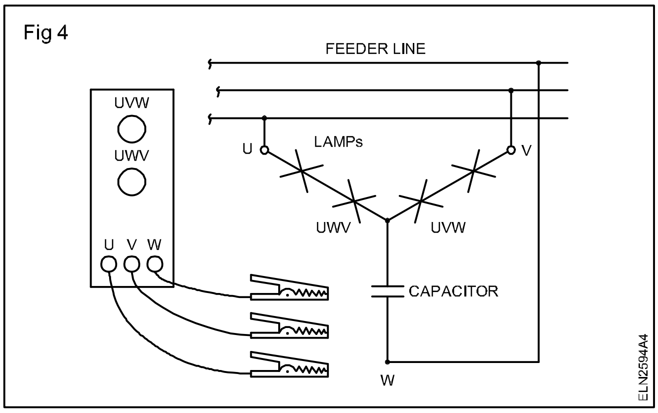


Fig 4

Frequency meter

Objectives: At the end of this lesson you shall be able to
- **state the types of frequency meters**
- **describe the principle, construction and working of a mechanical resonance (vibrating reed) type frequency meter**
- **describe the construction and working principle of an electrical resonance type frequency meter**
- **describe the construction and working principle of a ratiometer type frequency meter.**

The following types of frequency meters are used for measuring power frequencies.

- Mechanical resonance type
- Electrical resonance type
- Electro-dynamic type
- Electro-dynamometer type
- Weston type
- Ratiometer type
- Saturable core type

Apart from the above power frequency meters, there are other types of equipment, like electronic frequency counters, frequency bridges, stroboscope and oscilloscope which are used for measuring a wide range of frequencies.

The explanation given here is for three types of power frequency meters only as indicated below.

They are :

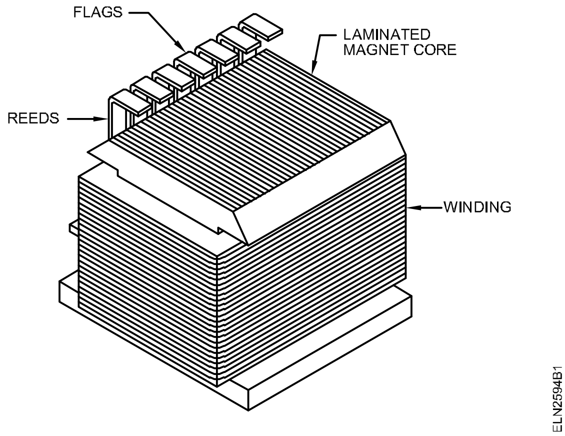
- mechanical resonance type
- electrical resonance type
- ratiometer type.

The trainees are advised to refer to books on electrical measuring instruments for learning about the other types of frequency meters.

Mechanical resonance type frequency meter (vibration reed type)

Principle: The vibration reed type frequency meter shown in Fig 1 works on the principle of natural frequency. Every object in the world has its natural frequency, depending upon its weight and dimensions. When an object is kept in a vibrating medium, it starts vibrating, if the frequency of the medium attains the natural frequency of the object.

Fig 1



If the vibrations are not controlled, the object may even get totally destroyed. A good example of this phenomenon is the shattering of window glass panes due to the vibration caused by low flying aircraft.

Construction: Mechanical resonance type frequency meters consist of an eletromagnet and a set of metallic reeds arranged in front of the electromagnet. The frequency meter is connected across the supply like a voltmeter, taking care about the voltage rating (Fig 2) .

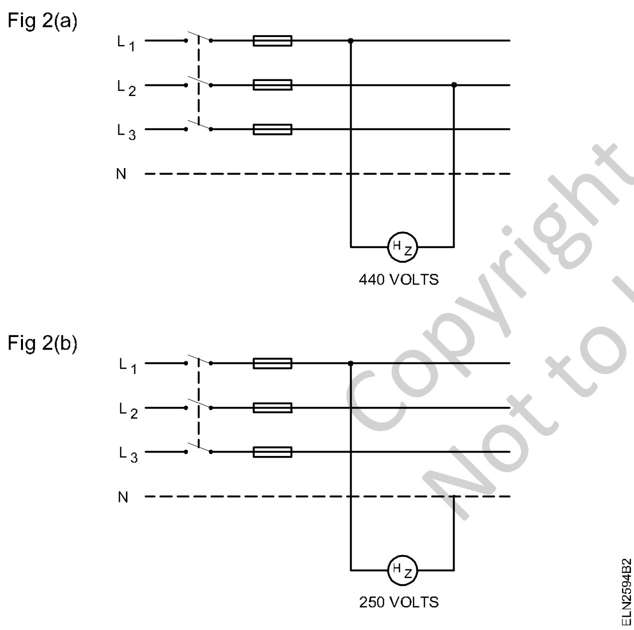
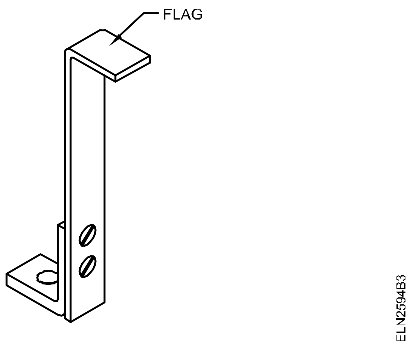


Fig 3 shows the shape of the reed and these reeds are of about 4mm wide and 0.5 mm thick. One end of the reed is fitted on a base, and the other overhanging end carries a white painted surface as the indicator and sometimes referred to as flag.

The reeds are arranged in a row and the natural frequency of the reeds differs by 1/2 cycle. This 1/2 cycle difference is possible between the reeds due to the difference in the weights of the reeds. The reeds are arranged in an ascending order (Fig 4a), and generally the natural frequency of the centre reed is the same as that of the supply frequency (50Hz).

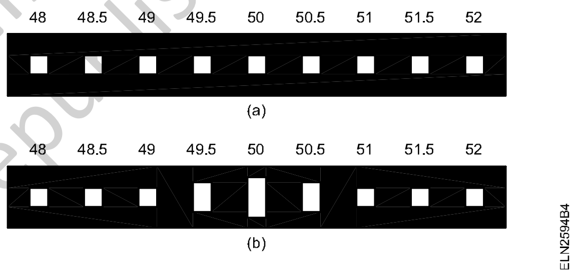
Fig 3



Working: When the frequency meter is connected to the supply, the electromagnet produces a magnetic field which alternates at the rate of the supply frequency. The reed, which has its natural frequency coincident with that of the alternating magnetic field, vibrates more than the adjacent reeds Fig 4(b).

The flag of this vibrating reed makes it possible to note the frequency of the supply from the scale marking of the frequency meter. Though the other reeds also vibrate, Fig 4(b), their magnitude will be much less than the reed whose natural frequency is exactly in coincidence with the supply frequency.

Fig 4



Advantages and disadvantages

The reed type frequency meter has the following advantages.

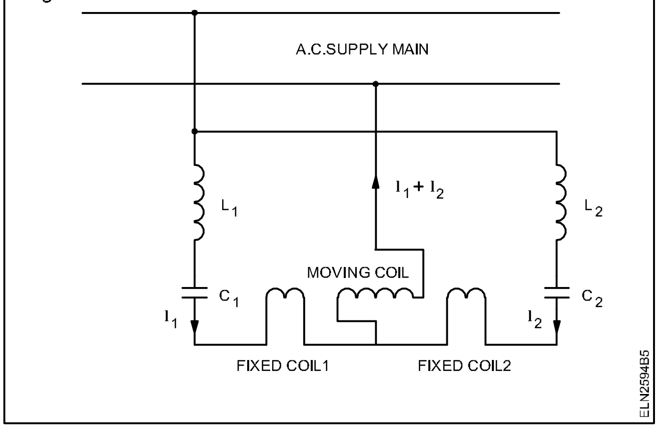
The indications are independent of i) the wave form of the applied voltage and ii) magnitude of the applied voltage, provided that the voltage is not too low. At a low voltage the flag indication of the reed will not be reliable.

The disadvantages are the meter cannot read closer than half the cycle frequency difference between adjacent reeds and the accuracy greatly depends upon the proper tuning of the reeds.

Electrical resonance frequency meter - Electro dynanometer type

Construction: This meter consists of two fixed coils and one moving coil, connected to the supply mains (Fig 5). The fixed coil (1) is connected to the mains through a resonant circuit consisting of an inductor L_1 and a capacitor C_1. Similarly the fixed coil (2) is connected to the resonant circuit consisting of the inductor L_2 and the capacitor C_2.

Fig 5



The resonant circuit of the fixed coil (1) is tuned for a frequency f_1 and say 45 Hz, which is lower than the tuned frequency f_2, say, 60Hz of the fixed coil 2. The moving coil carries the vector sum of current I_1 and I_2 of the two fixed coils.

Working: When the meter is connected to the supply, whose frequency is to be measured, the fixed coils carry out of phase currents, depending upon the magnitude of the frequency. For example, at 50Hz supply frequency, the current in the fixed coil (1) will be inductive (lagging current as its resonant frequency is lower than 50Hz) and the current in fixed coil (2) will be capacitive (leading current as its resonant frequency is higher than 50Hz).

At this instant, the inductive current in the fixed coil (1) and the capacitive current in the fixed coil (2) will have the same magnitude but will have opposite phases. Hence, they will cancel each other, and no current flows through the moving coil, resulting in no torque.

The pointer, therefore, will be at the centre position where 50Hz is marked on the dial. At frequencies lower than 50Hz, the movement of the pointer is influenced by the current in the fixed coil (1) and shows correspondingly by lower frequencies, and at frequencies higher than 50Hz, the pointer is influenced by the current in the fixed coil (2) and shows correspondingly higher frequencies.

This meter has a small iron vane mounted in the moving system for producing the controlling torque.

Advantages: The scale of the instrument spreads to about 90°and can be used for power frequency measurements.

DIsadvantages: The frequency range of the instrument is limited by the values of L and C.

Ratiometer type frequency meter

Construction: This meter has a frequency dial on which a pointer moves to indicate the frequency. It has two moving coils X and Y, fixed at right angles to each other, mounted on a spindle and kept between the strong field of a permanent magnet (Fig 6).

Fig 6

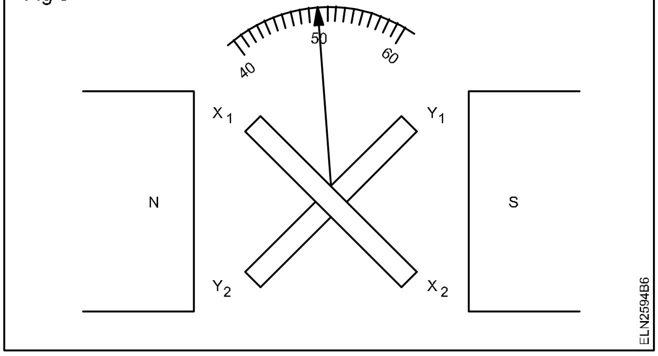
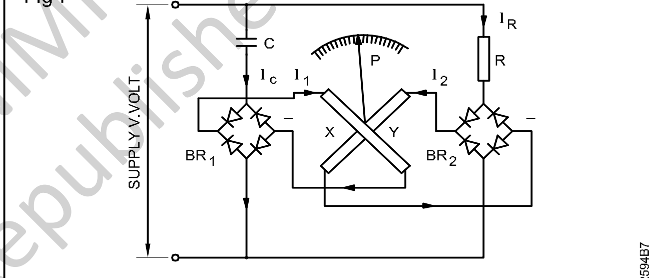


Figure 7 shows the circuit connections of the ratiometer type frequency meter.

The moving coils X and Y are connected to the supply through their respective rectifiers and passive components (Fig 7). The direct current I_1 flowing through 'X' represents the R.M.S. value of the capacitor current I_c as rectified by BR_1, in the same way, the current I_2 flowing through 'Y' represents the RMS value of the resistance current I_R as rectified by BR_2.

Fig 7



FREQUENCY METER - RATIO METER TYPE

Working: The current through the coil depends upon the supply frequency. At higher frequency, the current through the coil X is higher whereas the current through coil `Y' is independent of the frequency. The torque developed in the coil depends upon the interaction between the permanent magnetic field and the resultant field created by the coil currents.

The coils 'X' and 'Y' will exert almost equal torque at the predetermined supply frequency making the pointer to be at the centre of the scale where the supply frequency is marked. On the other hand, at higher frequencies the increased current in coil 'X' produces more torque and moves the pointer to a higher frequency position of the dial or vice versa.

Advantages:

This meter has the following advantages.

- It has a linear scale.
- The meter is independent of the supply voltage and, hence, is used for a fairly wide range of voltages.

Disadvantages

As the values of the capacitor 'C' and the resistor 'R' decide the range of frequency to be measured, this meter cannot be used for a wide range of frequencies, unless a set of C and R values are selected through a range switch.

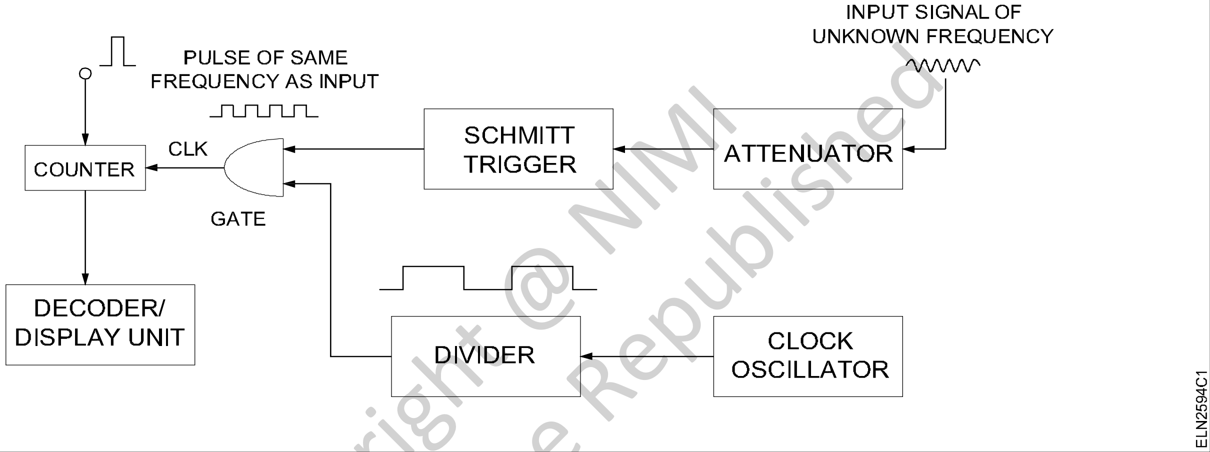
Digital Frequency Meter

Objectives: At the end of this lesson you shall be able to
- **state the function of digital frequency meter**
- **describe the block diagram of digital frequency meters.**

A frequency counter is a digital instrument that can measure and display the frequency of any periodic waveform. It operates on the principle of gating the unknown input signal into the counter for a predetermined time.

If the unknown input signal were gated into the counter for exactly 1 second, the number of counts allowed into the counter would be the frequency of the input signal. The term gated comes from the fact that an AND or an OR gate is employed for allowing the unknown input signal into the counter to be accumulated. Fig 1

Fig 1



Discription of block diagram:

The simplified form of block diagram of frequency counter is in Fig 1. It consists of a counter with its associated display/decoder circuitry, clock oscillator, a divider and an AND gate. The counter is usually made up of cascaded Binary Coded Decimal(BCD) counters and the display/ decoder unit converts the BCD outputs into a decimal display for easy monitoring.

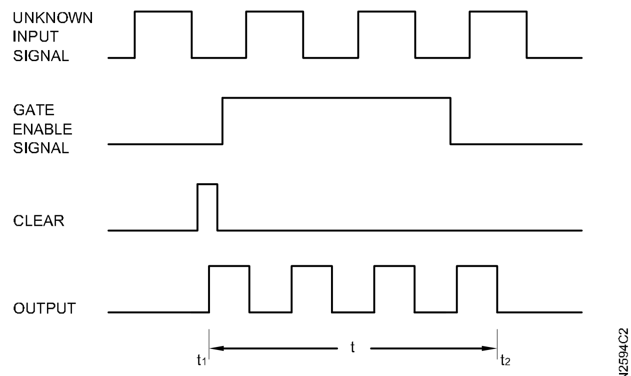
A GATE ENABLE signal of known time period is generated with a clock oscillator and a divider circuit and is applied to one leg of an AND gate.

The unknown signal is applied to the other leg of the AND gate and acts as the clock for the counter. The counter advances one count for each transition of the unknown signal, and at the end of the known time interval, the contents of the counter will be equal to the number of periods of the unknown input signal that have occurred during time interval, t.In other words, the counter contents will be proportional to the frequency of the unknown input signal.

For instance if the gate signal is of a time of exactly 1 second and the unknown input signal is a 600-Hz square wave, at the end of 1 second the counter will counts up to 600, which is exactly the frequency of the unknown input signal

The wave form in Fig 2 shows that a clear pulse is applied to the counter at t_0 to set the counter at zero. Prior to t_1, the GATE ENABLE signal is LOW, and so the output of the AND gate will be LOW and the counter will not be counting. The GATE ENABLE goes HIGH from t_1 t_0 t_2 and during this time interval $t=(t_2 - t_1)$ the unknown input signal pulses will pass through the AND gate and will be counted by the counter

Fig 2



DIFFERENT WAVEFORMS IN A FREQUENCY COUNTER

After t_2, the AND gate output will be again LOW and the counter will stop counting. Thus, the counter will have counted the number of pulses that occurred during the time interval, t of the GATE ENABLE SIGNAL, and the resulting contents of the counter are a direct measure of the frequency of the input signal

Power factor meter

Objectives: At the end of this lesson you shall be able to

- **state the disadvantage of the indirect method of measuring power factor**
- **state the different types of power factor meters**
- **explain the construction and connection of 3-phase dynamometer type power factor meter**
- **explain the construction, connection and operation of a 3-phase moving iron type power factor meter**
- **explain the construction, connection and operation of a single phase moving iron type power factor meter.**

Power factor of a single phase AC circuit can be calculated by the formula

$$P.F. = \frac{Power}{EI}$$

provided an ammeter, a voltmeter and a wattmeter are connected to the circuit.

On the other hand, for measuring power factor in a balanced 3-phase circuit we have to use the formula

$$P.F. = \frac{3\text{-phase power}}{3E_{PH}I_{PH}} \text{ or } \frac{3\text{-phase power}}{\sqrt{3}\,E_L I_L}$$

However when the, 3-phase circuit is unbalanced, the above formula cannot be used.

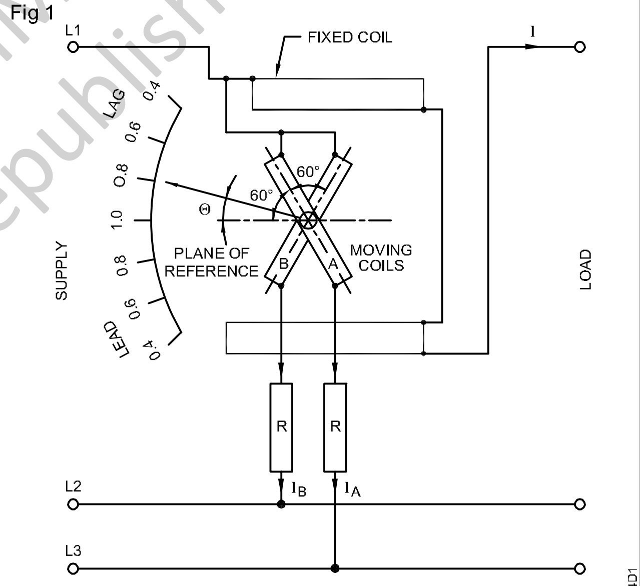
This indirect method has the following disadvantages.

- Low accuracy due to the number of meters
- Reading errors
- Cumbersome connections
- Involves calculation every time when the load changes and hence not suitable for changing load.

To get the instantaneous reading of the power factor, direct reading P.F. meters are used which are reasonably accurate.

3-phase dynamometer type power factor meter for balanced load: Fig 1 shows the construction and connections of a 3-phase power factor meter used for balanced loads.

Fig 1



DYNAMOMMETER TYPE THREE PHASE POWER FACTOR METER

In this meter, the field coils are connected in series with the load along with one phase. The two moving coils are rigidly attached to each other at an angle of 120°. These coils are connected to two different phases. A resistance is connected in series with each coil.

Phase splitting through reactance is not necessary since the required phase displacement between currents in the two moving coils can be obtained by the supply itself.

Operation of the meter is in the same way as in a single phase meter. However this meter is suitable only for balanced loads.

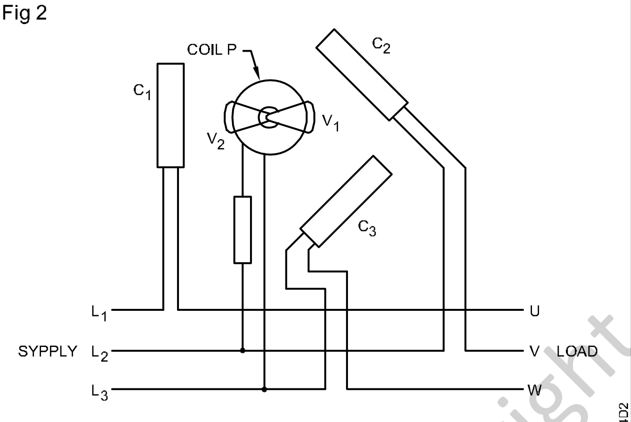
Since the currents in the two moving coils are both affected in the same way by any change in frequency or wave-form, this meter is independent of frequency and wave-form.

Moving iron power factor meters: This type of power factor meter is more popular than the dynamometer type due to the following advantages.

- Torque-weight ratio (working forces) is large compared to the dynamometer type meter.
- As all the coils are fixed there is no ligament connection necessary.
- The scale can be extended to 360°.
- This meter is simple and robust in construction.
- Comparatively cheaper in cost.

Fig 2 shows the construction and connection of a moving iron type power factor meter used for balanced loads.

Fig 2



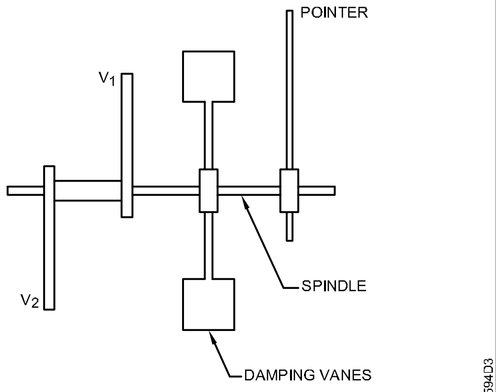
MOVING IRON TYPE POWER-FACTOR METER FOR A BALANCED 3-PHASE LOAD

There are three similar coils at C_1, C_2 and C_3 placed 120° degrees apart and connected to 3-phase supply directly (Fig 2) or through the secondary of the current transformers. Coil P is placed in the middle of the three coils C_1, C_2 and C_3 and connected in series with a resistance across two lines of the supply. Inside the coil B there are are two vanes V_1, and V_2 mounted at the ends of a freely moving spindle but kept at 180° to each other. The spindle also has damping vanes and the pointer (Fig 3).

The rotating magnetic field produced by the three coils C_1, C_2 and C_3 interacts with the flux produced by the coil P. This causes the moving system to take up an angular position depending upon the phase angle of the current.

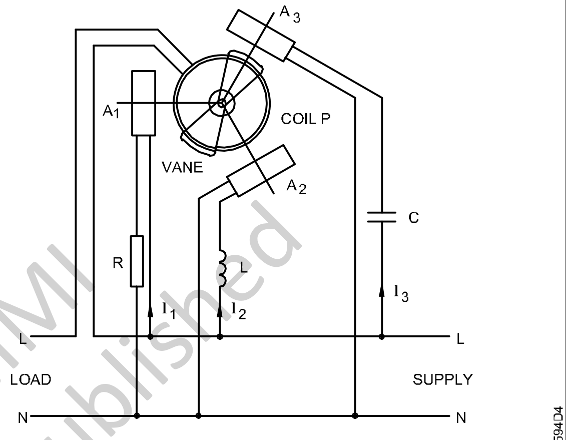
Single phase moving iron power factor meter: A single phase moving iron power factor meter (Fig 4) uses a phase splitting network comprising of a capacitor, an inductor and a resistor.

Fig 3



ARRANGEMENT OF THE SPINDLE

Fig 4



SINGLE PHAGE MOVING IRON TYPE POWER FACTOR METER

3-phase power factor meters for unbalanced load: For measurement of power factor in 3-phase unbalanced systems 2-element or 3-element power factor meters with each element with a current coil and pressure coil is used. The pressure coils are (moving coils) similar to that of single phase P.F. meters are mounted one below the other on a single spindle. The pointer shows the resultant power factor.

Low power factor meter: Power factor meters are generally available to read power factor from 0.5 lag-unity - 0.5 lead. Low power factor meters specially constructed to read power factor 0.0 lag to unity power factor are also used.

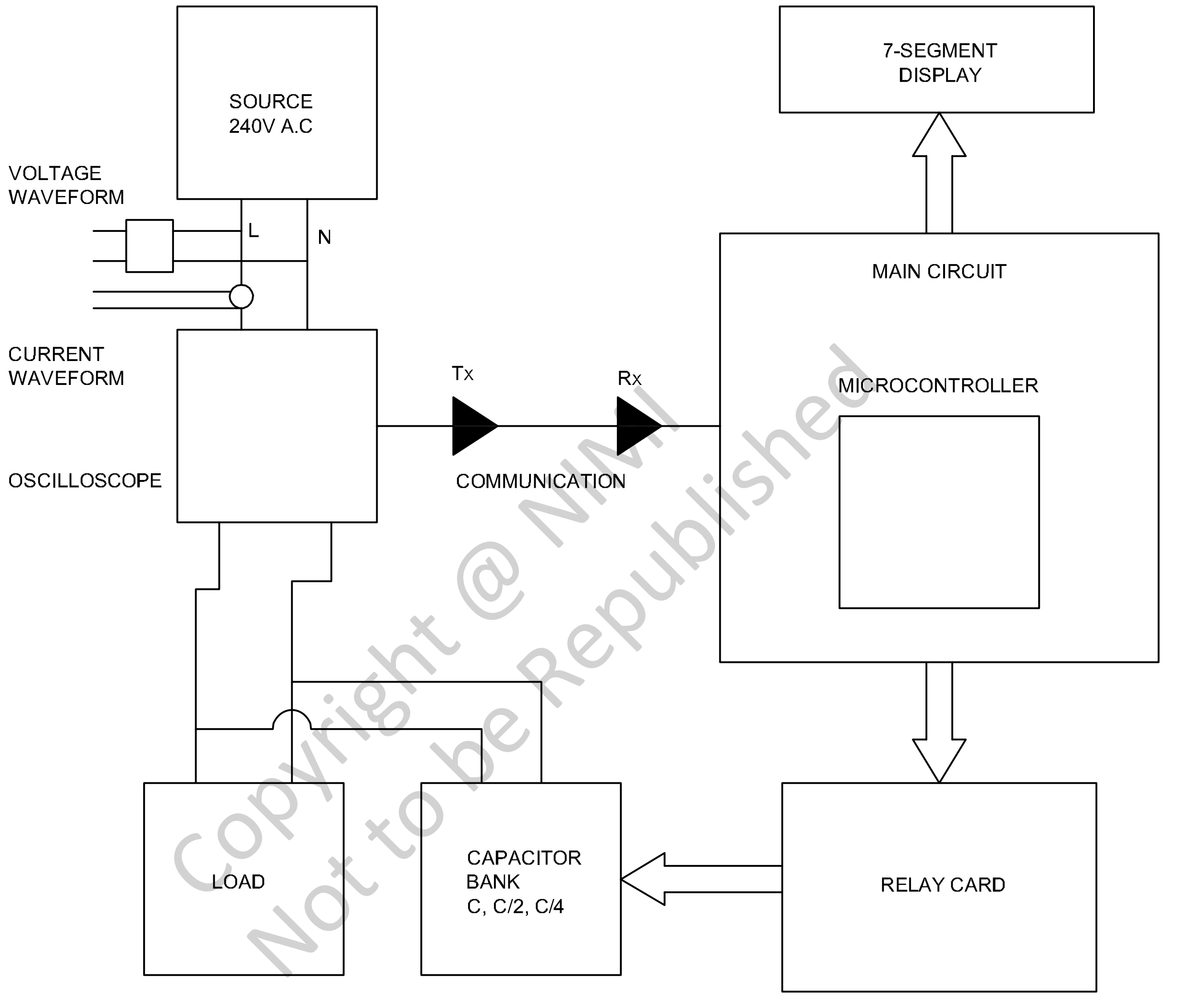
Digital Power Factor Meter

Objectives: At the end of this lesson you shall be able to
- **describe the block diagram of power factor**

Digital power factor meter:

The Fig 1 Shows the block diagram of digital power factor meter.

Fig 1



BLOCK DIAGRAM OF APFC

The power factor meter is used to calculate the present power factor of the system. The power factor is corrected using the true power technique. The power factor value so obtained is communicated to the microcontroller via the pins TX and RX.

The program fed to the microcontroller then analyses the power factor. The power factor gets displayed on the 7 segment display connected to the microcontroller. If the power factor is above the pre-set value, then no action in microcontroller and the relays will remain in their normal positions of NO and NC. Once the power factor lowers to a value below the pre-set mark, the signal is sent to relay card

The relay card consists of relays along with LED's for detecting the operation of relays. The input to relays is sent via an opto-coupler and then through a current amplifier before it reaches the relay. The particular relay operates and connects the respective capacitor bank to it. The operates and connects the respective capacitor bank to it. The operation of relay is detected by the LED thereby leading to emission of light from the LED

The microcontroller has been programmed in such a way that out of the three relays, it will make the relay or combination of relays in such a way that the capacitor banks are included which correct the power factor in the best possible way to the best possible value. The capacitor banks are preset as C, C/2 and C/4, which have been created using series combinations of capacitors of value C.

A long with these, a current transformer and a voltage transformer have been provided so as to analyse the particular wave forms at different instants of time with the help of an oscilloscope. The image of the digital PF meter is shown in Fig 2

Fig 2

ELN2594E2

Measurement of 3 phase power by single and two wattmeters

Objectives: At the end of this lesson you shall be able to
- **explain the measurement 3 phase power using single wattmeter**
- **explain the measurement of 3 phase power using two wattmeters**
- **calculate the power factor by two wattmeter method power measurement.**

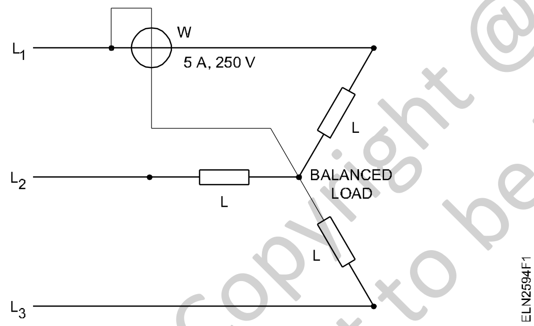
The measurement of power: The number of wattmeters used to obtain power in a three-phase system depends on whether the load is balanced or not, and whether the neutral point, if there is one, is accessible

- Measurement of power in a star-connected balanced load with neutral point is possible by a single wattmeter
- Measurement of power in a star or delta-connected, balanced or unbalanced load (with or without neutral) is possible with two wattmeter method

Single wattmeter method: Fig 1 shows the circuit diagram to measure the three-phase power of a star-connected, balanced load with the neutral point accessible the current coil of the wattmeter being connected to one line, and the voltage coil between that line and neutral point. The wattmeter reading gives the power per phase. So the total is three times the wattmeter reading.

$P = 3E_P I_P \cos\varphi = 3P = 3W$

Fig 1



The two wattmeter method of measuring power

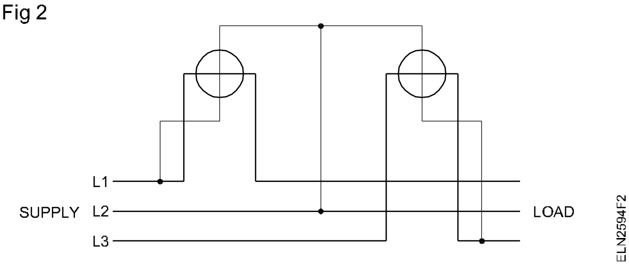
Power in a three-phase, three-wire system is normally measured by the `two-wattmeter' method. It may be used with balanced or unbalanced loads, and separate connections to the phases are not required. This method is not, however, used in four-wire systems because current may flow in the fourth wire, if the load is unbalanced and the assumption that $I_U + I_V + I_W = 0$ will not be valid.

The two wattmeters are connected to the supply system (Fig 2). The current coils of the two wattmeters are connected in two of the lines, and the voltage coils are connected from the same two lines to the third line. The total power is then obtained by adding the two readings:

$P_T = P_1 + P_2.$

Consider the total instantaneous power in the system $P_T = P_1 + P_2 + P_3$ where P_1, P_2 and P_3 are the instantaneous values of the power in each of the three phases.

Fig 2



$P_T = V_{UN}\, i_U + V_{VN}\, i_V + V_{WN}\, I_W$

Since there is no fourth wire, $i_U + i_V + i_W = 0$; $i_V = -(i_U + i_W)$.

$$P_T = V_{UN} i_U - V_{VN}(i_U + i_W) + V_{WN}\, i_W$$
$$= i_U(V_{UN} - V_{VN}) + i_W(V_{WN} - V_{UN})$$
$$= i_U V_{UV} + i_W V_{WV}$$

Now $i_U V_{UV}$ is the instantaneous power in the first wattmeter, and $i_W V_{WV}$ is the instantaneous power in the second wattmeter. Therefore, the total mean power is the sum of the mean powers read by the two wattmeters.

It is possible that with the wattmeters connected correctly, one of them will attempt to read a negative value because of the large phase angle between the voltage and current for that instrument. The current coil or voltage coil must then be reversed and the reading given a negative sign when combined with the other wattmeter readings to obtain the total power.

At unity power factor, the readings of two wattmeter will be equal. Total power = 2 x one wattmeter reading.

When the power factor = 0.5, one of the wattmeter's reading is zero and the other reads total power.

When the power factor is less than 0.5, one of the wattmeters will give negative indication. In order to read the wattmeter, reverse the pressure coil or current coil connection. The wattmeter will then give a positive reading but this must be taken as negative for calculating the total power.

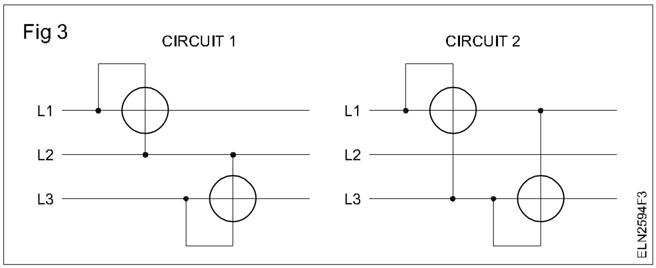
When the power factor is zero, the readings of the two wattmeters are equal but of opposite signs.

Self-evaluation test

1 Draw a general wiring diagram for the two-wattmeter method of three-phase power measurement.

2 Why is it desirable, in practice, to use the two-wattmeter method? (Fig 3)

Fig 3



3 Why can the two-wattmeter method not be used in a three-phase, four-wire system with random loading?

4 Which of the above circuits is used for the two-wattmeter method of power measurement?

Power factor calculation in the two -wattmeter of measuring power

As you have learnt in the previous lesson, the total power $P_T = P_1 + P_2$ in the two-wattmeter method of measuring power in a 3-phase, 3-wire system.

From the readings obtained from the two wattmeters, the tan ϕ can be calculated from the given formula

$$\tan\phi = \frac{\sqrt{3}(P_1 - P_2)}{(P_1 + P_2)} = \frac{\sqrt{3}(W_1 - W_2)}{(W_1 + W_2)}$$

from which ϕ and power factor of the load may be found.

Example 1: Two wattmeters connected to measure the power input to a balanced three-phase circuit indicate 4.5 KW and 3 KW respectively. Find the power factor of the circuit.

Solution

$$\tan\phi = \frac{\sqrt{3}(P_1 - P_2)}{(P_1 + P_2)}$$

$P_1 = 4.5$ KW

$P_2 = 3$ KW

$P_1 + P_2 = 4.5 + 3 = 7.5$ KW

$P_1 - P_2 = 4.5 - 3 = 1.5$ KW

$$\tan\phi = \frac{\sqrt{3} \times 1.5}{7.5} = \frac{\sqrt{3}}{5} = 0.3464$$

$\phi = \tan^{-1} 0.3464 = 19^0 6'$

Power factor Cos $19^0 6'$ = 0.95

Example 2: Two wattmeters connected to measure the power input to a balanced three-phase circuit indicate 4.5 KW and 3 KW respectively. The latter reading is obtained after reversing the connection of the voltage coil of that wattmeter. Find the power factor of the circuit.

Soultion

$$\tan\phi = \frac{\sqrt{3}(P_1 - P_2)}{(P_1 + P_2)}$$

$\phi = \tan^{-1} 8.66 = 83^o.27'$

since power factor (Cos $83^o 27'$) = 0.114.

Example 3: The reading on the two wattmeters connected to measure the power input to the three-phase, balanced load are 600W and 300W respectively.

Calculate the total power input and power factor of the load.

Solution

Total power = $P_T = P_1 + P_2$

$P_1 = 600$W.

$P_2 = 300$W.

$P_T =$ 600 + 300 = 900

$$\tan\phi = \frac{\sqrt{3}(P_1 - P_2)}{(P_1 + P_2)} = \frac{\sqrt{3}(600 - 300)}{600 + 300} = \frac{\sqrt{3} \times 300}{900}$$

$$= \frac{\sqrt{3}}{3} = \frac{1}{\sqrt{3}} = 0.5774$$

$\phi = \tan^{-1} 0.5774 = 30^o$

Power factor = Cos 30^o = 0.866.

Example 4: Two wattmeters connected to measure the power input to a balanced, three-phase load indicate 25KW and 5KW respectively.

Find the power factor of the circuit when (i) both readings are positive and (ii) the latter reading is obtained after reversing the connections of the pressure coil of the wattmeter.

Solution

a P_1 = 25 KW

P_2 = 5 KW

$$\tan\phi = \frac{\sqrt{3}(P_1 - P_2)}{(P_1 + P_2)} = \frac{\sqrt{3}(25 - 5)}{25+5}$$

$$= \frac{\sqrt{3}\times 20}{30} = \frac{\sqrt{3}\times 2}{3} = \frac{2}{\sqrt{3}} = 1.1547$$

ϕ = $\tan^{-1}$ 1.1547 = 49°6'

Power factor ($\cos\phi$) = Cos 49°6' = 0.6547

b P_1 = 25 KW

P_2 = –5 KW

$$\tan\phi = \frac{\sqrt{3}(P_1 - P_2)}{(P_1 + P_2)} = \frac{\sqrt{3}(25 - (-5))}{25+(-5)}$$

$$= \frac{\sqrt{3}\ (25+5)}{25-5} = \frac{\sqrt{3}\times 30}{20}$$

$$= \frac{\sqrt{3}\times 3}{2} = 2.5980$$

ϕ = $\tan^{-1}$ 2.5980= 68°57'

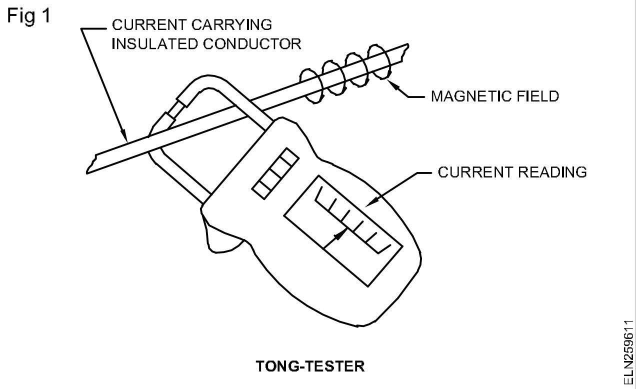
Power factor = Cos 68° 57' = 0.3592

Tong - tester (clamp - on ammeter)

Objectives: At the end of this lesson you shall be able to
- **state the necessity of tong-testers**
- **state the construction and working of a tong-tester**
- **state the precautions to be observed while using a tong-tester.**

A tong-tester is an instrument devised for the measurement of A.C current, without interrupting the circuit. It is also called clip-on ammeter, or sometimes a clamp-on ammeter (Fig 1).

Fig 1

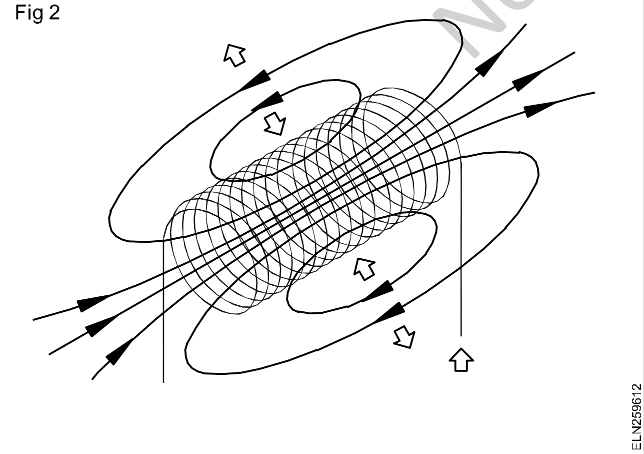


Working principle

The instrument can function only when current passes through its deflecting system. It works under the mutual induction principle.

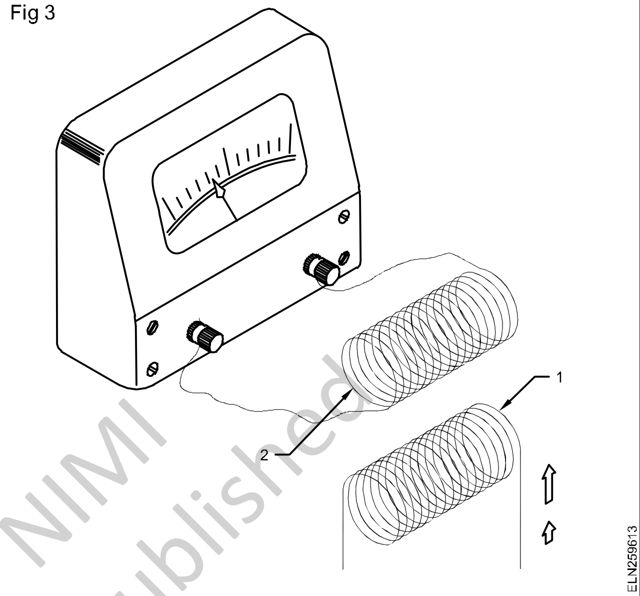
Electromagnetic induction: When a changing flux is linked with the coil, an emf is induced in the coil. The current in a coil so produced changes as that of the changing magnetic flux. If an alternating current is flowing through the coil, the magnetic flux produced is also alternative i.e. changing continuously.(Fig 2)

Fig 2



Placing another coil (2) in the changing flux of coil (1), an emf will be induced. (Fig 3)

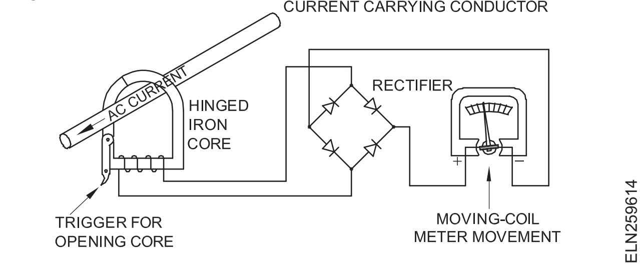
Fig 3



This induced emf will send the current, causing deflection of the meter. Introduction of a magnetic core between the coils increases the induced emf. The coil (1) is called primary and the coil (2) is called secondary.

Construction: Fig 4 shows a tong-tester (the clamp-on ammeter) circuit. The split-core meter consists of a secondary coil with the split-core and a rectifier type instrument connected to the secondary. The current to be measured in the conductor serves as the primary of one turn coil. It induces a current in the secondary winding and this current causes the meter to deflect.

Fig 4



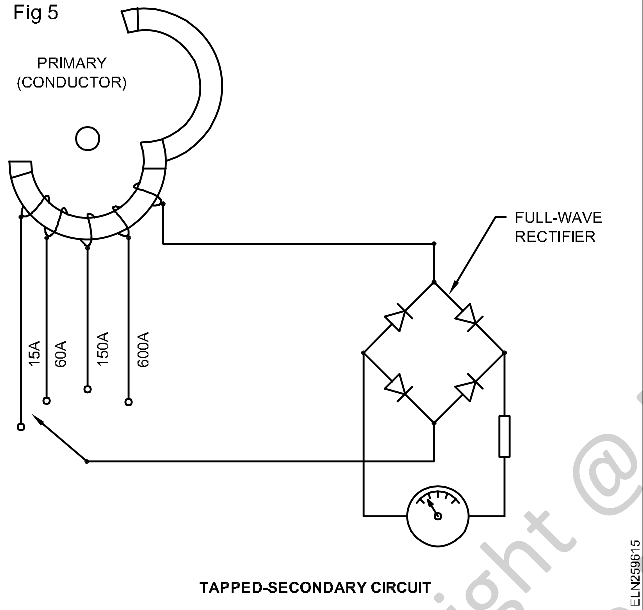
The core is so designed that there is only one break in the magnetic path. The hinge and the opening both fit tightly when the instrument closes around the conductor. The tight fit of the instrument ensures minimum variation in the response of the magnetic circuit.

To measure current with a clamp-on meter, open the jaws of the instrument and place them around the conductor in which you want to measure the current. Once the jaws are in place, allow them to close securely. Then, read the indicator position on the scale.

When the core is clamped around a current-carrying conductor, the alternating magnetic field induced in the core, produces a current in the secondary winding.

This current causes a deflection on the scale of the meter movement. The current range can be changed by means of a `range switch', which changes the taps on the transformer secondary (Fig 5).

Fig 5

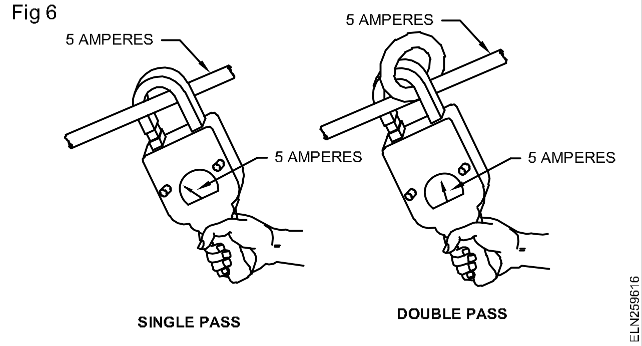


Safety: The secondary winding of the current transformer should always be either shunted or connected to the ammeter; otherwise, dangerous potential differences may occur across the open secondary.

Before taking any measurement, make sure the indication is at zero on the scale. If it is not, reset by the zero-adjustment screw. It is usually located near the bottom of the meter.

Looping the conductor more than once through the core is another means of changing the range. If the current is far below the meter's maximum range, we can loop the conductor through the core two or more times (Fig 6).

Fig 6



Application

1 For measuring the incoming current in the main panel board.

2 Primary current of AC welding generators.

3 Secondary current of AC welding generators.

4 Newly rewinded AC motor phase current and line current.

5 Starting current of all AC machines.

6 Load current of all AC machines and cables.

7 For measuring the unbalanced or balanced loads.

8 For finding the faults in AC, 3-phase induction motors.

Precaution

1 Set the ampere range from higher to low if the measuring value is not known.

2 The ampere-range switch should not be changed when the clamp is closed.

3 Before taking any measurement make sure the indication is at zero on the scale.

4 Do not clamp on a bare conductor for current measurement.

5 Seating of the core should be perfect.

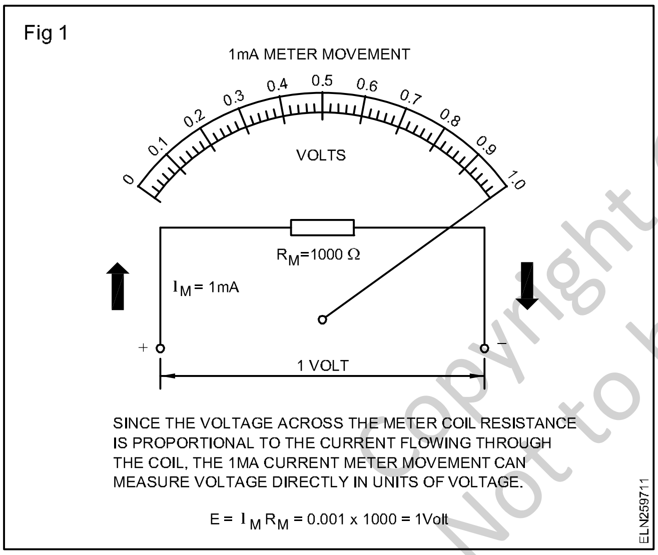
Extension of range of MC voltmeters - loading effect - voltage drop effect

Objectives: At the end of this lesson you shall be able to
- **state the function of the additional series resistance in a voltmeter**
- **calculate the value of the total resistance of the meter with respect to voltage and full scale deflection of current**
- **determine the resistance of a multiplier.**

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, in Fig 1 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:

Fig 1



$E = I_M R_M = 0.001 \times 1000 = 1$ 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, 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

$$R_{TOT} = E_{MAX}/I_M = 10 \text{ volts}/0.001 \text{ ampere}$$
$$= 10{,}000 \text{ ohms.}$$

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 2).

Multiplying factor (M.F)

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

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?

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

$$v = I_M \times R_M$$

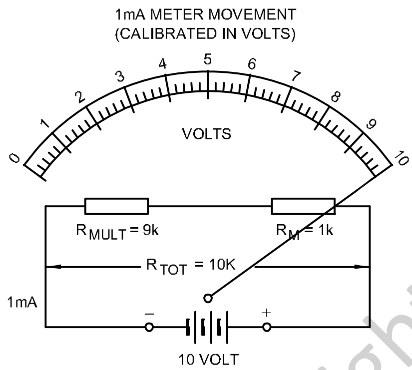
$$= 1 \times 10^{-3} \times 1000 = 1V$$

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

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

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

Fig 2

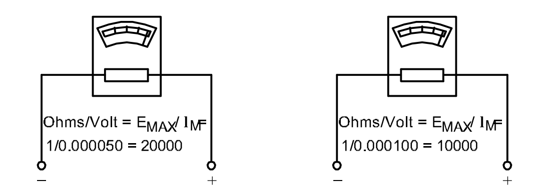


BY CONNECTING A MULTIPLIER RESISTOR IN SERIES WITH THE METER RESISTANCE, THE RANGE OF A BASIC METER MOVEMENT CAN BE EXTENDED TO MEASURE VOLTAGES HIGHER THAN THE $I_M R_M$ VOLTAGE DROP ACROSS THE METER COIL.

ELN259712

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 3) ohms/volt = E_{MAX}/I_M.

Fig 3



THE VOLTMETER ON THE LEFT IS MORE SENSITIVE THAN THE ONE ON THE RIGHT BECAUSE IT OFFERS MORE RESISTANCE TO OBTAIN A DEFLECTION OF 1 VOLT; OR, TO PUT IT ANOTHER WAY, IT REQUIRES LESS CURRENT FROM THE CIRCUIT IT IS MEASURING FOR FULL-SCALE DEFLECTION.

ELN259713

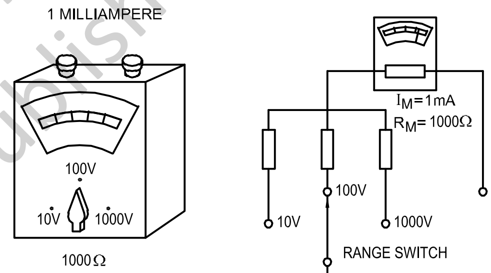
Multi-range voltmeters: In many types of equipment, one encounters voltages from a few tenths of a volt up to hundreds, and even thousands, of volts. To use single-range meters in these cases will be impractical, and costly. Instead, multi-range voltmeters that can measure several ranges of voltage, 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 (Fig 4). Also, in some cases, separate terminals for each range are mounted on the meter case (Fig 5).

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, Manganin and Constantan are used for multipliers.

Fig 4

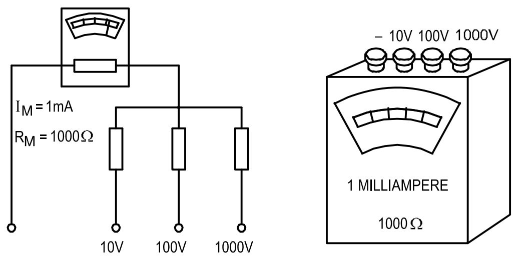
THE RANGE OF THIS 1mA, 1000 METER MOVEMENT, WHICH CAN MEASURE ONLY 0-1 VOLT, HAS BEEN EXTENDED TO MEASURE 0-10, 0-100, AND 0-1000 VOLTS BY USING MULTIPLIER RESISTORS FOR EACH RANGE.



A RANGE SWITCH PROVIDES THE SIMPLEST METHOD OF SETTING THE METER TO THE DESIRED RANGE.

ELN259714

Fig 5



SOME METERS HAVE SEPARATE TERMINALS FOR SETTING THE METER TO THE DESIRED RANGE.

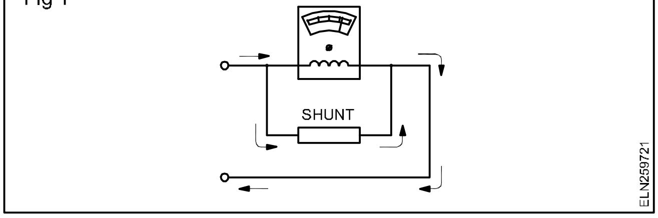
ELN259715

Extension of range of MC ammeters

Objectives: At the end of this lesson you shall be able to
- **define shunt used in ammeter**
- **calculate a shunt resistance to extend the range of an ammeter**
- **name the material used for shunt**
- **apply the use of terminals in standard shunts.**

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 (Fig 1).

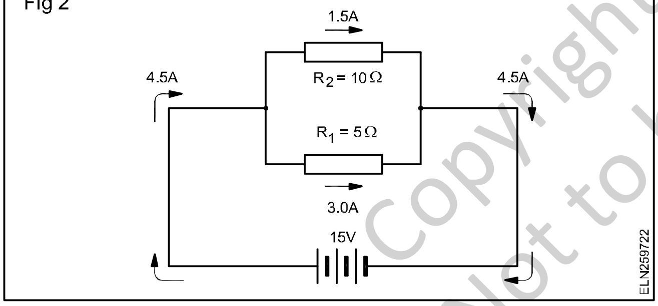
Fig 1



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

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. (Fig 2)

Fig 2



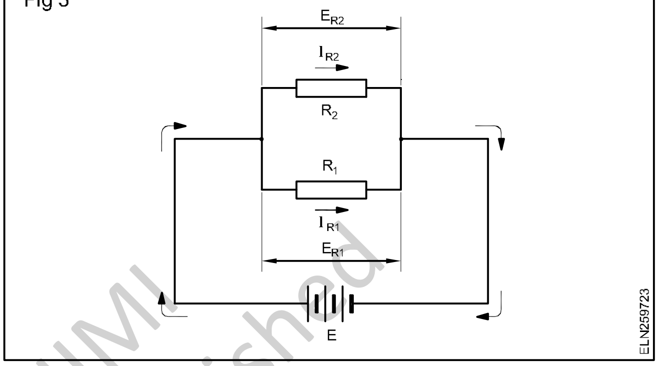
Current flow divides between two resistors parallel in a ratio inversly proportional to their resistance.

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.

Voltage drops in parallel circuits: Examine the parallel circuit shown in Fig 3. It can be seen that the voltage across both resistors is the same. As already explained Ohm's Law states that the voltage across a resistor equals the current through the resistor times the value of the resistor.

Fig 3



Since the same voltage appears across R_1 and R_2 then $E_{R1} = E_{R2}$. From this we derive $I_{R1}R_1 = I_{R2}R_2$. This equation can be used to calculate the shunt needed for a particular current measurement.

Therefore, the voltage across R_1 is $E_{R1} = I_1R_1$ and the voltage across R_2 is

$$E_{R2} = I_2R_2.$$

However, since the same voltage is across both R1 & R2 then

$$E_{R1} = E_{R2}, \text{ therefore,}$$

$$I_{R1}R_1 = I_{R2}R_2.$$

This simple equation, with very slight modifications, can be used to calculate the value of a shunt for a current meter for any application.

The shunt equation: A meter and shunt combination is identical to the parallel circuit shown in Fig 4. Instead of labelling the top resistor R_2, it can be labeled R_M, which represents the resistance of the moving coil. Resistor R_1 can be labelled R_{SH} to represent the resistance of the shunt. I_{R1} and I_{R2} then become I_{SH} and I_M to indicate the current flow through the shunt and through the meter. This means that the equation $I_{R1}R_1 = I_{R2}R_2$ can now be written as $I_{SH}R_{SH} = I_MR_M$.

Therefore, if three of these values are known, the fourth can be calculated. Since the shunt resistance R_{SH} is always the unknown quantity, the basic equation

$$I_{SH}R_{SH} = I_M R_M \text{ becomes } R_{SH} = \frac{I_M R_M}{I_{SH}}$$

From this equation, shunts can be calculated to extend the range of a current meter to any value,

where R_{SH} = shunt resistance

I_M = meter current

R_M = resistance of moving coil instrument

I_{SH} = current flow through shunt.

The value of current through the shunt(I_{SH}) is simply the difference between the total current you want to measure, and the actual full-scale deflection of the meter.

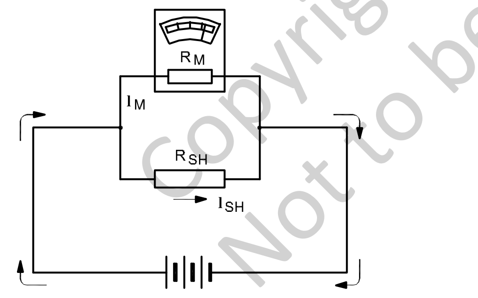
$I_{SH} = I - I_M$ where I = total current.

The meter and shunt act like R_1 and R_2 in parallel.

$$\text{So, } R_{SH} = \frac{I_M R_M}{I_{SH}}$$

Calculating shunt resistance: Assume that the range of a one milliampere meter movement is to be extended to 10 milliamperes, and the moving coil has a resistance of 27 ohms. Extending the range of the meter to 10 milliamperes means that 10 milliamperes will be flowing in the overall circuit when the pointer is deflected full scale. (Fig 5)

Fig 4



THE METER AND SHUNT ACT LIKE R_1 AND R_2 IN PARALLEL. SO, $R_{SH} = \frac{I_M R_M}{I_{SH}}$

ELN259724

I_M = 1 mA (0.001 A)

I = Current to be measured = 10mA

R_M = 27 Ohms

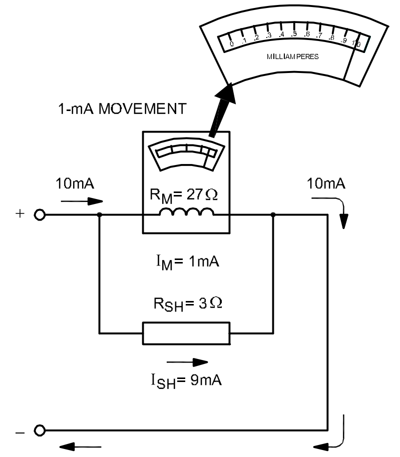
$I_{SH} = I - I_M$ = 10 mA – 1 mA

= 9 mA (0.009 A)

$$R_{SH} = \frac{I_M R_M}{I_{SH}} = \frac{0.001 \times 27}{0.009} = 3 \text{ ohms.}$$

Shunt material: The resistance of shunt should not vary due to the temperature. The shunt is usually made of Manganin which has negligible temperature coefficient of resistance. A high current shunt of a switch board instrument is shown in Fig 6.

Fig 5



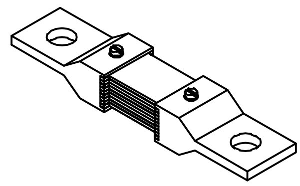
THE RANGE OF THIS 1-MILLIAMPERE METER MOVEMENT WAS EXTENDED TO 10 MILLIAMPERES BY USING THE SHUNT EQUATION $R_{SH} = \frac{I_M R_M}{I_{SH}}$

ELN259725

Multi-range ampere meters: In only some applications, it is practical to use an ampere meter having only one range; for example, only 0-1 ampere or 0-100 milliamperes, 0-10 ampere, and so on.

In many places, particularly when trouble shooting, it would be impractical to use a number of separate ampere meters to measure all of the currents encountered in a piece of equipment. In these cases, a multi-range ampere meter is used. (Fig 7)

Fig 6



HIGH CURRENT SHUNT FOR A SWITCHBOARD INSTRUMENT

ELN259726

A multi-range ampere meter is one containing a basic meter movement and several shunts that can be connected across the meter movement. A range switch is usually used to select the particular shunt for the desired current range. (Fig 7) Sometimes, however, separate terminals for each range are mounted on the meter case. (Fig 8).

Fig 7

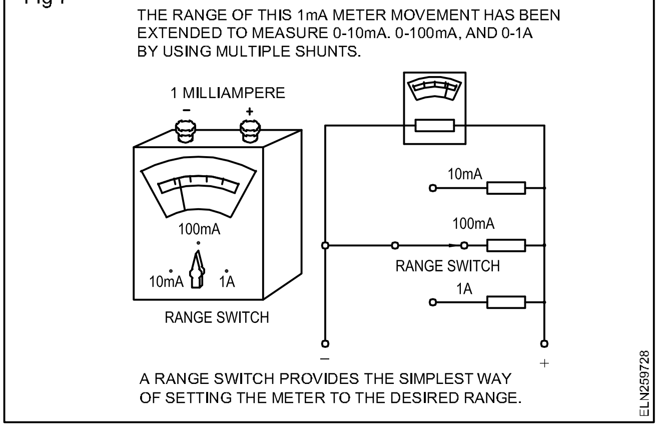
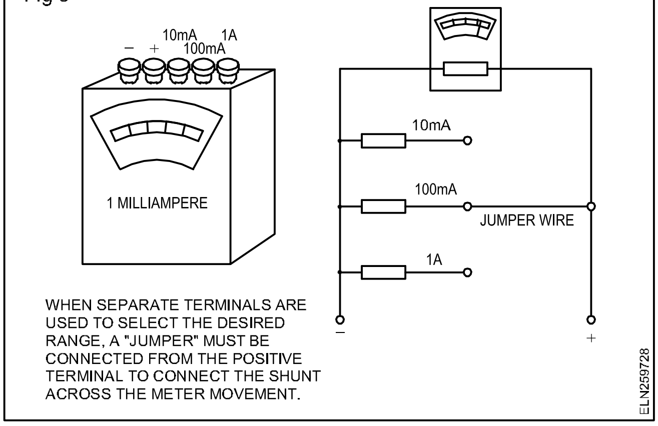


Fig 8



Calibration of MI Ammeter and Voltmeter

Objectives: At the end of this lesson you shall be able to
- **define the term 'calibration' and standards accuracy precision,resolution and sensitivity**
- **explain the calibration of voltmeter and ammeter**
- **state precaution to be observed during using ammeter and voltmeter.**

In many industrial operations, measurement instruments must be trusted to provide the accuracy stipulated by the original design to assure a satisfactory product. This confidence is provided by a periodic testing and adjustment of the instrument to verify the required performance. This type of maintenance is called calibration.

Standards

Before calibration can begin, you must have the accurately known values of the measured quantities against which to compare the measurements made by the instrument being calibrated. Thus, for an instrument that is supposed to measure current of 1 milli ampere, you must have, for comparison, a source of current that is known to within at least that range or better. Only then you can say whether the instrument performs satisfactorily.

A very accurately known quantity used for calibration of instruments is known as a standard.

Calibration standards	
Quantity	**Standard**
Voltage	Standard cell, high precision source
Current	Voltage standard and standard resistance standard milli volt source, gas filled/ mercury filled thermometers.
Pressure	Dead weight tester, Standard Hg monometer, sub standard pres sure gauges, pneumatic calibrator

Accuracy

Accuracy is defined as the ability of a device to respond to a true value of a measured variable under reference conditions. Accuracy is usually expressed as a percent uncertainty with reference to some part of measurement.

Precision

The term precision refers to the ability of the measuring instrument to agree with itself repeatedly.

Resolution

The resolution of a measurement system refers to the minimum detectable change in the measured variable.

Sensitivity

Sensitivity can be defined as the ratio of a change in output to the change in input causes it.

CALIBRATING DC AND AC METERS (AMMETER & VOLTMETER)

Both DC and AC meters are calibrated in essentially the same way. To calibrate a DC meter, a very accurate DC current source is connected to the meter. The output of the current source must be variable, and some means must be available to monitor the output current of the source. Many sources have built-in meter for this purpose.

The output of the current source is varied in very small steps, and at each step the scale of the meter being calibrated is marked to correspond to the reading on the monitoring device. This procedure is continued until the entire scale of the meter is calibrated.

Same procedure is used to calibrate an AC meter, except that a 50/60 cps sine wave is used mostly. Also, you know that an a-c meter reads the average value of a sine wave, but it is desirable for the meter to indicate rms values. Therefore the rms equivalent are calculated and marked on the scale.

Thermocouple meters are calibrated on the basis of a sine wave. But the calibration is made at the frequency at which the meter will be used. At the extremely high frequencies at which it is used, a phenomenon known as skin effect occurs.

At these frequencies, the current in a wire travels at the surface of the wire, the higher the frequency, the closer the current moves to the surface of the wire. This effect increases the resistance of the thermocouple heater wire because the diameter of the wire becomes, in effect, smaller.

Thus the resistance of the heater wire varies with frequency. Since the resistance of the heater wire varies with frequency, thermocouple meters must be calibrated at specific frequencies.

METER ACCURACY

METER	TYPICAL ACCURACY
Moving coil	0.1 to 2%
Moving iron	5%
Rectifier type moving coil	5%
Thermocouple	1 to 3%

Precautions to be observed when using an ammeter in measurement work

1 Never connect an ammeter across a source of EMF. Because of its low resistance it would draw damaging high currents and damage the delicate movement. Always connect an ammeter in series with a load capable of limiting the current.

2 Observe the correct polarity. Reverse polarity causes the meter to deflect against the mechanical stop and this may damage the pointer.

3 When using a multi range meter, first use the highest current range, then decrease the current range until substantial deflection is obtained. To increase the accuracy of the observation, use the range that will give a reading as near to full scale as possible.

The following general precautions should be observed when using a Voltmeter

1 Observe the correct polarity. Wrong polarity causes the meter to deflect against the mechanical stop and this may damage the pointer.

2 Place the voltmeter across the circuit or component whose voltage is to be measured.

3 When using a multi range voltmeter, always use the highest voltage range and then decrease the range until a good up scale reading is obtained.

4 Always be aware of the loading effect. The effect can be minimised by using the high voltage range (and highest sensitivity) as possible. The precision of measurement decreases if the indication is at the low end of the scale.

Loading effect of voltmeter and voltage drop effect of ammeter in circuits

Objectives: At the end of the lesson you shall be able to
- **define the term 'multiplier'**
- **analyse the effect of sensitivity/resistance across the terminals of a voltmeter,while measuring resistance by the voltage drop method (loading effect of the voltmeter)**
- **solve simple problems pertaining to the loading effect of voltmeter**
- **analyse the effect of voltage drop across the ammeter in the resistance measurement.**

Multipiler

In the case of P.M.M.C. instruments, we have seen that the moving coil consists of fine gauge copper wire. This copper wire can carry very low current in the order of milli or micro amperes only.

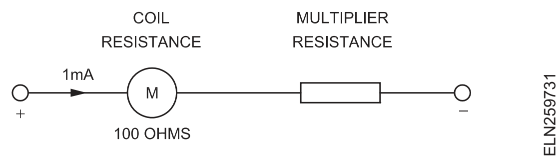
The acceptable current which enables the instrument to read full scale is called full scale deflection current or F.S.D. current. When such a P.M.M.C. instrument is to be converted as a voltmeter, the moving coil has to be connected with a high resistance in series so that the current could be restricted within the F.S.D. current value. This series resistance is called **multiplier** resistance.

Example: A P.M.M.C. instrument with an internal resistance (coil resistance) of 100 ohms has full scale deflection current of 1mA. This instrument has to be converted as a voltmeter to measure 10V.

Calculate the value of the multiplier resistance.

Referring to Fig 1, for 10V range, the safe current which could be allowed through the coil will be = 1mA.

Fig 1



As such the total resistance between the terminals of the 10V voltmeter should be

$$R_T = \frac{\text{Volts}}{\text{FSD current}} = \frac{10V}{\frac{1}{1000}} \text{ amps.}$$

$$= 10000 \text{ ohms.}$$

The value of the coil resistance = 100 ohms

The value of multiplier resistance

$$R_{Multiplier} = R_{Total} - R_{coil\ resistance}$$

$$= 10000 - 100 = 9900 \text{ ohms.}$$

From the above it is clear that the current through the P.M.M.C. instrument cannot be more than the FSD current, and, if the current in the meter exceeds the FSD current, the meter may burn out. The ratio between the set voltage range and the resistance of the voltmeter is called the sensitivity or ohms per volt rating of the voltmeter.

Therefore

$$\text{Sensitivity 'S'} = \frac{\text{Resistance between terminals of the voltmeter}}{\text{Range of voltmeter}}$$

In the above example we have sensitivity

$$= \frac{10000}{10} = 1000 \text{ ohms / volt.}$$

Note that the sensitivity S is essentially the reciprocal of the full scale deflection current of the basic meter movement.

$$S = \frac{1}{I_{FSD}} = \frac{1}{1mA} = \frac{1}{\frac{1}{1000}} \text{ ohms/volt}$$

$$= 1000 \text{ ohms/volt.}$$

Let us study how the voltmeter sensitivity causes loading effect in the circuit by the voltmeter.

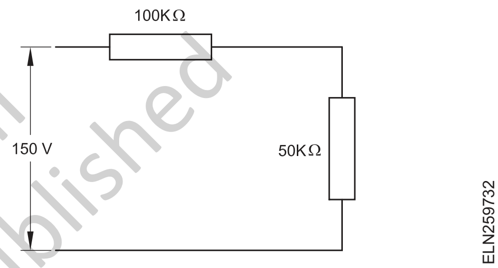
Loading effect of a voltmeter: The sensitivity of a voltmeter is an important factor when selecting a meter for a certain voltage measurement. A low sensitivity voltmeter may give an almost correct reading when measuring voltages in low-resistance circuits, but it is certain to produce very high errors in high resistance circuits. It is due to the fact that the voltmeter, when connected across a high resistance circuit, acts as a shunt for that portion of the circuit, and, thereby, reduces the equivalent resistance in that portion of the circuit.

As such, the meter will then give a lower indication of the voltage drop than what actually existed before the meter was connected. This effect is called the loading effect of a voltmeter and it is caused principally by the low sensitivity of the voltmeter.

The loading effect of a voltmeter could be explained through the following example.

Example: It is desired to measure the voltage across the 50-k ohm resistor in the circuit of Fig 2. Two voltmeters are available for this measurement, voltmeter 1 with a sensitivity of 1,000 ohms/V and voltmeter 2 with a sensitivity of 20,000 ohms/V. Both meters are used on their 50 V range.

Fig 2



Calculate (i) the reading of the meters (ii) the error in each reading, expressed as a percentage of the true value.

Solution

An inspection of the circuit indicates that the voltage across the 50-k ohm resistor

$$V_1 = \frac{50k \text{ ohm}}{150k \text{ ohm}} \times 150V = 50V$$

This is the true value of the voltage across the 50-k ohm resistor.

Voltmeter 1 (S=1,000 ohm/V)has a resistance of 50V x 1,000 ohm/V = 50-k ohm on its 50V range. Connecting the meter across the 50-k ohm resistor (Fig 3) causes the equivalent parallel resistance to be decreased to 25k Ohm, and the total circuit resistance to 125 kilo ohms (Fig 4).The potential difference across the combination of the meter and the 50-k ohms resistor is

$$V_1 = \frac{25k \text{ ohm}}{125k \text{ ohm}} \times 150V = 30V$$

Hence, the voltmeter indicates a voltage of 30V instead of the actual 50V.

Fig 3

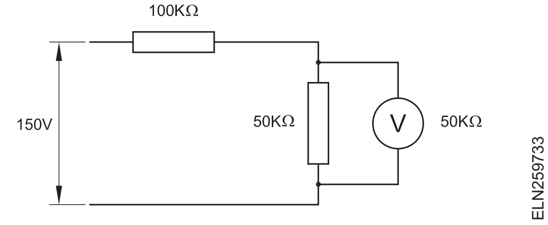
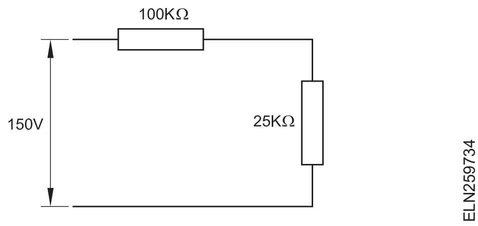
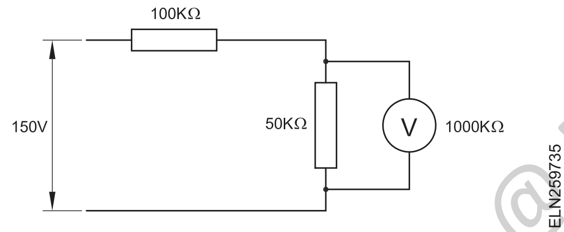


Fig 4



Voltmeter 2 (S=20k ohm/V) has a resistance of 50V x 20k ohm/V = one megohm on its 50V range. When this meter is connected (Fig 5) across the 50-k ohm. the equivalent parallel resistance equals 47.6k ohm.

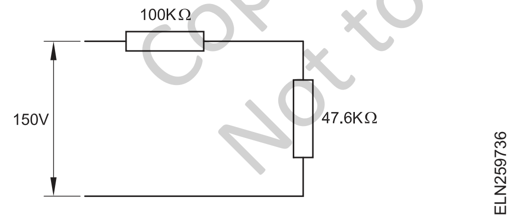
Fig 5



The total resistance of the circuit will be 147.6k ohm (Fig 6).

This combination produces a voltage of

Fig 6



$$V_2 = \frac{47.6\text{k ohm}}{147.6\text{k ohm}} \times 150\text{V} = 48.36\text{V}$$

which is indicated on the voltmeter instead of the actual 50V.

The error in the reading of voltmeter 1.64V

$$\%\text{error} = \frac{\text{true voltage - apparent voltage}}{\text{true voltage}} \times 100$$

$$= \frac{50\text{V} - 30\text{V}}{50\text{V}} \times 100 = 40\%$$

The error in the reading of voltmeter 2 is

$$= \frac{50\text{V} - 48.36\text{V}}{50\text{V}} \times 100 = 3.28\%.$$

The calculation of the error in the example indicates that the meter with the higher sensitivity of ohms/volt rating gives the most reliable result. It is important to realize the factor of sensitivity, particularly when voltage measurements are made in high-resistance circuits. Hence the following points are required to be followed while using a voltmeter.

- When using a multi-range voltmeter, always use the highest voltage range, and then decrease the range until a good up-scale (above mid-scale) reading is obtained.
- Always be aware of the loading effect. This effect can be minimised by using a voltmeter of high sensitivity and highest range in voltmeter.
- Before reading the meter, try to select a range in the multi-scale instrument such that the reading obtained is above mid-scale. The precision of the measurement decreases if the indication is at the low end of the scale.

Effect of voltage drop across the ammeter in resistance measurement: The ammeter/voltmeter method of measuring resistance is very popular since the instrument required for this is usually available in the laboratory.

In this method, two types of connections of meters are possible (Figs 7a and b).

Fig 7a

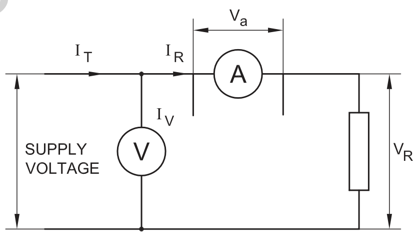
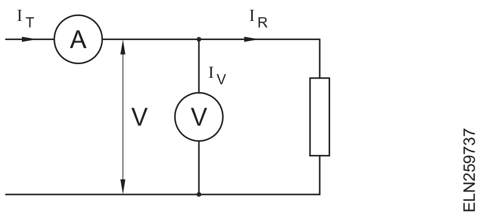


Fig 7b



In both the cases, if readings of the ammeter and voltmeter are taken, then the measured value of resistance is given by

$$R_m \frac{\text{Voltmeter reading}}{\text{Ammeter reading}} = \frac{V}{I}$$

The measured value of resistance R_m, would be equal to the true value R, provided the ammeter resistance is zero and the voltmeter resistance is infinite, to make the circuit condition undisturbed.

However, in practice this is not possible, and hence, both the methods give inaccurate results. But the error in measurement could be reduced under different values of resistance to be measured as explained below.

Circuit (Fig 7a): In this circuit, the ammeter measures the true value of the current through the resistor. But the voltmeter does not read the true voltage across the resistance. On the other hand, the voltmeter measures the voltage drop across the resistance and also the ammeter.

Let R_a be the resistance of the ammeter.

Then the voltage drop across the ammeter $V_a = IR_a$

$$R_{mt} = \frac{V}{I} = \frac{V_R + V_a}{I_R} = \frac{IR + IR_a}{I_R}$$

$$= R + R_a \text{ ....Eqn.(1)}$$

true value of resistance $R = R_{m1} - R_a$ ... Eqn.(2)

From equation 2, it is clear that the measured value of resistance is higher than the true value. It is also clear from the above equation, that the true value is equal to the measured value only if the ammeter resistance R_a is zero.

$$\text{Relavtive error } e_r = \frac{R_{m1} - R}{R}$$

$$e_r = \frac{R_{m1} - (R_{m1} - R_a)}{R}$$

$$= \frac{R_a}{R} \text{ ....Eqn.(3)}$$

Conclusion: From equation 3, it is clear that the error in measurement would be small if the value of resistance under measurement is large as compared to the internal resistance of the ammeter. Therefore, the circuit shown in Fig 7(a) is most suitable for measuring high resistance values only.

Circuit (Fig 7b): In this circuit the voltmeter measures the true value of the voltage across the resistance but the ammeter measures the sum of currents through the resistance and the voltmeter.

Let R_V be the resistance of the voltmeter. Then the current through the voltmeter

$$I_V = \frac{V}{R_V}$$

Measured value of the resistance

$$R_{m2} = \frac{V}{I} = \frac{V}{I_R + I_V}$$

$$R_{m2} = \frac{V}{\frac{V}{R} + \frac{V}{R_V}} \text{ .....Eqn.(4)}$$

By multiplying the denominator and numerator by $\frac{R}{V}$, Eqn.(4) becomes

$$R_{m2} = \frac{R}{1 + \frac{R}{R_V}} \text{ .....Eqn.(4)}$$

From equation 4, it is clear that the true value of resistance is equal to the measured value only if

- the resistance of the voltmeter R_V is infinite
- the resistance to be measured 'R' is very small when compared to the resistance of the voltmeter.

$$\text{Relative error } e_r = \frac{R_{m2} - R}{R}$$

By elimination process, we get

$$e_r = \frac{R_{m2} - R}{R} \text{ ...Eqn.(5)}$$

The value of R_{m2} is approximately equal to R.

$$\text{Therefore } e_r = \frac{-R}{R_V} \text{ .....Eqn.(6)}$$

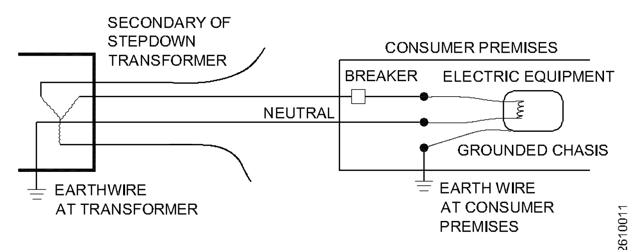
Conclusion: From equation (6), it is clear that the error in measurement would be small if the value of resistance under measurement is very small as compared to the resistance of the voltmeter. Hence the circuit shown in Fig 7(b) should be used when measuring resistances of a lower value.

Concept of Neutral and Earth - Cooking range

Objectives: At the end of this lesson you shall be able to
- **state the concept of neutral and earth**
- **define the domestic appliance**
- **define the cooking range**
- **explain the parts of electric range**
- **list out the problems, possible causes and remedies.**

Concept of neutral and earth (Fig 1)

Fig 1



CONCEPT OF NEUTRAL AND EARTH

Earth point is the point connected to the ground, i.e. earthed locally at the consumer premises while Neutral point is the star point of the secondary stepdown transformer feeding the consumer premises.

The role of Neutral point (Nuetral wire) is to close the circuit and carry the consumer load current (return current) back to the transformer. The earth point (earth wire at consumer premises) shall carry no current in normal situations.

The earth point (earth wire) is used to connect the metallic chassis of consumer equipment with the earth and isolate them from the live wires. Hence, the earth wire is used to ensure safety of equipment and personnel.

The earth wire will carry (short) currents in case of chassis of the equipment becomes electrified, i.e. a bare live conductor touches the metallic chassis. This short current will trip some circuit breaker in the way immediately.

The earth wire will carry (Leakage) small currents due to insulation deterioration, humidity and carbon deposit on the insulator. In this case a special breaker called ELCB (Earth Leakage Circuit Breaker) or RCCB (Residual Current Circuit Breaker) that is calibrated to trip at small currents (of the order of 6-30 mA for residual purposes and 300 mA for industrial purposes). Not all electric codes enforces the uses of ELCBs or RCCBs.

Domestic appliances:

Domestic appliance is an electrical equipment/machine used in houses for the various house hold tasks like cooking, washing and cleaning etc.

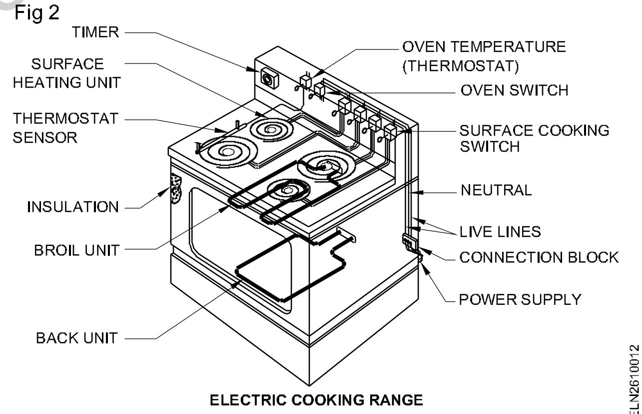
> **Standard safety norms: Trainees may be instructed to refer the international Electrotechnical commission (IECF 60335 -part 2 - section 64) for the standard safety norms related with domestic appliances for the further details.**

Cooking range

Electric cooking range is the combination of an oven and hot plate. The electric range consist of highly efficient heating elements, it gives better cooking control, has shelf oven, fingertip controls and designs to fit almost every possible kitchen need.

The surface heating units are set in the top of the range, the electric connections for these units are carried in the space between the top of the range (Fig 2). Oven controls are also kept in the top but in separate elevated pedestal.

Fig 2



ELECTRIC COOKING RANGE

The parts of a cooking range

Surface heating elements: In present day cooking range the nichrome element is encased in a metal tube with magnesium oxide insulation. This enclosed surface heating element (Fig 2) more efficient, more durable and safe to handle.

Step/Selector switches: A step switch is simply a rotary switch, which can select four or six different heats (wattages) Fig 3 and 4.

The step switch connected to two or three elements to 240 volts. The total circuit resistance or the voltage is changed to provide different heats.

High heat is obtained by connecting total elements in parallel. For low heat all the coils are connected in series (Figs 3 & 4).

Oven unit: The oven unit consists of two heating elements, an upper element and a lower element.

Fig 3

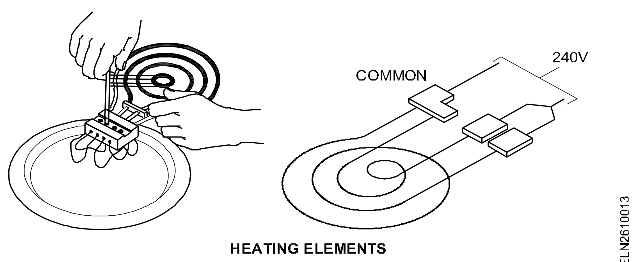
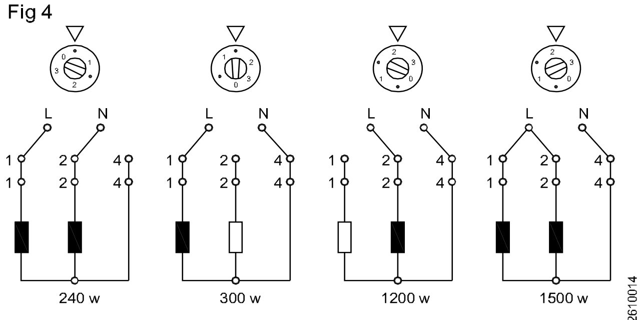


Fig 4



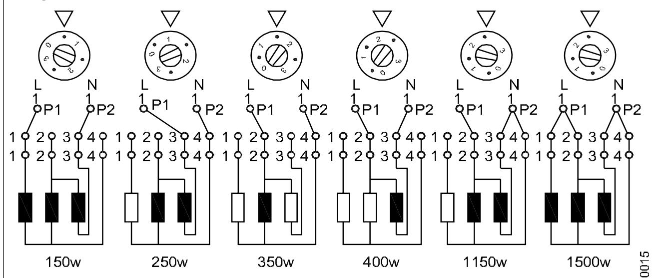
STEP/SELECTOR SWITCH-4 POSITION

The oven heat is normally controlled by thermostat and timing device.

In a oven electric circuit, the broil unit is constructed by stringing the element through the frame in two separate coils, whereas the bake unit is strung with only one coil.

Now-a-days instead of thermostat switch, the typical infinite-heat switches are used (Fig 5). This switch operates the internal heater causes the bimetal to open and close the switch that controls the range heater element. This bimetal heater is series the cooking range and must have the correct resistance for the element being controlled.

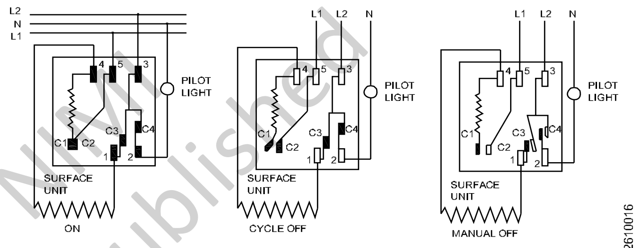
Fig 5



STEP/SELECTOR SWITCH-6 POSITION

A schematic diagram of a typical electric range is given in Fig 6.

Fig 6

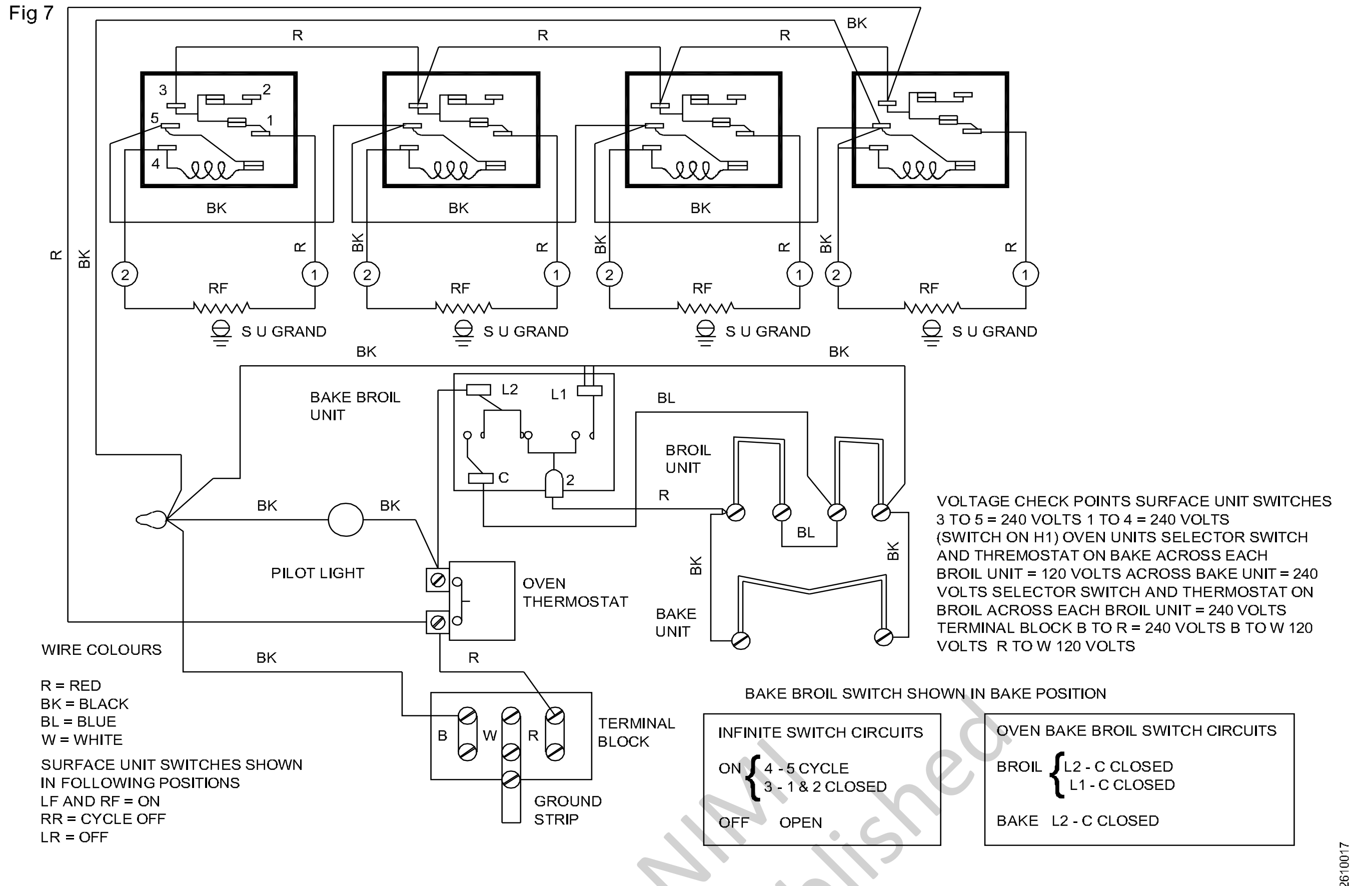


TYPICAL INFINITE-HEAT SWITCHES

Troubleshooting Chart for Electric Ranges

Problem	Possible cause	Corrective Action
Oven will not heat.	Selector switch is OFF. Blown fuse. Inoperative oven control. Open circuit in oven element Loose connection. Timer inoperative.	Set selector switch. Check fuses. Check controls. Check circuit continuity. Tighten all connections. Check timer setting.
Oven too hot or cold.	Thermostat calibration. Improper oven door fit.	Check "Thermostat adjustment". Check "Door seal and fit".
Oven will not turn off.	Inoperative selector switch. Inoperative timer.	Check selector switch. Check timer setting.
Oven interior light does not light.	Loose or inoperative bulb. Inoperative light switch. Loose connections.	Tighten or replace bulb. Light switch replacement. Tighten all connections
Oven door opens under heat.	Door needs adjustment. Loose or worn pin.	Check "door seal and fit". Replace bracket.
Oven door drops down.	Worn hinge bracket.	Replace bracket.

Fig 7



SCHEMATIC DIAGRAM OF A TYPICAL ELECTRIC RANGE

Problem	Possible cause	Corrective Action
Timer does not operate properly.	Incorrect setting Loose connection Inoperative motor Inoperative mechanism	Refer to owner's manual. See "Timer operation." Tighten all connections Replace motor Replace timer.
Timer will not control often.	Incorrect connection Inoperative timer Selector switch not correctly set.	Check wiring diagram. Replace timer. Set selector switch.
Oven drips water or sweats.	Oven not preheated with door open Oven temperature excessive Door does not seal at the top Clogged oven vent.	Check oven operation. Check thermostat calibration Adjust oven door. Clean vent
Surface unit does not heat.	Blown main fuse. Loose connection. Inoperative switch. Open unit. Incorrect connection. Broken wire.	Check fuse Tighten Replace switch. Check wiring diagram. Check wiring diagram. Continuity check.

Geyser

Objectives: At the end of this lesson you shall be able to
- **define the geyser**
- **list the parts of a geyser from the schematic and constructional diagrams**
- **explain the construction and operation of a geyser**
- **list the care and maintenance practices specific to the geyser**
- **explain the possible faults in a geyser and their remedies.**

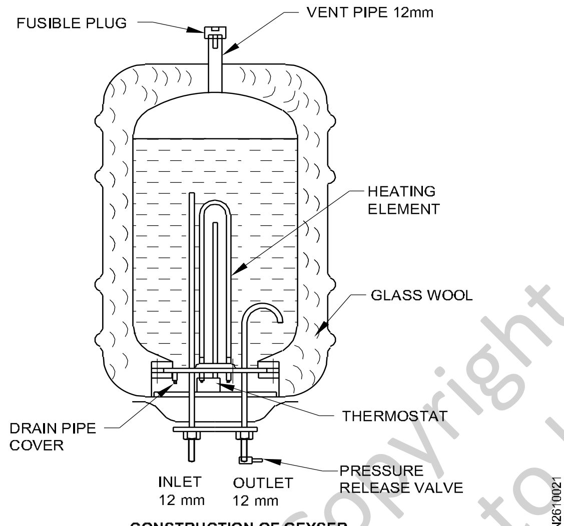
Geyser

It is an electric water heater which heats and maintains the temperature of the water stored in it.

There are several types of water heaters. The most usual one is the geyser, which is more efficient as the hot water can be directly drawn through a tap at different points.

Construction of geysers: The construction of a hot water geyser or storage water heater is simple (Fig 1).

Fig 1



CONSTRUCTION OF GEYSER

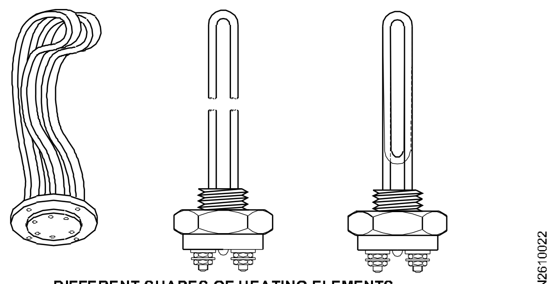
The outer casing is made of mild steel sheet. The inner tank is made of heavy gauge copper which is tinned to prevent corrosion. The space between the outer casing and the inner tank is filled with glass wool as heat insulation to avoid excess heat losses. Heating elements, thermostat, inlet and outlet pipes are fitted to the tank.

Heating elements are similar to those of immersion heaters but with different shapes to suit the tank sizes and the screw base. Fig 2 shows a few shapes of heating elements.

The rating of the heating elements depends on the capacity of the geyser. For up to 25 litres capacity, 1 KW elements are used while for 50 litres capacity 2 KW are used, for 100 litres capacity 3 KW are used.

Thermostats: Thermostats are used in water heaters to control the current to the heating elements and thereby regulate and maintain the water temperature between 32°C to 88°C.

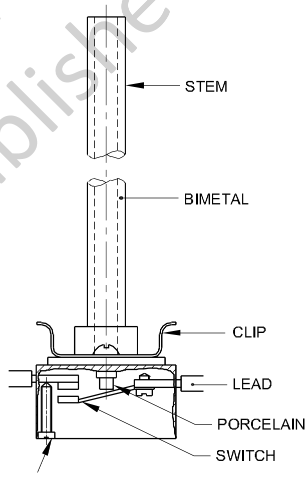
Fig 2



DIFFERENT SHAPES OF HEATING ELEMENTS

A typical thermostat used in geysers: A thermostat used in a geyser is of tube and rod bimetal type (Fig 3).

Fig 3



A TYPICAL TERMOSTAT USED IN WATER HEATER

Thermostats are available in sizes of 8 mm diameter with a length of 175 mm, 275mm or 450 mm depending on the height of the geyser. Thermostats are fixed in a tube and are connected in series with the heating element.

The outlet pipe is provided with a `U' bend inside the tank as shown in Fig 1 to prevent complete draining of water from the geyser. A pilot lamp is fitted on the outer case indicating the automatic working of the unit.

A fusible plug is fitted on the top of the unit to protect the inner tank to release the excess pressure that may be developed due to failure of the thermostat.

Working: When a geyser is fitted initially, open the inlet cock, fill the innertank and maintain the water level. When switched `on' the heater heats the water. When the temperature of water reaches to a set value the thermostat disconnects the heater from the supply. (Fig 3) The water drawn from the outlet pipe reduces the temperature and hence the thermostat, re-connects the heater with the supply.

Care and maintenance: A geyser requires less maintenance. The scale deposits that may adhere to the inside surface should be removed. It depends on the amount and kind of mineral content in the water. The only care required is not to energise the geyser without initially filling with water.

Troubleshooting of geysers

The following chart lists out complaints, causes and possible remedies.

Troubleshooting in water heaters/geysers

Complaints	Causes	Test and remedy
No hot water	1 Blown fuse.	1 Replace fuse.
	2 Open circuit.	2 Check wiring all the way for broken wire or loose connections.
	3 Heater element burnt out.	3 Check elements for burn-out.
Insufficient quantity of hot water and less hot	1 Thermostat setting too low.	1 Check thermostat setting. Should be 60°C to 65°C.
	2 Lower heating element burnt out.	2 Check the lower heating element and replace if burnt out.
	3 Capacity of tank is insufficient for one's needs.	3 Check quantity of water used. Explain to the user if tank capacity is too small.
Constantly/repeatedly blowing the fuse	1 Grounded heating element.	1 Check the heater element for ground.
	2 Grounded lead wire.	2 Check wiring for grounds.
	3 Incorrect connections.	3 Check electrical connections all the way.
Steam in hot water	1 Thermostat improperly connected.	1 Check wiring and correct any improper connections.
	2 Thermostat contacts burnt together.	2 Check thermostat.
	3 Grounded heating element.	3 Check unit for ground.
	4 Thermostat set too high or out of calibration.	4 Reset thermostat.
High consumption of power leading to increased electricity bill	1 Leaking faucets (taps).	1 Replace washers in all leaking faucets (taps).
	2 Excessively exposed hot water pipes.	2 Hot water lines should be as short as possible.
	3 Thermostat setting too high.	3 Reset thermostat. Setting should be 60°C to 65°C.
	4 Short to ground in heating element.	4 Check element for ground.
	5 Scale deposit on heating units.	5 Remove unit and check.
Leaking tank	1 Leakage around thermostat and heating unit flange.	1 Check all points for possible leakage before condemning tank.

Washing machine

Objectives: At the end of this lesson you shall be able to
- **define the washing machine**
- **state the types of washing machines and wash techniques**
- **state the function of mangle wringer for drying**
- **explain the function of drain pump and drive motor**
- **state the points to be noted while placing the washing machine at a suitable place.**

Washing machine

It is a domestic electric appliance which is used to soak, rinse, wash, wringle /dry the cloth/fabrics etc.

Types of washing machines: The modern washing machines can be divided roughly into three main groups according to their function.

They are

– Ordinary

– Semi automatic

– Fully automatic.

i Ordinary type

Ordinary without timer: This machine uses the pulsator type technique in which a disc is fitted to the motor.

It has only one tub and one motor the dirty cloth is loaded in the tub, water is filled manually in the tub, detergent is added. The motor is switched on the pulsator disc moves the cloth around the tub and the time duration of washing is decided by the operator.

Ordinary with timer: Similar to the ordinary type, but added with a clock timer to select the time of wash from 1 to 15 minutes.

ii Semi-automatic type

This type has two tubs. One for washing and rinsing, the other for spin drying the cloths. The washing tub operates at lower speed whereas the spin drier tub operates at a higher speed. The machine may contain either one or two motors.

iii Fully automatic type

In this type, the micro processor enables to programme the wash cycle. There will be only one tub. The machine could be programmed for wash cycle, detergent intake and water input. The machine does washing, rinsing and also dry the cloth and stops.

Further to the above types the washing machine could be further divided by the type of loading i.e. top loading and front loading. In some machines the water used for washing could be preheated with the help of an electric heater.

Types of wash techniques

In addition to the above classification, the washing machine could be catagorised according to the wash technique used as explained below.

The pulsator wash technique (Fig 1)**:** This is the most common type pulsator wash technique, it has disc in concave shape used to rotate the clothes in water. Dirt is removed from the cloth by rubbing against tub wall surfaces and the disc. (Fig 1 & 2)

Fig 1

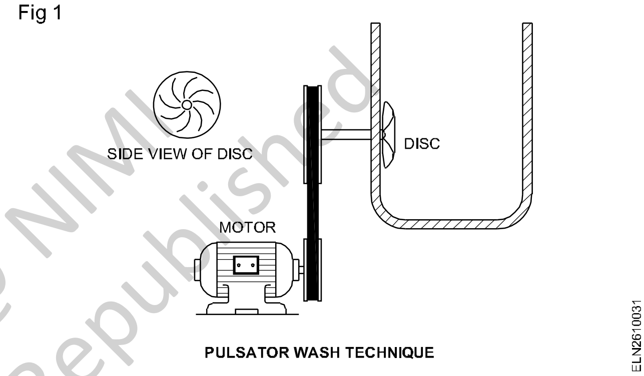
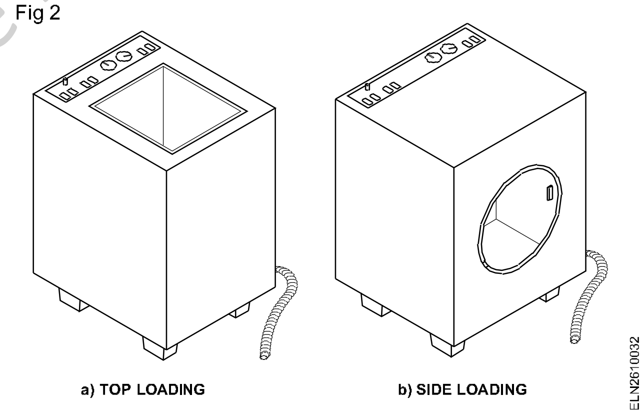


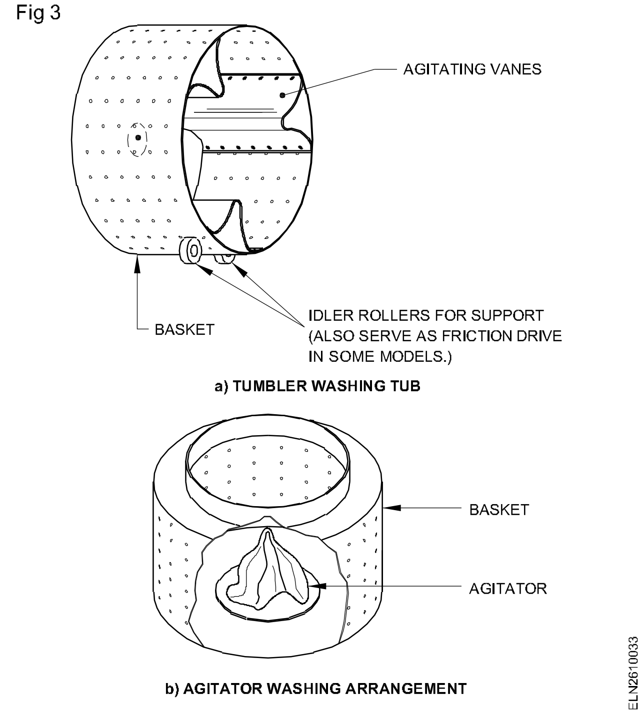
Fig 2



Tumbler type (Fig 3 a)**:** In the tumbler type the washing is carried out by tumbling the cloths with the help of a simple drum. Here the construction is simple and cloths are tumbled around the drum by virtue of the drum itself being rotated by means of a pulley at the rear or the friction drive of the idlers.

The agitator wash technique (Fig 3b)**:** An agitator which is long and cylindrical is installed at the centre of the washing tub. The water and cloths circulate around the agitator, thereby under going a thorough cleaning process. Not suitable for delicate fabric.

Fig 3



The air power wash technique: This machine uses air bubble technique to wash delicate fabrics smoothly.

The chaos punch wash technique: A multifaceted method of washing, where in water is propelled upwards in the machine to prevent entanglement of garments punching, is done on clothes by forced water.

The neuro fuzzy logic technique: Machines use this technique uses micro processor for their programming and can make decisions about the type of washing to be used depending upon type of fabric and the extend of dirt.

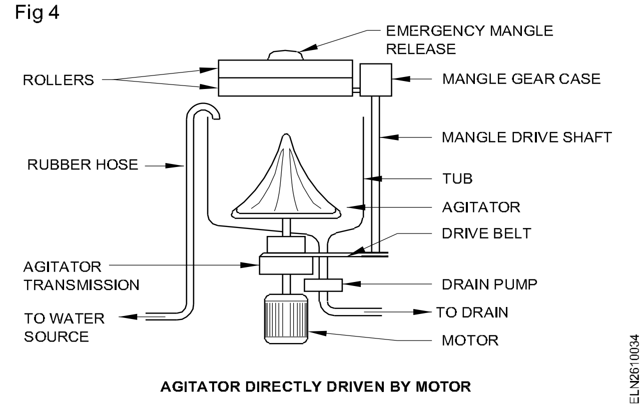
The water fall technique: This is more or less similar to chaos punch technique. This machine use jets of water which are pumped from below the pulsator in to the tub. The velocity and force of water removes the dirt. Most of the washing machines could be repaired by the electrician but micro processor controlled washing machine repair needs some more training and experience.

The conventional type with mangle wringer for drying: The conventional washing machines are relatively simple in operation and construction. The washing cycle in such a type of machine would consist of the user filling the central tub with water up to the water level mark. Soap and bleach are added.

Depending upon the types of the clothes to be washed the 'ON' time or the wash time of the machine is set and then 'the machine is switched 'ON'. Most machines have the agitator directly driven without any intermediate gears (Fig 4).

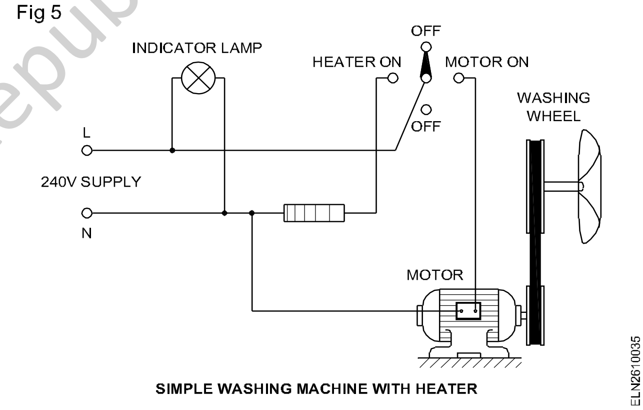
The wash is stopped by the timer setting on the machine. The agitator is brought to a standstill and the drain pump is operated or the valve for gravity draining is activated. For rinsing the clothes the machine is switched 'ON' for a time duration such that all the detergent or soap is removed off the clothes. This cycle is called the rinse cycle. The clothes are then put through the mangle wringer to press and roll out all the water from the clothes.

Fig 4



Some type washing machines having heater, is generally immersion rod type which is permanently fixed in the bottom of the washing machine. The purpose is to produce warm water for loosening stubborn dirt particles of the clothes for quick cleaning. In these types generally heater is not repairable, once found defective it has to be replaced. Fig 5 shows the connection diagram of simple washing machine with heater .

Fig 5



Precaution

i The agitator should be stopped during the drain period, because if it were to continue operating without water in the tub, the required force on the agitator to rotate the clothes in the absence of water would be many times more causing motor to overload.

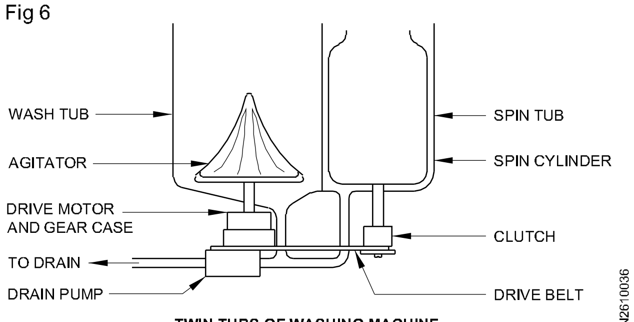
ii The bottom cable should be protected from the damage by the rats by using a rust proof welded mesh.

Twin - tub washing machine

The other type of conventional washing machine available is called the twin tub washer (Figs 6 & 7).

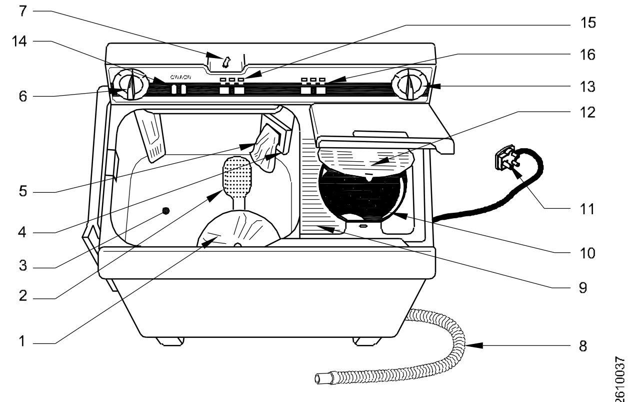
In the twin tub washer an additional tub is present to dry the cloths called a spin tub. Here the clothes after being washed are placed in the spin tub and it is rotated at a high

Fig 6



TWIN TUBS OF WASHING MACHINE

Fig 7



SEMI AUTOMATIC WASHING MACHINE

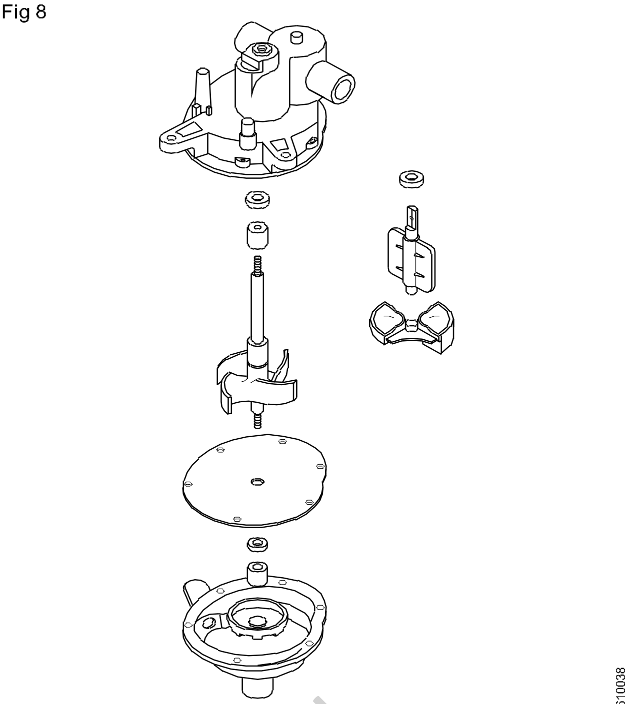
1 - PULSATOR	9 - SCRUBBER
2 - WATER STRAINER	10 - SPIN DRUM
3 - WASH DRUM	11 - 3-PIN PLUG
4 - WATER LEVEL SELECTOR	12 - SPIN DRUM COVER
5 - LINT FILTER	13 - SPIN TIMER
6 - WASH TIMER	14 - AGITATOR DIRECTION SWITCH
7 - WATER INLET PIPE	15 - WATER INLET-OUTLET KNOB
8 - DRAIN HOSE	16 - WATER INLET KNOB FOR SPINING

speed and due to centrifugal action the water from the clothes is removed fully till it is just damp dry. The time duration spin operation may be manual or automatic with the help of a timer depending upon the model.

The mechanical timer: The mechanical timer is a unit that has a spring-loaded gear train reduction arrangement. Normally called as clock timer. In case of defect in the timer it is better to replace it.

The drain pump: Some of the washing machines have a pump for quick removal of water from the drum for fast operation. This may either be gravity drain method or

Fig 8



ASSEMBLY OF WATER PUMP

driven by means of a friction pulley and lever from the main driver or a small sized motor with a water pump (Fig 8).

The drive motor: The most popular type of motor used in a washing machine is a single phase 240 volts 50 Hz. capacitor start squirrel cage induction motor. These motors may range from 1/3 to 1/2 HP rating. These motors are normally protected from overload and overheating conditions by means of a bimetallic overload relay or a thermal switch. The motor is located in such a way that water leakages do not fall on to these motors.

Locating the machine: The machine should be so located that soft water is freely available, and outlet or water drain arrangement is also easily available. The supply board should have the rated 3 pin socket arrangement with proper earth brought to the 3 pin plug point. The flooring should be in level such that the machine rests properly to avoid unnecessary loading on the machine drum and vibrations.

Installation of a pump set

Objectives: At the end of this lesson you shall be able to
- **define the pump set**
- **explain the method of selection of the type of pump and capacity of the motor taking various factor into consideration**
- **explain the types of pumps and use the table for selecting a proper type and capacity for requirement**
- **state how to select a proper location of pump installation and select proper control devices**
- **state perform troubleshoot in pumps.**

Pump set

Pump set is a combination of an electric motor and a impeller/pump coupled together to pump the water from well (or) bore (or) sump etc.,

Selection of pump : The following points are to be considered before selecting a pump for lifting the water.

- The quantity of water to be lifted
- Height of water to be delivered
- The time for lifting.

Based on the above considerations the pump has to be selected along with the motor to lift the water from a well/ sump.

An illustration is given below to show how to calculate the required HP of the motor to a particular height and quantity of water to be lifted within a specified time.

Example: Calculation of HP for domestic pump set.

A pump driven by a single phase AC motor of 240V, 50 Hz has to deliver 1000 litre to a height of 30 metre within 15 minutes. Find the HP of the motor if the efficiency of the motor is 80%.

Given

Working voltage - 240V, 50 Hz

Quanity of water to be delivered - 1000 litre

Height of the water delivered - 30 m

Efficiency of motor - 80%

Time of delivery - 15 minute

Solution

Work done by the pump / minute =

$$\frac{\text{weight of the water x Height}}{\text{Time}} = \frac{1000 \times 30}{15} \text{ kgm/min.}$$

since 1 litre of water = 1 kg. of water

and 4500 kgm/minute = 1HP

$$\text{Pump output in HP} = \frac{1000 \times 30}{15 \times 4500} = 0.44 \text{ or } 0.5 \text{ HP}$$

$$\text{Input of the pump} = \frac{0.5 \times 100}{80} = 0.625 \text{ HP}$$

Next nearest HP of the motor recommended is 0.75 HP.

Example 2: Calculation of HP required.

A pump is to be driven by a 3-phase 415V, 50 Hz induction motor to deliver 45,000 litre of water to a height of 50 metres in 25 minutes. Calculate the HP of the motor assuming the efficiency of the pump is 70% and that of the motor is 95%.

Given

Working voltage - 415V, 50 Hz

Quanity of water to be delivered - 45,000 litre

Height of the water delivered - 50 m

Efficiency of the pump - 70%

Efficiency of the motor - 95%

Time of delivery - 25 min.

Solution

Work done by the pump / minute =

$$\frac{\text{weight of the water x Height}}{\text{Time}} = \frac{1000 \times 30}{15} \text{ kgm/min.}$$

since 1 litre of water = 1 kg. of water

and 4500 kgm/min = 1 HP

$$\text{Pump output in HP} = \frac{45000 \times 50}{25 \times 4500} = 20 \text{ HP}$$

$$\text{Input of the pump} = \frac{20 \times 100}{70} = 28.6 \text{ HP}$$

$$\text{HP of the motor} = \frac{\text{Input of the pump}}{\text{Efficiency of the motor}}$$

$$\frac{28.6 \times 100}{95} = 30.1 \text{ HP}$$

Say approx. 30 HP motor will be suitable.

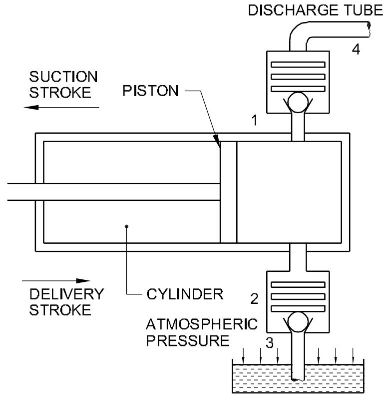
Pumps : Pumps can be classified mainly into two categories. They are

- Reciprocating pumps
- Rotary pumps.

Reciprocating pumps : In this type of pump, the main moving part has reciprocating motion only and hence the name. Fig 1 shows the main parts of a reciprocating pump.

When the piston moves towards left, a partial vacuum is created inside the cylinder. The check valve 1 in Fig 1 closes due to the suction effect of the vacuum, spring action and head of water in the discharge tube 4 but valve

Fig 1



RECIPROCATING PUMP

2 Fig 1 opens and allows the water to fill the cylinder through the suction pipe 3 due to atmospheric pressure outside. This stroke of the piston is called suction stroke.

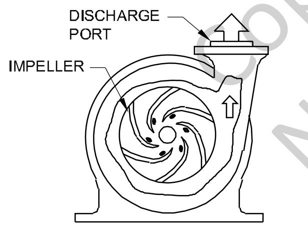
On the other hand when the piston moves towards right ie discharge or delivery stroke the liquid inside the cylinder is pushed out through check valve 1 and delivery pipe 4. During the delivery stroke valve 2 remains closed by the action of spring and the water pressure inside the cylinder.

However, as the discharge of water takes place in this type of pump only during the discharge stroke, the pump creates a pulsating flow of water and not a continuous flow. This type of pump is called a piston pump.

Rotary pumps : There are very many varieties of this pump in the market. However centrifugal pumps, jet pumps and submersible pumps are the commonly used pumps for lifting water in houses.

Centrifugal pumps : Fig 2 shows the construction and operation of a centrifugal pump.

Fig 2



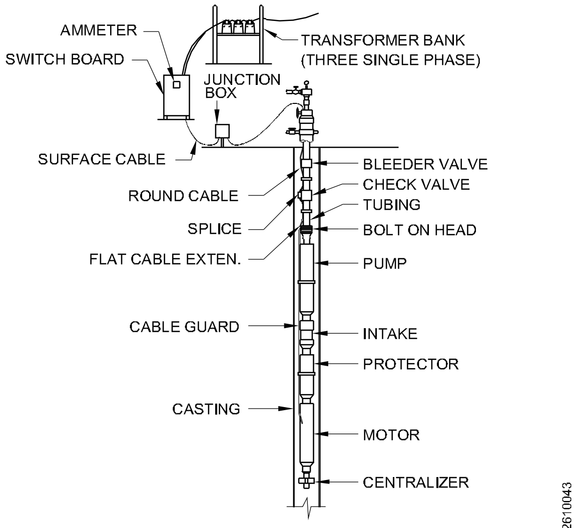
FLUID FLOW IN A CENTRIFUGAL PUMP

The operation of a centrifugal pump is based on centrifugal force. As the fluid being pumped enters the inlet or central section of the pump, the rotating action of the impeller vanes forces it to the outside of the pump casing (Fig 2).

Because the fluid moves faster at the outer edge of the impeller the momentum increases. As more fluid enters the pump, more fluid momentum is built up in the casing that encloses the impeller. This momentum forces the fluid out of the pump discharge port.

The centrifugal pumps are used where large volumes of water are to be pumped at relatively low pressure.

Fig 3



ELECTRIC SUBMERSIBLE CENTRIFUGAL PUMP SYSTEM

Submersible pumps : This pump also comes under the category of centrifugal pumps and is found in use at places where water is found in great depth.

Submersible pumps have motor and pump in an axial length are submerged in water (Fig 3). Generally such pumps are used for borewells where the volume of water to be lifted exceeds the capacity of reciprocating pumps. The motor used in such types of pumps is of 3-phase.

The cables and motor windings have water proof sealing as they are immersed in water. Such pump sets will have following advantages.

– Diameter is smaller.
– Motor and pump are submerged in water. Hence needs no space on ground level.
– The motor and pump are entirely connected through metal pipes for delivering water.
– Efficiency is more as the motor with the pump will be to the level of water or inside the water.
– Cooling is effectively done by water only.
– Can be used for lifting water from any depth of sump or borewell as suction pipe is not used.

Disadvantages

– Erection cost and initial cost of purchasing will be high.
– In case of any defects, it is necessary to remove entire unit along with the pipe line.
– Requires skilled worker for both erection and maintenance work.

Jet pumps : Another variety of centrifugal pump commonly used in the domestic wells an d borewells is the jet pump. In jet pumps, the motor and pump are assembled together in one block (Fig 4).

The bottom portion of the pump has two connecting pipes. One is called suction pipe and the other is called ejection pipe. A portion of the water is sent through the ejection pipe to the jet assembly and it aids the water in the suction pipe to be lifted upwards by Venturi principle.

Suction, ejection and delivery pipes and motor capacity could be selected with the help of the performance Table 1.

Almost all types of pumps may be independent units to be coupled with an electric motor through belts or couplings or may be single(mono) blocks comprising both motor and pumps.

Location of pump set : The pump should be installed as near as possible to the water source in order to reduce the suction lift and to achieve better performance.

Ample space should be provided around the pump for easy inspection and maintenance whenever required.

Fig 4

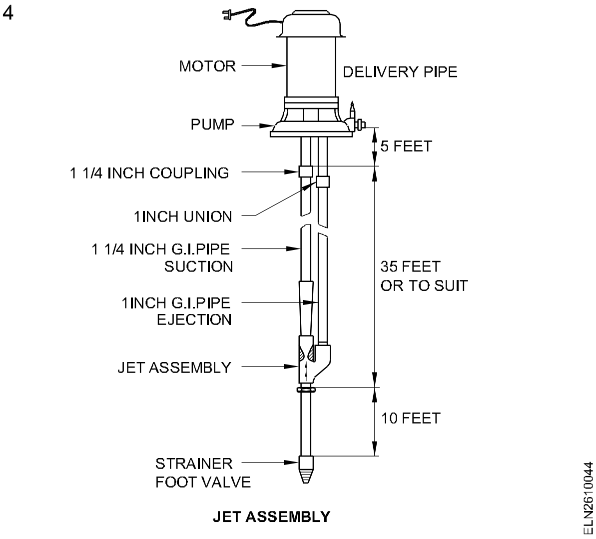


Table 1

Performance with AC 50 Hz, 2880 rpm electric motors for 220/240V single phase and 400/440V 3-phase

Motor rating	Discharge in litres per hour at various suction lifts										Pipe sizes in inches				Minimum
KW (HP)	30'	40'	50'	60'	70'	80'	90'	100'	120'	140'	at discharge pressure of	Suc-tion	Ejec-tion	Deli-very	bore diameter (inches)
0.37(1/2)															
Single phase	2370	1690	1200	900	700						20 lbs/ Sq.in.	1"	¾"	¾"	3
only	2500	1820	1370	1100	820						(46 ft)	1¼"	1"	1"	4" & Well
0.75(1.0) Single phase &	3650	2600	2140	1700	1525	1370	1200	1050	700		30 lbs/Sq.in.	1¼"	1"	1"	4" & Well
3-phase	3870	2730	2275	1820	1640	1460	1275	1100			(69 ft)	1½"	1¼"	1¼"	5" & Well
1.5(2.0)	4550	3180	2730	2160	1660	1550	1300	1070	910	730	40 lbs/	1¼"	1"	1"	4"
3-phase	6350	4460	3550	2900	2460	2260	2000	1730	1370	910	Sq.in.	1½"	1¼"	1¼"	5" & Well
only	8400	5700	4800	3800	3200	2910	2460	1820			(92 ft)	2"	1½"	1½"	6" & Well
2.2(3.0)															
3-phase	8900	6000	4840	3820	3250	2960	2530	2180	1820	1250	40 lbs/Sq.in.	1½"	1¼"	1¼"	5"
only	10000	7050	5640	4550	4000	3640	3250	2700	2100		(92 ft)	2"	1½"	1½"	6" & Well

NOTE For suction lifts up to 20 feet the pumpsets can work without jet assembly.

Controlling devices

– A switch and starter of a suitable type and capacity may be purchased as per calculated HP of motor.

– Proper size of cable should be used between supply and motor terminals to minimize voltage drop.

– Nuts at connecting terminals should be tightened properly to avoid any chance of the motor burning out.

– Proper double earthing connections should be made at bolts provided for earthing at motor,starter and switch

Operational instructions

Before starting the pump ensure that.

– Shaft rotates freely by hand.

– The gland box is properly tightened.

– The valve, if there is any on the delivery branch, is opened.

Check the following during running condition.

– The direction of rotation is correct.

– Pump is running smoothly.

– Leakage of stuffing box is normal ie., 50 to 60 drops per minute in gland packed pump.

– The ball bearings do not get excessively hot.

To get optimum performance from any pump, the following maintenance schedule is suggested.

Quarterly check.

– Pump noise.

– Pipe connections and nut/bolts.

– Foot valve strainer.

– Moving parts for lubrication.

Yearly check.

– Remove impeller, replace if vanes are worn out totally.

– Replace shaft sleeves, if worn out.

– Replace gland packing, if worn out.

– Replace any other worn out part.

– Replace mechanical seal if damaged.

Trouble shooting in pumps : In case of trouble in pumps, with the help of the trouble shooting chart (Table 2), locate the fault and rectify the defects.

Table 2

Troubleshooting chart

Sl.No.	Problems	Probable reason
1	Pump does not deliver water.	Pump casing and suction pipe is not primed.
2	Delivered water is not enough.	Delivery head is too high. Suction lift is too high.
3	Not enough pressure.	Impeller/suction pipe choked. Wrong direction of rotation. Leakage in suction pipe. Gland packings/mechanical seal worn out. Foot valve choked/not immersed in water. Impeller damaged. Wearing of shaft sleeve.
4	Pump takes too much power.	Damaged ball bearing. Head is much lower. Mechanical friction is more in the rotating part. Shaft bent. Stuffing box is too tight (gland is too tight).
5	Pump leaks excessively.	Gland packings/mechanical seal worn out. Shaft sleeve worn out. Gland packings/mechanical seal are not in proper position.
6	Pump is noisy.	Hydraulic cavitation. Foundation is not rigid. Shaft bent. Rotating parts are loose or broken. Bearing worn out.

Non - Automatic electric iron

Objectives: At the end of this lesson you shall be able to

- **define electric iron and its types**
- **state the function of the parts of an electric iron from the constructional diagram**
- **state the possible faults occured in non - automatic electric iron**
- **explain the method of testing of non - automatic iron.**

Electric iron

An electric iron is a heating device in which the heat is concentrated on a smooth, flat, bottom surface which is applied to the fabrics to be ironed.

The electric iron will probably be the first appliance that an individual will be called upon to repair when entering the appliance servicing field. Inspite of the fact that irons are quite inexpensive, many old irons are in use today.

Types of electric irons : There are three general types of electric irons:

- the non-automatic electric iron
- the automatic electric iron
- the steam iron.

The automatic iron is rapidly replacing the non-automatic iron.

Parts of an Electric Iron

The flat bottom surface is called the sole-plate.

The sole-plate is heated by an element made of resistance wire or ribbon (Nichrome), placed in or on the sole-plate. Thus, the iron converts electricity into heat at the sole-plate, where it can be utilized to iron clothes.

Figure 1 shows the component parts of an ordinary electric iron. The power cord (1) delivers power from the house electrical circuit to the iron. A cord sleeve (2) reduces flexing of the electrical wires as they enter the handle (3).

The cord, cord sleeve and plug cause more iron troubles than any other part or parts of an iron. The cover (4) serves mainly a decorative purpose to hide the unsightly parts below and to keep one's hands away from the electrical terminals. It also serves to keep the heat where it belongs. A pressure plate (5) clamps the heating element (7) to the sole-plate (9) with an electric insulator (8) in between. The asbestos sheet (6) placed in between the pressure plate and the heating element provides heat insulation and reduces the heat being transferred upwardly towards the cover and the handle. The heel plate (10) allows the iron to be tilted back on its handle when the iron is not in use.

Modern irons use a permanently attached cord rather than the detachable cords which can be misplaced easily. One advantage of the permanent cord is that the wall plug is the only electric disconnecting point in the circuit.

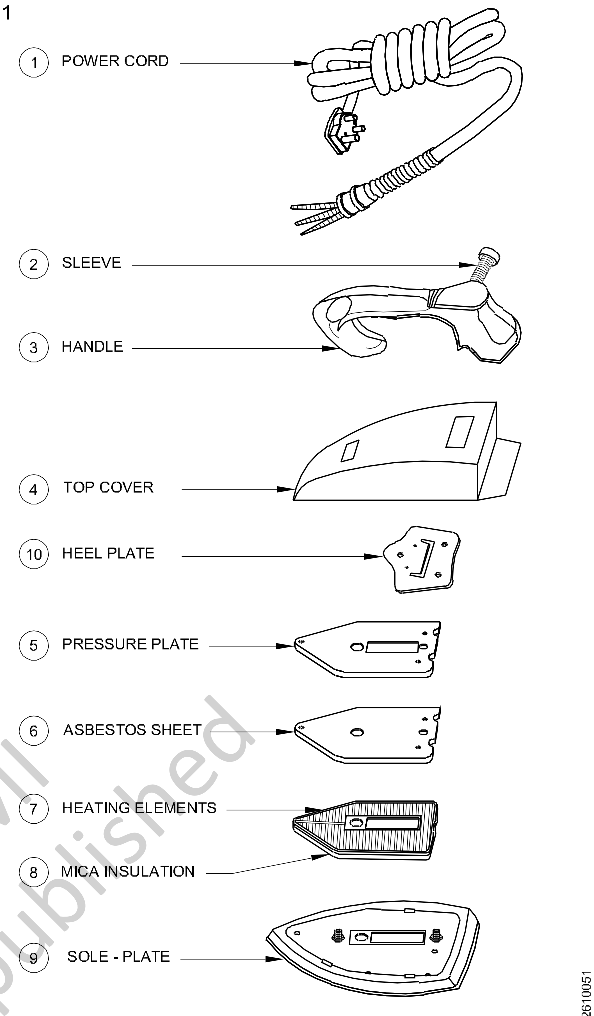
With detachable cords, resistive oxides may form at the iron connector. The resistive oxides formed will in course of time reduce the current input to the heating element.

The electric circuit of any iron is very simple. In many irons it is nothing more than a heating element with a cord and plug attached to connect it to an outlet.

Note that the only troubles possible in this circuit are short circuits and open circuits. Figure 2 shows the four possible parts of the circuit which may be defective. This is an electric diagram of the simple non-automatic type of iron and does not show other non-electrical parts such as the handle cover and sole-plate.

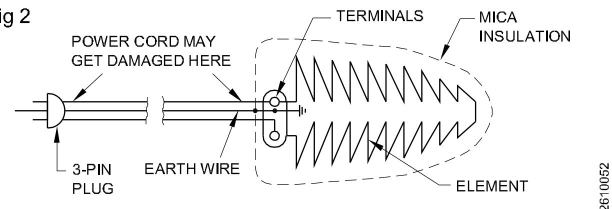
There are six basic steps you should follow to effect an efficient, prompt repair.

Fig 1



PARTS OF AN ELECTRIC IRON

Fig 2



CIRCUIT OF AN ELECTRIC IRON

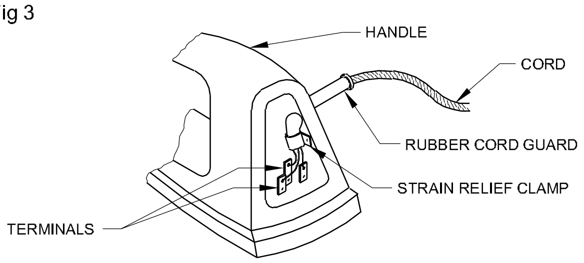
- Conduct a visual examination.
- Listen to the customer's complaint.
- Conduct preliminary tests.
- Repair the iron.
- Make final tests.
- Prepare the iron for delivery.

These basic steps, while not necessarily rigid, provide a good working procedure for the repair of all types of electrical appliance.

General parts: Before you study the method of servicing electric irons, it would be good to learn the names of their principal parts.

Cords: Cords are insulated with asbestos to protect them from the high temperatures produced by the iron. They are covered with braided cotton or nylon (Fig 3). Eyelets or lugs connect a permanent iron cord to the electrical circuit of the iron. A strain relief clamp is firmly fastened to the cord. Any pulls or yanks on the cord are absorbed by this clamp rather than the eyelets.

Fig 3



TERMINALS OF AN ELECTRIC IRON

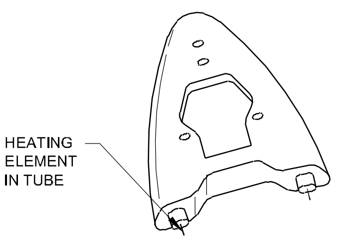
Handles: Handles are made of wood or plastic. In modern irons, plastic handles are made in large units combining the handle and brackets in a single unit mounted directly on the cover. Sometimes handles are split to provide access to the terminal covering and an entrance for the cord. When disassembling an iron for repair, the handle and its part are usually the first to be disassembled.

Cover: This part covers the heating element's internal connections of the iron. It also serves as a shield to protect one's hands from the generated heat and electric terminals.

Pressure plate: The purpose of the pressure plate is to keep the heating element firmly against the sole-plate. Often the pressure plate has an asbestos insulation sheet of the same shape.The asbestos sheet is placed just above the heating element. The pressure plate must be a good fit. (Fitted with two nuts)

Heating elements: There are two types of heating elements. One is made of a ribbon resistance wire wound around a sheet of mica. This type of element is placed on the top of the sole-plate. The other type of element is made up of a round resistance wire, coiled on a ceramic form and cast directly into the sole-plate (Fig 4). The flat type element is easily replaceable. The other type has its element casted into the sole-plate is replaced fully by installing a new sole-plate.

Fig 4



SOLE PLATE WITH SEALED ELEMENT

Sole-plate: The transfer of heat from the heating element within to the material being ironed is done by the sole-plate (Fig 4). The material being pressed can be easily damaged if the sole-plate is not smooth and free from scratches. If the sole-plates are scratched, they can be buffed and polished.

Heel - plate: The purpose of the heel-plate is to supply a resting point when the iron is tilted back on the rear of its handle. The heel plate is not intended to reach a high temperature. The figure shows the other type of heel plate used for resting the iron.

Terminals: The terminals are the point at which the heating element of the iron is connected to the cord (Fig 3).

Electric irons are available for operation on 240V domestic electric supply, and are of different wattages, 450W, 500W, 600W, 750W and 1000 W.

Possible faults

1 Disconnection of element strips from the terminals.

2 Breakage in the element.

3 Breakage in the cord, disconnection of wires in the plug top or connection.

4 Strips at the terminals may touch together which may cause a short circuit.

5 Any part of the element or strip at the terminals may touch the metal body of the iron which may cause earth fault.

6 Porcelain cleats may be broken.

7 Mica and asbestos sheet may be damaged.

Repairs

1 Open circuit fault

Connect the broken element or disconnected strips. Connect the wire ends in the plug top or connector. If there is breakage in the cord. check it and connect the broken wires if possible, otherwise replace the cord.

2 Short circuit fault

It the strips of the element, wires in the plug top or connector are touching together, separate them and insulate them. If the cord is too old and the current is leaking through the insulation, replace the cord.

3 Earth fault

If any part of the element or strips of the element are touching the metal part of body, separate them from the body and insulate them.

4 Leakage fault

If the insulation has become weak and the current is leaking, then add some more insulating material or replace the insulating material.

5 Other faults

If the cleats are broken, get these replaced. If the mica and asbestos sheets are damaged, replace them also.

Precautions at the time of fitting

1 There should be no gap between the pressure plate and the sub-plate, otherwise the element will be damaged soon.

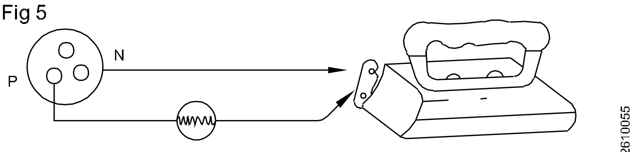
2 Place the asbestos sheet between the pressure plate and the upper side of the element.

3 Fitting of the components should be made fully tight.

Testing

To find out the fault, use the test lamp (Fig 5).

Fig 5



TESTING OF ELECTRIC IRON

Connect two ends of the testing leads to the terminals of the iron. If the lamp gives dim light, it means that the element is in working order. If the lamp does not light up, there is breakage in the element or disconnection of the strip from the terminal.

If the lamp gives full light, it means there is a short circuit. For earth testing, connect one lead to one terminal and the other lead to the body of the iron. If the lamp lights up, it means that there is an earth fault.

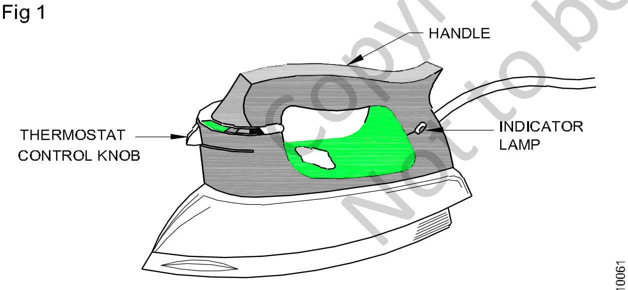
Automatic electric iron

Objectives: At the end of this lesson you shall be able to
- **state the difference between non-automatic and automatic irons**
- **describe the construction of a bimetal thermostat**
- **illustrate the working of an adjustable thermostat**
- **list the possible faults, their causes and corrective action to be taken in an automatic iron.**

Automatic electric iron

The difference between an automatic iron and the ordinary (non-automatic) iron is that the automatic type has a thermostatic device to regulate the temperature. The other parts are more or less the same in both the types of irons. (Fig 1)

Fig 1



AUTOMATIC ELECTRIC IRON

Automatic irons are fitted with a thermostatic switch to regulate the heat to a specific predetermined value. The thermostatic switch disconnects the supply when the predetermined value is reached and reconnects the supply when the iron cools down. A turning knob with a dial just below the handle, marked as rayon, cotton, silk, wool etc. can be operated to select the preset temperature.

They are two types of automatic electric iron, they are:

1 Dry Automatic Iron

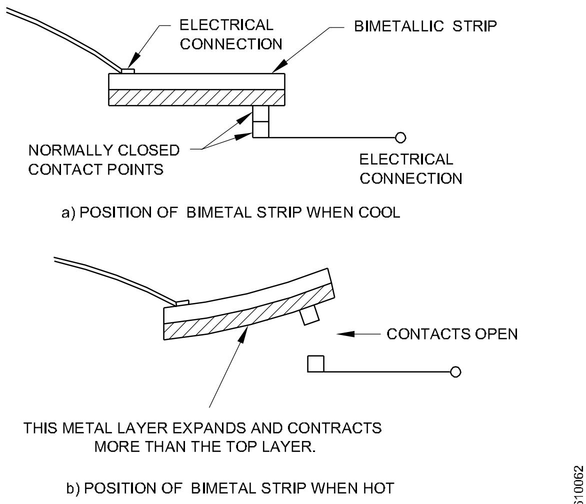
2 Spray/Steam Automatic Iron

Thermostats

A thermostat is a switch which can be designed to close or open a circuit at predetermined temperature. One of the simplest and most dependable components in the modern heating appliances is the BIMETAL THERMOSTAT. It controls the temperature in stoves, toasters, food warmers, irons etc. It serves as a safety device to prevent overheating of the appliances.

Bimetal thermostat (Fig 2)

Fig 2



A SIMPLE BIMETAL THERMOSTAT

In the thermostat there is a bimetal strip made of two strips of metal with different expansion rates welded together. The metal strip expands when heated and contracts when cooled. One metal in the bimetal strip has a high rate of expansion when heated, and the other has a low rate.

When a bimetal strip is heated, both the metals in the strip expand but the one at the bottom with a higher rate of expansion expands faster and forces the upper half to curl up or bend away from the contact point (Fig 2b). The strip curls or bends enough to break the contact, opening the circuit.

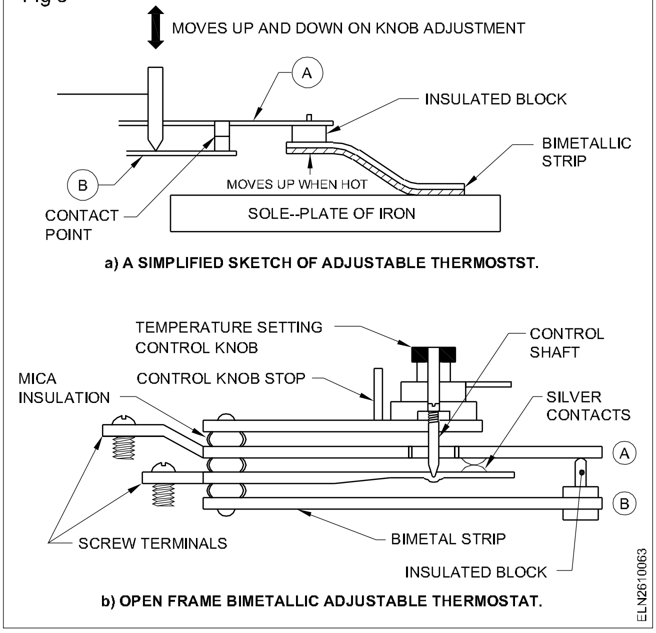
As the strip cools, it straightens and restores contact with the stationary point. The bending of the bimetal strip on heating, is towards the side that has the smaller expansion rate.

Adjustable thermostat (Fig 3)

The operation of the thermostat is as follows. The strip B (Fig 3 (a) part B) along with the silver contact is designed such that it has upward tension whereas the control shaft moves the strip B either upward or downward depending upon the temperature setting.

The strip A (Fig 3(a) part A) along with its silver contact is designed such that it has downward tension. But its downward movement is restricted by the insulated block.

Fig 3



a) A SIMPLIFIED SKETCH OF ADJUSTABLE THERMOSTST.

b) OPEN FRAME BIMETALLIC ADJUSTABLE THERMOSTAT.

In the 'OFF' position of the temperature setting control knob, the strips A and B will be away from each other, keeping the silver contacts in an opened condition, thereby, keeping the heating element circuit open.

When the temperature setting control knob is set to minimum position, the control shaft moves up and allows the strip B and its silver contact to move upwards to some distance and make contact with the silver contact of the strip A.

Troubleshooting chart

(Dry Iron)

Trouble	Possible causes	Corrective action to be taken
No heat	No power at outlet. Defective cord or plug. Loose terminal connections. Broken lead in iron. Loose thermostat control knob. Defective thermostat. Defective heater element. Open thermal fuse.	Check outlet for power. Repair or replace. Check and tighten the terminals. Repair or replace lead. Clean and tighten. Replace thermostat. Replace the element if separate. If cast in, replace sole-plate assembly. Replace.
Insufficient heat	Low line voltage. Incorrect thermostat setting. Defective thermostat. Loose connection.	Check voltage at outlet. Adjust and recalibrate thermostat. Replace thermostat. Clean and tighten connections.
Excessive heat	Incorrect thermostat setting. Defective thermostat.	Adjust and recalibrate thermostat or replace. Replace thermostat.
Blisters on sole-plate	Excessive heat.	First repair the thermostat control. Then replace or repair the sole-plate, depending on its condition.

Trouble	Possible causes	Corrective action to be taken
Tears clothes.	Rough spot, nick,scratch, burr on sole-plate.	Remove these spots with fine emery and polish the area with buff.
Iron do not turned off automatically.	Thermostat switch contacts are welded together	Check the thermostat switch contact. Open them by force. The contact points should be in open condition at off position of the control knob.
Sticks to clothes.	Dirty sole-plate.	Clean.
	Excessive starch in clothes.	Iron at a lower temperature. Use less starch next time.
	Wrong setting of the thermostat knob.	Set the knob to correct temperature.
	Iron too hot for fabric being ironed.	Lower the thermostat setting.
Iron gives shock.	Disconnected earth connection.	Check earth connection and connect properly.
	Weak insulation of heating element.	Check insulation resistance of heating element; if necessary replace element.
	Earth continuity with common earth not available.	Check the main earth continuity and connect properly.

Thus the heating element circuit is closed, the iron heats up. The bimetal strip which is also heated, bends upwards and the insulated block pushes the strip A, thereby, separating the silver contacts and the heating element circuit opens.

When the iron cools down, the bimetallic strip also cools and comes back to the straight position. The downward movement of the insulated block allows silver contact strip A to come in contact with the silver contact strip B; thereby the circuit is closed and the iron heats up.

A lamp fitted near/into the handle of the iron goes off when the desired temperature is attained.

This cycle goes on and off in that setting

At the highest temperature setting, the distance between the strip A and the insulated block of the bimetal strip will be more and it takes more time to switch OFF the heater element, and, thereby, the temperature of the iron will be more.

The knob adjustment does not determine the amount of current that flows into the appliance but usually controls the ON-OFF cycle of the unit; thereby, increases the heat required for wool or reduces the heat for rayon.

Bimetal thermostats open and close slowly and as a result the contacts are prone to arcing.

The mica insulation between the two strips A & B act as a condenser and the arc is suppressed by the condenser action. Sometimes, the mica gets deteriorated and allows the arc to exist between the contacts. Each time the contacts open, they cause a small arc which leaves a deposit of oxide on the contact surface.

Corroded contact points increase the arcing and lose electrical conductivity. Eventually the contacts no longer allow the current to flow. This can occur even though they may seem to be touching each other.

Generally, a good thermostat will show zero ohms resistance, or at most a few ohms. When a thermostat indicates high resistance or infinity, it should be replaced. Do not try to bend the strips A or B unless otherwise you know what you are doing is correct.

Troubleshooting in an automatic iron

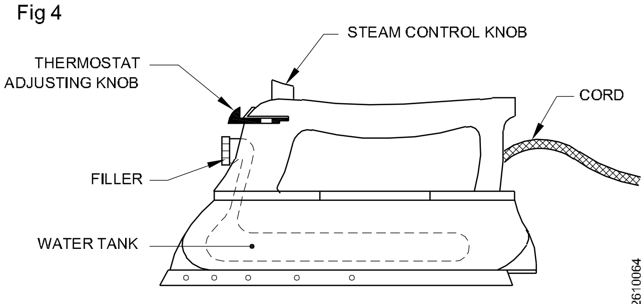
Follow the troubleshooting chart to repair an automatic iron.

Steam/spray irons (IS 6290)

Electrically there is no difference between steam irons and dry irons. A steam iron has a small reservoir mounted above the heating element. A control valve on this allows the water to drip slowly into recesses in the sole-plate.

A check valve keeps the water from going back up into the tank. When the water hits the hot position of the sole-plate, it is converted to steam and goes out through holes in the bottom of the sole-plate. Fig 4 shows a diagram of the construction of a typical steam iron.

Fig 4



OUTLINE OF A TYPICAL STEAM IRON

Method of repair

In most of the steam irons, the heating element is sealed along with the sole-plate. When the element is found to be open or shorted, the sole-plate along with the sealed heating element has to be replaced. Apart from defective power cord set and thermostat as found in the irons, the steam iron may develop problems in the water/steam container parts due to the following reasons:

i) The consumer might have used tap water instead of distilled water to fill the water tank in steam irons. This may result in deposit of salts in the tank and clog the entry and exit points.

ii) The consumer might have left the iron with water for some period resulting in salt and rust formation.

The salt deposit can be removed by filling the tank with diluted vinegar and plugging the iron to the power supply. A number of attempts may have to be made to clear the deposits.

Electric kettle

Objectives: At the end of this lesson you shall be able to

- **define electric kettle and its types**
- **list and state the parts of an electric kettle**
- **describe the method of fitting a new element**
- **state the general care and maintenance.**

Electric kettle

Electrical kettle is a heating device which is used to heat the liquid (like water, milk, etc) poured in it.

There are two types of electric kettles:

– Saucepan type

– Immersion heating type.

Saucepan type: The construction of the sauce pan type kettle is given in Fig 1. The parts are as follows.

1 Bolt, nut and washer holding bottom cover

2 Heating element

3 Asbestos sheet

4 Sole-plate

5 Pressure plate

6 Bottom cover

7 Handle

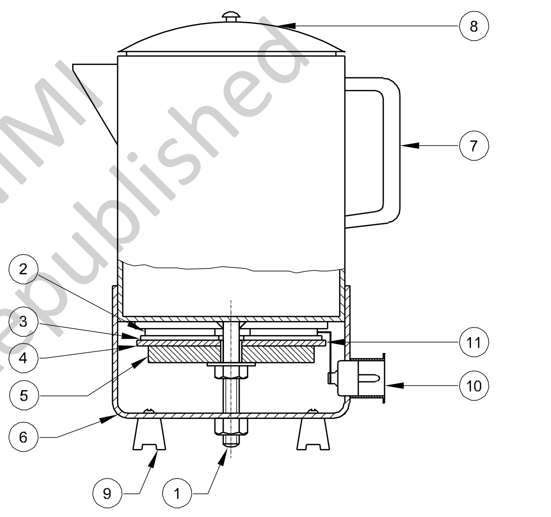
8 Top lid

9 Ebonite leg

10 Outlet socket

11 Brass strips

Fig 1



CONSTRUCTION OF SAUCEPAN TYPE KETTLE

Bottom cover: The bottom cover is fitted to the central bolt of the body by a nut and washer. On removal of the bottom cover, ready access is made to the terminal and heating element assembly (Fig 1).

Heating element: In its general construction, the heating element is made of Nichrome ribbon. The Nichrome ribbon is wound over mica. This is placed between two circular mica pieces, so that the Nichrome wire may not come in contact with any metallic part of the kettle. The two ends of the elements are connected to the outlet socket terminals of the kettle through two brass strips.

Asbestos sheet: This is placed below the element and mica insulation to serve as a heat insulator. It reduces the heat loss in the kettle in addition it gives increased insulation.

Sole-plate: The sole plate is a cast iron plate neatly ground to have a flat surface and its main function is to keep the element in close contact with the container and to avoid deformation of the element when heated.

Pressure plate: This is made of cast iron and fitted by a nut on the middle bolt. The pressure plate holds the sole plate in position. If this pressure plate is loosely fitted, the sole plate and the element become loose. This leads to expansion and contraction of the element during working and the element will get damaged.

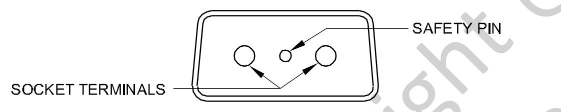
Method of fitting new element: Dismantle the kettle by the following steps.

- Invert the kettle and loosen the bottom cover holding nut. Take out the nut and remove the bottom cover.
- Remove the brass strip connections of the elements at the socket terminal sides.
- Remove the terminal socket by loosening the fitting screws.
- Open the nut of the pressure plate.
- Take out the pressure plate, sole-plate, asbestos sheet and then the heating element.
- Replace with a new heating element having the correct size and rating.
- Reassemble the kettle.
- Test the insulation resistance for any earth fault and insulation failure.

Immersion type: The heating element in this type is of tubular immersion heating design. In some kettles an ejector type safety device is incorporated in the socket terminal side.

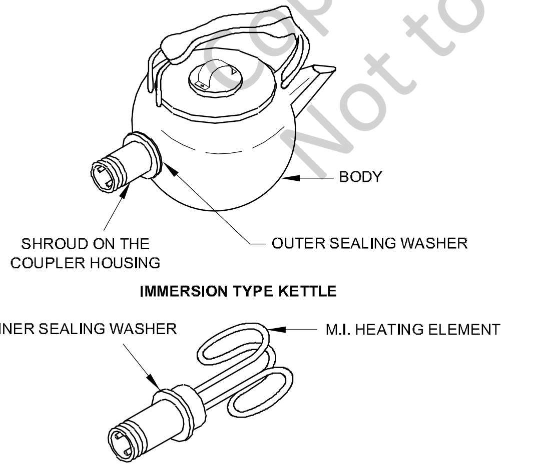
In case the kettle is switched ON without water the safety pin (Fig 2) which is soldered against a spring which is under tension comes out and pushes the plug out. This safety pin can be placed in position by soldering. The heating element is concealed inside a hollow tube and mineral insulated (Fig 3).

Fig 2



SOCKET WITH SAFETY PIN

Fig 3



KETTLE HEATING ELEMENT

New elements can be fitted to most types of kettles without difficulty.

Fitting a new element: A new element should be fitted in the following manner.

- Hold the element in one hand and unscrew the shroud on the coupler housing.
- Slide out the outer fibre sealing washer.
- Twist the element assembly inside the kettle and pull it out gently through the top.
- Take the old element to an electric shop to make sure that the replacement is of the exact design and wattage.
- Remove stubborn scales inside the kettle with a blunt knife without knocking the metal surface.
- Put an inner sealing washer, usually made of fibre, on the new element.
- Take care to fit new washers at the coupler housing in the correct order. Reassemble.

Care and maintenance

- Never empty a kettle while it is still switched 'ON'.
- Remove the plug from the socket before carrying out maintenance or repairs.
- Never pour water into a kettle which has just boiled dry, which apart from danger to the users, may damage the element.
- The metal portion of the kettle should be earthed using a 3-pin plug and a 3-pin appliance socket.
- Replace cracked or damaged sealing washer.
- Check for the good condition of asbestos sheet. Replace with a new one, if damaged during removal.
- Immediately replace the defective plug, socket or cable, if once noticed.
- Earth clips of the appliance power cord plug should snugly fit into the inner side of the appliance socket to have perfect earth connection. Check for proper fitting and cleanliness.

Calculation of heater efficiency

Objectives: At the end of this lesson you shall be able to
- **define heat unit and joule's law**
- **list the method of heat transfer**
- **solve problem related to efficiency of heaters.**

Heat Unit

The kilocalorie (kcal) is the unit of heat in the MKS system. It is defined as the amount of heat required to increase the temperature of one Kg of water through 1°C. It has been experimentally proved that, if 4187J of electrical energy is completely converted to heat, it produces one kilocalorie of heat energy, i.e. 1 kilocalorie = 4187J.

Joule's Law of heating : This law states that whenever the current flow through a conductor the heat is generated in the conductor and it is proportional to the square of the current value, the resistance of the conductor and the time for which the current flows.

The above law can be expressed in the form of an equation as follows :

$H = I^2 Rt$ watt - seconds or joules

where I = current in the conductor in amperes

R = resistance of the conductor in Ohms

t = time for which the current flows in seconds

H = quantity of heat developed in joules.

If current 'I' ampere flows for 't' seconds through a resistance of R Ohms, then the electrical energy consumed (I^2 Rt joules) is converted into heat so that we have.

$H = I^2 Rt$ joules or watt - seconds

or

$$H = \frac{I^2Rt}{J} \text{ calories}$$

where J is joule constant

Mechanical equivalent of heat J = 4.2

because 4.2 joules = 1 calorie

Then one joule = 0.24 calories, and

4187 joules = 1 K calories

$$\text{Thus } H = \frac{I^2Rt}{4187} \text{ K Cal.}$$

Methods of heat transfer : Heat energy is generally transferred from one place or object to another by one of the following three methods: conduction, convection and radiation.

The heat generated by the heater is not fully utilised for our purpose and some losses are taking place. The efficiency of the heater is therefore less than 100%. The efficiency of the heater is the ratio between the heat actually utilised and the heat produced by the heater.

$$\text{So, efficiency } = \frac{\text{Heat utilised}}{\text{Heat generated}}$$

- Therefore, the percentage efficiency

$$= \frac{\text{Heat utilised}}{\text{Heat generated}} \times 100$$

- The heat generated is calculated using Joule's law. Accordingly we have,

$$H = \frac{I^2Rt}{j} \text{ calories}$$

or 0.24 I^2Rt calories

where I is current in amperes

R is resistance in ohms

t is time in seconds

j is the mechanical equivalent of heat = 4.2.

The bigger unit of heat is the kilo-calorie.

Calorie: It is the amount of heat required to raise the temperature of one gram of water to one degree celsius.

1 Calorie = 4.2 joule or watt second

Heat obtained by a substance

$= ms(T_2 - T_1)$ calories

where m - mass in grams

s - specific heat of the substance

$(T_2 - T_1)$ - raise in temperature (degrees celsius).

Example

An electric heater is marked 1000 W 240V. It is found to take 8 minutes to bring 1 Kg of water from 20°C to boiling point (100°C). Determine the efficiency.

Given data

where m - mass in grams

Mass of water m = 1 Kg or 1000 grams

Initial temperature T_1 = 20^oC

Boiling temperature T_2 = 100^oC

Raise in temp$(T_2 - T_1)$ = $100^oC - 20^oC = 80^oC$

Time t = 8 minutes = 480 sec.

Heater wattage = 1000 W

Heater voltage = 240 V

Specific heat of water is 1.

Heat utilised by water = $ms(T_2 - T_1)$

= mass x sp. heat x $(T_2 - T_1)$

= 1000 x 1 x 80

= 8000 calories.

Heat generated = $0.24 \times I^2Rt$ calories

= 0.24 x 1000 x 480.

(where $I^2R = 1000$)

Therefore, efficiency $= \frac{\text{Heat utilised}}{\text{Heat generated}} \times 100$

$= \frac{8000}{0.24 \times 1000 \times 480} \times 100$

= 70% (approximate).

Electric Bell and Buzzer

Objectives: At the end of this lesson you shall be able to
- **define an electric bell**
- **explain the functioning of interrupter bell and single stroke bell**
- **describe the working of buzzer and type of buzzer.**

Electric bell

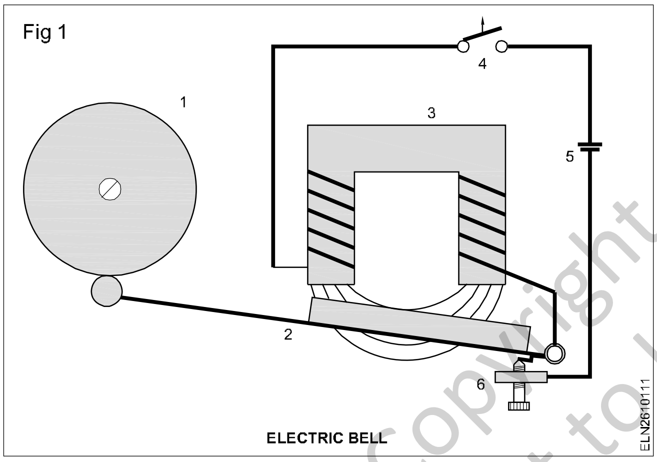
An electric bell is a mechanical bell that works of an electromagnet. When the current is passed through it, produces buzzing sound. It is used in rail road crossings, telephones, fire/burglar alarms, school bells and door bells etc, Now, they are replaced with electronic sounders.

Interrupter Bell

This interrupter bell produces continuous sound when the current is passed through it.

It consists of the following parts (Fig 1).

Fig 1



- Bell (or) gang (1)
- Arm (2)
- Electromagnet (3)
- Switch (4)
- Cell (5)
- Electrical contacts (6)

Working

The bell (or) gang (1) is often in the shape of a cup or half - sphere, is struck by a spring loaded arm (2) with a metal ball on the end called a clapper, actuated by an electromagnet (3). In its rest position the clapper is held away from the bell a short distance by its arm.

When an electric current is passed through the winding of the electromagnet, when closing the switch (4) , it makes a magnetic field that attracts the iron arm of the clapper, pulling it over to give the bell a tap. This opens a pair of electrical contacts (6) attached to the clapper arm, interrupting the current to the electromagnet, and it is demagnetized, the clapper releases away from the bell. This closes the contacts again, allowing the current to flow to the electromagnet again, so the magnet pulls the clapper over to strike the bell again. It repeats several time per second resulting in continuous ringing.

The tone of the sound generated depends on the shape and size of the bell or its natural frequency. Where several bells are installed together. By using different size and shape of gangs, different sounds can be obtained.

Single stroke bell

Another type of bell is called single stroke bell, has no interrupting contacts. The hammer strikes the gang once each time when the circuit is closed. These are used in signal and shops etc.

In this bell, when the current is passed to an electromagnet, It pulls the clapper against the bell or gang. It did not ring continuously, but only with a single ring, until current was applied again. Bells, gangs and spiral chimes could all be used, giving a distinct tone for each instrument.

Sprung bell

A simple development of the single stroke bell was the sprung bell. It is mechanically actuated, for servant call - bells in large houses. The inertia of the heavy bell on the light spring would continue ringing for some seconds after the stroke.

Electric buzzer

A buzzer or beeper is an audio signalling device, which may be mechanical, electromechanical (or) piezoelectric.

Types of buzzers

Electromechanical buzzer

The electric buzzer was invented in 1831 by "Joseph Henry'. It is mainly used for door bell with louder tone.

Early device is based on an electromechanical system identical to an electric bell without the metal gang. Similarly a relay may be connected to interrupt it's own actuating current causing the contacts to buzz. These unit is attached to a wall or ceiling to use it as a sounding board.

The word 'buzzer' comes from the rasping noise that electro mechanical buzzers made. Mechanical buzzer requires drivers. Joy buzzer is an example of mechanical buzzer.

Piezoelectric buzzer

A piezoelectric element may be driven by an oscillating electronic circuit (or) other audio signal source, driven with a piezoelectric audio amplifier. Sounds commonly used to indicate that a button has been pressed are a click a ring (or) a beep.

Application of buzzers

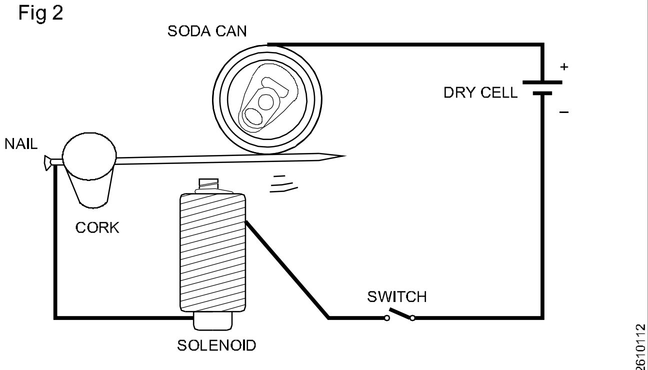
The present day applications of buzzers are

- In modern Toys and entertainment games.
- Judging panels.
- Educational purposes.
- Announciator panels.
- Game show- lock - out device.
- Microwave ovens and other house hold appliances.
- Sporting events.
- Electrical alarms.

Working of buzzer

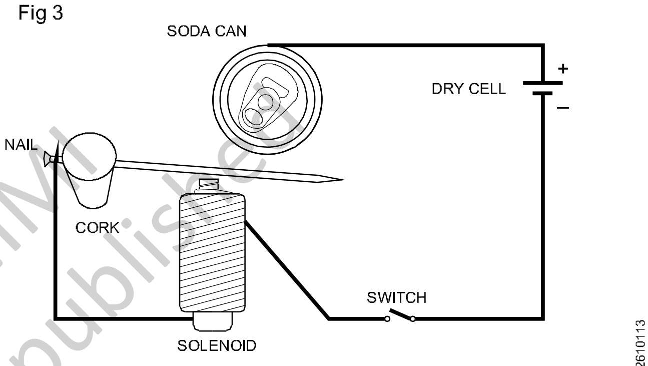
The connection of the simple buzzer is shown in the Fig 2. When the circuit is closed, the current flows from the battery through the coil around the bolt (an electromagnet) The nail file and the soda can (Fig 2), so the solenoid is magnetized immediately. Since the nail file is magnetic, it is attracted towards the coil- when nail file and the soda can are no longer touching, the connection is disconnected and stops the current flow (Fig 3). This demagnetizes the coil causing the nail file to return back to it's original position, where it strikes the soda can to make a sound.

Fig 2



BUZZER CIRCUIT IN CLOSED POSITION

Fig 3



BUZZER CIRCUIT IN OPEN POSITION

Then the circuit completes the current flow again and repeats the cycle. Each time the nail strikes back at the can, a sound is produced. Depending on the distance between the electromagnet and the nail several sound is produced.

Heating element, heater/immersion heater, electric stove and hot plate

Objectives: At the end of this lesson you shall be able to
- **define electric heater and its type**
- **select a suitable size and length of 'heating element' wire for a given wattage and voltage rating**
- **describe the various parts of an exposed element type of an electric heater**
- **describe the precautions to be followed in a heater while repairing**
- **state the properties of Nichrome wire**
- **explain room heater and immersion heater and their care and maintenance**
- **explain the electric stove and hot plate.**

Elecric heater: One of the methods of obtaining heat for cooking is to use the heating effect of electricity. An electric heater is the simplest form of an electric cooking device.

Types: There are two types of electric heaters.

– Exposed element type heater

– Enclosed element type heater

Element: In an exposed element type of heater the element is made of Nichrome wire. It possesses high resistivity, and withstands a working temperature of 900°C. Nichrome does not readily oxidise even at such a high temperature. Increase in the length of the element at such temperature is very small.

Table 1

Nichrome wire sizes

Sl. No.	Size of wire		Resistance in ohms per metre at 500°C	Current in amperes to produce 500° C
	SWG	*Dia in mm		
1	18	1.18	0.9744	12.6
2	20	0.90	1.7355	8.6
3	22	0.71	2.8707	6.3
4	24	0.56	4.6587	4.45
5	26	0.45	6.9553	3.5
6	28	0.375	10.2690	2.8
7	30	0.315	14.665	2.3
8	32	0.28	19.291	1.99

*Size equivalent to SWG is as per IS No. SP:2 - 1982.

Different wattage heaters are made for working at the rated supply voltage of 240V. The wattage is given by the formula

$W = V \times I = I^2R$ Watts.

From the above formula it is clear that increased wattage heaters carry more current. The element wire of 2000W should be of a higher diameter than that for a lower wattage, say, 1000W heater. An increased diameter wire decreases its resistance per metre length. The resistance per metre length of some readily available Nichrome wires with relevent particulars are given in Table 1.

Selection of nichrome wire size (Diameter)**:** The current to be carried is calculated for a given wattage and rated voltage. Referring to Table 1, the nearest size (diameter) nichrome wire is selected.

The resistance of the heater element is determined from the formula $I^2R = W$ watts

$$\text{or Resistance} = \frac{W}{I^2} \text{ Ohms,}$$

Length: The length of the Nichrome wire that can produce the above calculated resistance is found by using the data of resistance per metre length in Table 1.

Length required =

$$= \frac{\text{Calculated resistance}}{\text{resistance per metre of selected dia of wire}} \text{ Metres}$$

Example : Calculate the length of heating el;ement wire for a heater 250 V, 1000 watts working at 500° C. (Use the Table given)

Table 1 shows the safe current capacity for the different sizes of wires and their resistance per metre.

Data given :

Supply voltage V = 250 volt

Power W = 1000 watts

Working temperature = 500° C.

Current taken by the heater = I

$$I = \frac{W}{V}$$

$$= \frac{1000}{250}$$

= 4 amperes

Resistance of heating element = R

$$R = \frac{V}{I}$$

$$= \frac{250}{4}$$

= 62.5 ohms

Refer to the table and see column 5

For the current of about 4 amps. note the wire size from the Table 1.

It is 24 SWG.

Now see column 3 for this wire size (24 SWG).

It is 4.6587 ohms per metre.

But total resistance required = R = 62.5 ohms

$$\text{So, the length of the wire} = \frac{62.5}{4.6587}$$

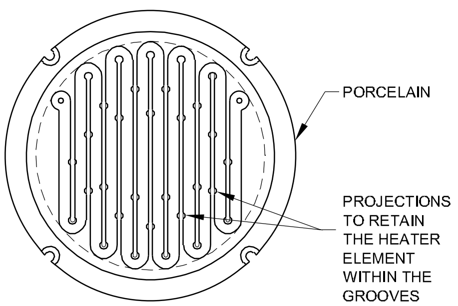
= 13.42 m.

So, for a 1000 watts, 250 V heater, 24 SWG Nichrome wire of 13.42 metres is needed.

Parts of exposed type heater

Heater plate: A porcelain plate with a groove is made, similar to the one shown in Fig 1. It houses the Nichrome wire in a coil form.

Fig 1



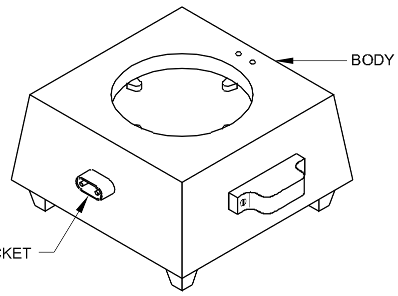
PORCELAIN PLATE OF THE HEATER

Porcelain withstands high temperature and remains as a good insulator even at high temperatures, say 1300°C. The coiled Nichrome heating element is housed in the grooves. The grooves are designed with projections at various places (Fig 1). The projections prevent the heating element from coming out of the grooves.

As the heater plate is brittle, care should be taken while mounting or dismounting it from the frame, to avoid breakage. The plate thickness varies from 10 mm to 25 mm, depending upon the wattage. The ends of the coiled element are terminated with bolts and nuts in the plate itself.

Body or frame: A body is provided to house the heater plate in it. It is made of cast iron or M.S. sheet, painted or electroplated. The socket is fixed to the body (Fig 2). An insulated handle is fixed on the body for safe handling.

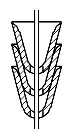
Fig 2



FRAME OF THE HEATER

Connecting leads: The lead wires should have a larger cross-section made of bare copper, insulated with porcelain beads or glass beads (Fig 3).

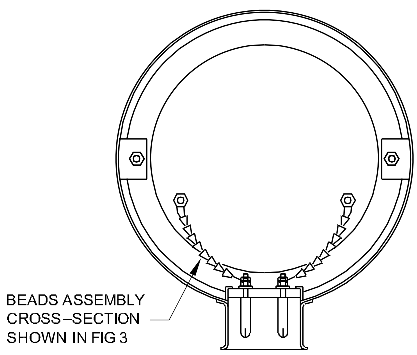
Fig 3



CROSS - SECTION OF THE BEADS

The beads are available in different sizes. The beads can be replaced by glass wool or asbestos sleeves.The leads are connected to the socket terminal and heater plate terminal (Fig 4).

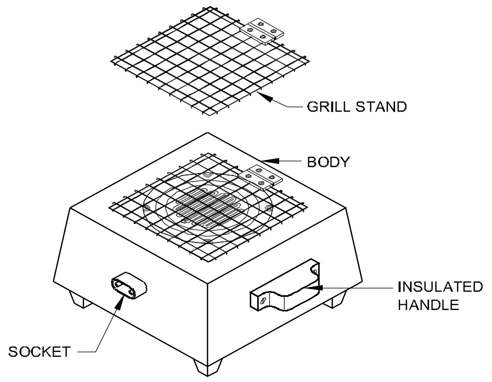
Fig 4



Grill stand: It is made of chromium/nickel plated MS rods, and hinged to the body. It supports the vessels kept on the heater and acts as a barrier between the exposed heater element and the vessel (Fig 5).

For safety, this grill should have electrical continuity to the body, and both must have earth connection. As oil or paint in the hinges interferes with earth continuity, they should be avoided. A properly earthed grill and body will enable the fuse to blow in case of accidental contact of live parts with them, thereby avoiding shock to the user.

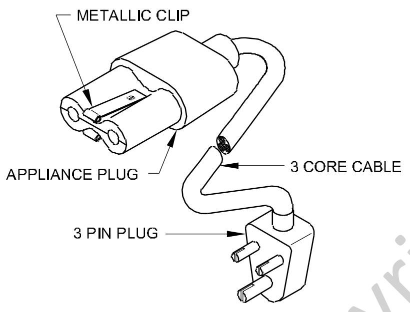
Fig 5



OPEN ELEMENT TYPE HEATER

Heater socket: This is used for plugging the power supply appliance plug. The socket (Fig 6) has two male terminals, one for the phase, and the other for the neutral. However, for safety, the heater body should be connected to the general mass of earth through the earth continuity conductor.

Fig 6



APPLIANCE POWER CORD

For this the appliance plug has two spring-loaded, metallic clips on either side of it which makes the contact with metallic enclosure of the socket when plugged. As rusting prevents proper contact of these clips with the socket, for safety, these clips and sockets are made of nickel-plated brass. If the spring tension of the clip is lost, it should be replaced. Otherwise earth contact will not be proper.

The appliance socket and pin should be tight fitting to avoid sparks and overheating. When sparks occur, the terminal points will get corroded and lead to loose connection. Such sockets and plugs should be replaced.

Safe installation: The insulation resistance between the heater element and the body should be not less than one Mega ohm.

The switch which controls the wall socket should be in the phase of the supply to ensure isolation of supply to the heater when the switch is 'OFF'.

User's safety practice: A user should avoid spillage of food articles on the heater as it will result in blowing of the fuse as well as breakage of the heater element/plate. The user should not drop metal articles on the heater as the live elements may short the body.

Precautions to be followed while repairing a heater: Check for overheated terminals of sockets and plugs. Check the cable for continuity and insulation. Check the cable near the entry points of the plugs for breakage or signs of overheating. Too rigid a portion of the cable insulation will indicate overheating, and too much flexibility is an indication of breakage of the conductor. Check the body for rust, particularly at the socket inner surface and at the fixing holes.

Rusted socket or earth clips of plugs should be replaced. Never paint them. But the rust in the fixing holes may be removed and repainted. If necessary, replace with screws of a bigger size. Heavily pitted, welded terminals of socket and plug should be replaced, and the replaced plug should be checked for proper tight fitting in the socket.

Check the heater plate for breakage. Broken plates need to be replaced. Earth continuity of body and grill plate should be checked. Insulation resistance between the live parts and body should not be less than one megohm.

Nichrome wire : Generally, all the electrical heating appliances having the heating element made of nichrome wire or ribbon. The principle of heat conversion of electrical energy into thermal energy is used in most of the appliances. The nichrome which is a alloy of 80% Nickel and 20% Chromium is used, because of the following properties:

Properties

(i) It has a high specific resistance i.e., $9x10^{-8}$ Ωm.Therefore less length of wire will be sufficient to produce the required resistance.

(ii) It can withstand the thermal stress.

(iii) Its mechanical strength is good.

(iv) It has high melting temperature i.e. approximately 1380^0C.

(v) It has low temperature coefficient i.e., 0.00017 per degree centigrade.

In most of the cases, all the heating elements are designed to produce a temperature approximately 500^0C,so far the designing of heating element these points are taken into account:

(i) The wire of proper size and capacity, according to the wattage of the heater.

(ii) Sufficient length of the wire required according to the wattage of the heater.

In most of the cases, for general heater element 20 SWG nichrome wire is used for 2000 W heater, 22 SWG for 1500 W,24 SWG for 1000 W heater and 26 SWG wire for 750 W heater.

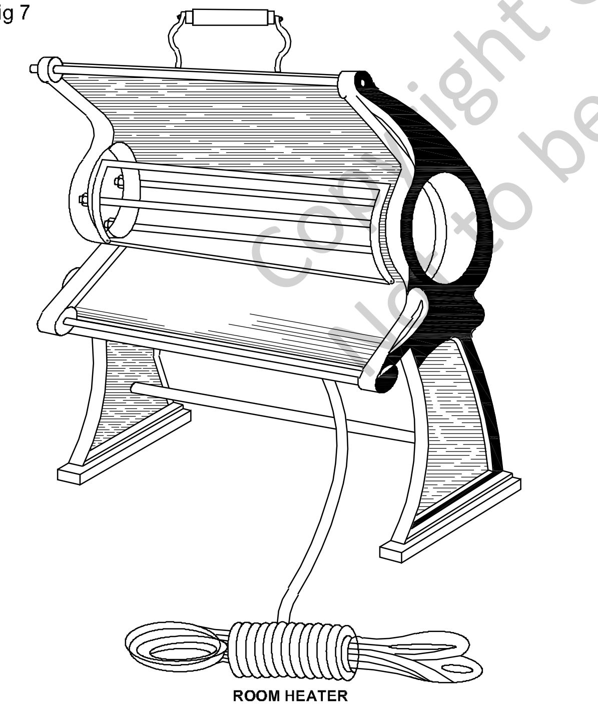
Soldering iron. A soldering iron is used for soldering the joints etc. In its simple construction the heating element is made by winding the nichrome wire or ribbon over the mica sheets.

Generally there are two elements in an iron which are connected in parallel or in series. These elements are pressed in a case of iron sheet which is placed in a solid iron. The two main leads of the element are connected to the supply in a connector. The body of the iron is connected with earth for the purpose of safety from shock. These are available in different wattages 15W, 25W, 40W, 65W, 125W, 240W,etc.

Room heater : These are also known as the radiant heater or bar type heater. These are used to heat a room, or a particular place.

In general the construction of the heater is wound with spiral nichrome wire over a china clay bar. Two ends of the element are brought out to the terminals on both the ends of the rod. The rod is fixed in the connector by means of screws, supply is given to these two ends. To increase the efficiency the polished reflector is used behined the rod (Fig 7), which radiate the heat efficiently.

Fig 7



These heaters are having sometimes the bowl of china clay and a round polished reflector.

The position of the reflector can be adjusted according to the need in any direction. The number of the bar may be one or more than one. Heating element in both the cases is fixed possibly at the focus of the reflector.

Immersion heater : As the name implies, these heaters are used in immersed conditions. These are used to heat the water or other liquid directly. The heat produced is directly dissipated to the water and thus the water is heated. In general the construction of the heating element is made of spiral shape wound with nichrome wire. The element is placed in the copper tube and insulated from the walls etc. by means of the insulated and fire proof powder or sand all around.

The ends of the tube are sealed with thermal and water proof compound. Two ends are taken to the connector for main supply. The tube is bend into the spiral shape to concentrate in a less space (Fig 8 and Fig 9). There is a level indicator marked to avoid the damage of the tube. For the safety the earth wire is connected to the tube. These heaters are available in different shape and wattage. For example 250W, 500W, 1000W, 1500W and 2000W etc.

Fig 8

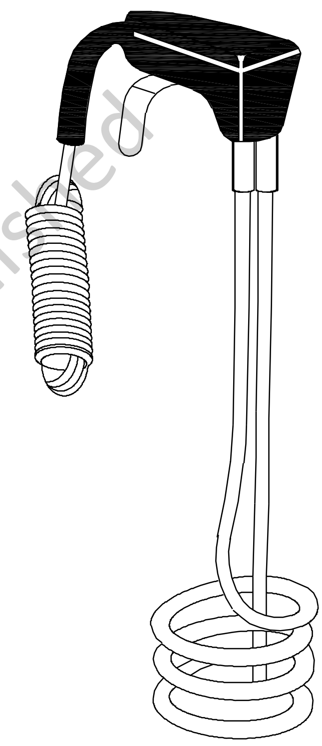
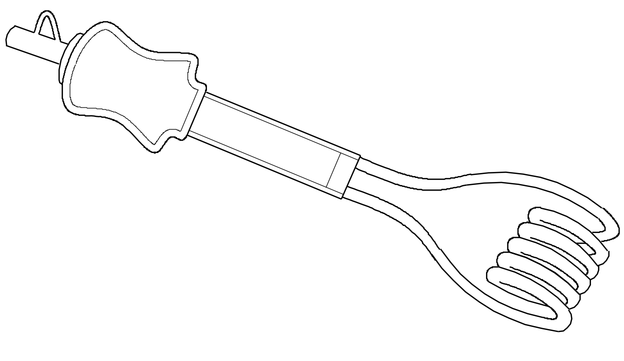


Fig 9



Immersion heater consists of

1 Metal tube containing the heating element.
2 Terminal housing made of bakelite.
3 Three core flexible cord.
4 Water level indicator.
5 Three pin plug.

Precautions in the use of immersion water heater

1 Immersion heater should be dipped upto the indicated level. In no case should water enter the terminal housing.
2 Supply should be switched 'ON', only after the immersion heater has been dipped into water.
3 Supply should be switched 'OFF' first, before taking it out of water. It should not be taken out immediately after switching OFF, but should be allowed to cool down before taking it out.

Possible faults

1 Breakage of element in the tube.
2 Element wire touching the tube at exit.
3 Metal tube might have burst.
4 Terminal housing may be broken.
5 Discontinuity due to broken cord at terminals or in plug top.
6 Leakage in cord.
7 Break in the cord.

Testing

Make use of the test lamp for testing. Connect the two ends of the testing leads to the terminals of the plug top. If the lamp does not glow, it means there is an open circuit i.e., breakage of element, disconnection of wire ends at the terminals of water heater or at the terminals of plug top or there may be breakage there in the cord.

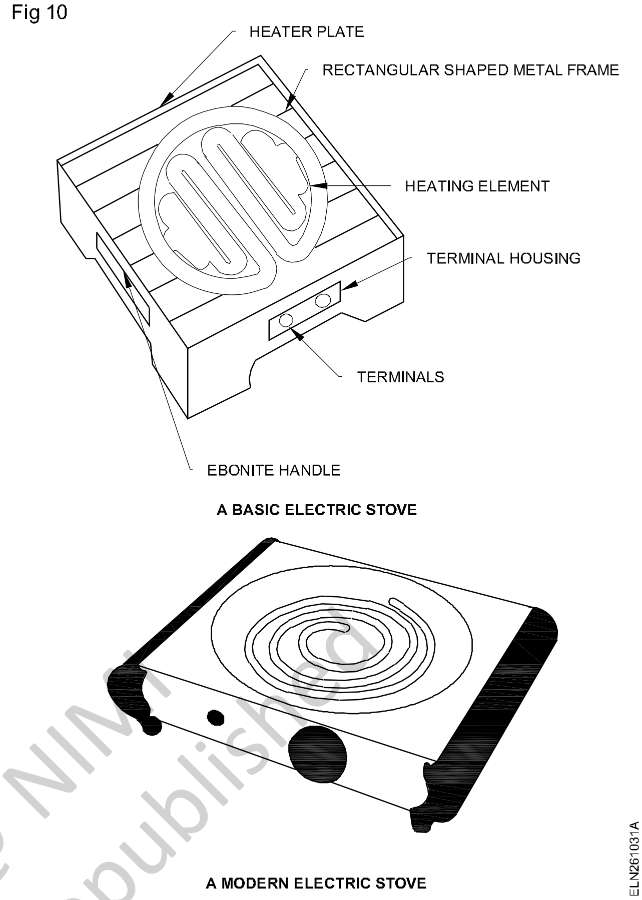
If the lamp gives full light, it means there is short circuit i.e., wire ends at the terminals are touching together. If the lamp gives dim light, it means the element of the water heater is in working order and it is called a closed circuit.

For testing the earth fault, connect one end of testing lead to one terminal of plug top and another to the body of water heater (metal part of the body). If the lamp gives light, it means there is an earth fault i.e., some part of the element is touching the body of water heaters.

Electric stove

An electric stove is a common domestic heating appliances used for cooking. It works with 240V volt AC supply and different models are available with power rating usually from 750 to 1500 watts (Fig 10).

Fig 10



The basic electric stove consists of

1 Heating element.
2 Insulator base with grooves.
3 Metal frame.
4 Power cord.

The heating element is made of coiled nichrome wire. The insulator base is made of porcelain or fire proof china clay and the heating element is placed in the grooves of the base. The base is fitted to the metal frame.

The metal frame which is made up of cast iron or iron sheet acts as a stand, provide the mechanical protection and give shape to stove. The two ends of the heating element are taken to the terminals by means of flexible cables. These flexible leads are insulated with beads of insulating material like porcelain.

Care and maintenance

If water or any other item like tea, milk etc. fails on the heating element when it is red hot, the oxidation of the heating element becomes rapid and it may get broken. Earthing should be proper and the metal frame should be properly earthed.

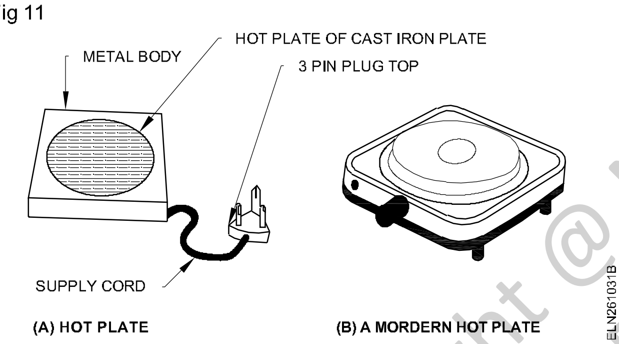
Because of alternate expansion and contraction due to alternate heating and cooling. loose connection and hence sparking at the terminal is a common problems. The end terminal should be tightened properly.

When the heating element is broken the whole heating element should be replaced. The connecting power cord should be of suitable capacity and capable of carrying the current. The power cord should not become warm or hot when the stove is ON. It should be operated with the rated supply voltage. A modern electric stove may contain controls for variable heat.

Hot plate

A hot plate is a heating appliance which is basically an electrically heated plate on which flat bottomed containers to be heated are placed (Fig 11). It requires 240V volt AC input supply and are usually available in 1KW and 2KW. It is used for cooking and for heating liquids in laboratory. A hot plate may be a single unit type or double unit type.

Fig 11



A basic hot plate consists of

1 Base.

2 Plate.

3 Heater plate.

4 Heating element.

5 Switch.

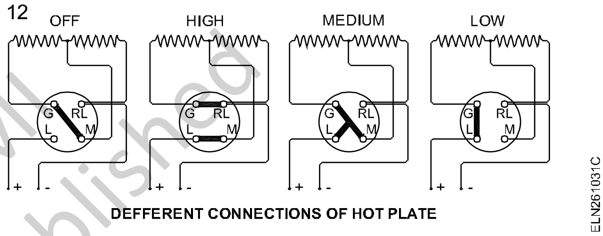
The base is made of cast iron or mild steel and may be circular or rectangular in shape. The plate is a thick circular plate made of sheet of cast iron or iron alloy and is on the top of the heater plate. Heater plate is made electrically insulating but thermally conducting material like china clay or fire clay, cement or plaster of paris.

The heating element is a nichrome wire or ribbon. The heating element is embedded in the heater plate and the heater plate is attached to the metal plate.

The end terminals of the heating elements are brought out to the power socket fitted in the base. In case of a single unit type hot plate, having one heating element two end terminals will come out. In case of twin unit type hot plate having two heating elements three terminals come out one terminal being common to both the heating elements.

In twin unit type hot plates, a rotary selector switch connects the heating elements in different position. Fig 12 shows the different connections of hot plate for various wattage output.

Fig 12



Care and maintenance

The heating element is not exposed. Commen problem are (1) burning out of supply lead elements and (2) break in the element. In case of break in the heating element, it is to be replaced.

- Loose connections should be avoided.
- Any sparking at terminals to be cleaned.
- Power cord should be capable to carry the rated current.
- Hot plate should be operated at the rated voltage.
- Hot plate should be allowed to cool after every usage, before housing it in a proper place, where the children are unable to reach it.

Microwave oven

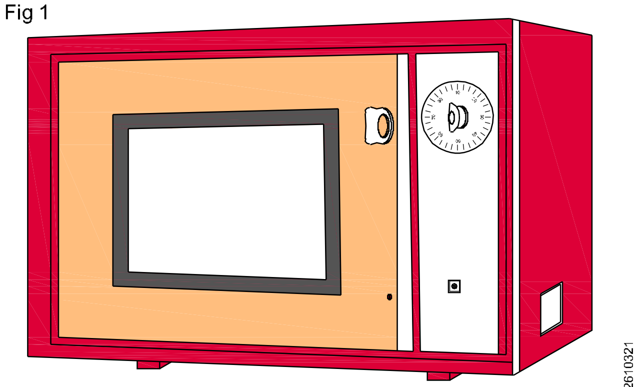
Objectives: At the end of this lesson you shall be able to
- **define microwave oven**
- **state the function of microwave oven**
- **explain operation sequence**
- **exlain the function of each components**
- **list out the problems, causes and remedies.**

Microwave Oven

It is an electronic cooking device which uses energy of microwaves to cook /prepare/perserve the foods.

Unlike the conventional ovens, microwave energy cooks the food without applying external heat (Fig 1).

Fig 1



TYPICAL MICROWAVE OVEN ASSEMBLY

Function of microwave oven

The microwaves are short electromagnetic waves of radio frequency (RF) energy which would pass through materials such as paper, glass and plastics. Aluminum and other metal tend to reflect the microwaves so they should not be used inside.

Food with a high moisture content will absorb microwave energy. As the microwave energy (frequency of approximately 2450 MHz) enters the food. the molecules align themselves with the energy. Since the microwaves are changing polarity (or direction) every half cycle, the food molecules are changing direction every half cycle or oscillating back and forth 4,900,000,000 times per second. This high speed oscillation causes friction buildup between the molecules, thereby converting the microwave energy to heat which cooks the foods.

Operation sequence

Three stages of oven operation as follows.

1 OFF condition,

2 Idle condition,

3 Cooking condition.

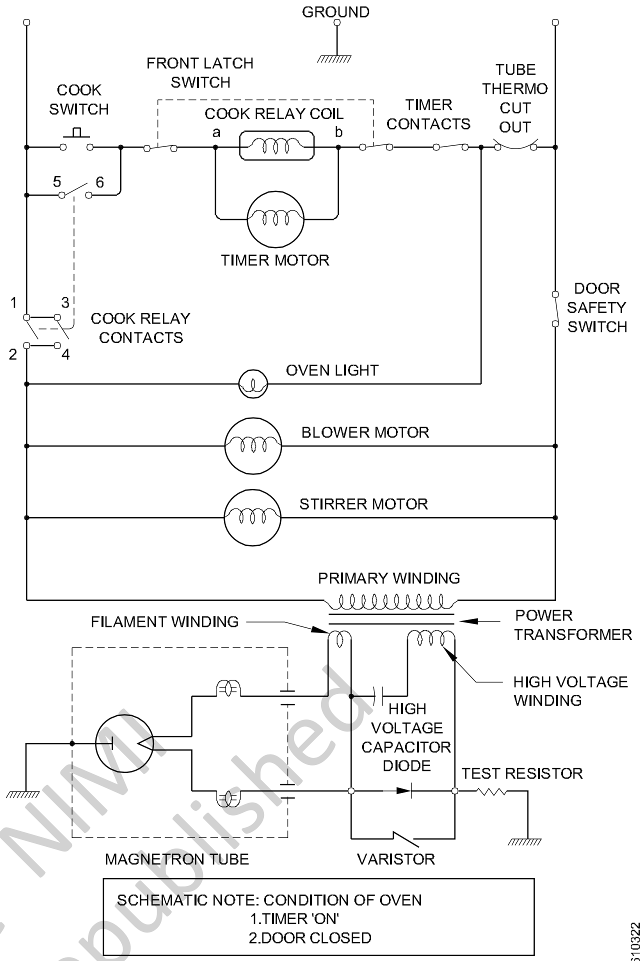
OFF Condition : When the pointer on the timer knob is at the `o' position, no component in the oven will operate.

Idle Condition : When the door is closed, both door interlock switches are activated; the front latch switch and the rear safety switch. When a cooking time is selected, the timer switch contacts leading to the cook relay coil and timer motor closes.

Cooking Condition : When the cook switch is depressed the following operations occur (Fig 2).

1 The Coil of the cook relay is energized. Terminals 5 and 6 of the relay contacts close to provide a current path to the timer motor. This also provides the holding circuit which energizes the coil of the cook relay when the start switch is released. Terminals 1,3 and 2,4 close to provide a current path to the oven light, blower motor, stirrer motor and power transformer.

Fig 2



OVEN CIRCUIT COOKING CONDITION

2 The filament winding of the power transformer 3.2 V AC heats the magnetron filament and the output from the high-voltage winding (1900VAC) is sent to a voltage-doubler circuit consisting of a capacitor and diodes. This 1900 volts is converted to approximately 3800 volts DC (negative-peak-to-peak) by the voltage doubler circuit and sent to the magnetron tube assembly.

3 The negative 3800 volts DC applied to the cathode of the magnetron tube causes it to oscillate and produce the 2450 MHz cooking frequency.

4 The RF energy produced by the magnetron tube is channeled through a waveguide into the cavity feedbox, past the stirrer blade, and into the cavity where the food is placed to be heated.

When the cooking time expires, the timer switch opens and the coil of the cook relay is de-energized. The contacts of the cook relay open with the following results:

1 The oven light goes off,

2 High voltage is cut off from the magnetron so no RF energy is produced.

3 The timer bell rings to indicate the end of the cooking cycle. The oven has reverted to the off position.

Description and function of components

Oven Light : The oven cavity light illuminates the interior of the oven so that the food being heated can be examined visually through the door window without having to open the door. The oven cavity light also serves as the cook indicator.

Blower Motor : The blower motor drives an impeller blade which draws cooling air through the oven base. This cooling air is directed through the air vanes surrounding the tube and cools the magnetron assembly. Most of the air is then exhausted directly through the back vents.

Stirrer Motor : The stirrer motor turns the stirrer blade assembly at the top of the oven cavity. The stirrer blade assembly revolves slowly and reflects the electromagnetic energy. Thus allows the RF energy to reach the food from all angles giving a uniform heating pattern.

Dual Latch Switch : Both sections of the front latch switch are activated by the latch on the door handle. A cook cycle cannot take place until the door is closed and the thumb latch on the door handle closes the front latch switch.

Timer Assembly : (Timer switch contacts) The timer switch contacts are mechanically opened or closed by turning the dial knob located on the timer motor shaft.

(Timer bell) The bell striker is mechanically driven by the timer motor and rings at the end of the cook cycle.

(Timer motor) Cooking time from 0 to 25 minutes may be selected with the timer. When the timer reaches the 0 point on the scale, the timer switch opens the circuit.

Cook Switch : when depressed, the cook switch completes the circuit to the coil of the cook relay through the front latch switch.

Cook Relay : The coil of the cook relay is initially energized by the closing of the cook switch.

The cook relay also provide a current path to the stirrer motor, the power transformer and cook light, provided the rear door safety switch is activated (closed by the door cam arm).

Thermo Cut-Out ; The thermo cut-out, located on the magnetron assembly, is designed to prevent damage to the magnetron if an overheated condition due to blower failure, obstructed air ducts, dirty or blocked filter, etc.

Under normal operating conditions, the thermo cut-out remains closed. However, when abnormally high temperatures the thermo cut-out will interrupt the circuit and stop the cycle. When the magnetron has cooled the thermo cut-out closes, and a cook cycle can be resumed.

Door safety switch : The door safety switch is activated (closed) by the cam arm of the oven door and closes the circuit.

When the oven door is opened, the door safety switch open the circuit and de-energize the cook relay coil.

Power Transformer : The power transformer consists of three windings:

1 Primary,

2 Filament,

3 High voltage.

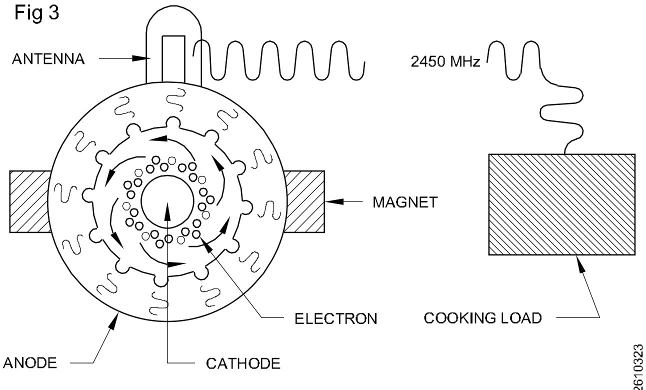
During a cook cycle, the 120 volts AC applied to the primary winding of the transformer is converted to 3.2 volts AC on the filament winding and approximately 1900 volts AC on the high - voltage winding. The 3.2 volts AC heats the magnetron filaments. This causes the tube cathode to readily emit the electrons (negative 3800 volts DC) applied to the cathode. The 1900 volts AC is fed to the voltage - doubler circuit.

Voltage - Doubler Circuit : The voltage - doubler circuit consists of a diode assembly and a capacitor. The 1900 volts AC is applied to the voltage-doubler circuit, where it is rectified and converted to approximately 3800 volts DC (negative) needed for the magnetron operation (Diode).

Magnetron Tube : The basic magnetron tube is a cylindrical cathode within a cylindrical anode surrounded by a magnetic field. When the cathode is heated by the filament winding of the transformer, electrons are given off by the cathode.

Ordinarily the electrons would travel in a straight line from the cathode to the anode. The addition of a magnetic field, provided by permanent magnets surrounding the anode, causes the electrons to take an orbital path between the cathode and anode (Fig 3).

Fig 3



BASIC MAGNETRON WITH MAGNETIC FIELD

As the electrons approach the anode, they travel past the small resonant cavities to oscillate at a very high frequency of 2450 MHz. This RF energy is radiated into the cooking cavity where food is placed to be heated.

Servicing

When troubleshooting the microwave oven, it is helpful to follow the sequence of operation in performing the checks.

Many of the possible causes of trouble will require that a specific test be performed. Note: Never operate oven with outside cabinet removed.

Troubleshooting Chart

Problem	Possible cause/ Remedies
	OFF CONDITION
Line fuse blows when power cord is plugged into wall receptacle.	Shorted wire in power cord or wire harness. Replace cord or check wiring.
CONDITION	COOKING
Blower motor inoperative	Defective blower motor - replace. Open wiring in circuit to blower. Check wiring.
Heat produced in oven load, but oven cavity light does not illuminate.	Burned out bulb -replace Open wiring in circuit to light.Check wiring.
Oven cavity light does not illuminate and no heating.	Defective cook relay/ Check and replace if necessary. Defective thermo cut-out. Replace. Open wiring in circuit to thermo cut-out. Check wiring.
Oven does not go into cook cycle when cook switch is activated.	Defective contacts on timer switch. Front latch switch defective or out of adjustment. Defective cook switch. Replace. Defective cook relay. Open wiring between the above components Check wiring.
Oven goes into cook cycle but timer does not time out.	Defective timer motor. Replace.Open wiring in circuit to timer motor. Check wiring.

Problem	Possible cause/ Remedies
Oven goes into cook cycle but stirrer motor inoperative.	Defective stirrer motor. Replace. Open wiring in circuit to stirrer motor. Check wiring.
Oven cooking light indicates cycle, but little or no heat is produced in oven load.	Shorted high-voltage circuit between voltage-doubler circuit and magnetron. Check wiring. Defective power transformer. Replace. Defective diode. Replace. Defective high-voltage capacitor. Replace. Defective magnetron. Replace. Rear door safety switch defective or out of adjustment. Check and replace, if necessary.
Oven goes into cook cycle but shuts down before end of cycle.	Thermo cut-out opened. Check circuit.
Power source fuse blows when the cook switch is depressed.	Defective power transformer, replace if necessary. Secondary circuit of power transformer is shorted. Replace.

Food mixer

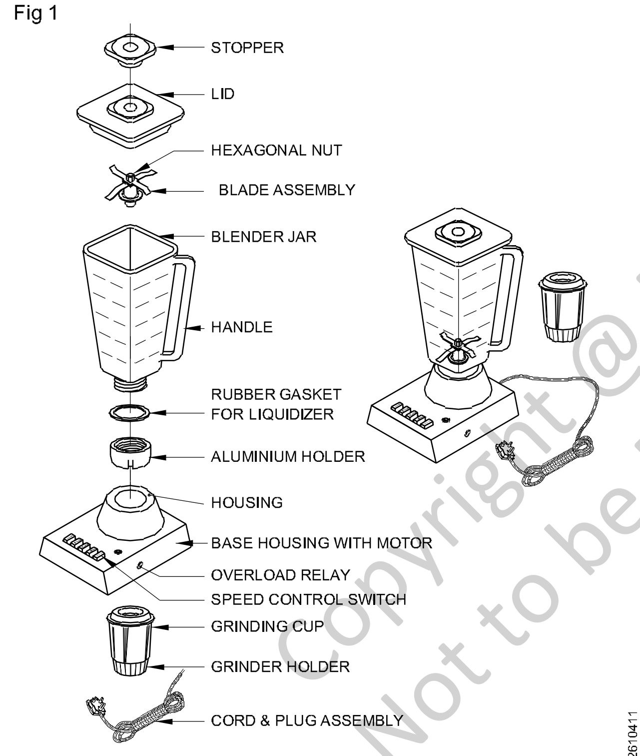
Objectives: At the end of this lesson you shall be able to
- **define the food mixer and its features**
- **state the maintenance and service procedures of mixer**
- **list their common problems, causes and suggest remedial measures.**

Food mixer

It is an electric domestic appliance which is used to mix, juice, grind and blend the fruits and food grains.

A medium sized universal motor is used in it. Fig 1 shows an exploded view of a mixer.

Fig 1



EXPLODED VIEW OF A FOOD MIXER

Features of the food mixer

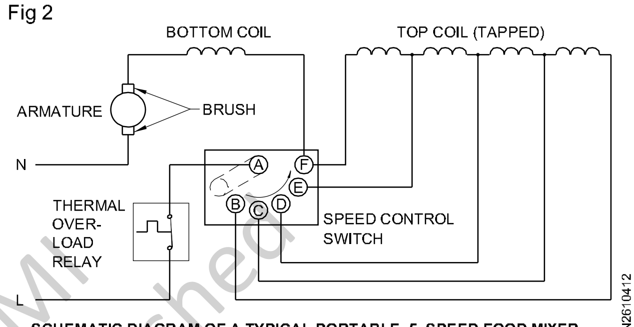
The motor housing differs widely depending on the manufacturer. Special care to be taken for vibration-free running. Safety features such as overload trip, jar mounting lock (fixing) and proper lid closing are included in the appliances.

An AC universal motor is housed in the base. The jar contains the cutting knives which is the heart of the blending action. Fig 2 shows a schematic diagram of a typical mixer.

A food mixer power rating ranges from 100 to 750 watts. The revolution of the food mixer is 3000 to 14000 revolutions per min. The desired speed is selected on the control switch.

The time rating of running the mixer varies from 1 minute to 60 minutes depending upon the type. A tapped field coil enables speed selection through a rotary or push button switch.The food mixer normally runs at 3 speeds.

Fig 2



SCHEMATIC DIAGRAM OF A TYPICAL PORTABLE 5 SPEED FOOD MIXER

Maintenance and servicing of a food mixer: The manufacturer's service manual, if available, read it a number of times and follow the instruction. First listen to the complaint from the customer and make a note of it. Visually check the mixer right from the plug to the speed selector switch connections and enter the details in the maintenance card.

Test the mixer with and without the power cord for the continuity and insulation resistance. Enter the details in the same card. The insulation resistance value for the individual part should not be less than 1 Megohm. The metal bodied mixer should have effective earth connection to the body, the power cord should be 3-core and the plug and socket should be of 3-pin/socket type with effective earth.

But double insulated (PVC body) mixers may have two core cable and 2-pin plug type. A damaged plug or power cord should be replaced. Check the brush tension and make it normal. Check the brush length; if found short by 2/3rd of its original length, replace it with the same specification brush or a brush obtained from the manufacturer of the mixer.

Check the switch for its proper function. Better to replace a faulty one with a new one having the same specification. Before opening the motor assembly, check the couplings for their proper form. Check the ply of the shaft and vertical movement to get an idea of the condition of the bearings.

Tight bearing may be due to misalignment, bend in the shaft, dried grease or lubricant, dirt, damaged commutator or due to damaged bearing. Overheating due to bearing problems will be indicated by the change of colour of the shaft near the bearing to blue colour.

While removing the motor assembly remember the holding nuts in the centre shaft, the coupling etc. provided in line with the shaft on left handed threads. Clockwise rotation will tighten them. Certain types of mixies may have right hand thread. Check these differences.

Check the winding for burnt smell or discoloured look. Ascertain through the tests whether the winding is shorted, open or has lost its insulation resistance value. If required rewind or get the rewinding done from outside agencies.

Always remember the sequence in which you opened the parts. It will help you to reassemble them without difficulty.

Check the ply between the bushings and the shaft. If the gap is too much it will be better to change the bushings. Lubricate the bearings with a thin oil as recommended by the manufacturer. One or two drops of thin oil will be sufficient. As the speed of the mixer is in the range of 3000 to 14000 r.p.m. thin spindle oil is recommended.

The ebonite washers and rubber gaskets may be replaced with new ones. While replacing see the order in which these washers and gaskets were fitted earlier and refix them in the same order.

A record may be maintained with all the required details so that if the same mixer or similar mixer comes for repair it will be easy to repair it.

Any part to be replaced should be of the same specification or from the original manufacturer preferably.

Make certain that each bearing is free on the shaft but not very much slack.

While tightening the screws on the motor housing, spin the armature with your fingers at intervals during the assembling process to ensure that it is not getting bound.

Reassemble the switch and do all the connections.

Reassemble the base plate, tighten the screw.

Reassemble the blade with the washer inside the jar and with the bottom coupling. If the coupling of the jar is not snugly fitting to the male coupling of the motor assembly, the jar coupling will get easily damaged at frequent intervals. Correct height alignments could be made by replacing or alternate sequencing of the fibre washers.

Fix the jar/container on the drive coupling.

Connect the supply cord as per the circuit diagram.

Test the mixer for continuity and insulation resistance. Minimum acceptable insulation resistance value is 1 Megohm.

Connect the supply, and test for its working.

Repairs

Some of the common troubles encountered in the repair of mixers are given in the Table 1 which also gives the possible causes and their remedies.

Table 1

Trouble Shooting Chart

Problem	Possible cause	Corrective action
Mixer does not run.	a) Overload trip might have tripped.	a) Reset the overload relay and advice the customer not to overload the mixer in future.
	b) No power at the outlet.	b) If the mixer is running in your shop but not running at the customer's house ask the customer to get the socket repaired.
	c) Defective power cord or plug.	c) Test, repair or replace the power cord/plug.
	d) Locked shaft.	d) Unplug the supply and try to rotate the shaft by hand. Clean the bearings; lubricate the bearings as advised by the manufacturer. If the shaft is still tight, recondition or replace the bearings. The shaft might have got bent. Replace the shaft or armature assembly.
	e) Worn out brushes.	e) Replace the brushes and loose springs
	f) Open circuited.	f) Check the field and armature windings. If found defective get it rewound or replace.

Problem	Possible cause	Corrective action
Blows fuse when switched on.	a) Shorted power cord.	a) Replace the cord.
	b) Locked shaft.	b) As in 'd' above.
	c) Defective armature or field coils.	c) Test the windings for short. If short is found, rewind or replace.
	d) Poor insulation resistance.	d) Check, test and repair.
	e) Low capacity fuse.	e) Check the capacity of the fuse against the mixer rating. Replace if required.
Slow speed with weak power.	a) Wrong materials or too much quantity loaded for mixing.	a) Verify from the customer about the load and advise accordingly.
	b) Jammed rotor.	b) Rotate by hand. If found tight, clean the bearing / bush and lubricate it. If it is found still tight, change the bearings or check for bent shaft.
	c) Tight blade assembly.	c) Check the spring, washer and assembly. Repair or replace if required.
	d) Worn out brushes or loose spring.	d) Check, repair or replace if required.
	e) Bent shaft.	e) Check, repair or replace if required.
	f) Partially shorted or grounded winding or poor insulation resistance.	f) Check, test and repair/rewind if required.
Mixer runs but becomes hot.	a) Overloading of mixer.	a) Bring down the load in the mixer or advise the customer to go for a higher capacity mixer.
	b) Time rating of mixer is exceeded.	b) Check the duration the mixer is switched on by the customer and compare with the mixer rating. Advise accordingly.
	c) Bent shaft and rotor is rubbing the stator.	c) Check, repair or replace if required.
	d) Improper coupling.	d) Check, repair or replace if required.
	e) Shorted winding.	e) Check, test and rewind if required.
Mixer makes noise	a) Dry bearing.	a) Check and lubricate.
	b) Loose mounting screws.	b) Check and tighten the loose screws.
	c) Rotor rubbing against stator.	c) Check the alignment and shaft for bend. Repair or replace the shaft if required.
	d) Bent fan blades.	d) Check and straighten the blades. If not possible replace the fan blades.
	e) Broken or missing gasket.	e) Replace.
Motor runs on one speed only.	a) Check the speed selector switch connections and function of switch.	a) Repair or replace the switch.
	b) Partially burnt out field winding.	b) Test with multimeter. Repair or rewind.
Bad sparking at motor brushes.	a) Struck or worn out or loose brushes.	a) Check, reshape the brushes, replace the springs or reposition the brushes for proper tension.
	b) Pittings or uneven commutator surface.	b) Use sand paper or turn the commutator on a lathe.

Problem	Possible cause	Corrective action
Mixer gives shock.	a) Water leaking and coming in contact with live terminals. (Double insulated mixers with plastic body and two pin plug. No earth connection).	a) Check the drain hole in the coupler head assembly for blockage. Check the jar examine for leakage due to loose shaft or worn out bearing, ebonite washer breakage. Repair or replace.
	b) Vent hole in the mixer body clogged.	b) Clean the vent hole.
	c) Damaged power cord.	c) Check and replace if required.
	d) Absence of earth connection.	d) Check the earth connection in the mixer motor, power cord and at socket. Repair and re-do the earth connection if required.
	e) Live parts coming in contact with metal body.	e) Check with a Megger and take corrective action if required.
Smoke coming from coupling.	a) Improper seating between coupling.	a) Check whether male and female parts of the coupling are properly seated. If not include additional washers in the detachable blade assembly to make proper seating between couplings.
	b) Worn out coupling.	b) Check and change the coupling if required.
	c) Misaligned coupling.	c) Check the motor assembly and re-align if required.

Wet grinder

Objectives: At the end of this lesson you shall be able to
- **define the wet grinder**
- **state the different types of wet grinders**
- **explain the parts of a wet grinder**
- **explain the possible faults in wet grinders and their remedies.**

Wet grinder

It is a domestic electrical appliance, which is used to grind the wet grains.

Types: There are three types of wet grinders

– Conventional (regular) wet grinder.

– Table top wet grinder.

– Tilting wet grinder.

Conventional (regular) wet grinder (Fig 1)

The most common wet grinder used in houses is the container rotating type wet grinder.

Parts

The important parts of a wet grinder are :

– Motor

– grinding stone

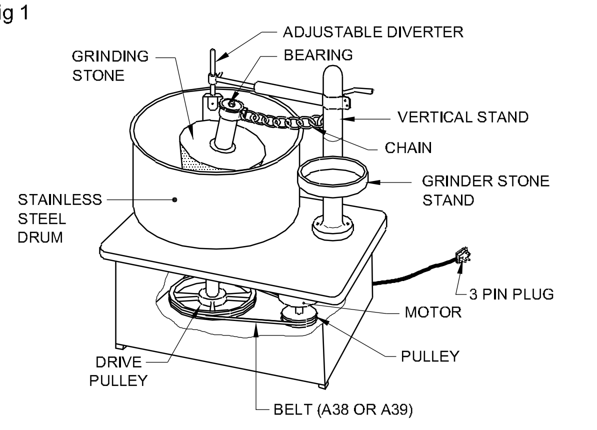
– container

– pulley

– belt

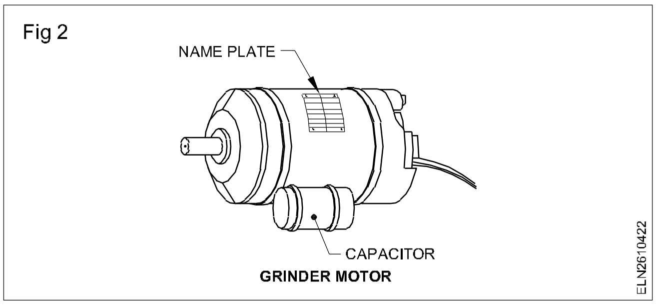
– frame and stand

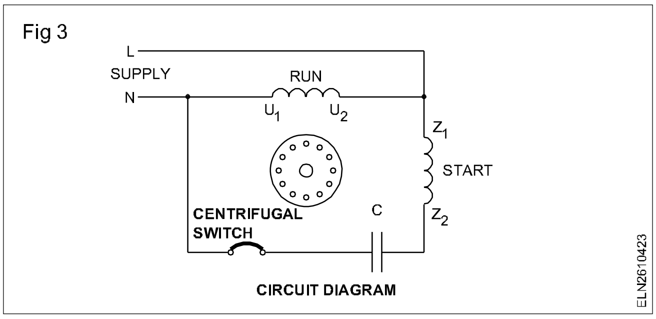
Fig 1



CONVENTIONAL WET GRINDER

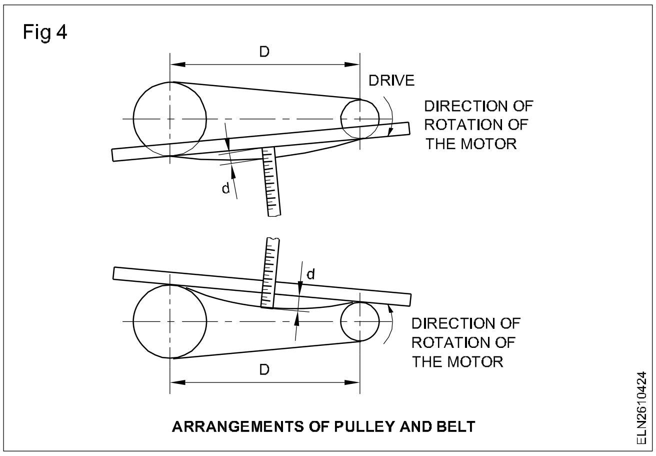
Motor: The motor used in the wet grinders is usually the capacitor start-induction motor (Fig 2 & 3). It has two windings. Both the starting and running windings are energised to start the motor, when the 70 to 80 % of the rated speed is reached, the starting winding is switched off by the centrifugal switching system. The motor then operates only on running winding.





Stone: The grinder stone consists of two parts of stones. One male and one female. The male part grinds the grains during rotation against conical cavity in the base (female stone). This female part is actually attached to the stainless steel container which rotates when the motor is energised. Both the stones are manufactured with hard granite which is usually whitish black in colour.

Pulley: The drum speed is lower than the motor speed, normally 500 to 600 r.p.m. The motor speed is normally 1450 r.p.m. and the speed of the drum is reduced by using a larger diameter pulley than the driven pulley, usually in the ratio of 1:3. The transmission of force between the driver pulley and the driven pulley is through a V belt of type No A 36 or A 39 (Fig 4).



Frame and stand: The grinding stones, motor pulleys are all housed in a rectangular frame with sunmica or stainless steel covering or plastic moulding for decoration as well as safety. A separate vertical stand is provided on one side of the grinder for holding the male grinding stone. If the MS frame is used, it is usually to be chromium plated.

Wet grinder- maintenance and servicing: In wet grinders, the trouble may be classified into two types. Electrical faults and Mechanical faults. Some mechanical faults create electrical faults too.

Some common problems and their rectifications are given in the Table 1.

Table -1

Sl.No.	Complaints	Causes	Test and remedy
1	Motor does not start	Short-circuited windings. Grounded winding. Open circuited windings. Broken wire from line cord to windings. Defective capacitor. Blown fuse. Excessive load. Defective centrifugal switch.	Rewind the windings. Rectify or rewind the windings. Solder the joints; if not possible rewind the windings. Solder the broken wire in the line cord or change the line cord. Replace the correct capacitor. Find the cause and replace the fuse. Reduce the load. Rectify or replace the defective switch.
2	Motor does not start but will run in either direction when started manually	Defective capacitor. Contacts of centrifugal switch not closed. Starting winding open.	Replace the capacitor. Clean the contacts of the centrifugal switch and check for operation. Replace, if found defective. Solder the open joints or rewind the winding.
3	Motor starts but heats up rapidly	Centrifugal switch not opening. Short-circuited winding. Grounded winding.	Rectify or replace the centrifugal switch. Rewind the windings. Rectify or rewind the windings.

Sl.No.	Complaints	Causes	Test and remedy
4	Motor runs too hot	Short circuited windings. Grounded winding. Bearing too tight. Short capacitor. Worn out bearings.	Rewind the windings. Rectify or rewind the windings. Clean and relubricate the bearing. Replace the capacitor. Replace the bearings.
5	Motor runs slow.	Insufficient lubrication or foul lubrication that tends to bind the motor shaft.	Clean and re-lubricate the bearing.
6	Motor slows down and runs with insufficient power under working condition.	Short circuited windings. Open circuited windings. Shaft bent.	Rewind the windings. Solder the joints; if not possible, rewind the windings. Straighten or replace the shaft.
7	Motor runs intermittently	Intermittently open line cord.	Repair or replace the line cord.
8	Motor is noisy	Worn out bearings. Excessive end play. Bent shaft. Unbalanced rotor. Burrs on shaft. Loose parts. Worn out belts. Misalignment. Worn out centrifugal switch. Rotor rubs stator.	Clean and lubricate or replace the bearings. If necessary, add additional end play washers. Straighten or replace the shaft. Balance rotor. Remove burrs. Tighten the parts. Replace the belts . Align pulleys correctly. Replace centrifugal switch. Find the cause and rectify.
9	The user gets a shock	Contact between live parts and body of the motor. Broken ground strap. Poor ground connection.	Rectify isolation between body and the live parts of the motor. Replace ground strap. Inspect and repair ground connection.
10	Reduction in power of the motor. Gets too hot	Short-circuited or grounded windings. Sticky or tight bearings Interference between stator and rotor.	Rectify or rewind the windings. Clean and re-lubricate the bearings. Install new bearings.
11	Motor fuse blows	Grounded or short-circuited windings. Low capacity of fuses Grounded near the switch end of the winding.	Rectify or rewind the windings. Replace with proper capacity of fuses. Repair or rewind the winding.
12	Smoke from motor (motor burnt out)	Overload. Shorter windings. Faulty centrifugal switch. Frozen bearing. Short capacitor.	Reduce the load. Rewind the windings. Repair or replace the centrifugal switch. Clean and lubricate or replace the bearing. Replace the capacitor.
13	Rotor rubs stator	Dirt in motor. Burrs on rotor or stator. Worn out bearings. Bent shaft.	Clean the motor. Remove burrs. Replace the bearing. Straighten or replace the shaft.

Sl.No.	Complaints	Causes	Test and remedy
14	Excessive bearing wear	Belt too tight tension Dirty bearings Insufficient lubrication Thrust over load Bent shaft	Correct the mechanical condition. Clean and lubricate or replace the bearing Lubricate with appropriate lubricant. Reduce thrust load Straighten or replace the shaft.
15	Radio interference	Faulty ground Loose connections Defective suppression	Rectify poor ground connections. Tighten loose connections. Check filter, capacitors, chokes, if possible or replace the complete filter unit.

Causes of failure in drive belts

Appearance	Causes of failure
Worn out sides.	Normal wear, misalignment, grit or dust
Underside cracked, belt hardened.	High temperature
Narrow spots.	Broken cords from prying or running belt on to sheaves.
Swollen and spongy,	Belt exposed to oil, grease or chemicals.
Spot wear or burns	Slippage when starting or at peak loads.
Ply separation	Sheave too small
Excessive stretching	Broken internal cords, possibly from too much tension.
Frayed or gouged	Misalignment, rubbing, damaged sheaves.

Safety measures

- Make sure power is turned off before working on electrical equipment.
- Plug to be removed from the socket.

Maintenance practices: An electrical machine or appliance to be maintained according to the programme already made. Certain maintenance practices to be observed are,

Measuring slack in V-belt and chain drives

Distance between shaft centers (cms)	Proper amount of sag (cms)
45	9
60	12
75	15
90	18
105	22
120	25
135	28
150	30

– Daily maintenance

– Monthly maintenance

– Yearly maintenance

Daily maintenance: The parts are to be cleaned with cloth and the stone bearing is to be oiled. Inspect the belt tension and vibration.

Monthly maintenance: Oil and grease the main shaft of the grinder. Insulation test is to be carried out and recorded in the sheet provided.

Yearly maintenance: The electrical machine must be removed and overhauled. Insulate the winding by applying varnish. Check all the mechanical parts and rectify the defects, if any.

AC ceiling fan

Objectives: At the end of this lesson you shall be able to
- **define the ceiling fan**
- **explain the construction of a ceiling fan**
- **describe the dismantling and assembling procedure for a ceiling fan**
- **state about electronic fan regulator and its advantage**
- **describe the causes for common faults and their remedies.**

Ceiling fan: It is a domestic electric appliance which is hanged from ceiling to circulate air for cooling purposes. The capacity of the fan is usually expressed in cubic feet per minute and is determined largely by the length, pitch and speed of the blades.

Construction: The ceiling fan consists of a:

– rotating part

– stationary part.

The rotating part (Fig 1) consists of a:

– body (rotor)

– fan blades

– bearings

– squirrel cage winding.(Rotor)

The stationary part consists of a:

– canopy

– shackle, bolt, nut and split pin

– suspension rod (down rod)

– terminal block

– capacitor

– stator winding.

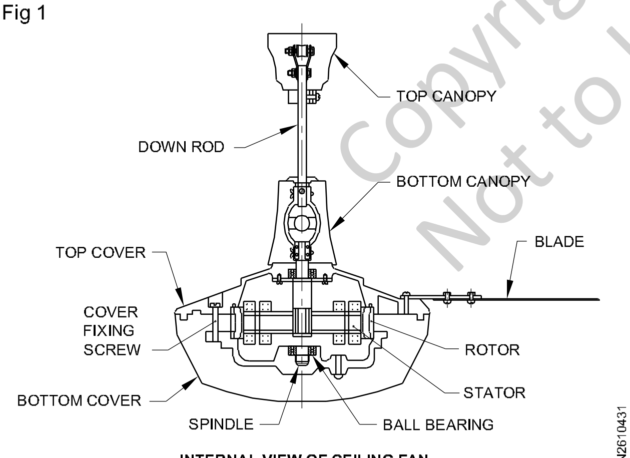
The stator winding has a:

– starting winding

– running winding.

Figs 1 and 2 shows the parts of a ceiling fan.

Fig 1



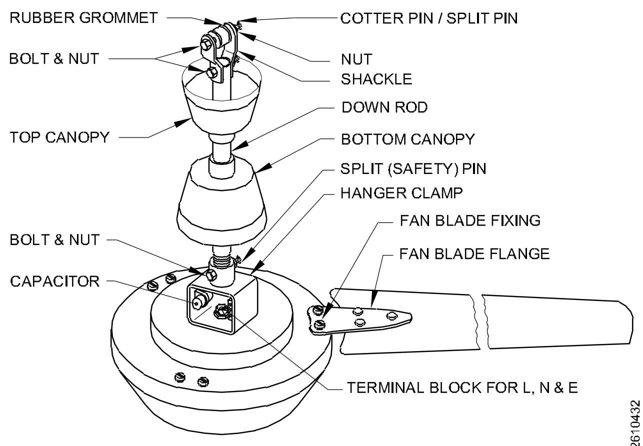
INTERNAL VIEW OF CEILING FAN

The rotor and the bottom cover are integrally diecast in high conductivity aluminium alloy which gives better accuracy and thus improves the efficiency of the cooling system.

The present day fan motor has a capacitor to give a good starting torque.

The top cover is made of aluminium diecast.

Fig 2



OVERALL VIEW OF CEILING FAN

The fan blades are made from aluminium sheet. The size of the fan blades will depend on the area of the room, usage and appearance. The performance of the fan depends on the number of blades and their pitch angle, say 10 to 15^o. Ceiling fans are available with three or four blades. The size of the fan is generally determined by its **sweep**. The following sweeps are available, 900 mm, 1050 mm, 1200 mm and 1400 mm.

The body (rotor) and blades rotate freely with the help of ball bearings or bush bearings which are housed on the top and bottom covers of the fan. The blade is fixed to the top cover and is fastened by clamps and bolts.

The entire unit is then hung to from the ceiling with a suitable G.I. pipe threaded on both sides and tightened with a suitable check nut, and with a split pin so as to prevent the entire unit from falling. The ceiling top clamp must be fitted to the ceiling hook with a shackle and bolt and nut.

The starting winding is connected in series with a capacitor and the running winding is connected across the supply. The two windings cause a rotating magnetic field. The capacitor used is an electrolytic, non-polarised one. The capacitor value varies according to the sweep of the fan. i.e. from 2 micro farad to 5 micro farad.

Regulator: The speed of the fan can be varied by changing the applied voltage.

The most common method is to vary the applied voltage by

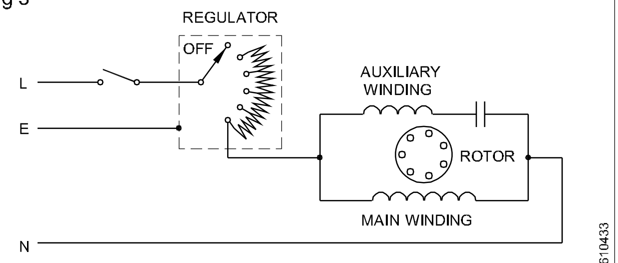
– adding series resistors to lower the voltage

– adding series inductors or tapped reactors to lower the voltage.

Fig 3 shows the schematic diagram of a fan with a resistance regulator .

The speed control of the fan may be obtained by means of a tapped-reactor (induction coil) circuit, which is normally used in the smaller fans. Now-a-days electronic regulators are gaining more popularity. They are small in size and dissipate no heat.

Fig 3



FAN CONNECTION USING A RESISTANCE TYPE REGULATOR

Care and use: Manufacturers are very careful to balance the fan blades and other moving parts of the fan. The technician should also be careful in assembling and working around the fan so as not to damage the blades or disturb their balance.

Carelessness in handling will cause the blades to wobble or vibrate, which will be noisy and shorten the life of the fan. Check the blade attachment screws periodically since a loose screw can cause noise and/or wobble.

Dismantling and assembling of fans

- Disconnect the supply by switching off the control switch and removing the circuit fuse or switching off the main isolating switch.
- Remove the blades by reaching to the height of the ceiling fan by climbing a stable elevation (ladder or table).
- Disconnect the wires from the ceiling rose.
- Lower the top canopy.
- Bring down the fan after removing the bolt from the shackle and clamp.
- Disconnect the supply cord from the terminal block and separate the down-rod along with the canopy from the condenser house.
- Note down the connection and colour of wires, if any, and disconnect the fan terminal from the terminal block.
- Remove the decorating cup, if present, by unscrewing in an anticlockwise direction and remove the false cover.
- Mark and unscrew the cover-fixing screws and separate out the bottom cover and the rotor.
- Remove the split pin and the set screw.
- Remove the condenser (capacitor) from the housing.
- Pull out the rotor and stator from the top cover.
- Inspect all the parts which were removed.
- Replace the defective components.

Assembling: Assemble the dismantled parts in the reverse order to that of dismantling. Check the screws whether they are tightly fitted.

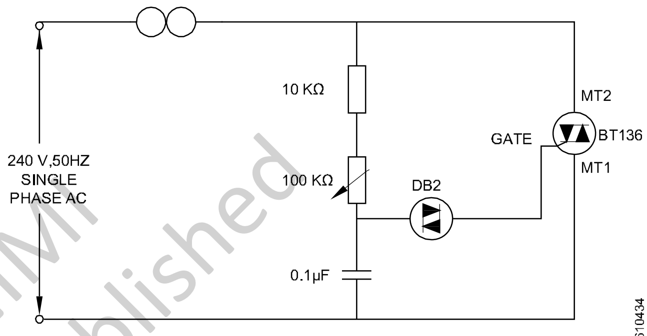
Before installing the ceiling fan, care has to be taken to test the fan for its insulation resistance between the winding and the body.

Electronic fan regulators

It is an electronic controlling device which regulates / controls the speed of the fan.

The conventional type regulators which are bulky in size, use a tapped resistor to control the speed of fan, consumes considerable amount of energy. The number of speed can be achieved is only limited upto 5 different speed. But the electronic regulators over come these problems by using electronic components. Circuits diagram of electronic regulator using triac and diac is given in Fig 4.

Fig 4



CIRCUIT DIAGRAM

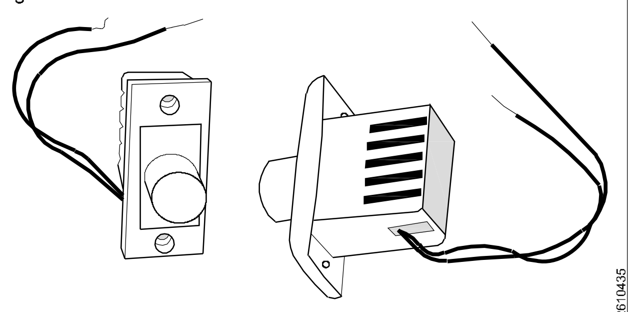
Advantages of the electronic fan regulators

1 It provides a continuous and step less speed control.

2 No power loss and energy loss at all the speed.

3 Compact, small size and less weight (Fig 5).

Fig 5



ELECTRONIC FAN REGULATOR

4 Simple circuit and less number of components used.

5 More efficient when compare with conventional type regulators.

6 Cost - effective .

7 Simple to operate and smooth operation.

General faults, its causes and remedies are given in Table 1.

Table 1

General faults and remedy

Fault	Causes	Remedy
Noise	1 It is due to worn out bearings or absence of lubricating oil or grease.	The bearings must be replaced, if worn out. Otherwise lubricate with a proper lubricant.
	2 Humming or induction noise is due to non-uniform air gap due to the displacement of the rotor.	Dismantle and reassemble properly.
Low Speed	1 It is due to defective or leaky capacitor.	Replace the capacitor with the same value.
	2 Low applied voltage.	Check the voltage and adjust, if possible.
Jamming	1 It is due to misalignment.	Dismantle and assemble properly, after the proper lubrication.
	2 Defective bearing.	Rectify/replace the bearing/bush.
Not starting	1 Supply failure.	Check the supply points.
	2 Open in winding.	Check for the continuity of starting and running winding.
	3 Condenser open or short.	Check the capacitor with a Megger.
	4 Open in regulator/ switch/ line	Check for open or loose contact in the regulator/ switch/ line.

Table fan

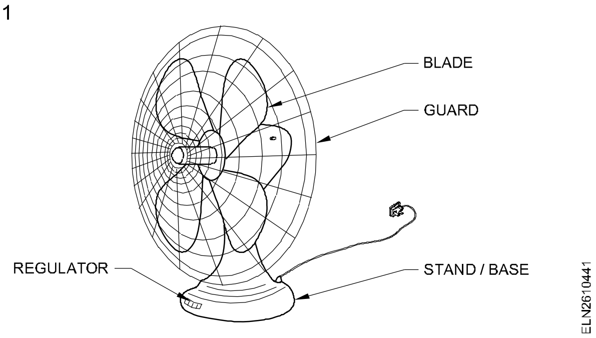
Objectives : At the end of this lesson you shall be able to
- **describe the construction and working of a table fan**
- **list the faults and remedies in a table fan**
- **describe the safe procedure of dismantling and assembling a table fan.**

Table fan

The table fan is also called the desk fan which can be oscillating or non-oscillating. They are commonly mounted on a heavy base and are furnished with a set of blades.

Oscillating fans are so termed because they oscillate in a back and forth motion as the motor of the fan rotates. In this manner they can move a larger volume of air in the room or area in which the fan is placed. The table fan is a portable fan which can be kept on the table or wherever air circulation is needed (Fig 1).

Fig 1



The table fan motor is mostly of a capacitor start or split phase, single phase induction type.

Construction: The table fan has parts that are stationary and rotating.

The stationary part consists of:

– guard (front and back)

– body and stand

– oscillating unit and gearbox

– regulator

– winding (stator)

– capacitor

– bush bearings (or)

– captive ball bearings.

The rotating part consists of:

– squirrel cage rotor

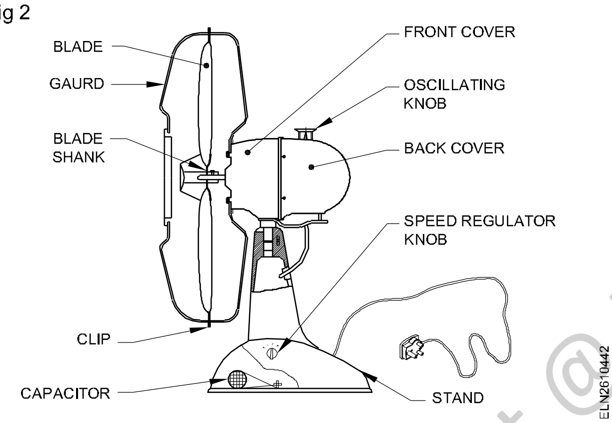
– fan blades.

Construction: The body of the table fan is usually made of diecast iron or aluminium alloy. The body is fitted or mounted to the heavy base stand, made of diecast iron or aluminium.

The body consists of stator windings. There are two sets of coils called starting and running windings. The windings are placed in slots of laminated iron core. The winding ends are brought out to the terminal block or connector. A flexible cable from it connects to the supply main via the regulator. The regulator, capacitor, and the switch are fitted in the space provided at the stand.

The front and rear of the the fan guard's are made out of wire mesh which covers the blade. It prevents the external objects coming in contact with the blade thus preventing an accident. The blades' assembly is fitted to the rotor shaft with a bolt (Fig 2).

Fig 2



The blades are fabricated out of aluminium for light weight. Modern table fans have moulded blades of plastic material. The sweep of the blade varies from 100mm to 400mm. The number of blades varies from two to six. The speed of the fan is limited to 1000 r.p.m.

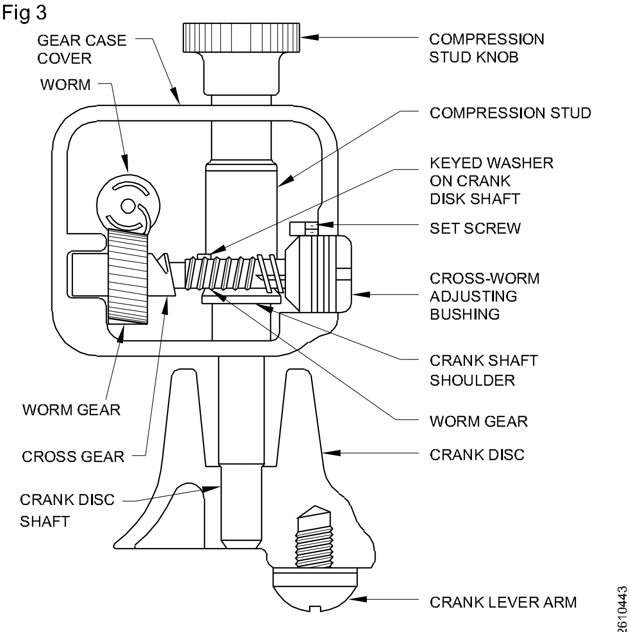
Oscillating unit:

The oscillating unit mechanism (Fig 3) consists of a worm gear of a motor shaft that engages a gear on a short jack with the gear on the vertical shaft. A disc attached to the lower end of the vertical shaft rotates at a very slow speed and by means of a stout lever attached to the disk at one end and the motor at the other end, the fan is caused to oscillate. This principle is employed in most oscillating fans.

Some models use a vertical shaft with a knob that is built into the gear mechanism with a clutch device. This design permits the fan to be used either as a stationary or oscillating model.

Bearing: Most of the fan motors use phosphor bronze sleeve bearings mounted in the bell housings, and use felt wicks to supply oil to a small hole drilled through the bearing wall. The felt receives oil from a hole in the bell housing. Most of the fan motors use a captive ball bearing to locate the rotor. It is held in place by spring clips in the bell housing and is self-aligned.

Fig 3



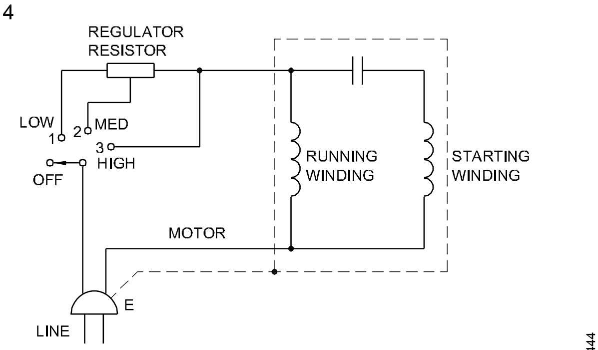
OSCILLATING MECHANISM

Faults and remedy: The faults in a table fan may be

- mechanical fault
- electrical fault.

Servicing: As was mentioned earlier, a fan consists of a motor, blade assembly and selector control switch. Most fans use a series-inductor or resistor in the speed control system. The majority of the three-speed fans employ the tapped series resistor control. In a three-speed fan not all the series resistors are used except in the low speed (Fig 4).

Fig 4



SCHEMATIC DIAGRAM OF A THREE-SPEED FAN MOTOR. THERE ARE NO ELECTRICAL CONNECTIONS TO THE ROTOR OF THIS MOTOR

Then, if the fan motor will run only on high or medium speed but not on low speed, the problem is usually in the portion of the series resistor between the medium and low terminals. Or, if the fan motor runs only in the high position, the trouble is in the series resistance between the high and medium terminals. Also check for a dirty switch and a loose contact or wire. Often a dirty switch contact will cause one or more speeds to go dead.

If a fan runs on any one speed, the chances are that the motor is in good operating condition. For example, if it will runs on medium but not on high or low, the switch is almost surely faulty. Most of the time, cleaning the control switch contacts with a contact cleaner will solve the problem. If it does not, replacement of the switch is the only answer. If a resistor is found by a continuity test to be either open or shorted, it should be replaced.

A fan that runs slowly may have shorted field winding or it may have a defective speed control. Lack of proper lubrication can also cause a fan to operate more slowly than normal. For specific information on lubrication, check the user's guide or the service manual.

If the fan motor refuses to run at all, check the cord-set. The cord set because of constant pulling, might have opened wires; the line cord itself may have problems near the plug.

The wires may be broken inside the insulation. Since most of the plugs are of the moulded-on type, the only repair usually is to cut off about 8 or 10 cms of the cord and install a replacement type line plug. If the jacket of the cord itself is worn out, frayed, or broken in places, replace it.

If the fan is not oscillating the cause may be with the compression stud, worm gear and pinion and also the spur gear (broken teeth). Sometimes bent shaft causes the oscillation to stop.

Condition of fan and suggested action

Motor does not run.

- Check the cord-set, selector switch, winding and connections for continuity.
- Check for binding rotor.

Motor does not respond properly when the selector switch is operated.

- Check the speed control switch.
- Check the series resistance or the reactance choke.

Motor runs hot, slowly or intermittently; fan consumes above-normal power.

- Check for shorted winding. If defective, replace the complete motor winding.
- Check for bent rotor shaft.
- Check for bound or frozen bearings. Clean and lubricate the bearings.

Fan is noisy or vibrates.

- Check the blade for distortion, breakage, warpage, imbalance and misalignment.
- Check the blade for loose hub or elements.
- Check the bearings for dirt or lack of lubrication.
- Check the rotor shaft. If it is loose or bent, replace the rotor.
- Check for steel chips in between stator and rotor. Remove the rotor and blow out the winding with compressed air, if any chips are found.
- Check for loose guards.
- Check whether the rotor is rubbing with the stator.
- Check for loose or missing screws.
- Check to see that the blades are out of balance.

Fan does not oscillate.

- Check the compression stud, worm gear and pinion.
- Check the spur gear for broken teeth.
- Check for a bent rotor shaft.
- Check the spur gear pin for proper setting. If it is loose, either knurl the end slightly and press it into place or replace the complete gear assembly.

Fan has magnetic hum.

- Check the air gap for unevenness. If the gap is incorrect, loosen the field screws and correct the position of the field.
- Check the armature for a bent shaft.
- Check for worn out or loose bearing fit. If bearings are defective, replace them. When replacing, clean the gear case of all old grease. The bearing swivel stud washers and rotor shaft should be lubricated with a light film of SAE-30 motor oil.

Bearings of the oscillating mechanism rattle.

- Check for worn out bearings, particularly at the motor end.
- Check the rotor shaft for excessive wear.
- Check for proper grease. Clean out the gear case and replace with the grease recommended by the service manual.

How to dismantle?: Follow the manufacturer's instructions and drawing. If they are not available, the steps suggested here may be of use.

- Open the front guard by sliding up the guard clips. Pull out the decorating cup.
- Unscrew the blade set by unscrewing the screw on the blade shank bush at the back.
- Unscrew four numbers of hexagonal head bolts/ screws and take out the back guard.

- Unscrew the oscillating knob-fixing screw and remove the knob.
- Unscrew the back cover fixing screw at the back and take out the back cover.
- Disconnect all connecting leads from the motor terminal after proper marking.
- Unscrew the link-fixing screw to the rotating pivot.
- Unscrew the pivot pin-holding screw from the stand.
- Remove the motor from the stand. Take care of the steel ball.
- Unscrew the three grub screws from the front cover where the back cover sits. Separate and remove the back cover with the gearbox from the front cover by lightly tapping the spindle backward. Take out the rotor.
- Unscrew the three screws fixed on the back cover to remove the gearbox.
- Now check up the components. These should be repaired/replaced as the case may be.
- Unscrew the bottom base screw at the bottom of the stand and remove the base plate. Check up the connections, resistor and switch etc. Repair/replace the defective parts.

The assembling is to be carried out step by step in the reverse order to that of dismantling.

Transformer - Principle - Classification - EMF Equation

Objectives: At the end of this lesson you shall be able to
- **define a transformer**
- **explain the construction of two winding transformer**
- **state the reasons for laminated silicon steel being used as core material.**

Transformer

Transformer is a static electric device which transfer the electric energy from one circuit to other without changing the frequency and power.

The three-phase synchronous generator is used extensively to generate bulk power. The voltage levels at which this power is generated is typically in the range 11 kV to 22 kV. Electrical power is to be provided at a considerable distance from a generating station. It is possible to transmit the generated power directly but this results in unacceptable power losses and voltage drops.

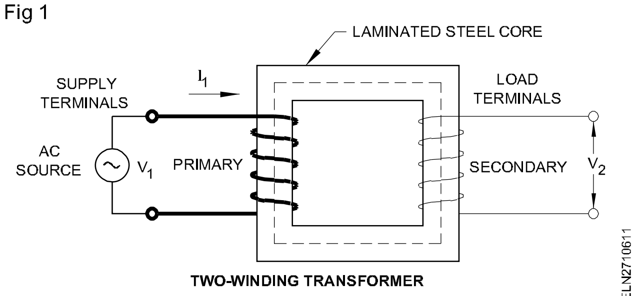
Transmission voltages vary up to the 400 kV level. This is made possible by power transformers. At the receiving end this high voltage must be reduced because ultimately it must supply three phase load at 415V or single phase load at 240V.

The transformer makes it possible for various parts of a power system to operate at different voltage levels.

> **Standard safety norms: Trainees can be instructed to refer the standard safety norms related with transformer in the International Electrotechnical commission (IEC - 60076-1) for the further details.**

Two-winding transformers: A transformer consists of two stationary windings generally called as high voltage and low voltage sides which are electrically isolated but magnetically coupled (Fig 1). The coils are said to be magnetically coupled because they link a common flux.

Fig 1



TWO-WINDING TRANSFORMER

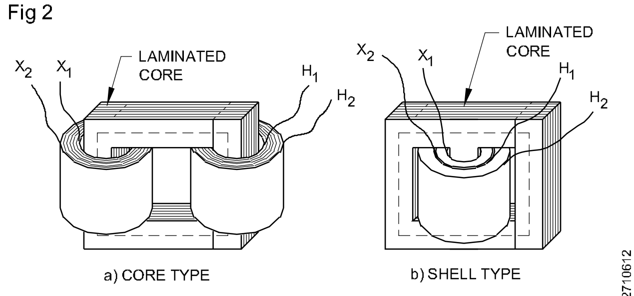
Laminated steel core transformers are used in power applications. Fig 1, the current flowing in the coil connected to the AC source is called the primary winding or simply primary. The primary is the input to a transformer. It sets up the flux in the core, which varies periodically both in magnitude and direction. The flux links the second coil, called the secondary winding or simply the secondary.

The flux is changing; therefore, it induces a voltage in the secondary by electromagnetic induction. Thus the primary receives its power from the source while the secondary supplies this power to the load. This action is known as transformer action. There is no electrical connection between these two coils.

Transformers are efficient and reliable devices used mainly to change voltage levels.Transformers are efficient because the rotational losses are absent; so little power is lost when transforming power from one voltage level to another. Typical efficiencies are in the range of 92 to 99%.The higher values apply to the large power transformers. There is no change in frequency of voltage.

Construction: There are basically two types of iron-core construction. Fig 2a shows core type already represented in Fig 1. It consists of two separate coils, one on each of the two opposite legs of a rectangular core.

Fig 2



TRANSFORMER CONSTRUCTIONS

Normally, this is not a desirable design. Its disadvantage is the large leakage fluxes associated with it. The large leakage fluxes cause poor voltage regulation. Therefore, to ensure that most of the flux set by the primary will link the secondary, the construction Fig 2b is employed. This is called shell type construction.

Here the two windings are wound concentrically. The higher voltage winding is wound on top of the lower voltage winding. The low-voltage winding is then located closer to the steel. This arrangement is preferable from an electrical insulating point of view. From the electrical viewpoint there is not much difference between the two constructions.

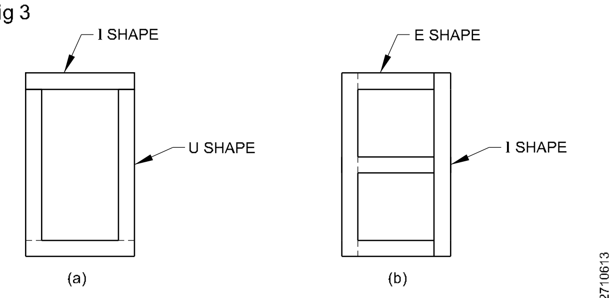
Cores may be built up of lamination silicon steel sheet.

Most laminating materials have an approximate alloy content of 3% silicon and 97% iron. The silicon content reduces the magnetizing losses. Particularly, the loss due to hysteresis is reduced. The silicon makes the material brittle. The brittleness causes problems in stamping operation.

Most laminated materials are cold-rolled and often specially annealed to orient the grain or iron crystals. This provides very high permeability and low hysteresis to the flux in the direction of rolling. Transformer laminations are usually 0.25 to 0.27 mm thick for 50 Hz. operation. The laminations are coated on one side by a thin layer of varnish or paper to insulate them from each other.

Coils are pre-wound, and the core design must be such that it permits placing the coil on the core. Ofcourse, the core must then be made in atleast two sections. The laminations for the core-type transformer of Fig 2a may be made up of (L and ˥) shaped laminations, as shown in Fig 3a. The core for the shell type transformer of Fig 2b is normally made up of E and I shaped laminations Fig 3b.

Fig 3

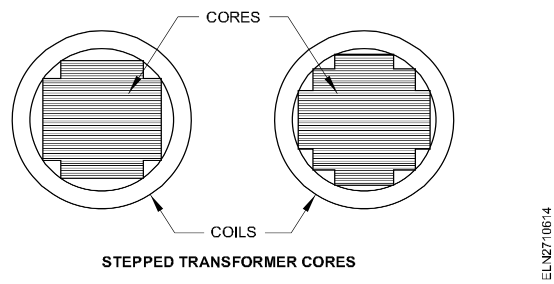


CORE CONSTRUCTION BUILT OF SEPARATE LAMINATIONS

Core construction : As a rule, the number of butt joints is to be limited. The joints are tightly made and laminations interleaved so as to minimize the reluctance of the magnetic circuit. The stacking of laminations to the required core cross-section results in the core legs of square or rectangular cross-section. This permits coils to be fitted on the core legs with either square, rectangular, or circular coil spools or forms.

In larger transformers, a stepped-core arrangement is used to minimise the use of copper and reduce copper loss. (Fig 4) This construction guarantees that each length of copper conductor embraces the maximum cross-sectional area of steel.

Fig 4



STEPPED TRANSFORMER CORES

In practice, the primary and secondary windings of a transformer have two or more coils per leg. They may be arranged in series or parallel. The laminations are pressed together by clamping in such a way as to prevent any fluttering or shifting.

The coils are impregnated. Insufficient clamping of laminations usually results in a humming sound. This generates objectionable and audible noise by the iron core of the transformer.

Transformers are usually air-cooled. Larger transformers are placed in tanks with a special transformer oil. The oil serves a dual purpose as an insulating medium as well as a cooling medium.

The heat generated in the transformer is removed by the transformer oil surrounding the source and is transmitted either to atmospheric air or water. No matter what size of transformer is dealt with, they all operate on the same principle.

Transformer principle

Objectives: At the end of this lesson you shall be able to
- **describe an ideal transformer and its operation on load and noload**
- **explain the principle of the operation of a transformer**
- **derive the EMFequation of a two-winding transformer**
- **derive the transformation ratio of a transformer.**

An ideal transformer: An ideal transformer is one which has no losses, ie. its windings have no ohmic resistance and there is no magnetic leakage. An ideal transformer consists of two coils which are purely inductive and wound on a loss-free core.

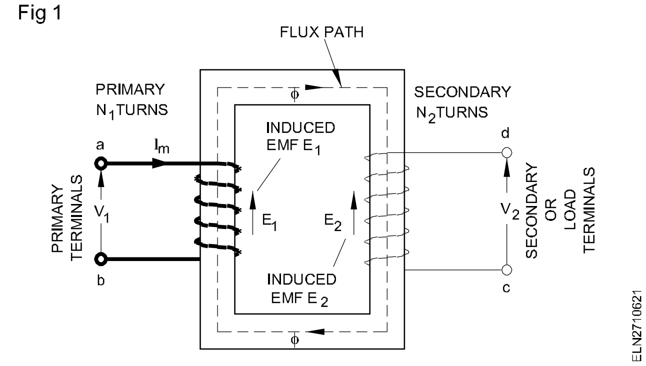
However, it may be noted that it is impossible to realize such a transformer in practice; yet for convenience, we will first analyse such a transformer and then an actual transformer.

Let us consider an ideal transformer (Fig 1) whose secondary is open and whose primary is connected to a sinusoidal voltage V_1.

Working principle

The transformers work on the principle of mutual induction of Faraday's law of electro - magenetic induction.

Fig 1



The applied voltage causes a small current to flow in the primary winding. This no-load current is meant to build up a counter-electromotive force equal and opposite to the applied voltage.

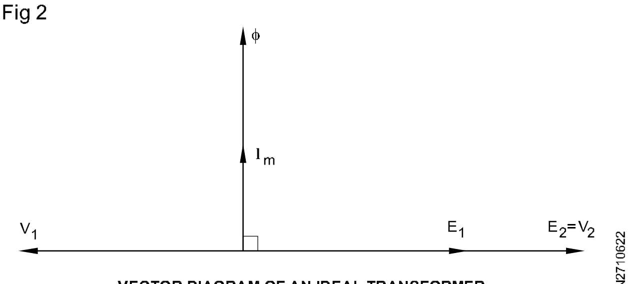
Since the primary winding is purely inductive and there is no output, the primary draws the magnetizing current I_m only. The function of this current is merely to magnetise the core. The I_m is small in magnitude and lags V_1 by 90°. This alternating current I_m produces an alternating flux ϕ which is proportional to the current and hence is in phase with it (I_m). This changing flux is linked with both the windings. Therefore, it produces self-induced EMF $(E)_1$ in the primary which lags the flux 'ϕ' by 90^0. This is shown in vector diagram Fig 2.

The flux 'ø' produced by the primary links with the secondary winding and induces an EMF (E_2) by mutual induction which lags behind the flux 'ø' by 90°Fig 2. As the EMF induced in primary or secondary per turn is same the secondary EMFwill depend on the number of turns of the secondary.

When secondary is open circuit, its terminal voltage 'V_2' is the same as the induced EMF (E_2). On the other hand, the primary current at no load is very small, hence the applied voltage 'V_1' is practically equal and opposite to the primary induced EMF (E_1). The relationship between primary and secondary voltages Fig 2.

Hence we can say that

Fig 2



VECTOR DIAGRAM OF AN IDEAL TRANSFORMER

Ideal Transformer on Load: When the secondary is connected to a load, secondary current flows this in turn makes the primary current to increase. How this happens is explained below.

The relationship between primary and secondary currents is based upon a comparison of the primary and secondary ampere turns.

When the secondary is open circuit, the primary current is such that the primary ampere turns are just sufficient to produce the flux 'ø' necessary to induce an EMF (E_1) that is practically equal and opposite to the applied voltage 'V_1'. The magnetising current is usually about 2 to 5 percent of the full load primary current.

When a load is connected across the secondary terminals, the secondary current - by **Lenz's law** - produces demagnetising effect. Consequently the flux and the EMFinduced in the primary are reduced slightly.

But this small change may increase the difference between applied voltage 'V_1' and the induced EMF (E_1) by say 1 percent in which case the new primary current would be 20 times the no load current.

The demagnetising ampere turns of the secondary are thus nearly neutralized by the increase in the primary ampere turns and since the primary ampere turns on no load are very small compared with the full load ampere turns.

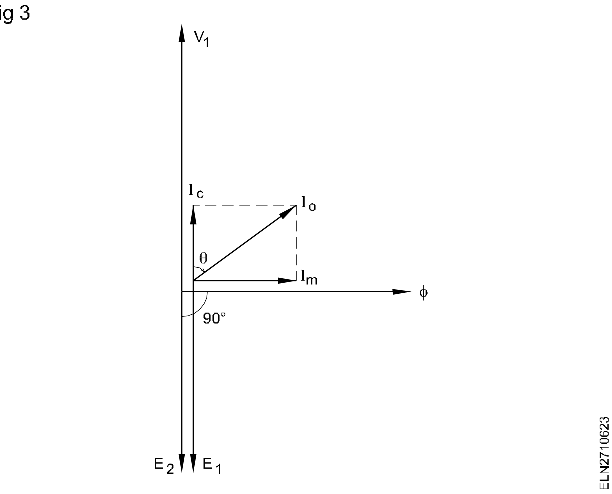
Therefore Full load primary ampere turns $\simeq$ full load secondary ampere turns

i.e $I_1N_1 \simeq I_2N_2$

so that $\frac{I_1}{I_2} \simeq \frac{N_2}{N_1} \simeq \frac{V_2}{V_1}$ Transformation ratio

From the above statement, it is clear that the magnetic flux forms the connecting link between the primary and secondary circuits and that any variation of the secondary current is accompanied by a small variation of the flux and therefore of the EMFinduced in the primary, thereby enabling the primary current to vary approximately, proportional to the secondary current.

Fig 3



Theory of No-load Operation: With the secondary winding open-circuited, the no-load current I_o flows in the primary winding. This no-load current has two functions:

1) It produces the magnetic flux in the core, which varies sinusoidally between zero and $\pm ø_m$ where $ø_m$ is the maximum value of the core flux; and

2) It provides a component to account for the hysteresis and eddy current losses in the core. These combined losses are normally referred to as the core losses or iron losses.

The no-load current I_o is usually a small percentage of the rated full load current of the transformer (about 2 to 5%). Since at no-load the primary winding acts as a large reactance due to the iron core, the I_o will lag the primary voltage 'V_1' by nearly 90°. Fig 3 illustrates this relationship where θ^0 is the no-load power factor angle.

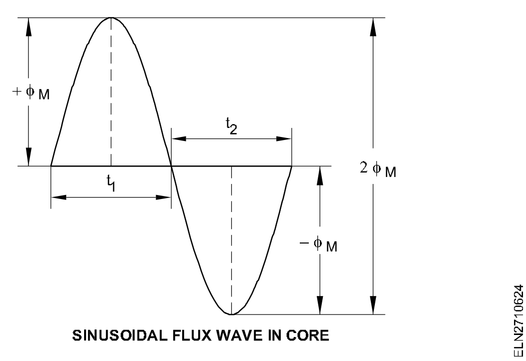
Magnetising current = $I_m = I_o \sin\theta$ is 90° in phase behind the primary voltage V_1. It is this component that sets up the flux in the core; ø is therefore in phase I_m.

The second component, $I_c = I_o \cos ø_o$ is 90° is in phase with the primary voltage V_1. It is the current component that supplies the iron-loss plus a small quantity of primary Cu-loss. As I_o is very small, the no-load primary copper-loss is negligibly small.

EMF equation of a transformer: Since the magnetic flux set up by the primary winding links the secondary winding, an EMF will be an induced E_2, in the secondary, in accordance with Faraday's law, namely, $E = N (\delta ø/\delta t)$. The same flux also links the primary itself, inducing in it an emf, E_1. The induced voltage must lag the flux by 90°, therefore, they are 180° out of phase with the applied voltage V_1.

Since there is no current in the secondary winding, $E_2 = V_2$. The primary voltage and the resulting flux are sinusoidal; thus the induced quantities E_1 and E_2 vary as a sine function. The average value of the induced voltage is given by

Fig 4



$$E_{avg} = \text{turns} \times \frac{\text{change in flux in a given time}}{\text{given time}} \quad ...(1)$$

Referring to Fig 4, it is seen that the flux change in time interval t_1 to t_2 is $2\phi_m$ where ϕ_m is the maximum value of the flux, in webers. The time interval represents the time in which this flux change occurs and equals one-half cycle of $(\frac{1}{2f})$ seconds, where f is the supply frequency, in hertz. It follows that

$$E_{avg} = N \times \frac{2\phi_m}{\frac{1}{2f}} = 4fN\phi_m \quad ...(2)$$

where N is the number of turns on the winding.

The effective or rms voltage for a sine wave is 1.11 times the average voltage, thus

$$E = 4.44\ f\ N\phi_m \quad ...(3)$$

Since the flux links with the primary and secondary windings, the voltage per turn in each winding is the same. Hence

$$E_1 = 4.44\ f\ N_1\phi_m \quad ...(4)$$

and

$$E_2 = 4.44\ f\ N_2\phi_m \quad ...(5)$$

where N_1 and N_2 are the number of turns in the primary and secondary windings respectively.

Voltage Transformation Ratio (K): From the equations 4 and 5, we get

$$\frac{E_2}{E_1} = \frac{N_2}{N_1} = K \text{ (Constant)} \quad ...(6)$$

This constant is known as voltage transformation ratio. Although the true transformation ratio is constant, the ratio of terminal voltages varies somewhat depending on the load and its power factor. In practice, the transformation ratio is obtained from the name plate data refers the voltages of primary and secondary on full load condition.

When the secondary voltage V_2 is less compared to the primary voltage, the transformer is said to be step down transformer. If the secondary voltage is higher it is called a step-up transformer. In other words

(a) $N_2<N_1$ i.e K<1, then the transformer is called a step-down transformer

(b) $N_2>N_1$ i.e K>1, then the transformer is called a step-up transformer

Assume that the power output of a transformer is equal to its input i.e we are dealing with an ideal transformer.

Thus $P_{in} = P_{out}$ (or)

$V_1 I_1$ x primary PF = $V_2 I_2$ x secondary PF

where PF is the power factor. For the above stated assumption it means that the power factor on primary and secondary sides are equal. (It is possible when I_o is neglected). Therefore,

$V_1 I_1 = V_2 I_2$ (or)

$$\frac{V_2}{V_1} = \frac{I_1}{I_2} = \frac{E_2}{E_1} = \frac{N_2}{N_1} = K \qquad ...(7)$$

Equation 7 shows that as an approximation the terminal voltage ratio equals the turns ratio.

Transformer - simple calculations

Objective: At the end of this lesson you shall be able to
- **define the rating of transformer**
- **calculate the voltage, current and turns of primary from the secondary data and vice versa.**

Rating of transformer

The capacity of the transformers are always rated by its apparent power (volt amp - VA (or KVA), not by its true power (watt (or) KW) (ie.) KW = KVA x Cosϕ . The transformer can be loaded with either resistive, inductive, capacitive (or) combined. The power factor (Cosϕ) depends on the load of the transformer. If the PF. is known of the specific load, then only the load current can be calculated otherwise the load current may be more than rated. If the transformer rating is in KVA the load current can be determined directly by knowing its voltage.

Hence the transformer are rated in VA (or) KVA, because the safety maximum load current can be calculated without knowing power factor.

The KVA of the primary must equal to the KVA of the secondary under the ideal transformer concept. We know that the terminal voltage ratio is equal to turns ratio. The primary and secondary currents are inversely related to the turns ratio.

Example 1: A 100 KVA 2400/240V, 50 Hz. transformer has 300 turns on the secondary winding. Calculate (a) the approximate value of primary and secondary currents (b) the number of primary turns and (c) the maximum flux ϕ_m in the core.

Data given : Transformer rating 100 KVA

Frequency f = 50 Hz

Primary voltage V_P = 2400 V

Secondary voltage V_S = 240 V

Secondary turns N_S = 300

Known: $E_P = (4.44 \times f \times N_P \times \phi_m)$ volts

$$\frac{V_P}{V_S} = \frac{I_S}{I_P} \cong \frac{E_P}{E_S} \cong \frac{N_P}{N_S}$$

$V_P I_P = V_S I_S$ = KVA

Find: Primary current I_P

Secondary current I_P

Primary turns N_P

Maximum flux Φ_m

Solution

(a) $I_P \text{ (full load)} = \frac{KVA \times 1000}{V_p} = \frac{100000}{2400} = 41.7A$

and $I_S = \frac{100000}{240} = 417A$

(b) $\frac{V_P}{V_S} = \frac{2400}{240} = 10 = \frac{N_P}{N_S}$

Therefore, $N_P = 10 \times N_S$

= 10 x 300 = 3000 turns.

(c) $4.44 \times f \times N_P \times \phi_m = E_P$

$$\Phi_m = \frac{2400}{4.44 \times 50 \times 3000} = 0.0036 \text{ Wb.}$$

Example 2: In a transformer the number of turns per volt (i.e N/V) is 8. The primary voltage is 110V. Find the primary and secondary turns of wire if V_2 is to be 25 volts.

Data given: V_1 = 110V

$$\frac{\text{Primary turns}}{\text{Primary volts}} = \frac{N_1}{V_1} = 8$$

V_2 = 25

Known: $\frac{V_1}{V_2} = \frac{N_1}{N_2}$ or $\frac{N_1}{V_1} = \frac{N_2}{V_2}$

Find: N_1 and N_2

Solution: Primary turns $\frac{N_1}{V_1} = 8$

N_1 = 8 x 110 = 880 turns

Secondary turns N_2 = 8 x 25 = 200 turns

Classification of transformers

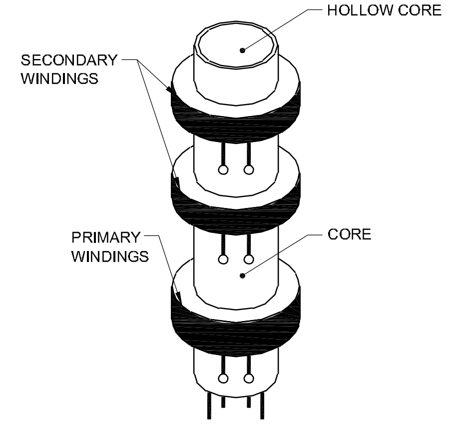
Objectives : At the end of this exercise you shall be able to
- **state the classification of transformers based on various factors**
- **state about the dry type transformers.**

Classification of Transformers

1. Classification based on the type of Core Material used

- **Air core transformers** : Fig 1, air core transformers consists of a hollow non magnetic core, made of paper or plastic over which the primary and secondary windings are wound. These transformers will have values of k less than 1. Air core transformers are generally used in high frequency applications because these will have no iron-loss as there is no magnetic core material.

Fig 1



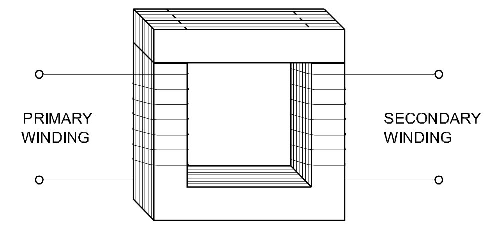
AIR CORE TRANSFORMER

Iron-loss is a type of transformer loss due to core material.

- **Iron core transformers**: Fig 2 shows a laminated iron-core transformer. This is the most common type of transformer used with mains power supply transformers,

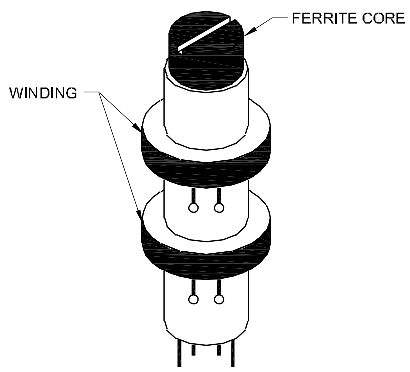
- **Ferrite core transformers**: Fig 3, these transformers have Ferrite material as its core Fig 3. In most cases, the primary and secondary windings are wound on a hollow plastic core and the ferrite material is then

Fig 2



inserted into the hollow core. These transformers are used in high frequency to very high frequency applications as they have the advantage of introducing minimum losses.

Fig 3



2 Classification based on the shape of core

- **Core type transformers**: In Core type of transformer, the primary and secondary windings are on two separate sections/limb of core. (Fig 1 in chart 1)

- **Shell type transformers**: In this type, both the primary and the secondary windings are wound on the same section/limb of the core.These are widely used as voltage and power transformers. (Fig 2 in chart 1)

- **Ring type transformers**: In this, the core is made up of circular or semicircular laminations (Fig 3). These are stacked and clamped together to form a ring. The primary and secondary windings are then wound on the ring. The disadvantage of this type of construction is the difficulty involved in winding the primary and secondary coils. Ring type transformers are generally used as instrument transformers for measurement of high voltage and current.

3 Classification based on the Transformation ratio

- **Step-up Transformers**: Transformers in which, the induced secondary voltage is higher than the source voltage given at primary are called step-up transformers.
- **Step-down Transformers**: Transformers in which, the induced secondary voltage is lower than the source voltage given at primary are called step-down transformers.
- **Isolation transformers**: Transformers in which, the induced secondary voltage is same as that of the source voltage given at primary are called one-to-one or isolation transformers. In these transformers the number of turns in the secondary will be equal to the number of turns in the primary making the turns ratio equal to 1.

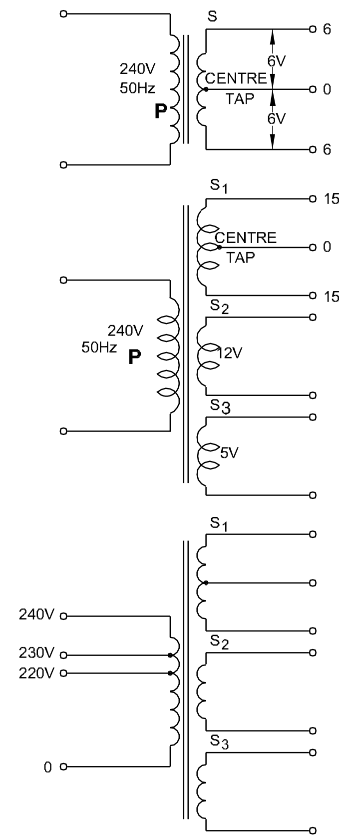
4 Classification based on the operating frequency

- **Mains frequency transformer**: These are basically, iron-core shell type transformers. These transformers form the link between AC mains source and other devices requiring AC or DC power example, radius receivers. The secondary winding of these transformers may have a centre tap as shown in Fig 4a or may have more than one secondary windings Fig 4b. These transformers may also have more than two terminals at primary winding Fig 4c to accommodate for different AC mains levels. Tapped primary also allows changes in the secondary-primary turns ratio. All the power transformers are generally designed to work at mains supply frequency(50 Hz).

Power transformers use colour coding scheme to identify the primary and secondary windings. (Fig 5)

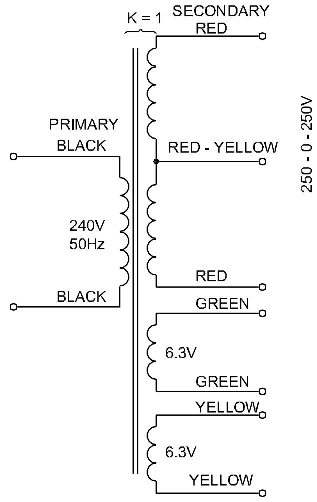
- **Audio frequency (AF) transformers**: Refer Fig 5 in Chart 1. These AF transformers are very small in size. Most AF transformers are of PCB mounting type. These transformers are designed to operate over the audio frequency range of 20 Hz to 20 KHz. Audio transformers are used in,
- coupling the output of one stage of audio amplifier to the input of the next stage (interstage coupling)
- the amplified audio signal from an amplifier to the speaker of a sound system.
- **High frequency transformers**: Refer Fig 6 in Chart 1. The core of high frequency transformers are made of powdered iron or ferrite or brass or air core(hollow core) Fig 1 and 3. These transformers are called Radio frequency transformers (RFTs) and Intermediate frequency transformers (IFTs).

Fig 4



CENTRE TAPPED SECONDARY

Fig 5



A TYPICAL COLOUR CODING SCHEME FOR POWER TRANSFORMERS

These transformers are used for coupling any two stages of high frequency circuits such as radio receivers. The upper frequency limit of these transformers is 30 MHz.

Another speciality of these transformers is that the position of the core can be altered, which results in varied coupling and energy transfer. These transformers also have a capacitor connected across the windings in parallel. This results in a different behavior of the transformer at different frequencies. Hence these transformer are also called Tuned transformers.

These transformers are smaller than even audio frequency (AF) transformers. These transformers will generally be shielded/screened using a good conductor.

- **Very high frequency transformers**: These transformers also have air or ferrite or brass as core material. These transformers are constructed specially to minimize energy losses at very high frequencies. Some of these find wide application in Television receivers.

5 Single phase and three phase transformers

Transformers Fig 4 of Chart 1 are designed for use with single phase AC mains supply. Such transformers are known as single phase transformers. Transformers are also available for 3 phase AC mains supply. These are known as poly-phase transformers. Refer Fig 7 in Chart 1. Three phase transformers are used in electrical distribution and for industrial applications.

6 Classification based on application

Transformers can also be classified depending upon their application for a specialized work. There are innumerable number of applications, However a few of these are listed below:

Instrument Transformers - used in clip - on current meters, overload trip circuits etc.,

Constant voltage transformers - used to obtain stabilized voltage supply for sensitive equipments

Ignition transformers - used in automobiles

Welding transformers - used in welding equipments

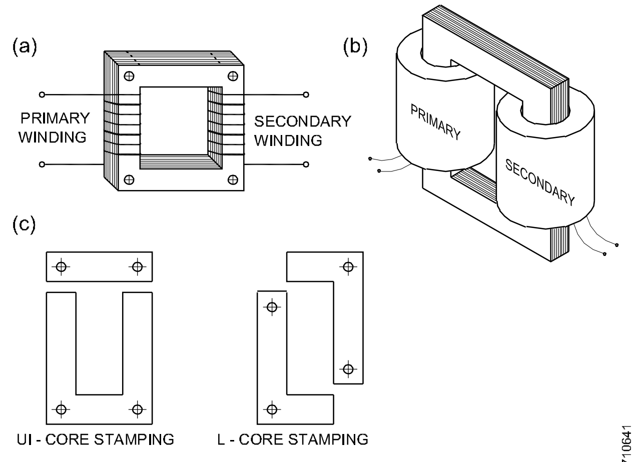
Pulse transformers - used in electronic circuits

Dry Type Transfomers

Dry type, or air-cooled, transformers are commonly used for indoor applications where other transformer types are considered too risky.

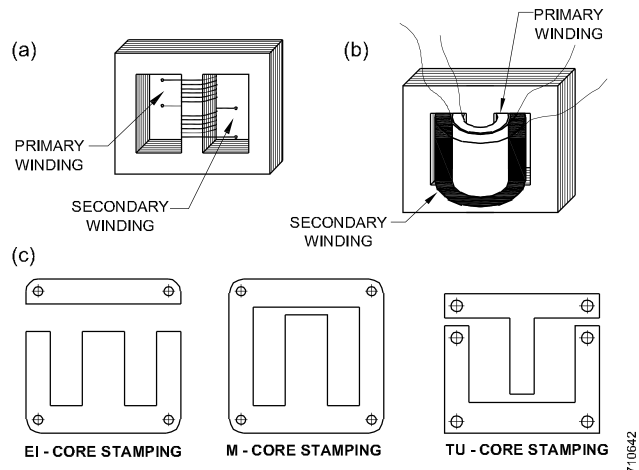
Chart - 1
Types of transformers

Fig 1 **CORE - TYPE TRANSFORMER**



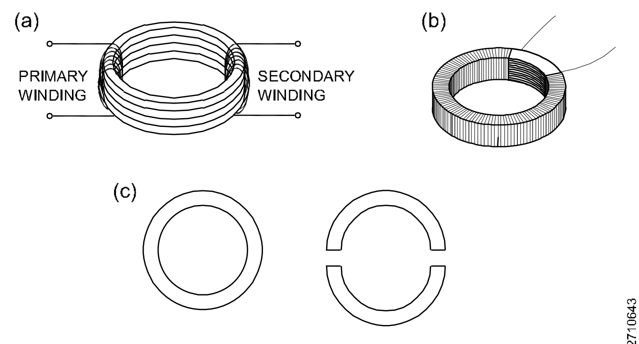
CORE-TYPE TRANSFORMER

Fig 2 **SHELL - TYPE TRANSFORMER**



SHELL-TYPE TRANSFORMER

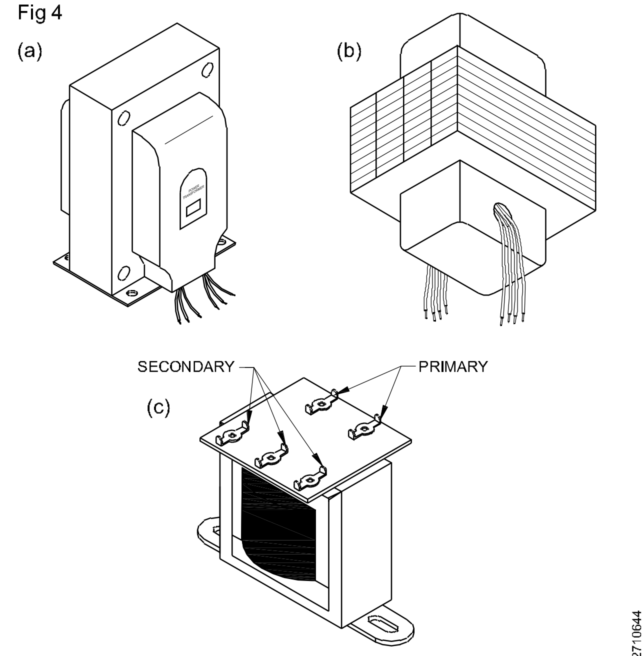
Fig 3 **RING - TYPE TRANSFORMER**



RING - TYPE TRANSFORMER

MAINS FREQUENCY TRANSFORMER

Fig 4

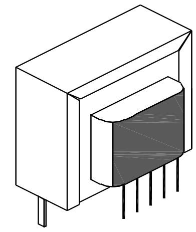


MAINS FREQUENCY TRANSFORMER

Chart - 1 Continued....
Types of transformers

AUDIO FREQUENCY TRANSFORMER

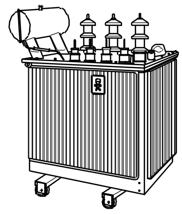
Fig 5



AUDIO FREQUENCY TRANSFORMER

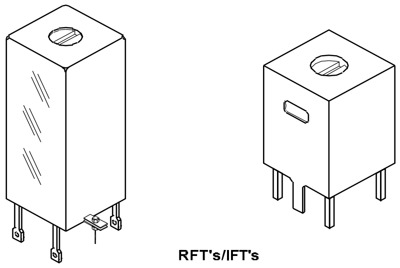
POLY - PHASE TRANSFORMER

Fig 7



POLY - PHASE TRANSFORMER

Fig 6 **HIGH FREQUENCY TRANSFORMER**



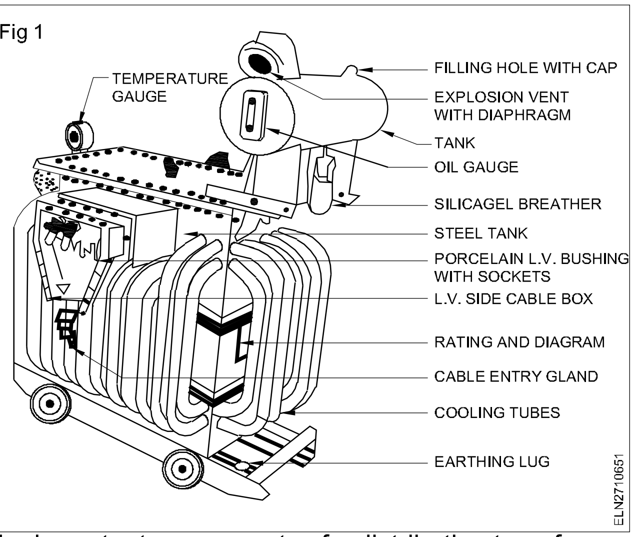
HIGH FREQUENCY TRANSFORMER

Parts and their functions of transformer

Objectives: At the end of this lesson you shall be able to
- **list out the mainparts of transformer**
- **explain the parts of a distribution transformer.**

Distribution transformer: Fig 1 shows the essential parts of a distribution transformer.

Fig 1



The important components of a distribution transformer are briefly described below:-

The important components of transformer are : -

1 Steel tank

2 Conservation tank

3 Temperature gauge

4 Explosion vent

5 Cooling tubes

6 Tap changer

7 Bushing termination

8 Silical gel breather

9 Buchholz relay

1 Steel tank

It is a fabricated M.S plate tank used for housing the core, winding and for mounting various accessories required for the operation of a transformer. Core is built from cold rolled grain oriented silicon steel lamination. The L.V winding is normally close to the core and the H.V winding is kept around the L.V winding.

2 Conservator tank

It is in the shape of a drum, mounted on the top of the transformer. An oil level indicator is fitted to the conservator tank. Conservator is connected to the transformer tank through a pipe. The conservator carries the transformer oil to a specified level. When transformer is heated up due to normal load operation, the oil expands and the level of oil in conservator tank is increased or vice versa. A pipe connected to the top of the conservator tank allows the internal air to go out or get in through the breather.

It reduces the oxidation of oil when it get contact with air.

3 Temperature gauge

It is fitted to the transformer which indicates the temperature of the transformer oil.

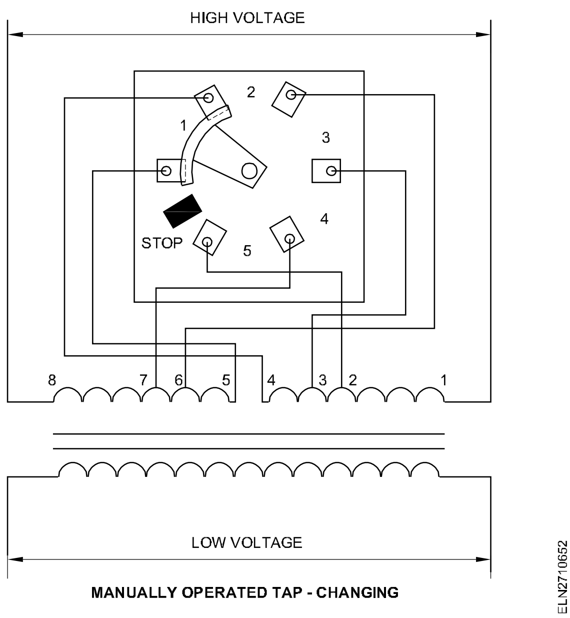
4 Cooling tubes

In earlier discussions, we found that the transformer is heated up, when the transformer is connected to the supply is due to iron loss and copper loss. To keep down the temperature of the windings, when the transformer is put on load, the heat generated inside the transformer should be radiated to the atmosphere. To dissipate the heat produced inside the winding and core, the transformer tank is filled with an insulating oil. The oil carries the heat to the cooling pipes where the heat is dissipated to atmosphere due to surface contact with air.

5 Tap changer

When voltages are transmitted over long distances there will be voltage drop in the conductors, resulting in lower voltage at the receiving end. To compensate this line voltage drops in the conductors, it is customary to increase the sending end voltage by tap changing transformers. These transformers may have several winding taps in their primary winding (Fig 2).

Fig 2



MANUALLY OPERATED TAP - CHANGING

There are two methods of tap changing. In one method, these taps are manually changed through a tap changing switch. (Fig 2) In this method load switch has to be opened, before the tap changing operation is to avoid heavy sparking at the contact points. This method is often referred to as "OFF-LOAD" tap changing method.

In another method the tap changing is done with the load called as ON-LOAD' tap changer. In this method the following parameters are met.

- The load current must not be interrupted during a tap change.
- The tap changing must be carried out without short circuiting a tapped section of the winding.

To meet both criteria some form of bridging or transfer impedance is required during the tap changing operation.

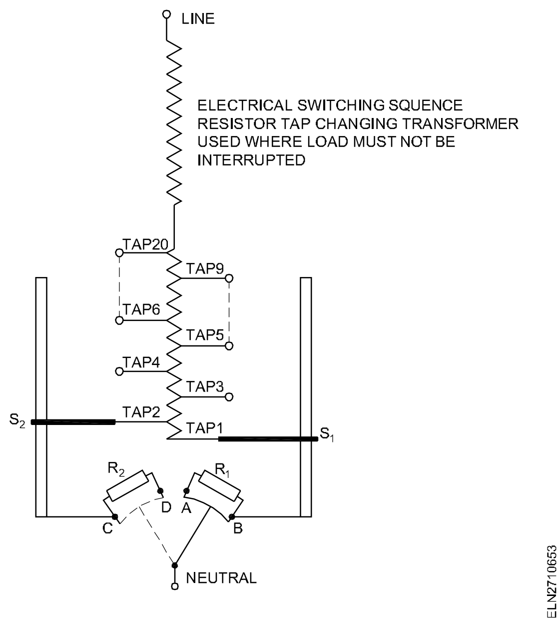
The tap changer has two main units. The tap selector switch is the unit responsible for selecting the tap on the transformer winding as shown in Fig 3, but does not make or break the load current. The diverter switch is where the actual switching of the load takes place.

The selector switch first moves to the desired tap position by the internal mechanism as selected either by automatic voltage regulator or by manual method. Then the diverter switch operates at a faster rate to the desired setting.

The operation of the ON-LOAD tap changer could be explained as below. (Only single phase operation is shown)

Referring to Fig 3, in the initial position selector switch S_1 is on tap 1 and S_2 on tap 2. The diverter switch connects tap 1 to the neutral point of the transformer winding. The sequence of operation in changing to tap 2 is as follows.

Fig 3



- The mechanism operates, the moving contact starts to travel from one side of the diverter to the other; contact 'B' is opened and the load current flows through resistor R_1 to contact 'A'.
- The moving contact 'D' then closes. Both resistors R_1 and R_2 are now in series across tap 1 and 2 and the load current flows through the mid point of these resistors.
- Further travel of the moving contact opens contact 'A' and the load current then passes from tap 2 through resistor R_2 and contact 'D'.

- Finally when moving contact reaches the other side of the diverter switch, contacts 'C' is closed and resistor R_2 is shorted out. Load current from tap 2 now flows through contact 'c' the normal running position of tap2.

The change from position 1 to 2 as described involves the movement of selector switch. If any further change in the same direction is required i.e from 2 to 3, the selector switch ST travels to tap 3 before the diverter switch moves and the diverter switch then repeats the above sequence but in the reverse order.

If a change in the reverse direction, the selector switches remain stationary and the tap change is carried out by the movement of the diverter switch only.

6 Bushing termination

High voltage Power transformers are used in transmission and distribution sector. The windings of such transformers are energised with very high voltage. Generally, when an energized conductor (may be Copper or Aluminium) is passing through a metallic section.

The metallic part is directly connected with earth, then the potential of it will be equal to the earth potential. Therefore the field of the charged conductor gets distorted with the effect of the earth potential.

The electric field of the conductor will interact with the earth potential. To prevent this, Transformer Bushings are provided with each input and output terminals. So, Transformer Bushings are used to provide a electrical isolation for the winding terminals, when any earthed material is present near to the conductors.

Generally, Transformer Bushings are designed to withstand the high electrical energy of the charged conductors passing through them. Therefore they should have sufficient dielectric strength.

Porcelain bushing of transformer

This type of Transformer Bushings are used in several power industries for their robustness and they are also very cheap. Porcelain offers very good and reliable electrical insulation for a wide range of voltages as well as they have high dielectric strength too.

A porcelain bushing is a hollow cylindrical shaped arrangement made by porcelain discs which is fitted to the top portion of the transformer. And the energised conductors are passed through the centre portion of the bushings.

After inserting the conductor, the ends of the porcelain bushings are tightly sealed with glaze and this arrangement ensures a prevention from any type of moisture.

The entire bushing arrangement is checked and it should not contain any leakage paths. If the operating voltage level is very high then the vacuum space of the Transformer Bushing is filled with insulating oil.

Capacitance graded bushing of transformer (capacitor bushings)

Basically, capacitance graded bushing is the modification of Paper Bushing. Here, very fine layers of smooth metallic foils are inserted into the paper during the winding process. The inserted foils are metallic. so they are conductive in nature.

Therefore, when these foils are interacting with charged conductors, then they develop a capacitive effect which dissipates the electrical energy more evenly throughout the Bushing.

In this way, the electric field stress is distributed throughout the Bushing and this causes lesser chance of Insulation Puncture. This type of bushing is also known as Capacitor Bushing.

There are 4 types of Capacitance graded Bushing, namely:-

- Resin Bounded Paper Bushing.
- Oil Impregnated Paper Bushing.
- Resin Impregnated Paper Bushing.
- Epoxy Resin Impregnated Paper Bushing.

Testing and maintenance of transformer bushing

There are several types of tests for transformer bushing. Some of them are done before the installation and some of them are used for routine maintenance.

1 **Measurement of tangent delta (tan δ) or capacitance:** This is a routine maintenance test. Initially, the transformer is separated from service and a strong local earthing is done for operator safety. In this test, electrical connection in between the transformer tank and bushing flange is checked for instance with a buzzer. For capacitance measurement, a capacitor test kit is required.

   The transformer capacitance has negligible value so it can be ignored during the measurement of bushing capacitance. This measurement is carried out for each phase of the transformer. The measured capacitance is further compared with the rating chart.

2 **Measurement of Partial Discharge:** This is also a routine checking process for maintenance purpose. This measurement of Partial Discharge indicates the week points of insulation. As per the new technology the partial discharges are located by using sophisticated acoustic sensors.

3 **Dissolved gas analysis:** This test is only for oil filled bushings. After opening the seal oil sample is collected from the bushing and then the necessary procedures are carried out. After the sample collection, the glaze seal of bushing should br properly placed. This test is commonly known as the DGA test of transformer bushing.

4 **Moisture analysis:** This is an important test for oil filled bushings are any type of moisture is harmful for proper operation. The oil bushings of transformer are tightly sealed.

After some period the oil sample is collected to measure the moisture content. Depending on the operating temperature, the moisture of bushings will move from paper to oil or oil to paper.

5 **Maintenance of Porcelain:** The porcelain part of bushings sometime chipped or cracked, or the glaze seal sometime eroded. So, proper maintenance of porcelain is necessary and the defected porcelain should be replaced with new one.

Beside of these, the metal parts, taps and oil levels are checked as routine maintenance.

7 Protective - devices / parts of transformers:

1 Breather

Transformer oil deterioration takes place due to moisture. Moisture can appear in a transformer from three sources, viz. by leakage through gasket, by absorption from air in contact with the oil surface or by its formation within the transformer as a product of deterioration as insulation ages at high temperature.

The effect of moisture in oil is to reduce the di-electric strength, especially if loose fibres or dust particles are present.

Methods available to reduce oil contamination from moisture are:

- by the use of silica gel breather
- by the use of rubber diaphragm
- by using sealed conservator tank
- by using gas cushion
- by using thermosyphon filter

Silica gel breather

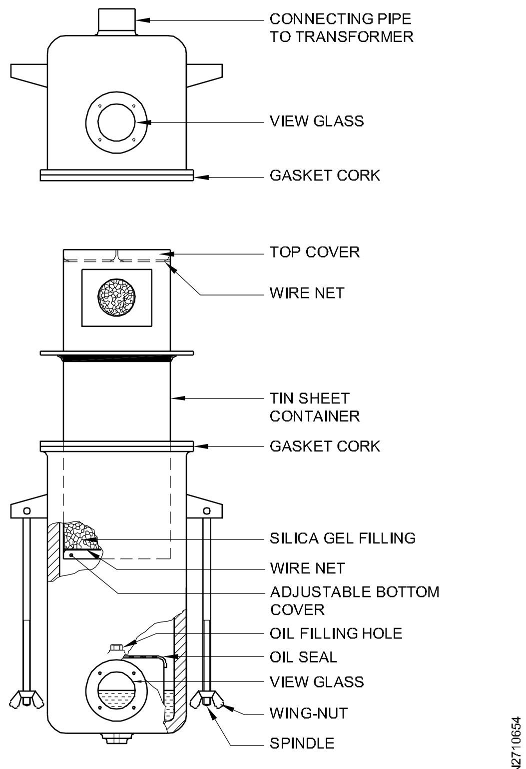
Silica gel breather is a protective device fitted to the conservator through a pipe and allows the moisture free air to and fro into the conservator when the transformer oil get heated and cools down.

As the load and heat on a transformer reduces, air is drawn in to the conservator through a cartridge pakced with **silica gel crystals**.

The silica gel effectively dries the air and thus prevent the moistured dust entering into transformer oil. The fresh silica gel is available in blue colour. The colour of the silica gel changes to pure white or light pink colour as it absorbs moisture from air.

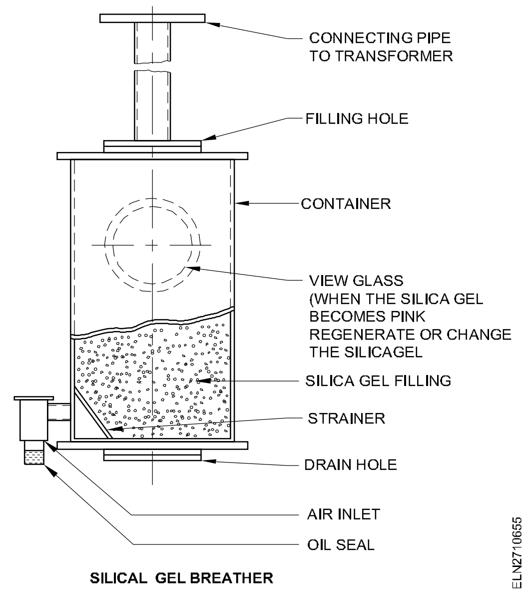
To recondition silica gel either it can be dried in sun or it could be dry roasted on a frying pan kept over a stove.Fig 4 & 5 show a cross-sectional view of such a silica gel breather.

Fig 4



SILICA GEL BREATHER

Fig 5



SILICAL GEL BREATHER

The oil seal at the bottom of the breather absorbs the dust particles that are present in the air entering the conservator.

2 Buchholz relay

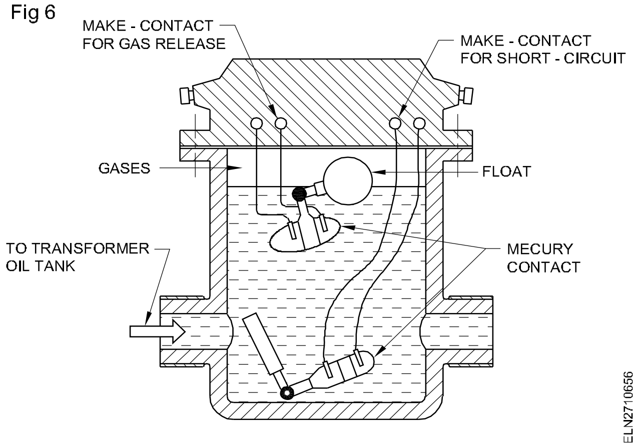
Buchholz relay is a gas operated - protective device which is connected between the transformer oil tank and the conservator tank.

If a fault is present inside a transformer, it may be indicated by the presence of bubbles (gas) in the transformer oil. Presence of gas could be viewed from class in window of by the Buchholz relay.

The relay comprises of a cast iron chamber which have two floats Fig 6. Top float assembly operates during initial stages of gas/air bubble formation due to minor fault in the transformer.

When sufficient gas bubbles formed around the top float, the float operates in pneumatic pressure principle to close an electric circuit through mercury switch which causes the siren or alarm bell to operate to caution the operator.

Fig 6



On hearing the alarm sound the operator takes necessary preventive steps to safeguard the transformer.

If any major fault like earth, fault etc, occurs in the transformer then the production of gas bubbles are more severe and hence the bottom float activates the mercury switch and closes the relay contacts.

Closing of the bottom relay contacts trips the transformer circuit breaker and opens the transformer from main line to protect the transformer from further damage.

3 Explosion vent

It is a pressure release device fitted to the transformer. The mouth of the explosion pipe is tightly closed using either a thin glass or laminated sheet.

If, by any, chance the transformer is overheated either due to short circuited or sustained overload, the gases produced inside the transformer tank creates tremendous pressure which may damage the tank.

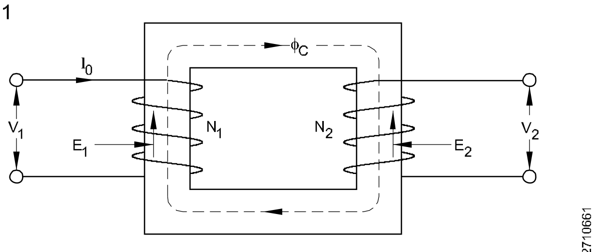
On the other hand the pressure built inside the transformer may break the glass/laminated diaphragm of the explosion pipe and thereby the tank can be saved from total damage.

Transformer on load

Objectives: At the end of this lesson you shall be able to
- **explain how the loading of a transformer takes place considering instantaneous value**
- **describe leakage flux and leakage reactance.**

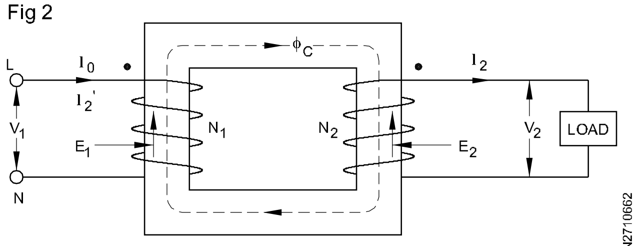
Fig 1 shows the equivalent circuit of a transformer with-out load. Fig 2 shows the equivalent circuit of a transformer supplying a load. The primary and secondary voltages shown have similar polarities, as indicated by the dot-marking convention.

Fig 1



EQUIVALENT CIRCUIT OF TRANSFORMER WITH-OUT LOAD

Fig 2



EQUIVALENT CIRCUIT OF TRANSFORMER WITH LOAD

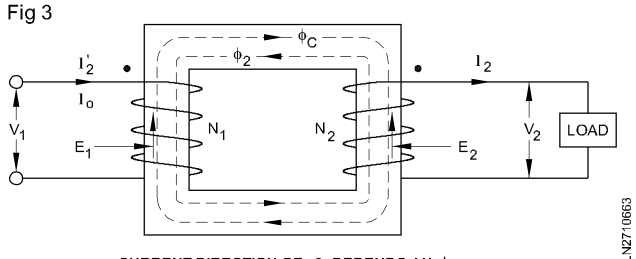
The marked terminals have the same polarity. Thus when the load is connected to the secondary, the instantaneous load current is in the direction shown.

Since the secondary voltage depends on the core flux f_c, it must be clear that the flux should not change appreciably if E_2 is to remain essentially constant. With the load connected, current I_2 will flow in the secondary circuit, because the induced EMF (E_2) will act as a voltage source. The magnitude of I_2 is determined by the characteristic of the load.

The secondary current sets up its own mmf ($N_2 I_2$), that is, a flux f_2. This flux has such a direction that at any instant it opposes the main flux f_c, that created it in the first place. This is Lenz's law in action. (Fig 3) If we assume that f_c increases, the current I_2 must have the direction indicated in Fig 3, if its resulting flux is to oppose the core flux.

Thus the mmf represented by $N_2 I_2$ tends to reduce the core flux f_c. This means that the flux linking the primary winding reduces and consequently the primary induced voltage E_1. This reduction in E_1 causes a greater difference between the impressed voltage and the counter-induced emf, thereby allowing more current to flow in the primary. The fact

Fig 3



CURRENT DIRECTION OF I_2 DEPENDS AN ϕ_C

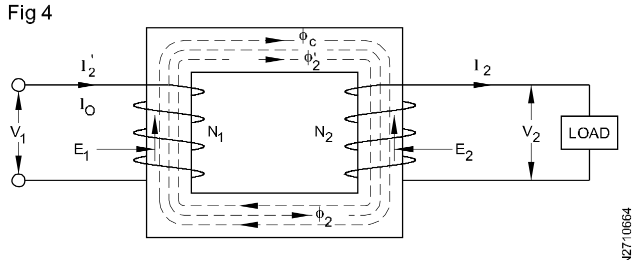
that the primary current (I_2') increases means the following two conditions are fulfilled.

- The power input increases to match the power output.
- The primary mmf increases to offset the tendency of the secondary mmf to reduce the flux.

In general, it will be found that the transformer reacts almost instantaneously to keep the resultant core flux essentially constant. The current I_2' is known as load component of primary current. This current is in phase opposition to current I_2.

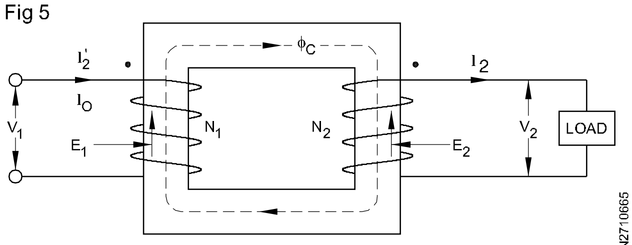
The additional primary mmf N_1 I_2' sets up a flux f_2' which opposes f_2 and is equal in magnitude. Thus, the magnetic effect of I_2 gets neutralised immediately by the additional primary current I_2' . (Fig 4) Hence, whatever may be the load condition, the net flux passing through the core is approximately the same as at no-load (Fig 5).

Fig 4



CURRENT I_2 NEUTRALISED BY ADDITIONAL CURRENT I_2

Fig 5

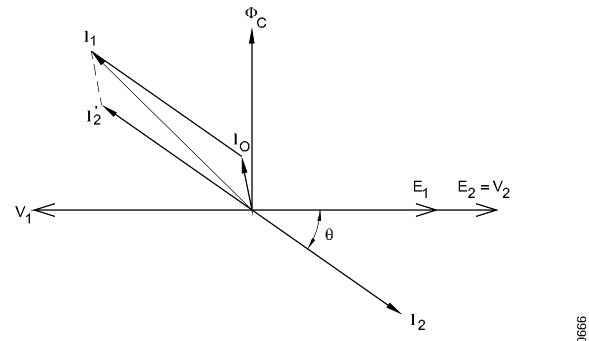


NET FLUX THROUGH CORE IS SAME AT NO-LOAD

When the transformer is in no-load, the primary winding has two currents I_o and I_2' . The total primary current I_1 is the vector of I_o and I_2' . The elementary vector diagram of the transformer with load (Fig 6)

Because the no-load current is relatively small, it is correct to assume that the primary ampere-turns equal the seconadry ampere-hours. Thus, N_1 I_1 = N_2 I_2. We will assume that I_o is negligible, as it is only a small component of the full load current.

Fig 6



ELEMENTRARY PHASOR DIAGRAM OF TRANSFORMER WITH LOAD.
ONLY CORE LOSSES ARE CONSIDERED IN THIS DIAGRAM.

Leakage fluxes: When a current flows in the secondary winding, the resulting mmf (N_2 I_2) creates a separate flux, apart from the flux f_c produced by I_o, which links the secondary winding only. This flux does not link with the primary winding and is therefore not a mutual flux.

In addition, the load current that flows through the primary winding creates a flux that links with the primary winding only, it is called the primary leakage flux.

Fig 7 illustrates these fluxes. On account of the leakage flux, both the primary and secondary windings have leakage reactance, that is, each will become the seat of an emf of self-induction.

The magnitude of this EMF is equal to a small fraction of the emf due to the main flux. The terminal voltage V_1 applied to the primary must, therefore, have a component I_1 X_1 (where X_1 is leakage reactance of primary) to balance the primary leakage EMF.

The primary and secondary coils in Fig 7 are shown on separate limbs. This arrangement would result in exceptionally large leakage. Leakage between primary and secondary could be eliminated if the windings could be made to occupy the same space.

This, of course, is physically impossible. By placing the coils of the primary and secondary concentrically, an approximation is achieved with very low leakage.

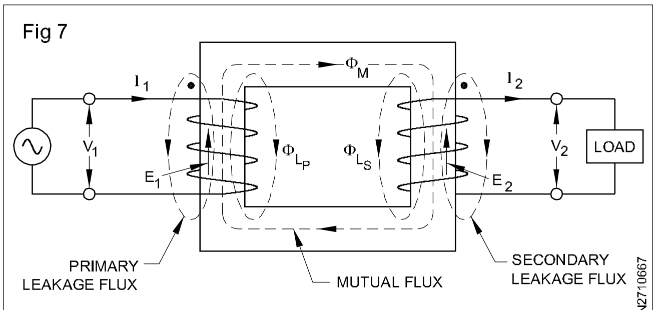
Transformer with resistance and leakage reactance

The primary impedance is given by

$$Z_1 = \sqrt{R_1^2 + X_1^2}$$

and the secondary impedance is given by

$$Z_2 = \sqrt{R_2^2 + X_2^2} .$$



PRIMARY AND SECONDARY ARE IN SEPERATE LIMBS

Autotransformer - principle - construction - advantages - applications

Objectives: At the end of this lesson you shall be able to
- **state the principle of auto-transformer**
- **describe the construction of auto-transformer**
- **state the advantages, disadvantages and appliations of auto-transformer.**

Auto transformer

- The auto transformer is a transformer having single winding which acts as primary as well as secondary winding.
- The auto transformer works on the principle of self inductance of Faraday's Law of electro - magnetic induction.

It may be recalled that in the discussion of transformer operation a counter emf was induced in the winding which acted as primary.

The induced voltage per turn was the same in each and every turn linking with the common flux in the core.

Therefore, fundamentally it makes no difference in the operation whether the secondary induced voltage is obtained from a separate winding linked with the core, or from a portion of the primary turns. The same voltage transformation results in both the situations.

Construction

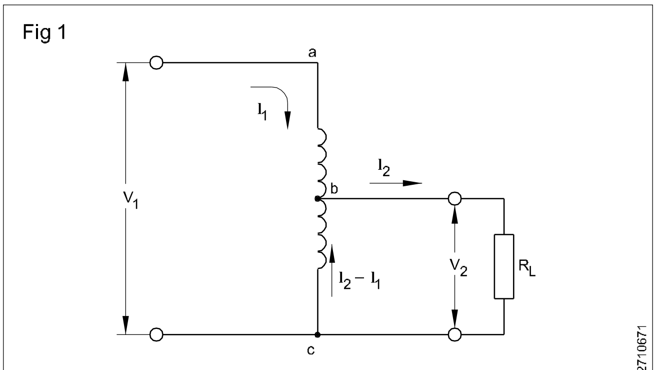
An ordinary two winding transformer may also be used as an auto-transformer by connecting the two windings in series and applying the voltage across the two, or merely to one of the windings.

It depends on whether it is desired to keep the voltage down or up, respectively.

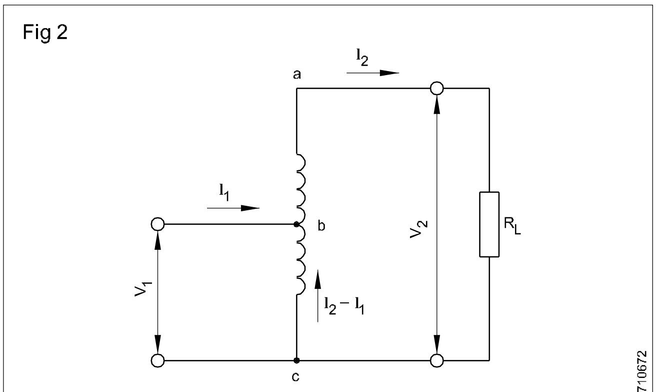
Figs 1 and 2 show these connections.

Considering Fig 1, the input voltage V_1 is connected to the complete winding a - c and the load R_L is across a portion of the winding, that is, b - c. The voltage V_2 is related to V_1 as in a conventional two winding transformer, namely,

$$V_2 = V_1 \times \frac{N_{bc}}{N_{ac}} \qquad ....(1)$$



AUTOTRANSFORMER STEP-DOWN



AUTOTRANSFORMER STEP-UP

where N_{bc} and N_{ac} are the number of turns on the respective windings. The ratio of voltage transformation in an autotransformer is the same as that for an ordinary transformer, thus

$$a = \frac{N_{bc}}{N_{ac}} = \frac{V_2}{V_1} = \frac{I_1}{I_2} \qquad ....(2)$$

with a < 1 for step down.

Assume a resistive load for convenience and the secondary current, $I_2 = V_2 / R_L$ further, the assumption is made that the transformer is 100% efficient, the power output is

$$P_L = V_2 I_2 \qquad ....(3)$$

Note that I_1 flows in the portion of the winding **ab**, whereas the current $(I_2 - I_1)$ flows in the remaining portion bc. The resulting current flowing in the winding **bc** is always the arithmatical difference between I_1 and I_2, since they are always in the opposite direction. Remember that the induced voltage in the primary opposes the primary applied voltage. As a result, the current caused by the induced voltage flows opposite to the input current. In an auto-transformer, the secondary current is thus induced that is

$$I_1 + (I_2 - I_1) = I_2 \qquad ....(4)$$

Hence the ampere turns due to section bc, where the substitution $I_2 = \frac{I_1}{a}$ and $N_{bc} = N_{ac} \times a$ are made according to Fig 2 we have

Ampere turns of

$$bc = (I_2 - I_1) N_{bc} = \left(\frac{I_1}{a} - I_1 \right) N_{bc} = \frac{I_1 N_{bc}}{a} - I_1 N_{bc}$$

$$= I_1 N_{ac} - I_1 N_{bc} = I_1 N_{ab}$$

(ie) ampere turns due to ab.

Thus the ampere turns due to sections bc and ab balance each other, a characteristic of all transformers.

Power delivered: Equation (3) gives the power determined by the load. To see how this power is delivered, the equation is written in a slightly modified form. Substituting the equation (4) in equation (3), the following result is obtained.

$$P_L = V_2 (I_1 + (I_2 - I_1))$$

$$= V_2 I_1 + V_2 (I_2 - I_1) \text{ watts}$$

This indicates that the load power consists of two parts.

The first part is $P_c = V_2 I_1$ = conducted power to load through ab.

The second part is $P_{tr} = V_2 (I_2 - I_1)$ = transformed power to load through bc.

Advantages : Auto-transformers:

- less cost
- have better voltage regulation
- are smaller
- are lighter in weight
- are more efficient when compared with two winding transformers of the same capacity.

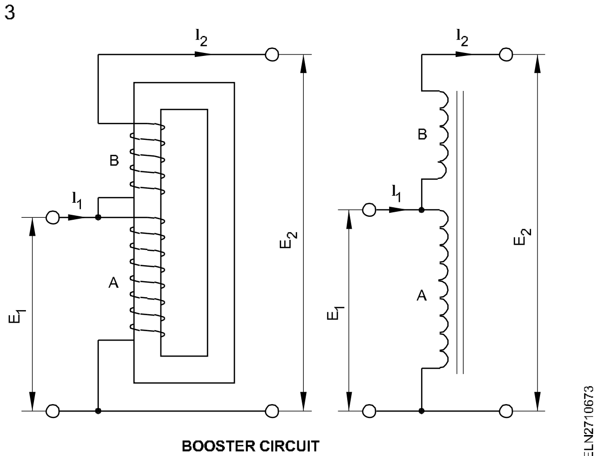
Disadvantages: Auto-transformers have two disadvantages.

- An auto-transformer does not isolate the secondary from the primary circuit.
- If the common winding bc becomes open circuit, referring to Fig 1 or 2, the primary voltage can still feed the load. With a step-down auto-transformer this could result in burnt out secondary load and/or a serious shock hazard, particularly if the step down ratio is high.

Application: The common applications are:

- fluorescent lamps (where supply voltage is less than the rated voltage)
- reduced voltage motor starter
- series line boosters for fixed adjustment of line voltage (Fig 3)
- servo-line voltage correctors.

Fig 3



BOOSTER CIRCUIT

Instrument transformers - current transformer

Objectives: At the end of this lesson you shall be able to
- **state the necessity, types and principle of the instrument transformer**
- **explain the construction and connection of the current transformer**
- **state the general terms like accuracy, phase displacement, burden and output with respect to the current transformer**
- **identify the I.S. symbols and markings used in the current transformer**
- **state the precautions to be followed while using the current transformer**
- **specify the current transformer.**

Necessity of instrument transformers: Transformers used in conjunction with measuring instruments for measurement purposes are called **'instrument transformers'**. the actual measurements are done by the measuring instruments only.

Where the current and voltage are very high, direct measurements are not possible as, these current and voltage are too large for reasonably sized instruments and the cost of the meter will be high.

The solution is to step-down the current and voltage with instrument transformers, so that, they could be metered with instruments of moderate size.

These instrument transformers electrically isolate the instruments and relays from high current/voltage lines thereby reducing danger to the men and equipment. To obtain perfect isolation, the secondary of the instrument transformers and the core should be grounded.

Type of instrument transformers: Three are two types of instrument transformers.

- Current transformer
- Potential transformer

The transformer used for measurement of high current is called 'current transformer' or simply 'CT'

the transformer used for high voltage measurement is called 'voltage transformer or potential transformer' or simply 'PT' in short.

Instrument transformers can be further divided according to their use as a) instrument transformer used as measuring instruments and b) instrument transformers used for control relays.

The instrument transformer used for measurement purposes should have high accuracy. But for control and protective relays instrument transformers of moderate accuracy are sufficient but high reliability and ruggedness are essential.

Principle: Instrument transformers work on the principle of mutual induction similar to the two winding transformers.

In the case of an instrument transformer, the following design features are to be considered.

Core: In order to minimise the error, the magnetizing current must be kept low. This means the cores should have low reactance and low core losses.

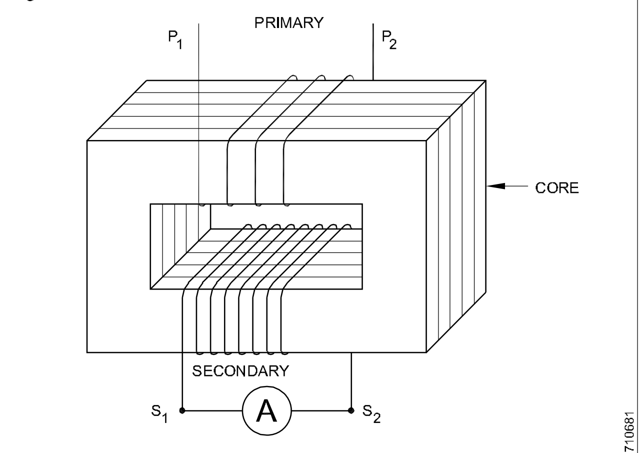
Winding: The winding should be close together to reduce the secondary leakage reactance; otherwise the ratio error will increase. In the case of a current transformer the winding must be so designed as to withstand the large short circuit current without damage.

Current transformers - types of construction and connection

The following are the different types of current transformers.

Wound type current transformer: This is one in which the primary winding is having more than one full turn wound on the core (Fig 1)

Fig 1



WOUND TYPE CURRENT TRANSFORMER

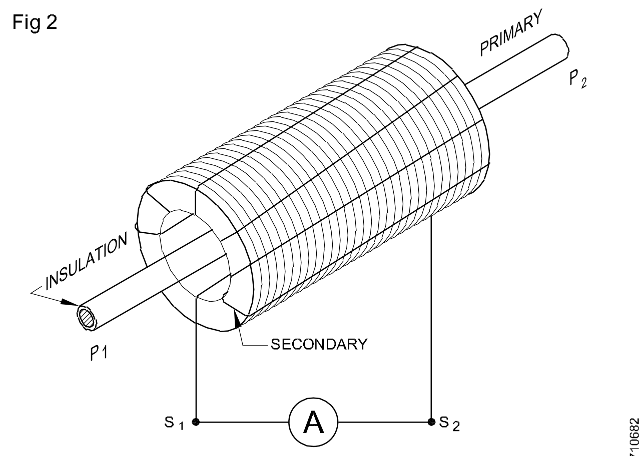
Fig 1 shows the connections of a wound type current transformer having a rectangular type of core. In general the ammeter is arranged to give full scale deflection with 5A or 1A when connected to the secondary of the current transformer.

The ratio between the primary and secondary turns of the current transformer decides the primary current which could be measured with fixed secondary current rating of 5 or 1 amp.

For example if the primary current is 100 amps and there are two turns in the primary, then the full load primary ampere turns is 200. Consequently, to circulate 5 amps in the secondary, the number of secondary turns must be 200/5, that is 40 turns.

Ring type current transformer: This has an opening in the centre to accommodate a primary winding through it Fig 2 shows a ring type current transformer with single turn primary. In this current transformer, the insulated conductor that carries the current to be measured passes directly through an opening in the transformer assembly.

Fig 2



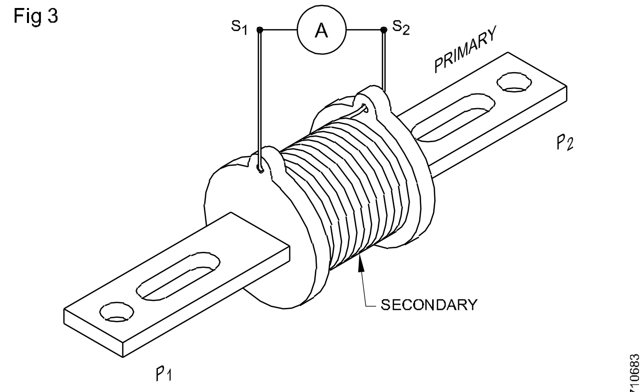
RING TYPE CURRENT TRANSFORMER

If there are 20 turns in the secondary having a current range of 5 amps, this current transformer according to the transformation ratio, could measure a primary current of 100 amps.

Clamp on or clip on ammeters work on this principle only but the core is made such that it can open to pass the insulated conductor and then get closed to complete the magnetic circuit.

Bar type current transformer: This is one in which the primary winding consists of a bar of suitable size and secondary winding and core assembly material forming an integral part of the current transformer (Fig 3).

Fig 3



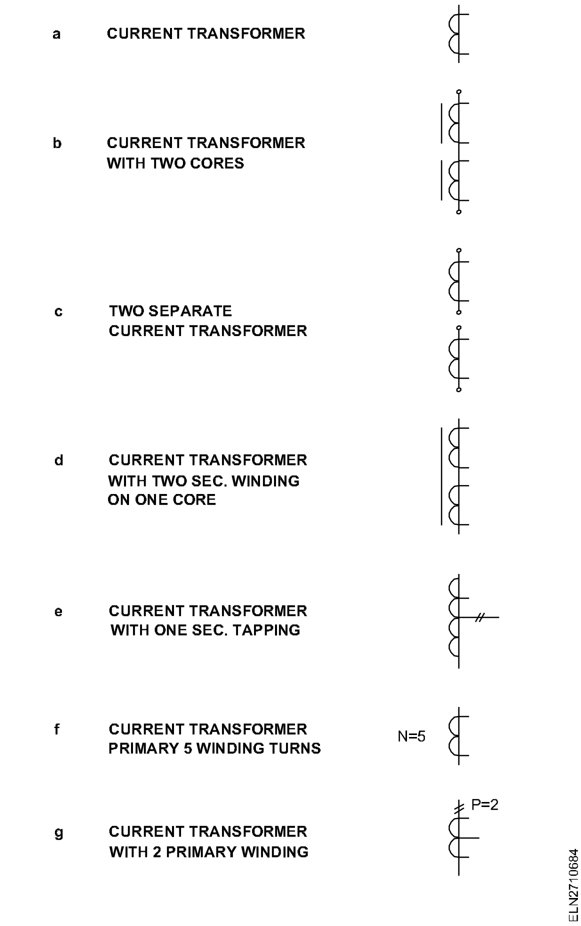
BAR TYPE CURRENT TRANSFORMER

Dry type current transformer :This is one which does not require the use of any liquid or semi-liquid material for the purpose of cooling.

Oil immersed current transformer: This is one which requires the use of an oil of suitable characteristic as insulating and cooling medium.

Recommended symbols and terminal marking as per I.S. 2012(Part XX11)-1978 (Fig 4)

Fig 4



Method of marking

Marking should be done following the guidelines given below. (I.S. 2705(Part I) - 1981)

The terminals shall be marked clearly and indelibly either on their surface or in their immediate vicinity.

The marking shall consist of letters, followed or preceded where necessary, by numbers. The letters shall be in block capitals.

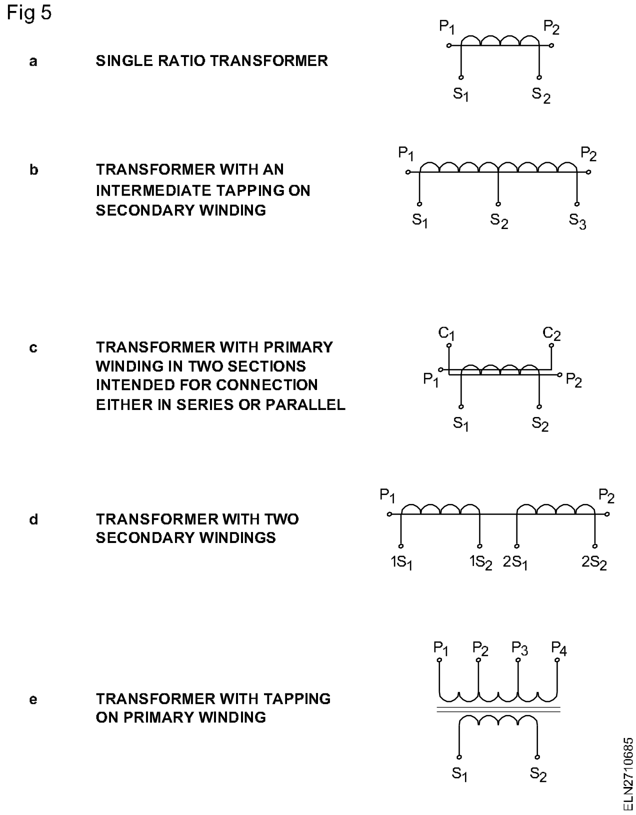
The marking of current transformers shall be as indicated in Figs 5a to 5e.

All the terminals marked P1, S1 and C1 shall have the same polarity at any instant.

General terms used

Accuracy class: Accuracy class is a designation assigned to a current transformer the errors of which remain within the specified limits under prescribed conditions of use. The standard accuracy classes for measuring current transformers shall be 0.1, 0.2, 0.5, 1.0, 3.0 and 5.0.

Fig 5



Phase displacement: This is the difference in phase between primary and secondary current vectors, the direction of the vector being so chosen that the angle is zero for a perfect transformer.

The phase displacement is said to be positive when the secondary current vector leads the primary current vector. It is usually expressed in minutes.

The above definition is strictly for sinusoidal currents only. The phase displacement is an important factor to be considered when connecting several current transformers together in a circuit for various measurements.

Burden: Burden is usually expressed as the apparent power in **volt amperes** absorbed at a specified power factor and at the rated secondary current. Rated burden is the value on which the accuracy requirement of this specification is based.

Rated output: This is the value of the apparent power (in volt amperes at a specified power factor) which the current transformer is intended to supply to the secondary circuit at the rated secondary current and with the rated burden connected to it. The standard values of rated outputs are 2.5, 5.0, 7.5, 10, 15 and 30 VA.

Precautions while using the current transformer: In the case of an ordinary transformer the supply voltage almost remains constant and the magnitude of primary current depends upon the load current.

However in a current transformer the secondary current depends upon the primary current. Futher the secondary of the current transformer could be assumed to be almost short circuited as the ammeter resistance is extremely low.

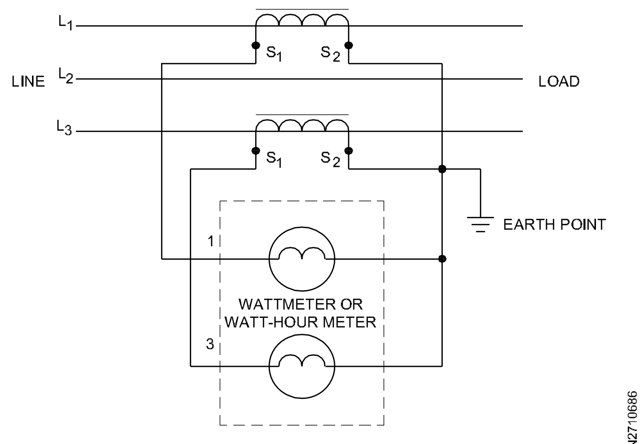
In any case, the secondary winding of the current transformer should not be open circuited. This may happen when the ammeter become open circuited or when the ammeter is removed from the secondary.

In such cases the secondary should be short circuited. If the secondary is not short circuited, in the absence of secondary ampere-turns, the primary current will produce abnormally high flux in the core thereby heating up the core and resulting in burning out the transformer.

Further secondary will produce a high voltage across its open terminals endangering safety. In addition to earthing non-current carrying metal parts of the current transformer, we have to earth one end of the secondary of the current transformer to prevent a high static potential difference in case of open circuit. It also serves as a safeguard in case of insulation failure.

While using more than one current transformer in a circuit, the grounding should be done by connecting the similar polarity ends of the current transformer and grounding the circuit at a point (Fig 6)

Fig 6



GROUP OF CURRENT TRANSFORMER WITH GROUNDING POINT

Specification of a current transformer: While purchasing a current transformer, the following specifications need to be checked.

- Rated voltage, type of supply and earthing conditions (for example, 7.2 kV, three phase, whether earthed through a resistor or solidly earthed).
- Insulation level
- Frequency
- Transformation ratio
- Rated output
- Class of accuracy

- Short time thermal current and its duration
- Service conditions including, for example, whether the current transformer is for use indoors or outdoors, whether for use at unusually low temperature altitudes (if over 1000 metres), humidity and any special conditions likely to exist or arise, such as exposure to steam or vapour, fumes, explosive gases, vibrations excessive dust etc.
- Accuray limit factor and any other additional requirement for current transformers for protective purposes.
- Special features, such as limiting dimensions.

Standard values of rated primary current: The standard values in amperes of rated frequency are 10, 15, 20, 30, 50, 75 amperes and their decimal multiples.

Standard values of rated secondary current: The standard values of rated secondary current shall be either 1 ampere or 5 amperes.

Potential transformer

Objectives: At the end of this lesson you shall be able to
- **explain the construction and connection of the potential transformer**
- **identify the I.S. symbols and markings used in the potential transformer**
- **state the general terms like accuracy, phase displacement, burden and output with respect to the potential transformer**
- **specify the potential transformer.**

Potential transformer

Construction and connection: The construction of a potential transformer is essentially the same as that of a power transformer. The main difference is that the volt-ampere rating of a potential transformer is very small.

To reduce the error in a potential transformer, it is required to provide a short magnetic path, good quality of core materials, low flux density and proper assembling and interlaying of cores.

To reduce resistance and leakage reactance, thick conductors are used and the two windings are kept as close as possible.

The core may be of shell or core type construction. Shell type construction is normally used for low voltage transformers.

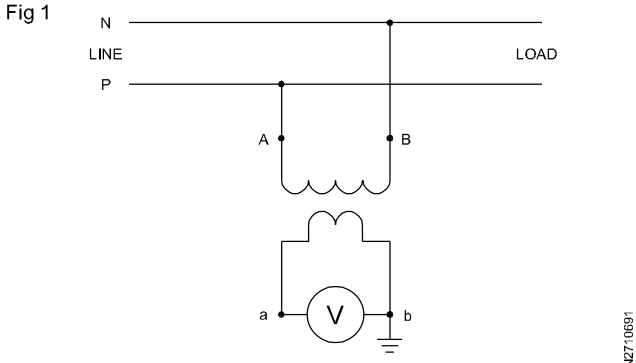
The primary and secondary windings are coaxial to reduce the leakage reactance to the minimum. In order to simplify the insulation problem, generally a low voltage winding (secondary) is put next to the core.

The primary winding may be of a single coil in the case of low voltage transformers but in the case of high voltage transformers the winding is divided into a number of short coils.

Fig 1 shows the connections of a potential transformer. In general, the voltmeter connected to the secondary of the potential transformer is arranged to give full scale deflection at 110 volts.

The ratio between the primary and secondary turns of the potential transformers decides the primary voltage which could be measured with the fixed secondary voltage rating of 110 volts (Fig 1).

Fig 1

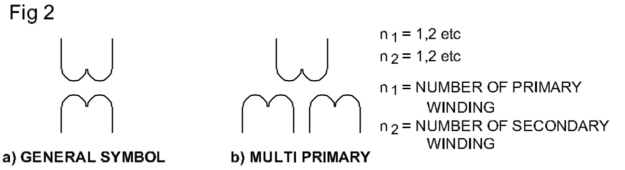


CONNETION OF POTENTIAL TRANSFORMER

If the primary turns are four, the secondary turns are two and the primary is connected to a voltage source of magnitude 220 volts, the secondary voltage will be 110 volts according to the transformation ratio.

Recommended symbols and terminal marking as per I.S. 3156 (Part I) 1978 Fig 2

Fig 2



a) GENERAL SYMBOL   b) MULTI PRIMARY AND SECONDARY WINDINGS

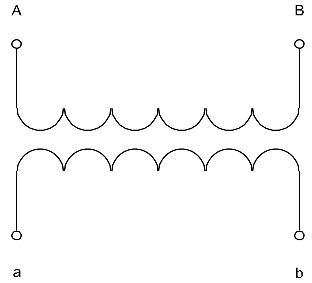
Method of marking

Marking the terminals should be done following the guidelines given below (I.S. 3156 (Part - I) - 1978.)

Figs 3 to 10 give the recommended markings used in a potential transformer as per I.S.

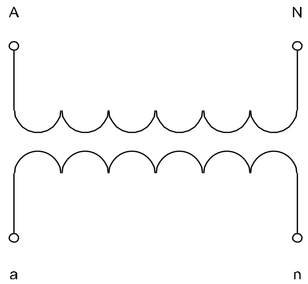
Marking shall be in accordance with Figs 3 to 10 as appropriate. Capital A,B,C and N denote the primary winding terminals and the lower case letters a,b,c and n the corresponding secondary winding terminals.

Fig 3



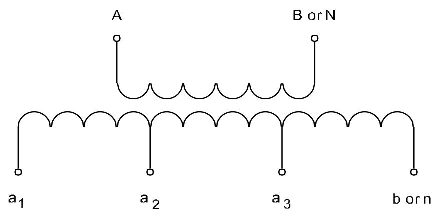
SINGLE PHASE TRANSFORMERS
WITH FULL INSULATED TERMINALS
AND A SINGLE SECONDARY

Fig 4



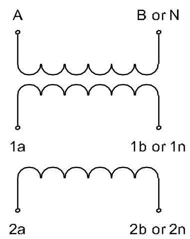
SINGLE PHASE TRANSFORMER WITH A NEUTRAL PRIMARY
TERMINAL WITH REDUCED INSULATION AND A SINGLE SECONDARY

Fig 5



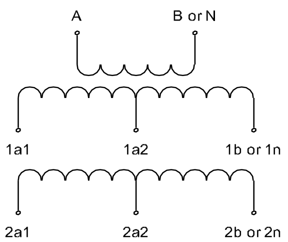
SINGLE PHASE TRANSFORMER WITH
ONE MULTI-TAP SECONDARY

Fig 6



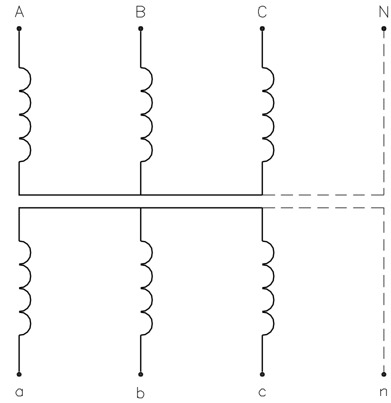
SINGLE PHASE TRANSFORMER
WITH TWO SECONDARIES

Fig 7



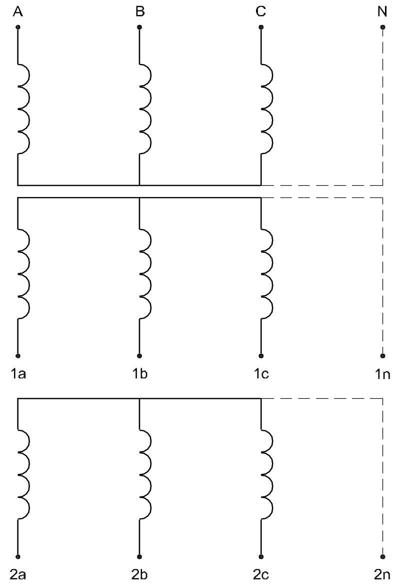
SINGLE PHASE TRANSFORMER
WITH TWO MULTI-TAP SECONDARIES

Fig 8



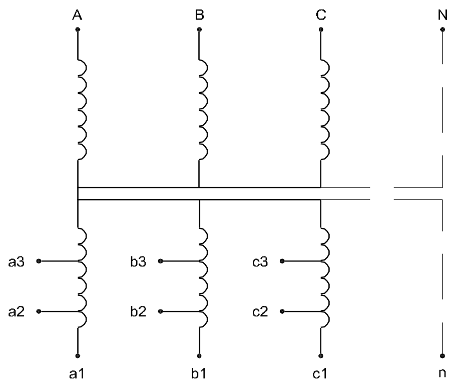
THREE PHASE ASSEMBLY
WITH A SINGLE SECONDARY

Fig 9



THREE PHASE ASSEMBLY
WITH TWO SECONDARIES

Fig 10



THREE PHASE ASSEMBLY WITH ONE MULTI-TAP SECONDARY

The letters A,B,C denote fully insulated terminals and the letter N denotes a terminal intended to be earthed and the insulation of which is less than that of the other terminals.

Accuracy class designation: For measuring voltage transformers, the accuracy class is designated by the highest permissible percentage voltage error at the rated voltage and with the rated burden, prescribed for the accuracy class concerned.

The standard accuracy classes for single phase measuring voltage transformers shall be 0.1, 0.2, 0.5, 1.0 and 3.0.

Phase displacement: This is the difference in phase between the primary voltage and the secondary voltage vectors. The direction of the vectors is so chosen that the angle is zero for a perfect transformer.

Phase displacement is an important factor to be considered when several potential transformers are to be connected in a system for various measurements.

Burden: The rated burden of a voltage transformer is usually expressed as the apparent power in volt amperes absorbed at the rated secondary voltage.

The burden is composed of the individual burdens of the associated voltage coils of the instruments, relays or trip coils to which the voltage transformer is connected.

When the individual burdens are expressed in ohmic values, the total burden may be computed by adding the admittance values. This admittance value should then be converted to VA burden by multiplying the admittance value by the square of the rated voltage.

Rated output: This is the value of the apparent power (in volt-amperes at a specified power factor) which the transformer is intended to supply to the secondary circuit at the rated secondary voltage and with the rated burden connected to it.

The rated output at a power factor of 0.8 lagging, expressed in volt-amperes should be one of the values given here: 10, 15, 25, 30, 50, 75, 100, 150, 200, 300, 400 and 500 VA.

Typical values of VA burden imposed by different meters are given below.

- Voltmeters, voltage coils of wattmeters power factor meter and recording voltmeter - 5 VA.
- Voltage coils of frequency meters (pointer and reed type), voltage coils of KWH, KVAR meters, voltage coils of recording power factor meters and wattmeters - 7.5 VA.
- Voltage coils of synchroscope - 15 VA.

Precautions to be followed while using a potential transformer: The assembly comprising of the chasis frame work and the fixed part of the metal casing of the voltage transformer shall be provided with two separate, readily accessible, corrosion-free terminals marked legibly as earth terminals.

Specification of a potential transformer: While purchasing a potential transformer, the following specifications need to be checked.

- Rated voltage, type of supply and earthing conditions (for example 6.6 KV, 3 phase solid earthed)
- Insulation level
- Frequency
- Transformation ratio
- Rated output
- Accuracy class
- Winding connection
- Rated voltage factor
- Service conditions including whether voltage transformers are for indoor or outdoor use, whether for use at unsually low temperatures, altitudes (if over 1000 metres), humidity and any special conditions likely to exist or arise, such as exposure to steam or vapour, fumes, explosive gases, excessive dust, vibrations etc.
- Special features, such as limiting dimensions.
- Whether the voltage transformer is required for connection between the star point of the generator and earth.
- Any additional requirement for voltage transformers for protective purposes.
- Whether the installation is electrically exposed or not.
- Any other information.
- Fig 10 shows three phase assembly with one multi-tap secondary

Standard rating of potential transformer

Rated frequency: The rated frequency shall be 50 Hz.

Rated primary voltage: The rated primary nominal system voltage of a 3-phase transformer. 0.6, 3.3, 6.6, 11, 15, 22, 33, 47, 66, 110, 220, 400, and 500 KV.

The standard value of primary voltage of a single phase transformer connected between one line of a 3-phase system and neutral point shall be $\frac{1}{\sqrt{3}}$ times of the above values of the nominal system voltages.

The rated secondary voltage: The rated value of secondary voltage for a single phase transformer or for a 3-phase transformer shall be either 100 and 110V.

Measurement of power in single phase circuit using CT and PT

Objective: At the end of this lesson you shall be able to
- **solve the problem pertaining to power measurement in multirange watt meter in single phase circuit using CT and PT.**

Reading multi-range wattmeters: Multi-range wattmeters will have a meter constant which has to be taken into account while measuring the power. Meter constant (multiplication factor MF) normally is written on the inner side of the top cover. In the absence of such information, we can calculate the meter constant as explained below.

Pressure coil range x Current coil range

Meter constant (Multiplication factor) =

$$\frac{\text{Pressure coil range x Current coil range}}{\text{Maximum dial reading in watts(Full scale reading in watts)}}$$

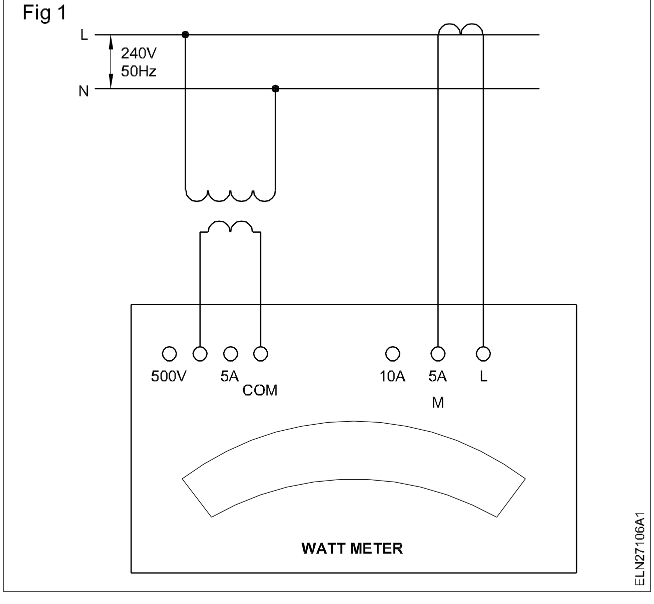
The following example will guide the trainees in finding the meter constant while using a multi-range wattmeter.

Example: A wattmeter has the following multi-ranges.

Pressure coil 500/250/125 volts

Current coil 20/10/5 amps (Fig 1)

Fig 1



The maximum dial reading (Full scale deflection FSD) indicates 625 watts. Find the meter constant and actual power if the meter reads 600watts against the following ranges.

A 500V, 10A

B 125V, 5A

RANGE A 500V, 10A

$$\frac{\text{Pressure coil range x Current coil range}}{\text{Maximum dial reading in watts(Full scale reading in watts)}}$$

$$= \frac{500 \times 10}{625} = 8$$

Actual power = Wattmeter reading x Meter constant (Multiplication factor MF)

= 600 x 8 = 4800 watts

RANGE B 125V, 5 A

Meter constant $= \frac{125 \times 5}{625} = 1$

(Multiplication factor MF)

Actual power = 600 x 1= 600 watts

Reading multiscale wattmeters when connected to CT and PT: In case the wattmeter is connected to a circuit through CT and PT to measure the power dissipated in the circuit, we have to take into consideration the CT ratio and PT ratio.

In such cases the actual power consumed in the circuit

P = Wattmeter reading x Multiplication factor MF (Meter constant MC) x CT ratio x PT ratio = ... watts.

Example: A single phase mutiscale watt meter is having the following ranges.

500/250/125V and 10A / 5A .

This watt meter is connected to a circuit of 240V rating through CT and PT and their ranges are 25/5 and 250/110 respectively.

The watt meter pressure coil is connected at 125V range and current coil is in 5 Amps range. Calculate the power consumed in the circuit if the wattmeter reads 500 watts at its maximum dial reading of 625 watts.

The Multiplication factor MF $= \frac{\text{Voltage range} \times \text{Current range}}{\text{Maximum dial reading}}$

Meter constant $= \frac{125 \times 5}{625} = 1$

Actual power consumed in the circuit P

= Watt meter reading x MF x CT ratio x PT ratio

$$= 500 \times 1 \times \frac{25}{5} \times \frac{250}{110}$$

$$= 500 \times 1 \times 5 \times 2.272$$

$$= 5680 \text{ W or } 5.68 \text{ KW}$$

Measurement of three phase energy using CT and PT

Objectives: At the end of this lesson you shall be able to
- **state the method of selecting the ranges of CT and PT according to load and meter requirement**
- **differentiate between CT and PT with a 3-phase energy meter.**

CTs and PTs with 3-phase energy meter: Standard ratings of energy meters are 10, 20, 30, 50 and 100 A and of voltages 120 or 240V or 415V. Current transformers and potential transformers are also used along with 3-phase energy meters when used to measure energy with higher current and voltages.

For selecting CT for an energy meter the primary current of the CT should be rated to that of the maximum line current or the next higher standard rating, while secondary should be that of the meter's maximum current rating. For selecting PT the primary voltage of PT should be that of line voltage and the secondary voltage should be that of the meter pressure coil voltage.

The instrument transformer-operated 3-phase and 1 phase energy meter should have separate terminals for pressure and current coils.

When an usual energy meter is used, its pressure coil links are to be disconnected, before connecting CTs and PTs.

For standard instrument transformer-operated energy meters the current coils are rated for 5A or 1A, while potential coils are rated for 110V or 100V.

A current transformer is used when the load current rating is higher than the available meter rating.

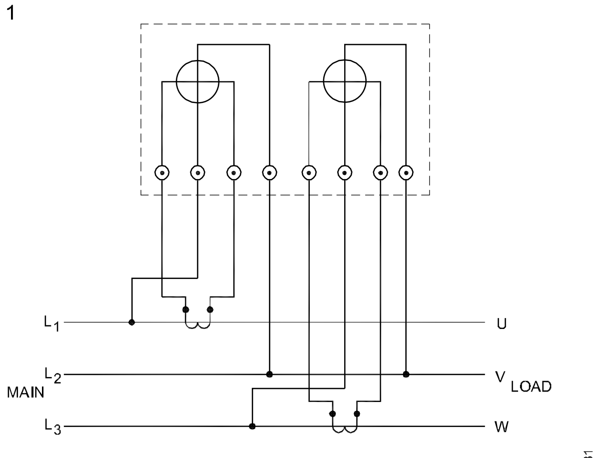
CTs with 2-element energy meter: The method of connecting a two element energy meter with 2 CTs suitable for 3-phase 3-wire system.(Fig 1)

CTs with 3-element energy meter: Fig 2 shows the method of connecting a 3-element energy meter with 3 CTs. This arrangement is suitable for a 3-phase 4-wire system.

Example 1: An industry has a connected load of 200 HP for 400V 3-phase 50Hz. What should be the current rating of the current transformer and its ratio? Assume PF is unity.

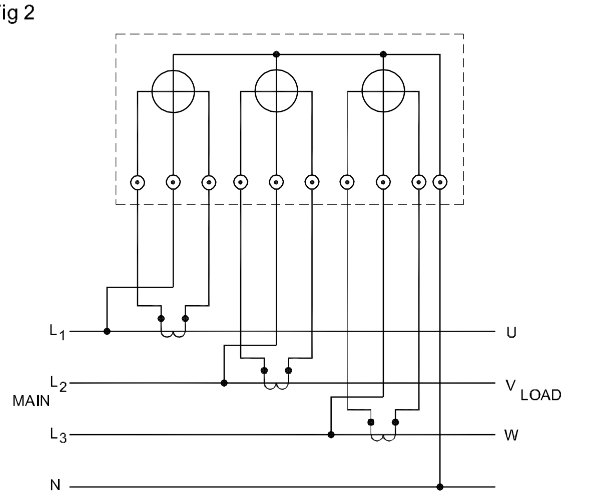
Connected load = 200 HP

Fig 1



3-PHASE TWO ELEMENT ENERGY METER WITH CURRENT TRANSFORMERS USED ON A 3-PHASE 3-WIRE SYSTEM. SEQUENCE IS UVW.

Fig 2



3-PHASE TWO ELEMENT ENERGY METER WITH CURRENT TRANSFORMERS USED ON A 3-PHASE 4-WIRE SYSTEM. SEQUENCE IS UVW.

Supply voltage = 400V 3-phase

$$I_L = \frac{HP \times 746}{\sqrt{3}\ V \times PF} = \frac{200 \times 746}{\sqrt{3} \times 400 \times 1} = 215A$$

Rating of CT $\frac{215}{5}$ = 43

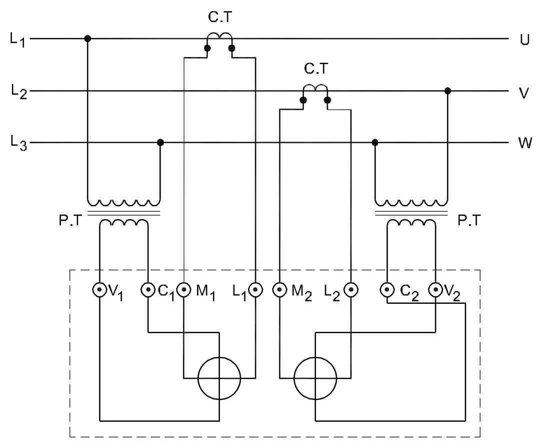
CT ratio = 43: 1 or 50:1 or 250A/5A.

CT and PT with 2-element energy meter: A connection diagram for a 2-element energy meter with 2 CTs and 2 PTs. (Fig 3)

A three phase P.T and two C.Ts connected with a two element energy meter used in a 3-phase, 3-wire system (Fig 4)

CT and PT with 3-element energy meter: A 3-element energy meter with C.T and P.T connected to a 3-phase 4-wire system is shown in Fig 5.

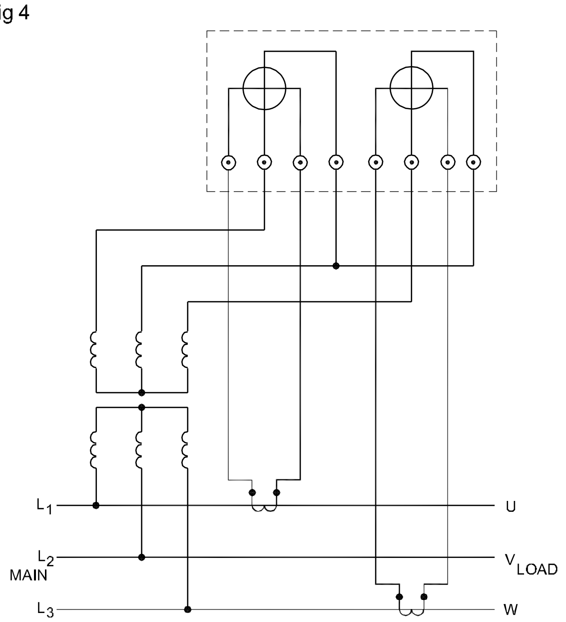
Fig 3



3-PHASE, 2 ELEMENT ENERGY METER WITH CT & PT

The metering cubicle used along with HT line of 11KV or higher voltages consists of 2 or 3 CTs and a three phase PTs known as a kiosk.

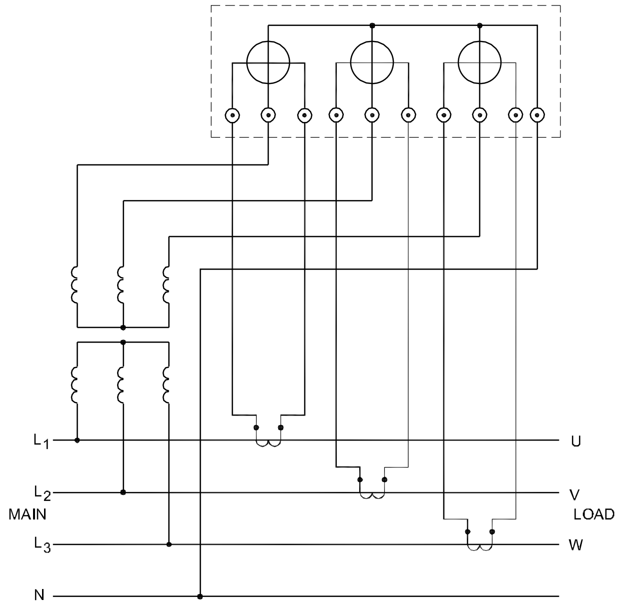
Fig 4



3-PHASE THREE ELEMENT ENERGY METER WITH CURRENT AND VOLTAGE TRANSFORMERS USED ON A 3-PHASE 3-WIRE SYSTEM. SEQUENCE IS UVW.

From the kiosks, cables are run to the meter panel. Normally to measure KWH, KVARH, MD and KVAH, a trivector meter is used.

Fig 5



3-PHASE THREE ELEMENT ENERGY METER WITH CURRENT AND VOLTAGE TRANSFORMERS USED ON A 3-PHASE 4-WIRE SYSTEM. SEQUENCE IS UVW.

Tri vector meter is an instrument used to measure the energy used by the load in terms of KWH, KVARH , MD and KVAH.

Maximum demand (MD): This trivector meter also has a maximum demand indicator to show the maximum reactive power persists in the load in term of KVA.

The tariff will be charged for this maximum demand in KVA. A penalty will be levied if this rating exceeds the sanctioned KVA rating of the factory.

Example 2: An industry is supplied with 800KVA 11KV 3-phase energy to be recorded through a 5A 110V 3-phase energy meter. Calculate the ratio of PT and CT.

Industry supply voltage = 11kV

Rating of transformer = 800kVA

Therefore, the current

$$= \frac{800}{11 \times \sqrt{3}} = \frac{800 \times \sqrt{3}}{11 \times \sqrt{3} \times \sqrt{3}}$$

$$= \frac{800 \times 1.732}{33} = \frac{1385.600}{33} = 42A$$

3-phase energy meter available = 5A, 110V.

CT ratio = 42/5 = 8.4 or say 10 = 10:1

PT ratio = 11000/110 = 100 = 100:1

Example 3: An energy meter connected through C.T and P.T to an industry recorded a reading of 369 units on 1st May. On 31st May the reading is found to be 426. If the C.T ratio is 50A/5A and the P.T ratio is of 11000V/110V calculate the metering constant and the energy consumed during the month.

Metering constant = CT ratio x PT ratio

$$= \frac{50}{5} \times \frac{11000}{110} = 10 \times 100 = 1000$$

Energy consumed = Difference in reading x MC

= (426 - 369) x 1000

= 57 x 1000 = 57000 Units.

Transformer losses - OC and SC test - efficiency - Voltage Regulation

Objectives: At the end of this lesson you shall be able to
- **state the type of losses occured in transformer**
- **explain Iron (No - load) losses and copper (load) losses in transformer.**

Losses

There are two type of losses occured in the transformer such as iron (core) loss (Hysterisis + eddy current) and copper (Ohmic) or load loss

Iron (or) No-load losses: The no load losses consist of two components i.e hysteresis and eddy current loss.The hysteresis loss due to the cyclic variation of the magnetic flux in the ferrous metal.

The eddy current occurs because of the changing flux in the core,(according to Lenz's law) inducing a voltage in the core. As a result, circulating eddy currents set up in the core with subsequent I^2R loss. This is also called as **iron loss (or) core loss (or) constant losses**.

As the core flux in a transformer remains practically constant at all loads, the core-loss is also constant at all loads. This is also known as no-load losses.

Hysteresis loss W_h = $K_h B^{1.6}_m$ watts

Eddy current loss W_e = $K_e f^2 K_f B_m^2$

where K_h = the hysteresis constant

K_f = the form factor

K_e = the eddy current constant

These losses are minimised by using steel of high silicon content (from 1.0 to 4.0 percent) for the core and by using very thin laminations.

Silicon steel has a high saturation point, good permeability at high flux density, and moderate losses. Silicon steel is widely used in power transformers, audio output transformers and many other applications.

The input power of a transformer, when on no-load, measures the core-loss.

Copper (or) Load losses: This loss is mainly due to the ohmic resistance of the transformer windings. The load current through the resistances of the primary and secondary windings creates I^2R losses that heat up the copper wires and causes voltage drops. This loss is also called **copper losses (or) variable losses**. Copper losses are measured by the short circuit test.

The core loss in a transformer is a constant loss for all load conditions. The copper loss varies proportionally to the square of the current.

Open Circuit (O.C) test of a transformer

Objective: At the end of this lesson you shall be able to
- **explain the method of conducting an open circuit test**
- **calculate the exact iron loss.**

The open circuit

The open circuit test is performed to determine the no-load losses or the core losses.

In this test, a rated voltage is applied to one winding, usually the low-voltage winding for safety reasons, while the other is left open-circuited. The input power supplied to the transformer represents mainly core losses. Since the no-load current is relatively small the copper loss may be neglected during this test.

The circuit instruments are shown in Fig 1. The wattmeter indicates the core loss. The voltmeter will register the rated voltage. The ammeter reading in conjunction with voltage will provide the necessary data to obtain information about the magnetizing branch.

The core loss can be measured on either side of the transformer. For instance, if a 3300/240V transformer were to be tested the voltage would be applied to the secondary side, since 240V is more readily available.

The core loss measured on either side of the transformer would be the same, because 240V is applied to a winding that has fewer turns than the high voltage side. Thus the volt/turn ratio is the same. This implies that the value of the maximum flux in the core is the same in either case. The core loss depends on the maximum flux.

The frequency of the o.c. test supply should be equal to the rated frequency of the transformer.

The actual (exact) iron loss (W_i) can be calculated by the formula

Iron loss $= W_i = W_0$ - no load copper loss

$W_i = W_o - (I_0)^2 R$

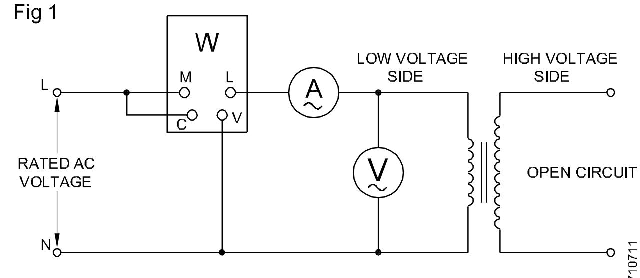
W0 = Wattmeter reading on no load

No Load copper loss = $(I_0)^2 R$

R = Resistance of winding in which the OC test calculated

I_0 = No - load current

Fig 1



OPEN CIRCUIT TEST CONNECTIONS

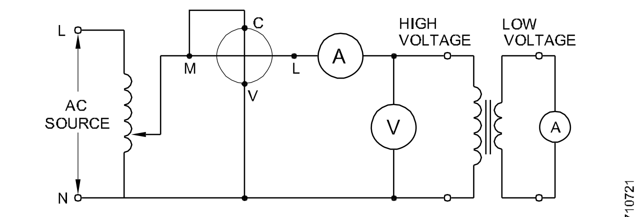
Short circuit (S.C) test of a transformer

Objectives: At the end of this lesson you shall be able to
- **explain the method of conducting the short circuit test on a single phase transformer**
- **calculate the equivalent resistance and equivalent reactance of the transformer, with respect to high voltage circuit**
- **calculate the copper loss.**

Short circuit test:

A short circuit test is required to determine the transformer equivalent circuit parameters and copper losses. The connected diagram for the short circuit test is shown in Fig 1.

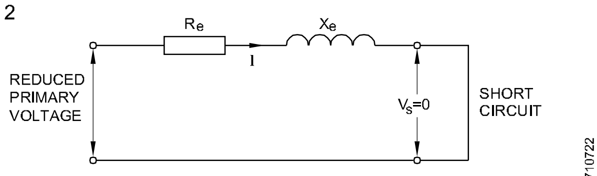
Fig 1



CONNECTION DIAGRAM

The low voltage side of the transformer is short circuited. A reduced voltage applied on the high voltage winding of the transformer such that the rated current flows through the ammeter. In this condition the impedance of the transformer is merely as equivalent impedence (Fig 2).

Fig 2



EQUIVALENT CIRCUIT

The test is performed on the high voltage side because it is convenient to apply a small percentage of the rated voltage. In the case of a 3300V/240V transformer, it is easier and more accurate to deal with 5% of 3300V than with 5% of 240V.

With the primary voltage greatly reduced, the flux will be reduced to the same extent. Since the core loss is somewhat proportional to the square of the flux, it is practically zero.

Thus a wattmeter used to measure the input power will indicate the copper losses only; the output power is zero. From the input data obtained from the instruments, the equivalent reactance, can be calculated. All the values calculated are in terms of high voltage side.

R_e is equivalent resistance

X_e is equivalent reactance

R_{eH} is equivalent resistance on high voltage side

X_{eH} is equivalent reactance on high voltage side

Z_{eH} is equivalent impedance on high voltage side

$$R_{eH} = \frac{P_{SC}}{I^2_{SC}} \text{ ohms}$$

$$Z_{eH} = \frac{V_{SC}}{I_{SC}} \text{ ohms}$$

and $X_{eH} = \sqrt{Z^2_{eH} - R^2_{eH}}$ ohms

where I_{sc}, V_{SC} and P_{SC} are the short circuit amperes, volts and watts respectively, and R_{eH}, Z_{eH} and X_{eH} are equivalent Resistance, Impedance and Reactance respectively in terms of high voltage side.

Example

The following data were obtained in a short circuit test on a 20 KVA 2400V/240V 50 Hz. transformer.

V_{SC}, = 72V, I_{SC} = 8.33A, P_{SC} = 268W.

Instruments were placed in the high voltage side and the secondary is short-circuited. Obtain the equivalent transformer parameters of the high voltage side.

Solution

$$R_{eH} = \frac{P_{SC}}{I^2_{SC}} = \frac{268}{(8.332)^2} = 3.86\,\Omega$$

$$Z_{eH} = \frac{V_{SC}}{I_{SC}} = \frac{72}{8.33} = 8.64\,\Omega$$

and $X_{eH} = \sqrt{Z^2_{eH} - R^2_{eH}}$

$= \sqrt{8.64^2 - 3.86^2} = 7.73\,\Omega$

Efficiency of transformer

Objectives: At the end of this lesson you shall be able to

- **calculate efficiency from the losses**
- **state the condition for maximum efficiency**
- **define all-day efficiency of a distribution transformer.**

Efficiency of transformer:

In general, the efficiency of any electrical apparatus is

$$\eta = \frac{\text{output power}}{\text{input power}} = \left|\frac{\text{output power}}{\text{output power} + \text{losses}}\right| \quad .....(1)$$

where η is the symbol used to denote efficiency. When equation (1) is multiplied by the factor 100, the efficiency will be in percent.

The efficiency of a transformer is high and in the range 95 to 98%. This implies that the transformer losses are as low as 2 to 5% of the input power.

While calculating the efficiency, it is generally much better to determine the transformer losses rather than measured the input and output powers directly.

In transformer, the open circuit test yields the core losses and the short circuit test provides the copper losses. Thus the efficiency can be determined from these data with reasonable accuracy.

The transformer ratings are based on output KVA (MVA). Therefore, the equation for efficiency may be written as

$$\eta = \left|\frac{KVA_{out} \times PF}{(KVA_{out} \times PF) + \text{Copper loss} + \text{core loss}}\right|$$

Condition for maximum efficiency:

The efficiency of a transformer is at a maximum when the fixed losses are equal to the variable losses. In other words, when the copper losses is equal to the iron losses, the efficiency is maximum.

Example: A transformer with a rating of 10 KVA 2200/220V 50 Hz was tested with the following results.

Short circuit test power input = 340 W

Open circuit test power input = 168 W

Determine

(i) the efficiency of this transformer at full load

(ii) the load at which maximum efficiency occurs.

The load power factor is 0.80 lagging.

Solution

(i) Efficiency at full load, η_{FL}

$$\eta = \frac{P_{out}}{P_{in}} = \frac{(10 \times 10^3 \times 0.8)\,100}{(10 \times 10^3 \times 0.8) + \text{Cu loss} + \text{Iron loss}}$$

$$= \frac{(10000 \times 0.8)\,100}{(10000 \times 0.8) + 340 + 168}$$

= 94.0%.

(ii) The maximum efficiency occurs at a load when the copper loss = core loss.

Thus the copper loss = core loss = 168 W.

Let the current at full load = I.

The current at maximum efficiency = I'.

Then, the copper loss at full load = I^2R_{eq} = 340 W

the copper loss at h_{max} = $(I')^2R_{eq}$ = 168 W.

Therefore, $\frac{I^2 R_{eq}}{I'^2 R_{eq}} = \frac{340}{168}$

or $I' = I\sqrt{\frac{168}{340}}$

This is the factor by which the power decreases,

Therefore, $P_{atmax\eta} = \sqrt{\frac{168}{340}} \times (10000 x 0.8)$

$= 5623$ W

$P_{atmax\eta} = 5623$ W

$= 70.26\%$ of 8000 W

$= 0.7026$ of full load.

or

Therefore, $\eta_{max} = \frac{5623}{5623 + 168 + 168} \times 100$

$= 94.36\%$.

All day efficiency

Lighting transformers and most distribution transformers will not have full load for all the 24 hours in a day. To keep the operational efficiency of such distribution transformers are designed to have their maximum efficiency at a lower value than full load.

Allday efficiency

$$\frac{\text{Output in24hours}}{\text{Output in24hours} \quad \text{losses in24hours}}$$

η_{allday}

$$= \frac{\text{Output KWh 24 hours}}{\text{Output KWh(24 hours)} + \text{losses KWh (24 hours)}}$$

Here, the iron loss is considered through out the period where as copper loss depends up on the period for which transformer is loaded and percentage load.

Example: A 100 KVA distribution transformer has a full load loss of 3 KW. At full load the losses are equally divided between iron and copper loss. During a certain day the transformer connected to the lighting load operated with loads as given below.

a) On full load, unity PF 3 hours.

b) On half full load, unity PF 4 hours.

c) Negligible and during the remaining part of the day.

Calculate the all day efficiency.

Solution

As the load is primarily lighting, the PF = 1.0.

(a) Output energy at FL in 3 hours

= 100 KVA x 1 x 3 = 300 KWh

(b) Output energy at 1/2 FL in 4 hours

= 100 x 1/2 x 1 x 4 = 200 KWh.

Energy wasted in kWh during full load

= 3 KW x 3h = 9 KWh.

At full load

Iron loss = copper loss = 3.0¸2 = 1.5 KW.

Copper loss at 1/2 full load

= 1.5 x $(1/2)^2$ = 1.5/4 KW.

Total energy loss during half full load

= iron loss for 4 hours + copper loss for 4 hours

= (1.5 x 4) + (1.5/4 x 4)

= 6 + 1.5 = 7.5 KWh.

The transformer has no load for

= (24 - 7) hours = 17 hours.

Constant loss for 17 hours

= 1.5 x 17 = 25.5 KWh.

The total loss for 24 hours= (9 + 7.5 + 25.5) KWh = 42

η_{allday}

$$= \frac{\text{Output KWh 24 hours}}{\text{Output KWh(24 hours)} + \text{losses (24 hours)}}$$

KWh $\frac{(300 + 200)}{(300 + 200) + 42} = 0.922$

$\eta_{allday} = 92.2\%$

Voltage regulation of transformers

Objectives: At the end of this lesson you shall be able to
- **define the voltage regulation of a transformer**
- **calculate the voltage regulation of a transformer.**

Voltage regulation:

The voltage regulation of a transformer is the difference between the no-load and full load secondary voltage expressed as a percentage of the full load voltage. The primary or applied voltage must remain constant.

This is an additional condition that must be fulfilled in the case of transformers.

Also, the power factor of the load must be stated since the voltage regulation does depend on the load power factor.

In general,

$$\text{Voltage regulation} = \frac{V_{noload} - V_{load}}{V_{load}} \times 100\%$$

Let V_0 = Secondary terminal voltage at no-load

V_S = Secondary terminal voltage at load.

$$\text{Then \% regulation} = \frac{V_o - V_S}{V_S} \times 100$$

The numerical values employed in the calculations depend on which winding is used as a reference for the equivalent circuit. Similar results are obtained whether all impedance values are transferred to the primary or to the secondary side of the transformer.

Example:

The secondary voltage of 11KV/440V, 100KVA transformer is 426 V at no-load. Under the full load condition, the same is 410V at 0.92 Power factor. Calculate the percentage voltage regulation of the transformer.

solution:

$$\text{\% of Voltage regulation} = \frac{V_o - V_S}{V_S} \times 100$$

$$\text{\% of Voltage regulation} = \frac{426-410}{410} \times 100$$

$$= \frac{16}{10} \times 100$$

$$= 3.9\%$$

Parallel operation of two single phase transformers

Objectives: At the end of this lesson you shall be able to
- **state the necessity of parallel operation of transformers**
- **state the conditions to be full filled for the parallel operation of transformers**
- **explain how to determine the polarity terminals of transformer.**

Necessity of parallel operation of transformers

1 When the power demand of the load increases, two or more transformer may be operated in parallel.

2 When the power demand decreases, only required numbers of transformer may be operated with their full load capacity. Where as the remaining transformers may be switched "OFF" and taken for general maintenance/service.

3 Thus the efficiencies and life of the transformers increases and the losses are reduced.

4 It provides more reliability of power i.e., even one transformer fails or become out of service, other transformers will supply to the certain amount of load.

5 It is not economical to manufacture a single very large capacity transformer. Thus operationg two or more numbers of optimal capacity transformers in parallel is more economical.

6 It is easy to plan the maintenance schedule of the transforemers, hence the cost of maintenance and spares are reduced.

Conditions

1 the same voltage ratio

2 Input voltage must be same

3 the same per unit (or percentage) impedance

4 the same polarity

5 the same phase sequence and zero relative phase displacement, for 3 phase transformers.

Of these (4) and (5) are absolutely essential (1) and (2) must be satisfied to a close degree.

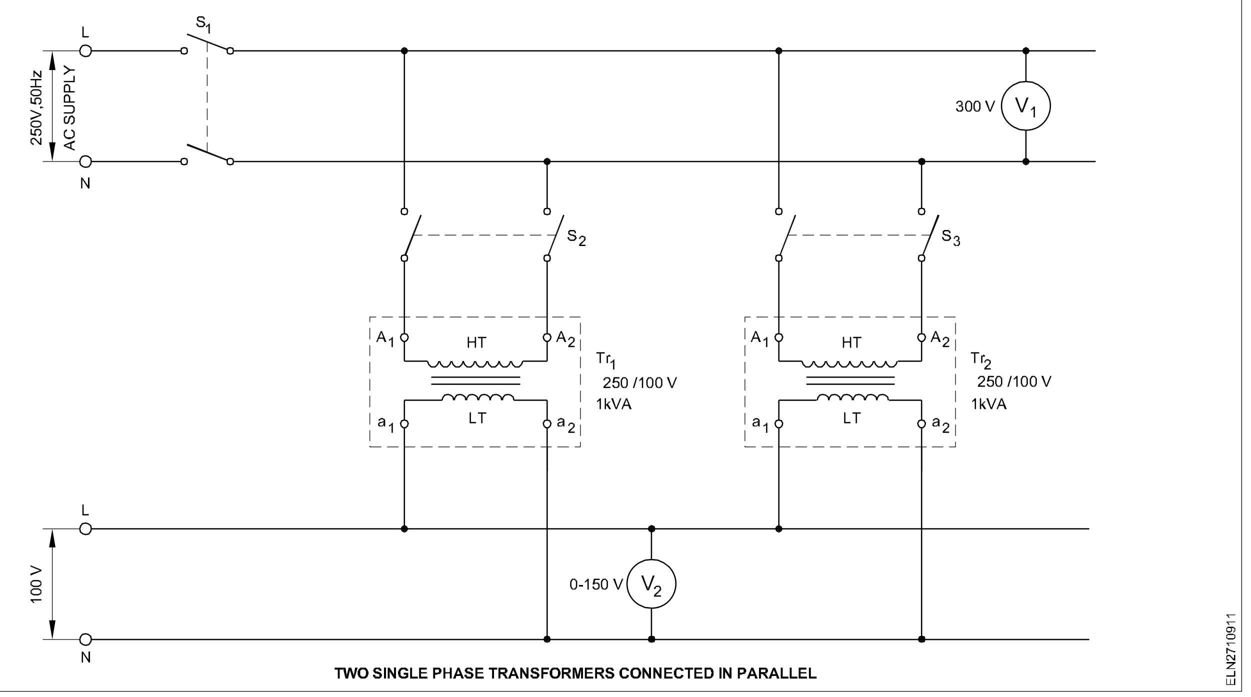
There is more allowance for a wide extent with (3), but the more nearly it is true, the better will be the load division between several transformers.

Parallel operation

Fig 1 shows two single phase transformers connected in parallel with their primary windings connected to the same supply and their secondary windings supplying a common load.

When operating two or more transformers in parallel, to have satisfactory performance the following conditions should be met

Fig 1



TWO SINGLE PHASE TRANSFORMERS CONNECTED IN PARALLEL

Voltage ratio: If voltage readings on the open secondaries of various transformers, to be run in parallel, do not show identical values, there will be circulating currents between the secondaries (and therefore between primaries also) when the secondary terminals are connected in parallel. The impedances of transformers is small, so that a small percentage voltage difference may be sufficient to circulate considerable current and cause additional I^2R loss.

When secondaries are loaded, the circulating current will tend to produce unequal loading conditions. Thus it may be impossible to take the full load output from the parallel connected group without one of the transformers becoming excessively heated.

Impedance: The currents carried by the two transformers are proportional to their ratings:

- if their numerical or ohmic impedances are inversely proportional to those ratings, and
- their per unit impedances are identical.

A difference in the quality factor (i.e the ratio of reactance to resistance) of the per unit impedance results in a divergence of the phase angle of the currents, so that one transformer will be working with a higher and the other with a lower power factor than that of the combined output.

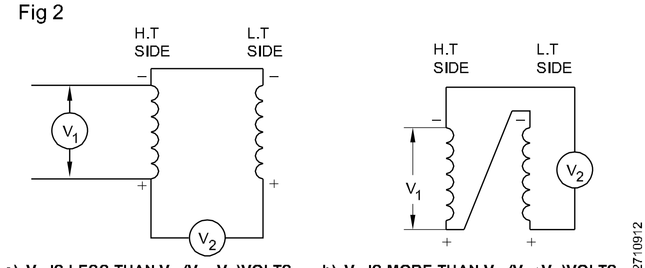
Verification of terminals or Polarity: Polarity in case of transformers means the relative marking to the terminals of the primary and secondary windings reaching the maximum value of emf at the same instant. When two or more transformers are to be connected in parallel on their primary and secondary sides, the terminals of the same polarity only can be connected together, otherwise a heavy circulating current will be produced between the windings.

Standard procedure to determine the polarity is explained below:-

- connect one end of the high voltage winding to one end of the low voltage winding as shown in Fig 2a.
- Connect a voltmeter between the two open ends.
- Apply a voltage not greater than the rated voltage of the winding to either high or low voltage winding.

If V_2 reads less than V_1 (Fig 2a) the primary and secondary emfs are in opposition. The marking on primary will be A_1 for +ve side and A_2 for –ve side and a_1 for +ve side of secondary and a_2 for –ve side. If the connections are made (Fig 2b) the voltmeter V_2 will read more than V_1. Thereby it is ascertained opposite ends are connected.

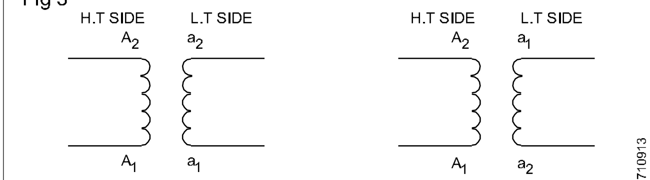
Fig 2



a) V_2 IS LESS THAN V_1 $(V_P - V_S)$VOLTS   b) V_2 IS MORE THAN V_1 $(V_P + V_S)$VOLTS

If in transformer has similar ends in one side (Fig 3a) the polarity marking is said to be subtractive polarity marking on the other hand if the opposite ends are in one side (Fig 3b) the polarity marking is called as additive polarity marking.

Fig 3



a) SUBTRACTIVE POLARITY MARKING   b) ADDITIVE POLARITY MARKING

Series (Secondary only) operation of transformers

Objectives: At the end of this lesson you shall be able to
- **state the necessity of series operations**
- **state the conditions to be fulfilled for series operation**

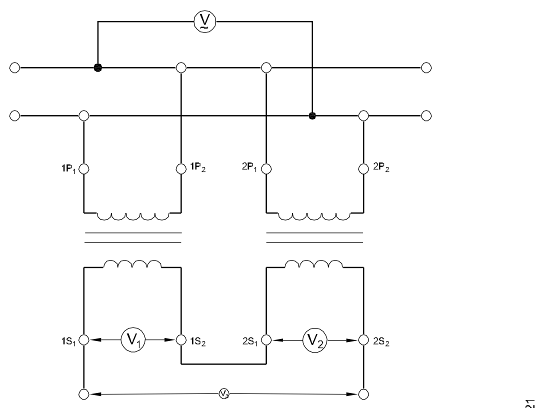
Series operation:

The connection diagram for series operation (secondary only) of two identical transformers is given below (Fig 1)

Necessity for series operations:

In general, the transformers are available with some standard input (primary) and output (secondary) voltages. In order to get some intermediate voltage for example , 36V, 48 V for special purpose, the series operation of transformers (secondary only) are necessary.

Fig 1



SERIES OPERATION OF TRANSFORMERS (SECONDARY ONLY)

In series operation, individual secondary voltages of both transformers are added if they are connected with proper polarity, but the current ratings are remains same.

Condition for series operation:

Both transformers should be identical i.e,

a) Voltage ratio/turns ratio must be same

b) Polarities must be same

c) Type of core of both transformers (core or shell type) must be same.

d) Input voltages of both transformers must be same.

e) KVA ratings of both transformers must be same.

f) Percentage impedance or per unit impedance of both the transfers must be same.

Precautions:

- **The polarities of secondary of both transformers should be connected in proper way, same as series connection, to get the voltage added, otherwise the output voltage will be zero.**
- **As the output voltage is double that the individual secondary voltages, care to be given to ascertain the insulation level of the secondary windings.**

Three Phase transformer - Connections

Objectives: At the end of this lesson you shall be able to
- **state the transformer connections, angular divergence of the 3 phase transformers**
- **represent the phase difference between high voltage and low voltage windings for different types of connection by the hour hand of a clock**
- **state the vector group of the transformer**
- **explain the scott connection of transformer and its uses.**

Transformer Bank

Transformers, like other electrical devices, may be connected into series, parallel, two-phase or three-phase arrangements. When they are grouped together in any of these arrangements the group is called a transformer bank.

The high voltage and low voltage winding terminals of a three-phase transformer are connected either in star or in delta for connections to a three-phase system.

When the primary high voltage winding terminals are connected in, say, star and the secondary low voltage winding terminals are connected in, say, delta, it is said that the transformer windings are connected in star-delta(Y – Δ or Y – d). Similarly

star-star (Yy)

delta-delta (Dd)

and, delta-star (Dy) connections can be used.

Type of connection	High voltage side	Low voltage side
Delta	D	d
Star	Y	y
Zigzag	Z	z

Angular displacement (divergence)**:**There is a definite time phase relationship between the terminal voltages of the high voltage side and low voltage side for these connections. The time phase relationship between the voltages of high voltage side and low voltage sides will depend upon the manner in which the windings are connected.

If the high voltage side and low voltage side windings are connected in star-star (as in Fig 1a and 1b). The phase displacement will be zero. If, however, the low voltage winding connections are reversed, as shown in Figs 2(a) and (b), the time phase displacement in induced voltages between the high voltage and low voltage windings will be 180 degrees.

Fig 1

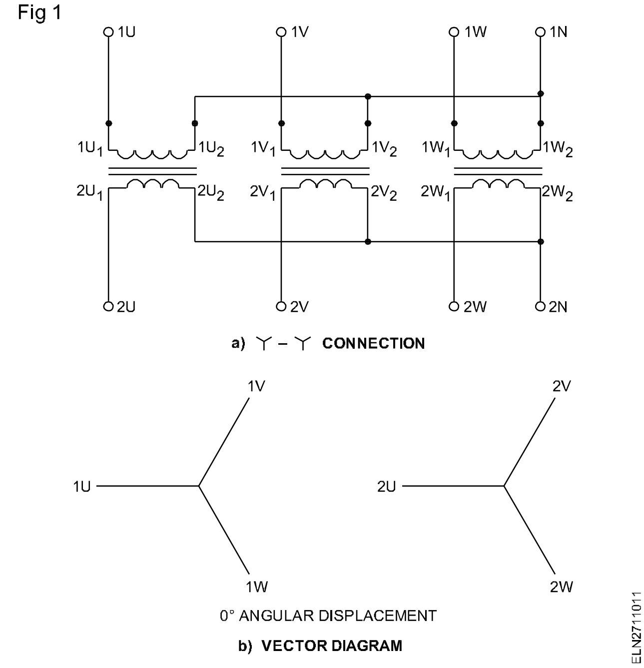
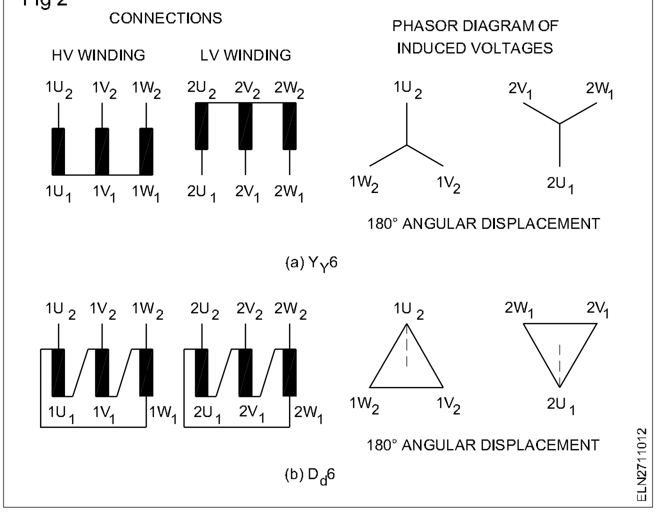


Fig 2



If the primary high voltage and secondary low voltage side windings are connected in Yd or Dy as shown in Figs 3(a) and (b), the phase displacement will be 30 degrees.

The displacement in the clockwise direction is negative. Anti clockwise is positive.

If the windings are connected in Yd or Dy as Figs 4 (a) & (b), the displacement of the terminal voltage will be + 30°.

Observe the change in connections made at the low voltage side in Figs 3(a) and Fig 4(a). Similarly the change in the high voltage side winding connections Figs 3(b) and Fig 4(b) causes the difference in displacement angle.

Fig 3

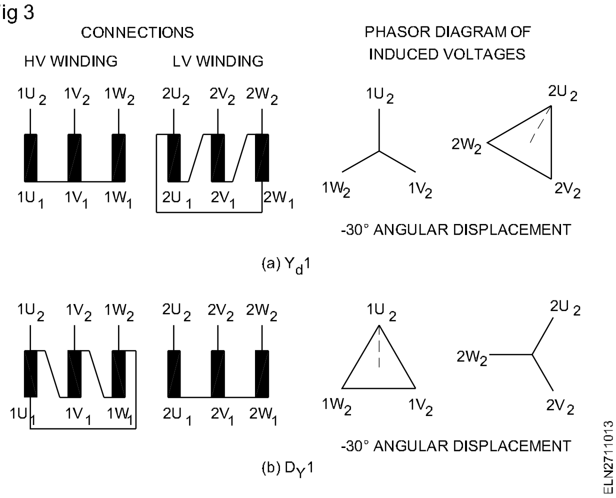
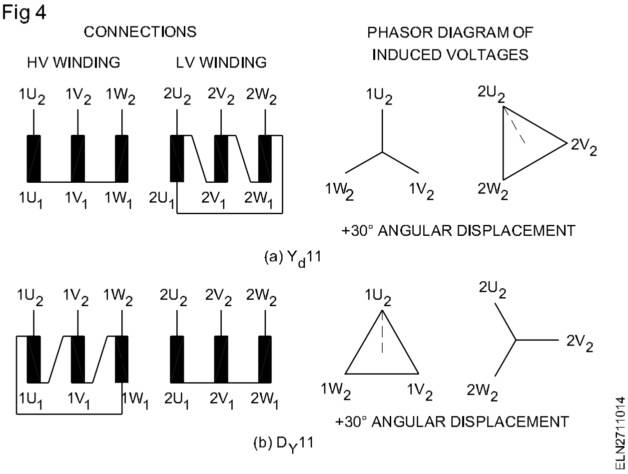


Fig 4



Representation of phase displacement by hour hand of a clock: The phase difference between the HV and LV windings for different types of connections can be represented by comparing it with the hour hand of a clock.

When the hour hand of the clock is at the 12^{O} clock position it is considered zero displacement Fig 5(a).

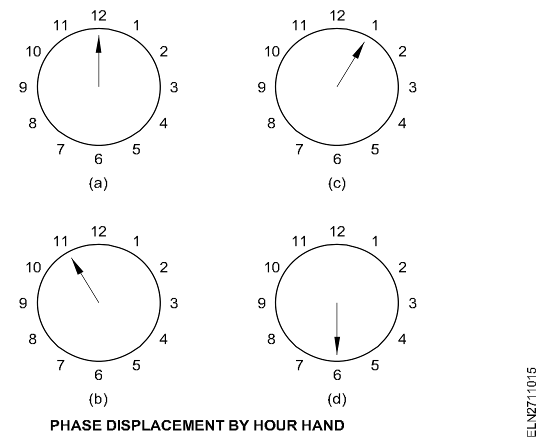
When the hour hand is at the 6^{O} clock position the displacement is 180°

When the hour hand is at the 1^{O} clock position the displacement is -30°.

When it is at the 11^{O} clock position the displacement is +30 degrees. (Anticlockwise is positive.)

The connections of the Fig 1 to Fig 4 can respectively be represented.

Fig 5



Vector groups: Depending on the phase displacement of the voltages of HV and LV sides, transformers are classified into groups called 'vector groups'. Transformers with the same phase displacement between the HV and LV sides are classified into one group. Various vector group arrangements used and their connections symbols are given in Indian Standard IS:2026 (PartIV)-1977.

For satisfactory parallel operation of transformers, they should belong to the same vector group. Following are the typical of the connections for which, from the view- point of phase sequence and angular displacement, transformers can be operated in parallel.

Transformer 1:	Yy	Yd	Yd
Transformer 2:	Dd	Dy	Dy

Different groups	Types of connections	
0	Dd0	Yy0
1	Yd1	Dy1
5	Dy5	Yd5
6	Dd6	Yy6
11	Dy11	Yd11

Scott connection or T.T. connection: In certain special equipment the line voltage required for its 3-phase connection may not be of standard rating as available in the system. Further, the power consumption in these equipment may also be high. To meet this requirement Scott connected transformers are used. These Scott connected transformers enable transformation of 3-phase to 3-phase more economically.

This Scott connection can also be used for 3-phase to 2-phase transformation as explained subsequently.

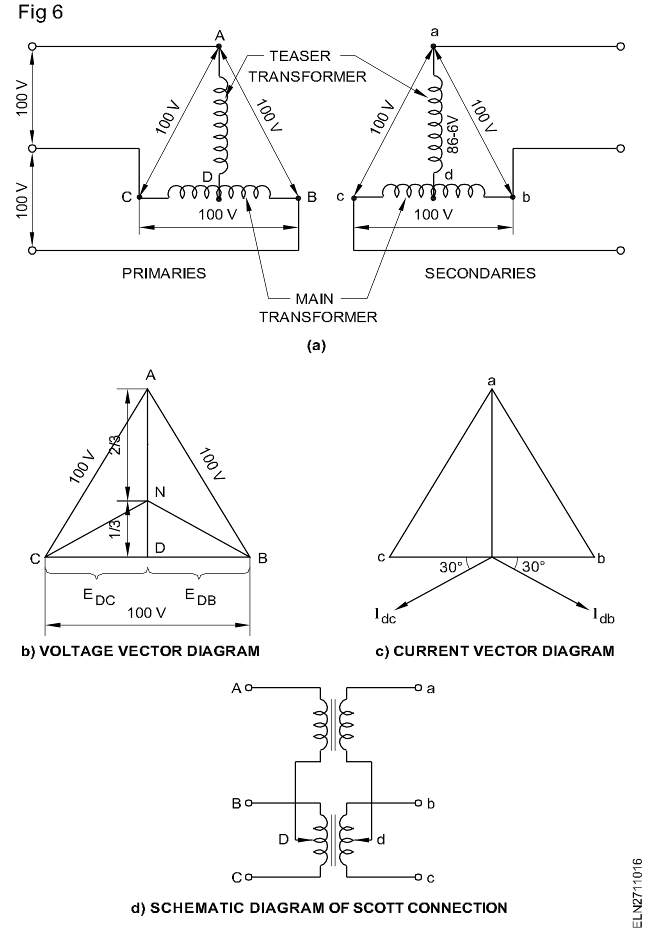
The main transformer has centre tapped primary and secondary windings Fig 6. The primary and secondary windings are indicated by CB and cb respectively in the Fig 6. Another transformer called teaser transformer has a 0.866 tap and one end of both the primary and secondary windings of the teaser transformer (say D and d) is joined to the centre tap of both primary and secondary of the main transformer.

The other end A of the teaser transformer and the two ends B and C of the main transformer primary are connected the 3-phase supply.

3-phase supply is taken out from one end 'a' of the teaser transformer secondary and the two ends b and c of the secondary of the main transformer.

For convenience unity transformation ratio is choosen and the supply line voltage is assumed as 100V the (Fig 6).

Fig 6



By analysing the vector diagram Fig6b, it is found that voltage E_{DC} and E_{DB} are each 50V and differ in phase by 180^0 because both the coils DB and DC are in the same magnetic circuit and are connected in opposition. Fig 1d shows the schematic connection diagram.

Each side of the equilateral triangle represents 100V. The voltage E_{DA} being the altitude of the equilateral triangle is equal to $\sqrt{3}/2 \times 100 = 86.6V$ and legs behind the voltage across the main by 90^0. The same relation holds good for the secondary voltages. The transformer rating is restricted to 86.6% of its KVA rating. By suitable turn ratio the trnsformer rating can be improved to 92.8%.

Example: Two scott connected transformers are used to supply a 660V 33 KVA balanced load from a balanced 3-phase supply of 11000V. Calculate (a) voltage and current rating of each coil (b) KVA rating of the main and teaser transformer.

Voltage across primary 11000V

Voltage across the teaser primary = 0.866x11000

Current is same in the teaser and the main and equal to

$$\text{line current} = I_{LP} = \frac{KVA \times 1000}{\sqrt{3}EL}$$

$$= \frac{33 \times 1000}{\sqrt{3} \times 11000} = \frac{3}{\sqrt{3}} = 1.732A$$

Secondary voltage across the mains = 660V

Teaser secondary voltage = 660 x 0.866 = 572V.

$$\text{The secondary line current } I_{LS} = \frac{I_{LP}}{k} = \frac{1.732}{\frac{660}{11000}}$$

$$= \frac{1.732 \times 11000}{660}$$

$$= \frac{173.2}{6} = 28.87A$$

Main KVA rating = 11000 x 1.732 x 10^{-3}

= 19.05KVA.

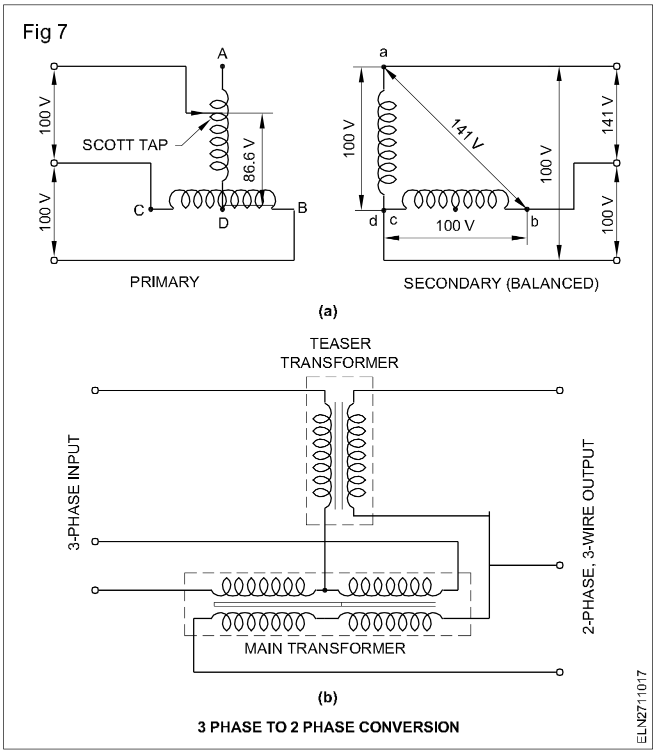
Teaser KVA = 0.866 x main KVA

= 0.866 x 19.05 = 16.4 KVA.

3-phase to 2-phase conversion and vice versa: In industrial application of electric power supply certain equipment like electric furnaces and welding transformers require two phase supply.

At present, the available electrical supply is in variably three phase it is necessary to convert the 3 phase supply to 2 phase supply. This is accomplished by Scott connection.

For convenience 100V supply and the tranformation ratio of unity are chosen Fig 7. But the transformer could be designed for required voltage and suitable tranformation ratio. Fig 7(a) shows the arrangement of connection where as Fig 7(b) shows the circuit arrangement.



Three single phase transformers for three phase operation

Objectives: At the end of this lesson you shall be able to
- **list and interpret the four types of connections of primary and secondary windings**
- **state the phase and line values of current and voltage.**

There are various methods available for transforming 3-phase voltages, that is for handling a considerable amount of power. There are four possible ways in which the primary and secondary windings of a group of three transformers may be connected together to transfer energy from one 3-phase circuit to another. They are:

Primaries in Y, Secondaries in Y

Primaries in Y, Secondaries in Δ

Primaries in Δ, Secondaries in Δ

Primaries in Δ, Secondaries in Y.

Star/Star or Y/Y connection: Fig 1 shows the connection of a bank of 3 trans-formers in a star-star. This connection is most economical for small, high voltage transformers because the number of turns per phase and the amount of insulation required is minimum. This connection works satisfactorily only if the load is balanced. For a given voltage V between lines, the voltage across the terminals of a Y connected transformer is $V/\sqrt{3}$; the coil current is equal to the line current I.

Star - Delta or Y/Δ connection: In primary side 3 transformers are connected in star and the secondary consist of their secondary connected in delta as shown in Fig 2. The ratio between the secondary and primary line voltage is $1/\sqrt{3}$ times the transformation ratio of each transformer. There is a 30° shift between the primary and secondary line voltages. The main use of this connection is at the substation end of the transmission line.

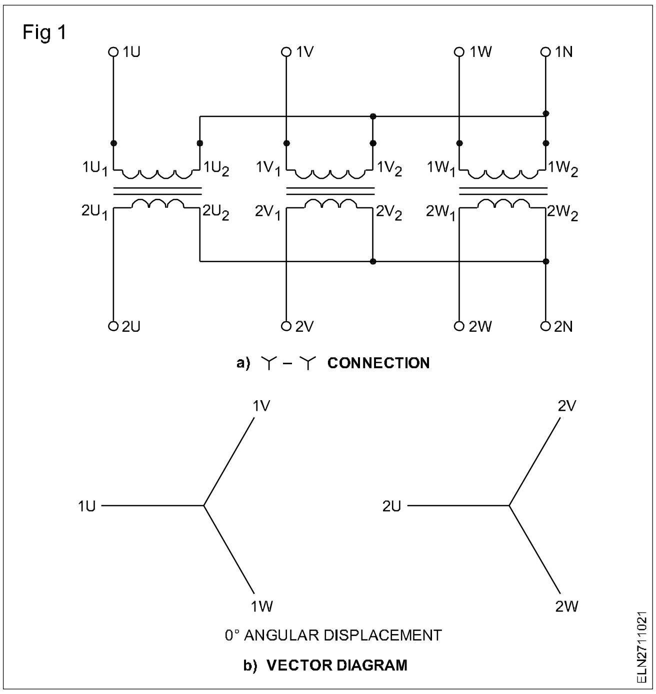


Fig 2

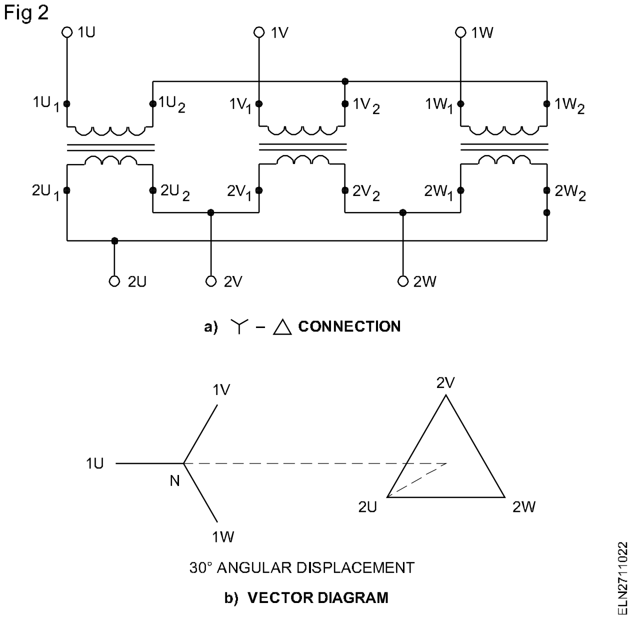


Fig 3

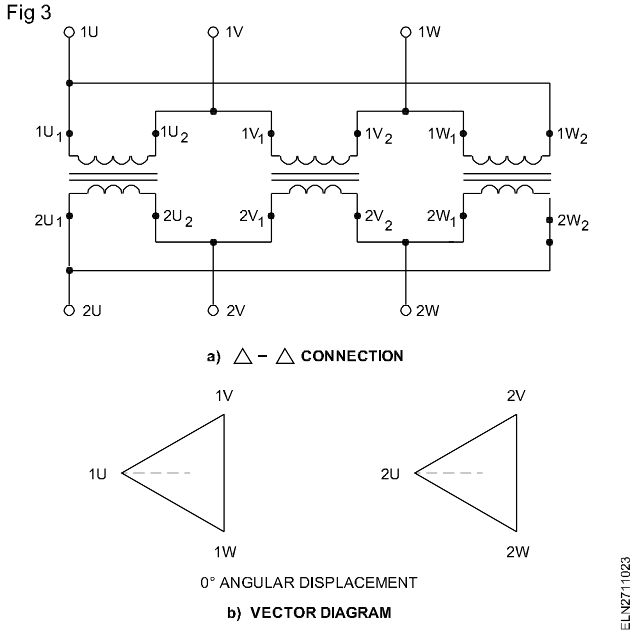
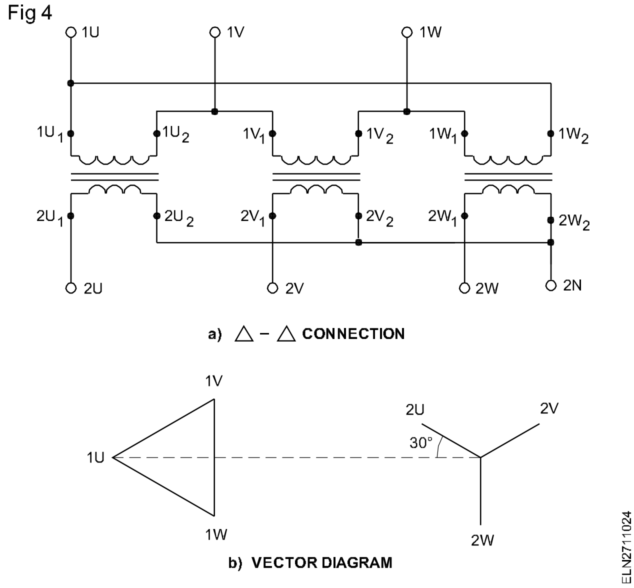


Fig 4



Delta - Delta or Δ/Δ connection: Fig 3 shows three transformers, connected in Δ on both primary and secondary sides. There is no angular displacement between the primary and secondary line voltages. An added advantage of this connection is that if one transformer becomes disabled, the system can continue to operate in open-delta or in V-V. In V-V it can be operated with a reduced capacity of 58% and not 66.6% of the normal value.

Delta - Star or Δ/Y connection: (Fig 4) This connection is generally employed where it is necessary to step up the voltage, as for example, at the beginning of high tension transmission system.

The primary and secondary line voltages and line currents are out of phase with each other by 30°. The ratio of secondary to primary voltage is $\sqrt{3}$ times the transformation ratio of each transformer.

Parallel operation of 3-phase transformer

Objectives: At the end of this lesson you shall be able to
- **Define parallel opration**
- **States the conditions for parallel operation of 3 phase transformer**
- **Sates the necessity of parallel opertion.**

Parallel operation

Operating two or more transformers by connecting their primaries in parallel to a common supply line and connecting their respective secondaries in parallel with a common load-busbars (Fig 1) is called as parallel operaion of transformers.

Conditions for pararllel opertion of transformers:

When operating two or more transformer in parallel, the following conditions have to be satisfied for the best performance of the transformer.

1 The voltage ratio must be same.

2 The per unit impedance or percentage impedance should be same i.e., the ratio between the equivalent leakage reactance and the equivalent resistance(X/R)should be same.

3 The polarities must be same.

4 For three phase transformers

i) The phase sequence must be same

ii) The vector group must be same (i.e., The relative phase displacement between the secondary line voltages must be zero)

Parallel operation of 3-phase transformer:

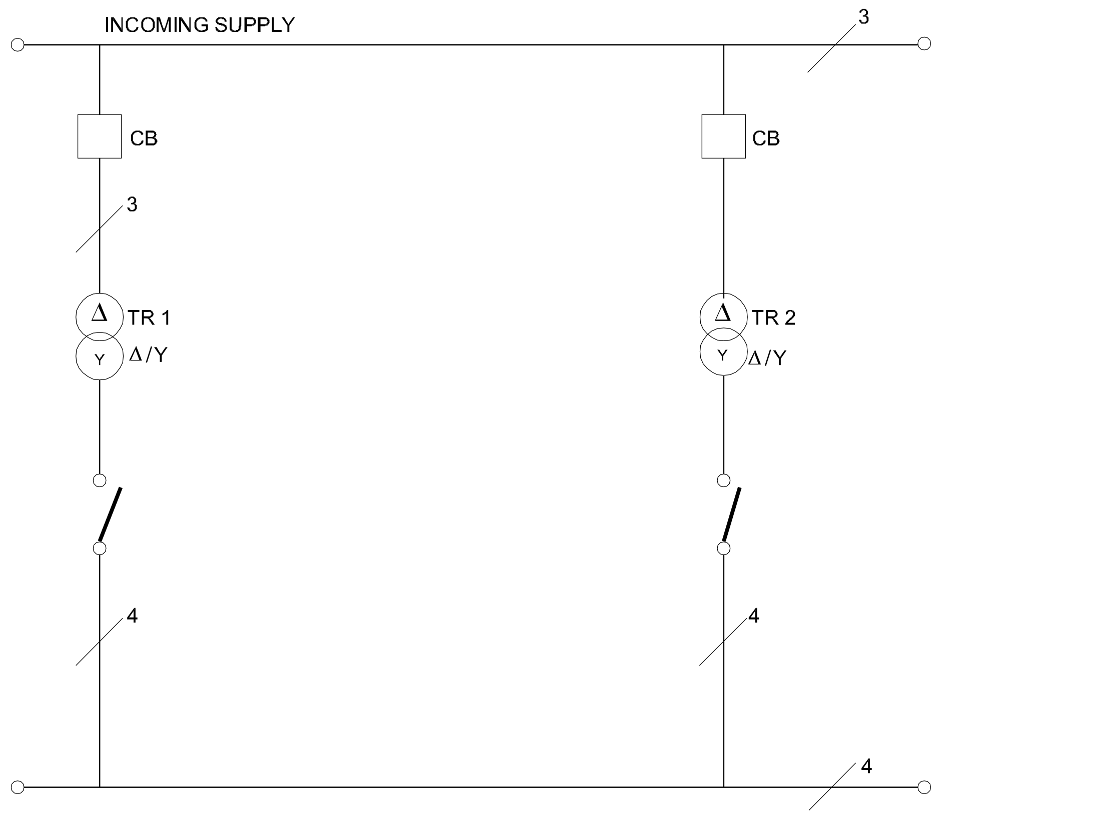
Fig 2 shows the connection diagram for parallel operation of two numbers of 3-phase transformers. In this case, the connection of both of transformer 1 and 2 are (delta - star)same.

However to operate the 2 transformers of having Y/Δ and connection, their primary and secondary line voltage Δ/Y must be same. In this case,the turns ratio may not be equal, but the voltage ratio between the terminal voltage of primary and secondary must be same.

If two transformers having different ratings, are connected in parallel the their percentage impedance must be same, where as the numerical impedance of transformer 1 will have half the impedance of transformer 2. In this case both the transformers will share the common load in propertional to their KVA ratings.(Fig 2)

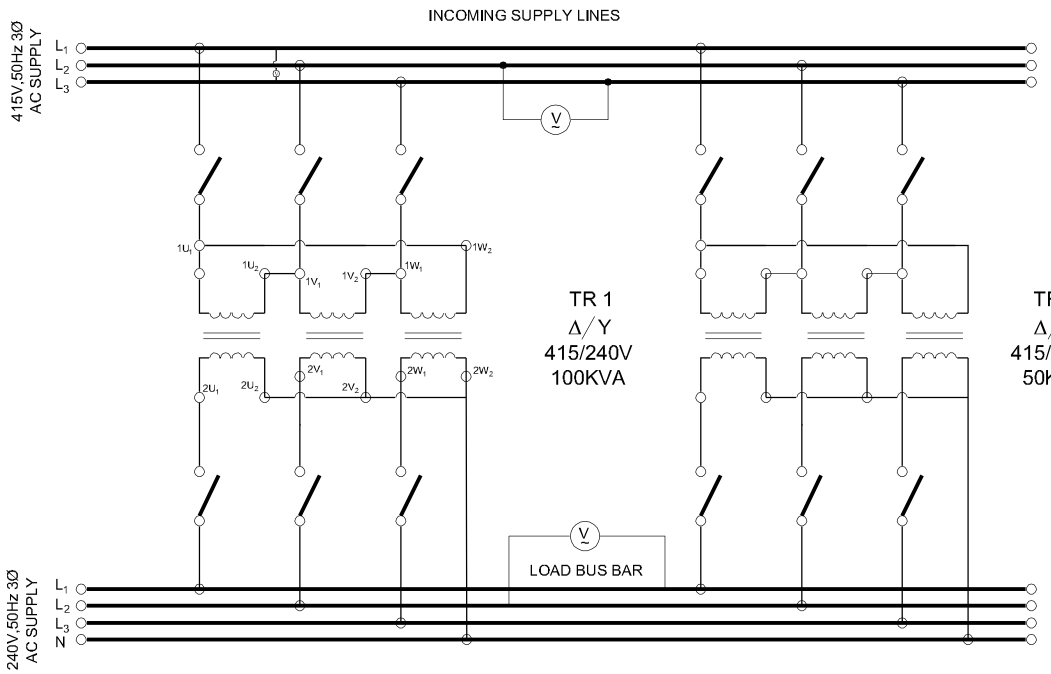
For best performance of the parallel operation, the regulation of both the transformers must be same . If the percentage impedance of both the transformers are different. Than one transformer will be operating at a higer power factor and other will be operating at a lower power factor.

Fig 1



PARALLEL OPERATION - 3PHASE TRANSFORMER

Fig 2



PARALLEL OPERATION - 3 PHASE
TRANSFORMER - CONNECTION DIAGRAM

ELN2711032

Cooling of transformer - Transformer oil and testing

Objectives: At the end of this lesson you shall be able to
- **explain the necessity of cooling**
- **state the methods of cooling.**

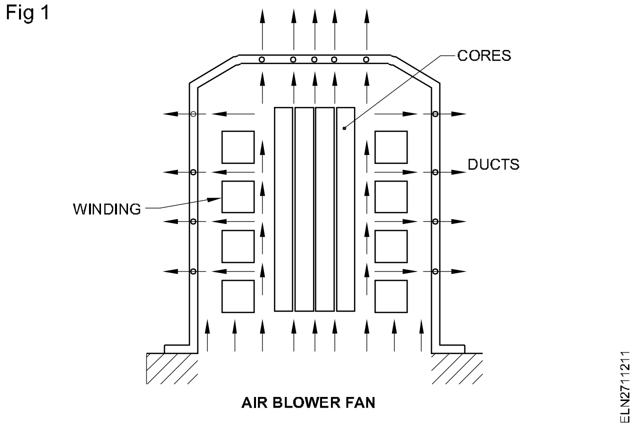
Necessity of cooling

Transformer is heated up when current flows through its, winding. This causes the liberation of heat. In large size transformer, where power rating is high, large amount of heat is liberated. This will affect the insulation of the windings as well as reduction of transformer efficiency. This heat should be transformed from transformer winding and dissipated in the atmosphere .

Methods for cooling transformers: Following are the methods of cooling employed in transformers. Any one or more methods could be adopted depending upon the size, application and location of the transformer.

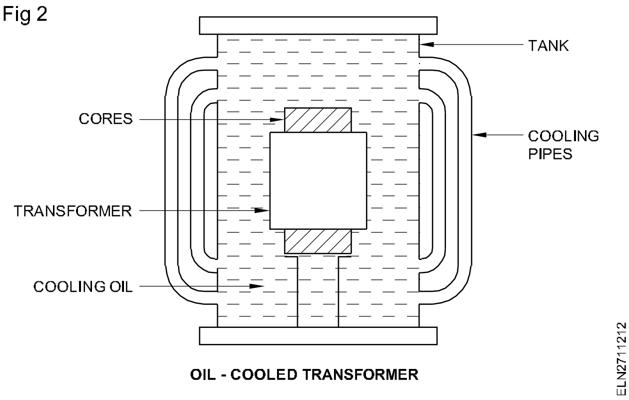
- Natural air method
- Air blast method (Fig 1)

Fig 1



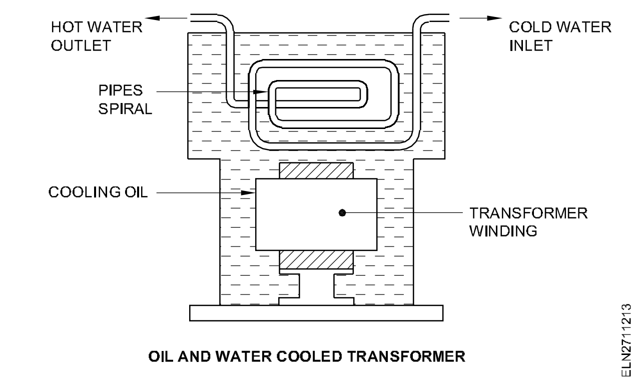
- Natural oil cooled method (Fig 2)

Fig 2



- Oil blast method
- Forced circulation of oil
- Oil and water cooled (Fig 3) and
- Forced oil and water cooled

Fig 3



Natural air cooling method is generally adopted for low capacity distribution transformer upto 100KVA. The natural circulation of the surrounding air is used to carry away the heat from the transformer winding.

In air blast method, the fans are used to blow the air on the surface of the transformer thereby the heat generated is carried away by the air blast.

Transformer of 200KVA above capacity are cooled by using an insulating oil. The winding and core are immersed in oil. The area of the tank is increased by using cooling tubes. (Radiator tubes)

In oil and water cooled system, the low pressure water tubes through the heated oil used to remove the heat from the transformer.

Transformer oil and testing

Objectives: At the end of this lesson you shall be able to
- **define the transformer oil**
- **name three insulating oils used in transformer**
- **list the important properties of a transformers oil**
- **state the necessity of transformer oil**
- **state the causes for deterioration of oil**
- **explain the methods of testings the oil for its parameter.**

Transformer oil :

It is an insulating liquid, used to cool and insulate the transformer windigs and core.A cooling liquid is also considered as a part of the transformer.

Three kinds of cooling oils/liquids are used in transformers today.

- Mineral oil (inflammable)
- Silicon liquids(low flammable) and
- Hydrocarbon liquids (non-flammable)

The common transformer oil is a mineral oil obtained by refining crude petroleum. Clean and dry mineral oil is an excellent insulator. Its loss by evaporation is small. But it is an inflammable liquid and readily absorbs moisture from the air. Great care should be taken to keep the oil away from flame and moisture.

Synthetic liquids do not catch fire easily. Synthetic liquids are therefore replace mineral transformer oils of those transformers used in

- underground mines
- refineries and hazardous location
- tunnels
- workshop and plants of metal processing theatres and cinemas etc.

Transformer oil consists of organic compounds, namely paraffin, naphthalene and aromatics. All these are hydro carbons, hence insulating oil/transformer oil/ synthetic transformer oil known as ASKARELS and PYROCLORE are also in use.

Properties of transformer oil

A good transformer oil should have the following properties.

1 High specific resistance so that high insulation resistance

2 Better heat conductivity, (i.e) higher specific heat.

3 High firing point, so that not to catch fire at low temperature.

4 Do not absorb moisture easily, when exposed to air.

5 Low viscosity

Necessity of transformer oil

Large capacity distribution transformers produces more heat due to losses like core losses and copper losses, on load. It is necessary to stablize the heat within temperature class by providing suitable insulating materials.

Transformer oil acts as a good electrical insulating material. Thus it reduces electrical break down. Transformer oil will also act as cooling agent. Thus it brings thermal stability to all the internal parts of transformer.

Causes for deterioration of transformer oil

When the oil cooled transformers are in use, the oils of the transformers are subjected to normal deterioration due to the conditions of the use.

For example

1 The oil may come in contact with the air, there by presence of moisture and dust in the oil. The presence of moisture is harmful and affects the electrical characteristics of oil and will accelerate deterioration of insulating materials.

2 Sediment and precipitable sludge may be formed on the winding and core surfaces. It will reduce the cooling rate and hence it may lead to deterioration of the insulating materials.

3 The presence of certain solid iron, copper and dissolved metallic compounds will increase the acidity. In such cases, the resistivity decreases, and electrical strength also decreases, and it is also the causes for deterioration of transformer oil.

Testing of transformer oil

For reliable use and maintenance of oil cooled transformer, the transformer oil shall be tested before initial filling of the oil as well as during service of the transformers. As per the test result it may be required to filter the transformer oil or in some cases, new oil may be recommended for safe and better maintenance of oil cooled transformers.

The following tests are conducted periodically to decide the performance of the transformer oil.

1 Field test of insulation oil

2 Crackle test of insulating oil

3 Dielectric test of insulating oil

4 Acidity test.

1 Field test of insulating oil

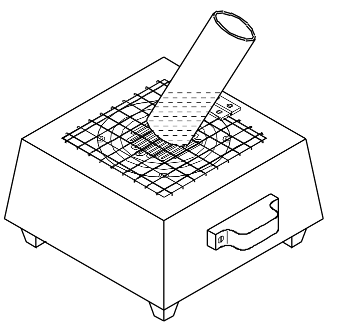
A drop of transformer oil, when placed slowly from a pipette on the still surface of a distilled water contained in heater should retain its shape when the oil is new.

In the case of used cyclo-octane oils (or) paraffin oils (even though unused) the drop usually flattened. If this flattened drop occupies an area of diameter less than 15 to 18 mm, the oil may be used. Otherwise, it has to be reconditioned. Oils with the longer spreads are unsuitable.

2 Crackle test of transformer oil (Fig1)

A rough test may be made, by closing one end of steel tube, and heating the closed end to just dull red hot. (Fig 1) When the oil sample is plunging into the tube, a sharp Crackle sound will be heard, if the oil contains much moisture. Dry oil will only sizzle.

Fig 1

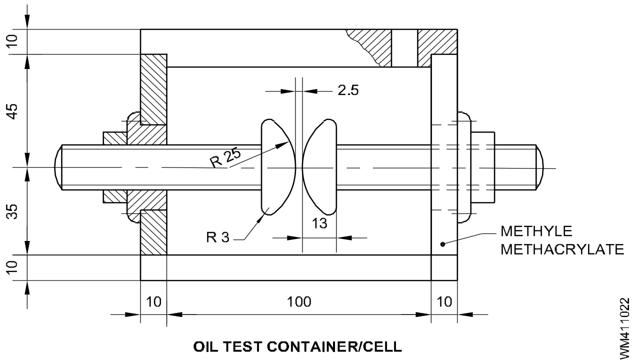


CRACKLE TEST

3 Dielectric test of transformer oil

This test is preferably conducted using standard oil test set. The oil test set consists of a container/cell made up of glass or plastic.(Fig 2)

Fig 2



OIL TEST CONTAINER/CELL

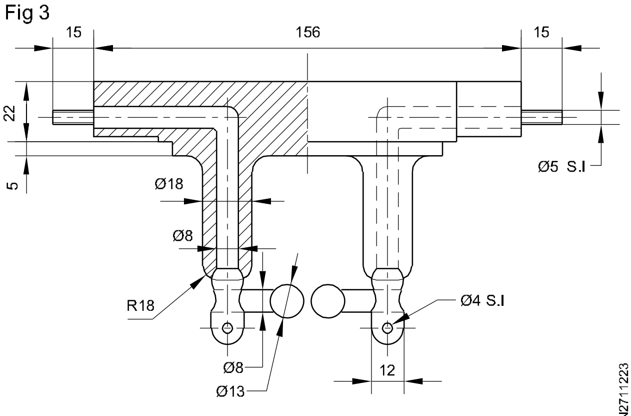
The cell shall have an effective volume between 300 to 500 ml. It should be preferably closed. Section view of container. (Fig 3)

Two numbers of the copper, brass, bronze or stainless steel in the shape of sphere of diameter 12.5 to 13 mm elliptical are mounted on a horizontal axis at 2.5 mm apart, is used as electrodes, for oil test of 11KV transformer.

The cell is mounted on a test set. HT connection to the electrodes, is made by the point contact arrangements.

The test set is also provided into step up transformer where the voltage can be varied from zero to 60KV. In some designs, the voltage is varied by electric motor, with the operation of push button switch.

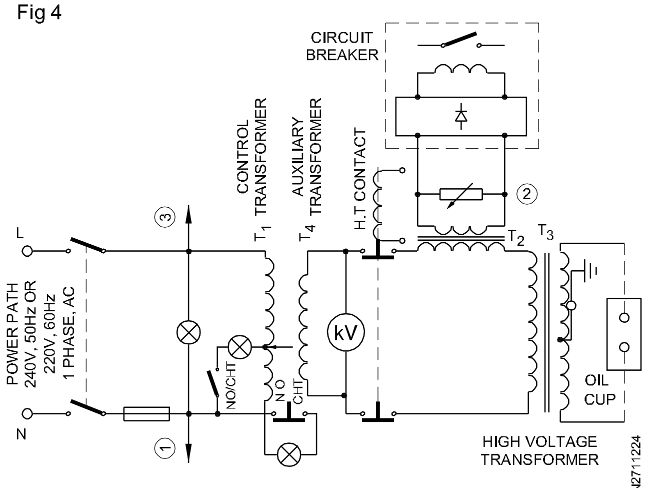
Fig 3



DIELECTRIC TEST

Electrical circuit diagram of dielectric test unit (Fig 4)

Fig 4



CIRCUIT DIAGRAM OF DIELECTRIC TEST

For conducting dielectric test on transformer oil, the oil is to be gently agitated and turned over several times so that homogeneous distribution of the impurities contained in the oil is spread all over.

Immediately after this, the oil is poured down into the test cell slowly in order to avoid air bubbles. The operation is carried out in a dry place free from dust. The oil temperature at the time of test shall be same as that of ambient.

After fulfilling the above conditions the cover of the cell is placed in position. The cell is placed in the test unit and power is switched “ON”.

The AC voltage across the electrode of frequency 40 to 60Hz is increased uniformly at the rate of 2KV RMS starting from ‘O’ up to the value of producing break down. The break down voltage is the voltage reached during the test at the time the first spark occurs between electrodes.

The circuit is opened automatically if an arc is established between electrodes. The break down voltage is recorded and the reading is interpreted according to the standard ratings. The requirements as per IS-335-1983 is: Electrical Strength (break down voltage)

1 New unfiltered transformer oil - 30KV (RMS)

2 After filtration transformer oil - 50KV (RMS)

It is recommended to filter the transformer oil if the break down voltage does not attain 30KV (RMS).

The test shall be carried out 6 times on the same cell filling. The electric strength shall be the arithmetic mean of the 6 results which have been obtained.

Acidity test

The acid products are formed by the oxidation of the oil. This oxidation will deteriorate the insulating materials like insulating paper and press boards used in transformer windings. It is therefore essential to detect and monitor the acidity formation.

To conduct this test portable test kit is available consisting of:

1 Two polythene bottles containing 100ml each of ethyl alcohol and sodium carbonate solution of 0.0085N concentration.

2 An indicator bottle containing universal indicator.

3 Four clean glass test tube.

4 Three graduated droppers, which serves as pipettes.

5 Colour chart with acidity range.

6 Instruction booklet.

PROCEDURE

The test is conducted by taking 1.1 ml of insulating oil (to be tested) in test tube, 8 ml oil 1 ml of rectified spirit is added and mixture is to be gently shakened. Further 1 ml of solution of 0.008 5 N sodium carbonate added. After shaking the test tube once again 5 drops of universal indicator is added. The resulting mixture develops a colour depending on the acidity value of the mixture.

The approximate colour range will be as follows:

Total acidity value in No.	Colour
0.00	Black
0.2	Green
0.5	Yellow
1.0	Orange

Any how the colour chart will be provided with the test kit to indicate exact value.

Small transformer winding - Winding machine

Objectives: At the end of this lesson you shall be able to
- **state the important data to be taken for rewinding the transformer**
- **explain the rewinding procedure for small transformers**
- **calculate the number of turns per volt using the formula and determine primary and secondary turns**
- **read and interpret the tables pertaining to the rewinding of transformers and determine the dimensions of the transformer, size of bobbin and size of winding wire**
- **explain the tests to be carried out after winding the transformer.**

Rewinding of small transformer:

It is necessary to rewind a transformer when the winding is burnt out or badly damaged.

While dismantling transformers, care should be taken to record the necessary particulars (data) by which the rewinding process becomes easy and the original performance of the transformer is assured.

Recording the data : The following data have to be taken from the transformer before and during disassembling.

1 Number of windings/turns/ layers.
2 Size of wires and insulation.
3 Input/output voltages & currents.
4 KVA ratings.
5 Conncetion diagrams.
6 Terminal marking / lead position
7 Types of cores / number of stampings
8 Physical condition of bobin / core.
9 Insulation schemes like size and specification of bindings, layer,interlayer,inter windings, bobin,lead wires, sleeves etc.

If the old bobbin is reused for winding, it shall be cleaned well and shall be free from any break or crack. If a new bobbin is used it shall be checked with the stamping (core) for proper assembly to avoid too much air gap or too tight a fitting.

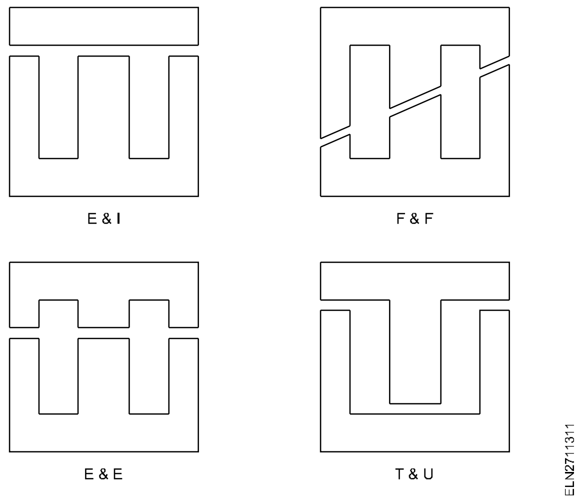
For winding, a suitable size of wire shall be selected from the data and the size of wire shall be measured as per I.S. 4800 (Part - I) 1968.

The size of the wire can be measured with insulation but it shall be within the limit of tolerance. The insulation scheme shall be followed as per the data taken. Where proper material is not available an equivalent type and size may be selected. Turns and tapping of the winding shall be made as in the original.

Method of stacking : Before stacking the core, stampings shall be checked for dents, bends and core insulation. Dents on the core shall be removed, and any mangled core shall be set right. Stacking shall be done as in the original sequence and pattern.

All the stampings available for the transformer shall be stacked without leaving out any. Fig 1 shows the different shapes of cores used for a shell type transformer. Leads shall be properly sleeved and terminated.

Fig 1



Procedure of rewinding a transformer: As stated above, if all the necessary winding details are obtained while disassembling the burnt out transformer, the rewinding procedure is more or less easy. However, if you have to prepare a new transformer the following information will be of great help.

Designing a transformer : Small transformers are generally of 'SHELL TYPE'. In shell type, both the primary and secondary windings are mounted on the centre limb of the core. For designing of a small power transformer proceed as stated below.

STEP NO.1

Find the total output power from the load voltage and current of the transformer.

$P_2 = E_2 \times I_2$ ....Formula 1.

The following example is given for your guidance.

Primary voltage - 240 V

Secondary voltage - 6V

Secondary total current - 2A

Frequency - 50 Hz

From the example the output power is calculated as 6 x 2 = 12VA.

STEP NO.2

Find the input watts.

$$P_1 = \frac{P_2}{\%\,\text{Efficiency}}$$ .... Formula 2

Normally the efficiency of a transformer will be 80 to 90. As in the example

$$P_1 = \frac{6 \times 2 \times 100}{80} = 15 \text{ VA.}$$

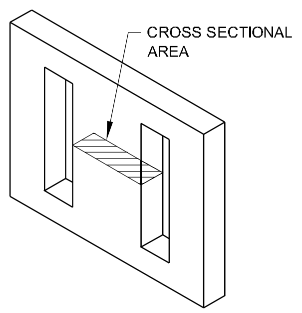
STEP NO.3

Determine the required cross-sectional area of the core of the transformer.

For finding the cross-sectional area, certain parameters like the flux density of the metal used for laminations, frequency of supply, allowable current density in the winding wire and power input to the transformer need to be known.

The cross-sectional area to be considered for a shell type and core type transformers respectively (Figs 2 and 3)

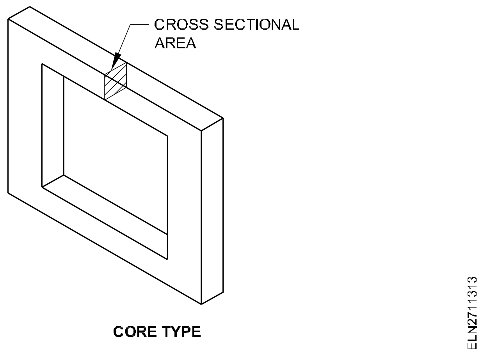
Fig 2



Area of cross-section required for a transformer under specified conditions is given as

$$A = 3.8 \times \sqrt{\frac{P_1}{B \times f \times S \times 10^{-1}}}$$ ..... Formula 3.

Fig 3



where

A - is the area of cross-section of the iron core in cm^2

B - is the flux density in tesla

f - is the frequency of supply in Hertz

S - is the current density of the winding wire in ampere/ mm^2.

P_1 - is the input power of the transformer in watts.

Out of the above parameters the frequency of the main supply could be taken as 50 Hertz. Power in VA could be determined from step 1 and step 2. However the value of B could be determined from the following information depending upon the material with which the core is made.

Normal iron metal sheet B = 0.6 to 0.8 tesla

Dynamo steel sheet B = 1.2 to 1.3 tesla

High alloy sheet B = 1.5 to 1.9 tesla

Manufacturers of the stampings specify the flux density value of their product on request.

Further the current density (S) could be taken for super-enamelled copper wire for transformer is approx.as under.

1. 2.5 KVA and above 1A/mm^2
2. 0.75 to 2.4 KVA 1.5A/mm^2
3. 0.3 to 0.74 KVA 2A/mm^2
4. below 0.29 KVA 3A/mm^2

For intermittent working, the current could be multiplied by factor 1.5.

According to the example taken, the required effective area of the cross-section of the core, for the input of 15VA will be

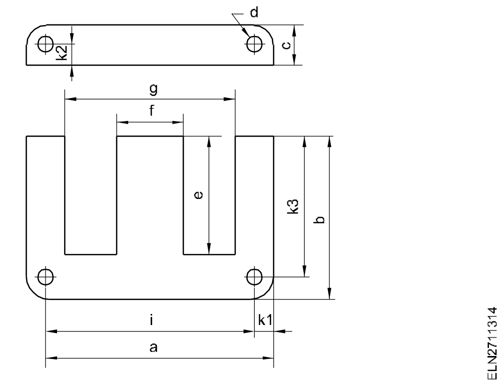
$$A = 3.8 \times \sqrt{\frac{15}{0.8 \times 50 \times 3 \times 10^{-1}}} = 4.248 \text{ cm}^2$$

Assumption made in the above calculation are a normal iron core of 0.8 tesla is used and the current density is 3A/mm². For the core area 4.248 sq.cm we can use the core of dimension having 20 mm as width and core thickness of 21 mm.

Cross section = 20 x 21=420 sq.mm or 4.2 sq. cm

Table 1 gives the standard size of stampings having E and I type laminations as available in the market which is given for your guidance. Fig 4 gives the dimensions of the stampings.

Fig 4



The nearest size sheet should be selected from the standard size of the stamping table. Here we assume the centre limb width to be 20 mm, and hence, the core E.I. 60 is selected. However, you may select any other type to suit the cross-section. But the other details like the number of stampings and the bobbin dimensions may change accordingly.

STEP NO.4

The next step is to calculate the voltage per turn using Formula 4.

$e = 4.44 \times B \times A \times f \times 10^{-4}$ ....Formula 4.

where e - voltage per turn

B - flux density in tesla

A - area of iron core in cm^2

f - frequency in Hertz

Example

$e = 4.44 \times 0.8 \times 4.24 \times 50 \times 10^{-4} = 0.0753$ volts.

STEP NO.5

Calculate the primary coil turns.

$$N_1 = \frac{240}{0.0753} = 3187 \text{ turns (approx.)}$$

Calculate the secondary coil turns.

$$N_2 = \frac{6}{0.0753} = 80 \text{ turns (approx.)}$$

Add 10% to compensate the voltage drop (internal) in the secondary winding i.e. N_2 = 88 turns.

STEP NO.6

Calculate the size of wire with respect to the input power.

P = E x I ; I = P/E and according to the example,

Primary current = I_1 = 15/240 = 0.0625A

Secondary current = I_2 = 15/6 = 2.5A.

Cross-section of primary conductor considering 3A/mm² as current density will be

A = 0.0625/3 = 0.020833 mm²

Diameter = 0.1628 mm

Say i.e. = 0.160 mm dia. or 37 SWG approximately

Cross-section of secondary conductor considering 3A/mm² as current density will be

A = 2.5/3A = 0.8333 mm²

Diameter = 1.029 mm

Say = 1.00 mm dia. Hence 19 SWG.

STEP NO.7

Fig 5 gives the general dimensions of a bobbin and Table 2 gives the standard sizes of bobbins available in the market to suit the standard stampings. Here the bobbin selected is EI 60/21 which suits the core thickness of the centre limb taken earlier as 21 mm and core width as 20 mm.

Fig 5

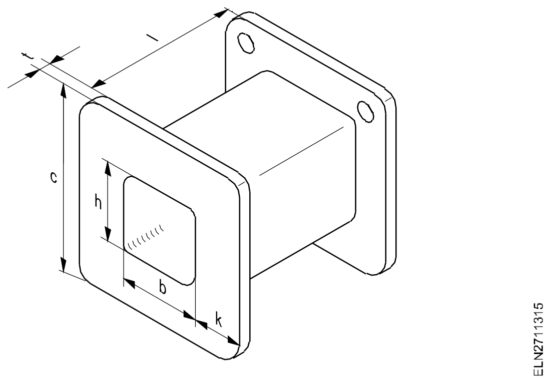


Table 1
Standard size of stampings

Specification of stampings	a	b	c	d	e	f	g	i	k1	k2	k3
EI42	42	28	7	3.5	21	14	28	35	3.5	—	24.5
EI48	48	52	8	3.5	24	16	32	40	4	—	28
EI54	54	36	9	3.5	27	18	36	45	4.5	—	31.5
EI60	60	40	10	3.5	30	20	40	50	5	—	35
EI66	66	44	11	4.5	33	22	44	55	5.5	—	38.5
EI78	78	52	13	4.5	39	26	52	65	6.5	—	45.5
EI84	84	56	14	4.5	42	28	56	70	7	—	49
EI92	92	62.3	11.3	4.5	51	23	69	82	5	6.5	57.5
EI106	106	70.5	14.5	5.5	56	29	77	94	6	8.5	64.5
EI130	130	87.5	17.5	6.8	70	35	95	115	7.5	10	80
EI150	150	100	20	7.8	80	40	110	135	7.5	12.5	92.5
EI170	170	117.5	22.5	8	95	45	125	150	10	12.5	107.5
EI195	195	134.5	25.5	9.5	109	51	144	171	12	13.5	122.5
EI231	231	166	29	10	137	58	173	204	13.5	15.5	152.5
Nominal thickness of stampings:0.35 mm and 0.5 mm.											

Table 2
Standard size of bobbins

Specific-ation of bobbins	b	h	c	k	L
EI 42/15	14.5	14.8	30.2	5.1	18.6
EI 48/16	16.5	16.8	34.2	6.0	21.6
EI 54/18	18.5	18.8	38.2	6.8	24.2
EI 60/21	20.6	21.0	42.7	7.7	26.7
EI 66/23	22.6	23.0	48.7	8.7	28.6
EI 78/27	26.6	27.5	56.2	10.7	34.6
EI 84/29	28.6	29.5	60.2	11.7	37.6
EI 84/43		43.5	74.2		
EI 92/24	24.5	75.0	20.2	46.6	23.5
EI 92/33		33.5	84.0		
EI 106/33	29.6	33.5	88.1	20.6	46.6
EI 106/46		46.5	101.1		
EI 130/38	35.7	37.7	105.4	25.9	64.5
EI 130/48		47.7	115.4		
EI 150/42		41.7	122.5		
EI 150/52	40.7	51.7	132.5	29.8	70.1
EI 150/62		61.7	142.5		
EI 170/57		56.7	151.7		

Specific-ation of bobbins	b	h	c	k	L
EI 170/67	45.7	66.7	161.7	33.7	85.1
EI 170/77		76.7	171.7		
EI 195/58		51.7	186.7		
EI 195/71	51.7	70.7	199.7	40.2	109.4
EI 195/86		85.7	214.7		
EI 231/65		64.7	215.7		
EI 231/81	58.7	80.7	232.7	47.5	127.4
EI 231/100		99.7	250.7		

STEP NO.8

Check the feasibility of accommodating the number of turns of primary and secondary within the winding space.

Though the number of turns in the primary is to be 3187 of 37 SWG and the secondary to be 88 turns of 19 SWG super enamelled copper wire, it is atmost important to check whether these windings along with the respective insulation could be accommodated within the winding space of the core. This has to be determined before taking up the winding.

Table 3 gives information regarding the number of turns of the winding wire which could be accomodated in one square centimetre area. With the help of the Table 3 we could predetermine whether it is possible to accommodate the winding in the space.

Winding space available in bobbin = l x k.

(See Fig 5 and refer Table 2 for selected bobbin EI 60/21) = 26.7 x 7.7 sq. mm = 2.055 sq.cm.

Use Table 3 to find the area required for primary and secondary turns.

Primary number of turns = 3187

Gauge of wire = 37 SWG

As per Table 3 the winding wire 37 SWG of 2820 turns could be accommodated in 1 sq. cm space. As such for 3187 turns the space required

$$= \frac{3187 \times 1}{2820} = 1.130 \text{ cm}^2$$

Secondary number of turns = 88

Gauge of wire = 19 SWG

As per Table 3 the winding wire 19 SWG of 85 turns could be accommodated in 1 sq. cm space. As such for 88 turns the space required.

$$= \frac{88 \times 1}{85} = 1.035 \text{ sq.cm.}$$

Total space required =

space required for primary + space required for secondary

= 1.130 + 1.035 = 2.165 sq.cm.

Hence the space required is just sufficient. You may choose the next larger core for the transformer and the next larger bobbin but these are not necessary considering economy and experience. The number of turns given in Table 3 includes the normal insulation used in the winding. As such insulation allowance need not be separately taken into account.

CONCLUSION

For the transformer as in the example, the derived winding data is as follows.

Transformer rating

Primary - 240V

Secondary - 6V

Frequency - 50 Hz

Volt ampere input - 15 VA

Table 3

Wire size in mm.	SWG	Turns per sq.cm.
1.60	16	34
1.40	17	44
1.22	18	60
1.00	19	85
0.90	20	104
0.80	21	132
0.710	22	172
0.600	23	233
0.560	24	279
0.500	25	333
0.450	26	411
0.425	27	493
0.375	28	605
0.345	29	705
0.315	30	860
0.295	31	976
0.274	32	1131
0.250	33	1302
0.230	34	1550
0.212	35	1860
0.190	36	2247
0.170	37	2820
0.150	38	3565
0.132	39	4758
0.122	40	5487
0.112	41	6742
0.100	42	7874
0.090	43	10198
0.080	44	12632
0.071	45	16119
0.061	46	22000
0.050	47	30533

Core : Core area 20 x 21 mm as decided in Step 3.

Bobbin: Breadth 20.6 mm, height 21 mm, length 26.7 mm and the total height of the flange 42.7 mm as decided in step 7.

Wire sizes and turns

Primary - 3187 turns of size 0.16 mm or 37 SWG

Secondary - 88 turns of size 1.00 mm or 19 SWG

Stampings: Considering the thickness of each stamping as 0.35 mm, from the Table 1 for the total thickness of 21 mm we may require 60 stampings. Considering the space between stampings and the stacking we may require 55 stampings only. Hence EI 60/21 type 55 numbers of stampings having 0.35 mm thickness are to be procured.

Testing of transformer after rewinding: After rewinding the core assembly, the transformer is to be inspected for proper tightness of the core and coil as well as proper termination of the end leads.

Insulation resistance test : Insulation resistance is measured between windings and core with a 500 volts Megger. The reading so obtained shall be infinity and in no case below one megohm.

Transformation ratio test: Keeping the transformer secondary open, the primary shall be connected to the rated AC voltage. With the help of suitable voltmeters both the primary and secondary voltage shall be measured. The readings so obtained shall be of the ratio designed.

Load test : The transformer shall be connected with a suitable load, so that the full load secondary current flows through the secondary of the transformer winding. The raise in the winding temperature shall be observed by a suitable industrial thermometer, on the load.

The transformer temperature will raise initially and after some time the temperature will come to a standstill. This raise in temperature shall be noted and it shall be within the limit of class of insulation of the transformer designed.

Short circuit test : Where it is not possible to load the transformer directly, the secondary winding of the transformer shall be short circuited and the low voltage on the primary shall be adjusted through a dimmerstat so that full load secondary current flows through the secondary winding of the transformer. The transformer so switched on shall be tested for raise in temperature to ascertain the class of insulation.

Generally oil-cooled transformers are of class-A where-as air-cooled transformers may be class 'A' or 'E'.

Method of measuring the winding wire size - Parts of winding machine

Objectives: At the end of this lesson you shall be able to

- **explain the method of measuring the winding wire size as per the recommendations of I.S.4800 Part - I 1968**
- **interpret the details from a winding table**
- **explain the major parts of the winding machine and their functions**

Method of measuring the winding wire size: An enamelled solid conductor (mostly copper and in some cases aluminium) of circular section is used for winding the no-volt coil.

The conductor shall be checked for diameter by a micrometer in the case of thick conductors, and in the case of thin conductors the size of the winding wire is derived by measuring the resistance of the unit length of the conductor (i.e. one metre) and Table 1 shows the diameter and resistance relations as per I.S. 4800(Part I) - 1968.

Table 1

Diameter in mm	Measurement
Less than 0.071	Only by resistance
Over and including 0.071 up to including 1.000	By resistance and diameter
Over 1.000	Only by diameter

Table 2 shows the conductor size and resistance values as recommended by I.S 4800 (Part 1) - 1960.

Coil winding machine: No-volt coils are normally wound by coil winding machines. In coil winding machines the following facilities are normally provided as shown in Figs 1 and 2.

1 Number of turns indicator or counter.

2 Wire-feed control as per arrangement - setting pitch according to diameter of wires.

3 Coil length/coil width setting.

4 Mandrel.

5 Reel/spool carrier.

6 Wire guides etc.

Turn indicator : Turn indicators have digital display normally. They are provided with reset arrangements to bring back the counter display to Zero. For determining the exact number of turns in a coil, the counter has to be set for zero initially. The initial readings of the counter have to be noted at the starting in the case of successive windings.

Wire-feed control arrangements or setting pitch : The wire-feed has to be adjusted depending upon the size (diameter) of the wire. The adjustment shall be made so that the wires do not overlap nor should a gap exist between the wires.

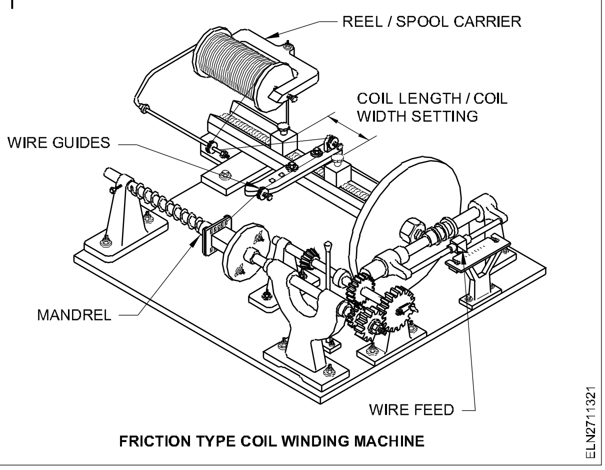
Hence before actually winding the coil, a trial run has to be made to ascertain a uniform layer of winding without overlap or gap exists. The feed controls are adjusted by selecting proper gear/pulley ratio or by setting proper friction depending on the design of the machine. Figs 1 and 2 shows wire feed arrangement by friction and gear respectively.

TABLE 2

Diameters and resistance of round conductors

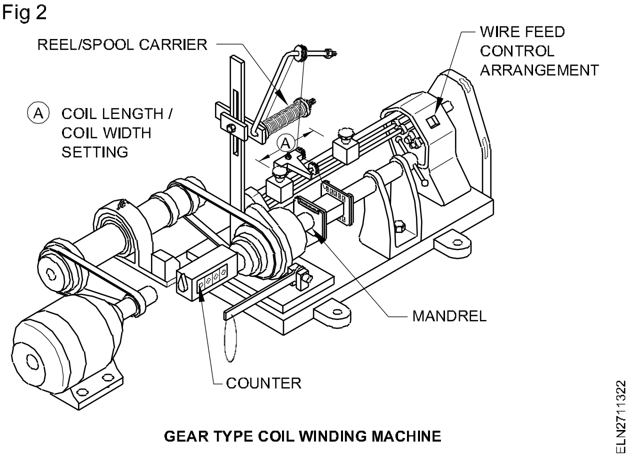
Nominal Conductor Diameter mm. (1)	Tolerance mm. (2)	Resistance in ohms per metre at 20°C: Copper Nominal (3)	Copper Max. (4)	Copper Min. (5)	Aluminium Nominal (6)	Aluminium Max. (7)	Aluminium Min. (8)
0.020	-	54.88	65.31	46.63	-	-	-
0.025	-	35.12	41.09	30.55	-	-	-
0.032	-	21.44	24.44	18.87	-	-	-
0.040	-	13.72	15.37	12.21	-	-	-
0.050	-	8.781	9.559	7.903	-	-	-
0.063	-	5.531	6.029	5.033	-	-	-
0.071	0.003	4.355	4.725	3.985	-	-	-
0.080	0.003	3.430	3.704	3.156	-	-	-
0.090	0.003	2.710	2.913	2.507	-	-	-
0.100	0.003	2.195	2.349	2.041	-	-	-
0.112	0.003	1.750	1.864	1.646	-	-	-
0.125	0.003	1.405	1.488	1.328	-	-	-
0.140	0.003	1.120	1.180	1.064	-	-	-
0.160	0.003	0.8575	0.8983	0.8192	-	-	-
0.180	0.003	0.6775	0.7068	0.6499	-	-	-
0.200	0.003	0.5488	0.5706	0.5282	0.8913	0.9317	0.8528
0.224	0.003	0.4375	0.4534	0.4224	0.7105	0.7404	0.6820
0.250	0.004	0.3512	0.3659	0.3374	0.5704	0.5975	0.5447
0.280	0.004	0.2800	0.2907	0.2698	0.4547	0.4747	0.4357
0.315	0.004	0.2212	0.2289	0.2139	0.3593	0.3739	0.3453
0.355	0.004	0.1742	0.1797	0.1689	0.2829	0.293	0.2727
0.400	0.005	0.1372	0.1419	0.1327	0.2228	0.2318	0.2142
0.450	0.005	0.1084	0.1118	0.1051	0.1761	0.1826	0.1697
0.500	0.005	0.08781	0.09037	0.08534	0.1426	0.1476	0.1378
0.560	0.006	0.07000	0.07215	0.06794	0.1137	0.1178	0.1097
0.630	0.006	0.05531	0.05687	0.05381	0.08982	0.09287	0.08688
0.710	0.007	0.04355	0.04481	0.04234	0.07072	0.07317	0.06836
0.750	0.008	0.03903	0.04022	0.03788	0.06338	0.06568	0.06116
0.800	0.008	0.03430	0.03530	0.03334	0.05570	0.05765	0.05383
0.850	0.069	0.03038	0.03131	0.02950	0.04934	0.05113	0.04762
0.900	0.009	0.02710	0.02789	0.02634	0.04401	0.04555	0.04253
0.950	0.010	0.02432	0.02506	0.02362	0.03950	0.04092	0.03813
1.000	0.010	0.02195	0.02259	0.02134	0.03565	0.03689	0.03445
1.060	0.011	0.01954	-	-	0.03173	-	-
1.120	0.011	0.01750	-	-	0.02842	-	-
1.180	0.012	0.01577	-	-	0.02560	-	-
1.250	0.013	0.01405	-	-	0.02282	-	-
1.320	0.013	0.01260	-	-	0.02046	-	-
1.400	0.014	0.01120	-	-	0.01819	-	-
1.500	0.015	0.009757	-	-	0.01584	-	-
1.600	0.016	0.008575	-	-	0.01393	-	-
1.700	0.017	0.007596	-	-	0.01234	-	-
1.800	0.018	0.006775	-	-	0.01100	-	-
1.900	0.019	0.006081	-	-	0.009876	-	-
2.000	0.020	0.005488	-	-	0.008913	-	-
2.120	0.021	0.004884	-	-	0.007932	-	-
2.240	0.022	0.004375	-	-	0.007105	-	-
2.360	0.024	0.003941	-	-	0.006401	-	-

Fig 1



FRICTION TYPE COIL WINDING MACHINE

Fig 2

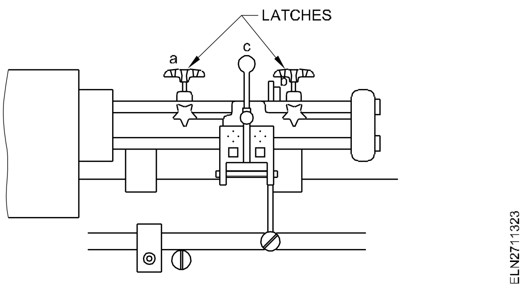


GEAR TYPE COIL WINDING MACHINE

Coil length setting or layer width setting: To wind the coil of a designated length i.e. within the inner length of the bobbin two latches are provided on the transverse pulley mechanism to stop and reverse the feed at the desired point (Fig 3).

Both these latches have to be set such that the wire is wound to the full length of the coil/bobbin and does not go out of the flanges of the bobbin. For this setting, several test runs are required before actually starting the winding of a coil.

Fig 3



Mandrel : Normally along with winding machines, different sizes and types of mandrels are supplied. In case they are not provided they have to be prepared from wood to the required shape and size. The mandrel assists to hold the bobbin firmly. A mandrel and a wooden block in (Fig 4 and Fig 5)

Fig 4

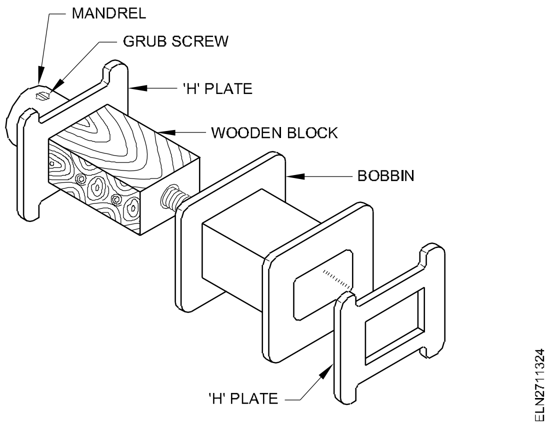
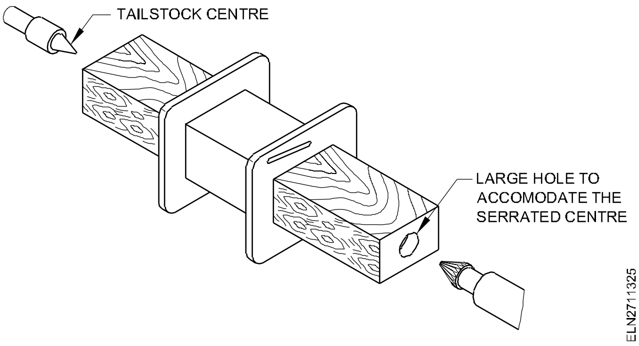


Fig 5



Reel spool carrier : Particularly for the fine wire, the over end de-reeling is provided to ensure that there are no restrictions preventing the wire from running freely. (Figs 1 and 2)

Wire guides : From the reel, the winding wire is taken through the wire guides to ensure that the wire is under proper tension between the pulley and the bobbin. Wire guides. (Figs 1 and 2)

For setting and operating details of the winding machine available in your section refer to the manufacturer's leaflet or seek advice from your instructor.

General maintenance of three-phase transformers

Objectives: At the end of this lesson you shall be able to
- **explain the need and advantages of maintenance of transformer**
- **state the factors affecting the life of transformers**
- **state the various periodical maintenance to be carried out in a transformer.**

Necessity of maintenance

Power transformer is required to give a long and trouble free service, It should be under constant attention and maintenance as it is a costly device.

A rigid system of inspection and preventive maintenance will ensure long life, trouble free service and low maintenance cost. Maintenance shall consists of regular inspection, testing and reconditioning wherever necessary.

Causes of breakdown: Generally the causes of breakdown of transformers may be classified as follows.

i faulty design or construction

ii incorrect installation or use

iii overloading

iv wear and tear, other deterioration

v negligence, accidents, environmental hazards

vi natural calamity.

Principal object of maintenance: The principal object of maintenance is to maintain the insulation in good condition. Moisture, dirt and excessive heat in contact with oxygen are the main causes of insulation deterioration and avoidance of these will keep the insulation in good condition.

There will be a decline in the quality of insulation during the ageing process due to chemical and physical effects. The decay of the insulation follows the chemical reaction rate and if the sustained operating temperature exceeds the normal operating temperature of 75^0C by about 10^0C the life of the transformer will get shortened.

FACTORS AFFECTING THE LIFE OF TRANSFORMERS

1 Effect of moisture

Transformer oil readily absorbs moisture from air. The effect of water in the oil is to decrease the dielectric strength of the oil. Therefore preventive steps should be taken to guard against moisture penetration to the inside of transformers. This will include blocking of all openings for free access of air and frequent reactivation of breathers in service.

2 Effect of oxygen

Oxygen present inside the transformer due to air in oil, reacts on the cellulose of insulation. Due to decomposition of the cellulose product, an organic acid soluble in oil is formed which will lead to a thick sludge. This sludge blocks the free circulation of the oil and deposited in bottom there by causing damage to coils/cores.

3 Effect of solid impurities

The dielectric strength of oil is diminished by minute quantities of solid impurities present in the oil. It is therefore a good practice to filter the oil after it has been in service for a short time.

4 Effect of varnishes

Some varnishes particularly of oxidizing type reacts with transformer oil and precipitate sludge on the windings. This should be kept in mind by the maintenance engineer when rewinding and replacing the coils during repairs.

5 Effect of slackness of windings

Slackness of windings may cause a failure due to repeated movement of coils which may wear the conductor insulation at some places and lead to an inter turn failure, momentary short circuit which may cause electric and magnetic unbalance. It is a good practice to lift the core and windings of a transformer and take up any slackness which may have developed by tightening the tie rods.

MAINTENANCE PROCEDURE

1 Safety precautions

i Before starting any maintenance work the transformers should be isolated from the supply and the terminals are earthed.

ii The oil level should be noted before unsealing the tank.

iii No fire should be kept near the transformer while maintenance work is going on.

2 Breather

Generally two types of breathers are used namely

a) Silicagel breather

b) Oil filled silicagel breather

a) Silica gel breather

The colour of the crystals changes from blue to pink as the crystals absorbs moisture. When the crystals gets saturated with moisture they become predominantly pink and it should be reactivated / reconditioned.

b) Oil filled silicagel breather

Oil available in the oil chamber attached with silicagel breather should be replaced, if it is gel condeminated.

External connections: All terminal connections should be tight. If they appear blackened or corroded, remove the connection and clean down to bright metal with emery paper. Remake the connection and give it a heavy coating of grease.

Earth connections: All earth connections should be properly maintained. A small copper loop to bridge the top cover of the transformer and the tank may be provided to avoid earth fault current passing through the bolts when there is a lightening surge, high voltage surge or failure of bushings.

Bushings: Clean the bushing projection and examine them for cracks and chips. It is recommended to have a spare in stock. In transformers located in control areas to avoid salt formation, a thin coating of grease pasted on the bushings.

Recommended maintenance schedules for transformers of rating less than 1000 KVA and for ratings of 1000KVA and above are given in Table 1 and 2 respectively.

Table 1

Maintenance schedule for transformers of capacities less than 1000 KVA

Sl.No.	Inspection Frequency	Items to be inspected	Inspection Notes	Action required during inspection if defects are noticed
1	Hourly	Load (Amperes)	Check against rated figures	Regulated with the values
2	Hourly	Voltage	- do -	- do -
3	Daily	De-hydrating breather	Check that air passages are clear. Check the colour of silica gel.	If silicagel is pink colour re place it or reactivate it.
4	Monthly	Oil level in transformer	Check transformer oil level	If low top-up with dry oil. Examine for oil leakage.
5	Quarterly	Bushings	Examine for cracks and dirt deposits	Clean or replace.
6	Half-yearly	Non-conservator transformer	Check for moisture under cover	Improve ventilation. Check oil
7	Yearly	Oil in transformer	Check dielectric strength acidity and sludge	Restore the quality of oil
8	Yearly	Earth resistance	Check the connection - nuts & bolts	Take suitable action if earth resistance is high.
9	1 year	Relay, alarms their circuits etc.	Examine relay and alarm contacts, their operation fuses etc.,check relay accuracy.	Clean the components, replace contacts change the setting if required
10	2 year	Non-conservator transformers	Internal Inspection	Filter oil regardless of condition
11	3 year	All parts	Overall inspection by lifting of core and coils	Wash by Flushing down with clean dry oil.

Table 2

Maintenance schedule for transformers of capacities of 1000KVA and above

Sl.No.	Inspection Frequency	Items to be inspect	Inspection Notes	Action required during inspection if defects are noticed
1	Hourly	Ambient temp	Check with normal values	Preventions/pre production from direct sum rays in summer season
2	Hourly	Winding,oil Temperature	Check that temperature rise is reasonable	Shut down the transformer and investigate whether it is higher than normal persistenly.
3	Hourly	Load (current) Voltage	Check against rated figures.	Regulates to normal values
4	Daily	Oil level in transformer	Check against transformer Oil level mark	If low top-up with dry oil. Examine for leakage.
5	Daily	Oil level in bushing leakage of water into cooler radiator fan	Check any leakage in coolents	Arrest the leakge if any
6	Daily	Relief Diaphragm	Leatheriod/ glass	Replace if cracked or broken.
7	Daily	Dehydrating breather	Check air passages are free, colour of silica gel. Check oil level in oil cap.	If silica gel is pink colour replace it or reactivate it. If oil level is low, top - up.
8	Quarterly	Bushing	Examine for cracks and dirt deposits	Clean or replace
9	Quarterly	Oil in transformer	Check for dielectric strength	Take suitable action to restore quality of oil.
10	Quarterly	Cooler fan bearings, motors and operating mechanisms	Lubricate bearings, check gear box. Check manual control and interlocks box.	Replace burnt or worn out contacts or other parts.
11	Half -yearly	Oil cooler	Test for pressure	Restore the requried prenure level
12	1 year	OLTC	Oil BDV (dielectrical strength) and moisture (PPM) content	Recondition or replace the oil, if the necessary .
13	1 year	Buchholz relay	Mechanical inspection for floats	Take suitable action if it found no free movement of floats
14	1 year	Oil in transformer	Check for acidity and moisture	Filter or replace.
15	1 year	Oil filled bushings.	Test oil	Filter or replace.
16	1 year	Gasket joints.	indication for leakage	Replace gaskets if leaking.

Sl.No.	Inspection Frequency	Items to be inspect	Inspection Notes	Action required during inspection if defects are noticed
17	1 year	Cable boxes	Check for sealing arrange- ments for filling holes, check compound for cracks.	Tighten the bolts to avoid unevenpressure.
18	1 year	Surge diverter and gaps.	Examine for cracks and dirt deposits	Clean or replace.
19	1 year	Relays, alarms their circuits etc.	Examine relay and alarm contacts, their operation and fuses.Check relay accuracy etc.	Clean the components, replace contacts, fuses if necessary. Change the setting if necessary
21	1 year	Insulator resistance	Check the IR value of primary and secondary windings	Take suitable actions if required
22	1 year	Ohmic value	Check the ohmic value of primary and secondary	Take suitable action it required windings
23	2 year	Oil temperature and winding temperature	Check and calibrate the OTI/WTI along with their	Replace or recalibrate them it required thermistor/CT.
20	1 year	Earth resistance	Earth conductor connection	Take suitable action if earth resistance is high.
24	5 year	1000-3000KVA	Overall inspection including lifting of core and coils.	Wash by Flushing down with clean dry oil.
25	7-10 year	Above 3000KVA	Overall inspection including lifting of core and coils.	Wash by Flushing down with clean dry oil.

Project work

Objectives: At the end of this lesson you shall be able to
- **define project work**
- **state the purpose of project work**
- **state the steps involving in project works.**

Project work

It is a type of activities which allow the trainees/ students to study, investigate, research, develop a model or find a conclusion/ solution and submit the report for a particular issues/ assignments towards the interest of public, nation and resources etc by applying their skill, ability, knowledge and experience.

Purpose of project work: The general purpose of any project should fulfill anyone or more of the following:

- Overcome the problems/ risks available in existing activities or technology etc.
- Simplifying the existing procedure/ activities of any operation or works.
- Reducing the cost of production or maintenence and increasing the productivity.
- Increasing the safety towards human lives/ machineries.
- Conserve the natural resources.
- Use of renewable energy sources such as wind, tide and solar etc.
- Using of new technology/ concept which is not available in market.
- Broadcasting or predicting any dangers/ risk involves in human lives/ machineries .. etc.

Steps involved in project works

- Deciding the objectives – purpose
- Deciding what to do – investigating and planning
- Find out the cost – costing
- Arranging the requirements – organising
- Selecting the right people – staffing
- Giving the instructions – directing
- Participating in works – involving
- Arranging the sequence – assembling or compiling
- Executing the project – testing or surveying
- Submitting the result conclusion – reporting

List of projector works may be assigned to the group of trainees as per syallabus

1 Overload protection of electrical equipments.
2 Automatic control of street light/ night lamp.
3 Fuse and power failure indicator using relays.
4 Door alarm/ indicator.
5 Decorative light with electrical flasher.