Approved by TEVTA, Punjab

TEXT BOOK OF
WORKSHOP PRACTICE (ELECTRICAL) ET-143

DIPLOMA OF ASSOCIATE ENGINEER
ELECTRICAL TECHNOLOGY, FIRST YEAR

Developed by Academic Wings, TEVTA

A Text Book of

WORKSHOP PRACTICE-I (ELECTRICAL)

Electrical Wiring

ET-143

For

DAE, First Year Electrical Technology

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PREFACE

Exclusively, it is the blessing of ALLAH who gave me the opportunity to write the text book of WORKSHOP PRACTICE-I (ELECTRICAL) ET 143 for DAE first year electrical students. The book has been written according to the new scheme of study (2020). Basically, this is the thorough revised edition of the text book ET 146, which was published by TEVTA Punjab in 2016. Although the time given to write the book was quit in-sufficient, more over no rules, regulations or standards for reference are available on the subject. In these circumstances, it was a hard job to "write a book". In spite of this, I, along with my co-writer have tried my best to prepare a good book. I have used I.E.E regulations and British standards as reference. It is the first book of its nature in Pakistan, which has been written in S.I units. In 1963, a standard book on this subject with the title "WIRING MANUAL" for electrical installations in Pakistan was published by PAKISTAN CABLES LTD. But this is now out dated in the sense that it was written in FPS system and it is no more being published.

I am very thankful to my TEVTA officers who rely on me and my co-writer in this regard. I would like to express, my truthful gratitude to a very humble and co-operating person Engr. Syed. Muhammad Waqar-ud-Din, Manager (Technical) Curriculum Section, Academics Wing TEVTA Punjab.

I was not able to complete the book in such a short time without the true help of my co-writers Mr. Khalid Mahmood, Instructor Electrical GCT Sialkot. Mr. Khalid Mahmood also checked the book with professional eye and prepared title of the book.

Another special bundle of thank is due for Mr. Muhammad Yousaf Sulehri, HOD Electrical for facilitating me. A common friend of all and master of all fields "*the Internet*" has shared a lot in preparing this book too. Most of the pictures used in the book, has been taken from internet.

We have tried our best to make the book free of errors, but keep in view that this book has been written in only 18 days.

AFZAL BASHIR
Sr. Instructor Electrical GCT Sialkot
(Convener MDC for the subject ET 143)
Dated**:** October 2020

New Course at a Glance

Main contents of new course
Workshop Practice (Electrical) contains following!

1. **ELECTRICAL WIRING**
   - 1.1 House Wiring
   - 1.2 Industrial and Commercial Wiring
2. **ELECTRICITY RULES AND REGULATIONS**
   - 2.1 Pakistan Electricity Rules 1973.
   - 2.2 I.E.E Regulation for Building Installation.
3. **FIRE PROTECTION AND SAFETY**
   - 3.1 Fire
   - 3.2 Safety from Electricity.

Name of Chapters and Page Numbers

Section-1
ELECTRICAL WIRING

Unit: 1.1- House Wiring

Topics included in this unit:
(Wiring Cables, Wiring accessories, Wiring systems,
Protection of house wiring, Distribution boxes, testing of wiring,
Electricity rules about domestic wiring and earthing)

Ch-1: Wiring Cables

Main Topics in this chapter

(1)Terms related to cables,(2) Types, systems and sizes of wiring cables and their current carrying capacity, (3) Flexible cables and cords,(4) L.T and H.T power cables, (5) Special purpose cables, (6) Selection of electrical cables for a particular application, (7) Voltage drops in cables and simple calculation, Cable jointing

Introduction: Different types and sizes of cables are used for electrical installations (wiring)**.**In this chapter electrical wiring cables will be discussed.

Purpose of Cables in Wiring: The purpose of electric cables is to carry currentfrom supply point to different machines and appliancesinstalled in a building efficiently and safely.

1. Terms related to cables

Cable: A stranded insulated conductor (with or without outer cover) is called cable.

Examples: All stranded cables from 1.5mm2, 2.5mm^2, 4mm^2 to 630mm^2 sizes

Wire: A bare solid or stranded conductor is called wire. Insulated conductor with single strand is also called wire.

Examples: Stranded bare conductors of transmission and distribution lines, enamelled conductors of motor winding andfuse element wire in fuses.

Core: Insulated conductor/conductors in a protective cover/sheath is called core of the cable.

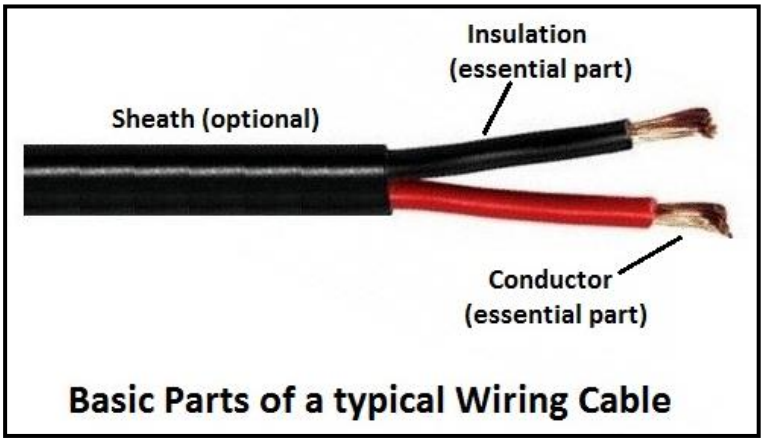


Fig 1.1

Armouring: A twisted layer of galvanized steel wires (or sometimes steel tape) over the sheath of cables is called armouring. Armouring is provided for the mechanical protection of sheath and insulation of cables from mechanical damage. Sometimes aluminium wires are also used in Pakistan for this purpose. Armouring is usually provided in power cables for underground use.

Conductor: The inner most essential part of wiring cable that is used to pass current is called conductor.Size of conductor depends upon the amount of current to be passes through the conductor. Mostly annealed copper conductor is used in wiring cables. Aluminium conductor above 10mm^2 size can also be used in wiring cables .Conductors in wiring cables may be solid or most usually stranded.

Insulation: An insulating material is used over the cable conductorto prevent leakage/flow of current from conductor to earth, is called cable insulation.It is also an essential part of electric cables used. Thickness of insulation on cables mainly depends upon the voltage level on which cable is to be used.

Purpose of Cable insulation

a. Prevent leakage of current from conductor to ground.
b. To save the humans from electric shock
c. To prevent short circuit and fire.
d. Transmit electric power with maximum efficiency.

Sheath: The outer protective cover over the insulated conductor is called sheath. In wiring cables, it serves as mechanical protection layer of insulation. American calls it Jacket.

i. Types, systems and sizes of wiring cables and their current carrying capacity

a. Types of wiring cables:

Wiring cables can be classified in many ways such as

1. Types of cables with respect to application
2. Types of cables with respect to insulation
3. Types of cables with respect to No of cores
4. Types of cables with respect to voltage grade
5. Types of cables with respect to conductors
6. Types of cables with respect to mechanical Protection
7. Types of cables with respect to shape

Cable insulation should have

(a) High resistance
(b) High dielectric strength
(c) Non inflammable.
(d) Resistant to acids, moister, and alkalies.
(e) Withstand high temperature.
(f) Should be non-hygroscopic.
(g) Good conductor of heat
(h) Should emit low smoke zero halogen

Types of electrical cables with respect to applications:

1. **Wiring Cables:** These are mostly used as single core for internal wiring; however two, three or four cores are also used. Available in low and medium voltage grade.
2. **Control Cables:** Control cables are usedon substations and industries to transmit control signals from machines/ equipment to any alarming devices or protecting relays. Usually these are multi core (2, 4, 5, 7, 12, 20, 30, 48, 70, and 100) and manufactured in 0.75, 1, 1.5 and 2.5mm^{2}sizes. Usually these are designed to work on 11KV on substations.
3. **Power cables:** Used in power system to carry high power for transmission and distribution purpose. In wiring, these may be used as service, main or sub main cables in high load installations.

Types of cables with respect to insulation:

a. **P.V.C** (poly vinyl chloride) Insulated cables.
b. **V.R.I** (Vulcanized rubber insulation) cables.
c. **TRS & CTS cables** i.e. TRS (tough rubber sheathed cables) and CTS (Cab tyre sheathed cables).
d. **Butyl rubber**insulated cables.
e. **Silicon rubber**insulated cables.
f. **Ethylene propylene rubber**insulated cables.
g. **Mineral** (Magnesium Oxide) **insulated** cables. Used in fire places.
h. **Impregnated paper**insulated cables. (Used ashigh voltage underground supply cables).
i. **Varnished cambric** insulated cables.(old version, now outdated)

Types of wiring cables with respect to cores:

a. **Single core.** Mainly used for internal wiring.Single core armoured cables shall not be used for AC supply (IEE Regulation B-9)

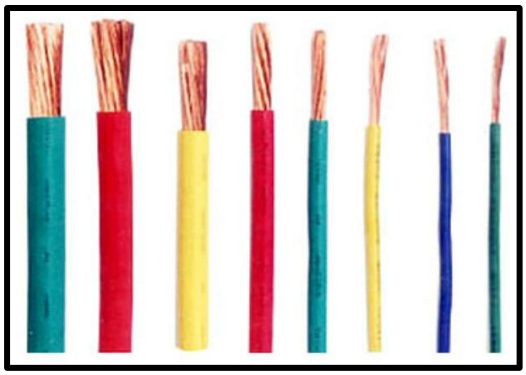


Fig. 1.2(a): Some typical single core wiring cables

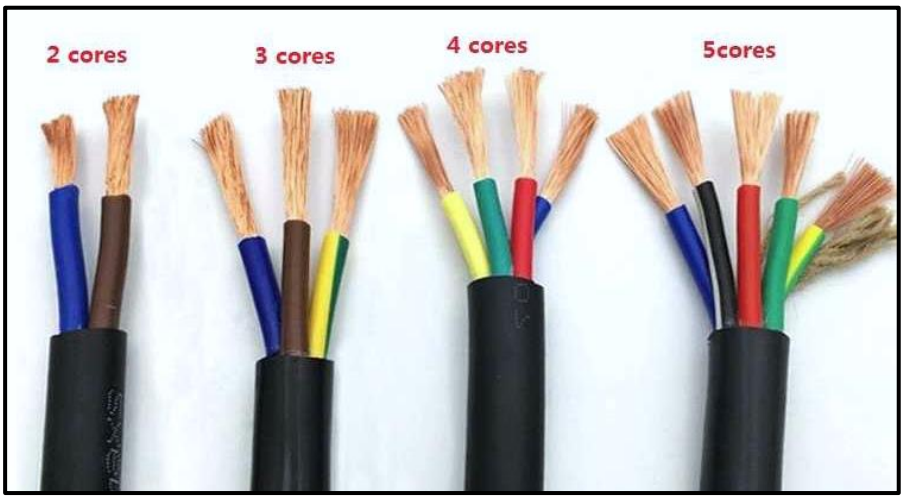


Fig. 1.2(b): Two ,three , four and five core wiring cables

b. **Two core or twin core.** Used as a main cable, sub main cable or internal wiring cable in single phase supply.
c. **Three core.** Used as service cable, main cable or sub main cable in industries and three phase installations.
d. **Three and half core.**Used as service cable, main cable or sub main cable in industries and three phase installations.
e. **Four core.**Used as service cable, main cable or sub main cable in industries and three phase installations.
f. **Five core.** Three phases, one neutral and one earth core.Used as service cable, main cable or sub main cable in industries and three phase installations.

Types of wiring cables with respect to voltage grade:

Wiring cables are being manufactured in following voltage grades.

a. Low voltage grade(250/440V)

Low voltage grade cables are so manufactured that their insulation can withstand 250 volts from conductor to earth and 440 volts from conductor to conductor.

b. Medium voltage grade (600/1000V, old 650V/1100V).

Medium voltage grade cables are so manufactured that their insulation can withstand 600V from conductor to earth and 1000 volts from conductor to conductor.

The low voltage grade (250/440V) cables are suitable for both single phase (230V) and three phase (400V) supply systems in Pakistan. The medium voltage grade (600/1000V) cables are suitable for three phase supply

systems where voltage between each conductor and earth does not exceed 600V and between phase conductor to other phase conductor 1000V.
1.9/3.3KV, 6.350/11 KV, 8.7/15 KV and 19/33 KV voltage grade cables are also being manufactured in Pakistan but these are mostly used as supply distribution cables and service cables.

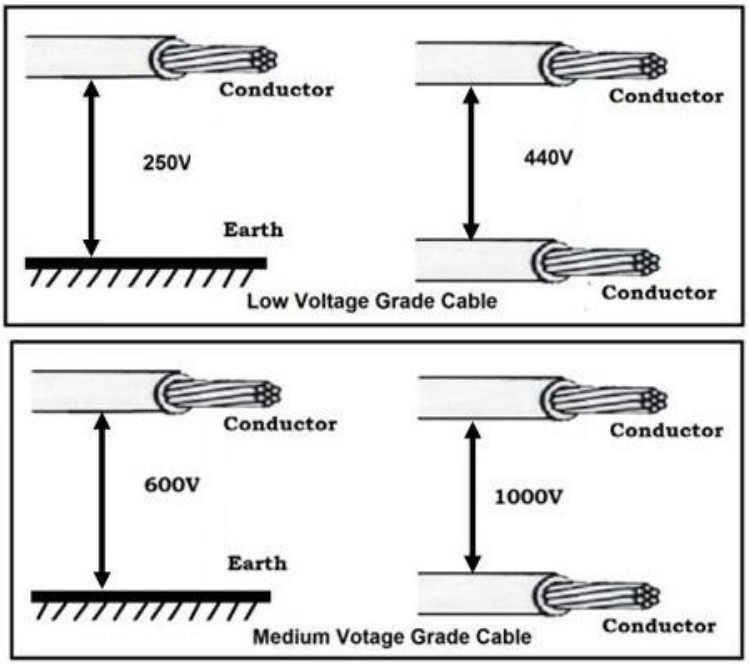


Fig. 1.3: Low (above) and medium (below) voltage grade cables

Cores colours of cables used in Pakistan
Phase-1: Red
Phase-2: Yellow
Phase-3: Blue
Neutral: Black
Earth: Green with yellow strip

Voltage grade of flexible cords and cables

- Flexible cords are manufactured in 300V/300V & 300V/500V grade.
- Flexible cables are manufactured in 600V/1000V grade.

Types of cables with respect to conductor:

Annealed copper and Aluminium conductors are used in wiring cables.
Copper: Annealed copper is mainly used for internal wiring cables for all sizes.

Aluminium: Cables with Aluminium conductor are not used for internal wiring cables in Pakistan. However above $10mm^2$ size, cables with Aluminium conductor can be used as, main cables, sub main cables and service cables of an electrical installation.

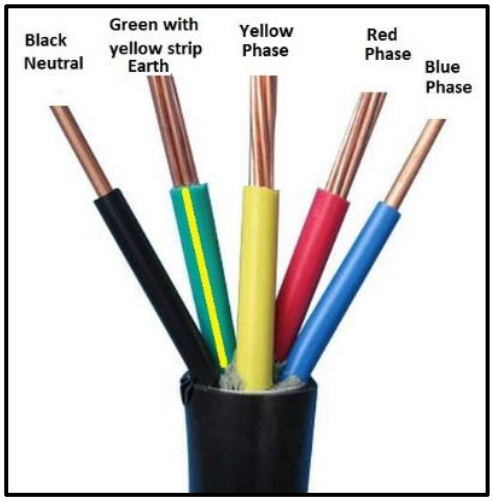


Fig. 1.4: colours of cable cores in Pakistan

Conductors of wiring cables are manufactured both in solid and stranded form as give below.

- $1mm^2$ size: In solid form only
- $1.5mm^2$and $2.5mm^2$ size: Both in solid and stranded form.
- $4mm^2$ to $630mm^2$ sizes: In stranded form only

No of strands in stranded conductors used are: 1, 7,19,37,61,127

Strands and conductors of wiring cables are manufactured in circular shape.

Advantages of stranded conductors over solid conductors

4. More flexible
5. Less chance of cracking of insulation on bends.
6. Stronger and long life joints and connections.
7. less risk of breakage when suspended between two points

Types of cables with respect to shapes and flexibility:

Wiring **c**ables may be round or flat and flexible or non-flexible.

Types of cables with respect to mechanical protection:

Wiring cables may be armoured or non-armoured type.

b. Systems of wiring cable sizes

There are two methods of describing the cable sizes.

1. **Imperial** (or British or English) **system.** This is the old system used in England, India and Pakistan. In Pakistan, this system is still in use but not being used in England now.
2. **Metric system.**This is the new system of cables sizes used almost worldwide now days.

In Pakistan, wiring cables are being manufactured in both imperial and Metric sizes.

c. Explanation of cable conductor sizes

In imperial system, the diameter of each strand of cable conductors is described in inches and cross sectional area of cable conductors is described in inches^2.

In metric system, the diameter of each strand of cable conductors is described in mm and cross sectional area of cable conductors is described in mm^2

Explanation

The imperial system: Some imperial sizes of cables are 1/0.044", 3/0.029",3/0.036", 7/0.029", and 7/0.044" etc.

7/0.029" is a typical size of cable in imperial system. In this cable size, the digit 7 represents the number of strands in the cable conductor and 0.029" is the diameter of each strand of conductor in inches. Over all diameter of cable conductor is described in square inches.

Similarly, in 3/0.036" size, the digit 3 represents the number of strands in the cable conductor and 0.036" is the diameter of each strand of conductor in inches.

The Metrics system: Some metric sizes of cables are 1.0mm^2 (1/1.13), 1.5mm^2(1/1.38)' 2.5 mm^2 (1/1.78), 4mm^2(7/0.85)' 6mm^2(7/1.04), 10mm^2 (7/1.35), 16mm^2 (7/1.70) and 25mm^2 (7/2.14).

In 6mm^2 (7/1.04) cable size, 6mm^2 is the overall cross sectional area of conductor square millimetres. The digit 7 represents the number of strands in the cable conductor and 1.04 is the diameter of each strand of conductor in mm.

Metric sized cables are usually described in overall cross sectional area of conductor.

Current carrying capacity of wiring cables

Current carrying capacity (Ampacity in USA) of cables depends mainly upon the type of conductor material and size (cross sectional area) of the conductor. Cable manufactures provide tables of cable sizes and their

respective current carrying capacity in given conditions. It is also called ***rated current*** of any specific type and size of cable.

Rated current of any cable is "that current which can safely pass through it continuously without considerable heat loss and voltage drop". Rated current of cables is usually given for 30^{o}C temperature.

Comparison between standard imperial and the nearest metric size of conductors of cables and their current rating at 30^{o}C

(Amended Table 4D1A of Pakistan Cables)

Imperial sizes, No of strands and their diameter in inches	Cross sectional area of conductor in $Inch^2$	Current Rating in Amperes	Colum (I) Converted to $(mm)^2$	Nearest Metric Standard Size $(mm)^2$	No. and Nominal Diameter of wires in circular conductor	Current Rating in Amperes
(1/0.44")	0.00152	11	0.98	1.0	…….	10.9
(3/.029")	.0020	13	1.29	1.5	1/1.38	14.5
(3/0.36")	.0030	16	1.94	1.5	1/1.38	14.5
(7/.029")	.0045	21	2.90	2.5	1/1.78	19.5
(7/.036")	0.007	28	4.52	4	7/0.85	26
(7/.044")	0.01	32	6.45	6	7/1.04	34
(7/0.52")	0.0145	43	9.35	10	7/1.35	46
(7/.064")	0.0225	56	14.52	16	7/1.70	61
(19/.052")	0.04	77	25.81	25	7/2.14	80
(19/.064")	0.06	105 approx.	38.71	35	19/1.53	99
(19/.072")	.075	145 approx.	48.39	50	19/1.78	119
(19/.083")	0.10	180 approx.	64.52	70	19/2.14	151
(37/.072")	0.45	……..	96.77	95	19/2.52	182
(37/.083")	0.2	183 approx.	129.0	120	37/2.03	210
(37/.093")	0.25	225 approx.	161.3	150	37/2.25	240
(37/103")	0.3	290 approx.	193.6	185	37/2.52	273
(61/.093")	0.4	334 approx.	258.1	240	61/2.25	320
(61/.103")	0.5	385 approx.	322.6	300	61/2.52	367
(91/.093")	0.6	537 approx.	387.1	400	61/2.85	
(91/.103")	0.75	600 approx.	438.9	500	61/3.20	
(127/.103")	1.0	680 approx.	645.2	630	127/2.52	
	1.25		806.4	800	127/2.85	
	1.5		967.7	1000	127/3.20	

Above table is for PVC insulated copper conductors with or without sheath run in conduit/trunking 250/440 and 600/1000V 2 cables (Single phase ac. or dc.)

Current rating of cable conductors (normal conditions and 30^{o}C ambient temperature) for both metric and imperial systems

Metric or SI System			Imperial or British System		
Cross sectional area of conductor inin mm^2	No of strands and their diameter in mm	Current Rating in Amperes	Cross sectional area of conductor inin inch^2	No of strands and their diameter in inches	Current Rating in Amperes
1	1/1.13	11	0.00152	(1/0.44")	11
1.5	1/1.38	13	0.002	(3/.029")	13
2.5	1/1.78	18	0.003	(3/0.36")	16
4	7/0.85	24	0.0045	(7/.029")	21
6	7/1.04	31	0.007	(7/.036")	28
10	7/1.35	42	0.01	(7/.044")	34
16	7/1.70	56	0.0145	(7/0.52")	43
25	7/2.14	73	0.0225	(7/.064")	56
35	19/1.53	90	0.03	(19/.044")	66
50	19/1.78	145	0.04	(19/.052")	77
70	19/2.14	185	0.06	(19/.064")	105
95	19/2.52	230	0.10	(19/.072")	180

Many manufacturers, sellers and electricians tell that 3/0.029"cable is equal to 1.5mm^2 and 7/0.029"cable is equal to 2.5mm^2 cables. But, as seen from the above table, sizes of both systems are different. So their rated current, voltage drop and market rates are also different.

Many other factors also affect the current carrying capacity of cables, such as

a. Ambient temperature.
b. Class of access current protection.
c. Bunching of cables
d. Method of installation. (Cable installed in open air such as in batten wiring system or cleat wiring system has more current capacity than concealed systems).
e. Type of cable insulation and sheath.
f. Length of cable

ii. Flexible Cables and Cords

Flexible Cords: Insulated wires with fine gauge strands (0.2mm diameter) and conductor size from 0.5mm^2(16/0.20) to 4mm^2 (56/0.30) are called flexible cords.

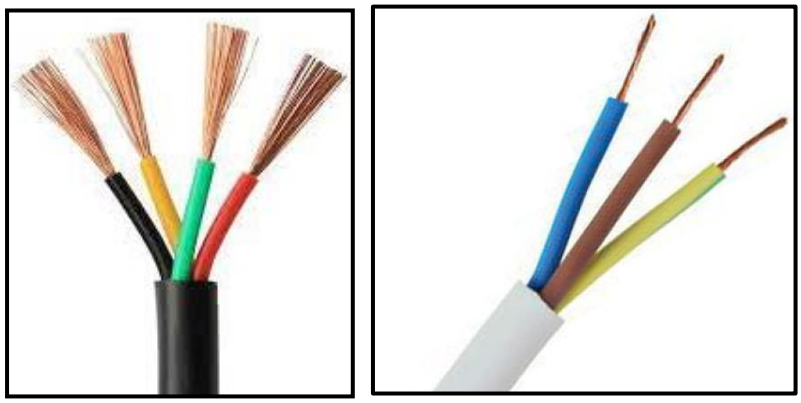


Fig 1.5: A typical 4 core & 3 core flexible cords

Flexible Cables: Insulated wires with fine gauge strands (0.2 to 0.3mm) (sometimes up to 0.6mm diameter also used for some manufacturers)andfrom 6mm^2 84/0.30) to 630mm^2(2257/0.60) size are called flexible cables.

d. Due to fine gauge strands, these are much more flexible than ordinary wiring cables and are used for ceiling rose to lamp holder, or from socket outlet to portable apparatus etc.

Difference between flexible cables and cords

As is clear from above definitions, both flexible cables and cords have fine gauge strands. The basic difference between flexible cables and flexible cord is that flexible cords are made in sizes from 0.5mm^2 to 4mm^2 while flexible cables are made from 6mm^2(84/0.30) size to 630mm^2(2257/0.60) size

Flexible cables must not be used in fix wiring unless contained in an enclosure affording mechanical protection. Exposed length of flexible cords and flexible cables should be as short as possible and connected to the fixed wiring by a suitable accessory.

Types of flexible cords:

Complete range of flexible cords can be found in BS 6500. Some of them are:

1) **Vulcanized Rubber insulated cords** (braided, twisted twin, circular twin and three cores, ordinary and un-kinkable (un-twistable). Rubber or PVC sheathed, single core, twin, 3 core and 4 core.).

2) **PVC insulated cords**, other than heat resisting. (Single core, twisted twin and parallel twin. PVC sheathed, single core, twin, 3 and 4 cores).
3) **PVC insulated cords**, heat resisting. (Single core, twin, 3 cores and 4 cores).
4) **Butyl-rubber or ethylene-propylene rubber insulated cords**. (Single core, twin, 3 and 4 cores, sheathed with either PVC heat resistant compound or H.O.F.R compound).
5) **Silicon-rubber insulated cords**. (Single core, twisted twin, circular twin, and 3 cores, all glass fibre braided).
6) **Varnished glass fibre braided cords**. (Single core, twisted twin, circular twin, and 3 core).

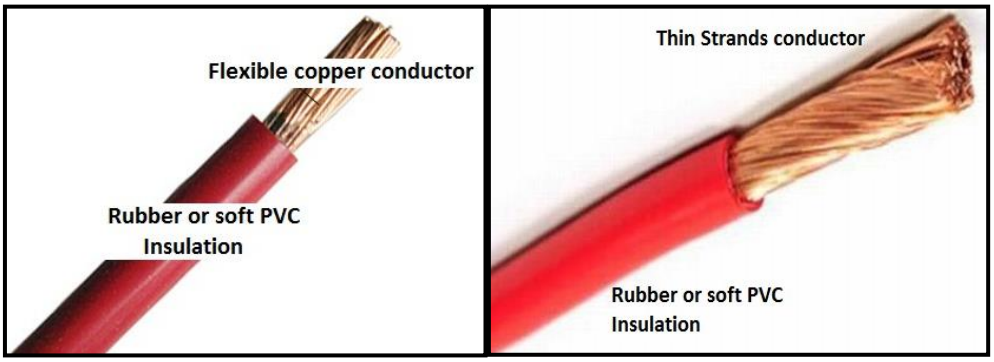


Fig 1.6: Samples of two flexible cables

Flexible cords are manufactured in 300V/300Vrange and 300V/500V range.

Current ratings of some flexible cords

Sr. No	Size of cords (No of strands and their diameter)	Over all area of conductor in mm^2	Current carrying capacity	Nearest imperial sizes for reference	Current carrying capacity
01	16/0.20	0.5	3	14/0.0076″	3A
02	24/0.20	.075	6	23/0.0076″	6A
03	32/0.20	1.00	10	40/0.0076″	13A
04	40/0.20	1.25	13	70/0.0076″	18A
05	48/0.20	1.5	15	110/0.0076″	24A
06	80/0.20	2.5	20	162/0.0076″	31A

Flexible cables:

Flexible cables are made in 600/1000V range, and include single core, and circular twin and multi core cables. Tinned annealed copper is used as a conductor and vulcanized rubber, butyl rubber, or EP rubber is used as insulation. Sheath is used of heavy duty-O and Fr. In some cases flexible cables are armoured.

iii. LT and HT power cables

Power cables

Power cables are designed to carry high current than ordinary wiring cables Power cables are used for the transmission and distribution of electric power. Cables come in various shapes, sizes and voltage ranges. These are made for low, high, extra high and ultrahigh voltage. Up to 11KV, both circular and shaped (having shape other than circular) stranded copper and aluminium conductors are used in power cables. Power cables may be armoured type or non-armoured type.

Shaped conductors are made for better space factor and compact construction in the sizes of $25mm^2$ and above for multi-core cables. Reduced neutral and special conductors of these cables are usually circular.	Power cables may be armoured type or non-armoured type. Armouring is provided to protect the cable from mechanical injury. Jute or Polyethylene bedding layer between sheath and armouring is provided to save the sheath of cable form armouring. The serving layer, (jute immerse in adhesive compound) protects the cable from moisture and chemical fumes of soil or atmosphere.

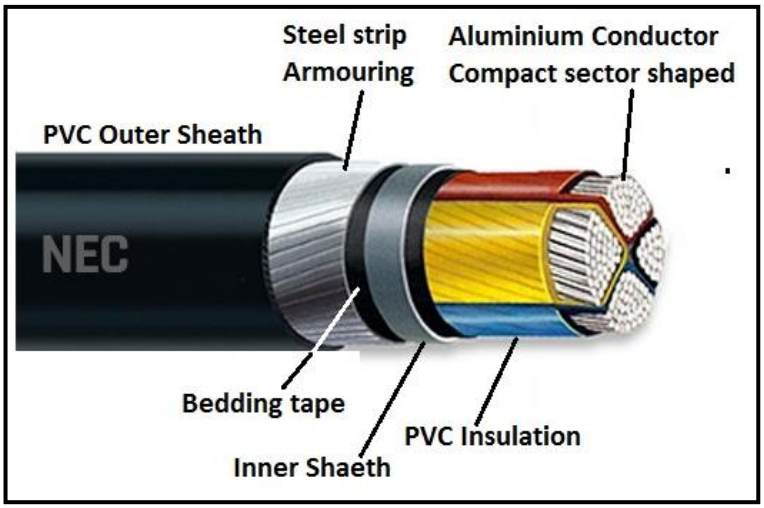


Fig 1.7: A typical 4 core armoured L.T Power cable

L.T power cables: *The term L.T power cables apply to those cables which are made to work on400/600V but can withstand 1000V. LT power cables are tested at 1KV.* Cores of L.T power cables may be single, two, three, three and half, four and five. Usually PVC and sometimes XLPE is used as insulation. A neutral core is available in multi core cables. L.T power cables may be armoured or non-armoured type.

L.T power cables are usually used as service cables, main cables and sometimes as sub main cables in commercial and industrial installations. Extruded PVC is most commonly used as outer sheath over L.T power cables in Pakistan. A filler material (polyethylene or jute) is used between cores to make the cable more solid and circular and to keep the cores in place.

Some typical metric sizes of L.T Power Cables

Size of cable conductor in mm^2	No and nominal dia. Of circular conductor No/mm	Size of cable conductor in mm^2	No and nominal dia. Of circular conductor No./mm
1.5	1/1.38	120	37/2.03
2.5	1/1.78	150	37/2.25
4	7/0.85	185	37/2.52
6	7/1.04	240	61/2.25
10	7/1.35	300	61/2.52
16	7/1.70	400	61/2.85
25	7/2.14	500	61/3.20
35	19/1.53	630	127/2.52
50	19/1.78	800	127/2.85
70	19/2.14	1000	127/3.20
95	19/2.52		

H.T power cables: *H.T power cables are designed to work on or more then1000 V.* These are made in single and three cores only and usually XLPE (cross Linked Polyethylene) is used as insulation. A neutral core is not available in multi core cables.HT cables are mostly armoured type. Solid galvanized steel wires or steel strips (or sometimes aluminium wires) spirally wrapped over the bedding layer are used as armouring.

***Application*:** HT cables are used in power transmission and distribution that has a range greater than 1.1 kV.

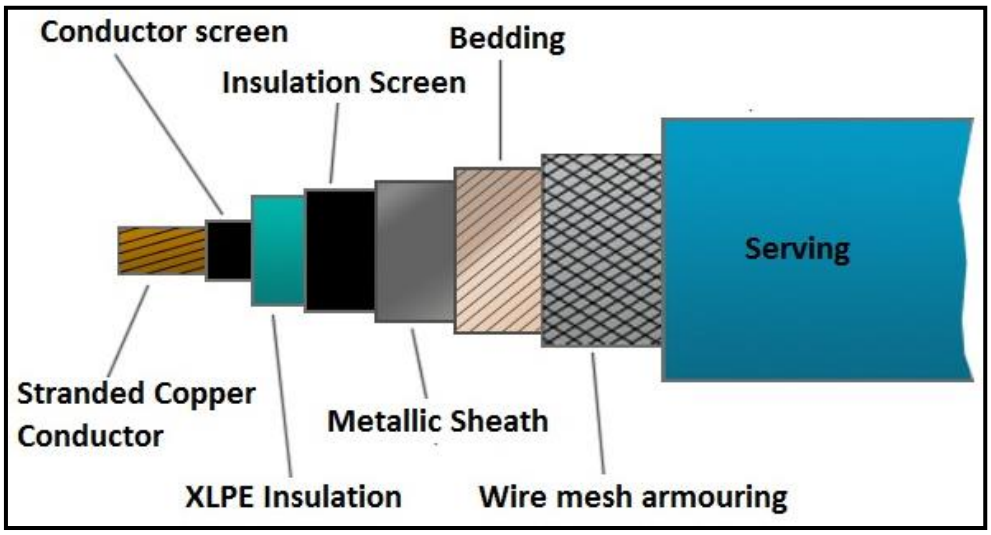


Fig 1.8: A typical single core XLPE insulated H.T armoured power cables

Parts of an armoured H.T power cable are given bellow.

A. Conductor (stranded annealed copper or aluminium).
B. Conductor screen (semiconductor)
C. Insulation (XLPE).
D. Insulation screen (semiconductor)
E. Copper tape screen
F. Bedding (extruded PVC or lapped PVC tape).
G. Armouring (galvanized steel wires or tape or aluminium wires).
H. Serving (hard sheath grade PVC).

Comparison between LT & HT Power Cables	
LT Cables	**LT Cables**
(a) Tested for1KV but designed to use on450/600 V	(e) Designed and used above 1.1KV
(b) Usually PVC or some time XLPE Insulation is used	(f) XLPE insulation is used
(c) Made in I,2,3,3.5,4 and 5 cores	(g) Made in single or three cores only
(d) Neutral wire is used in 3.5,4 and 5 core cables	(h) No neutral wire is used

iv. Special Purpose Cables

Special purpose cables: The cables which are made to work in special conditions are called special purpose cables. Three important categories out of many are given below.

1) Heat resistant cables.
2) Fire retarding / fire proof cables.
3) Welding cables.

(a) Heat resistant cables

Cables that are used where temperature is higher than 80^{o}C are called heat resistant cables. Special grade PVC, ethylene propylene rubber, butyl rubber and silicon rubber is used as insulation. Heat resistant cables/cords are used with pendant lights, heaters, cookers, immersion heaters, radiators, wash boiler, electric irons, toasters and other heat producing appliances. In some countries, asbestos, glass fibre tape or mica is also used in heat resistant cables.Rubber insulated cables are made in the 600/1000V range.

8. **Butyl (synthetic) rubber Insulated cables** are used up to 85^{o}Ctemperatures. These are used for flexible cords in pendant light fittings and on cables to bare conductors and bus bars. It requires heat, oil and fire resistant sheathing.

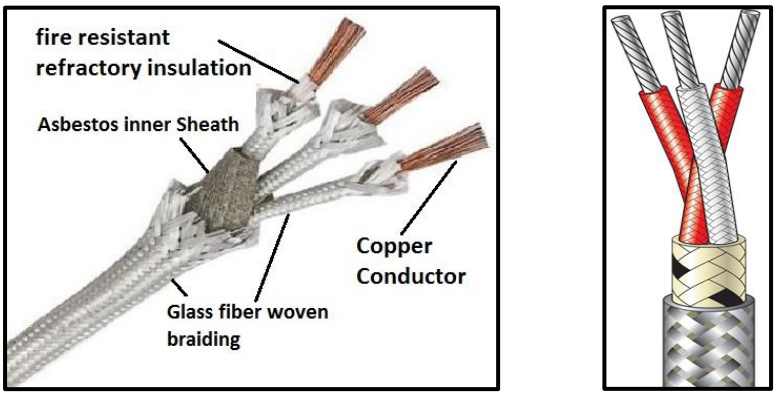


Fig 1.9: Typical heat resistant cables

Some typical heat resistant cables

9. **Silicon rubber Insulated cables** are more resistant to heat and can be used from -75^{o}C up to 150^{o}C and even up to 200^{o}C for short time.

Fibre glass, asbestos, special grade PVC and mica cables are mainly manufactured in USA for use on high temperatures. PVC version has a tinned copper braid and is then overall PVC sheathed. Fibreglass version is fibreglass braided then stainless steel braided overall. Heat Resistant Fibre glass cables

can be used up to480°C.

(b) Fire Resistant and Fire Retarding cables

Both types, fire resistant and fire retarding cables are different not only in construction but also in function.

Fire resistant (or fire proof) cables: A cable that is capable to continue to operate even in case of fire for a time from 30 to 180 minutes under defined conditions. This type of cable is also called as *Circuit Integrity Cable* or *fire rated cable*.A Fire resistant or fire proof cable continues to perform its main function, i.e. transmission of power and signals even during the fire. Fire proof cable is basically installed for life safety. Fire resistance cable shall pass test as per IEC 60331.With flame proof terminations, fire proof cables are suitable for operation in gaseous atmospheres such as in mines, oil refineries, petrol pumps etc. Due to high strength of outer sheath, this cable is also suitable for foundries, dockside installations, and concentration plants and mining. It is also suitable for earthed concentric wiring.

Fire retardant cable: Fire/flame retardant cables are designed to resist the spread of fire into a new area by slow downing the combustion. Fire retarding cables now come with special insulation and sheaths which emit very little toxic gases and fumes. So these are also called SZH, LSF, LSH, and LS0H, LSHF and/or HFFR cables. Fire retarding cables are now recommended to use in poorly ventilated areas and all public places. Like fire proof cables, these cables cannot maintain circuit integrity during fire.

Colour codes of Fire Resistant and Fire Retarding Cables

In term of cable color coding, it is essential to distinguish the outer sheath colour between flame retardant cable and fire resistant cable.

i. Commonly, fire resistant cable has **red outer sheath/jacket**
ii. Flame retardant may have **grey or black outer sheath/jacket.**

- **The Fire resistant/proof cables**

Conventional Mineral insulated copper covered cable (MICC)

This cable consists of solid copper or Nickel Clad Copper conductors, insulated with a highly compressed magnesium oxide (an inorganic mineral material in powder form) and enclosed in seamless solid drawn copper or copper alloy sheathing.

Installation and termination of this cable is not easy and a particular care has to be paid to prevent moisture absorption by the mineral oxide.

It is high performance true fire proof cable and continues to work even after destroying of a building with fire.

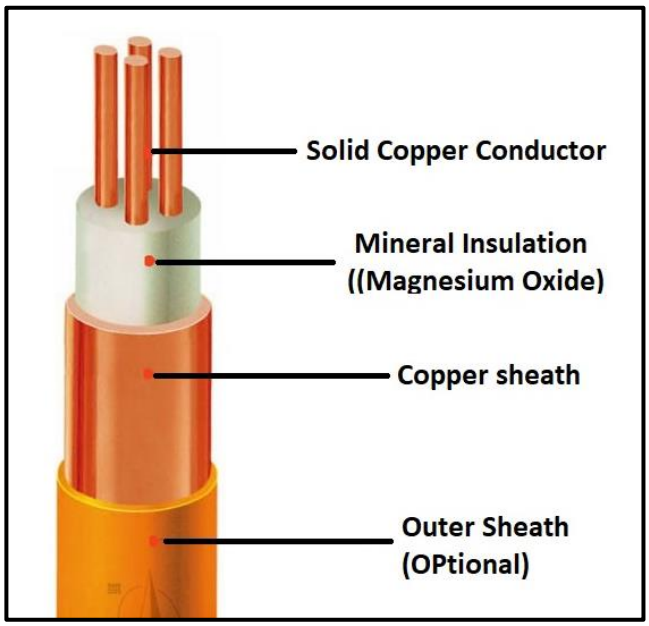


Fig 1.10: Mineral insulated (MICC) cable

Applications:

i. Mining
ii. Petroleum
iii. Energy.
iv. Foundries.
v. Docksides.
vi. Concentration plants.
vii. Oil refineries.
viii. Infrastructure.
ix. Construction Industries.
x. Aircrafts or rail cars
xi. 300/500 V grade fire resistant screened cables are used in fire alarm and emergency lighting applications.

- ***Fire Retarding (LSZH type) cables:***

Low Smoke Zero Halogen (LSZH) cable is cable with insulation and /or sheathing which emits very less amount of toxic fumes when burnt. It also has fire/flame retarding characteristics.

Following abbreviations are also used for such cables having similar characteristics!

i. *LSF(Low Smoke & Fume)*
ii. *LSH (Low Smoke & Halogen)*
iii. *LS0H(Low Smoke 0 Halogen)*
iv. *LSHF(Low Smoke Halogen Free)*
v. *HFFR((Halogen Free and Flame Retarding)*

Cables and Fire

Many conventional cables are insulated with polyethylene, PVC or thermoplastic urethane (TPU). In case of fire, insulation/sheath containing plastic material releases hydrogen chloride, a poisonous gas that forms hydrochloric acid when comes in contact with water during fire fighting efforts. It severely affects the respiratory system of human beings leading to a death. It also damages the electronic equipment and also the metal surfaces and even buildings. It also gives off thick black smoke, preventing people to find their way to exit and also make difficult for rescuer to evacuate the peoples from areas affected by fire and toxic fumes. On the other hand do not produce dangerous gas/acid combination or toxic smoke when exposed to fire/flame. So it is at all public places LSZH cables are recommended to be used.

Apart from special insulation, LSZHcables also have special sheathing composed of thermoplastic or thermosetting compounds that emit limited smoke and no Halogen when exposed to high sources of heat. Low smoke zero halogen cable reduces the amount of toxic and corrosive gas(only 0.5% in comparison with conventional cables which emit 25%). In Pakistan, *all LV and MV cables are manufactured by "Pakistan Cables Limited" with special PVC compound sheaths which not only emit less toxic gases but also resist the spreading of fire (fire retarding)*

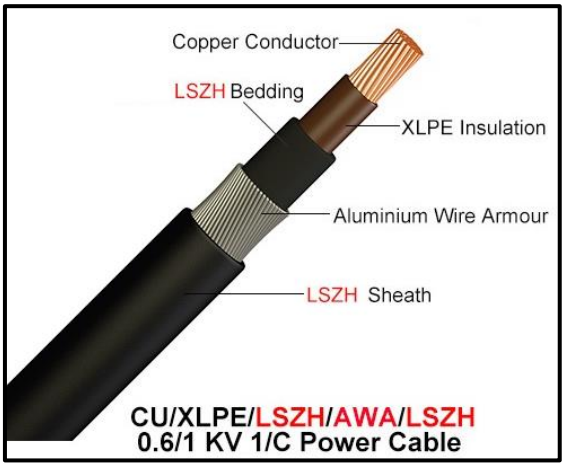


Fig.1.11 constructional parts of LSZH Fire rated cable

Applications: LSZH fire retarding cables are now recommended to use in poorly ventilated areas and all public places, such as!

(a) Hospitals
(b) Aircrafts and air ports
(c) Factories
(d) Hostels , Resorts and Hotels
(e) Cinemas
(f) Trains and train stations
(g) Ships and Sea ports
(h) Data centres
(i) Shopping malls
(j) Mass transits
(k) Gaskets for the air conditioning system in the railway industry

- **Welding cables**

The cables that are designed to use with welding plants or welding machines are called welding cables. Welding cables are high current special cables designed to work on low voltage. 80 to 100 volts are needed to strike the arc in ac arc welding machines and only 15 to 35 volts can maintain this arc. The value of current taken is very high as compared to general wiring circuits. It may be from 50 to 500 amperes, depending on the type and size of job to be welded.

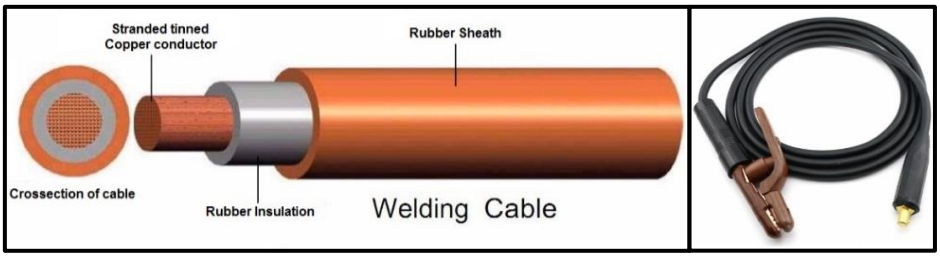


Fig.1.12: Secondary welding cables

Welding cables (which are used on secondary side of welding transformers sets) are special single core high current flexible cables. However these are different from general flexible cables used in wiring. Therefore general wiring cables of the same conductor area should not be used with welding plants.

To ensure flexibility, welding cables are made with large number of strands of fine and very thin diameter (0.2mm). Mostly rubber is used as insulation while tough rubber is use as sheath.If more flexibility is required, two smaller flexible cables can be used which have the same total area as one

large cable.

No flexible cable used should be longer than 33 meters.

Current	No of strands of 0.20 mm dia.
150	770
250	1330
400	1680
600	2200

On primary side of welding transformer sets, general wiring type cables are used, unless specifically asked by the manufacturer. For primary side multi core circular, sheathed cables are recommended. Primary cables for mobile single phase welding sets should be three core 600/1000 volt grade with tough rubber insulation or PVC sheath.Two cores should be used as current carrying conductors and the third one should be used as earth connection.

v. Selection of cable for a particular application

A variety of cables is manufactured to meet different requirements of electrical field. Selection of proper type and size of cable is of utmost importance for satisfactory service of electrical machines and circuits to whom this cable will feed the electric power. Selection of proper cable for a particular application depends upon following factors

- **Type of load** (either it is single phase or three phase, fluctuating or steady).
- **Atmospheric conditions and temperature.**
- **Required degree of mechanical protection according to the place of installation.**
- **Level of supply voltage where cable will be installed.**
- **Location in the installation** (either it will be used as main cable, as sub main cable or as final sub circuit cable)

vi. Voltage drops in cablesand its simple calculation

(To determine proper size of cable for a given load)

Points to consider for the calculation of voltage drops in cables

i. Voltage drop calculation is not needed if length of circuit is less than 33.3 meters. Or 100 feet.

ii. Maximum limit of voltage drop from main distribution box to any load point in the wiring is 1.25% of the declared supply voltage.

iii. Maximum limit of voltage drop from main distribution box to any load point in the wiring is 2.5% of the declared supply voltage.

So maximum voltage drop from main distribution box to any load point for different supply voltages will be as under!

6. For **220 volts**: 2.5/100x220= **5.5 volts**
7. For **230 volts**: 2.5/100x230= **5.75 volts**
8. For **240 volts**: 2.5/100x240= **6.0 volts**
9. For **250 volts**: 2.5/100x250= **6.25 volts**

iv. **Formula** of calculating voltage drop of a cable **in imperial system**forgiven length and load.(In Imperial system, the voltage drop of cables are given in volts per 100 feet)

$$= \frac{\text{length of circuit (go \& } return) \; in \; feet \; x \; voltage \; drop \; per \; 100 \; feet}{100} \text{ x cable load factor}$$

Where Cable Load factor $= \frac{\text{Load current of the cable}}{\text{rated current of cable in given conditions}}$

Formula to find actual voltage drop of a cable for given length and load of cable **in metric system** (in metric system the voltage drop of cables are given mV/Ampere/meter)

$$= \frac{\text{voltage drop im mV per ampere per meter x load current x length of cable in meters}}{1000}$$

i.e. $\frac{(\text{mV/A/m}) \text{ x I x} L}{1000}$

v. Use motor efficiency 90%, if not given. Use power factor 0.85, if not given.

vi. Formula to find single phase load current

$$I = \frac{\text{P (in Watts)}}{\text{V x Cos}\theta}$$

vii. Formula to find three phase load current

$$I = \frac{\text{P (in Watts)}}{\sqrt{3} \text{ x VL x Cos}\theta}$$

Steps to calculate proper size of cable

- **i.** Find the permissible limit of voltage drop (as 2.5 % of the supply voltage)
- **ii.** Note or calculate the load current.
- **iii.** Add 20% current in the load current for future extension for main and sub main cables
- **iv.** Apply diversity factor for main & sub main cables.

v. Select the nearest cable size from relevant table.(select the proper column according to the type of cable, supply and installation method)
vi. Note the rated current of cable from table at given temperature
vii. Find the rated current of cable at given temperature by multiplying it with temperature rating factor keeping in view the coarse or close access current protection.
viii. Note the voltage dropin mV per ampere per meter for metric system (or volts per100 feet for imperial system) from the table.
ix. Find the voltage drop for actual length of cable using formulae.
x. To find the voltage drop on given load, multiply this value with cable load factor.
xi. If the calculated voltage is within permissible limit, then cable size is OK, otherwise select the next higher size and repeat the procedure to check the voltage drop again.

EXAMPLE NO- 1(for metric system)

Find the suitable size of cable in metric system, run in conduit to deliver 40A at 230V for a distance of (i) 10 m (ii) 40 m

SOLUTION:

Load Current = 40A Supply Voltage = 230V

(i) Length of cable = 10m

(ii) Length of cable = 40 m

Permissible voltage drop = 2.5% of the supply voltage

= 2.5/100 x 230 = **5.75 V**

According to Pak. Cable & Table 9 (metric) under column 3 & 4

Size of cable which has nearest current rating to the load current =10mm^2 (7/1.135mm)

Current rating of this cable = 42A

Voltage drop of 10mm^2 (7/1.135mm) cable at 1A current for 1m length = 4mV

Case-1, checking of voltage drop of provisionally selected cable for 10m length

(i) Length of cable (L) = 10m

Formula of voltage drop in Metric system= i.e. $\frac{(\text{mV/A/m}) \text{ x I x} L}{1000}$

Voltage drop at given load current (40A) & given 10m length

= i.e. $\frac{4 \text{ x } 40 \text{ x} 10}{1000}$ = 1.6V

This voltage drop is within permissible limit;

So, the selected size of cable 10mm^2 (7/1.35mm) is suitable for 40A load and 10m rout length.

Case-2, checking of voltage drop for provisionally selected cable (10mm^2 (7/1.135mm)) for 40m length

(ii) Length of cable (L) = 40m

Voltage drop at given load current (40A) & given 40m length

= i.e. $\frac{4 \text{ x } 40 \text{ x} 40}{1000}$ = 6.40V

This voltage drop is more than the maximum permissible limit of voltage drop, which is **5.75 V**, sowecheck the next large size of cable.

The next large size of cable is =16mm^2 (7/1.7mm)

Current rating of this cable at 30^{o}C = 56A

Voltage drop of the cable for 1A current & 1m length = 2.6mV

Voltage drop at 40A current for 40m length = i.e. $\frac{2.6 \text{ x } 40 \text{ x} 40}{1000}$ = 4.16 V

Now this voltage drop is within permissible limit.

Thus the suitable size for 40A load current & 40m length is 16mm^2 (7/1.7mm)

EXAMPLE NO. 2 (for metric system)

A load of 3.4 KW at 250V AC is to be supplied on Batten at a distance of 25 meter from DFB. Average summer temperature is 45^{o}C. Find the size of twin core PVC insulated cable keeping in view the recommended limit of voltage drop.

SOLUTION:

Supply voltage = 250V

Ambient Temperature = 45^{o}C

Power factor assumed = 0.85

Load power = 3.4KW = 3.4 x 1000 = 3400 watt

Load current (I) = $\frac{W}{V \, Cos \, \theta} = \frac{3400}{250 \, X \, 0.85}$ = 16A

Length of twin core cable = 25m

Size of twin core cable run on batten =?

At Ambient temp. 30^oC

As cable is twin core run on batten, we refer; **Pakistan cables & table 11 under column 7 & 8**

The nearest current ratingin table to the load current of 16A is = 21A

Size of twin core PVC insulated cable for this current is= $2.5mm^2$(1/1.78)

At Ambient temperature of 45^oC, the same cable will be de-rated

So new rated current of the cable at 45^oC (For coarse excess protection)

= Current at 30^oC x temperature rating factor at 45^oC

= 21 x 0.91 = 19.11A

Since the load current is less than the new rated current even at 45^oC, so $2.5mm^2$(1/1.78) twin core PVC insulated cable is still suitable.

The distance between DFB and load is less than 33.3m. Therefore voltage drop calculation is not needed.

The suitable cable size is = twin core 2.5mm2(1/1.78).

EXAMPLE NO. 3 (for metric system)

Determination the size of sub-main cable run in conduit supplying a load of 3KW at a distance of 35 m from D.F.B. Declared supply voltage is 230V, 50Hz. The maximum ambient temperature is 40^oC. The load is protected by rewire able fuse.

SOLUTION:

Power of load (W) = 3KW or 3000 W

Supply Voltage (V) = 230 V

Power Factor (assumed) = 0.85

Length of Cable = 30 m

Maximum Ambient temp. = 40^oC

Max limit of permissible voltage drop = $\frac{2.5}{100}$ x 230 = **5.75V**

Load Current $= \frac{W}{V\ Cos\ \theta}$ $= \frac{3000}{230\ X\ 0.85}$ = **15.34A**

We shall select that cable which has equal or more rated current than load current. As cable is twin core run in conduit, we refer; **Pakistan cables & table 9 under column 3&4**

The nearest current rating in table to the load current of 15.34A is = 18A

Size of twin core PVC insulated cable for this current is =2.5mm^2(1/1.78)

At Ambient temperature of 40^{o}C

The same cable will be de-rated, so new rated current of the cable at 40^{o}C(For coarse excess protection)

= Rated current at 30^{o}C xtemperature rating factor for 40^{o}C

= 18 x 0.94 = 16.92 A

Since the load current (15.34A) is still less than the new rated current (16.92A)

So 2.5mm^2(1/1.78)twin core PVC insulated cable is suitable if voltage drop in cable is ignored.

The distance between DFB and load is more than 33.3m. Therefore voltage drop calculation is required.

Voltage drop per ampere per meter of this cable (2.5mm^2 (1/1.78)) = 16mV (reference to column 4 of table 9)

Actual voltage drop for 35 meter length at load current of 15.34A

$$= \frac{\text{voltage drop in mV per ampere per meter x load current x length of cable in meters}}{1000}$$

$$= \frac{16 \times 15.34 \times 35}{1000} = 8.5 \text{ V}$$

This voltage drop (8.5 V) is higher than our limit (5.75 V)

So next large size of cable will be selected and checked for voltage drops

The next size of cable is =4mm^2 (7/0.85)

Current rating of this cable at 30^{o}C is =24A

Current rating of this cable at 40^{o}C is = 24 x 0.94 =22.56A

This current is more than the load current, so it is suit able if voltage drop is ignored, but it will be not be ignored as distance of circuit run is more than 33.3m.

Voltage drop per ampere per meter of this cable are = 10mV (reference to column 4 of table 9)

Actual voltage drop in this cable for 15.34A load current and 35m length.

$$= \frac{\text{voltage drop im mV per ampere per meter x load current x length of cable in meters}}{1000}$$

$$= \frac{10 \times 15.34 \times 35}{1000} = 5.37 \text{ V}$$

Now this voltage drop is within permissible limit.

So the selected cable 4mm^2 (7/0.85) is suitable for 35 meter length and 15.34A load

EXAMPLE NO. 4 (for metric system)

Determination the sizeof conductor of two core cable required to carry the maximum current of 50A in conduit. It is given that the length of the cable is 60 meters and declared supply voltage is 200 V.

SOLUTION:

Declared supply voltage (V) = 200V

Load Current (I) = 50A

Length of Cable (L) = 60m

Suitable size of cable conductor =?

Permissible voltage drop @ 2.5% of the supply voltage 200V=

$$\frac{2.5 \text{ x } 200}{100} = 5V$$

From Table 11of "Pakistan Cable & Table (Metric) under column 3 and 4

The nearest rated current of cable tot the load current of 50A is = 53A

Size of cable for this current is = 16mm2 (7/1.70mm)

Voltage drop of this cable per 1A current for 1m length = 2.6mV

Voltage drop at 50A load current for 60m length

$$= \frac{mV \text{ x } I \text{ x } L}{1000} = \frac{2.6 \text{ x } 50 \text{ x } 60}{1000} = 7.8V$$

This voltage drop is greater than the maximum limit of permissible voltage drop which is 5V.

So we select next large size of cable (25mm^2 (7/2.14 mm) and check for voltage drops again

Rated current of new selected cable = 60A

Voltage drop of this cable per ampere per meter = 1.7mV

Voltage drop at 50A load current for 60m length

$$= \frac{mV \text{ x } I \text{ x } L}{1000} = \frac{1.7 \text{ x } 50 \text{ x } 60}{1000} = 5.1V$$

Now this voltage drop is within the permissible limit.

So the new selected cable size (25mm^2 (7/2.14) is suitable for 50A load at 60meter distance

EXAMPLE NO. 5 (for metric system)

A 5KW single phaseload at a power factor of 0.7 lagging is fed from a miniature circuit breaker at 240 volt supply, using PVC insulated copper cable enclosed in steel conduit. Length of run is 40 meter andambient temperature of the building is 45^oC (Rating factor of MCB is 1.33 and temperature factor for 45^oC is 0.79 with overall rating factor of 1.33 x 0.79 = 1.055)

Find *(a) Rating of the load in KVA*

(b) The line current

(c) The permissible voltage drop *(d) Actual voltage drop*

(e) Suitable size of cable

SOLUTION:

Load Power (P) = 5KW= 5000 W

Supply voltage (V) = 240V

Power Factor (assumed) = 0.85 lagging

Length of cable = 40 m

Maximum ambient temperature = 45^{o}C

(a) KVA $= \frac{KW}{Cos\theta} = \frac{5}{0.85}$ = 5.88

(b) Load Current, $I_L = \frac{Watts}{V \times Cos\theta} = \frac{5000}{240 \times 0.85}$ = 24.51 A

(c) Permissible Voltage drop $= \frac{2.5 \times 240}{100}$ = 6V

(d) Actual voltage drop for 40 meter length of cable at given load?

According to table 9 (metric) of "Pakistan cables and tables" under column 3 & 4.

Nearest current rating of cable at 30^{o}C to the load current of 24.51 A is = 31A

This is the rated current of cable size 6mm^2(7/1.04) at 30^{o}C

Rated current of this cable size at 45^{o}C (Close excess protection due to use of MCBs)

= 31 x 0.79 x 1.33 = 32.57A

Size of Cable 6mm^2 (7/1.04mm)

Voltage drop of this cable at 1A current for 1m length =6.8 mV

Voltage drop of this cable at given load current and given distance.

$$\frac{mV \times I \times L}{1000} = \frac{6.8 \times 24.51 \times 40}{1000} = 6.67 \text{ V}$$

This voltage drop is more than the maximum limit of permissible voltage drop. So the calculation is be repeated for the next large size of cable.

Next large size of cable = $10mm^2$ (7/1.35mm)

Current rating of this cable at 30^oC = 42A

Current rating of this cable at 45^oC (for MCB) = 42 x 0.79 x 1.33 =44.13A

Voltage drop of this cable at 1A current for 1m length = 4 mV

Voltage drop of this cable at 24.51A load current for 40m length

$$\frac{mV \times I \times L}{1000} = \frac{4 \times 24.51 \times 40}{1000} = 3.92 \text{ V}$$

Now this is within permissible limit.

So the suitable size of cable for given conditions is =$10mm^2$ (7/1.35mm)

EXAMPLE NO. 1 (for imperial system)

Declared single phase supply voltage is 250V, 40 yards run of one twin core cable installed in conduit, required to supply a 3.5 KW load straight from main distribution box. Current taken is 17A. Average summer temperature of building, where wiring is installed is 40^oC. Find the size of single core PVC insulated cable run in conduit that has voltage drop within recommended limit.

***SOLUTION*:**

Declared supply voltage = 250V

Length of twin core cable = 40 yards = 40 x 3 = 120 ft.

Load Current = 17A

Ambient Temperature = 40^oC

Size of single core PVC cable run in conduit =?

At Ambient temperature 30^oC

As cable is twin core run in conduit, we refer **Pakistan cables & tables 14 under column 3 & 4**

The nearest current rating to the load current of 17A = 19A

Size of PVC insulated cable for this current = 7/0.029"

Thegiven ambient temperature is 40^oC, so the same cable will be de-rated

(As load is provided with coarse excess current protection, so temperature factor is= 0.94 for 40^oC)

So rated current of 7/0.029" cable at 40°C = 19A x 0.94 = 17.86A

Since load current is still less than this rated current, so 7/0.029" twin core PVC insulated cable is suitable if voltage drop in cable is ignored, it should not be ignored because the distance between DFB& load is over 100 ft. (i.e. 120 ft.)

Maximum permissible voltage drop (2.5% of declared supply voltage)

$$= \frac{2.5 \text{ x } 250}{100} = \mathbf{6.25V}$$

Voltage drop per 100ft of 7/0.029" cable at rated current of 17.86A = 7.7V

Voltage drops of 7/0.029" cable for given length (120ft.) and given load 17A.

$$= \frac{7.7 \text{ x } 120 \text{ x } 17}{100 \; X \; 17.86} = 8.795 \text{ V}$$

This voltage drop is greater than the maximum permissible limit of voltage drop (6.25V), so the selected cable size is not suitable for given load and length.

So, next large size of cable is checked for suitability.

Next large size of cable = 7/0.036"

Rated current of 7/0.036" cable at 30°C = 26A

Rated current of this cable at 40°C = 26 x 0.94 = 24.44A

Voltage drop of 7/0.036" cable per 100 ft. = 7 Volt

Refer Pakistan cables & table 14 under column 3 & 4

Voltage drops of 7/0.036" cable for given load of 17A at given length 120 ft.

$$= \frac{7 \text{ x } 120 \text{ x } 17}{100 \; X \; 24.4} = 5.85\text{V}$$

Now this voltage drop is within the recommended limit.

So selected cable size 7/0.036" PVC insulated twin core, 250/440Vvoltage grade is suitable for given conditions.

vii. Cable Jointing

Necessity of Joints

Joints on electrical conductors/cables should be avoided if possible, if not; it should be electrically*[1] and mechanically*[1]sound and readily accessible *[2] for inspection and repair. However practically, joints cannot be avoided completely as because cables come in limited lengths.

I.E.E regulations (15th edition) 523 and 527 provide detailed guideline and instructions about joints.

*1: An electrically sound joint means that resistance of the conductor should not be greater than that of an un jointed length of same conductor. Mechanically sound joint means that any pulling on the joint should not lose it, i.e. its mechanical strength should be almost equal to the strength of sound portion of the conductor.

*2: Readily accessible means that, joint of any type should not be drawn into a pipe or in hidden portion but must be enclosed in easily approachable joint boxes/ inspection boxes.

Joints should be (where necessary) made with great care because bad or loose joints can cause following faults in wiring or power systems.

Cable joints may be Soldered type or mechanical type.

Drawbacks of cable joints

1. Loss of power in the form of heat on loose joints.
2. Open circuit may occur.
3. Can cause short circuit or ground fault.
4. Current can leak due to bad joint.
5. A main reason of fire in buildings is the short circuit of cables/conductors which is mainly due to bad joints.

Joint

It is a process of connecting two lengths of a cable (or of bare conductors) in such a way that they are mechanically and electrically as strong as the equal length of the sound cable itself.

Difference between joint and termination

Joint is made between two cables/conductors while termination is made between a cable/conductor and a terminal of any machine, device, bus bar etc.

Solder

It is an alloy of two or more metals used to join two surfaces (or ends of twoconductors) by filling the gaps between surfaces or of a joint by melting. To make the cable joints strong and homogenous, soldering is applied on joints. A solder also protects the jointsfrom corrosion.

Jointing of low voltage wiring cables

Jointing process of low voltage wiring cables is very simple as

compared to power cables, because the construction of wiring cables is very simple. Internal wiring cables have mostly stranded conductors with PVC or rubber insulation over them. Multi cores cables have a PVC outer sheath also.

A note on aluminium soldering

Aluminium oxidised very rapidly and much difficulty has been faced to make joint on the aluminium conductors in past. Now a days, special solders and fluxes have been developed for jointing aluminium conductors. *Special technique for soldering the aluminium*

Aluminium conductors should not be joined with copper conductors (or brass terminals) because a galvanic action corrode the joint resulting in open circuit

1.9 Steps of making a joint

1. *Skinning (or insulation removing).* In this process the insulation is removed from the end of cable up to required length with sharp knife or wire stripper (sometimes called skinner). Electrician pliers should not be used for this purpose. Insulation is removed with knife just like sharpening the lead pencil. See fig.1.13

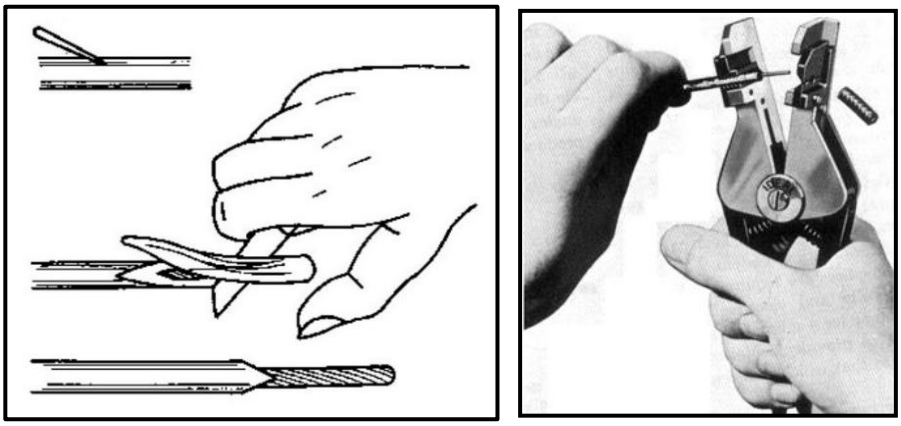


Fig.1.13: Removing the cable insulation with electrician knife and wire stripper

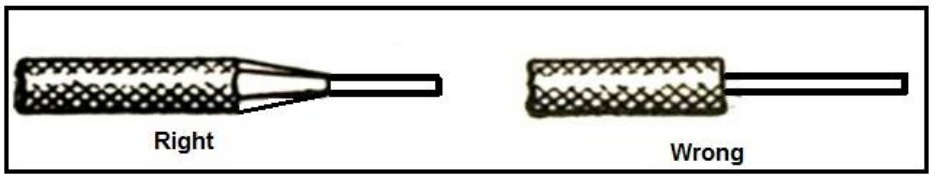


Fig.1.14: Right and wrong insulation removed

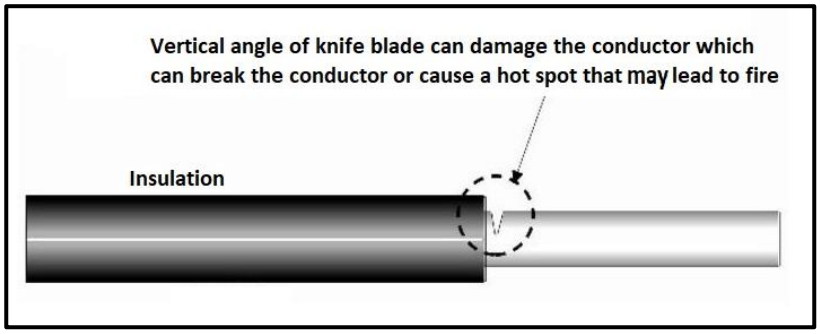


Fig.1.15: Result of insulation removing with wrong tool

Angle between knife blade and conductor is kept between 30^{o} to 35^{o}. Angle more than this can damage the conductor which will lead to condor breakage or generating hotspot that will cause fire.

2. *Scrapping*: Surface of conductor is cleaned and rubbed with an old sand paper to make its surface rough for better adhereing og solder. Oil or grease if there is, should also removed from the conductor surface. Care should be taken while scrapping tinned conductors.
3. *Jointing:* To make joint on wiring cables, the stranded conductors are twiststed firmly together with no strand or its sharp end out side the overall joint.The method of twisting are different for different single and multicore cables.

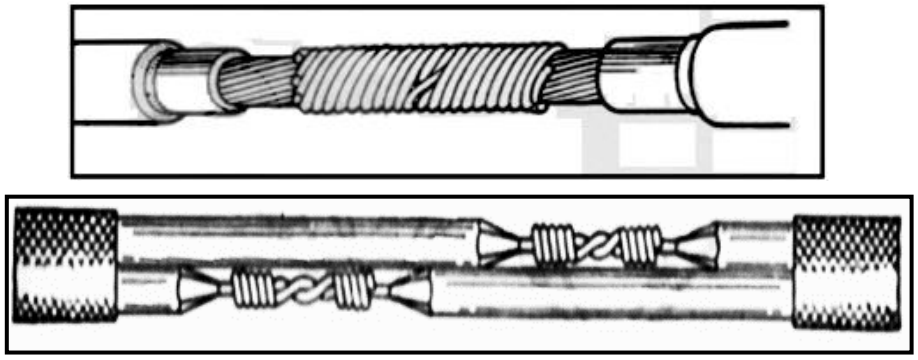


Fig.1.16: Jointing of cables

4. *Soldering*: Joint is soldered with soft solder wire for ultimate contact of conductor strands and to increase the strength of joint. For soldering, Joint is heated up to suffiect level with torch or sodering iron and then a thin layer of flux is applied on the surface of joint.

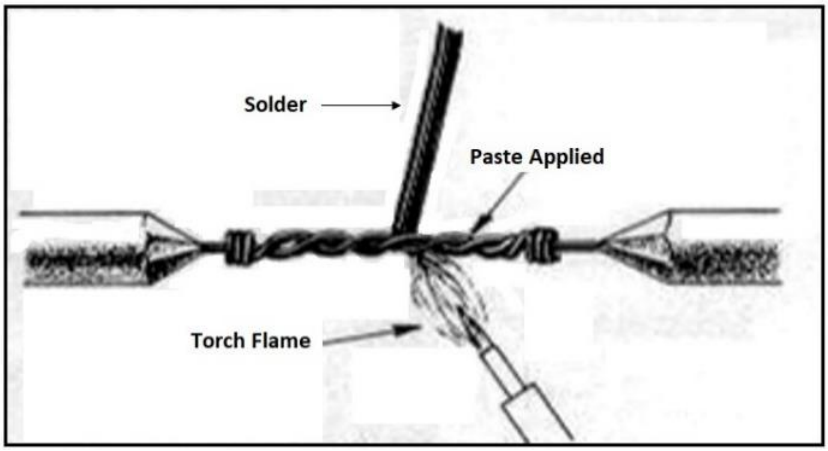


Fig.1.17: Soldering of small cables

Now solder wire is touched on the surface of joint to melt and fill the uneven suface of joint. Soldering iron can be used for cables up to 2.5 mm2 conductor size. Above this size, blow lamp and solder pot and ledle is used for soldering.

5. *Tapping:*A cable joint is never left unprotected.In small wiring cables two or three spirally wound successive layers of 19mm wide PVC or rubber insulation are applied on the joint for insutaion purpose.The procedure is clear from picture.

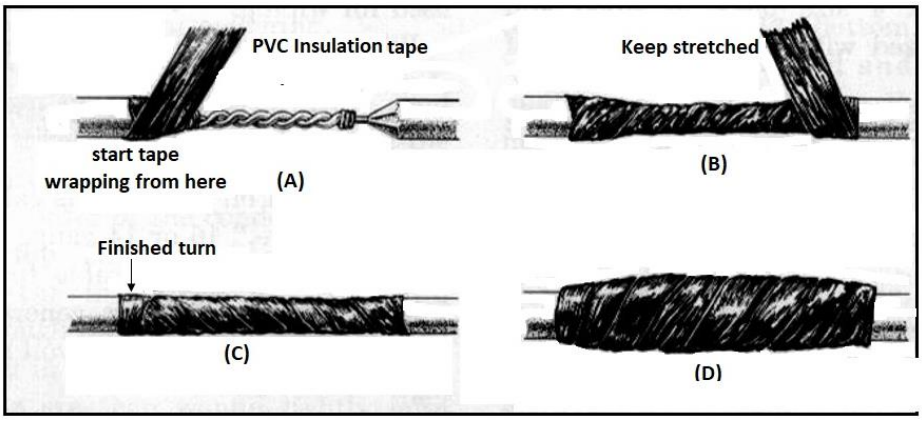


Fig.1.18: Tapping of cable joint

List of tools and material required for making joints of wiring cables.

1. 50 cm long pieceof 4mm^2 (7/0.85) Cable for married joint (multi core cable).
2. 50 cm long piece of 2.5mm2 (1/1.78) cable for married joint (single core

cable).
3. 100 cm long piece of $4mm^2$ (7/0.85) cable for Tee joint (multi core cable).
4. 100 cm long piece of 2.5mm2 (1/1.78) cable for Tee joint (single core cable).
5. 40cm long piece of 8 SWG (12.97mm2) wire for Britania joint.
6. Soldeering iron 100W.
7. Solder wire of 50-50 lead and tin and paste(flux).
8. 19mm wide PVC or rubber insulation tape.
9. Electrician knife or wire stripper.
10. Electrician pliers.
11. Side cutting pliers.
12. Sand paper.
13. Measuring tape or foot rule.
14. Hand and bench vice.
15. Cotton waste.
16. Wood hammer.
17. Flat file.
18. 18 SWG binding wire for Britania joint.

Dimensions Of joints:*The dimentions of cable pieces and of their different layers mentioned in the procedures to remove for wiring cable joints and power cable joints are arbitrary and not need to be followed strictly. It depend not only upon size of the cable but also upon the experience and practice of the jointer.*

Procedure to prepare Married Joint on multi strand conductor

1. Get a 50 cm long piece of $4mm^2$ (7/0.85) cable from store.
2. Cut it into two equal pieces.
3. Remove insulation of about 8 cm lengths from one end of each cable piece with the help of electrician knife or wire stripper, which one is available.
4. Remove cotton braid/sheath cover of about 1.5cm from each sharpen end of both the cable pieces.
5. Open the strands and clean them with used sand paper.
6. Re-twist the strands of conductor about 2.5 cm length and keep the remaining portion of strands stretched.
7. Cut off the central strand of each piece with side cutting pliers.
8. Bring the both pieces close together in such a way that all the strands insert each other.
9. Hold one piece in the left hand and twist strands one by one over the other closely.
10. Repeat the operation on the other side with the second piece and complete the joint.

11. Press and round off the salient ends of strands with electrician pliers.
12. Heat up the completed joint with soldering iron and then solder the joint.
13. Apply insulation tape and finish the joint.
14. Get a 50 cm long piece of 2.5mm2 (1/1.78) cable from store and perform the procedure on this single core cable as shown in the figure steps A,B,C,& D.
15. A streight twist married joint on two core cable should be made as shown in fig.1.19

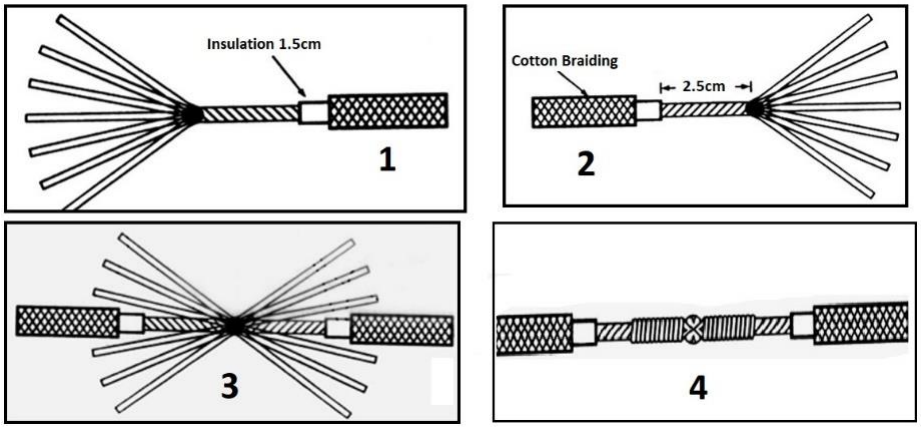


Fig.1.19: Married joint on single core 7/0.029" cable

Procedure to prepare a Tee (tap) Joint on multi strand conductor

1. Get a 100 cm long piece of $4mm^2$ (7/0.85) cable from store
2. Cut it into two pieces of 60 cm and 40 cm.
3. Remove insulation of about 6 cm lengths from centre of the 60cm long cable piece with the help of electrician knife.
4. Remove insulation from one end of vertical tapping cable piece for a length of about 8 cm.
5. Remove cotton braid/sheath cover of about 2.5cm from the upper end of vertical cable piece.
6. Open the strands of vertical tapping piece and clean them with used sand paper.
7. Twist the strands of vertical conductor about 2.5 cm length and keep the remaining portion of strands stretched about 60o from each other.
8. Divide the seven strands into two groups, with three strands in each group leaving thw central one ungrouped.
9. Hold both the cable pieces in such a way that they form the shape of Tee with vertical piece exactly in the middle of horizontal piece.

10. Twist the three strands of tapping piece closely and tightly in right direction on horizontal piece.
11. Similarly twist the three strands of tapping piece closely and tightly in the left direction on horizontal piece.
12. Pass the central strand over the horizontal piece and bring back and twist it over itself.
13. Press and round off the salient ends of strands with electrician pliers.
14. Heat up the completed joint with soldering iron and then solder the joint.
15. Apply insulation tape and finish the joint.
16. Get 40 cm long piece of 2.5mm2 (1/1.78) cable and cut into two pieces and then make Tee joint as shown in figure below on this single srand cable.

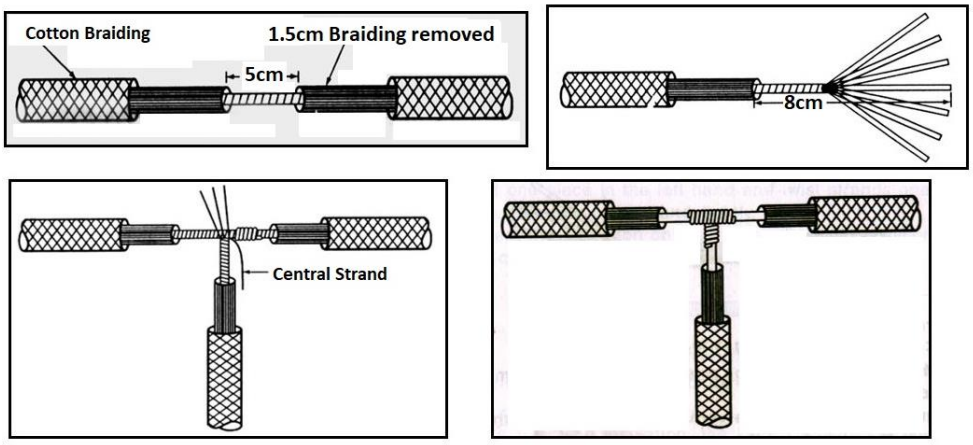


Fig.1.20: "T" joint on 7/0.029" cable

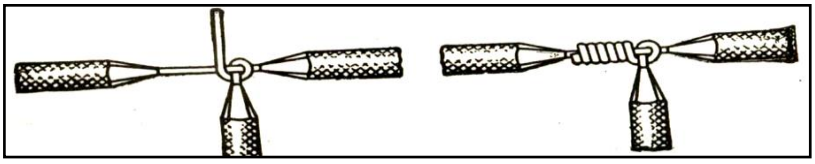


Fig.1.21: "T" joint on 1/0.044" cable

Procedure to prepare a Britannia Joint

Britannia joint can be used on both solid and stranded conductors of over head lines. Although its mechanical strength is enough high it should not be used where tensile strength on condutor is too high.

1. Take a40cm long piece of 8 SWG (12.97mm2) wire.
2. Cut this wire in two equal pieces.
3. Make both the pieces straight and clean them with emery paper.

4. Bend each piece from one end of about 01 to 02cm length at right angle.
5. Hold both the pieces together with bench vice, keeping the bent portions facing opposite and leaving a distance of about 8cm from the end of opposite conductor.
6. Take a copper bonding wire of No 18 SWG (1.167mm2), and clean it.
7. Start binding 1.5 cm ahead of the point of contact of the two pieces;cover the entire portion and then 1.5cm more after the joints.

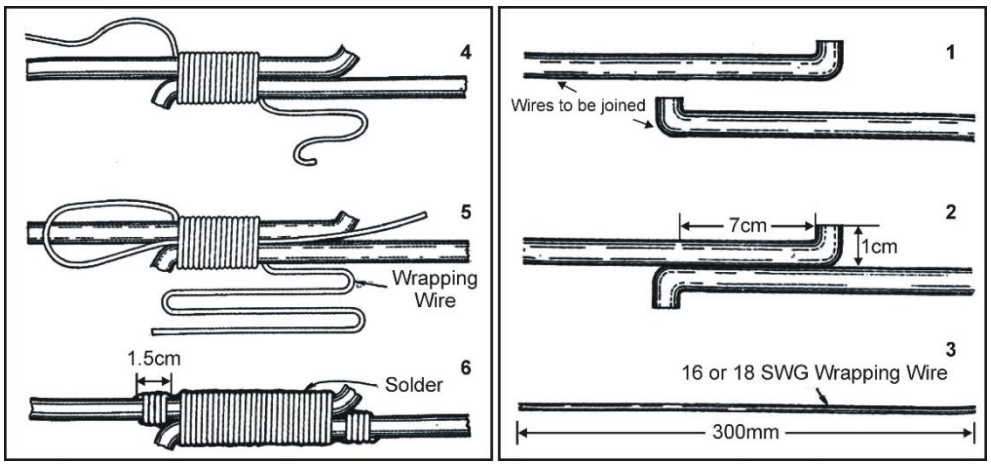


Fig. 1.22 (a)

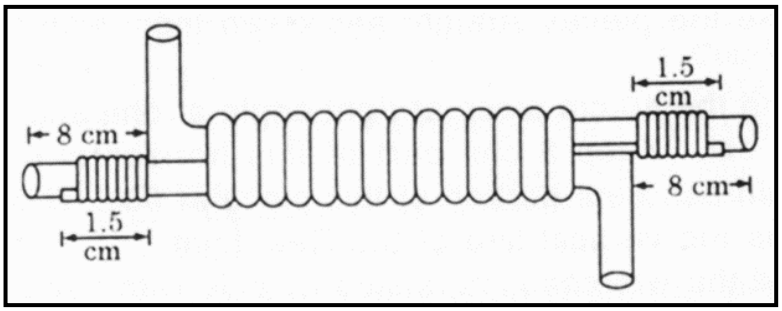


Fig. 1.22 (b)

Jointing of power cables

Following two types of power cables are used in installation work.

Low Tension (LT)& medium voltage power cables (PVC insulated PVC sheathed, armoured or un-armoured).

H.T (High Tension) XLPE insulated/paper insulated cables.

Jointing of low and medium voltage with PVC insulation and PVC sheath is comparatively simple as compared to high voltage paper insulated cables.

Special care should be taken when jointing the paper insulated and mineral insulated cables. These shall be protected from moisture to ingress during jointing process.

Material required for jointing power cables.

1. Flux.
2. Solder.
3. Ferrule.
4. Cost iron/PVC/Resin joint box.
5. Sleeves.
6. Cable compounds.
7. PVC Insulating tape.
8. Screening.

Tools required for power cable jointing

1. Blow lamp.
2. Kerosene pressure stove.
3. Hacksaw.
4. Solder melting pot and ladle of suitable size.
5. Cutting pliers.
6. Knife.
7. Thermometer to read up to 400^{o}C.
8. Measuring rule.
9. Stiff brush for applying flux.
10. Screw driver.
11. Steel wire brush.
12. Hammer.
13. Cold chisel.
14. Spanners of different sizes.
15. Rubber mat.
16. Lead scrapper.
17. Wiping cloth.
18. Compound melting pot.
19. Oven for melting the compound.
20. Files (half round, triangular, and smooth).
21. Rubber gloves.

Jointing of PVC insulated PVC Sheathedpower cables

PVC cables either armoured or non-armoured for medium (up to 600V) are very simple in construction as compared to paper insulated cables,

so their jointing is obviously simple. Both copper (not tinned) and aluminium conductors are used in PVC insulated PVC sheathed cables. If soldered joint is to be made on copper conductors, tinning is first necessary. Special sleeves, Special solders and flux is used for cables with aluminium conductors.

1. Special care should be taken to keep the joint clean and dry.
2. After cutting the cable, joint should be completed without any break of time.
3. Open ends of cables should be sealed if there is some delay in making a joint (especially in paper insulated cables).
4. Paper insulated cores should be lapped with dry tape as soon as the cable is stripped off.
5. Cable joint boxes, cable compound for sleeves and joint boxes, solder, flux and tapes etc. Should be used according to the type of cable.

Step wise procedure of PVC insulated cable jointing (3 or 4 core, medium and high voltage armoured type) see pictures below

Firs, let see the constructional parts of PVC insulated PVC sheathed armoured cable.

1. Conductor (non-tinned stranded copper or aluminium).
2. PVC insulation.
3. Inter phase filling.
4. PVC sheath (of sheath grade PVC).
5. PVC bedding (mostly not used in such cables).
6. Galvanized steel wire (sometimes steel strip) armouring or aluminium wire armour.
7. PVC outer sheath (sometimes called outer jacket or serving).
8. Before starting the jointing process, clean and dry up the tools and hands.
9. **Step 1**- ***Centre marking***: The cables are laid end to end with 9cm (more or less) overlap on each end from the centre of joint and marked.
10. **Step 2-** Make a longitudinal cut up to marked point of one cable end with knife. And then make a round cut at about 9cm at this point.
11. **Step 3-** Bind the armour layer at about 8.5cm by wrapping 3 or 4 rounds of 1.5mm^2 conductors and remove the outer jacket by pulling it with pliers.
12. **Step 5-** Cut the armour wires with hacksaw to half the depth and then removes the armour wires one by one by moving them with hand.
13. **Step 6-** Now cut and remove the PVC bedding layer (if it is).
14. **Step 7-** Repeat the procedure to remove the PVC sheath up to 8cm length from openend.
15. **Step 8**- Spread the cores outward and cut the inter phase filling.
16. **Step 9-** Make a longitudinal cut on one of the cores up to 7.5 cm length

with knife and then make a round cut at this point and remove the insulation.

17. **Step 10**- Remove the insulation of all the other cores of this cable and cover it with piece of cloth preferably impregnated in petrol.
18. **Step 11-** Prepare the end of other cable.
19. **Step 12-** Heat up the naked (bare) conductors with blow lamp carefully keeping in mind not to damage the insulation of the core.
20. **Step 13-** Apply layer of tin on each naked conductor.
21. **Step 14-** Slip sleeves on the conductors of one of the cable end.
22. **Step 15-** Now bring the other end of cable near and insert the condors of this end in the sleeves keeping in mind the relevant phase with relevant phase.
23. **Step 16**- Press sleeves tightly with cramping tool turn by turn.
24. **Step 17-** Pour molten solder into the sleeves cuts and on the conductor and spread it equally.
25. **Step 18**- Spread the cores to a suitable space and insert separators between cores.

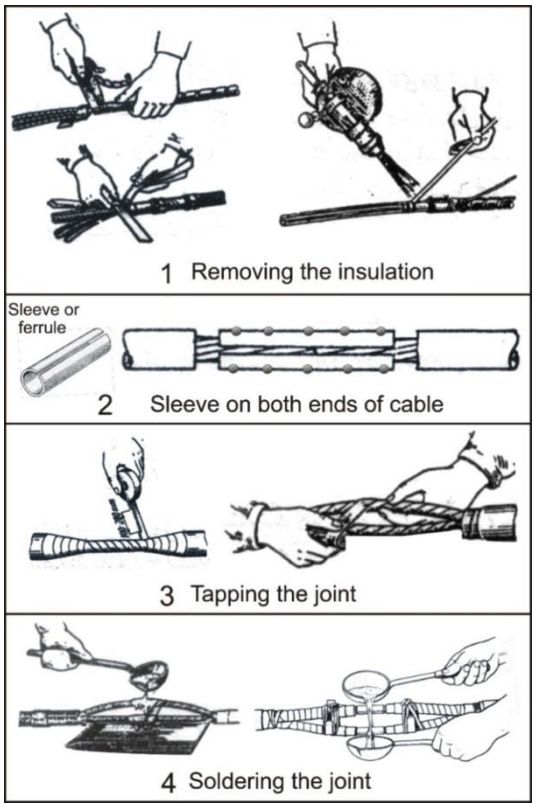


Fig. 1.23: steps of power cable jointing

Step 19- Apply PVC tape on each core up to suitable thickness and then apply PVC adhesive tape on each joint.

Step 20- Solder a copper wire on the armour of one core and the solder the other end of copper wire on other side of the armour. Make continuity of armour of all the cores in same way.

Step 21- Now put the lower half of epoxy resin joint box under the joint and then the upper half on it in such a way that it fits in the grooves of lower half.

Step 22- Tight the screws of joint box and pour bitumen compound in the joint box in four steps until complete filling of joint box.

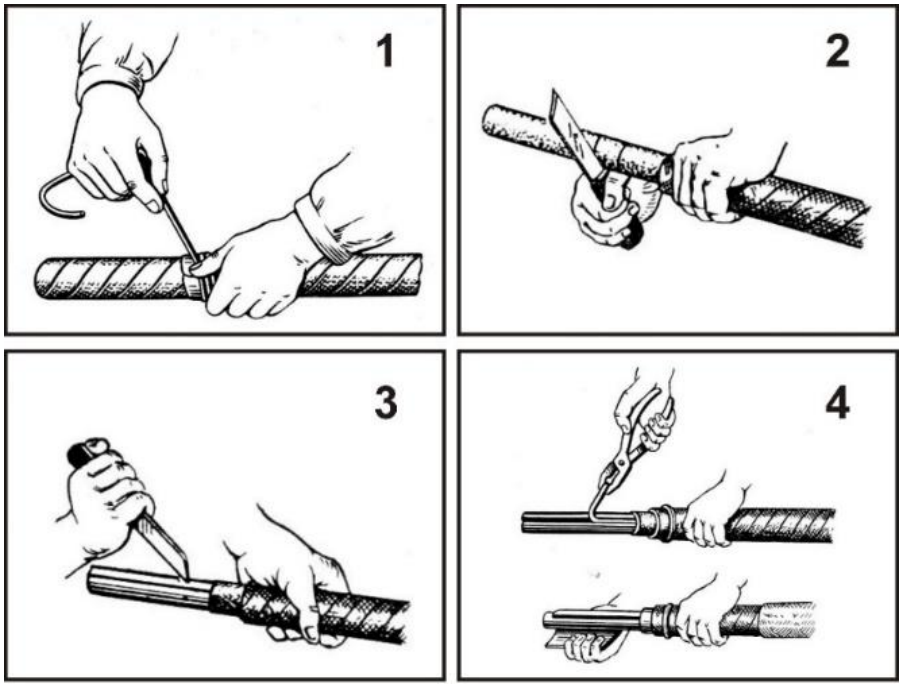
Step 23- Put and tight the cap of joint box.

Materials (solder, joint boxes, flux, filling compound and sleeves etc) for jointing aluminium conductors will be different from that of copper.

Jointing of Paper insulated cables

Basic procedure of making the joint on paper insulated cables is same as mentioned above for PVC insulated cables but it requires extra care during jointing process from the point of moisture ingress in the paper insulation and sheath.

Steps (pictorial) in jointing the belted paper insulated cable



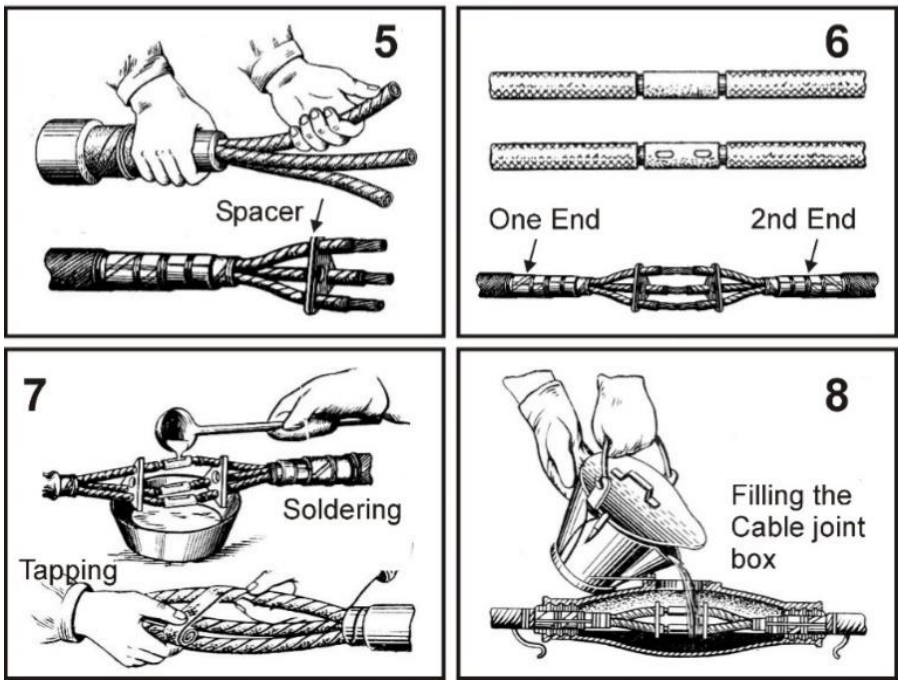


Fig. 1.24: Steps of power cable jointing

Exercise

Part-1: Subjective type Questions

Sample Long Answer type Questions

1) Write the types of wiring cables with respect to insulation along with characteristics of any two insulations.
2) (a) Write the types of wiring cables with respect to cores.
   (b) Write properties of cable insulations.
3) (a) Write the types of wiring cables with respect to voltage grade.
   (b) Explain 600/1000 voltage grade of cables.
4) (a) Write merits and demerits of VRI insulated cable.
   (b) Write merits and demerits of mineral insulated cable.
5) Write the names of material and their temperature rang used as insulation in heat resistant cables.
6) Write step wise procedure to find the proper metric size of cable for particular installation.

7) Determine the size of cable for two core cable required to carry the maximum current of 50A through metal conduits. It is given that the length of cable is 60 meter and declared supply voltage is 200 volt.

8) A 5KW single phase load at a power factor of 0.7 lagging is to be fed from a miniature circuit breaker (BS3871) at 240V supply, using PVC insulated copper cable enclosed in steel conduit. Length of run is 40 meter and ambient temperature of the building is 45°C. (Rating factor of MCB as per BS 3871 is 1.33aa and temperature factor for 45°C is 0.79 with overall rating factor of 1.33x0.79= 1.055). Find the suitable size of cable.
   (a) Rating of the load in KVA
   (b) The line current.
   (c) The value of permissible voltage drop.
   (d) Actual voltage drop for given load & conditions.
   (e) Minimum size of cable.

Ans. Minimum size of cable which will carry the required current and not exceed the permissible limit of voltage drop is $10mm^2$.

9) Write detail note on L.T power cables.
10) Write detail note on H.T power cables.
11) Name the Parts of an armoured L.T power cable and give function of each part.
12) Write names of parts of H.T. power cable.
13) Write the names of special purpose cables and give detail of heat resistant cables.
14) Write construction and uses of Mineral insulated cable.
15) Write construction and advantages of LSZH cable.
16) Write detailed note on heat resistant and fire resistant cables.
17) Write difference between L.T and H.T power cables and also write their construction
18) Enlist 20 tools required to make a joint on PVC insulated L.T power cable.
19) Define soldered joint. Which faults can occur due to bad joint on cables?
20) Write all steps for making a joint on wiring cable.
21) Make list of Material required for jointing power cables.
22) How a joint is made on paper insulated armoured power cable.
23) Write step wise procedure to prepare joint on PVC insulated 4 core, medium voltage armoured cable.

Part-2: Objective type Questions

Sample Short Answer type Questions

1) Define cable.
2) Define wire.
3) Write difference between wire and cable.
4) Define core of cable.
5) For which purpose sheath is used in wiring cables.
6) Write the names of main parts of a wiring cable.
7) Write the purpose of cable in internal wiring.
8) Write the minimum size of copper conductor cable that can be used in internal wiring for lighting circuits.
9) Write the names of four insulations that are used in internal wiring cables.
10) Write the names of four insulations that are used in heat resistant cables.
11) Write two properties of butyl rubber insulated cables.
12) Write two properties of silicon rubber insulated cable.
13) Write two advantages and two disadvantages of mineral insulated cable.
14) Write two advantages and two disadvantages of PVC insulated cable.
15) Write two advantages and two disadvantages of VRI insulated cable.
16) Write difference between flexible cord and flexible cable.
17) Define flexible cord.
18) Define flexible cable.
19) Where impregnated paper insulated cables are used in wiring.
20) Write the names of factors which affect the current carrying capacity of cables.
21) Write the names of two systems for describing the size of wiring cables.
22) Explain the cable size 7/1.04 in metric system.
23) Write formula to find voltage drop of a cable in metric system.
24) Write the limit of maximum voltage drop from MDB to any SDB in wiring.
25) Write the limit of maximum voltage drop from MDB to any load point in a wiring.
26) Write the limit of cable length which is necessary for calculating voltage drop in cables.
27) What is the difference between two cables having same conductor dia., but difference thickness of insulation?
28) Which insulating materials are used in heat resistant cables?
29) What are these abbreviations stand for
    a. CTS

b. TRS
c. PVC
d. VRI

30) Write two properties of lead sheathed cable.
31) What is meant by weather proof cable?
32) Write the constructional parts of mineral insulated cable.
33) Write the colours in five core flexible cords.
34) Write the colours of cores in five cores cable in Pakistan.
35) Which material is used as conductor of wiring cables?
36) Define load factor of a cable.
37) What is meant by multi core cable?
38) Which cable (having same size, load and construction) will pass less current and why?
    a. Cable run on batten.
    b. Cable run in concealed conduit.
39) Write two functions of cable insulation.
40) Write the voltage of medium voltage grade cable.
41) Write the names of three main categories of electric cables.
42) What is difference between wiring and power cable?
43) Define L.T power cable.
44) Define H.T power cable.
45) Write voltage limit of HT & LT power cables
46) Define special purpose cable?
47) Define heat resistance cable?
48) Define fire resistant cable?
49) Define fire retarding cable?
50) Write 04 applications of heat resistant cables.
51) Write 04 materials which are used as insulation in heat resistant cables.
52) What is meant by LSZH cable?
53) Write 02 advantages of LSZH cable?
54) Write the names of parts of mineral insulated cable.
55) Write 04 applications of fire resistant cables.
56) Write the names of 04 installations where fire resistant cables should be used.
57) Write the construction of welding cables in brief.
58) Why joints are used on electric cables.
59) What are two basic characteristics of a cable joint?
60) What is meant by mechanically sound joint?
61) What is meant by electrically sound joint?
62) What is meant by "accessibility" in jointing?

63) Write four drawbacks of a loose or bad cable joint.
64) Write the names of 05 steps of wiring cable jointing.
65) Write the names of 02 tools which can be used to remove the insulation of wring cable.
66) Why electrician pliers should not be used to remove the insulation of wiring cable.
67) Write the names of 04 joints of wiring cables.
68) Define HT power cable.
69) Write the names of two types of cable joints with respect to construction.
70) Define soldering.
71) Write difference between soft and hard solder.
72) Which materials are used in an Aluminium solder.
73) Which tool is used to heat up a wiring and a power cable for making a joint.
74) Write the names of 04 tools required for making a joint on wiring cable.
75) Write the names of 04 tools required for making a joint on PVC insulated L.T power cable.
76) Write the names of 04 accessories/materials required for making a joint on paper insulated power cable.
77) Write the names of 04 accessories/materials required for making a joint on PVC insulated power cable.
78) Where a Britannia Joint is used.
79) What is difference between cable joint and cable termination?

Sample Multiple Choice type Questions (MCQs)

1) A stranded insulated conductor is called
   a. Cable b. Core
   c. Wire d. sheath
2) A bare solid or stranded conductor is called
   a. wire b. Core
   c. Wire d. sheath
3) Protective cover over the insulated conductor of wiring cables is mainly provided for
   a. Mechanical protection
   b. Electrical protection
   c. To prevent leakage of current d.
   d. All these
4) This is not the part of internal wiring cable
   a. Conductor b. Insulation

c. Sheath d. Armouring

5) This cable should not be used below O°C.
   a. PVC insulated cable
   b. VRI cable
   c. Silicon rubber insulated cable
   d. Butyl rubber insulated cable
6) Cable insulation must have
   a. High resistance.
   b. High dielectric strength.
   c. Non inflammable.
   d. All these.
7) Wiring cables are manufactured for
   a. Low voltage grade
   b. Medium voltage grade
   c. High voltage grade
   d. Both a and b
8) No of strands in the conductors of stranded wiring cable may be
   a. 19 b. 07
   c. 37 d. All these
9) P.V.C (polyvinyl chloride) Insulated cables are
   a. Resistant to acids and alkalis.
   b. Not affected by grease oil and moister.
   c. Very reluctant to burn even at high temperature.
   d. All these
10) V.R.I cables are
   a. Resistant to acids and alkalis.
   b. Not affected by grease oil and moister.
   c. Very reluctant to burn even at high temperature.
   d. None of these
11) This insulation of cables is used for temperature up to 200°C
   a. PVC b. Vulcanized Rubber
   c. Silicon rubber d. Butyl rubber
12) This insulation is used for mineral insulated cables
   a. Silicon oxide b. Vulcanized Rubber
   c. Magnesium oxide d. Butyl rubber
13) Outer cover of mineral insulated cables is made of
   a. Aluminium b. Lead alloy
   c. Silicon rubber d. Copper
14) Mineral insulated copper covered (M.I.C.C) cable is a
   a. Fire proof cable b. Heat resistant cable

c. Nonflexible cable d. Both a and c

15) Insulated wires from 0.5mm2(16/0.20) size to 4mm2 (56/0.30) sizes with fine gauge strands are called.
   a. flexible cords b. flexible cables
   c. Non flexible cords d. Non flexible cables

16) Maximum allowable voltage drops in a cable from main DB to sub distribution board are.
   a. 2.5 volts
   b. 5 volts
   c. 1.25 % of the supply voltage
   d. 2.5 % of the supply voltage

17) Maximum allowable voltage drops in cable from main DB to any point of the wiring are.
   a. 2.5 volts b. 5 volts
   c. 1.25 volts d. 2.5 % of the supply voltage

18) Voltage drops in wiring cables are needed to be calculate, if length of cable is.
   a. 25 m b. 30.5 m or more
   c. 15m or less d. Less than 30m

19) Up to a size of 6mm2, this material is used as a conductor of internal wiring cables.
   a. Annealed copper b. Aluminium
   c. Galvanized steel d. Alloy of tin and lead

20) This is not a category of electric cables
   a. Wiring cable b. Power cable
   c. Control cable d. None of these

21) L.T power cables are manufactured for this voltage grade
   a. 600/1000V b. 1900/3300V
   c. 11000/33000V d. Both a & b

22) Cores of L.T power cables may be
   a. Single or two
   b. Three, three and half or four
   c. Five
   d. All these

23) In L.T power cables, conductors are used
   a. Non compact circular b. Compact circular
   c. Shaped d. All these

24) In L.T power cables, armouring is made of
   a. galvanized steel strips
   b. Galvanized steel wires

c. Aluminium wires d. All these

25) A filler material (polyethylene or jute) is used between cores of power cables to
   a. make the cable more circular
   b. make the cable more flexible
   c. make the cable more solid & confine the cores in Position.
   d. Both a & c

26) This is used as inter core filler material in L.T power cables
   a. XLPE b. Magnesium Oxide
   c. Butyl Rubber d. None of these

27) The cables which are made to work in particular conditions are called
   a. Special purpose cables b. Flexible cables
   c. L.T power cables d. Both a & b

28) This material is used as insulation of heat resistant cables
   a. Ethylene propylene rubber b. Butyl rubber
   c. Silicon rubber d. All these

29) Rubber insulated heat resistant cables can work continuously up to this temperature
   a. 150°C b. 100°C
   c. 500°C d. 900°C

30) Butyl (synthetic) rubber Insulated cables are used up to temperatures of
   a. 200°C b. 100°C
   c. 300°C d. 85°C

31) Silicon rubber Insulated cables can be used for temperature
   a. -75°C b. -25°C
   c. 150°C d. Any of these

32) Fibre glass cables can be used for temperature up to
   a. 450°C b. 950°C
   c. 750°C d. Any of these

33) A cable that is capable to continue to operate even in case of fire for a period of this time, is called fire resistant cable
   a. From 30 to 180 minutes b. From 3 to 5 hours
   c. From 30 to 80 seconds d. From 10 to 20 hours

34) This cable is not rated to continue to operate in fire
   a. Fire retardant cable b. Flame retardant cable
   c. Fire resistant cable d. Both a & b

35) LSZH means
   a. Low smoke zero halogen
   b. Less smooth zero degree
   c. Low smoke zero hydrogen d. Both a & c

36) The fire resistant cables are used in this installation
   a. Mining & Petroleum
   b. Foundries, Aircrafts or rail cars
   c. Docksides & Oil refineries
   d. All these
37) The insulation used in mineral insulated copper covered cable is
   a. Highly compressed Magnesium Oxide
   b. Highly compressed Silicon Oxide
   c. highly compressed fibre glass
   d. Any of these
38) This insulation is not used in mineral insulated copper covered cable
   a. Highly compressed magnesium oxide
   b. Highly compressed silicon oxide
   c. highly compressed fibre glass
   d. Both b & c
39) Fire resistant and fire retarding cables have
   a. Same construction but different application
   b. Same construction & same application
   c. Different construction & different application
   d. Different construction but same application
40) Welding cables are designed to
   a. Carry high current b. Work on low voltage
   c. Work on high voltage d. Both a & b
41) Diameter of each strand in the welding cable is
   a. 0.2mm b. 0.5mm
   c. 2.5mm d. 1.5mm
42) Number of strands of welding cables may be
   a. 770 b. 1330
   c. 1680 d. Any of these
43) Welding cables have cores
   a. Single b. Two
   c. Three d. Any of these
44) Cables on primary side of welding sets usually have this voltage grade.
   a. 50/100V b. 70/100V
   c. 600/1000V d. 1900/3300V
45) Joints on electrical conductors should be
   a. Avoided if possible b. Mechanically strong
   c. Electrically strong d. All these
46) The basic requirement of a cable joint is that, it should be
   a. Mechanically sound b. Electrically sound

c. Readily accessible for inspection and repair
d. All these

47) An electrically sound joint means that resistance of the conductor should not be greater than that of
a. An un-jointed length of same conductor
b. Any copper conductor
c. Any aluminium conductor
d. None of these

48) Cable joint of any type should not be drawn into a
a. Pipe b. Hidden portion
c. Inspection box d. Both a & b

49) Bad or loose joints can cause this fault in wiring or power systems
a. Loss of power in the form of heat
b. Open circuit or ground fault
c. Short circuit or fire in a building
d. Any of these

50) Joint on electrical conductors may be of this type
a. Soldered type b. Mechanical type
c. Thermal type d. Both a & b

51) It is an alloy of two or more metals used to joint ends of two conductors by melting
a. Solder b. Flux
c. Joint d. Brazing

52) Aluminium solder is an alloy of
a. Tin, cadmium and lead
b. Lead, cadmium and zinc
c. Tin, cadmium and zinc
d. Tin, lead, cadmium and zinc

53) Melting point of soft solder (tin & lead) is around
a. 200°C b. 250°C
c. 300°C d. 500°C

54) Hard solders are high zinc brasses which melts around
a. 350 to 400°C b. 450 to 500°C
c. 850 to 900°C d. 300 to 350°C

55) Working temperature of aluminium solder is between
a. 280°C to 290°C b. 180°C to 200°C
c. 300°C to 390°C d. 220°C to 250°C

56) It is a substance used during jointing to remove oxide layers on joints and causes easy flow of solder
a. Flux b. Solder

c. Braze d. None of these

57) Flux used for Tinman's Solder is
a. Hydrochloric acid b. Zinc Chloride
c. Tallow Turpentine d. Any of these

58) Aluminium conductors should not be soldered/attached with
a. Copper conductors b. Brass terminals
c. Aluminium Conductors d. Both a & b

59) The process of removing insulation of a cable end is called
a. Skinning b. Soldering
c. Tinning d. Scrapping

60) Cleaning the surface of conductor with sand paper to make its surface rough for better adhering of solder is called
a. Skinning b. Soldering
c. Tinning d. Scrapping

61) The joint of conductor of wiring cable is soldered with
a. Soft solder b. Hard solder
c. Porcelain tube d. None of these

62) This is not necessary on the joints of wiring cables
a. Solder b. Tape
c. Joint box d. None of these

63) This Tool is required for power cable jointing
a. Blow lamp b. Hacksaw
c. Kerosene pressure stove d. All these

64) To join the conductors of overhead lines, this joint is used
a. Britannia joint b. Telescope joint
c. Scarf joint d. Duplex straight joint

65) Insulation tape to be applied on the joint of PVC insulated cable should be
a. Teflon tape b. PVC tape
c. Rubber tape d. Any of these

ANSWER KEY

1	**a**	18	**b**	35	**a**	52	**d**
2	**a**	19	**a**	36	**d**	53	**a**
3	**a**	20	**d**	37	**d**	54	**c**
4	**d**	21	**a**	38	**d**	55	**a**
5	**a**	22	**b**	39	**c**	56	**a**
6	**d**	23	**d**	40	**d**	57	**b**
7	**d**	24	**d**	41	**a**	58	**d**
8	**d**	25	**d**	42	**d**	59	**a**
9	**d**	26	**d**	43	**a**	60	**d**
10	**d**	27	**a**	44	**c**	61	**a**
11	**c**	28	**d**	45	**d**	62	**c**
12	**c**	29	**a**	46	**d**	63	**d**
13	**d**	30	**d**	47	**a**	64	**a**
14	**d**	31	**d**	48	**d**	65	**b**
15	**a**	32	**a**	49	**d**		
16	**c**	33	**d**	50	**d**		
17	**d**	34	**d**	51	**a**		

Ch-2: Electrical Wiring Accessories

Main Topics in this chapter

Electrical Wiring accessories and their ratings

A large variety of electrical accessories is available in the market for electrical installation. To cover all these in detail is beyond the scope of this book. So, some important ones are being listed below along with their purpose and rating.

Definition: All the items that are fitted in a building (other than current consuming devices/equipments/machines) during electrical installation work to give/control supply to the electrical appliances and machines are called *electrical wiring accessories*.

For example switches, socket out lets, ceiling roses, cable clips, PVC conduit, lamp holders etc.

1. Important wiring accessories and their purpose

1. **Switches:** These are used to make or break the electric circuit (or to change the direction of current flow) manually.

a. *Types of switches with respect to poles are:*
Single pole (SP), Double pole (DP), Triple pole (TP), Four pole (TP&N).

b. *Types of switches with respect to materials:*
Iron clad (for TP and TP& N), Bakelite, Bakelite with porcelain base.

c. *Types of switches with respect to throw:* Single throw or double throw.

Simple piano type switch fitted in your room to control the fan is an example of single throw switch while change over switch is an example of double throw switch

d. *Types of switches with respect to ways:*
One way, Two way and intermediate (4 way in USA).

e. *Space between switch contactson opening for 230V:* 6mm

f. *Working voltage:* 250V and 500V.

g. *Current Rating:*

Branch switches: 5A, 6A, 15A, 30A.

h. *Shape and use*: Piano key switch, tumbler type switch, ceiling switch, bed switch, toggle switch, figure touch (short piano) switch, rotary switch etc.
i. *Fitting:* Surface type or flush type

Application: Main switches are used to control single or three phase main supply and branch switches are used to control branch circuits and final sub circuit.

For use on dc supply, switches should be of quick break type.

Types of switches with respect to shape and use: Piano, tumbler, ceiling, bed, toggle etc.

Tumbler switch:

It is small two-position or three-position round (or some time square shape) switch, operated by an arm-and-spring mechanism. Tumbler switches are mainly used for switching the lighting circuits of electrical apparatus, and devices. Their current rating is 5, 10 or 15 ampere and voltage rating 250V. These are made with Bakelite material. High current rating tumbler swathes have porcelain base.The switches are mounted on wooden board, fixed over the surface of the wall.

Fig 2.1: Typical surface fitting Bakelite old tumbler switch and socket

Piano type switch: These switches are used where good appearance is required. The switches are fixed in boards in flush form. Some type piano switch comes on plate which is directly fitted in flush type board. These switches are also known as "Piano Type Switches" due to their name.

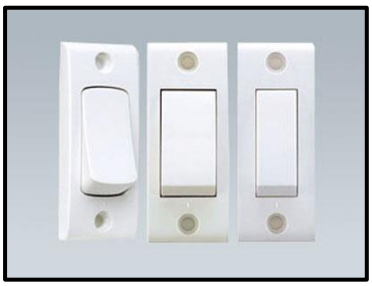


Fig 2.2: Flush type piano key switches

China Fitting type switch: Initially these switches were imported from china therefore these are called china fitting switches. Now these are being manufactured in Pakistan too. Usually they come along with fitting plate in special combination of switches and sockets. These are fancy fitting and available in matching colours with wall distemper colours.

Fig 2.3: 4+2 & 8+2 Flush type china fitting switches with plates

Bed switch: As the name indicates, it is used to switch "ON or OFF" the light from the place, other than switch-board or from near the bed, while going to sleep or getting up. This switch is hanged near bed through flexible cord/wire.

Rotary switch: This switch is used to control different lamps from one places one by one or as selector switch, to select different voltage tapping of transformer in voltage stabilizer.

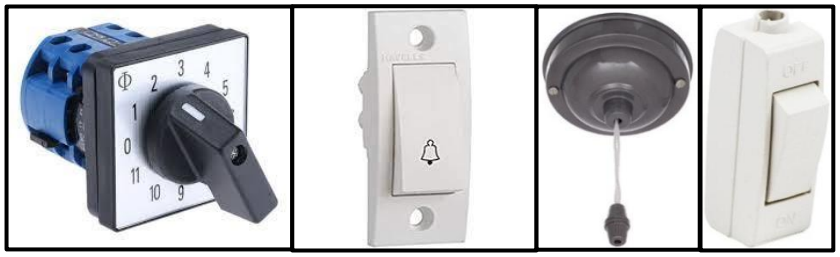


Fig 2.4: A typical rotary switch, bell push switch, ceiling switch bed switch

Bell Push switch: These switches are used to control the electric bell and indicating lamps etc. When the push button is pressed, the circuit is completed and the bell or lamp is switched on. The supply to bell or lamp is switched off as the push button is released.

Ceiling Switch: These switches are operated with a single pull of the cord, for the on and off position. These are also used in bedroom and bathroom. These switches are fixed near the ceiling and hence these are also known as "Ceiling Switches".

Intermediate switch: This switch has four terminals and four different connection position. The main function of this switch is to control a lamp from three or more different places, along with ordinary two-way switch. Generally this switch is used in double stair case wiring or corridor wiring. This switch is also known as four-way switch.

Fig 2.5: A typical intermediate switch front and back side view

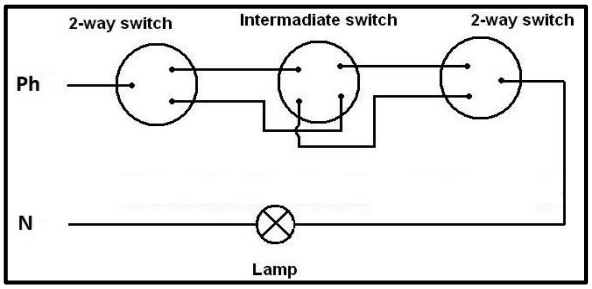


Fig 2.6: Connections of an intermediate switch to control one lamp from three places

Two Way Switch: A two way switch is a simple single pole "changeover" switch with three terminals. These are typically labelled COM, L1, and L2.In one switch position the COM terminal is connected to L1. In the other switch position it changes over so that COM is connected to L2. The design is a

"break before make" type, such that the connection to the first terminal is disconnected before the connection to the new one is made. Usually it is used to control one device from two places.

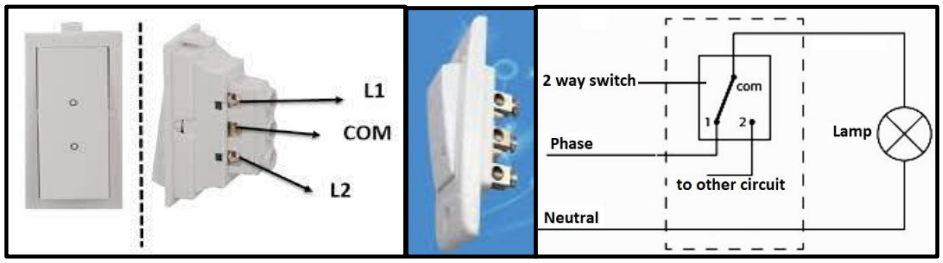


Fig 2.7: 2 way switch and its connections

Main Switch:

As the name indicates this switch is used to switch "ON or "OFF" the main supply. In other words these switches are used to control the whole supply for a house, office and machine. In single-phase circuit I.C.D.P. main switches are used,whereas in three-phase circuits I.C.T.P. main switches are used to control the supply. The main switches are of the following type

a) **Bakelite DP main switch:** Bakelite Double Pole main switchesare used to control single-phase supply at homes and shops. These are available in 15 Amp and 30 Amp current ratings. These are used to make and break phase and neutral wires at the same time. Usually an indicating light is housed in the body to show the availability of supply.

b) **I.C.D.P. Switch:** Iron Clad Double Pole main switch is used in single-phase supply circuits. These are available in 15 Amp, 30 Amp, 60 Amps and 100 amperes current rating.In these switches, either two numbers of fuse links are provided or a fuse link and a neutral link is provided. The neutral wire is directly connected with the neutral link and phase wire is connected with the fuse link.Normally 15 Amp current rating main switches are made of plastic moulding instead of iron.

c) **I.C.T.P Switch**: Iron Clad Triple Pole main switches are used to control the three phase supply circuit. These are available in 15 Amp, 30 Amp, 60 Amp, 100 Amp, 150 Amp, 200 Amps, 250Amps and 300Amps current rating. Generally these switches are also known as 3 phase 4 wires main switches. In these switches, three fuses and a neutral link is available. The neutral wire is directly connected with the neutral link and phase wires are connected with these fuse links.

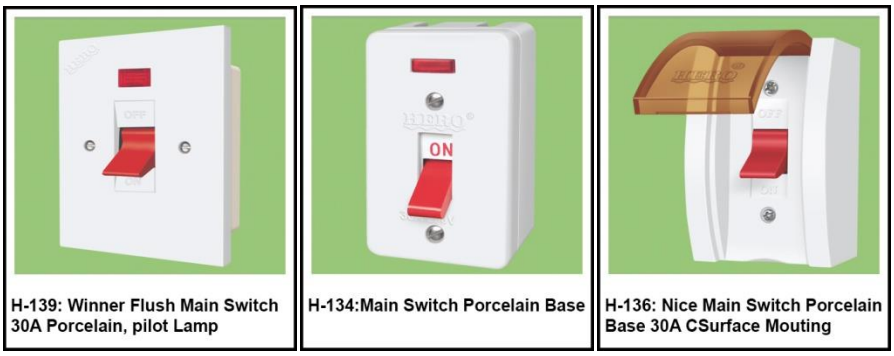


Fig 2.8: Two Pole Bakelite main switches
(Courtesy: Hero Pak Electrical Industries (Pvt) Ltd, Sargodha.)

Fig 2.9: DP Iron clad two poleand TP&N iron clad main switches

2. **Socket outlets:** These are fitted in wiring to give supply to the portable appliances by inserting a plug in the receptacles (tubes) of the sockets. Their proper quantity installed in the building reduces the extra use of loose wires which may lead to any accident.

Fig 2.10: Flush type piano and surface type two pin sockets

IEE regulation 56 & 57 requires that every portable appliance and lighting fitting shell be fed from an adjacent accessible socket outlet.

Every socket outlet should be controlled by a separate switch. Switch sockets have a switch fitted in the socket body. These may be three pin five pin or universal type. Three pin 30A switch socket is called power socket. Socket above 30 A should not be used.

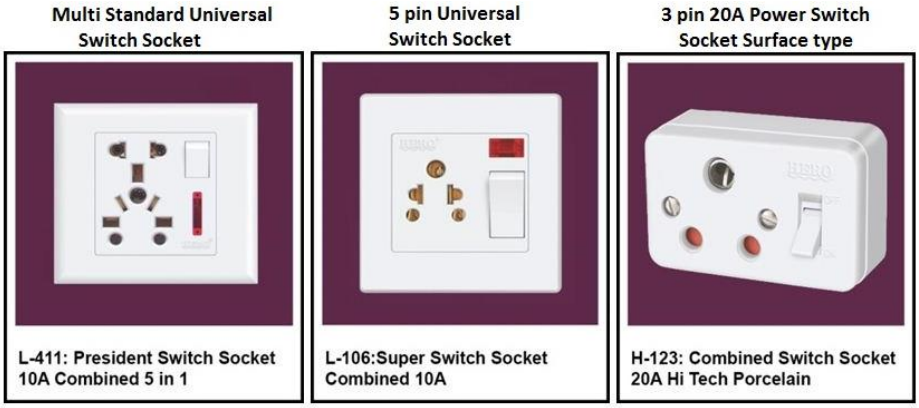


Fig 2.11: Some typical switch sockets

(Courtesy:Hero Pak Electrical Industries (Pvt.) Ltd, Sargodha.)

Types of Socket outletswith respect to pins: Two pins and three pins

a. *Shape of pins:* flat or round.
b. *Current rating:*
   Two pin 2A, 5A, 13A and 15A, Industrial: 16, 30, 32, 63and 125A.
c. *Working voltage:* 250V
d. *Materials:* Bakelite, Bakelite with porcelain base for higher ratings.
e. *Fitting:* Surface type or flush type.

3. Plugs: Plug is connected at the end of the flexible cord (supply lead) of portable electrical appliances. It is then inserted into the socket tubes to get supply for that appliance.Plugs may have two or three (straight flat, straight round) pins. These pins are made of phosphor bronze or hard drawn brass either solid or slotted. Slotted pins form the spring to make batter contact with socket tubes.

A fused plug has a cartridge fuse in it. The three pins of three pin fused plugs are clearly marked L (for line), N (for Neutral) and E (for earth). Male and female plugs are just like socket and plug. Ratings are similar to sockets.

Around the world,different types of plugs are used. Their names are!
Type A,Type B,Type C,Type D,Type E,Type F,Type G,Type H,Type I,Type J,Type K,Type L,Type M,Type N,Type O.
In Pakistan, Type C, Type D, Type G and Type M plugs are used.
The Type C Plug has only two pins (phase and neutral) and current rating of2.5A, voltage range of 220-240V.The pins of the Type C Plug (& Socket) have a diameter of .16"-.19" (4-4.8 mm), length of 0.75"(19 mm), and are fitted with a .39"(10 mm) insulating sleeve. The two pins are set .69"-.73" (17.5-18.6 mm) apart.

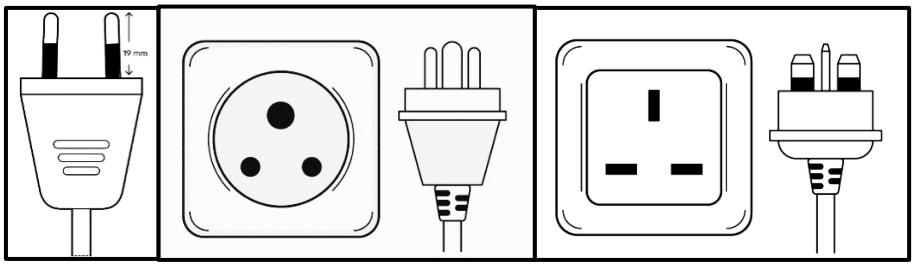


Fig 2.12(a): Type"**C**"2.5A, type "**D**"5A, type "**G**" 15A plugs

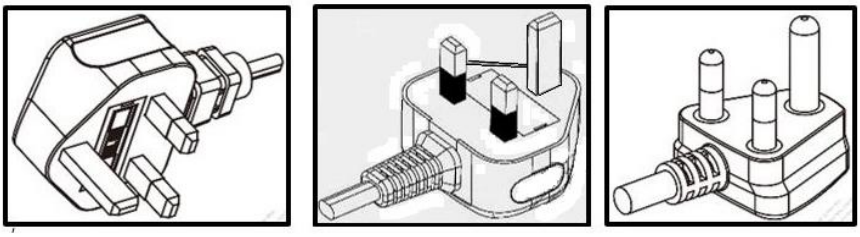


Fig 2.12(b): Three pin plugs of different current ratings

4. **Lamp holders:** As the name indicates, a lamp holder is used to hold the lamp, and connect it electrically to supply terminals, required for lighting purposes. The lamp holders may be bayonet cap and screw type.It is important that the lamp holder is well-matched with the type of lamp we want to use. Light bulb sockets are normally defined by a letter-number-letter (Third Letter is optional). An efficient cord grip is also necessary when the lamp is to be suspended to the flexible cord.

Definition: "A lamp holder a wiring accessory which is fitted in buildings to fit and remove the light lamp quickly and easily".

Material: Insulated Bakelite or brass with porcelain interior.

Shapes and designs: Batten type, angle type, bracket type, key type, pendant type. Energy savers of almost all ratings are available with pin cap (Bayonet

cap) or screwed caps lamp holders for lower power ratings are also being manufactured in both cap types.

a) **Batten Lamp Holder:**The holders are fixed on either on round block or wooden board with the help of wooden screws.

b) **Pendant Lamp Holder:** This lamp holder is used to hang the lamp from ceiling rose, with flexible cord/wire. Some time these holders are provided with lamp shades to divert the upper light to down ward. These may be of brass or Bakelite with brass plunger.

c) **Angle Lamp Holder:** The angle holder is used to focus the light at an angle and is fixed directly on wall or round block. These may be of brass or Bakelite with brass plunger.

d) **Swivel Lamp Holder:** These lamp holders are used for lighting of shop windows,show case etc. It consists of ball and socket joint fitted between back plate and lamp holder, for the purpose to move the light to a wide angle.

e) **Bracket Lamp Holder:** These lamp holders are used to focus the light on the floor or at some angle, slightly away from the walls. Light shades can also be used for diverting all light on floor. Suchlamps are provided with such fittings which make them water tight so that these can be used outside the houses or for street lighting. The lamp holder is simply a pendant holder made of brass or Bakelite.

Fig 2.13: Water tight Bracket type Lamp Hold

f) **Fluorescent Lamp (Tube) Holder:** These are used to hold the fluorescent tube rods.

g) **Switched lamp holders:** These lamp holders are provided with a switch from which lam can be made ON & OFF.

Fig 2.14: Some typical brass lamp holders

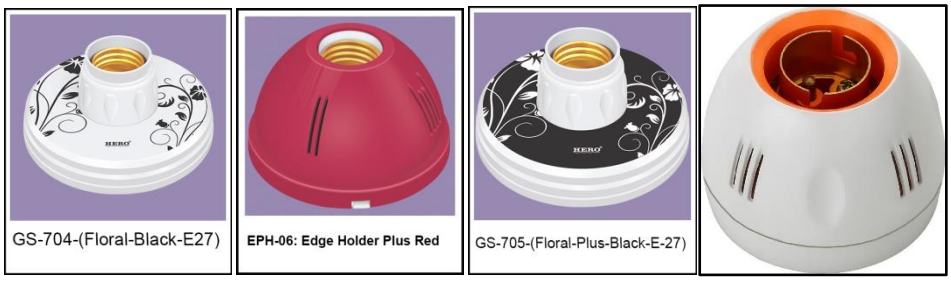


Fig 2.15: Some fancy Bakelite body screw and bayonet type lamp holders

(Courtesy: Hero Pak Electrical Industries (Pvt) Ltd, Sargodha.**)**

5. **Fuse:** It is the most common and important type of safety device used for domestic and commercial installations. These fuses are of kit-Kat type and are also known as cut-out.These cut-outs are made of porcelain in current rating of 15 to 300 amperes. The material used as a fuse wire is tin, lead, silver, antimony, copper and aluminum etc. Copper or lead, tin alloy is mostly used in ordinary fuse wire.

i. **Rewire able type fuse** also called kit Kat fuse. An old and cheap type. It is semi enclosed type fuse and not very reliable. Its fusing factor is 2. Standard Current rating of tinned wire rewire able fuse is3,5,1,15, 20, 25, 30, 45, 60,80 and 100A. Voltage rating: 250 and 500V

ii. **Cartridge type fuse:**Cartridge fuses are totally enclosed type fuse. Glass body is used for low currents and ceramic body for high current. Standard Current Ratings of Cartridge type fuse are as under: Fraction of an ampere to 600A. Voltage rating: 250 and 500V and above

iii. **HBC** (old name HRC) **type fuse**. Blade Type and Bolted Type

Standard Current Ratings of HBC fuseare as under:2,4,6,10,15,20,25,30,35,40,60,80,100,125,160,200,250,300A
Voltage rating: 250V
Body material:

i. Rewire able fuses: Bakelite or ceramic
ii. Cartridge fuses: Glass or porcelain
iii. HBC fuses: Quartz or porcelain

Fig. 2.16: Rewire able (left) and glass body & ceramic bodycartridge fuseright)

Fig. 2.17: Bolted link type HBC fuses

6. **Ceiling rose:** Final circuit of pendant lamps, ceiling fans, exhaust fans, and tube lights is terminated/ ended in ceiling rose. It is a round shaped accessory consisting of two parts i.e. base and cover. Two or three metallic terminals are fitted in ceiling rose to make connection to the fix devices via a flexible piece of twin cable.

Fig. 2.18: Two types of ceiling roses

7. Distribution Box/Board:

(The term distribution box is more appropriate than distribution board because it has length, width and depth**).** It is used to distribute electrical energy to final sub circuits or to other sub distribution boards in the installation. It is usually made with sheet steel. It has some protective devices (fuses, MCCBs or MCBs), line, earth and neutral bus bar, installed in it. Phase indicator lights, voltmeter, ampere meter and volt & am meter selector switch ore optional. No. of sub circuits through holes in the body. These are called "ways". No of ways may be from 2, 3, 4, 5, 6, 8, 10, 12…….. to 42

Current rating may be from few amperes to thousands ampere and voltage 250V and 500V and above.

Two types are:

- **a.** Main distribution box/board(MDB)
- **b.** Sub distribution box/board (SDB)

8. MCCB and MCB: A circuit breaker is a protective device used to make and break the electric circuit both in normal (manually) or abnormal (automatically) conditions. Moulded case circuit breakers are usually used as main circuit breaker and miniature circuit breakers are used as branch circuit breakers.

Tripping: Thermal or magnetic.

Body material: Bakelite.

Current ratings:

0.5,1,1.5,2,3,4,5,67,8,10,15,16,20,25,30,32,35,40,50,63,80,100,125,1510,175, 200,225,250,300,350,400,500,630,800A

Working Voltage: 250,380,400,500,660V

Fig. 2.19: MCCB and MCBs

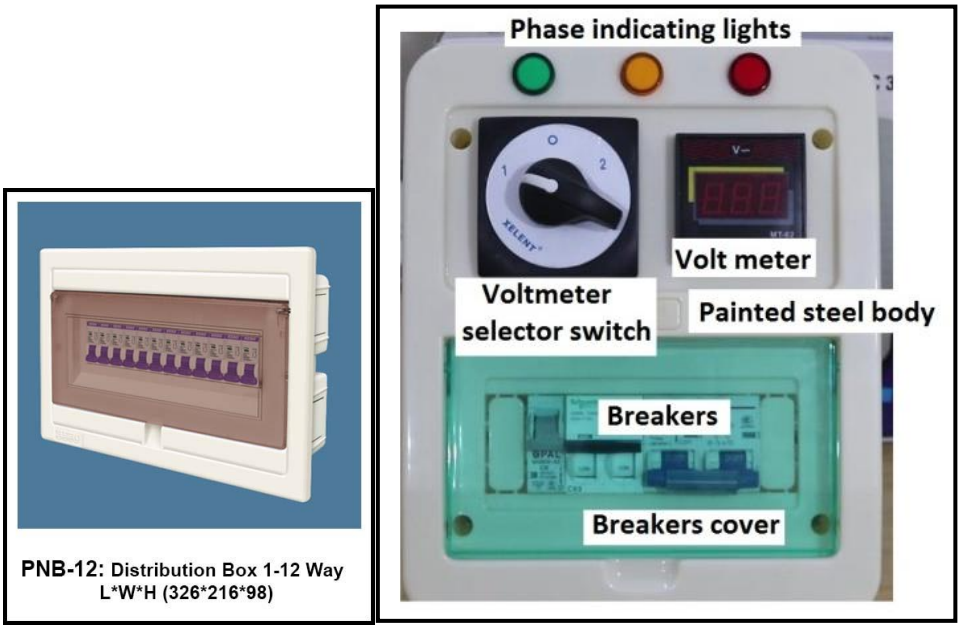


Fig. 2.20: Typical distribution boxes

9. Cables: Cables are installed in a building to transmit electric power from supply point to all the current consuming devices (points).Cables may be: Single core,twocore,threecore, three and half core, four core, fivecore.Conductors may be:Copper or Aluminium (above 10mm^2 only)

Insulation may be:

a. P.V.C (poly vinyl chloride).
b. V.R.I (or V.I.R) Vulcanized rubber insulation.

c. Rubber insulated cables i.e. TRS (tough rubber sheathed) and CTS (Cab tyre sheathed), butyl rubber, silicon rubber. Magnesium Oxide

Voltage grade: Low (250/400V) & Medium (600/1000V).

Conductor may be: Solid (1mm^2, 1.5mm^2 and 2.5mm^2).

Or Stranded (From2.5mm^2 and upward)

Cables may be round or flat, flexible or non-flexible, single or multi cored, armoured or non-armoured type.

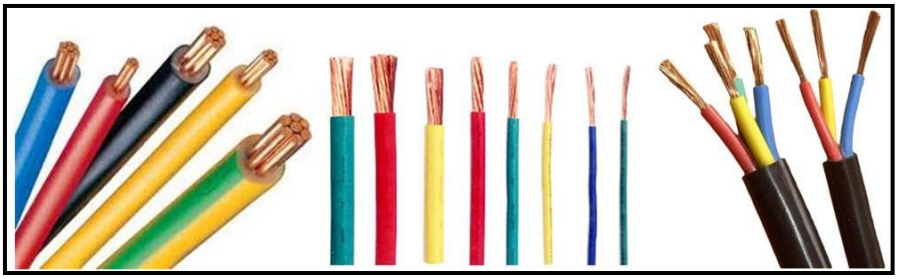


Fig. 2.21: Some typical wiring cables

10. Miscellaneous wiring accessories

i. Cleats (wood or plastic material, voltage 250V)
ii. Switch boards and switchboard frames (plastic, plastic with Bakelite sheet, sheet metal box with Bakelite sheet), sizes:4"x4",7"x4", 8"x10", 10"x12", 4"x10", 4"x12",4"x16".
iii. Cable saddles and cable clips(See fig below).
iv. Conduits: PVC conduit and fittings (3/4" to 3" size),heavy gauge metal conduits and fittings(3/4" to 3" size), light gauge metal conduits and fittings(3/4" to 2" size).
v. Batten and fittings (1/2",3/4" and 1" size)
vi. PVC duct ((used for single phase supply, for sizes, see chapter No 3)
vii. Rawal plugs
viii. Nails and screws (1/2" size to 3(3/4" to 3" size) size)
ix. Holder adopters, multi socket plug, fan regulators or dimmers etc.

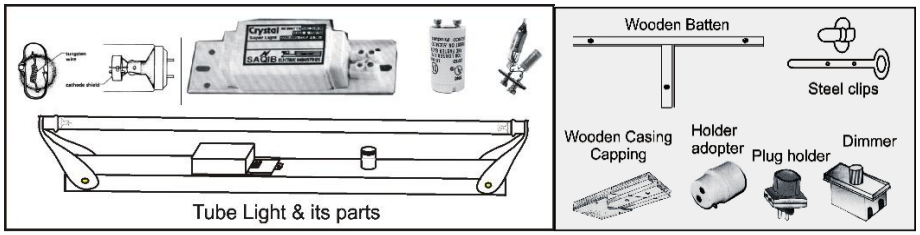


Fig. 2.22: Miscellaneous wiring accessories

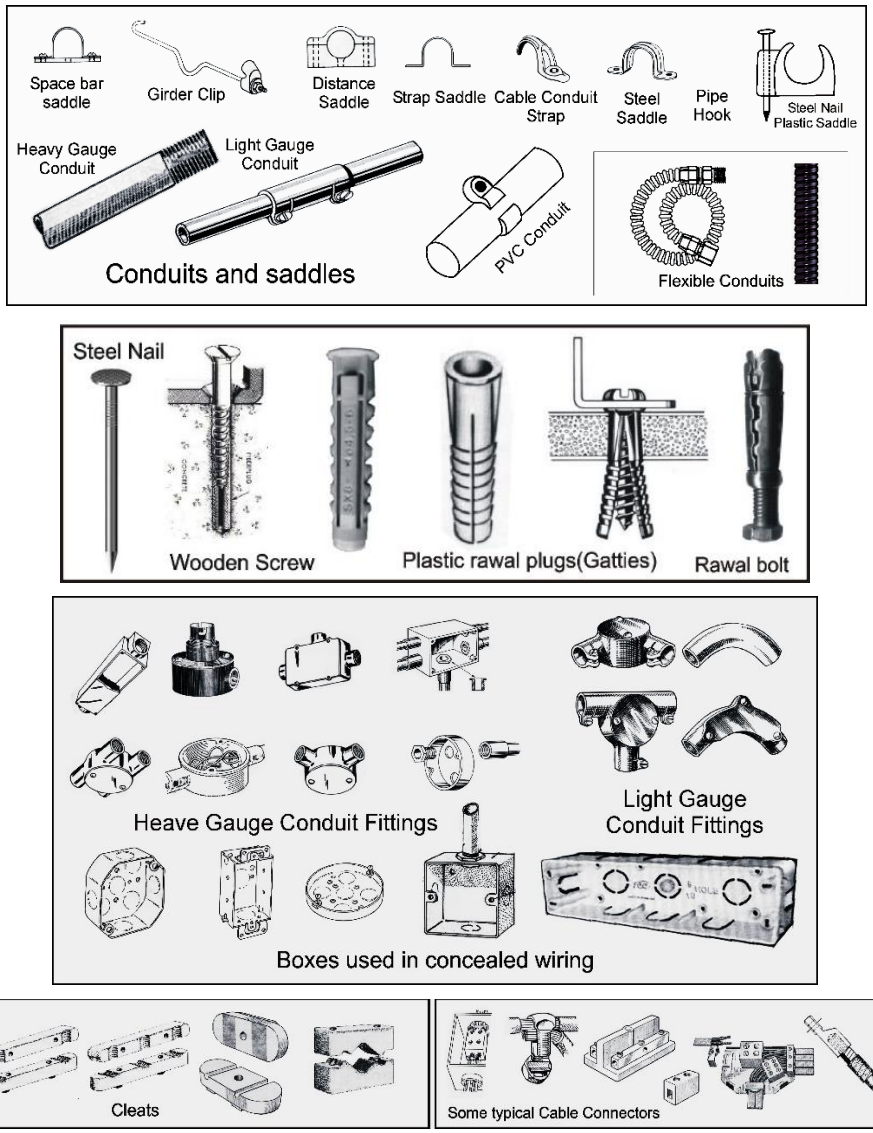


Fig. 2.23: Miscellaneous wiring accessories

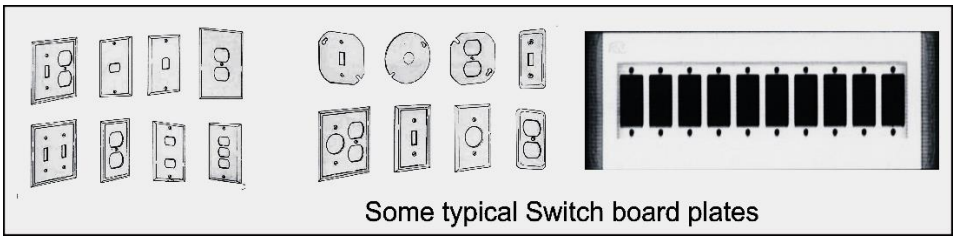


Fig. 2.24: Some typical switch board cover plates

Exercise

Part-1: Subjective type Questions

Sample Long Answer type questions

Q1. Enlist 10 wiring accessories along with their purpose.
Q2. Define and enlist types of socket outlets and plugs.
Q3. Write the purpose of fuse, distribution board, ceiling rose, lamp holder and cables in wiring.

Part-2: Objective type Questions

Sample Short Answer type Questions

Q1. Define wiring accessory.
Q2. Define switch.
Q3. Write the types of switch with respect to poles and throw.
Q4. Write the current rating of branch switches.
Q5. Write the current rating of main switches.
Q6. What is difference between branch switch and main switch?
Q7. Define main switch.
Q8. Define plug and write its types.
Q9. What types of pins of plugs are used in Pakistan?
Q10. Define main distribution board.
Q11. Which protective devices are installed in distribution boards against over current protection?
Q12. Write the names and numbers of bus bars used in distribution boards.
Q13. Write difference between socket outlet and switch socket.

Sample Multiple Choice Type Questions (MCQs)

Q1. A switch is used to
a. Make the electric circuit
b. Break the electric circuit
c. change the direction of current flow
d. All these

Q2. No of poles of switches used in wiring may be
a. one b. Two
c. Three or four b. Any of these

Q3. Switch with respect to throw may be
a. Single throw b. Double throw
c. Triple throw d. Both a and b

Q4. These are fitted in wiring to give supply to the portable appliances by inserting a plug in the metallic tubes.
a. Plugs b. Socket out lets
c. Ceiling roses d. Switches

Q5. Every portable appliance shell be fed from an adjacent accessible
a. Socket outlet b. Ceiling rose
c. Switch d. Plug

Q6. This is used to disconnect the main supply of a single phase domestic wiring
a. Change over switch
b. Two pole main switch
c. Triple pole and neutral iron clad main switch
d. Both b & c

Q7. No of terminals of an intermediate switch are
a. One b. Two
c. Three d. Four

Q8. Lamp holders are made of this material
a. Bakelite b. Brass
c. Copper d. Both a & b

Q9. Ceiling switch is used in
a. Bath rooms b. Restaurants
c. Bedrooms d. All these

Q10. A lamp holder having bar on it to make the lamp ON and OFF is called
a. Batten type lamp holder
b. Key type lamp holder
c. Bracket type lamp holder
d. Angle type lamp holder

Q11. The Bayonet cap type lamp holders are used for lamps power up to
a. 150W b. 100W
c. 200W d. 500W

Q12. Medium Edison screw type lamp holders are used for lamps power, up to
a. 150W b. 100W
c. 200W d. 500W

Q13. New name of HRC fuse is
a. HBC fuse b. MCB fuse
c. 0HMC fuse d. Rewire-able fuse

Q14. The cable ratings are given for ambient temperature of
a. 30°C b. 40°C

c. 20°C d. 35°C

Q15. Double Pole Switch is connected on
a. Phase Wire b. Neutral Wire
c. Earth Wire d. Both phase & Neutral Wires

Q16. This switch is used to control one lamp from more than two places.
a. Change over switch b. Two way switch
c. Intermediate switch d. Rotary switch

Q17. This switch should be used in bath rooms
a. Push button switch b. Ceiling switch
c. Toggle switch d. Iron clad switch

Q18. Single pole switch should be installed on
a. Phase wire b. Neutral wire
c. Both (a) & (b) d. None of these

Q19. Pins of electrical plug should be made of this material
a. Phosphor Bronze b. Hard Drawn Brass
c. Aluminium d. Any of (a) or (b)

ANSWER KEY

1	**d**	6	**b**	11	**a**	16	**b**
2	**d**	7	**d**	12	**c**	17	**b**
3	**d**	8	**d**	13	**a**	18	**a**
4	**b**	9	**d**	14	**a**	19	**d**
5	**a**	10	**b**	15	**d**		

Ch-3: Domestic Wiring Systems

Main Topics in this chapter

Domestic Wiring systems (PVC conduit and PVC channel/duct wiring)

Electrical wiring

Definition: Laying of wires/cables and fitting the wiring accessories in a building, according to the safety and electricity rules, keeping in view the architectural beauty of the building is called electrical wiring. The purpose of electrical wiring is to provide electric power to the electric machines/appliances.

Another definition: Electrical Wiring is a process of connecting cables and wires to the related devices such as fuse, switches, sockets, lights, fans etc. to the main distribution board in a specific building to the supply company distribution pole for continues power supply.

Classification of wiring systems:

Wiring systems can be classified in different ways. So wiring system may be:

- **Open (or exposed):** such as conduit, PVC duct, wood casing capping, batten or cleat wiring system.
- **Concealed:** Such as concealed conduit wiring system.
- **Domestic (or residential):** such as conduit, PVC duct, and wood casing capping, or batten wiring system.
- **Industrial or commercial:** Such as conduit, trunking, catenary, bus bar, ducting wiring system.
- **Indoor** (wiring carried out inside the premises such as in the offices, houses, shops, commercial buildings or factories).
- **Outdoor** (wiring carried out outside the premises such as wiring of flood lighting , rod or street lighting)

Methods of taking connections in wiring:

1) Joint box system (or Tee system)
2) Looping system(or Loop in system)

Both above methods have their own advantages and disadvantages

Types of Wiring Systems

❖ **Domestic (or residential) wiring systems.**

1. Cleat wiring system
2. Wood Casing and Capping wiring system (now obsolete).
3. PVC duct or PVC Casing - Capping wiring system.

4. Batten wiring (CTS or TRS) wiring system (Now obsolete).
5. Lead sheathed wiring system.
6. PVC Conduit wiring system.(open or concealed)

- **Industrial or commercial wiring.**(these have been discussed in chapter No 7)
  1. Steel Conduit wiring system.
  2. Metal Trunking wiring system.
  3. Ducting wiring system.
  4. Catenary wiring system
  5. Tough sheathed wiring system.
  6. Overhead bus bar wiring system or metal clad bus bar system.
- **Farm wiring.**

Detail of Conduit and PVC duct wiring systems

1. Conduit wiring system

Conduit wiring system can be classified as below

1. **Steel conduit wiring system** (mostly used in industry or large commercial buildings)
2. **Non Metallic (PVC) conduit wiring system**. (Usually used in homes and shops). It may be!
   a. Surface or open type PVC conduit wiring system
   b. Concealed type PVC conduit wiring system

Introduction to PVC conduit and duct wiring systems

Due to numerous advantages and easy availability of materials, Non-metallic conduit and duct wiring systems have almost swept away all wiring systems which use wood like batten wiring, wood casing capping wiring system and wood cleat wiring system.

Non-metallic Conduit or PVC conduit wiring system

A rigid/solid PVC conduit wiring system is very popular now a days in small buildings like homes, offices, shops, villas and bungalows etc. It is cheaper, flexible, light weight, easy to handle, easy to bend and easy to install as compared to steel conduit.PVC conduits are safe from corrosion, many chemicals, acids and insect attack. Since the PVC conduit is not conductive, so there is no risk of electric shock.PVC conduit fittings like connectors, couplings, tees, and bens/elbows are easily available in all sizes. PVC conduit and its fittings can easily be attached together with a PVC glue. Because PVC is an insulating material, so PVC conduit cannot be used as earth continuity conductor like steel conduit. Therefore a separate earth wire in the conduit is used as an earth continuity conductor. Mostly ¾ inch and 1 inch size of PVC pipe is used for final sub circuits of domestic wiring. However following sizes of conduits are also used in electrical wiring.

Sr. No	Cond. Size in mm(rounded)	Cond. Size in inches
1	13	0.5
2	20	.75
3	25	1
4	38	1.5
5	50	2
6	63.5	2.5

2. Surface type PVC Conduit wiring system

As the name indicates, it is a wiring method in which non-metallic (rigid PVC) conduits are installed on the surface of wall or roof with the help of conduit saddles. Saddles may be PVC side nail type or steel space bar type Saddle. In this wiring method, holes on the surface of wall or roof on equal distances are made with the help of electric drill machine or hand Rawal plug tool. Plastic or wooden Gatties are inserted in these holes. Then saddles are fitted on these Gatties and conduits are fixed and wired up. Space bar metal saddles should be used instead of plastic steel nail saddles.

Fig 3.1: Surface type PVC conduit wiring system

Material required for surface type PVC conduit wiring

1) PVC conduit and its fittings of required size and quantity/length.
2) Metal Saddles/ hooks/ clips of required size, type and quantity.
3) Rawal plugs or Gatties.
4) Cotton string and blue or black liquid for string immersion.
5) Wooden screws of different sizes.
6) Cables of different sizes as required.

7) Different accessories like switches, sockets, power sockets, switch boards, ceiling roses, lamp holders etc. as per requirement of the installation.
8) Draw wire/fish wire.
9) Conduit and fitting jointing glue.

Tools required for surface type PVC conduit wiring

1) Spirit level.
2) Heck saw.
3) Electric drill machine with concrete drill bit or hand Rawal plug tool.
4) Screw drivers of different types and sizes.
5) Phase tester.
6) Measuring tape.
7) Electrician pliers.
8) Long nose pliers.
9) Side cutting pliers.
10) Hammer.
11) Electrician knife or wire stripper.

Method of installation of surface type PVC conduit wiring system

1) Decide and indicate the circuit routes.
2) Mark blue coloured lines on these routs with the help of cotton string immersed with blue liquid. Ask the method of using cotton string to draw horizontal and vertical rout lines to your teacher.
3) Mark dots at appropriate equal distances on the cable routs on walls and ceiling.
4) Make holes on doted points of walls and ceiling with electric drill machine or hand Rawal plug tool.

(Distance between saddles depends upon the size and weight of cables and conduit and also on type of conduit run (horizontal or vertical. For 20mm PVC rigid conduit, distance between supports should not be more than 1.5m on horizontal runs and 1.75m on vertical runs and 300mm from any boards/boxes, bends etc. Reference table D3 of IEE regulations for building installation 18th edition.)

No need of making holes if plastic saddles with steel nail have to be use, but these are not recommended.

5) Insert the plastic Rawal plugs with hammer in these holes.
6) Fit the lower part of metal saddles on the holes as shown below.

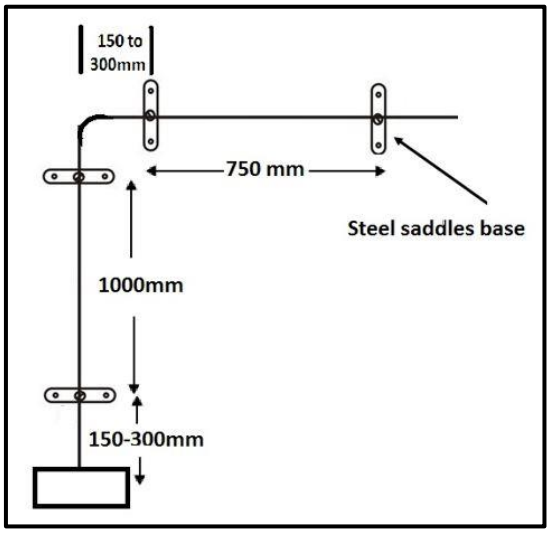


Fig 3.2: Distances of saddles on vertical & horizontal runs of surface conduit.

7) Put the conduit lengths on these saddle bases and fix the upper part of saddles.
8) Fit lamp holders, ceiling roses and switch boards etc. on their places as per drawing.
9) Draw the wires/cables in the conduits with fish wire.
10) Make connection with ceiling roses, lamp holders, switch boards and appliances etc.
11) Perform the necessary tests.

Maximum spacing of supports (Saddles) for surface type PVC conduits

Conduit size	Horizontal spacing	Vertical spacing
Up to 16mm	0.75meter	1.0 meter
16-25mm	1.5 meter	1.75 meter
25-40mm	1.75 meter	2 meter
Above 40mm	2 meter	2 meter

Advantage of surface type PVC Conduit Wiring System

1) Easy to install.
2) Cheaper in cost.
3) Take less time to install.

4) No danger of electric shock as in metal conduit.
5) No corrosion on plastic pipes as in metal conduit.
6) No need to earth the pipes like metal conduit.
7) No effect of acid, oil, grease etc. on pipes.
8) Repairing and maintenance is easy.
9) Any change can be made easily in future.
10) Alteration/addition is easy.
11) No risk of damage of insulation of cables during drawing in pipes.
12) Making new connections is easy.
13) No high skill is required to install this system.
14) Building strength does not effect as no channels are made in walls.
15) Fault can be easily detected and can be fixed quickly.
16) Less planning in advance is required as compared to concealed wiring.
17) No chances of leakage of water and cracks.
18) The whole wiring system can be replaced in short period of the time and material of wiring may be reused at another place.

Disadvantage of surface type PVC Conduit Wiring System

1) Appearance is not so good looking.
2) Mechanically weak and risk of mechanical injury is more
3) Life is short (15-20 years) as compared to concealed PVC conduit and metal conduit systems.
4) More risk of fire than concealed PVC conduit and metal conduit systems.
5) Saddles are required to fix the conduits.
6) Thermal expansion can make the conduits crooked.
7) Conduits become loose and saggy after some time which seems very ugly.

Precautions in the installation of surface type PVC Conduit Wiring System

1) Select the correct rout before installation of conduit.
2) Always use vertical or horizontal runs between two points instead of using diagonal run as shown in the figure below.

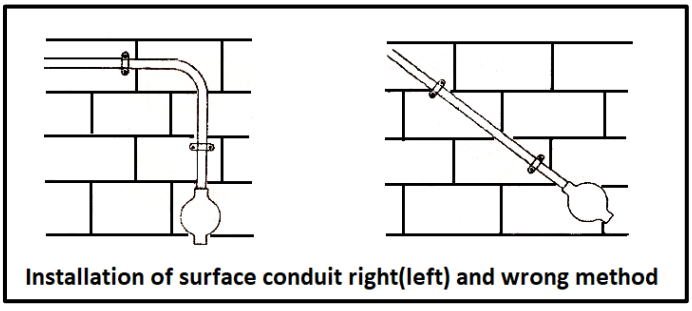


Fig 3.3: Correct (left) and incorrect (right) method of surface conduit fitting

3) Use correct size of saddle according to the size of conduit
4) Do not use steel nail plastic saddles for conduit installation.
5) To prevent the spread of fire, plastic conduits (and plastic trunking) must comply with ignitability characteristic 'P' of ES 476 Part 5.
6) A conduit system must be completely erected before cables are drawn in.
7) Allowance must be made, in the form of expansion loops, for the thermal expansion of long runs of metal or plastic conduit. Remember that plastic expands and contracts more than steel.
8) Use flexible joints when crossing building expansion joints
9) Use Tees, elbows and bends instead of bending the PVC conduit.
10) Always select the correct size of conduit according to the number and size of cables to be used in conduit.
11) Always use steel wire to draw cables/wires in conduits.
12) Do not use too much cables in conduit (keep at least 60% internal space of conduit free).
13) There should not be more than two 90^o bends (or their equivalents) between two draw in boxes. Moreover, bend over 90^o between two draw in boxes should be avoided.
14) Individual saddles for each conduit running in parallel should be used.
15) For more than one conduit in parallel, use multiple saddle instead of using one big saddle embracing two or more conduits.
16) Inspection "Ts", inspection bends or inspection type junction boxes should be used.
17) Size of conduit used should be one throughout the runs as far as possible even if the conduits to carry less number of cables than its capacity or duplicate conduits are to be run for a part of run.

Fields of Applications

This system of wiring is used in homes, shops, offices and small installations of single phase supply only.

3. Concealed type PVC conduit wiring system

Concealed means "Hidden". In this wiring system, PVC pipes are buried in the brick walls or roof surface and then plastered. After that, electrical wires/cables are pulled inside the conduits. Concealed conduit wiring system is the most popular, visually beautiful, safer and comparatively. It is most common type of electrical wiring system used nowadays in homes, bungalows, offices etc. because after wiring, the surface looks neat and clean.

Fig 3.4: Concealed conduit wiring under construction (left) and after finish (right)

Material required for concealed PVC conduit wiring system

1) PVC conduit and its fittings of required size and quantity/length.
2) Hooks to fix the conduits in wall grooves.
3) Cotton string and blue or black liquid for string immersion.
4) Wooden screws of different sizes.
5) Cables of different sizes as required.
6) Different flush type accessories like switches, sockets, power sockets, switch boards, ceiling roses, lamp holders etc. as per requirement of the installation.
7) Draw wire/fish wire.
8) Conduit/accessories jointing glue.

Tools required for concealed PVC conduit wiring

1) Wall chaser/Groove cutting machine or angle grinder cutting machine.
2) Cold chisel.
3) Lump hammer
4) Spirit level.
5) Heck saw.
6) Trowel.
7) Electric drill machine with concrete drill bit or hand Rawal plug tool.
8) Screw drivers of different types and sizes.
9) Phase tester.
10) Measuring tape.
11) Electrician pliers.
12) Long nose pliers.
13) Side cutting pliers.
14) Hammer.
15) Electrician knife or wire stripper.

Method of installation of concealed PVC conduit wiring

1) Decide and indicate the circuit routes.
2) Mark blue coloured lines on these routs with the help of cotton string immersed with blue liquid. Ask the method of using cotton string to draw horizontal and vertical rout lines to your teacher.
3) Cut chases/grooves/channels*on the cable routs on walls with the help of wall chaser/Groove cutting machine or angle grinder cutting machine.
4) Put the pipes in these grooves and fix them in place with pipe hooks.
5) Make pits/spaces for flush type switch boards, lamp holders and ceiling roses etc.
6) Once the conduits, boxes and accessories are fixed, fill the chiselled surface with cement mortar and chick mesh wrapped around the conduits.
7) Fit lamp holders, ceiling roses and switch boards etc. on their places as per drawing.
8) Fill the space around these accessories with cement mortar.
9) Also fill the grooves with cement mortar and level it.
10) Draw the wires/cables in the conduits with fish wire.
11) Make connection with ceiling roses, lamp holders, switch board sand appliances etc.
12) Perform the necessary tests.

Fig 3.5: Wall chasing and slotting machines

***Cutting of grooves in the brick walls**

Cutting the electrical chases/channels/grooves in brick walls is simple job and requires simple chasing tools. Basically, an angle grinder with two parallel cutting blades with a depth setting is used. A chasing machine can also be used for this purpose. The depth gauge simply sets and runs the grinder up, down or across the wall making two parallel cuts. The waste between the cuts is knocked out with the use of a cold chisel.

Fig 3.6: Grooves in brick wall for concealed conduit/boards installation

Precautions/rules for cutting the wall grooves

1) As far as possible, the services should be planned with the vertical chases. Horizontal electrical chases should be avoided, as they reduce the strength of the wall.
2) The depth of vertical chases and horizontal chases should not exceed one-third and one-sixth of the thickness of the masonry respectively.
3) If horizontal chases are unavoidable, then it should be located in the upper or lower one-third of storey and not more than three chases should be permitted in any stretch of a wall.
4) No continuous horizontal chase should exceed 1 meter in length.
5) If unavoidable, stresses in the affected area should be checked and kept within the permissible limits.
6) Vertical chases for fixing electric conduits, I pipes or a recess for fixing electrical metal boxes should not be cut within 1.5 feet from the edge of the wall.
7) No chases, horizontal or vertical, should be made back to back.

Filling the wall grooves

1) Once the cable is installed, use a paint brush to wet the sides and back of the chase by using clean water, and then apply a coat of neat PVA adhesive to the sides/back of the chase and conduit/ pipe. This will aid the adhesion of the filler.
2) As a filler, the materials to be used are:
3) A strong sand/ cement mix (3:1:1 – 3 part of soft sand: 1 part of sharp sand: 1 part of cement).

4) One coat of plaster or patching plaster.
5) A standard decorator's filler.
6) If applied to a deep chase, both the plaster and filler may sag and hence they need to be built up in layers.
7) The chases must be filled from the back and around the conduit/ pipe from the front. A small trowel will help push the filler into the back corners and behind the conduit/ pipe. Use the trowel across the sides of the wall surface to cut off the filler to the line of the wall. If channelling is used, there is no need to try to fill the chase behind it.
8) If the wall is to be tied, there is no need to give a fancy finish to the wall. But if the wall is to be painted or papered, cut back the surface of the filler by about 3 mm before it fully hardens.
9) Electrical chases can also be filled with a plaster called patching plaster or one coat plaster. This can generally be applied in coats up to 50 mm thick. If there is a deep chase, build the fill up in layers. If using one coat plaster, make sure that you wet the chase really well before applying it. The plaster will dry out quickly and crack badly if its moisture content is not maintained. Recon fibres with mortar can also be used for filling the chases.

Advantage of concealed type PVC Conduit Wiring System

1) Appearance is good looking.
2) Finished surface is neat and clean.
3) Mechanically safe and risk of mechanical injury is almost nil.
4) No risk of damage of cable insulation.
5) Comparatively long life as compared to surface PVC conduit system.
6) Less risk of fire than surface PVC conduit system.
7) No saddles are required to fix the conduits.
8) Safe from humidity, chemical affects and smoke
9) Safe from weather conditions.
10) Conduits do not become loose and saggy after passage of time.
11) No risk of shock
12) Most Reliable and popular wiring system for domestic installations.
13) Do not hamper interior layout as conduits are concealed in wall.
14) Renovations can be easily performed by replacing the old wires.
15) No corrosion on plastic pipes as in metal conduit.
16) No need to earth the pipes.
17) No effect of acid, oil, grease on pipes.
18) No risk of damage of insulation during drawing.

Disadvantage of concealed PVC Conduit Wiring System

1) Installation is difficult as compared to surface conduit method.
2) Expensive as compared to surface conduit method.

3) Take more time to install.
4) Repairing and maintenance is not easy.
5) Any change cannot be made easily in future.
6) Difficult to add/manage additional connection in the future.
7) High skill is required to install this system.
8) Building strength become weak when grooves/channels are made in walls.
9) Fault cannot be detected and fixed quickly and easily.
10) Good planning in advance is required.
11) Chances of leakage of water and cracks.
12) The whole wiring system cannot be replaced in short period of the time and material of wiring may not be reused at another place.

Precautions in the installation of concealed type PVC Conduit Wiring

1) Conduit must be installed during construction work of concrete ceiling
2) Select the correct rout before installation of conduit.
3) Use hooks to hold in place the conduit in grooves.
4) Apply at least 12mm layer of plaster over the conduit in groove.
5) Metal boxes should not be cut within 1.5 feet from the edge of the wall.
6) No chases, horizontal or vertical, should be made back to back on a wall.
7) No continuous horizontal chase should exceed 1 meter in length.
8) Horizontal electrical chases should be avoided, as they reduce the strength of the wall.
9) Use Tees, elbows and bends instead of bending the PVC conduit.
10) Always select the correct size of conduit according to the number and size of cables to be used in conduit.
11) Always use steel wire to draw cables/wires in conduits.
12) Do not use too much cables in conduit (keep at least 60% internal space of conduit free).
13) There should not be more than two 90o bends (or their equivalents) between two draw in boxes. Moreover, bend over 90o between two draw in boxes should be avoided.
14) Inspection “Ts”, inspection bends or inspection type junction boxes should be used.
15) If the ceiling is of reinforced concrete type, then it is necessary to erect the conduit on the shuttering and secure it.
16) Bury the concealed/flush type boxes in walls before plastering and fill them with paper or similar substance to prevent them being filled with plaster.
17) Also secure the conduit ends before plastering to prevent the plaster to enter in the conduits.
18) Finish the surface neatly round the outside edges of flush type boxes.

Fields of Applications

Concealed conduit electrical wiring system is the most popular, visually beautiful more safe and stronger. It is most common type of electrical wiring used nowadays in homes, bungalows, offices etc., as the surface looks neat and clean.

4. Steel conduit wiring system

In this system of wiring, heavy gauge steel conduits are installed on the surface of walls by means of saddles or pipe hooks and V R I or P V C cables are drawn into pipes by means of a G.I draw/fish wire. This system is mostly used in industry for medium voltage (250 V to 600 V) circuits and in places where good mechanical protection and absolute protections from moisture is desired. As this system of wiring provides protection against fire, mechanical damage, and dampness so this is the only approved system of wiring for:-

Places where considerable dust of fluff is present such as in textile mills, saw, flourmills etc. in damp situations, in workshops for lighting and motor wirings, places, where there is possibility of fire hazards such as in oil mills, varnish factories etc., in record room.

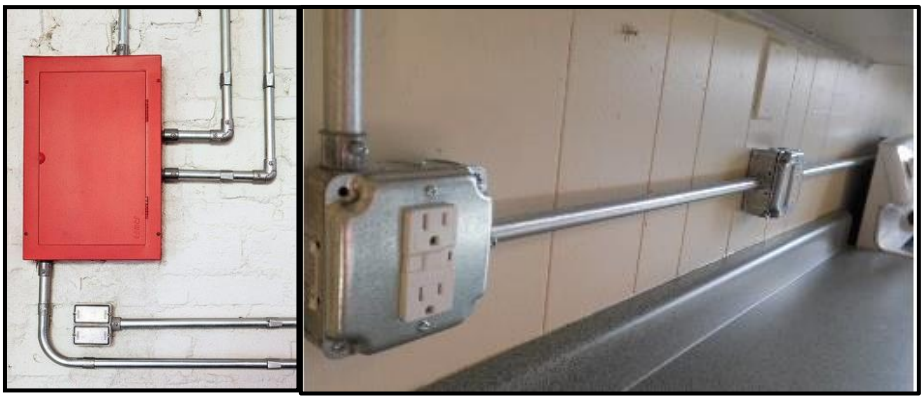


Fig 3.7: Surface steel conduit installation

Note: *See detail of Steel conduit wiring system in Chapter No. 7*

Comparison between steel conduit and PVC conduit wiring

Sr. No	**Steel conduit wiring system**	**PVC conduit wiring system**
1	Mechanically strong	Mechanically weak
2	Durable and long life	Not so durable, short life

3	Pipes do not deteriorate for long time.	Pipes deteriorate in few years.
4	Heavy weight and difficult to install.	Light weight and easy to install.
5	High cost	Low cost
6	Special tools and highly skilled labour required	No special tools and highly skilled labour is required
7	Fire and water proof wiring	Not fire and water proof wiring
10	Suitable for industrial and commercial buildings.	Installed in residential buildings, offices, shops etc.
11	Usually used for three phase installations.	Usually used for single phase installations.
12	Metallic pipes can be used as earth continuity conductor	Plastic pipes not be used as earth continuity conductor
13	Danger of electric shock	No danger of electric shock
14	Earthing of pipes is needed	Earthing of pipes is not needed

Comparison between surface and concealed type PVC conduit wiring

Sr. No	**Surface type PVC conduit wiring system**	**Concealed type PVC conduit wiring system**
1	Not very good appearance.	Appearance is good looking.
2	Seems not neat and clean.	Neat and clean.
3	Mechanically weak and risk of breakage with mechanical injury.	Mechanically safe and no risk of mechanical injury.
4	Short life.	Comparatively long life.
5	More risk of fire	Less risk of fire
6	Saddles are required.	No saddles are required.
7	Safe from chemical affects and smoke	Also safe from humidity, chemical affects and smoke
10	Weather conditions effect on pipe life.	Safe from weather conditions.

11	Conduits become loose and saggy after passage of time.	Conduits do not become loose and saggy after passage of time.
12	Not durable and popular	More reliable and popular.
13	Installation is easy.	Installation is difficult.
14	Less expansive	More expensive.
15	Can be installed in less time.	Take more time to install.
16	Any change is easy	Any change is difficult.
17	Additional connections are easy	Additional connections are difficult
18	No high skill is required.	High skill is required for installation.
19	No effect on building strength as grooves are not made.	Grooves/channel in walls weaken the building strength.
20	Fault can be detected and removed easily	Fault detection and fixing quickly is not easily.
21	Material of wiring can be reused at another place	Material of wiring may not be reused at another place after dismantling.

5. PVC duct (PVC Channel) wiring system

Due to ease in installation and alteration, PVC duct system has almost replaced the surface type PVC conduit wiring system in Pakistan. It is called PVC ducting or PVC channel wiring system. PVC trunking is another name used for this system. Because it was introduced as substitute of wood casing and capping system, so it is also sometimes called PVC casing and capping wiring system. PVC ducting system is particularly suitable for corrosive atmospheres. Plastics material is easier to cut, handle and install but plastic material is affected by high temperature. Buckling occurs at high temperatures and the PVC becomes brittle at low temperature around 0^{o}C.

Fig 3.8: PVC Ducts

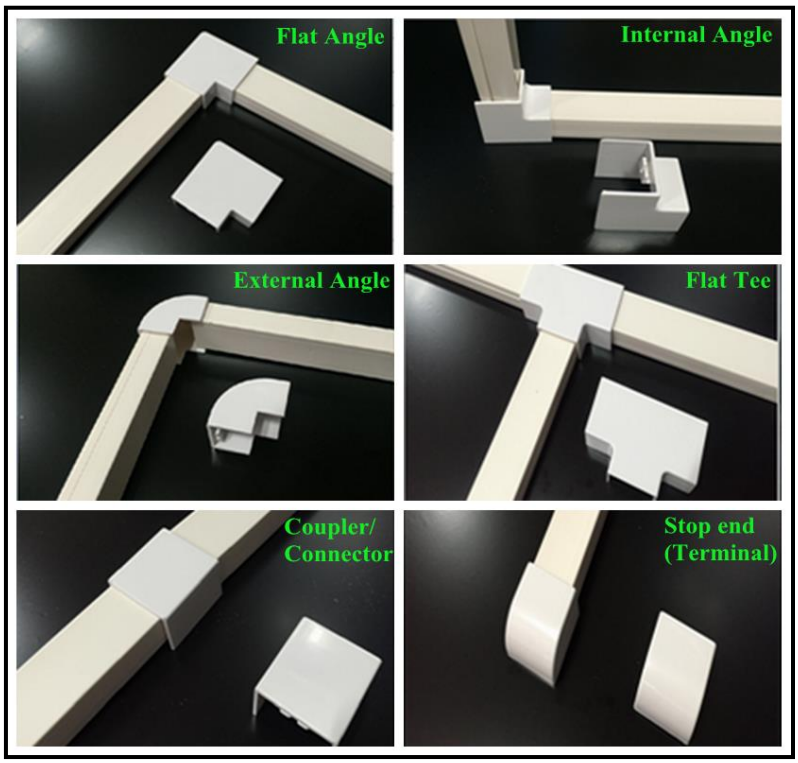


Fig 3.9: PVC Ducts fittings

Material required for the installation of PVC Duct Wiring

1) PVC duct and its fittings of required size and quantity/length.
2) Washer headed timber screws of 1 and1.5 inch size.
3) Cable ties.
4) Rawal plugs or Gatties.
5) Cotton string and blue or black liquid for string immersion.
6) Wooden screws of different sizes for fixing the switch boards, lamps, ceiling roses etc.
7) Cables of different sizes as required.
8) Different accessories like switches, sockets, power sockets, switch boards, ceiling roses, lamp holders etc. as per requirement of the installation.

Tools required for surface conduit wiring

1) Spirit level.
2) Heck saw.
3) Electric drill machine with concrete drill bit or hand Rawal plug tool.
4) Screw drivers of different types and sizes.
5) Phase tester.

6) Measuring tape.
7) Electrician pliers.
8) Long nose pliers
9) Side cutting pliers.
10) Hammer.
11) Electrician knife or wire stripper.

Method of installation of PVC Duct Wiring

1) Decide and indicate the circuit routes.
2) Mark blue coloured lines on these routs with the help of cotton string immersed with blue liquid. Ask the method of using cotton string to draw horizontal and vertical rout lines to your teacher.

> (Distance between fixing screw depends upon the size and weight of cables and duct and also on type of duct run (horizontal or vertical.For25mm x 25mm PVC duct, distance between fixing crews should not be more than 1m on horizontal runs and 1.5m on vertical runs and 150mm from any boards/boxes, bends etc.

3) Mark dots at appropriate equal distances on the cable routs on walls and ceiling.
4) Make holes on doted points of walls and ceiling with electric drill machine or hand Rawal plug tool.

> *No need of making holes if plastic saddles with steel nail have to be use, but these are not recommended.*

5) Insert the plastic Rawal plugs with hammer in these holes.
6) Fit the lower part of duct on the holes with washer headed wooden screws or use metal washers with wooden screws.
7) Fit lamp holders, ceiling roses and switch boards etc. on their places as per drawing.
8) Put the wires/cables in the ducts.
9) Hold the wires and cables in the duct with cable ties.
10) Put the upper part of the duct on lower part and press with hands to attach with the lower part.
11) Make connection with ceiling roses, lamp holders, switch boards and appliances etc.
12) Perform the necessary tests.

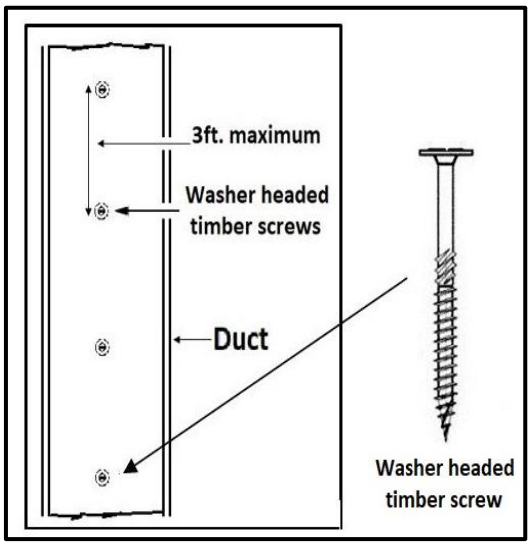


Fig 3.10: PVC Duct fixing method and screw

Some typical sizes of PVC duct (trunking) of Adam Jee. Co. Karachi.

Dura Duct Sizes with 3 meter length	
16mmx16mm	25mm x 40mm
16mm x 25mm	25mm x 60mm
16mm x40mm	40mm x 40mm
16mm x 60mm	50mm x 50mm
25mm x 25mm	40mm x 60mm
33mm x 33mm	60mm x 60mm
Dura Duct Sizes with 2 meter length	
80mmx 60mm	100mm x 50 3mm
80mm x 80mm	100mm x 100mm
100mm x 50 2mm	150mm x 150mm

Advantage of PVC duct Wiring System

1. Good substitute of PVC conduit.
2. Very cheap in cost.
3. Lighter in weight.
4. Very easy to install.
5. Less time is required to install.
6. No danger of electric shock.
7. No corrosion on plastic duct as in metal conduit.
8. No need to earth the duct like metal conduit.

9. No effect of acid, oil, grease etc. on pipes.
10. No risk of damage of insulation of cables during drawing in ducts.
11. Making new connections is easy.
12. No high skill is required to install this system.
13. Fault can be easily detected and can be fixed quickly.
14. No material wastage.
15. Good appearance.
16. Addition and alteration of cables is easy.
17. Laying of cables is easy than drawing of cables in conduits.
18. No special skill is required for installation.

Disadvantage of PVC duct Wiring System

1. Plastic ages, so less life.
2. Cannot bear the load of heavy cables.
3. Not suitable in high (above 70^oC) and very low(less than 0^oC) temperatures.
4. Not water and fire proof.
5. Thermal expansion can make the duct crooked.
6. Duct become loose after some time which seems very ugly
7. Mechanically weak than steel conduit and trunking.

Precautions in the installation of surface type PVC duct Wiring System

1) Select the correct rout before installation of conduit.
2) Always use vertical or horizontal runs between two points instead of using diagonal run.
3) Use washer headed wooden screws or use metal washers with wooden screws to fit the lower part of duct on walls or ceilings.
4) Use standard fittings of duct like Tees, internal, external 90^o bends etc. instead of bending the duct.
5) Always select the correct size of duct according to the number and size of cables to be used in duct.
6) Do not use too much cables in duct (keep at least 60% internal space of duct free).
7) There should not be more than two 90^o bends (or their equivalents) between two draw in boxes.

Fields of Applications of surface conduit

Like surface conduit, this system of wiring provides less protection against fire and mechanical damage, so this system is confine for use in homes, shops, computer labs, offices and small installations of single phase supply only.

Exercise

Part-1: Subjective type Questions

Sample Long Answer type questions

1) Write names of residential wiring systems and write advantages of surface type PVC conduit system.
2) Write advantages and disadvantages of steel conduit wiring system.
3) Which wiring systems have become obsolete in Pakistan, give reasons of their out dating?
4) Compare surface and concealed type conduit wiring system.
5) Compare PVC and metal conduit wiring system
6) Enlist accessories and material used in PVC conduit wiring system.
7) Enlist accessories and material used in PVC duct wiring system.
8) Write step wise procedure to install surface type steel conduit wiring system.
9) Write step wise procedure to install concealed type PVC conduit wiring system.
10) Write step wise procedure to install PVC duct wiring system.
11) Write advantages and disadvantages of steel conduit wiring system.
12) Write 10 precautions to be observed during installation of surface type steel conduit wiring system.
13) Compare PVC conduit and PVC duct system of wiring.
14) Write advantages of surface type PVC conduit wiring system.
15) Write advantages of surface type PVC duct wiring system
16) Write disadvantages surface type PVC conduit wiring system.
17) Write disadvantages surface type PVC duct wiring system

Part-2: Objective type Questions

Sample Short Answer type Questions

1) Define electric wiring.
2) Write the names of surface type wiring systems.
3) Define indoor and outdoor type wiring systems.
4) Write two differences between domestic and industrial wiring systems.
5) Write names of two methods of making connections in wiring.
6) Write two advantages of surface type PVC conduit wiring system.
7) Write two advantages of concealed type PVC conduit wiring system.
8) Write applications (uses) of surface type PVC conduit wiring system.
9) Write applications (uses) of concealed type PVC conduit wiring system.
10) Write two advantages and two disadvantages of PVC duct wiring system.

11) Enlist material required to install a PVC duct wiring system.
12) Write 02 advantages of heavy gauge steel conduit wiring system.
13) Which precaution is considered when a conduit is terminated at a metal box?
14) Write 02 disadvantages of metal conduit wiring system.
15) Write names of 08 tools required to install heavy gauge steel conduit wiring system.
16) Write 04 precautions which are considered during the installation of heavy gauge steel conduit wiring system.
17) Write the names of 04 fitting accessories of heavy gauge steel conduits.
18) In which type of buildings, the surface type PVC conduit wiring system is suitable.
19) In which type of buildings, the steel conduit wiring system is suitable.
20) Write the names of 04 types of conduit saddles.

Sample Multiple Choice Type Questions (MCQs)

1) This is not a domestic wiring system
   a. Batten wiring
   b. PVC conduit wiring
   c. Catenary wiring
   d. PVC duct (casing capping) wiring.
2) This wiring is very cheap and easy to install
   a. Cleat wiring
   b. Batten wiring
   c. PVC surface conduit wiring
   d. Concealed PVC conduit wiring
3) Conduit wiring system is installed
   a. on wall surface b. on ceiling surface
   c. concealed in walls and ceiling
   d. All these
4) This is a disadvantage of PVC conduit wiring system.
   a. Appearance is not good
   b. conduits are exposed to mechanical injury
   c. It has short life
   d. All these
5) The diameter of conduit used in wiring is 20 25 38 50
   a. 20mm b. 25mm
   c. 38mm d. All these
6) This system is not suitable for use in domestic premises
   a. Cleat wiring b. PVC surface conduit wiring
   c. PVC duct wiring d. PVC concealed conduit wiring

7) This wiring system is not being used in Pakistan, now a day.
   a. Batten wiring
   b. Wood casing and capping wiring
   c. PVC duct wiring
   d. Both a & b
8) There should be not more than this, the 90° turns between two junction boxes of conduit.
   a. 02 b. 03
   c. 04 d. 06
9) Cables of this insulation are used in steel conduit wiring system.
   a. VRI b. PVC
   c. XLPE d. Both a & b
10) This size of steel conduit is not used in electrical wiring.
   a. 20mm b. 32mm
   c. 38mm d. 48mm
11) This conduit is not used in electrical wiring.
   a. Heavy gauge Steel conduit.
   b. Flexible metal conduit.
   c. PVC conduit.
   d. None of these.
12) This wiring system should be installed in textile mills.
   a. PVC duct system. b. Steel conduit system
   c. Batten wiring system d. PVC conduit system
13) TRS wiring system is used for lighting load at this voltage.
   a. Low b. Medium
   c. High d. All these
14) Non Metallic (PVC)conduit wiring system is usually used in
   a. homes b. Workshops
   c. industry d. Jute mill
15) Steel conduit wiring system is mostly used in
   a. Both b & d b. Commercial buildings
   c. Domestic buildings d. industry

ANSWER KEY

1	**c**	5	**b**	9	**d**	13	**a**
2	**a**	6	**a**	10	**d**	14	**a**
3	**d**	7	**d**	11	**d**	15	**a**
4	**d**	8	**a**	12	**b**		

Ch-4: Protection of House Wiring

Main Topics in this chapter

Protection of house wiring (i) Fuses and circuit breakers. (ii) Earthing.

Need for the protection of house wiring

There are three main faults which can occur in wiring and can cause damage to a person or installation. These are!

a) Short circuit
b) Over load
c) Earth fault

In case of over load and short circuit, heavy current flows through wiring circuitswhich heats up and damage the cables and evencan lead tofire. In case of earth fault, heavy current flows towards ground, which can also damage the electrical wiring. In case of earth fault, one can also get electric shock if make contact with such a faulty apparatus.

If no protective device/system is provided in the wiring, then a dangerous situation could arise.

In order to ensure complete safety of installation, building and persons using electrical apparatus, every circuit in an installation must be provided with some form of protective devices.(It is also the requirement of I.E.E regulation A-10).

On the occurrence of fault, the protective devices/system should immediately operate and isolate the faulty circuit from supply.

Fuse and Circuit Breakers are the guards of whole the installation which protect the installation from short circuit and overload faults. A building and its installations have no value without protective devices.

Name of Protective derives/systems of electrical installations

Following protective devices/systems are used for the protection of electrical installations and persons who are using the electrical apparatus.

1. **Fuse:** (Rewire-able, Cartridge and HBC type)
2. **Miniature Circuit Breaker (MCB)**
3. **Moulded case circuit breakers (MCCBs)**
4. **Earth leakage circuit breakers:** (current and voltage operated type)
5. **Earthing system:**

Definitions:

1. **Fuse:** A fuse is a piece of copper or tin alloy wire which melts when

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more than rated current passes through this wire. ***A fuse is always connected in series of the circuit to which it is protecting.***

2. **Miniature Circuit Breaker:** A small device that senses the fault (overload or short circuit) and disconnects the faulty circuit automatically. It can also work like a switch to make or break the circuit manually.
3. **Moulded case circuit breakers (MCCB)**
   A moulded case circuit breaker (MCCB) is a type of electrical protective device that is used to protect the electrical circuit from excessive current, which may be due to overload or short circuit. Mostly it is used as main circuit breaker in electrical installations.
   According to the operating current and operating time, MCCBs are of type B, C, D, and K & Z.
4. **Earth leakage circuit breakers:** An Earth-leakage circuit breaker (ELCB) is a safety device used in electrical installations with high Earth impedance to prevent the humans and animals from electric shock. It detects small stray voltages on the metal bodies of electrical appliances/machines and interrupts the circuit if a dangerous voltage is present in their metal body.
5. **Earthing:** Effective connection of electrical system or electrical equipment to the general mass of earth is called earthing(grounding in USA)

1. Fuses

i. Rewire-able or semi enclosed fuse

Rewire-able or kit-kat fuse is a cheaper form of fuse.It is a low voltage fuse, which is used in small applications like wiring in the house, small-scale industries, and other small current applications.

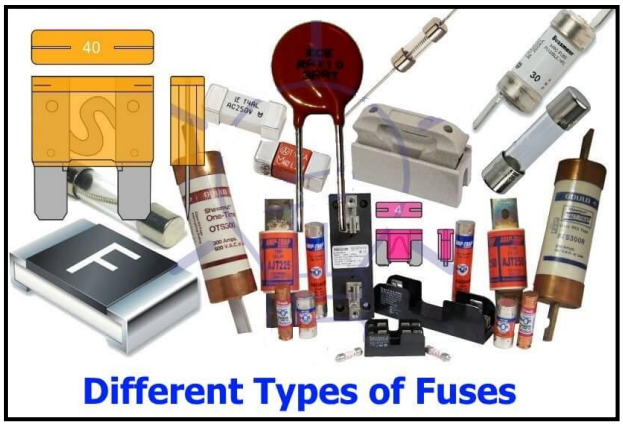

Fig. 4.1: Different types of fuses

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Construction of rewire-able or semi enclosed fuse: It consists of porcelain base (also called fuse grip) carrying the fixed contacts to which the incoming and outgoing live or phase wire is connected. This base is fitted on a board. The removable part is called fuse carrier (or fuse holder) holding the fuse element.Fuse base (or fuse grip) and fuse carrier (fuse holder), both the units are made up of porcelain or other suitable insulating material. The fuse element is connected between two blade type hard flat strips of fuse. The fuse carrier unit is push-fitted into the base unit to make the connection through suitable contacts. The fuse carrier unit is so constructed that there is no danger to the operator in removing the fuse link. Its higher fusing factor (which is 2) results in lower cable current capacity or conversely large cable size.

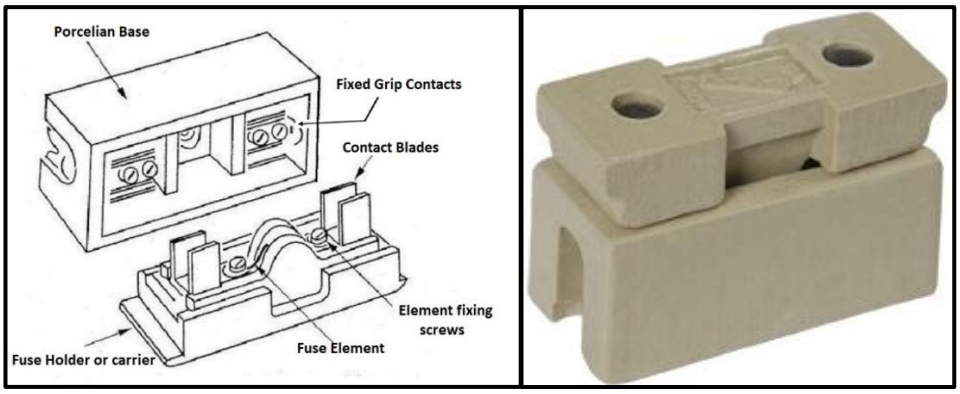

Fig. 4.2: Rewire able fuse

Application: Mainly used in domestic buildings but now gradually being replaced by other protective devices. These are used for coarse excess current protection.

Current rating: 5A to 200A

Size of fuse element composed of plain or tinned copper wire for use in semi-enclosed fuses.

Sr. No	Current rating of fuse	Nominal diameter of wire
1	3A	0.05mm
2	5A	0.20mm
3	10A	0.35mm
4	15A	0.50mm
5	20A	0.60mm
6	25A	0.75mm
7	30A	0.85mm
8	45A	1.25mm

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9	60A	1.53mm
10	80A	1.80mm
11	100A	2.00mm

ii. Cartridge fuse:

It consists of a sealed glass tube with metal end caps. The fuse wire passes through the tube from cap to cap and is welded to the inside of the cap. Cartridge fuses are used in fused plugs, washing machines, voltage stabilizers, multi-meters, radio, televisions etc. Cartridge fuse with ceramic body are basically HBC fuse in shape of cartridge.

Fig. 4.3: Cartridge fuses with ceramic and glass body

iii. High Breaking Capacity (HBC) Fuse

It gives excellent short circuit current protection. It does not cause cable de-rating like rewire-able fuse**.** The HBC fuse consists of a ceramic tube with metal end caps and fixing tags. The fuse element is in the form of a silver strip of special shape with a low melting point rivet in the centre. The strip is entirely surrounded by chemically purified silica (or quartz powder). When an overload occurs, fuse element melts. The silica prevents the formation of arc, thus preventing overheating of the fuse and the surroundings**.**

Rating:

i. (BS 88-6) from 2A to 1200A
ii. (BS 13-61) from 5A to 100A

Application:

i. (BS 88-6)Mainly used in commercial and industrial applications for protection against overload and short circuit. M type fuses are suitable for motor protection.
ii. (BS 13-61) Used in house consumer unit for the protection of wiring.

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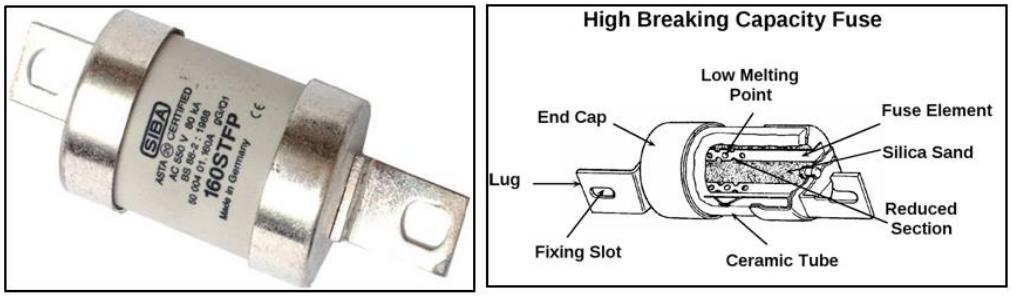

Fig. 4.4: HBC (old name HRC) Fuse and its parts

Circuit Breakers

i. Miniature Circuit Breaker (BS. 3871 and EN 60898)

Miniature Circuit Breakers (MCBs) are electromechanical devices which are used to protect an electrical circuit from an overcurrent, which could be a due to short circuit or overload. Unlike a Fuse, MCB does not have to be replaced every time after a fault occurs and it can be reused.Miniature circuit breakers have excellent operating characteristics**.** The tripping action may be either thermal or magnetic. In general, both actions are used in this type of circuit breaker*. Against constant over-current, thermal element trips the breaker with some time lag effect, while high speed protection against short circuit is given by magnetic element. It can be used as a switch to make or break the circuit manually. Every circuit breaker has specific ampere, voltage, and interrupting ratings. It may be single, two or three pole type.

Construction: A miniature circuit breaker consists of following parts

i. Operating handle (dolly).
ii. Thermal bimetal strip, works in case of over load
iii. Electro Magnetic relay works in case of short circuit.
iv. Fixed main contact.
v. Moveable main contacts.
vi. Trip catch.
vii. Arc control system.
viii. In and out connection terminals.

Applications: Used in domestic, commercial and industrial buildings for the protection of electrical appliances, lighting circuits, motor circuits and relay /contactor coils.

Current Rating: 1A to 63A with breaking capacity from 3KA to 25KA.
Poles: 1, 2, 3, & 4.

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The level of current will determine the method by which the breaker operates and therefore the speed of operation. With a fault of **less than 100A the **thermal** trip will operate. The current will not be sufficient to operate the magnetic coil. The speed of operation will be anything upwards of 10 seconds. Currents **above 100A and just below 1000A** will bring into play the magnetic operation. The **thermal trip will work in conjunction with the magnetic trip** to decrease the tripping time. Operation is between 0.5 and 10 seconds dependant on the fault current level. Currents **above 1000A** will operate the **magnetic trip** almost instantaneously before the thermal device has had an opportunity to start to operate. Operation is under 0.01 seconds.*

Fig. 4.5: A typical MCCB (left) &Single and double pole MCBs (right)

ii. Moulded Case Circuit Breaker (MCCB)

It is also a type of circuit breaker whose body is enclosed in moulded case. Its working principle is same as of miniature circuit breaker, however it is designed to operate on high currents in industries.

Current Ratings: 16A to 1200A

Breaking Capacity: From 22KA to 50KA

Poles: 2, 3, & 4

Comparison of MCB & MCCB

Sr. No	MCB	MCCB
1	Tripping mechanism thermal and magnetic	Tripping mechanism thermal and magnetic
2	Rated current up to100A	Rated current up to 2500 A.
3	Trip characteristics normally not adjustable specially in small ratings	Trip characteristics adjustable
4	These are basically single pole type, to make two, three or four pole MCB, 1, 2, 3 or 4 single pole MCBs are placed side by side and their knobs are attached together with a common strip.	These are 2,3 or 4 pole type enclosed in a single case.
5	Less accurate than MCCB	More accurate than MCB.
6	These are usually used to control branch circuits	These are usually used as main control Breakers.

Comparison of Fuse & Circuit Breaker

Fuse and circuit breaker, both are protective devices. Following are some differences between fuse and circuit breaker.

Sr. No	Fuse	MCB
1	Simple and cheaper	Expansive than fuse
2	Fuse is the oldest type of protection	MCB is a new type of protective device.
3	Works on thermal effect of current	Works on thermal and magnetic effect of current.
4	After melting, fuse element or complete unit has to be replaced	Circuit breaker can be reset for next operation after tripping.
5	Fuse element melts in case of fault.	No part melts in CBs.
6	Time lag cannot be added in general types of fuses.	Time lag can be added in many types of circuit breakers.
7	(Rewire-able)Fuse does not produce any voice during operation.	CBs produce voice during operation.
8	Rewire-able fuses are less reliable.	More reliable

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9	Fuse works for over current protection only.	Circuit breaker can work on overvoltage, under voltage, earth leakage along with over current duty too.
10	Looks not so beautiful	Looks beautiful
11	Wrong size of fuse wire in rewire-able fuse could be used by mistake.	No such problem
12	Not quick like breakers	Quicker in action

Advantages and disadvantages of rewire-able fuse

Advantages

1. It is the cheapest type of protection.
2. It requires no maintenance.
3. The minimum time of operation can be made much smaller than the CB.
4. It has current limiting effect.
5. Wire can easily be changed in short time without any special skill requirements.
6. Easily available.
7. Produces no smoke, considerable arcing or voice during operation.
8. Occupy less space.
9. Replacement of fuse wire is very cheap.

Disadvantages

1. Rating is unreliable.
2. Selection and grading of fuse wire is difficult.
3. Do not offer good short circuit protection.
4. Time is wasted in the replacement of fuse wire.
5. Discrimination between fuses in series is difficult.
6. Operation is slow in the case of short circuit or over loads.
7. It cannot withstand against starting current of motors due to which it cannot be used in motor circuits.
8. Has low breaking capacity.
9. There is chance of installing wrong size of fuse wire.
10. No indication of the melted fuse.
11. Fuse wire oxidized after some time and melts on less than the rated current.

Advantages and disadvantages of HBC fuse

Advantages

1. Simple, reliable and easy to install.
2. Cheaper than MCBs.
3. No maintenance is required.
4. The operation is quick and definite.
5. Capability of breaking high as well as low currents.
6. It has inverse time /current characteristics.
7. Fused unit can be recognized with naked eye.
8. Properties and current rating do not change with time.
9. No chance of using wrong sized wire like rewire-able fuse.

Disadvantages

1. Require to replace the complete unit after each operation.
2. More costly than rewire-able fuse.
3. Interlocking is not possible.

Advantages and disadvantages of MCB (as compared to fuse)

Advantages

1. Easy to operate and good looking appearance.
2. No replacement after operation (tripping). It can be reset for next operation.
3. Some varieties have facility of interlocking.
4. Time lag can be added.
5. Most reliable in operation.
6. Can withstand on instantaneous high currents (such as starting current of motors).
7. Circuit breakers are more reliable than fuses.
8. Circuit breakers can with stand for instantaneous high currents
9. Circuit breaker can be made to work on overvoltage, under voltage and earth leakage duty along with over current.
10. Circuit breakers can be interlocked while fuses do not.
11. There is a chance of using wrong size of fuse wire in rewire-able fuse but there is no chance of using wrong size of CB.
12. Circuit breakers are quicker in action (operate in 0.001 second in case of short circuit)

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Protection of electrical installations against phase to earth fault

Fuses and MCBs are basically designed to operate on over current, and they do not provide good protection against phase to earth fault especially when phase to earth fault impedance is high. To provide protection against earth leakage current especially in large electrical installations, earth leakage circuit breakers are recommended.

> IEE regulation D25 require that an Earth Leakage Circuit Breaker (ELCB) shall always be installed where the impedance of earth fault loop is high and fault current is insufficient to operate the fuse or other over current device.

There are two types of Earth leakage devices.

1. **Residual Current Circuit Breaker** (RCCB)or Current operated, or current balance or differential type Earth Leakage Devices. It is a new type of earth breaker and gives protection against overheating of conductors and fire. It is also called RCB (Residual Current Breaker)or RCD (Residual Current Device). It is less expensive and more popular now a days.
2. **Earth leakage CircuitBreaker (ELCB)** or Voltage operated earth leakage device. It is an old type of earth breaker and was designed to give protection against electric shock. They have many disadvantages* as compared to RCCBs but function is same as that ofRCCB.

Comparison of MCB & MCCB

Sr. No	ELCB	RCCB
01	ELCB stands for Earth leakage Circuit Breaker	RCCB stands for Residual Current Circuit Breaker.
02	Work on the principle of difference of voltage	Work on the principle of current balance.
03	Voltage Operated Device (Old Name, Old Technology).	Current Operated Device (New Name, New Technology).
04	It can only detect current that flow back through the main earth wire.	It ensures 100% detection of leakage current.
05	Connected to Phase, Neutral as well as Earth Wire.	It is only connected to Phase and Neutral Wire.
06	High cost	Low cost

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Voltage operated ELCB

It is an old earth leakage device and now seldom used. This device was designed to give protection against electric shock which can arise due to high impedance of earth fault loop. IEE regulation D25 states that a voltage operated ELCB should be fitted where fault impedance is greater than 40Ω.

Working principle of voltage operated ELCB

The basic principle of voltage operated ELCB is an operating coil which sense the voltage between protected metal work and earth electrode. When the potential difference (voltage) between the protected metalwork and earth reaches to a dangerous level i.e. 30V or above, the trip coil disconnects the consumer's main power supply. For an accurate detection of voltage rise, the voltage operated ELCB must have a separate electrode at least 30.5cm away from any other electrode. The earthing lead between the trip coil and the earth electrode must be insulated. For large installations, more than one voltage operated ELCBs should be installed with their own earth electrodes. Voltage operated ELCBs should not be used as a sole means of protection, and a backup protection (fuse or circuit breaker) is essential, because it can fail to operate due to some reason.

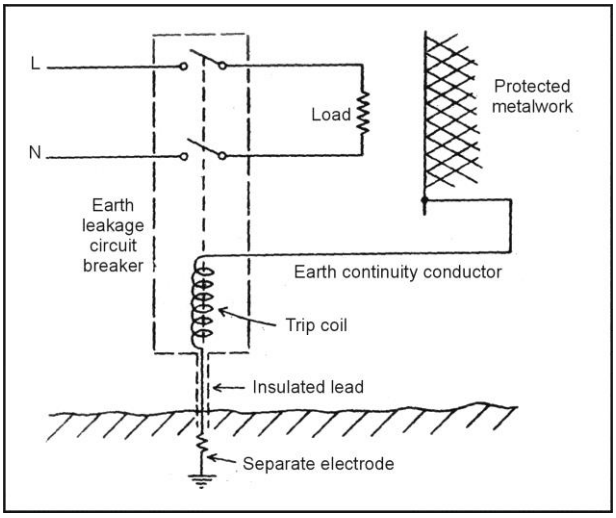

Fig. 4.6: Working of Voltage operated circuit breaker

Residual Current Circuit Breaker (RCCB) or *Current balance type ELD*

It is new earth leakage device which is now more popular due to its advantages and less cost than old voltage operated ELCB. Basically, current operated circuit breaker is designed to give protection against overheating of conductors and fire. It is installed in large installations where very heavy fault

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current would flow (causing overheating and even fire) before the over current devices operate.

According to the IEE regulation, differential earth leakage circuit breaker should be installed in the installation where the leakage current to the earth is more than the 15%of the rated currentor 5A, whichever is the greater. Its working depends upon the difference between currents of phase and neutral wire. (In normal healthy circuit, the algebraic sum of the currents of phase and neutral is zero at all the time).

Some drawbacks of an **ELCB** are as follow:

1. Without proper earth connection, ELCB will not work
2. In case of any a parallel path for the current to flow towards the earth (such as metallic pipes in a building), the ELCB will not be able to detect the dangerous voltage on the metallic body of the device, which may cause serious injury.
3. If someone gets in touch direct with live phase wire, ELCB will not Trip because in this case, there will be no current flow in the earth wire. In fact, current is flowing from the live wire to earth through the person's body.
4. In case of short circuit, ELCB will not trip because there will be no current in the earth wire.
5. In some cases, ELCB can trip without earth fault such a lightning strike.

Basic working principle of RCCB

When the live wire accidentally touches the metallic body of the connected device or appliance, then there is potential generated between the earthed electrode and the metallic body of that device. The ELCB senses the potential difference and if this potential difference reaches at 50 Volts then ELCB cuts off the main supply of the connected device. This way it ensures the safety of the human beings.

Explanation of working of RCCB

In the current operated ELCB, a current balance transformer is used with having two primary coils with opposite polarity in series of the load and one secondary coil. Under normal conditions, the current in phase and neutral wire is equal and opposite, hence their magnetic effect cancels each other. Therefore no flux flows in the iron core of transformer and no voltage is induced in the secondary coil. When an earth fault occurs, the fault current returns via the earth loop path instead of neutral wire. Thus current in phase wire increases than in the neutral wire. This unbalance of currents sets up a magnetic flux in the core which induces a voltage in the secondary (trip) coil. This coil activates and disconnects the main power supply of the consumer.

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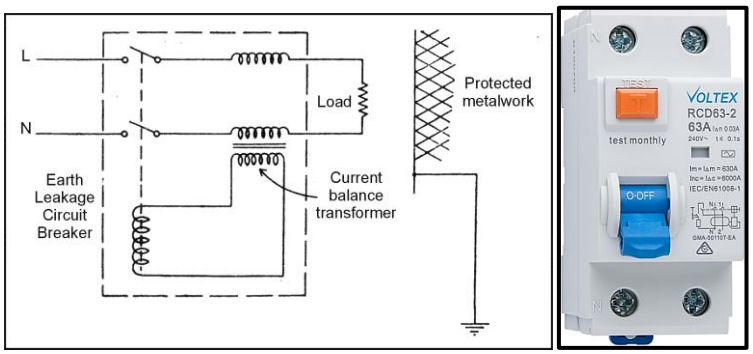

Fig. 4.7: Current operated circuit breaker, working diagram and sketch

It gives protection against electric shock if resistance to earth is low enough.

* It is very dangerous if there is another parallel path for leakage current. In this case the leakage current will flow to the earth through this parallel path and ELCB will not operate due to insufficient current through its trip coil.

Comparison of MCB &ELCB

Sr. No	MCB	ELCB
01	It works on the principle of thermal or magnetic trip	Earth breakers work on the principle of current balance (RCCB or RCD type) or on difference of potential (old ELCB) between neutral and earth.
02	MCB is designed to give protection against over current (over load and short circuit) in the circuit.	ELCB is designed to give protection against electric shock and RCCB is designed to give protection against overheating of conductors and fire.
03	It works when current in the circuit increases from a predetermined limit.	It responds only when the circuit current leaks towards the earth.
04	It is used to save the cables, devices, building from the danger of over current	RCCB version of earth breakers is also used to give protection against overheating of conductors and fire
	These MCBs may be SP, DP, or TP type.	These are 2 or 3 pole type enclosed in a single case.
05	There are different types of MCB depending upon the level of tripping current and operating time	Earth breakers are of instantaneous trip type.

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2. Earthing

Definition: Effective connection of electrical system or electrical equipment to the general mass of earth is called earthing (grounding in USA).The potential of earth is taken zero for all practical purposes.

OR

To connect all the accessible (reachable), exposed and noncurrent carrying metal parts of electrical machines/apparatus and the relevant metal work to the permanent wet part of the earth through a low resistance wire is called earthing.

Classification of earthing

1. ***Equipment earthing*** (earthing of outer metal body of electrical equipment and its supporting metal structure).
2. ***Neutral earthing*** (earthing of neutral of alternators and transformers).

Purpose of (equipment) earthing

The purpose of equipment earthing is to provide safety to personals and equipment from the danger of leakage current.It should be clearly in mind that an earthing system for the purpose of safety, works in combination with a backup of a protective device like fuse or breaker.

Parts of electrical installations that need to be earthed

1. Any metal work (other than the current carrying conductors) enclosing, supporting or associated with electrical machines/apparatus operating above 40V must be effectively earthed.
2. Earth pin of 3pin socket.
3. The metal casing of portable apparatus such as heaters, hand lamps, refrigerators, soldering irons, and electric drills.

Special precautionsare needed for bathrooms, kitchens, sculleries, laundries and all places where there are exposed water pipes.

Parts of an earthing system

1. Earth continuity conductor.
2. Earthing lead.
3. Earthing terminal.
4. Earth electrode (plate, rod or pipe).

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1. Earth continuity conductor

A cable or conductor to which the metal work to be earthed(conduits, ducts, boxes, metal casing switches, switch fuses, distribution boards, controlling and regulating apparatus, exposed metal work of machines and their mounting structure) is connected, and which itself is connected to the earthing lead through earthing terminal.

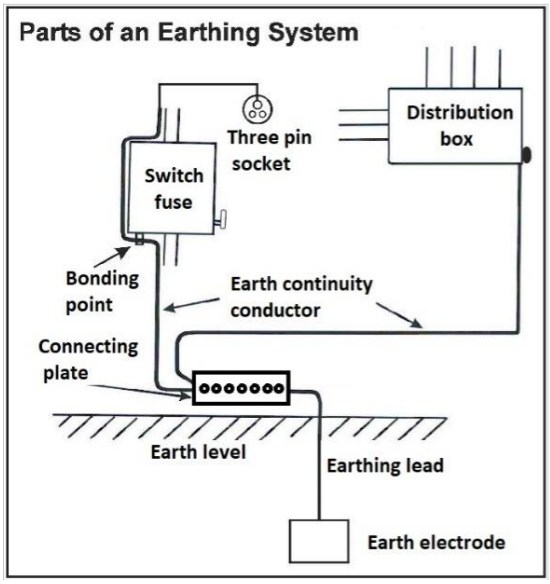

Fig. 4.8: Parts of an earthing system

2. Earthing lead

This is the conductor which connects the consumer's earthing terminal and the earth electrode or its equivalent buried in ground.

3. Earth connecting plate. It is thick metal plate with terminals on itusedas a source of connectionbetween the earth electrode and earth continuity conductor.

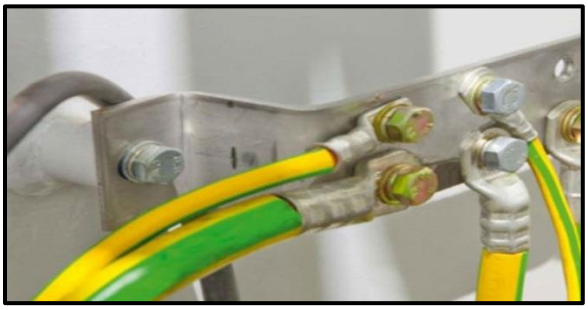

Fig. 4.9: Earth plate and connections of earthing lead and earth continuity conductors

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The material of earthing lead, earth continuity conductor, earth electrode&connecting nut bolts should be the same to avoid corrosion.

*The connection of an earthing lead to an earth electrode must be readily accessible and soundly made by soldered joint or clam. A permanent label marked **"Safety Electrical Earth", "Do Not Remove"** shall be permanently fixed at the point of this connection.*

4. Earth electrode

A metal plate, pipe, strip or rod of copper or galvanized steel buried (or driven) into the soil of the earth and to connect it to the electrical equipment is called earth electrode.

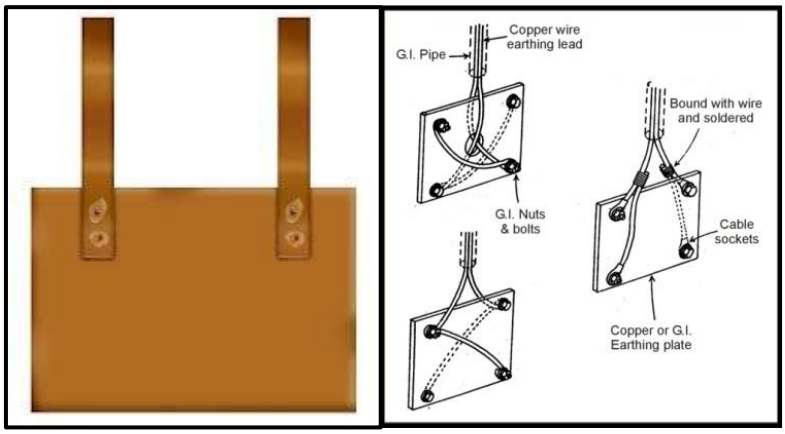

Fig. 4.10: Copper plate & methods of connecting earthing lead with it

Earth electrode may be in the form of:

1. Copper or G.I Plate
2. Copper rod.
3. G.I pipe.
4. Copper or G.I Strip or wire.

The number and type of earth electrode required in an installation depends upon the factors such as type of soil, type and capacity of installation and equipment and required level of earth resistance.

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The earth fault current

When the ground fault occurs, the fault current goes down to the ground through the metal casing of earthed electrical apparatus and earth conductor, to the consumer's earth electrode buried in earth. It then passes through the general mass of the earth and then to the neutral of the supply transformer forms a circuit called path of earth fault current.

*IEE Regulation D34 states that the **use of gas or water pipes as sole electrode is no longer recognized**. Thus, even if an earth connection to a water supply pipe is available and is agreed to by the water authority.*

This is called the ***fault current loop***. Since it is a circuit, having a particular impedance, so the level of fault current depends upon the impedance of this path i.e. less the impedance more the fault current to operate the protective device.

So it is obvious that impedance of fault loop should be minimum.

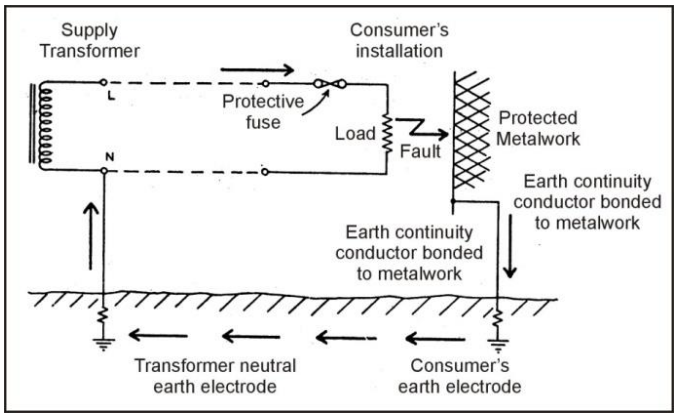

Fig. 4.11: Path of earth fault current

Maximum permissible resistance of earth system

Although, a low resistance of the earth path is the primary requirement of an earthing system, so that it could operate the protective device (fuse, circuit breaker or relay) installed for this purpose. If the resistance of an earthing is high enough, the best protective gear will be unreliable. Although there is no hard and fast rule for the level of earth resistance, however following are some values for reference:

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1. *Resistance of earth continuity conductor: F*rom the earth electrode to any point in the installation inside an installation= 1.0 Ω.
2. *Installations under 8KW: F*rom any point of the installationto the earth connection terminal = 3.0 Ω.
3. *Installations above 8KW:F*rom any point of the installationto the earth connection terminal = 1.0 Ω.
4. *Large Installations:F*rom any point of the installationto the earth electrode = 1.0 Ω.
5. *From earth connecting point to the earth electrode*= 1.0 Ω.

Method of earthing

1. Plate earthing method.

In this method of earthing, plate of copper or galvanized steel is buried at least 3 meter deep into the ground with its face vertical.Earth plate should be buried 30 cm below the permanent water level, if the ground water level is available whole the year.If the ground water level is very deep, then earth plate is buried 3m down in the earth. This earth plate is embedded in alternative layer of charcoal* (wood coal) dust, sand and lime (equal in portion) of minimum thickness of 15cm and up to30cm.This keeps the earth electrode wet thereby reducing the earth resistance. The earthing lead is bonded with earth plate at two places by nut bolts and washers of the same material as of plate.

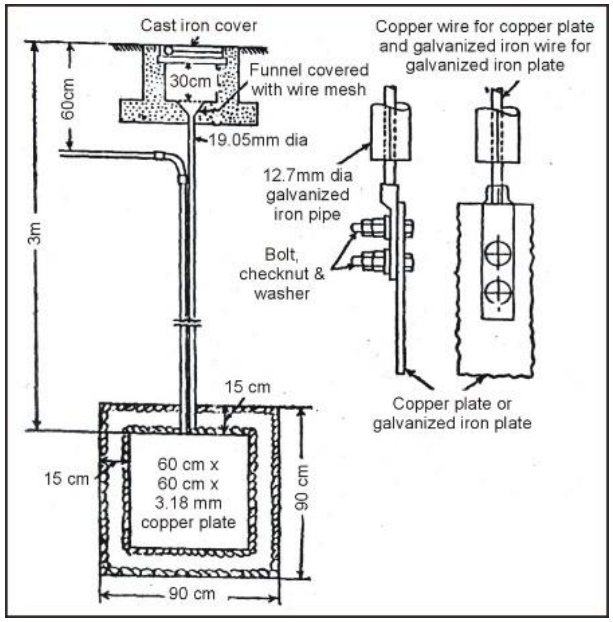

Fig. 4.12: Method of plate earthing

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The earthing lead is brought to earth terminal plate through a GI pipe of 19mm diameter. Another pipe with funnel and mesh at top is used to pour water for dampness around the earth electrode.

> Pour three to four buckets of water into sump after every few days to keep the soil moist around the earth plate.

Size of earth plate:

For all loads above 20KW at medium and high voltage

i. Copper = 600mm x 600mm x 3.15mm
ii. G.I = 600mm x 600mm x 6.15mm

For installations up to 66KW at 400V

i. Copper = 300mm x 300mm x 3.15mm
ii. G.I = 450mm x 450mm x 3.15mm

1) ***Pipe earthing method***

It is a cheapest and easy to install (ifthe soil is not rocky) method of earthing for small installations now a days. In this method, a galvanized and perforated pipe of approved length is used in place upright in a permanent wet soil. Usually a 2.5 meter long pipe of 38mm diameter is used for ordinary soil and of bigger size in case of dry soil. The lower end of the pipe is tapered for easy driving into ground. The depth at which the pipe must be buried depends upon the moister of the of the soil but not less than 3.0m. Along the length of pipe, holes of 12mm dia. at a distance of 75mm are made all around the four sides of pipe. The earthing lead (wire), soldered and connected to the pipe is covered through 13mm pipe which is connected to another pipe below funnel position.

The earth wire of sufficient diameter is buried in a pipe of 13mm dia. at a depth of 60cm from the ground. Alternative layers of lime and wood coal powder are provided to keep the surrounding of pipe always wet. *The contact surface area of G.I pipe with soil is more than the plate electrode, so it can carry heavy leakage currents for the same electrode size.*

3. ***Rod earthing method***

It is the cheapest method of earthing and is used in sandy areas. In this method of earthing, 12.5mm diameter solid copper rods (or 16mm dia. for galvanized steel rod) of length not less than 1.2 meter are directly driven vertically into the ground. To reduce the earth resistance to desire level in some applications, the length of rods is increased by hammering more than one rods one above the other**.** The rods are provided in sections fitted with screwed coupling, the lower one having a hardened steel tip and the upper

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one with a steel driving cap. In general, the length of a rod is more important than its diameter.

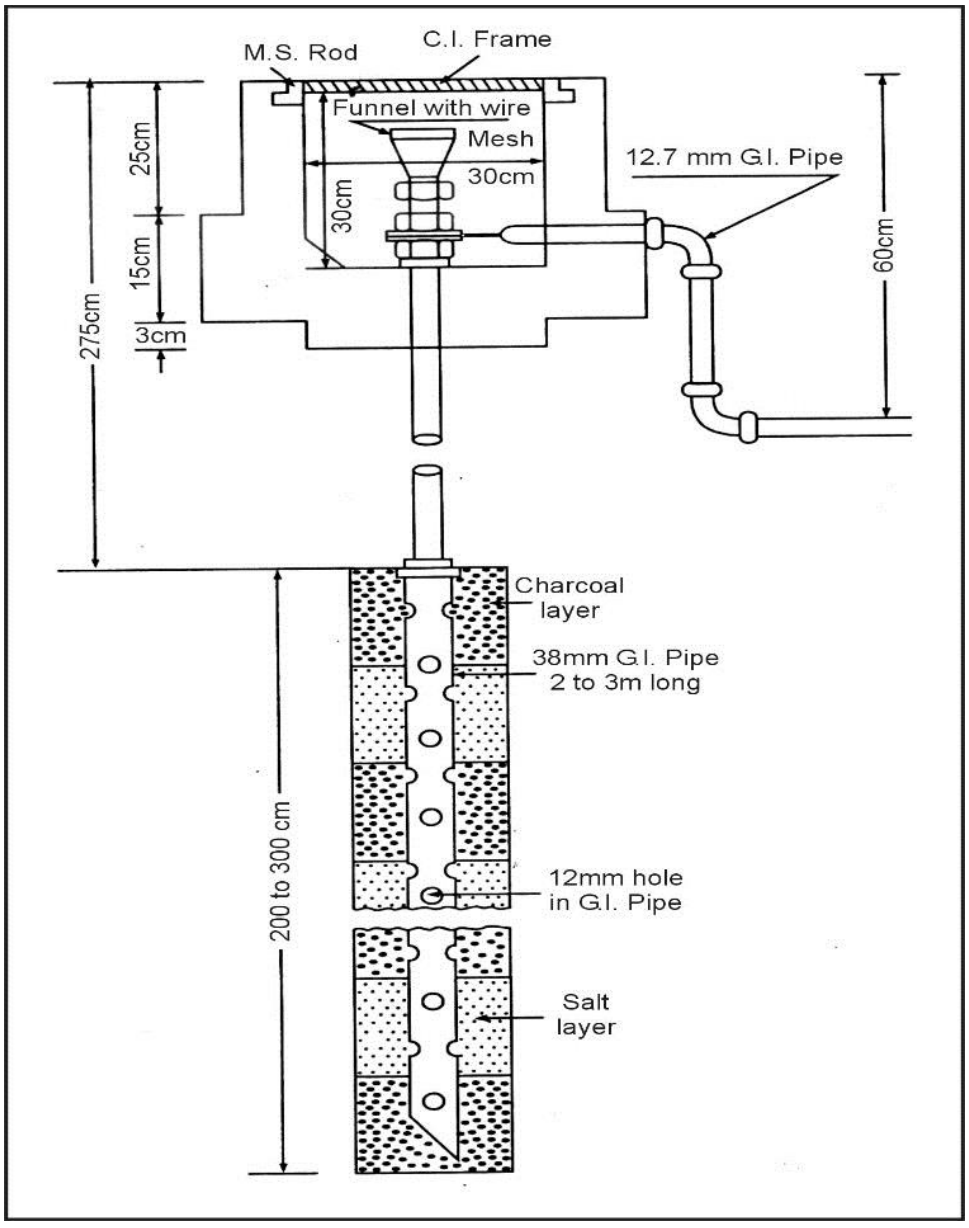

Fig. 4.13: Method of pipe earthing

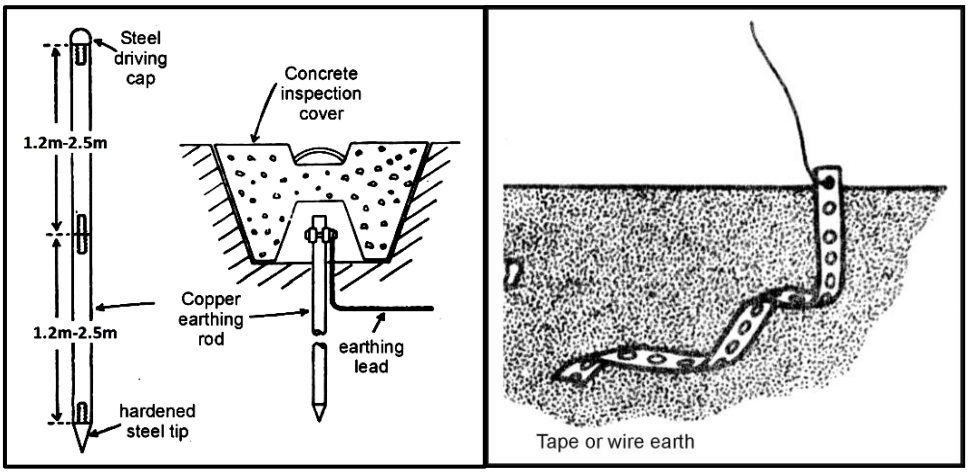

Fig. 4.14: Copper rod (left) and strip/tape earthing (right)

4. ***Strip or wire earthing method***

In this method of earthing, a strip electrode of cross section not less than 25mm x 1.6mm for copper and 25mm x 4mm for galvanized iron or steel are buried in horizontal trenches of minimum depth of 0.5m.If round conductors are to be used, their cross sectional area shall not be less than 3.0mm^2 for copper and 6mm^{2}for galvanized steel or iron. The length of buried conductor depends upon the level of resistance required and type of soil and its moisture content but it should not be less than 15 meters.

Rules about wiring and earthing

Rules about wiring

Following electricity rules are related to wiring, see their actual wording in Ch-9

Rule No 25: ***Precaution against leakage before connection.***

Supply Company will not provide connection to the consumer if amount of leakage current in the installation is more than 1/5000th of the demanded load current

Rule No 28: ***Declared pressure of supply to consumers.***

Supply Company will declare standard voltage of the supply and change in single phase supply voltage will not be more than $\pm$ 5% of the declared supply voltage. Suppose if frequency is 230V then maximum allowable change will be $\frac{5}{100}$x230 = $\pm$ 11.5V

(So supply voltage at consumer terminal should not be less than 218.5V and not more than 241.5V)

Rule No 29: ***Declared frequency of supply to consumers.***

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Supply Company will declare standard frequency of the supply and there will be no change in frequency more than $\pm$ 4% of the declared frequency. Suppose if frequency is 50Hz then maximum change will be $\frac{4}{100}$ x 50 = $\pm$ 2 Hz

(So frequency of supply should not be less than 48Hz and not more than 52Hz)

Rule No 32: ***Limits of errors in the meters.***

Error of meters manufactured according to BSS, the given rule should not be more than 3%.

Rule No 40 Cut-out on consumer's premises.

1) Supply Company will install a cut out fuse (according to the maximum demand of the consumer) at an accessible position as close as possible to the point of entry on phase wire of the service line and seal it inside the consumer building.
2) If more than one consumer are being supplied through a common service line, Supply Company will install individual cut out fuse for any consumer on his demand at junction point.

Rule No 51: ***Identification of earthed and earthed neutral conductors and positions of switches and cut-outs therein.***

(i) If two or more than two supply wires are used for power supply, then there should be arrangement of their identification (which one is phase, neutral and earth).

(ii) In general, single pole switch (or MCB) or fuse will not be installed on phase wire, however link can be used on neutral for testing purpose and SP switch or link on neutral or earth wire can be used for testing purpose on generating stations.

Rule No 57: ***Connection with earth of frames of generators, etc.***

At medium or high pressure supply!

(i) All live parts of apparatus shall be protected by mechanically strong metalcasings.

(ii) Every accessible conductor shall be protected by mechanically strong metalcasings and should be accessible to an authorized person only or should be out of reach.

(iii)The supply to every apparatus shall be efficiently controlled by suitablelinked switches, of requisite capacity.

(iv)The word '**Caution**', both in English and local language, shall be affixedpermanently in a conspicuous position, where possible, on every generator and every motor and every controlling or regulating apparatus.

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Rule No 60: ***General precautions applicable to supply at medium or high pressure.***

(i) Suitable linked switch, of required capacity to carry and break the current, shall be inserted in each conductor, near the point of origin on the consumer's premises.

(ii) The supply to very apparatus shall be efficiently controlled by suitable linked switched, of requisite capacity.

(iii) All accessible live parts of apparatus shall be protected mechanically by strong metal casings.

(iv) Suitable linked switch, of required capacity to carry and break the current, shall be inserted in each conductor, near the point of origin on the consumer's premises

Rule No 61: ***Main switchboard*** (of medium or high voltage)**.**

(i) Clear space of not less than 3 feet in width shall be provided in front of the switchboard of medium or high voltage.

(ii) At the back of the switchboard, there should be at least 9 inch (22.86cm) distance from any bare conductor.

(iii) If at the back of the switchboard, there is an open space of 2.5 feet (0.762m), then up to 6 feet (1.83m) height, there should be no hurdle for passing.

General Guidelines for wiring

1) Height of different wiring fittings from floor level should as given below.

a.	Wall socket out lets:	20-30cm
b.	Switch boards:	1.5m
c.	MDB and SDBs:	1.75m
d.	Distance of SB from door:	0.25m
e.	Ceiling from Horizontal run of wiring:	0.25-.5m
f.	Horizontal run of wiring:	2.75m

2) At least 2 two pin sockets in 3mx3m room.
3) Use wires/cables keep in mind the space factor for each wiring system.
4) Use suitable size of wooden screws to fix the wiring accessories.
5) Light and power circuits should be run and control separately from the starting point.
6) In case of three phase supply, put equal single phase load on each phase.
7) Each socket should be controlled by individual switch.
8) Use good quality cables of suitable size and type according to load.
9) All exposed metal work related to electricity should be earthed properly.

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10) Use at least 1 earth electrode for single phase supply and 2 for three phase supply.
11) Minimum size of cable for light loads is 1.5mm^{2}and 2.5mm^2 for power loads.
12) Don't use ceiling rose above 250V.
13) Maximum power on final sub circuit o 5A is 800W(1000W for pure resistive load)
14) Maximum No of points on 5A lighting sub circuits are 10 for incandescent lamps.
15) For loads above 5KW, use ELCB.
16) Main control box should be readily accessible at safe place near the load.
17) All single pole switches (or MCBs) or fuse should be installed on phase wire only.
18) Each sub circuit should be controlled with suitable size of fuse or breaker.
19) Don't use socket for load above 30A.

Rules about earthing

Rule No54. Metal casings. All metal casings/metallic coverings containing or protecting any electric supply shall be connected with earth.

Rule No 57 Connection with earth of frames of generators, etc. The frame of every generator, motor, transformer and all their controlling or regulating metallic parts should be earthed from two points.

Rule No 58 Connection with earth of a multi-wire system. Neutral wire of distribution system shall be earthed from two separate and distinct points of the neutral bus-bar. There are some exceptions.

Rule No 59. Connection with earth of concentric conductors:

When concentric conductors are used, the owner will maintain the insulation throughout, except that the external conductor may be connected with earth at one point.

Rule No 67. Connection with earth of metal supports and stay-wires

Rule No 76.Guard-wires. Every guard-wire shall be connected with the earth at each point at which its electrical continuity is broken and, in the case of electric traction lines.

- All metallic poles and towers of transmission and distribution lines should be earthed.
- Metallic conduits, Trunking and trays of wiring should be earthed.
- Earth pin of three pin sockets of wiring should also be earthed.

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Exercise

Part-1: Subjective type Questions
Sample Long Answer type questions

1) (a) Write note on the need of protection of house wiring.
   (b) Write the names of protective devices which are used in house wiring.
2) Write a note on MCB and HBC fuse.
3) Write 10 differences between MCB and HBC fuse.
4) Write about the construction of HBC and MCB.
5) Enlist parts of MCB and rewire-able fuse.
6) What is difference between current rating and breaking capacity of MCB?
7) Compare MCB and MCCB.
8) Compare HBC and rewire-able fuse.
9) Write 04 advantages and 04 disadvantages of rewire-able fuse.
10) Write 04 advantages and 04 disadvantages of HBC fuse.
11) Make sketch and explain working of current operated earth leakage circuit breaker.
12) Write in detail the method of plate earthing.
13) Write in detail the method of pipe earthing.
14) Write in detail the method of rod earthing.
15) Write limitations and advantages of plate earthing.
16) Write limitations and advantages of pipe earthing.
17) How earthing provides protection against electric shock, explain with the help of neat sketch.
18) Write note on strip earthing and protective multiple earthing.

Part-2: Objective type Questions
Sample Short Answer type Questions

1) Write IEE regulation A-10.
2) Define fuse.
3) Define MCB.
4) Write two differences between MCB and MCCB.
5) Write two differences between HBC and MCB.
6) Define earth leakage circuit breaker and enlist its types.
7) Write the names of parts of rewire-able fuse.
8) Enlist types of fuses.

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9) Define current rating of fuse.
10) Define breaking capacity of circuit breaker.
11) Write applications of MCB.
12) Write the types of MCB with respect to working principle.
13) Write 04 advantages of HBC fuse.
14) Write 04 disadvantages of HBC fuse.
15) Write 04 advantages of MCB.
16) Write 02 disadvantages of MCB over HBC fuse.
17) Enlist 04 parts of HBC fuse.
18) Define earthing.
19) Enlist types of earthing system.
20) What is difference between equipment earthing and neutral earthing?
21) What is the purpose of earthing?
22) Write the names of 04 metallic components of wiring which do not need to be earthed.
23) Write the names of 04 metallic components of wiring which must be earthed.
24) Write the names of parts of an earthing system.
25) Define earth continuity conductor (ECC).
26) Write the names of 04 components of wiring which can be used as earth continuity conductor.
27) Write minimum and maximum size of earth continuity conductor of copper.
28) Write two advantages of rod earthing over plate earthing.
29) Write the names of 04 types of earth electrode.
30) Define path of earth fault current.
31) Enlist the names of methods of earthing
32) Define protective multiple earthing.

Sample Multiple Choice Type Questions (MCQs)

1) A fuse is provided in an electric circuit for
   (a) Safeguarding the installation against fault currents
   (b) Reducing the current flowing in the circuit
   (c) Reducing the power consumption
   (d) All of the above
2) The rating of fuse wire is always expressed in;
   (a) Volts (b) Amperes
   (c) Volts-Ampere (d) Ampere hours
3) A fuse is normally a
   (a) Power limiting device

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(b) Voltage limiting device
(c) Current limiting device
(d) Power factor correcting device

4) The fuse blows off by
(a) Arcing (b) Burning
(c) Melting (d) None of the above

5) Protection of fuses is generally not used beyond
(a) 200 A (b) 50 A
(c) 25 A (d) 10 A

6) A material best suited for manufacturing of fuse wire is
(a) Silver (b) Copper
(c) Aluminium (d) Zinc

7) In comparison to rewire-able fuse, HBC fuses have the advantage(s) of
(a) High speed operation
(b) High rupturing capacity
(c) No ageing effect
(d) All of the above

8) MCB stands for
(a) Miniature Circuit Breaker
(b) Minimum Current Break
(c) Most Common Breaker
(d) None of these

9) HBC is a new name of
(a) HMC (b) HRC
(c) MCB (d) None of these

10) MCCB stands for
(a) Moulded Case Circuit Breaker
(b) Minimum Current Carrying Breaker
(c) Most Common Circuit Breaker
(d) Make Contact Control Brush

11) This need to be replaced completely after operation
(a) MCB (b) Rewireable fuse
(c) HBC fuse (d) MCCB

12) Body of cartridge fuse is made with this material
(a) Glass (b) Ceramic
(c) Mica (d) Both (a) & (b)

13) MCB as compared to MCCB
(a) Is less accurate
(b) Has less current rating
(c) Is used for single phase supply
(d) All these

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14) Tripping mechanism of MCB may be
   (a) Thermal type (b) Magnetic type
   (c) Mechanical type (d) Both (a) & (b)
15) Thermal part of MCB is designed to operate on
   (a) Overload (b) Short circuit
   (c) Open circuit (d) both a and b
16) Earthing of electrical equipment is necessary for the protection against
   (a) Overloading
   (b) Voltage fluctuation
   (c) Danger of electric shock
   (d) High conductor temperature
17) The earth wire should be
   (a) Good conductor of electricity
   (b) Mechanically strong
   (c) Mechanically strong but bad conductor of electricity
   (d) Both (a) & (b)
18) The resistance of earth should be
   (a) Infinite (b) High
   (c) Low (d) Minimum
19) Which of the following soil will be preferred for earthing
   (a) Wet clayey soil (b) Dry and rocky soil
   (c) Sandy soil (d) Both (a) & (b)
20) Earth electrode can be in the form of
   (a) Strip or wire (b) Rod or pipe
   (c) Plate (d) Any of these
21) Which of the following cannot be used as earth continuity conductor?
   (a) Gas pipe
   (b) Water pipe
   (c) Structural steel members
   (d) Both (a) & (b)
22) Which of the following mixture is preferred for filling around the earth electrode for effective earthing?
   (a) Coal-lime mixture
   (b) Lime-sand mixture
   (c) Sawdust-sand mixture
   (d) Any of the above
23) Inside the earth pit, the earthing electrode (plate) should be placed
   (a) Horizontally (b) Vertically
   (c) Inclined at 45° (d) In any position
24) Resistance of an earth continuity conductor should be less than;
   (a) 5 Ohm (b) 1 Ohm

`

(c) 10 Ohm (d) 70 Ohm

25) The size of copper earth plate for loads up to 66KW at 400 voltage
   (a) 600mm x 600mm x 3mm
   (b) 600mm x 600mm x 6mm
   (c) 300mm x 300mm x 3mm
   (d) 1200mm x 1200mm x 6mm

26) Protective multiple earthing system is used in areas
   (a) Hilly areas
   (b) Having clayey Soil
   (c) Where water level in not very deep
   (d) All these

27) This method of earthing is cheaper and easy to install
   (a) Pipe earthing (b) Rod earthing
   (c) Strip earthing (d) Plate earthing

28) This method of earthing is used in rocky soil bed where digging work is difficult
   (a) Pipe earthing (b) Rod earthing
   (c) Strip earthing (d) Plate earthing

29) In this method of earthing, the earth continuity conductor is connected to earth and to neutral wire also
   (a) Pipe earthing (b) Rod earthing
   (c) Strip earthing (d) Protective multiple earthing

30) It is not the part of an equipment earthing
   (a) Earthing lead
   (b) Earth continuity conductor
   (c) Earth connecting point (d) Earth wire

ANSWER KEY

1	**c**	9	**b**	17	**b**	25	**a**
2	**c**	10	**c**	18	**c**	26	**c**
3	**d**	11	**a**	19	**c**	27	**d**
4	**a**	12	**a**	20	**a**	28	**d**
5	**d**	13	**c**	21	**a**	29	**d**
6	**d**	14	**d**	22	**d**	30	**a**
7	**a**	15	**d**	23	**a**		
8	**b**	16	**a**	24	**b**		

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Ch-5: Distribution of Supply and Distribution Boxes

Main Topics in this chapter

Distribution of supply and distribution boxes. (Single and three phase)

Distribution Box*/board

Definition:

"It is an assembly of parts in a metal enclosure used for the distribution and control of electrical energy in a building is called distribution box/board".

If fuses are fitted in it, then it is called ***distribution fuse box/board***. (See Fig. 5.1 left). Sometimes, it is also called panel box/board, controlpanel or consumer box.

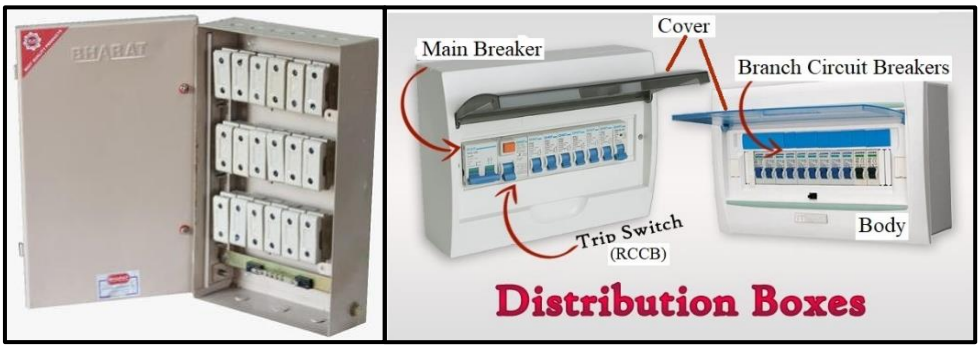


Fig. 5.1: A six way distribution fuse board (left) and single phase distribution boxes with RCCB &MCBs

*****The term distribution box is more appropriate than distribution board because today, it is a three dimensional unit having length, width and depth, therefore the term distribution box is being used internationally

Proper location of Distribution Box/Board

Following factors are considered for the selection of location of main DB and SDBs in a building.

1. It must be readily reachable in case of emergency.
2. Sufficient space must be available in front of box/board for the replacement of fuses/breakers and fault removal.

3. Should be safe from rain and flood water.
4. It should not be far from load centre.
5. Suitable walls/place should be available for fixing the DBs.
6. Cables could be run easily.
7. Location should be free from fumes and dampness.
8. Length of main and sub main cables should be minimized.

Depending on the installation and type of loading, distribution boxes/boards can be fed from one side or a ring form can be used.

Need and application: According to I.E.E regulations "A-1", *every consumer installation supplied from an external supply source shall be properly controlled by a control box having suitable switchgear installed in it* .It should be accessible to the consumer. The control box must be included as given below:

1. Means of isolation (main switch or MCCB).
2. Means of access current protection (fuses or MCBs)
3. Means of earth leakage protection(ELCB)

All these (Main switch or main fuse or main breaker, & distribution box/board) are combined in a unit for neatness, cheapness and ease of installation. This unit is called ***consumer's control unit.***

I.E.E regulation A-10 states that *"every conductor (cable) in an installation shell be protected by a fuse or circuit breaker fitted at the origin (starting point) of the circuit of which the conductor forms a part"*. The regulation also states that current rating of every fuse used for this purpose shall not exceed the current rating of the lowest rated conductor in the protected circuit, while every circuit breaker shall operate when subjected to a sustained current of 1.5 times the rated current of the lowest rated conductor.

Types of distribution box/board

1. With respect to phase.

i. *Single phase distribution boxes/ boards*. (For small residential installations with one bus bar for phase, one bus bar for neutral and one bar for earth connections).
ii. *Three phase distribution boxes/ boards*. (For large commercial & small industrial installations with three bus bars for three phases, one bus bar for neutral and one for earth connection).
iii. *Industrial Distribution boxes/ boards*: These are very large in size and rating. They also include bus bar chambers along with switch fuse units or

circuit breakers for separation of supply for different sections, separate switch room should be reserved for control gear with provision of future expected extension. The apparatus involved in the control gear of an industrial distribution board is as under:

i. One or more isolators.
ii. Main switchfuse.
iii. Bus bar chamber (TP&N)
iv. Main and sub main distribution boxes/boards.
v. Supply sealing box and cutouts.
vi. Energy meter (three phase).
vii. Consumer main control unit (includes mains fuse/MCCB, bus bar chamber and sub main switch fuses.

2. *With respect to duty*

i. Main distribution box/board (MDB): Installed for the main control of any installation. It must have!
   a. Control for light circuits.
   b. Control for power circuits
ii. Sub distribution boxes/ boards (SDBs). Installed for the control of different sub circuits.

3. *With respect to ways*.

No of spaces (holes) available at the top of a DB are called "Ways". According to the type of DB and need of installation, these may be from 2, 3, 4, 5, 6, 8, 10, 12…….. to 42 or more.

***4. With respect to material of DB*.**

i. *Distribution boxes/Boards made of electrostatic powder coatedsheet steel.*
ii. *Distribution Boards made of hard wood* (now outdated, and should not be used even if the wood is available)

5. *With respect to voltage and current rating*

Voltage and current rating of distribution boxes/boards depends upon the type and size of installation and its load. Following are two examples for reference only.

For medium sized residential Buildings

6-way, 250V, 16Apmeres of metal clad type.

For motor installations

6-way, 500V, 300A triple pole with or without neutral link iron clad

Construction of distribution boxes (Parts of a typical distribution board)

A distribution box may have following parts.

1. **Box:** All the components are installed in a cubical type box. Itis usually made of mild sheetsteel(of 12-16 gauge) with electrostatic powder coating. To ensure high degree of protection against corrosion and rust, all metal parts are -greased and pre heated before electrostatic powder coating. Hard wood of oak, teak, and mahogany has also been used in previous days, but now it not recommended. In Pakistan DBs of hard plastic are also available for low voltage installations, but these are also not recommended. The DB is usually provided with hinged door fitted with an earthing terminal. In small DBs, glass window is also provided in the door for looking into the distribution box/board. But for high voltage and high current ratings, this is not provided. Now a days, Miniature Circuit breakers are used instead of fuses in almost all types and sizes of DBs. Most of the distribution boards are being designed to fit circuit breakers
2. **Bus Bars:** One or three phase/line bus bars made of tinned plated copper of suitable current rating as per need of the installation are fitted in DB. Line and neutral bus bars are fitted on porcelain or Bakelite insulators to install in distribution box.Neutral bus bar having suitable no and size of screwed terminals of brass or copper.Earth bar is directly connected to the body of DB.

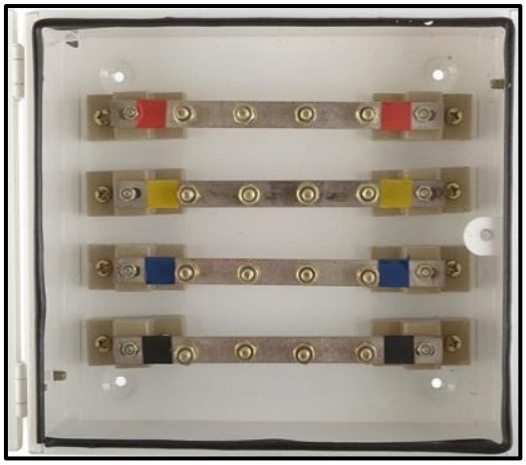


Fig. 5.2: Bus bars in distribution box

(Regulations require that the neutral conductors for the different sub circuits shall be connected in the same order as the live conductors to the fuses).

3. **Protective devices:** A moulded case circuit breaker (MCCB) for main control and number of miniature circuit breakers (or rewire-able or HBC fuses) of suitable rating are fitted in the DB. In small DBs of residential buildings, an earth leakage device is also fitted in the DB.
4. **Connecting cables and ventilated PVC duct:** Connecting cables of different ratings are used in DBs for connecting the protective devices with their respective circuits. These cables are connected with bus bars and breakers with suitable tinned copper thimbles. Ventilated type PVC duct is installed to accommodate all the cables.
5. **Ampere meter and volt meter**: Usually one volt meter and one ampere meter is fixed on the frontdoor of distribution box. In case of three phase supply, a selector switch for voltmeter and ampere meter is also fitted near the relevant meters. With the help of voltmeter selector switch, voltmeter can indicate line to line voltages and phase voltages. Similarly, ampere meter selector switch is used to indicate load on each phase. However, volt meter and ampere meter are optional to install.
6. **Phase indicating lights**. These are fitted on front side of control panel to indicate the availability of supply of each phase. In Pakistan, these are of Red, Yellow, Blue colour. Now a days, LED type lights are being used for this purpose. These are also optional.
7. **Insulators:** Up to 400V, Bakelite or porcelain insulators are fitted below the line and neutral bus bars to insulate them from metal body of DB. Above 400V, only porcelain insulators are used. Size of insulators depends upon voltage of the bus bar.
8. **Current Transformer (CTs):** In case of high current, ampere meter is not connected directly in series of loads. In such case ring type CTs are fitted on each phase to provide reduced current (in a definite ratio) to ampere meter. However meter shows original level of current on its scale.

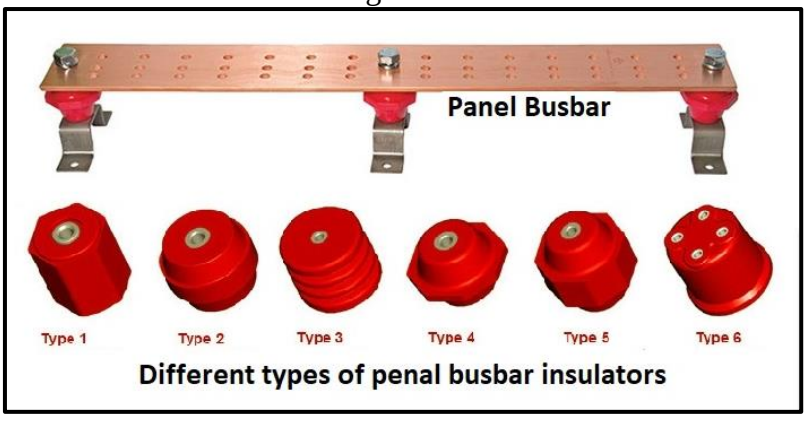


Fig 5.3: A typical DB bus bar and bus bar insulators

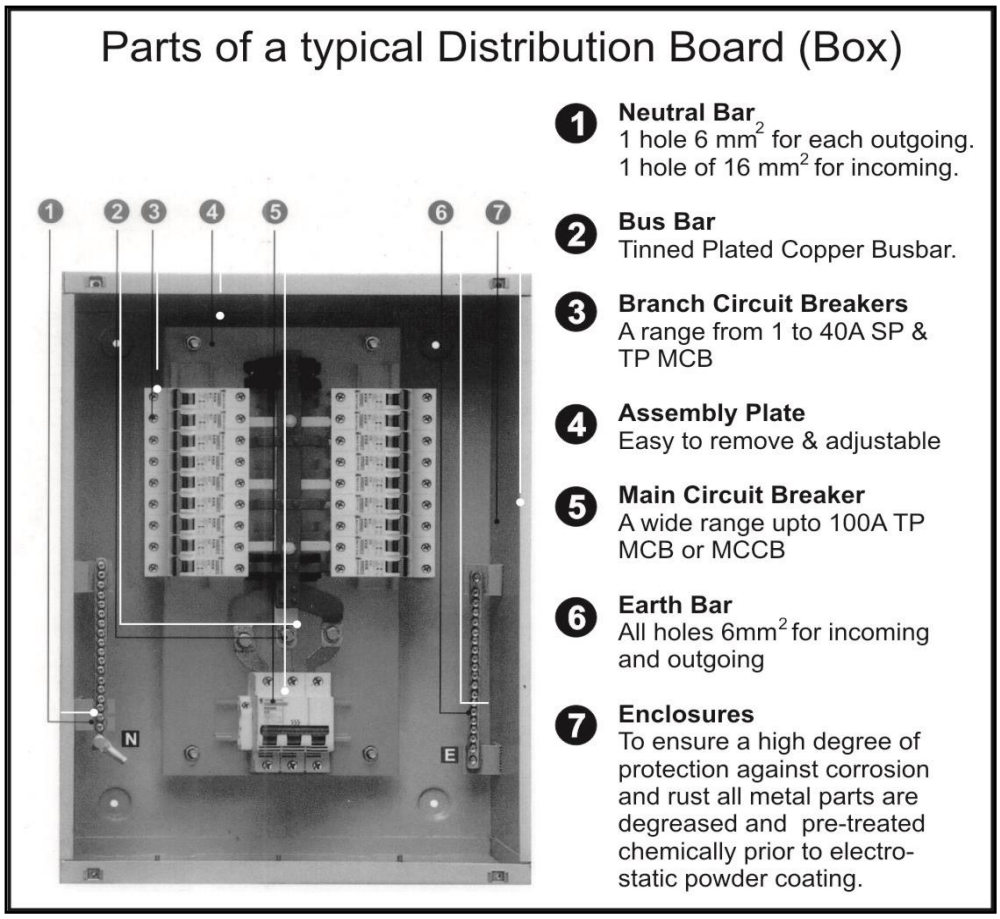


Fig 5.4: Parts in a typical three phase DB

Installing the distribution boards

Following are the steps for installation of Distribution Boards.

1. Preparation or buying the case of DB of suitable/required size.
2. Selection of proper location of main and sub main distribution boards.
3. Digging the space in the walls for DBs. Or DBs can be fitted on wall surface with rawl bolts. (Hollowing out process weakens the walls therefore space should be provided during construction work).
4. Fixing the DBs in place.
5. Fixing of insulators in the Distribution box.
6. Fixing of all the bus bars in place.
7. Fixing the fuses or circuit breakers.
8. Connecting the box body to earth.

9. Fixing and making connections of ampere meter, voltmeter, ampere meter and voltmeter selector switches and phase indicating lights.
10. Making connections of sub circuits to the relevant circuit breakers.
11. Making connections of neutral wires of different circuits to the neutral bus bar.
12. Making connections of earth continuity conductors of different sections to the earth bar.
13. Connecting the main breaker to main supply.

Distribution of supply in buildings

Distribution of supply in a smallsingle storey building

In case of singlephase supply for single story building, a service line is connected to the energy meter from the nearest distribution pole of Supply Company. Usually two core overhead cable is used for such installations. Before energy meter, a sealed cut out fuse should be installed by the supply company according to the demanded load, but in Pakistan this is not being practiced. After energy meter a two pole main switch is installed. From main switch, supply goes to a main distribution box/board, installed near the main switch. In small domestic buildings, only one DB is required. All the sub circuit fuses/breakers are fitted in this single distribution box. In large buildings, a main distribution box is fitted at a suitable place and main breaker and sub breakers are fitted in it. The supply is distributed from MDB to all sub main distribution boxes (SDBs) . No of SDBs depends upon the size of building and load of the building. Then each SDB supplies to a number sub circuits orfinal sub circuits in a particular portion of the building.

Parts of domestic wiring system

1. Service line (from distribution pole to energy meter).
2. Supply cut out fuse.
3. Energy meter.
4. Main cable or main circuit (cable or circuit from energy meter to MDB).
5. Sub main cable or sub main circuit (cable or circuit from MDB to SDB).
6. Final sub circuit (cable or circuit from switch board or from SDB to any current consuming device/machine in the wiring).
7. Point (the termination of fixed wiring feeding a lighting fitting, socket outlet, or any current consuming appliance in the building).

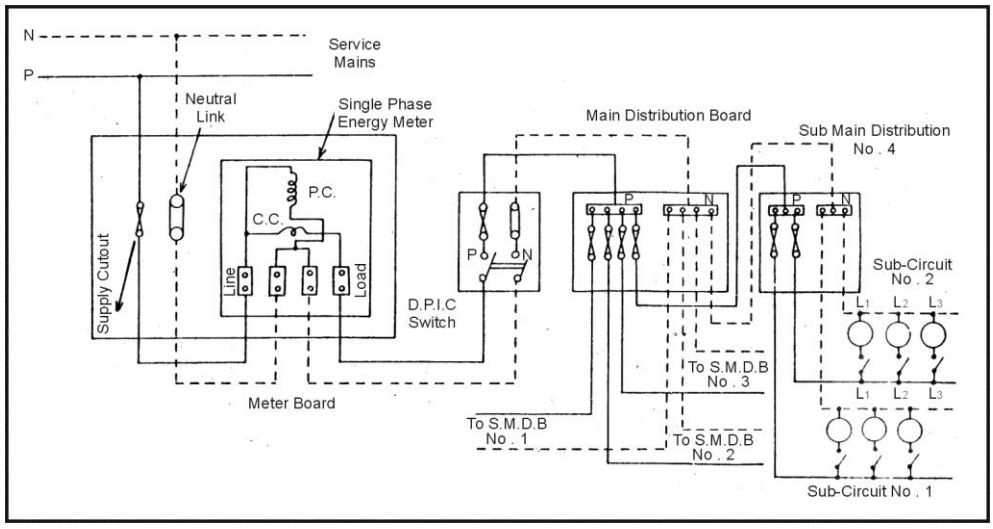


Fig. 5.5: Distribution of single phase supply in a small house

Distribution of single phase supply in a multi-storey building

In case of single phase ac supply for multi-storey buildings, the main control gear or consumer board is installed at suitable place on ground floor. No of ways of MDB depends upon No of SDBs that it has to feed. Usually one SDB is installed on each storey. Sometimes only SDB are fed direct from main switch.

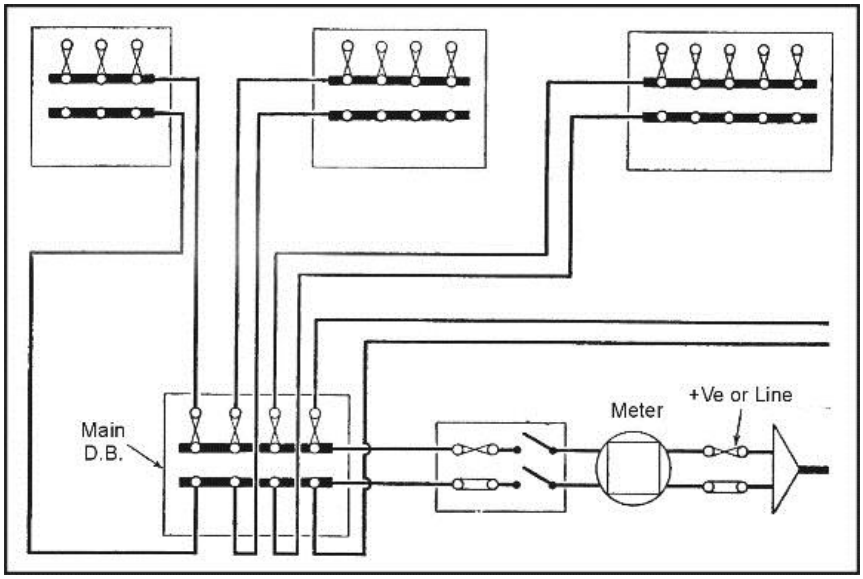


Fig. 5.6: A typical single phase Distribution of supply

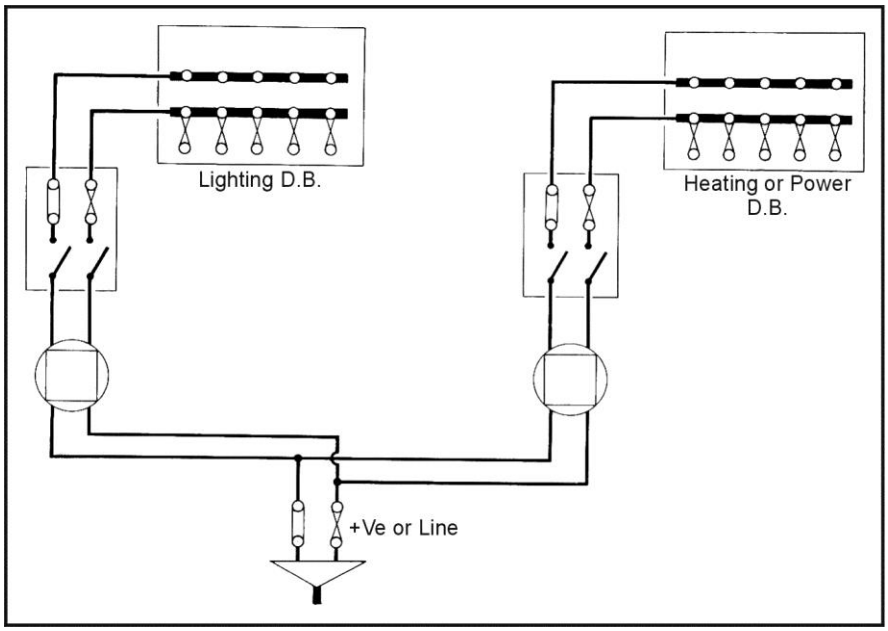


Fig. 5.7: A typical single phase Distribution of supply with separate Light and Power circuits

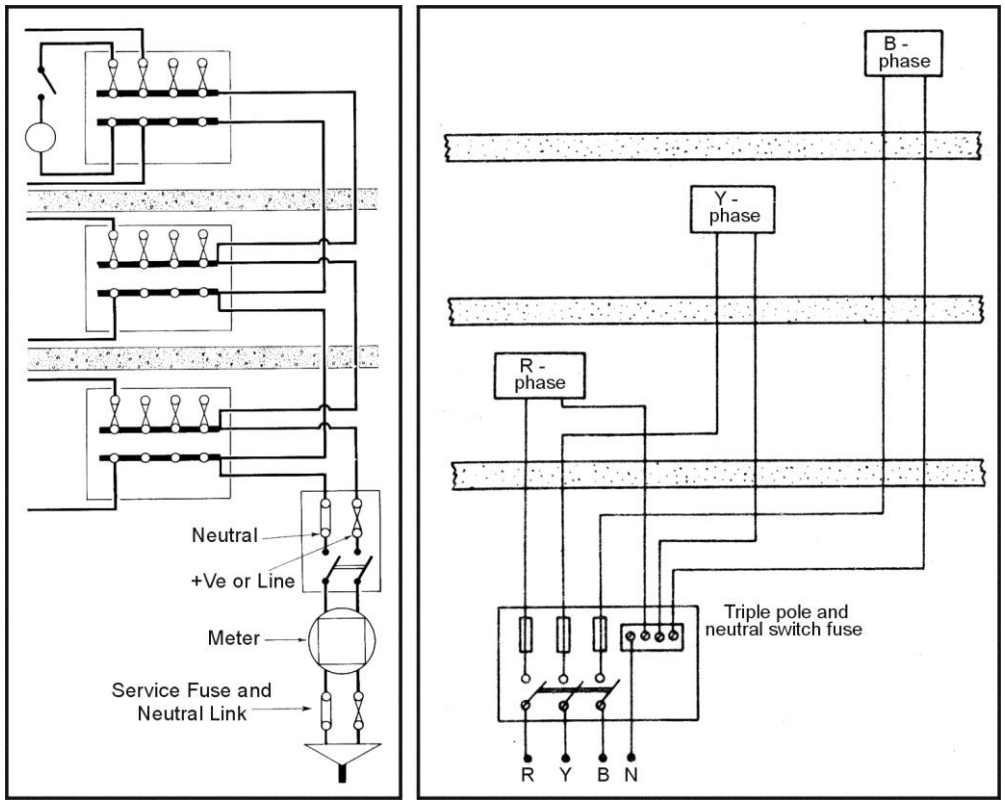


Fig. 5.8: Distribution of single phase (left side) and three phase supply in Triple storey building.

Distribution of three phase supply in small multi-storey building

If building is large enough with heavy load (above 5KW) then three phase supply is taken. Main consumer board is installed on ground floor at suitable place and SDBs on each floor. If No of stories are three, then each phase is given to each SDB. In other case, supply is distributed in such a way that each phase has almost equal load.

Exercise

Part-1: Subjective type Questions

Sample Long Answer type questions

1) What is purpose of distribution board (box), where it should be installed in a building?
2) Write the types of DB w. r .t duty, phase, ways, and construction.
3) Write the method of installation of a DB, also write difference between MDB and SDB.
4) Make diagram to show distribution of single phase supply in four storey building.
5) Write the names of parts of a wiring system in residential buildings.
6) Writ e the parts of three phase distribution board.
7) What factors are considered for the preparation of a distribution board?
8) Write the types of D.Bs w.r.tSize, current rating, voltage, No of C.Bs and No of phases.
9) Draw a circuit diagram of three phase supply in a three-storey building.
10) Make diagram to show distribution of three phase supply in a large industrial installation.

Part-2: Objective type Questions

Sample Short Answer type Questions

1) Define a distribution board.
2) What is difference between distribution board and distribution box.
3) Where a distribution board should be installed.
4) Which factors are to be considered for the selection of site for DBs.
5) Write the names of distribution boards with respect to "phases" and "ways".
6) Write the names of four items installed in the control gear of an industrial distribution board/box.
7) Write the names of four parts of a three phase distribution board.

8) Define main cable or main circuit of a domestic wiring.
9) Define sub main cable or sub main circuit of a wiring system.
10) Define final sub circuit of a wiring system.
11) Define point of a wiring system.
12) For what these abbreviations stand.
    (a) DB (b) MDB (c) SDB (d) TP & N

Sample Multiple Choice Type Questions (MCQs)

1) An assembly of parts used for the distribution of electrical energy in a building.
    a. Main switch b. Energy meter
    c. Distribution board d. Main circuit breaker
2) Main distribution board should be located
    a. As near as possible to the centre of the load
    b. Near the energy meter
    c. Near the main gate
    d. Any of these
3) This factor is considered for the selection of location of a DB.
    a. Cost of cables.
    b. Availability of suitable walls/place.
    c. Freedom from fumes and dampness.
    d. All these
4) Three phase distribution boards are installed in
    a. Large commercial buildings
    b. Industrial installations
    c. Small domestic installations
    d. Both a and b
5) The control gear of an industrial distribution board contains.
    a. One or more isolators.
    b. Bus bar chamber (TP&N)
    c. Main and sub main distribution boards.
    d. Supply sealing box and cut-outs..
    e. All these
6) No of ways of distribution boards may be
    a. 2 b. 8
    c. 16 d. Any of these
7) Distribution boards should be made of
    a. Powder coated sheet steel
    b. Hard wood
    c. Plastic

d. Any of these

8) Protective device provided in distribution boards is
   a. HBC fuses b. MCBs
   c. Thermal relays d. Both a & b

9) This is fitted in three phase distribution boards.
   a. 3 Line bus bars b. Neutral bus bar
   c. Earth bus bar d. All these

10) This is usually provided in a large distribution board
   a. Volt meter & ampere meter
   b. Voltmeter & ampere meter selector switch
   c. Phase indicating lights
   d. All these

11) This is an optional item in a distribution board
   a. Phase indicating lights
   b. Volt meter & ampere meter
   c. Line bus bar
   d. Both a & b

12) The cable or circuit from energy meter to MDB is called
   a. Main cable or circuit
   b. Sub main cable or circuit
   c. Final sub circuit
   d. Point

13) No of neutral bus bars used in three phase distribution bears are
   a. 1 b. 2
   c. 3 d. 4

14) It is provided in control panels of large industrial installations
   a. Bus bar chamber b. Rotary switches
   c. Tap changer d. All these

15) Capacity reserved for future extension is
   a. 5 - 10 % b. 10 - 20 %
   c. 20 - 30 % d. 30 - 40 %

ANSWER KEY

1	**c**	5	**e**	9	**d**	13	**a**
2	**a**	6	**d**	10	**d**	14	**a**
3	**d**	7	**a**	11	**d**	15	**b**
4	**d**	8	**d**	12	**a**		

Ch-6: Testing of Wiring

Main Topics in this chapter

Testing of Wiring

Testing of wiring

IEE regulation 501 states that "*every installation shell be tested on completion and the defects discovered shall be corrected"*.

Therefore the insulation resistance of a complete installation, section of an installation or an addition to an existence installation must be tested before connecting it to the permanent power supply.

Tests of wiring

Tests to be performed on an installation (section of an installation or an addition to an existence installation) are:

1. Polarity test.
2. Insulation resistance test.
    a. Insulation resistance test between wiring and earth (it is also called **leakage test** of wiring).
    b. Insulation resistance test between cables/conductors of wiring (it is also called **short circuit test** of wiring).
3. Continuity test.
    a. Test for the continuity of wiring cables.
    b. Test for the continuity of earthing system.
    c. Test for the continuity of wiring conduits/ trunking etc.

Instruments used in testing of wiring

Following instruments are used in different wiring tests.

1. Continuity tester
2. Megger (or Insulation resistance tester).
3. Test lamp.
4. Multi-meter.
5. Earth resistance tester.

Test lamp:

A test lamp is used to check the presence of power supply at any point in an installation. A general tungsten filament lamp fitted in insulated holder and guarded by steel wires is used for this purpose. Two insulated wires of required length are also attached as test leads. See fig. 6.1. An insulated handle is also fitted behind the lamp holder for holding purpose. Sometimes a neon test lamp can also be used for this purpose, see fig. 6.2

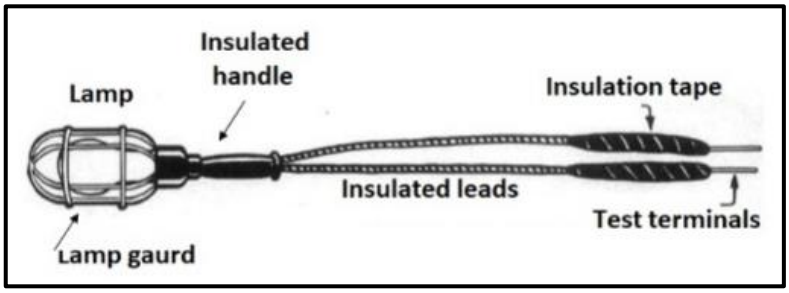


Fig 6.1: Proper homemade test lamp

Fig.6.2: A neon tester

Continuity tester:

It is a cheap test set and can be made at home. It consists of a 6V lamp in series with two 6V batteries housed in a box. Two terminals are fitted outside the box for connecting the test leads. It is used to check the continuity of cable conductors, conduits and earth continuity conductor.

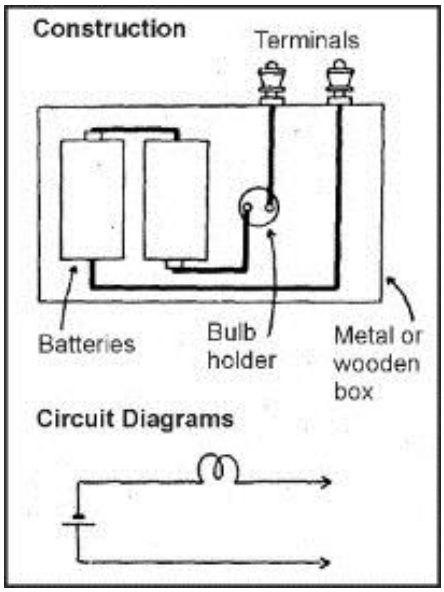


Fig. 6.3: A continuity tester

Megger (or Insulation tester):

It is a portable test instrument used to measure resistance of machines and electrical installations in mega ohms. It contains a hand driven dc generator and direct reading mega-ohm meter mounted altogether in a case with two terminals outside the case. One terminal is marked "L" and the other is marked "E". A third terminal is called the "guard terminal" to protect the operator from electric shock. Megger is available in 100V to 2500V. For testing the electrical installations, usually 500V Megger is used for single phase supply and 1000V Megger is used for the testing of installations having three phase supply.

Fig 6.4: High voltage digital insulation tester (Megger)

As a general rule, the voltage of Megger should be double of the voltage of machine/installation that is to be tested.

Some Megger are available with double scales, one is the mega-ohm scale for insulation resistance and the other is the continuity testing scale up to 100Ω range. Now a days, digital Megger are commonly used with multi range scale.

Multi-meter:

Multi-meter is also a portable test instrument less commonly used in wiring testing. However it can not only be used for measuring resistance but also to measure the ac or dc voltage in an installation. Continuity can also be checked with multi-meter.

Earth resistance tester

The earth tester is a Megger like test instrument specially designed to check the resistance of earth electrode to the surrounding ground. It has a generator, an ohm-meter and a current reversing mechanism in a common case having a handle outside the case.

Fig 6.5: A digital and an analogue multi-meter

It has four terminals C1, P1 & C2, P2. The two terminals are shorted together to form one common terminal. Here in the picture given below, E is the common terminal and Y, Z are the other two terminals. E terminal is connected to the main earth electrode under test and other two terminals are connected to the two electrodes (rods) driven in the ground near the main electrode during the test.

Fig. 6.6: An earth tester with accessories

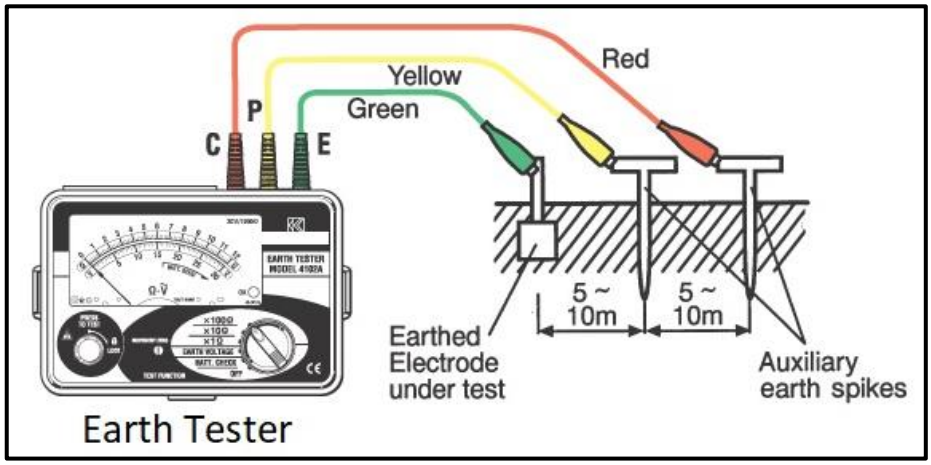


Fig. 6.7: Earth resistance arrangement

Testing the electrical installation (wiring)

1. Polarity test:

IEE regulation 501 and Pakistan electricity rule 51 states that

"in a two wire installation (connected to earth on one pole) all fuses and single pole switches, and single poles circuit breakers and like, shall be fitted on phase wire only".

Two wire non earthed installations require two pole main switches.

Connecting the single pole switches on phase wire is necessary, so that by making the S.P switches "OFF", the lamp and its circuit (wire from switch to lamp) could be made quit dead. If the single pole switch is provided on neutral wire, the metal type lamp holders and the fans as well as part of wiring will remain alive, even when the single pole switch is in OFF position. This may cause an accident. For example, a person who is replacing a lamp, even after opening (making off) the single pole switch, is liable to get electric shock if he comes in contact with the phase terminals of the lamp holder.

Polarity test is carried out to ensure that all the single pole switches are connected on phase line and not on the neutral line. However, if the proper coloured cables are used throughout the two wire installation i.e. red colour for phase wire and black colour for neutral wire (in Pakistan), then no confusion will arise.

Testing the polarity

Polarity test can be performed using following test instruments.

i. Test lamp.(If supply is available).
ii. Megger (if supply is not available and circuit is dead).
iii. Continuity tester (if supply is not available and circuit is dead).

<u>Testing of polarity if circuit is live</u>

Testing of polarity with test lamp

For this purpose, the test lamp is connected between phase wire (first terminal of switch) and earthed metal work of the installation. If lamp lights up, it means that switch is in phase wire and if lamp does not lit (give light), it means that switch is on neutral wire. In this way all the switches can be checked one by one.

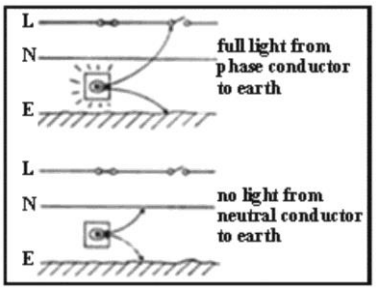


Fig 6.8(a): polarity test

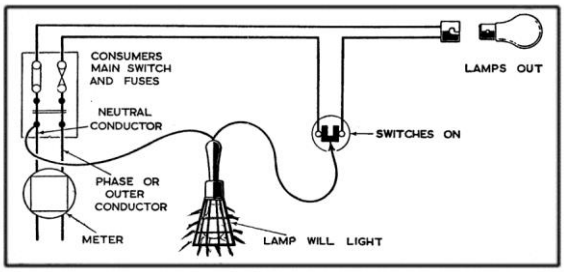


Fig. 6.8(b): Polarity test

If earthed point or earthed metal work is not available in the installation (as the case is usually in Pakistan), then use the neutral wire for

the above said purpose (i.e. testing the polarity of single pole switches).The method is as follows:

i. Switched on at the main switch.
ii. All single pole switches should be ON with their covers removed for old tumbler switches (and turn back the Bakelite sheet of switch board if piano type switches have been used).
iii. All lamps out and all other apparatus disconnected.

If the single pole switches are on the phase wire, they will be alive. The end of one probe is connected to the neutral wire at mains switch and the other probe is touched to the single pole switch terminals, the test lamp will light up. If the switch is wrongly connected on neutral wire, the lamp will not glow as the lamp is on earth potential. The procedure is repeated for all the switches turn by turn.

In testing, the screw type lamp holders should be used and ensure that the outer contact is earthed, one probe is touched to the live side of the mains switch and the other probe to the outer contact of the lamp holder, the test lamp lights up to indicate that the outer case is earthed.

- In the case of two way switches, the three terminals of the two way switches are temporarily connected together for test purpose.
- Three pin sockets should also be tested to verify that the terminal mark "L" of the socket out let is connected with phase wire or not.
- In a large installation, the work can be sectionalized by checking the polarity of the bus bars at the distribution boards and working from these positions instead of running the test lead back to the main switch.

Testing of polarity with neon tester (Phase tester)

It is very easy method of testing the polarity on live circuits. For testing the correct polarity of SP switches, the tip of tester is touched with both the terminals of SP switches and neutral turn by turn keeping the thumb on the metal part on back side of the tester. The phase tester lit on phase wire and does not on neutral wire.

If tester the tester glows on both phase and neutral wire, it indicates a fault.

Testing of polarity if circuit is dead

If supply is not available in newly constructed building, then battery pack continuity tester, Megger continuity tester or multi-meter can be used to test the correctness of polarity.

Testing of polarity with continuity tester

Before starting the test:

i. Turn OFF the main switch.
ii. Pull out the main fuses.
iii. Disconnect the apparatus and pull out the lamps from their holders.
iv. Turn ON all the single pole switches.

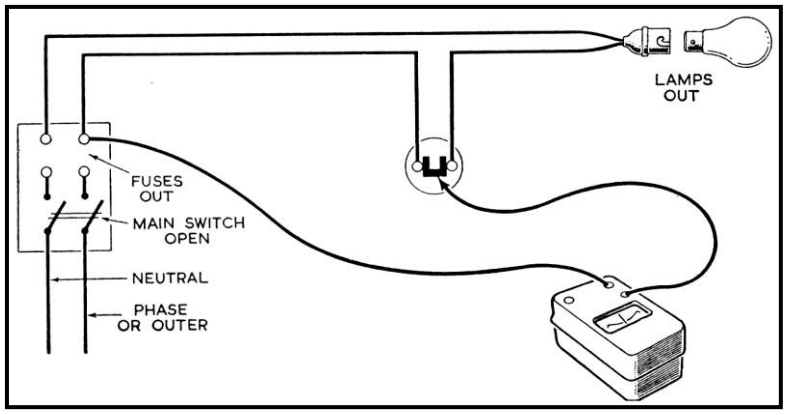


Fig. 6.9

Now connect one lead of the continuity tester to the phase wire at the outgoing side of main switch fuse and other lead to the terminals of single pole switches turn by turn. If lamp of tester lights up (or Megger continuity tester gives less than one ohm reading by rotating its handle at constant speed), it means polarity is correct. If switches are on wrong polarity, then lamp will not glow (or Megger continuity tester will give very high resistance).

2. Insulation resistance test:

a. *Leakage test* *(or testing of insulation resistance between the wires and earth)*

According to the Pakistan electricity rule no 25, the insulation between the wiring of an installation and earth should be of such a value that a leakage current may not exceed $1/5000^{th}$ of the full load current (or 0.02% of the full load current).

The aim of this test is to check the insulation of cables used in wiring, either these have sufficiently high resistance (it should be in mega-ohms) to avoid the leakage of current or not. Test is performed with 500V Megger.

Before making the insulation test, ensure that:

i. Main switch is in OFF position.
ii. Main fuse is taken out and all the other fuses in position.
iii. All the switches are in ON position.
iv. All the lamps are in position (or holder points are short circuited).
v. Phase and neutral wire is shorted together.

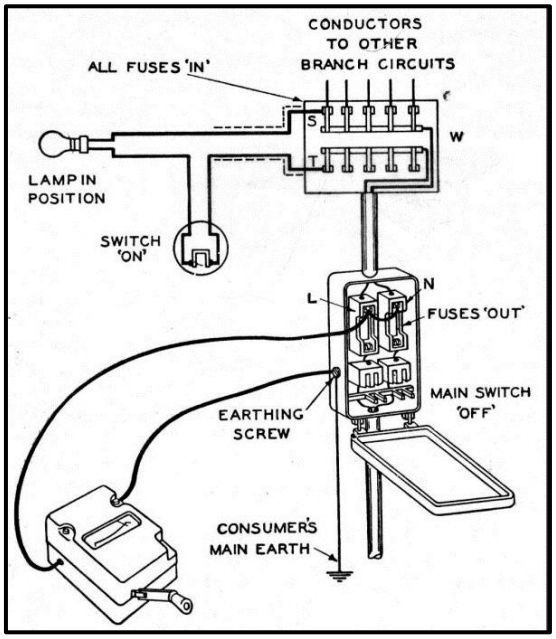


Fig. 6.10: Conductor to earth test

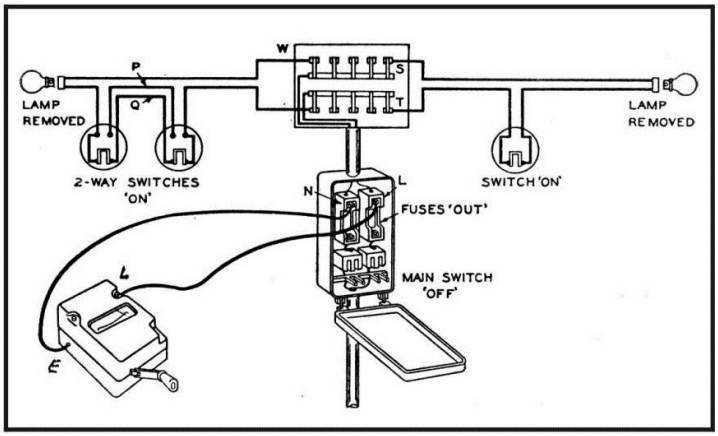


Fig. 6.11: Conductor to conductor test

The "L" terminal of Megger is connected to the point where phase and neutral wires at the main switch have been short circuited and "E" terminal of Megger is connected to the earth. Now handle of Megger is rotated at full constant speed and reading from the dial is noted.

Heating appliances should be checked separately for insulation test.

*Result:*The insulation resistance in no case should be less than 0.5 mega ohms.

OR

Measured resistance should not be less than 50 mega ohms divided by no of out lets*. If its result is more than unity, then one mega ohm should be taken as maximum working value.

b. *Testing of insulation resistance between the conductors of wiring (or short circuit test)*

*The socket outlet, appliance, or lighting fitting incorporating a switch is regarded as one outlet.

The purpose of this test is to ensure that the insulation is sound enough between conductors of wiring to prevent any leakage current between them and leading to a short circuit.

Before making the insulation test, ensure that:

i. Main switch is in OFF position.
ii. Main fuse is taken out and all the other fuses in position.
iii. All the switches are in ON position.
iv. All the lamps are taken out (and all the connections between phase and neutral are removed).
v. Phase and neutral wires are kept separate at main switch.

The "L" and "E" terminals of Megger are connected to the phase and neutral wire on wiring side of the main switch. Now handle of Megger is rotated at full constant speed and reading from the dial is noted.

Result: Measured resistance should not be less than 50 mega ohms divided by no of out lets but the insulation resistance in no case should be less than 0.5 mega ohms and need not to be more than one Mega-ohm.

For PVC insulated cables, the resistance should be 12.5/no of out lets.

Example-1: *If the wiring in a building consists of 30points of 100 watt lamps and four fans of 80 watts each. What would be the permissible insulation resistance to earth for a 230 volt supply?*

Solution:

Supply voltage = 230 Volts

Total load= 30 x 100+4x 80= 3320 watts
Full load current= 3320/230= 14.43Amperes.
Maximum permissible leakage current (as per Pakistan electricity rules)
= 1/5000 of full load current.
= 14.43 x1/5000 = 0.002886956 A
Maximum permissible insulation resistance to earth
= supply voltage to earth/ Maximum permissible current
=230/0.002886956
= 79668.69/ 1000000 = 0.08 Mega ohms

Example-2: *Electrical load in a domestic building is 30A.What should be the minimum insulation resistance to earth for a 230 volt supply?*

Solution:

Supply voltage = 230volts
Full load current = 30Amperes.
Maximum permissible leakage current (as per Pakistan electricity rules)
= 1/5000 of full load current.
= 30 x1/5000 = 0.006 A
Maximum permissible insulation resistance to earth
= supply voltage to earth/ Maximum permissible current
=230/0.006
= 38333.33/ 1000000 = 0.03833 Mega ohms

1. *Continuity test:*

Following are to be tested for continuity in an installation.

i. Continuity of wires.
ii. Continuity of earth system (earth continuity conductor)
iii. Continuity of metal conduits of wiring.

Testing the continuity of wires

The testing of continuity of short and long wires of conduit wiring is very clear in the fig.6.12 & 6.13 given below, if supply is not available. This test should be completed on wires before connecting them to the devices.

Following method is adopted for testing the continuity of wires of a wiring system if supply is available.

Before making the continuity test of wiring, ensure that:

i. Main switch is in OFF position.
ii. Main fuse is taken out and all the other fuses in position.

iii. All the switches are in ON position.
iv. All the lamps are taken out and all the apparatus is disconnected.
v. Terminals of ceiling roses, holders, and sockets are joined together.

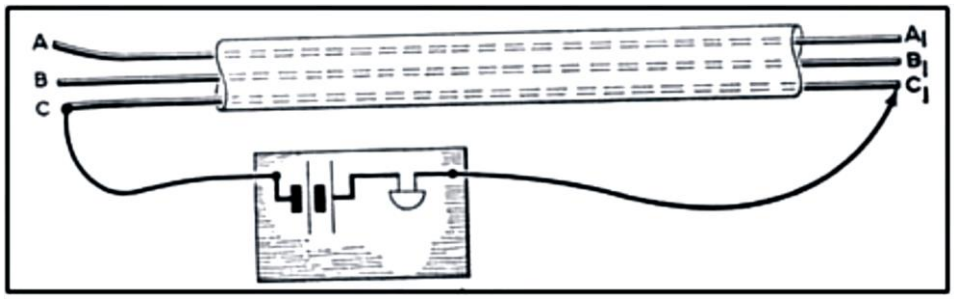


Fig. 6.12: Continuity test of short length wires

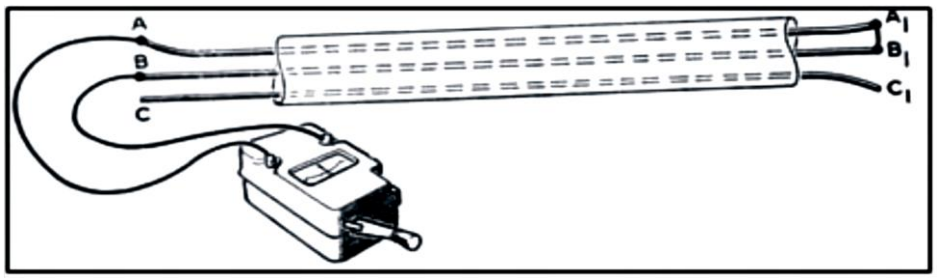


Fig. 6.13: Continuity test of long wires

The "L" and "E" terminals of Megger are connected to the phase and neutral wire on wiring side of the main switch. Now handle of Megger is rotated at full constant speed and reading from the dial is noted.

Result: If pointer of Megger comes to zero, it means good continuity of wires otherwise not.

All the metal conduits (especially if these are being used as earth continuity conductor), and other metal work must be solidly connected to earth for safety. Otherwise in case of insulation damage, the leakage current will start flowing to the ground and gives sever shock to a person touching it.

Before making the continuity test of conduits or ECC, ensure that:

Testing the continuity of conduits and earth continuity conductor

i. Main switch is in OFF position.
ii. Main fuse out and all the other fuses in position.
iii. All lamps in position and all the switches in ON position.
iv. Phase wire coming out of main board and "E" terminal of the Megger is connected to the earth connecting point.

v. The line wire of Megger is touched to all metal switches, lamp holders and conduits and earth continuity conductor (ECC) at different points and handle of Megger is rotated at constant speed.

vi. All the points are checked turn by turn.

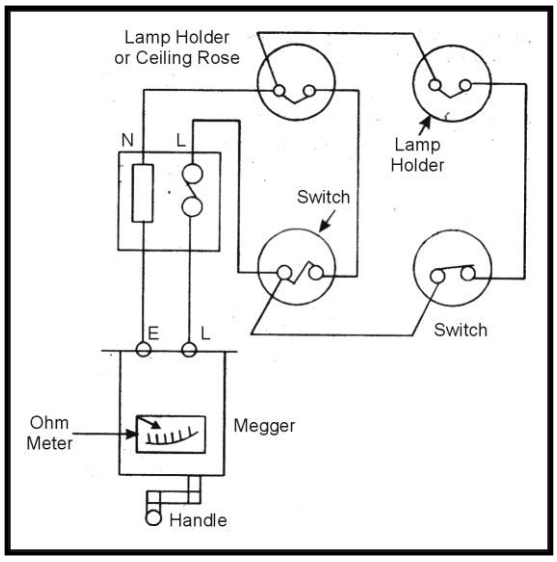


Fig. 6.14: continuity test of wiring

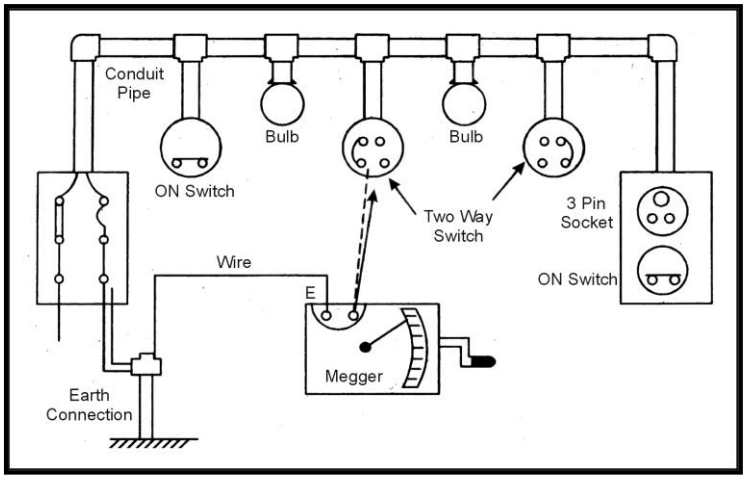


Fig. 6.15: Continuity test of conduits

Result: If pointer of Megger comes to zero, it shows good continuity of conduits/ECC, switches or other metal work to earth that is being tested. If it shows more than one ohm resistance, it means continuity is not good and need to be correct.

Testing the resistance of earth electrode

The common terminal P1& C1 (or E) is connected to the earth electrode via earthing lead and other two terminals are connected to the two other steel or copper rods A & B(or Y & Z as per given picture) specially driven in the ground for this test. Rod Y is driven in the ground 16.5 meter from the main electrode and rod Z is placed about 33meter away from main electrode. The instrument is placed on a horizontal firm stand free from the surrounding magnetic field. The range switch is set to a suitable scale and handle is rotated at required speed in proper direction. The reading is noted. Two more readings are taken by placing the middle rod about 7 meters towards and away from the main electrode. If these readings are equal to the first reading then OK, otherwise average of three readings is taken. Resistance should be less than one ohm.

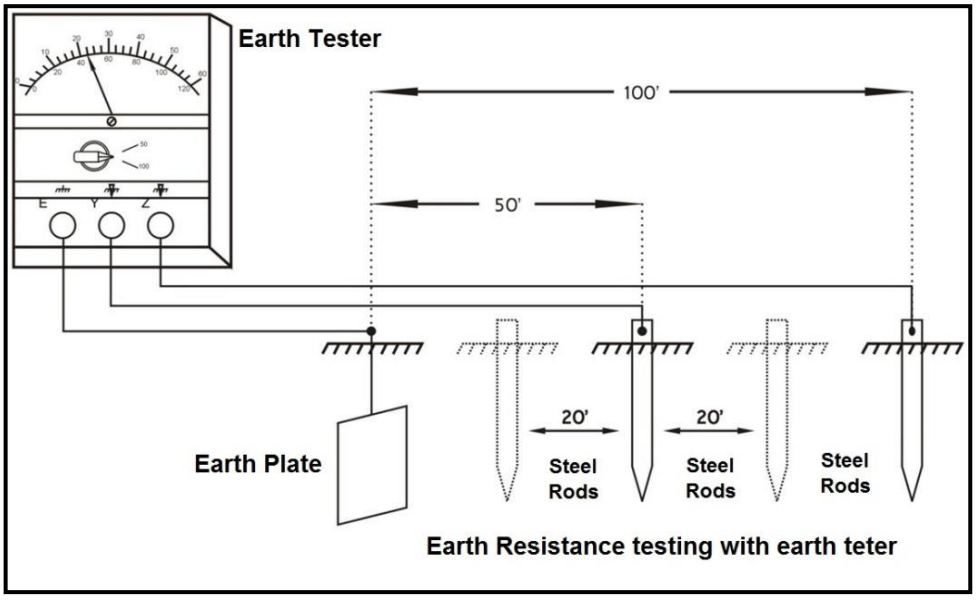


Fig. 6.16: Testing of earth resistance with earth tester

Exercise

Part-1: Subjective type Questions
Sample Long Answer type questions

1) Why testing of wiring are necessary, name different tests of wiring.
2) Write the purpose and method of polarity test.
3) Write the function of insulation resistance test of wiring & its method.
4) Enlist instruments used in wiring testing and write in detail about the Megger.
5) Write note on the following:
   a. Megger insulation tester. b. Continuity tester.
   c. Test lamp. d. Earth resistance tester.
6) How insulation leakage test is performed, write complete procedure.
7) Write complete procedure for testing of insulation resistance between the conductors of wiring.
8) If the wiring in a building consists of 20 points of 60 watt lamps, one 2000W heater and four fans of 100 watts each. What would be the permissible insulation resistance to earth for a 230 volt supply?
9) Electrical load in a domestic building is 25A.What should be the minimum insulation resistance to earth for a 250 volt supply?
10) Write complete procedure for testing the continuity of wiring conduits and continuity of earth continuity conductor in a building.

Part-2: Objective type Questions
Sample Short Answer type Questions

1) Write IEE regulation No 501 about wiring testing.
2) Enlist instruments used for testing of wiring.
3) Write at least 04 uses of Megger.
4) Write formula to find insulation resistance with Megger for VRI and PVC cables.
5) What is meant by polarity test?
6) What is the function of polarity test?
7) Why continuity in steel conduits of wiring is necessary.
8) What is the advantage of installing the single pole switches on phase wire?
9) What is the use of test lamp and phase tester in wiring?
10) Write the name of wiring components whose continuity is required to be tested.

11) If you install a single pole switch on neutral wire, will the lamp turn ON and OFF by making the switch ON and OFF.
12) Why the insulation resistance test of wiring is carried out.
13) Write briefly, the method of finding insulation resistance between conductor and earth with Megger.
14) No of outlets in PVC wiring is 20. What should be the minimum level of insulation resistance?
15) Write in brief, the method to find the resistance of earth electrode with earth tester.

Sample Multiple Choice Type Questions (MCQs)

1) Following tests are carries out after completion of a wiring
   a. Polarity test b. Continuity test
   c. Insulation resistance test d. All these
2) Instruments used in wiring testing
   a. Continuity tester
   b. Megger (or Insulation resistance tester).
   c. Test lamp.
   d. All these
3) In a wiring, test lamp is used to:
   a. Check the presence of power supply at any point in wiring.
   b. Check the polarity of switches.
   c. Check the leakage current in wiring.
   e. All these
4) The Megger is used
   a. To measure resistance of machines
   b. To measure the insulation resistance of cables
   c. For the testing of electrical installations
   d. All these
5) The Meggers are available in.
   a. 2500V. b. 500V
   c. 1000V. d. All these
6) For the testing of single phase domestic installations, This Megger should be used
   a. 2500V. b. 500V
   c. 1000V. d. Any of these
7) According to IEE regulation 501 and Pakistan electricity rule 5, this should be installed on phase wire
   a. Single pole switch b. Fuse
   c. Two pole switch d. Both a & b

8) Polarity test can be performed using this test instrument
   a. Test lamp. b. Megger
   c. Continuity tester d. All these
9) The purpose of polarity test is to check
   a. Either single pole switch are connected on line wire or not
   b. The insulation resistance of cables
   c. The short circuit
   d. All these
10) The leakage current in an installation should not exceed
   a. 1/5000th of the full load current
   b. 0.02% of the full load current
   c. 1/10th of the full load current
   d. Both a & b
11) The insulation resistance of cables of an installation in no case should be less than
   a. 0.5MW b. 0.2MW
   c. 50MW d. 0.1MW
12) This instrument is not used in wiring testing.
   a. Megger b. Continuity tester
   c. Voltmeter d. Test lamp
13) This test of wiring cannot be performed with continuity tester.
   a. Polarity test b. Continuity test
   c. Insulation resistance test d. Both a & b
14) This wiring test cannot be performed with multi meter.
   a. Insulation resistance test b. Polarity test
   c. Continuity test d. Both a & b
15) Resistance of wiring cables should be in the range of.
   a. Ohms b. Mega Ohms
   c. Kilo Ohms d. All these
16) For leakage test of wiring cables, L terminal of Megger is connected with this terminal on main fuse.
   a. Phase b. Neutral
   c. Fuse body d. Both a & b
17) Handle of Megger is rotated at a speed of -------for wiring tests.
   a. 120 RPM b. 160 RPM
   c. 80 RPM d. Any of these
18) Resistance from one terminal to any other terminal of metal conduits installed in wiring should be.
   a. Less than one ohm b. 12.5 Mega ohms
   c. 50 Mega ohms d. 25 Mega ohms

ANSWER KEY

1	**d**	6	**d**	11	**a**	16	**d**
2	**d**	7	**b**	12	**c**	17	**a**
3	**a**	8	**d**	13	**c**	18	**a**
4	**d**	9	**a**	14	**a**		
5	**d**	10	**d**	15	**c**		

Section-1
INDUSTRIAL & COMMERCIAL WIRING

Unit: 1.2: Industrial and Commercial Wiring

Topics included in this unit:

(Power Wiring Systems, Multi-storey Distribution System,
Skill in Installing the Power Wiring)

Ch-7: Power Wiring Systems

Main Topics in this Chapter

(1) Power wiring systems (Steel Conduit, Trunking & Ducting, Centenary, Overhead bus bar and Tough Sheathed system). (2) Multi-storey supply distribution system and installing power wiring systems. (3) Locate & rectify faults in power wiring.

Industrial and commercial wiring

*All the **wiring methods** which are used in industries and large commercial buildings to feed heavy loads are called power wiring systems*. These are also called industrial or commercial wiring systems. The selection of any particular power system depends upon the nature and level of load, type of building, conditions of installations and nature of work to be carried out in the building.

Following methods of electrical installation are used in industry and large and multi-storey commercial buildings:

1. Steel conduit system.
2. Trunking system.
3. Ducting system.
4. Catenary system.
5. Overhead bus bar system.
6. Tough sheeted cable system.

1. Steel conduit wiring system

In this wiring system, steel conduits of are used on brick walls and ceiling by means of steel saddles and then V R I or P V C cables are drawn into, afterwards. In damp situations the conduits are spaced from the walls by means of small ceramic cleats fixed below the pipes or spacer bar saddles are used at regular intervals. Numbers of inspection fittings are provided along its length. The conduits should be electrically and mechanically continuous and connected to earth at some suitable point.

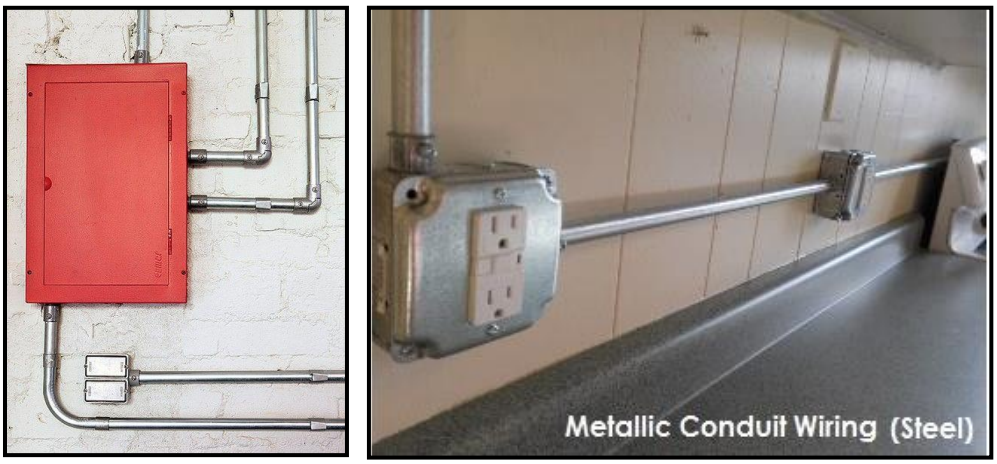


Fig 7.1: Steel conduit wiring system

Fig. 7.2: Different steel conduits and fixing saddles

The conduit used for this purpose is of two types namely!

i. Light gauge 0or type A or split type conduit

Not water tight or even damp proof, not permitted on medium voltage (i.e. on voltage higher than 250 V, used for cheap work only.

ii. Heavy gauge or type B or screwed type conduit (Screwed conduit (solid drawn or with welded seam). It may be of steel with black stove enamelled or galvanized type.

Water/damp and fire proof, have good mechanical protection for all medium voltage 250 V to 600 V.

Commonly used sizes of steel conduit for electrical wiring are16, 19, 25, 31, 38 , 50 ,63mm. Smallest size is 12mm which is seldom used.

Tools required for steel conduit wiring

i. Spirit level.
ii. Cold chisel of concrete cutter.
iii. Pipe wrenches of different sizes.
iv. Pipe cutter.
v. Pipe reamer or file.
vi. Pipe bending machine.
vii. Die and stock for threading the conduits. **Fig 7.3**
viii. Heck saw.
ix. Screw wrench set
x. Electric drill machine or hand rawal plug tool.
xi. Screw driver of different types and sizes.
xii. Phase tester.
xiii. Measuring tape.
xiv. Electrician pliers.
xv. Long nose pliers.
xvi. Side cutting pliers.
xvii. Hammer.
xviii. Electrician knife.

Material required for steel conduit wiring

i. Lubricating oil.
ii. Aluminium paint.
iii. Conduits and their fittings of required type and size.
iv. Saddles/ hooks/ clips of required type and size as per conduits to be used.
v. Rawal plugs.
vi. Cotton string and blue or black liquid for string immersion.
vii. Screws of different sizes
viii. Bushings.
ix. Cables of different sizes as required.
x. Different accessories as requirement of the installation.
xi. Small lengths of G.I pipes or porcelain tubes.
xii. Concealed boxes for switch boards, switch sockets and other fittings.

MAXIMUM CAPACITY OF CONDUITS FOR DRAWING_IN OF 250 V GRADE CABLES

Nominal X-sectional area in mm^2	Number and diameter of wires in mm	Material of conductors	Number of cables that can be accommodated in conduit of size											
			19mm		25mm		31mm		38mm		50mm		63mm	
			S	B	S	B	S	B	S	B	S	B	S	B
1.5	1/1.40	AI	7	5	12	10	20	14	-	-	-	-	-	-
2.5	1/1.80	AI	6	5	10	8	18	12	-	-	-	-	-	-
4.0	½.24	AI	4	3	7	6	12	10	-	-	-	-	-	-
6.0	½.80	AI	3	2	6	5	10	8	-	-	-	-	-	-
10	1/3.55	AI	2	-	5	4	8	7	-	-	-	-	-	-
16	7/1.70	AI	-	-	2	-	4	3	7	6	-	-	-	-
25	7/2.24	AI	-	-	-	-	3	2	5	4	8	6	9	7
35	7/2.50	AI	-	-	-	-	2	-	4	3	7	5	8	6

NOTE: The columns headed "S" apply to runs of conduit which have distance not exceeding 4.35 metres between draw –in-boxes , and which do not defect from straight by an angle of more than 15^0. The columns headed "B" apply to runs of conduit with defect from the straight by an angle of more than 15^o.

*. *In Pakistan and as per I.E.E regulations, cables with aluminium conductor having conductor area less than 10mm^2 should not be used for internal wiring.*

Method of installing the steel conduit wiring

1. Decide the rout of main, sub main, and final sub circuits.
2. Draw lines (or print lines with cotton string immersed in blue are black liquid and by stretching it between two points and then pulling the string from centre and then releasing it).
3. Mark the dots at suitable/recommended intervals as per the type of wiring system.
4. Drill the holes with suitable drill bit on marked points with electric drill machine or with rawal plug tool (hand bit).
5. Fix the rawal plugs in the holes with hammer.
6. Fix the saddles with screws.
7. Cut the required lengths of pipe with pipe cutter.

8. Bend the pipe length with bending machine where required.
9. Make threads on both sides of each length.
10. Apply aluminium paint on threads.
11. For concealed wiring, make trenches and box housings with cold chisel or concrete cutter in the walls.
12. Fit the conduits on saddles (or fasten the conduits in trenches in case of concealed wiring) and attach all fittings and boards.
13. Draw the wires in conduit with fish wire.
14. Make connection with switches and appliances etc.
15. Perform the necessary tests.
16. If results of all the tests are satisfactory, connect the wiring to power supply.

Advantages of steel conduit wiring

1. It provides good protection against mechanical damage.
2. It provides complete protection against fire due to short circuit etc.
3. The whole system is water proof.
4. Replacement and alteration of defective wiring is easy.
5. Its life is long if the work is properly executed and it is shock proof also if earthing and bonding is properly done.

Disadvantages of steel conduit wiring

1. It is very costly system of wiring.
2. Its erection is not so easy and requires time.
3. Experienced and highly skilled labour is required for carrying out job.
4. Internal condensation of moister may cause damage to the insulation unless the system outlets are properly drained and ventilated.

Fields of Application of steel conduit wiring

As this system of wiring provides protection against fire, mechanical damage, and dampness so this is the only approved system of wiring for:-

1) Places where considerable dust of fluff is present such as in textile mills, saw, flourmills etc.
2) Damp situation
3) In workshops for lighting and motor wirings.
4) Places, where there is possibility of fire hazards such as in oil mills, varnish factories etc.
5) Places, where important documents are kept such as a record room.

6) Residential and public buildings where the appearance is the prime thing.
7) The recessed type conduit wiring is preferred for residential and public buildings.

Precautions

1. A smooth bore brass bush or ring bush should be used when a conduit is terminated at a metal casing or box.

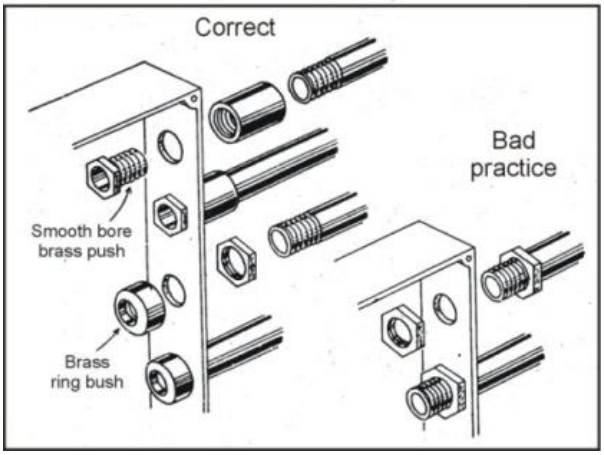


Fig 7.3

2. At the end of a run, conduit must be terminated in a metal box or in a accessory or recess lined with non-inflammable material.
3. There should not be more than two 90^o bends (or their equivalents) between draw in boxes. Moreover, bend over 90^o between two draw in boxes should be avoided.
4. Only 40% of the internal space of conduits should be used by the cables and remaining space should remain free (40% space factor).
5. In surface type wiring, multiple saddle or individual saddles for each conduit should be used for more than one conduits running in parallel. One big saddle embracing two or more conduits should not be used in such case.
6. In order to avoid condensation of water, the conduits must be well ventilated in order to allow circulation of free air. In horizontal runs a fall should be given and it should be ensured that no pocket is formed where condensation may rest.
7. Edges of conduit should be removed with file or pipe reamer before laying the cables, to remove burrs etc. and to save cable insulation from mechanical damage.

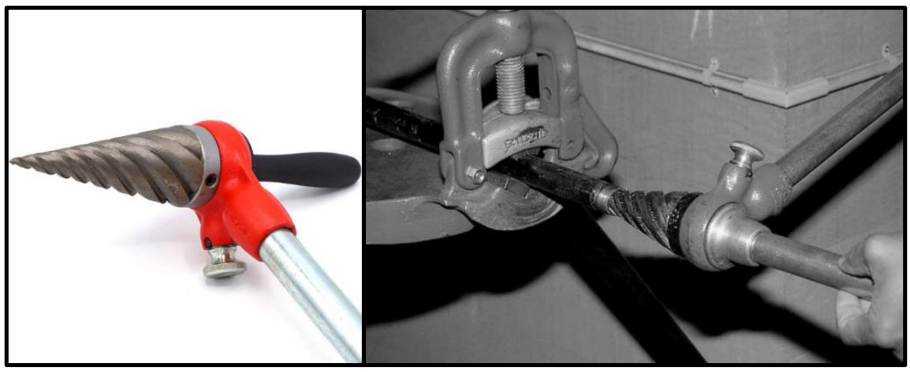


Fig 7.4: Pipe reamer (left) and removing burrs from the edge of steel pipe with pipe reamer (right)

8. The oil used for threading the conduits must be wiped off in order to save cable insulation from chemical injury.
   The thread should be coated with aluminium paint in order to keep the conduit electrically continuous.

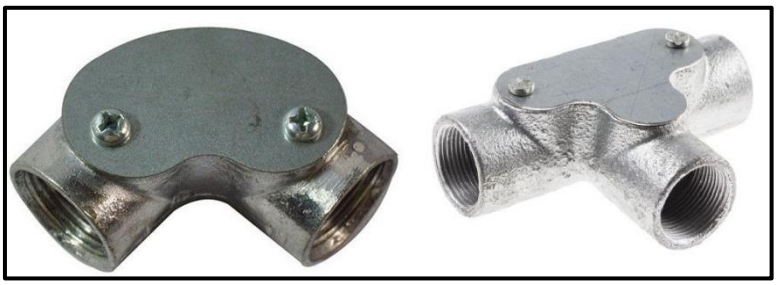


Fig 7.5: Inspection bend and "T"

9. Inspection "Ts", inspection bends or junction boxes should be used at all bends.
10. When the conduits are buried under plaster, the conduits must be fixed in place with pipe hooks to the wall behind it, so that it may not become loose afterwards.
11. The conduit should be well painted, even if it is G I conduit, before burying it under plaster.
12. Wooden or ebonite bushes must be used at the edges of conduits in order to save the cable insulation from mechanical damage.
13. The conduits should be thoroughly cleaned and dried before laying.
14. Over-crowding of cables should be avoided in conduits. (Only 40 % of the internal space of conduit should be occupied by cables).

15. In case of ac system, conductors of opposite polarity should be bounced together in order to avoid inducement of eddy currents in the conduit.
16. The conduit must be electrically continuous and properly earthed at some suitable point.
17. The pipe should be bent by pipe bending machine.
18. Use one size of conduit throughout the runs as far as possible.
19. Conduits pipes should be fixed by heavy gauge saddles.

2. Trunking wiring system:

Trunking is basically a channel (of metal or non-metal) with remove-able cover. The increase of load and number of cables in factories and commercial buildings has brought the need for all types of cable trunking. *This system is suitable where large number of small or small number of large cables is to be used.* The trunking in its basic form consists of a simple sheet steel box, two to three meters in length having screw or Snap-On removable lid.

According to IEE Regulation 523-8

In damp situations and where ever trunking is exposed to the weather shall be of corrosion resisting material or finish. Therefore trunking is either made of corrosion resistant materials or finished with stove enamelled, coating of zinc or galvanized.

IEE Regulation 523-7 states that no wiring system should be exposed to rain, dripping water, steam, condensed water, or accumulation of water, if not possible, it should be of the type designed to withstand such exposures. This also applies to trunking system

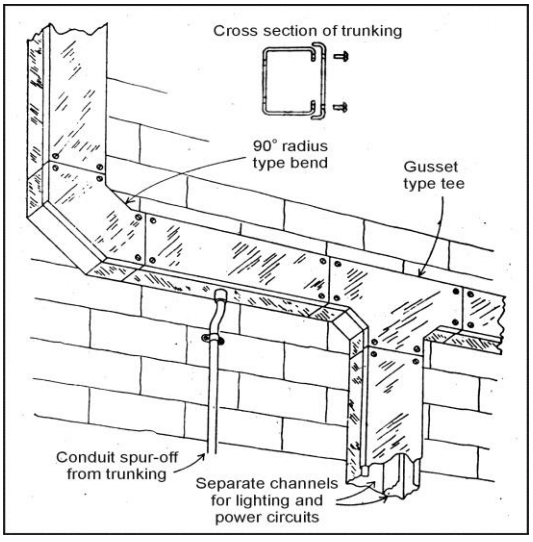


Fig.7.6: Section of a steel trunking system

Trunking provides a large space to accommodate large numbers of cables. A further advantage is that there is no need for the drawing-through operations as like conduit system. However, the grouping of circuits affects the current-carrying capacity.

Space factor (ratio of overall cross-sectional area of cables to cross-sectional area of trunking) is 45 % as compared to 40 % for conduits.

Trunking system is provided with all necessary fittings like bends, Ts, flanges (extensions), reducers etc.

Types and Sizes of Steel Trunking

There are a number of types of steel trunking such as:-

- Lighting Trunking
- Cable trunking
- Multi-Compartment trunking
- Bus-bar Trunking

Typical surface finishes of steel trunking may be (i) hot dipped galvanised coating, (ii) grey enamel on zinc coating, (iii) Silver enamel on zinc coating, (iv) stain less steel

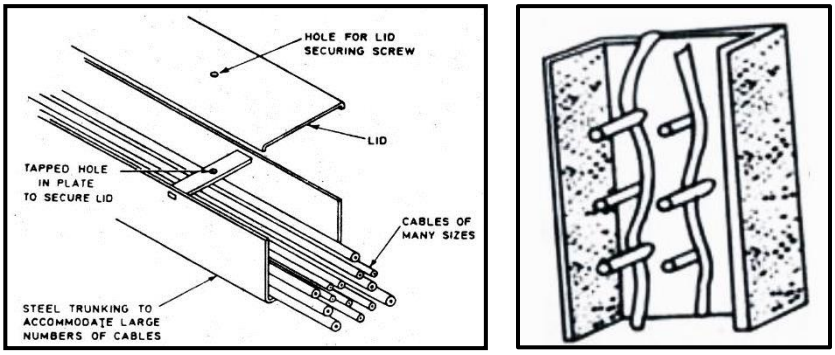


Fig.7.7: Lid removed to show cables in steel trunking & pin trunking (right)

Standard Sizes of Trunking

50mm x 50mm	150mm x 100mm
75mm x 50mm	200mm x 100mm
100mm x 50mm	225mm x 150mm
100mm x 75mm	250mm x 150mm
100mm x 100mm	300mm x 250mm

150mm x 75mm	

Trunking is generally supplied in 3 metre lengths. Lighting trunking is often supplied in 5 metre lengths.

Installation and Fitting

Trunking system can be erected quickly and easily. It can be screwed direct to walls or suspended across trusses. Where suspended, it should be supported at each joint by a hanger from above.

A check should be made, as a routine measure, at all trunking connection to ensure that there are no sharp edges which can cut the cable insulation.

Long lengths of vertical trunking are supported by PVC covered pin-racks or prongs, that are fitted to the inside back of the metal trunking .The prongs also assist in spreading out the cable evenly across the trunking ,especially where the trunking is mounted horizontally .See fig 7.8 right

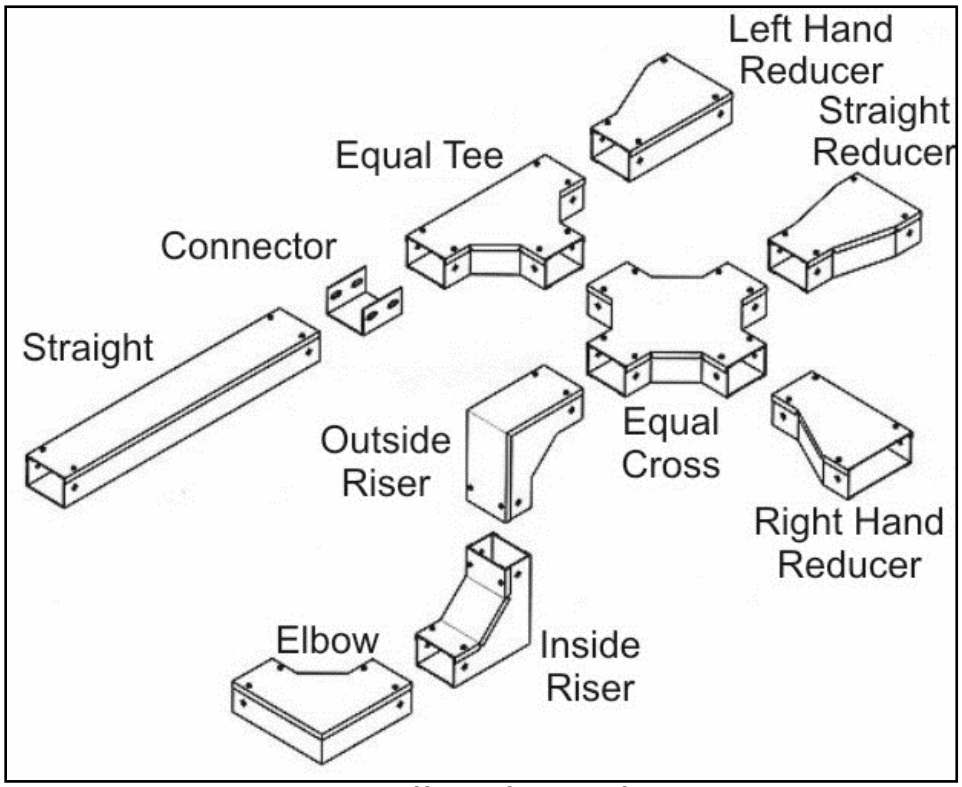


Fig.7.8: Different fittings of trunking

Precautions

The fact that heat arises has to be taken into account when fitting long vertical runs of trunking.

1. Fire barriers or baffles fixed at each floor level are a positive safety measure, while limiting the temperature arises at the top of the cable runs.
2. Fire resistant cement is necessary where trunking passes through floors and walls.
3. Since the various lengths of trunking and fittings are normally likened by simple screw fixings, great care is required to ensure low-resistance bonding.
4. The parts to be painted must perfectly clean and fitted vary tightly together.
5. Live and neutral cables must be bunched so as to neutralize the magnetic field and prevent the possibility of external flux being setup.

Overall diameter of BICC 600/1000V PVC cables	
Conductor cross-Sectional area (mm^2)	Overall diameter(mm)
1.0	2.9
1.5	3.1
2.5	3.5
4	4.3
6	4.9
10	6.2
16	7.3
25	9.0
35	10.3
50	12.0
70	13.8
95	16.1
120	17.7
150	19.6
185	22
240	25

Segregation (Separation of different voltage grade cables)

Multichannel trunking is necessary for circuits supplied by extra-low voltage (ELV), low voltage (LV) and medium voltage (MV). The I.E.E. wiring regulations requires three categories of circuits which require segregation into separate divisions of the trunking in order to prevent direct physical contact between the various categories.

Category 1: From ELV to 650 V (ELV are the voltage values not exceeding 50 V between conductors and not exceeding 30V ac. or 50V dc between any conductor and earth), with the exception of fire alarm circuits.

Category 2: Circuits supplied by ELV, examples being bells and burglar alarms. Again, fire alarm circuits are not included.

Category 3: Any fire alarm circuit.

Under no circumstances may category 1 and category 3 circuits be contained in the same multicore cable or flexible cord.

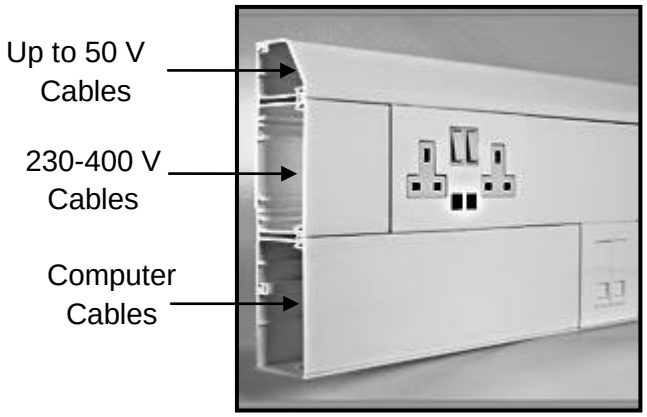


Fig. 7.9: Multi compartment skirting trunking

Advantages and disadvantages

Advantages

1. Lighter in weight than conduit.
2. Easy to install.
3. All sizes of cables including heavy cables above 120mm^2 can be used.
4. Different categories of cables (having different voltage grades and types) can be used in multichannel trunking.
5. Single unit of trunking is sufficient for large number of cables (in conduit system many conduits are run in parallel in such cases), so less fittings are required.
6. No material wastage.
7. Good appearance.
8. Addition and alteration of cables is easy.
9. Laying of cables is easy in comparison with drawing the cables in conduits.
10. Provide good mechanical protection to cables.

Disadvantages

11. Costly than conduit system.

12. Requires high skill for installation.
13. Not moister proof like conduit.

For plastics trunking (PVC channel or PVC duct) see chapter 3

Under floor trunking

Electrical apparatus on factory or laboratory benches, office desks, etc., when fixed away from walls, requires a special means of supply for these island positions. Under floor trunking in the form of a criss-cross grid arrangement, covering the whole of the floor area is becoming a standard method for delivering such supplies. This is a system of wiring, that must be installed during the building or floor construction and that avoids the dangers resulting from long flexible leads.

There are two main types of such systems:

1. Raised floor Trunking System
2. Flush floor Trunking

Raised floor Trunking system is designed for incorporation into the floor structure itself, such as Trunking systems for casting into the screed, etc. While Flush floor Trunking is designed to be installed below false floors in commercial buildings.

The principles of the two systems are the same but the strength of the construction is different.

Fig. 7.10: Under floor trunking

The boxes should be capable of adjustment to allow for a specified depth of floor fill and variations in level of floor constructions .Anchor screw adjustments permit the necessary raising or tilting of the cover plate. The latter is usually fashioned in the form of a tray ready to receive the finished floor material , in this way only a rim of metal (usually brass) is finally seen.

Joints between the various components and parts of the system have to be watertight during building construction and under normal conditions of use. All parts must provide a dose mechanical fit and, in addition, incorporate devices for establishing and maintaining the electrical continuity between the various parts.

(Rising Main) Bus bar trunking

Steel-cased trunking has proved itself well-suited to give a triple-pole and neutral main supply for high rise flats or offices. The conductors are generally in aluminium or copper bar form with capacities up to as high as 2000 A, and are carried on insulators mounted within the sheet steel enclosure.

The rising main would normally be tapped at each floor, a typical

arrangements, cables linking the bus bar and fuse must have a minimum cross-sectional area of 4mm^2 and be enclosed in conduit or metal trunking. The sub fusing could be part of a panel which would incorporate floor control and metering facilities.

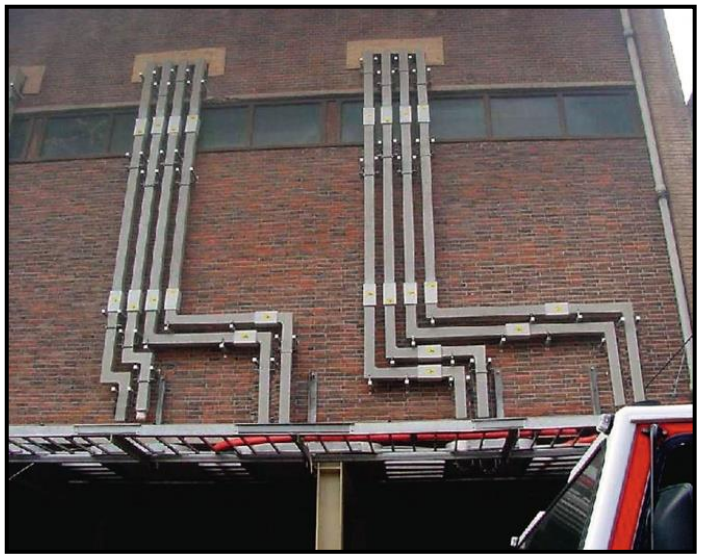


Fig. 7.11: Rising main trunking

3. Overhead bus bar (trunking) system:

It is used to give three phase supply to machines in factories. It is especially suitable in electroplating shops or welding shops to supply heavy current from a step down transformer to large no of electric arc welding plants. It is also suitable to supply large no of small motors in factories. Aluminium or copper bus bars are fitted on insulators in standard steel trunking. Trunking is available with all necessary fittings. A tap off point is provided after one meter to get supply.

Vertical rising mains have been successfully employed with appropriate modifications, for lateral or horizontal working when sited in factories it has becomes a form of distributions in its own right. Then trunking is arranged for tapings at intervals of 0.6 m which might be by special triple-pole and neutral plug-in boxes or by wiring connected directly into sub fuses.

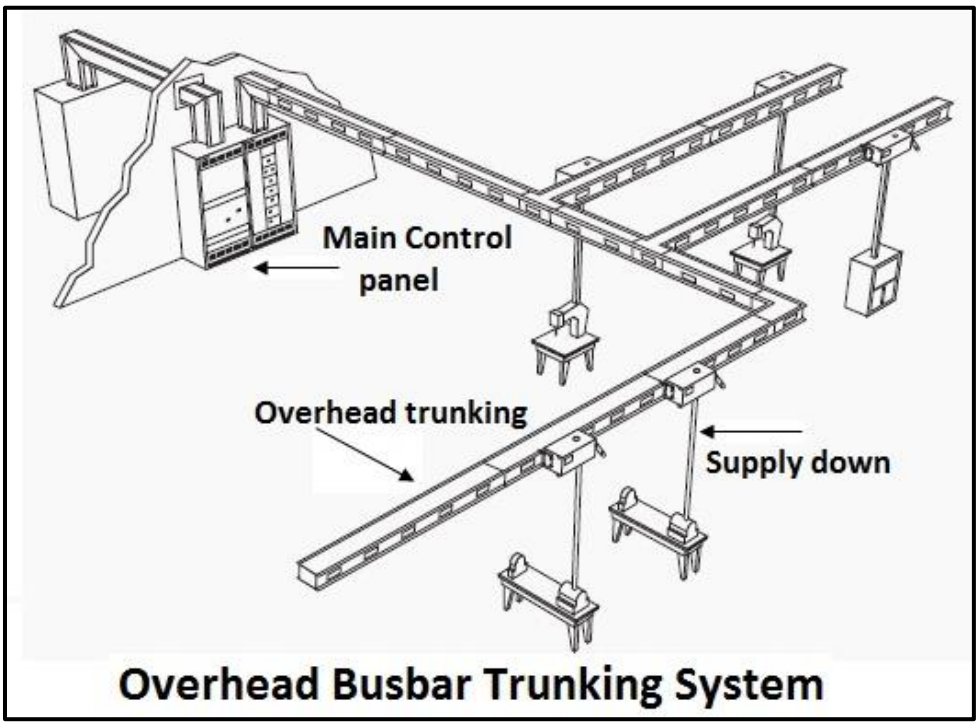


Fig 7.12: A typical overhead bus bar trunking system

Overhead bus bar arrangements allow speedy rearrangement of plant without shutdown for those machines not involved in the change, and with the minimum of disturbance to the general running of the factory.

The weight of the bus bars and trunking can be often be taken by the horizontal cross member of the frame girders or roof trusses.

Advantages and disadvantages

1. Can be fitted before installation of machines and other apparatus.
2. Plant layout can be changed easily.
3. Less voltage drop due to heavy bus bars near the load.
4. No use of large size and long power cables.
5. Extension and change can easily be made.
6. Initial cost is high.
7. Suitable for heavy current loads.
8. It is almost maintenance free.
9. Not suitable for places where there is moisture or explosive material is stored.

Precautions

- The covers of trunking should be so fitted that there is no space for insects, lizards etc. to enter in the trunking. These can cause short circuits.
- Conductors should be installed in such a way that no unauthorized person could access.
- Level of voltage and word **"danger"** should be written on trunking.
- Corrosion free material should be used for fixing and supports for damp places.
- Barriers should be provided in trunking where it has to pass through walls or floors.

4. Catenary System

Catenary system is especially suitable in buildings of high ceiling where conduit system is not easy to install.

> I.E.E Regulation B127 allows the use of catenary system between buildings/ between sections of a building which are at long distance to each other and for internal wiring in the high roofs buildings

The system consists of a number of VRI cables made up around a high tensile galvanized steel wire with suitable fillings of jute to produce a circular shape. This is braided and compounded overall. Now, no further protection is needed. But to meet special conditions, cable can be steel wire braided. Standard cables in 2, 3, 4 and 6 cores are available in England (these are not available in Pakistan) with sizes from 1.5mm^2(1/1.38) to70mm^2 (19/2.14).

The Catenary cable can be stretch fastened across the roof by means of steel wire by eye bolts and strainers. Maximum span between two points without support is 45m. One standard box is used for tee, angle, or through joints. It can also be used as fuse box. These boxes can also be used as fitting boxes from which lighting fittings can be suspended. Boxes also serve to anchor the steel wire at right angles and at mid-point positions. When installed outside, the boxed are filled with a plastic compound to prevent the entrance of water.

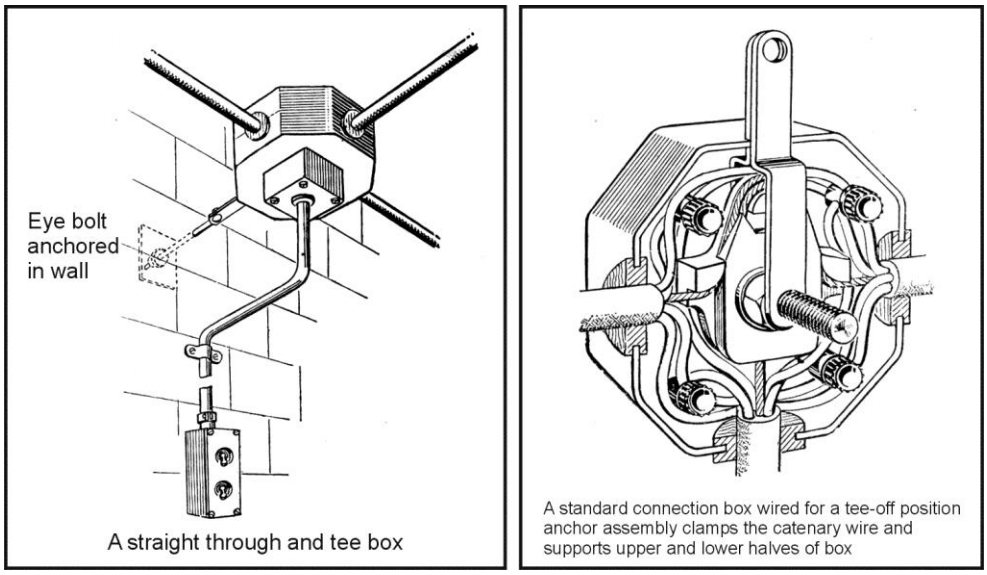


Fig. 7.13: Conduit feed and Tee joint box and standard box wired for a Tee off position of Catenary system

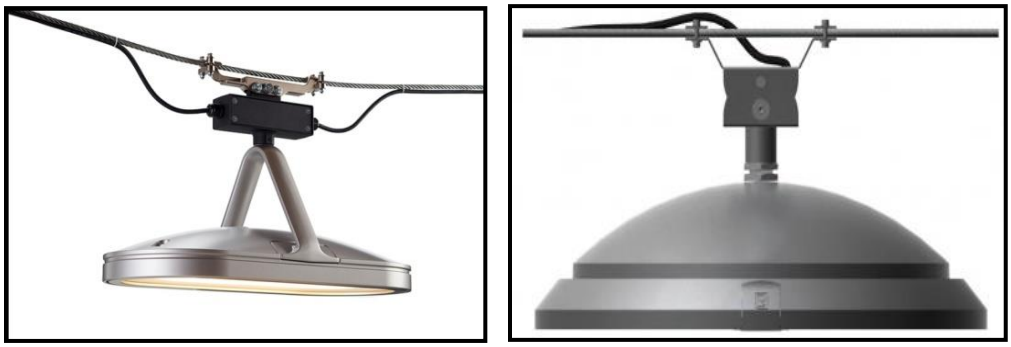


Fig 7.14: A catenary lighting fittings

A complete span (including boxes, lighting fittings, lamps etc.) can be assembled at ground level before erection. This saves the time and difficulty to work at high positions.

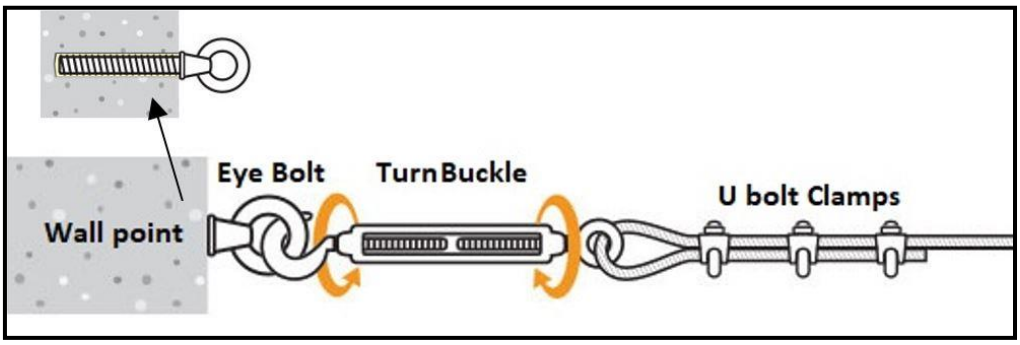


Fig. 7.15: Catenary wire fittings with wall

In Pakistan, fittings and special catenary cables(s described above) are not available. So a simple method is adopted here for the installation of catenary wiring.

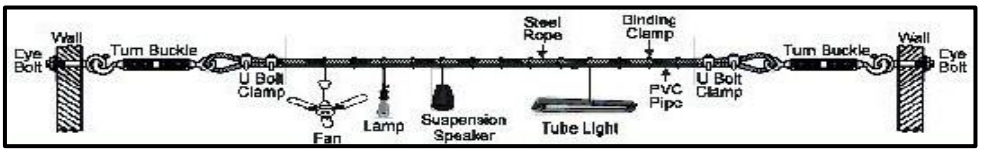


Fig. 7.16: A complete span of Catenary fittings

For this purpose a steel rope is fasten between two wall points by eye bolts. A turnbuckle is attached with eye bolt on each side. Steel rope is fasten with turn buckle using U bolts. Sag is adjusted with turnbuckle. PVC pipe along with its required fittings is run along the steel wire rope and is fasten with steel wire with mechanical clamps. Now lamps, fans, hanging speakers and tube lights are attached to the catenary steel rope.

Advantages

1. A complete length of fitting can be assembled on ground.
2. Can be installed easily in less time.
3. Lower load comes on building.
4. It is safe from moister, steam and water if proper fittings are used.
5. Less expensive.
6. Easy to repair

Applications: Suitable for high roof buildings and for crossing the overhead air gaps between two apartments.

5. Under floor ducting system

Hard wood, concrete, fibre or steel ducts of rectangular or round shaped with or without removable cover are used for use under the floor. This system is usually used to run main and sub main cables to give supply to the

buildings under construction. Ducts are buried near the walls so that supply for MDB and SDBs could be taken easily. Concrete ducts are fabricated in the trenches while ducts of other materials are prefabricated type. Only sheathed and armoured cables are recommended if these have to draw-in through lidless ducts. PVC non-sheathed cables are not permitted in ducts, and mineral-insulated cables also must have a sheathing of PVC. However non sheathed PVC or VRI type cables can be used if ducts have removable slab. Any change is easy. Moreover, fault can be easily traced and rectified in such type of ducts. Internal radius of the concrete ducts should not be less than 4 times the diameter of the circular ducts and 4 times that of the width of rectangular ducts. Space factor of under floor duct system is 35% if there are not more than two 90o bends. In case of more bends than two, then space factor should be less than 35%. Ducts may have single or multi-channel type. To avoid the possibility of such ducts caving-in or collapsing, the diameter must be at least 15mm.

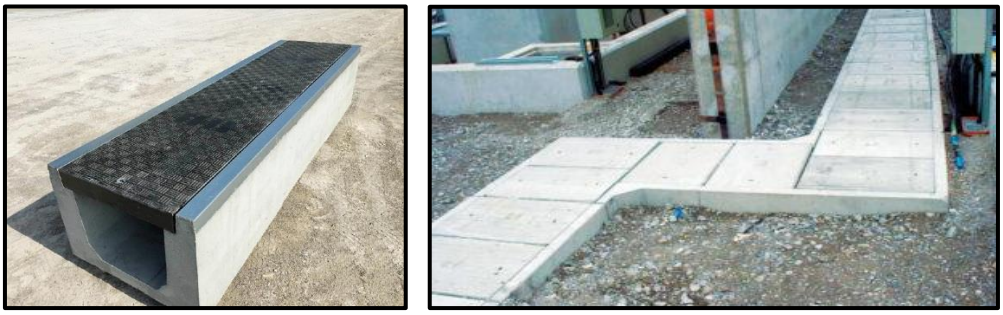


Fig 7.17(a): A concrete duct with removable lid and duct installed in a substation

Applications:

This method is used in large commercial buildings, air ports, oil refineries, power houses, and grid stations etc.

Advantages:

1. Large can be laid easily than any other system.
2. Layout can be altered easily.
3. Cables are mechanically safe.

Disadvantages

1. Water may enter and cause short circuit.
2. Trenches have to be made before laying of ducts.
3. Non sheathed cables cannot be drawn –in in the ducts without lid.

Insulation of connection cables to the bus bars must be stripped to 150 mm from the bus bars and this stripped portion covered with heat-resisting insulation.

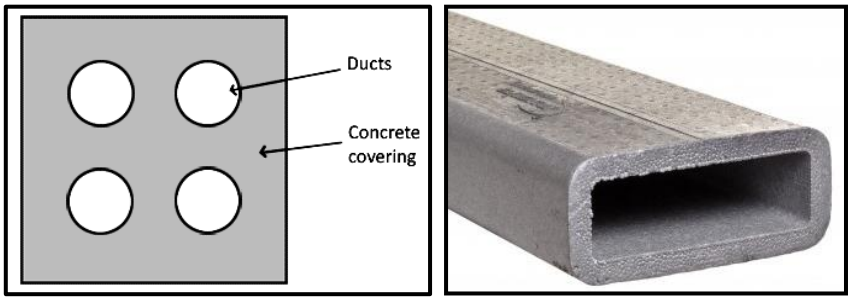


Fig 7.17(b) Multi-channel concrete duct and rectangular concrete duct

6. Tough sheathed cable wiring system

This is an old wiring system, had been used in some particular applications in England. In this system of wiring, cables are installed directly on walls, ceilings, or even under plaster*. It is called *tough sheathed wiring system* because the cables used in this system have hard sheaths over the insulation of their conductors. These cables are mechanically strong. Following materials are used for the sheaths of such cables.

1. PVC (sheath grade)
2. Lead alloy
3. Tough rubber
4. Hard plastic

*I.E.E regulations allow the use of such cables directly on walls, ceilings and under plaster etc.

Installation precautions are different for each type of cable, for example tough rubber sheathed cables should not be used in places where there is oil or acid etc. Similarly, lead sheathed cables should not be used in places where lime is in contact or under plaster.

Tough sheathed cables should be used directly on walls, ceilings etc. only for low voltage installations only.

i. Tough rubber-sheathed cables

Tough rubber-sheathed cables, commonly known as TRS consist of one, two, or three VRI cores. Cables laid up in flat formation, with a close covering of tough vulcanized rubber as mechanical protection. Since there is

no metal sheath, an earth-continuity-conductor must be enclosed within the rubber sheath. TRS cables may normally be used without further mechanical protection.

It is desirable however that they shall not be brought into contact with gas pipes, water pipes, or other metal work. As with lead-sheathed cables, extra protection may be necessary in special circumstances, in particular where nails may damage them. In addition to their use as a surface system, TRS, cables may be embedded in plaster or run under floors. All connections under floors should be accessible and be made in special boxes must be brought to the surface.

ii. **P.V.C.-sheathed cables.**

These cables are the more commonly used cables for domestic wiring. These are installed and handled in the same way as the TRS cables.

The cables may be 1-core, 2-core and 3-core, laid up flat. The fixing clips are tinned brass buckle clips or lead alloy saddles. The joint boxes are moulded plastic with terminals rigidly fixed in the base of the box. Loose shrouded porcelain connectors are used in certain other positions. Plastic shrouded connectors are also used.

iii. **Lead Sheathed cables**

The type of wiring employs conductors that are insulated with VRI and covered with an outer sheath of lead aluminium alloy containing about 95% of lead. The metal sheath gives protection to cables from mechanical damage, moisture and atmospheric corrosion.

The whole lead covering is made electrically continuous and is connected to earth at the point of entry to protect against electrolytic action due to leaking current and to provide safety in case the sheath becomes alive. The cables are run on wooden batten and fixed by means of link clips just as in TRS wiring.

Some of the reasons for the use of lead sheathed VRI or PVC cables are flexibility, unobtrusiveness, neatness and cheapness in comparison of conduit system. Related accessories are available like special metal junction boxes.

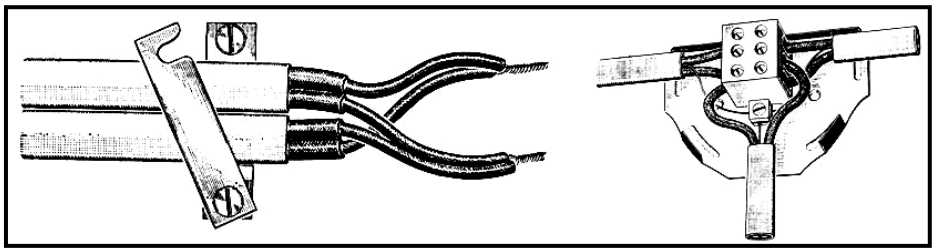


Fig 7.18

Precautions to install tough sheathed cables:

1. The cables must be supported by proper metal clips, saddles etc. which must not be more than 35 cm apart on vertical run and 22 cm on horizontal run for cables upto 7/0.736 mm.
2. Sharp bends should be avoided and at corners a round bend of radius not less 10 cm should be used.
3. When the cables are being clipped these should be dressed with a piece of hard wood to make it perfectly straight.
4. Power wiring should be carried separately from the wiring for fans and lights etc.
5. Contact with gas or water pipes, except at one definite bond to the water mains at the point of entry should be avoided.
6. While crossing a wall the cables must be run in the conduits. While passing through floors the conduit should be continued to a height not less than 1.5 meters above the floors.
7. The lead sheath must be continuous electrically and earthed at some suitable point, preferably at the point of entry.
8. The supports employed must not be of such material that may react chemically with the sheath.
9. According to IEE regulations the lead sheath should be continuous throughout the installation either by soldering or by bonding with clamps.
10. The cables should be properly protected where liable to mechanical damage.
11. The end of conduits employed must be filled to remove burrs and bushes may also be used a both ends.
12. The cable should not be run over damp places.

Advantages and disadvantages of lead sheathed wiring

Advantages

1. It is easy to fix and looks nice as it can be run in building without damaging decoration and can be painted to suit colour scheme of surroundings.
2. It can be used in damp situations provided protection against moisture effect on the ends of the cables are given.
3. It can be used in situations exposed to rain and sun provided no joint is exposed.
4. It provides protection against mechanical injury better than that of TRS wiring.
5. Its life is long if proper earth continuity is maintained throughout.

Disadvantages

1. In case of damage of insulation, the metal sheath becomes alive and gives shock so as to provide safety against, electrical shock it is necessary that the sheath is properly earthed and an earth wire is run side by side with it and all pieces are properly bonded or jointed together so that not a single cover unearthed.
2. It is not suitable for places where chemical corrosion may occur.
3. Skilled labour and proper supervisions is required.
4. It is costlier than TRS wiring.

Fixing the cables: The lead-sheathed wiring system is essentially a surface system in such that, the joint boxes must always be accessible. Wiring runs, such as vertical drops to switches without joints, may be buried in plaster without further protection. The wires may also be run in ceiling spaces and in wall partitions.

The cables are held in position by special buckle clips of tinned brass, which themselves are fastened to the wall surfaces by brass pins. Lead alloy fixing saddles may be used where a number of cables run together. After the cable runs are chosen, the clips are first fixed in position throughout the length of the run. The cable is then laid in the clips and the clips themselves are buckled over. The maximum spacing of clips is 400 mm horizontally, and 550 mm vertically, according to the size of the cables. Greater distances are allowable under floors and in partitions. Driven staples are not allowed in lieu of clips. Junction boxes must not be held in position by the wires but should be screwed down, and under floors they should be fixed either to a wooden joist or to a suitable batten.

Handling the cable: Special care must be taken in handling lead-sheathed cable, as twists and kinks are easily caused; therefore, unnecessary bending must be avoided. The cable should be kept on the drum as long as possible. Where the cable is liable to mechanical damage, such as when running upwards from the floor, further protection by steel channel or conduit is required. Where the cable is passed through party walls etc.

Lead-sheathed cables must be kept from contact with water pipes, gas pipes, etc. Bends are made by hand carefully and smoothly, and may be flat or edgewise as required.

Lead-sheathed cables may be used in conjunction with metal conduit fittings throughout, or as an extension from a conduit installation, by the use of lead-sheathed-to conduit adaptors.

Distribution of power supply in large multi-storey buildings

In large buildings, the type of electrical power supply distribution depends upon the type of building, dimension, the length of supply cables, and the loads.

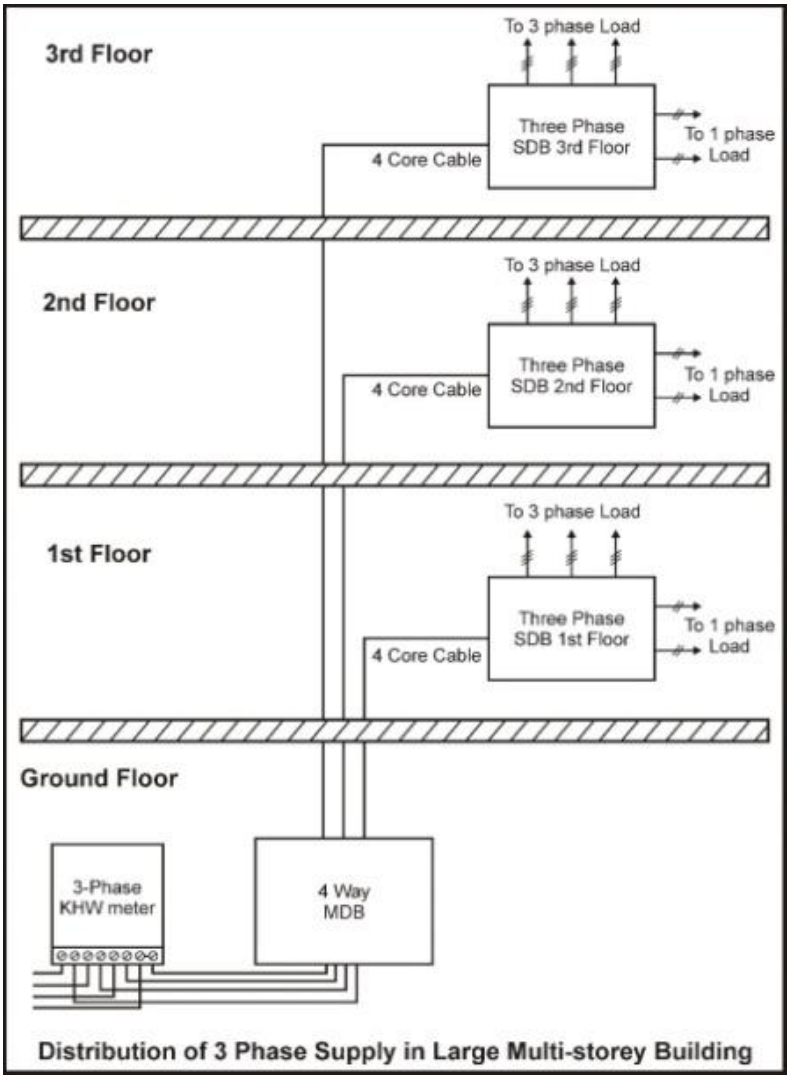


Fig.7.19: Block diagram of three phase distribution in block of flats

In most cases, a high voltage supply and transformer substation is required. Normally HV switchgear and substation transformers are installed at ground floor or basement in a special room. However, sometimes, appliances with large power demand are installed on the top floors such as converters and lift motors, air conditioning equipment and electric kitchens. Whatever is the location of such room, it should be locked and only an authorized person should be allowed to enter. A warning plate with words

*"danger of high voltage, no entry except the authorized person "*should be fixed at the door of the control room. To brining the high voltage supply as close as possible to the load centres, transformers are installed at the top floor, or if required, additional ones are installed on one of the intermediate floors. In such cases transformers with non-inflammable insulation and cooling are used.

Each floor should have its own SDB with separate light and power circuit arrangements.

For such buildings, arrangement is made so that each of three phases will have equal load to make the system balance. From the safety point of view, one apartment/flat should not be given supply from two phases. There should be 2 meter distance between equipment having supply from two different phases.

The distribution system large multi-storey buildings can be divided in to:

1. The vertical supply system (rising mains)
2. The horizontal supply (distribution at each floor level)

1. The vertical supply system (rising mains)

The vertical supply system (rising mains) are implemented in several ways, depending on the type of building and load. Some of vertical supply systems are:

1. **Single Rising Main** arrangement is used where high supply security is not important.

Advantages: -

a) The different loads of individual floors are balanced out.

b) Only a small main L.V board is required.

c) Simple in construction and operation.

Disadvantages: - Low supply security (a fault in the rising mains effect all floors).

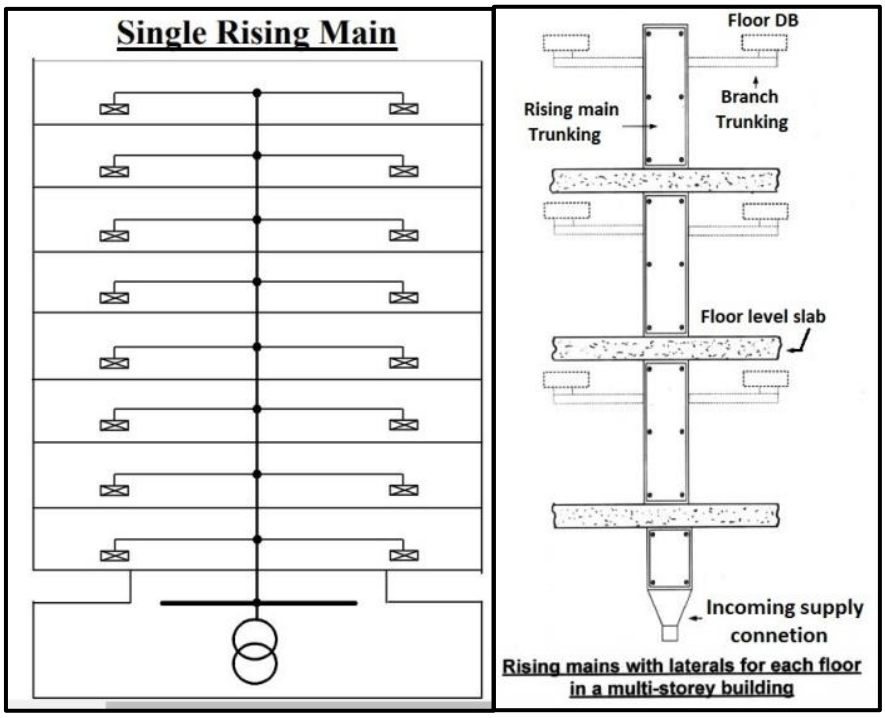


Fig 7.20: "Single Rising Main" distribution system in a multi-storey building

2. **Grouped Supply** arrangement is used for high rise building with high load concentration.

Advantages:-

a) Easier mounting.
b) Smaller size for rising mains.

Disadvantages:-

c) A fault in any rising mains effect several floors (relatively low security).
d) Loads are balanced only within each group.
e) Larger power distribution board.

3. **Individual Floor Supply** arrangement is used in high rise buildings were stories are let separately (metering is at central point at ground floor).

Advantages:-

a) Smaller size of cables can be used (easy installation).
b) In the case of a fault in arising main, only one story is affected.

Disadvantages:-

a) Different loading of the individual floors cannot be balanced out.
b) The rising main must be rated for the peak load of each floor.

c) Uneconomical – large number of cables and the size of the rising main shaft is quite large.
d) Large low voltage distribution board with numerous circuits.

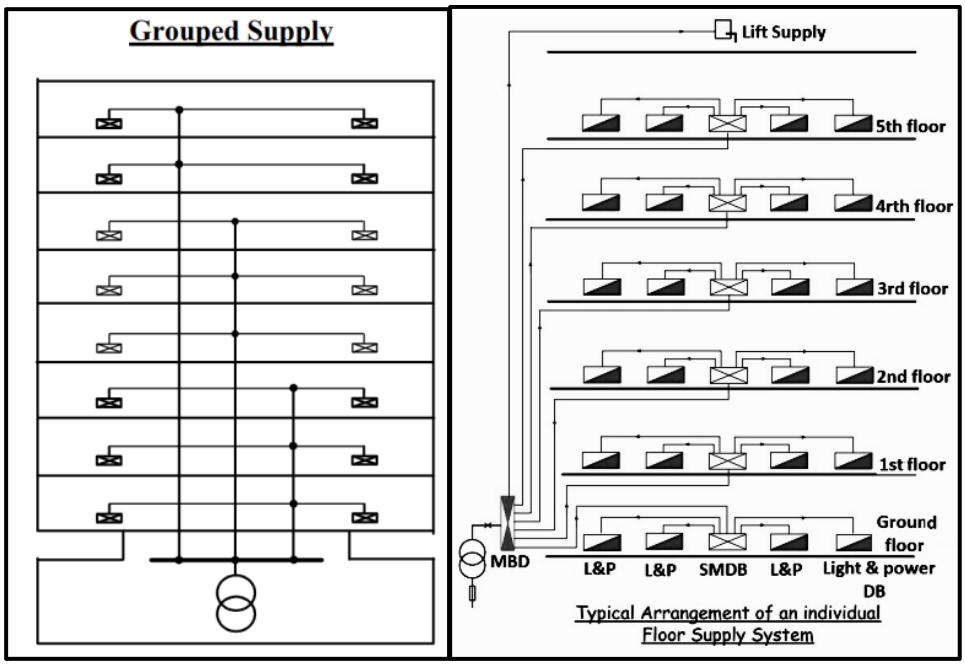


Fig 7.21: "Individual Floor Supply" arrangement in a multi-storey building

4. **Ring Main Supply** arrangement is used in large buildings when relatively higher security is required.

Advantages:-

a) Higher power supply security (in the event of a fault, it is possible to switch off the faulty part and leave the majority of the building operational)
b) A small low voltage distribution board is required.
c) The differing loading of individual floor are balanced out (smaller sizes for rising mains)

5. **Double Feed Supply** arrangement is used in large buildings with relatively large loads at the top floors (lifts, kitchen, and air-conditioning).

Advantages:-

a) Higher power supply security.
b) The differing loading of individual floors are balanced out.
c) Smaller L.V. distribution board required.

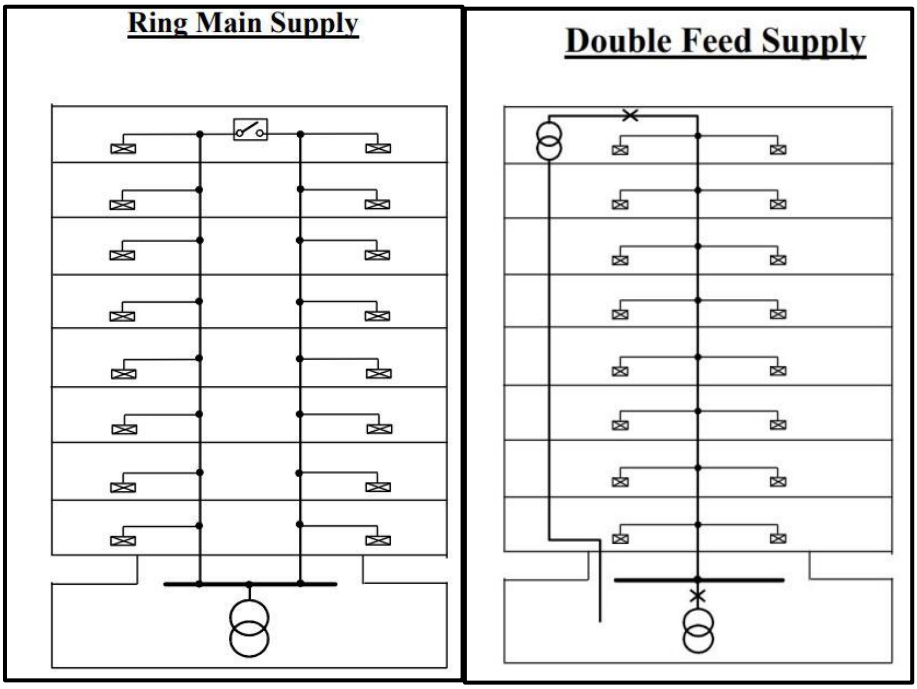


Fig 7.22: Rising Main and Double Feed supply arrangement

2. The horizontal supply (distribution at each floor level)

Distribution of power supply in Factories

Designing the distribution of electrical power supply system for factories, is very complicated because due to the fact that each factory has its own setup. Nature of heavy load is different in each factory. So power supply and distribution system of each factory should be planned and studied before construction.

Some factories, especially industrial manufacturing factories, have unique and special needs that differ from normal factories. This kind of factory would need larger areas for equipment and some need storage areas for flammable items. These kinds of factories would have to have an electrical power system that would account for those extra needs.

Some industries need essential backup of power supply source especially for food processing factories as without the electricity; the frozen food might go bad. Only the common one is the lighting load (lights, sockets and fans etc.).

Almost all factories have their own 11/0.4KV distribution transformer which step down the supply from 11KV to 40 Volts.

This transformer, control gear (Main Switch fuse or MCCB or ACB,MCBs, power factor correcting equipment) and meters (volt meter, ampere meters, KWH meter and KVARH meters are installed in a special room at suitable location (at ground floor or basement).Whatever is the location of such room, it should be locked and only an authorized person should be allowed to enter. A warning plate with words *"danger of high voltage, no entry except the authorized person "*should be fixed at the door of the control room.

Fig 7.23: Danger plate fixed on control room door

Some very large industries having machines which required special voltage, take bulk supply feeder from Supply Company and distribute it to the factory through their own substation. Some industries have bus bar chambers, from where supply goes to different distribution boxes.

Locate and rectify faults in power wiring

In power wiring, three phase supply is used for three phase machinery. However in factories and large commercial buildings, three phase four wire supply is provided because there is large No of lighting points which require single phase supply. The faults in power circuits, which may arise in an installation, are:

1. **Completely dead circuit in whole the building**. This can be checked with test lamp or multi-meter, starting from energy meter in put terminals to main DB. If supply is not available at meter's input terminals then complain to the relevant sub division of Supply Company. If supply at input terminals is available, then locate it up to main DB.

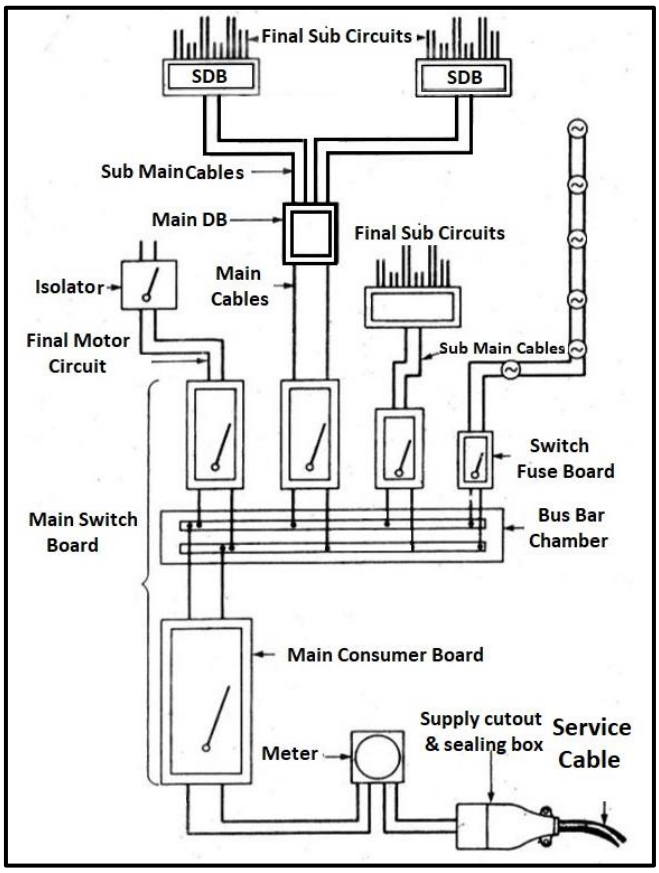


Fig 7.24: Block diagram of supply distribution in large factory

2. **A particular sub circuit is completely dead** (all other circuits are alive). This is the same situation as mentioned above and should be checked in main DB to end point of the sub circuit for location and rectification of the fault.
3. **Short circuit:** Its nature may be as given below,
   a. Dead short circuit within all the three phases.
   b. Short circuit between any two phases.
   c. Short circuit between any phase and neutral.
   d. Short circuit between any two phases and neutral.

The result of all the above faults is the tripping of main breaker or sub breaker. The fault can be traced using Megger with main switch off, between all conductors and between live conductors and neutral from main switch to main DB. All sub circuits fuses are then removed and are tested separately one by one until faulty one is found.

4. **Open circuit:** A broken wire itself shows very clearly as circuit beyond the break is dead. A continuity test of either of the wires at this point will show up the fault.
5. **Single phasing:** It is a very common fault in three phase circuits and cause serious damage in relevant machines and also in neighbouring apparatus too. The indication of single phasing can easily be seen from indicating lamps from main DB as one of the lamp will be off. If such a situation is seen, cut off the main supply promptly. Now confirm with multi-meter and rectify the fault.
6. **Earth fault (or leakage):** Because earth leakage circuit breakers are not usually installed in power circuits due to their sensitivity, earth fault may be seen in two ways.
    a. By reading of ammeter/ ammeters which show more than normal load current.
    b. By feeling electric shock (if earth is not proper and it can be fatal) when touching metal work of the installation**.**

Exercise

Part-1: Subjective type Questions

Sample Long Answer type questions

1) Write method of installation of surface type steel conduit wiring system.
2) Discuss the faults of power wiring.
3) Write advantages and disadvantages of steel conduit wiring system.
4) Write in detail method of installation of trunking system.
5) Write all about Catenary wiring system.
6) Write advantages and disadvantages of Catenary wiring system.
7) Write advantages and disadvantages of overhead bus bar wiring system.
8) What precautions should be considered during installation of overhead bus bar wiring system?
9) Explain how cables are fixed in lead sheathed wiring system.
10) Write advantages and disadvantages of lead sheathed wiring system.
11) Write 10 precautions to be observed during installation of lead sheathed wiring system.
12) Enlist 20 tools required to install heavy gauge steel conduit wiring system.

Part-2: Objective type Questions

Sample Short Answer type Questions

1) What is meant by power wiring?
2) Write two differences between domestic and industrial wiring.
3) What is difference between power and industrial wiring?
4) Define industrial wiring.
5) Write 04 advantages of surface type heavy gauge steel conduit wiring system.
6) Which wiring system will be preferred, if heavy and long cables have to be used in any installation.
7) Write four advantages of trunking wiring system.
8) Write the construction of cable used in Catenary wiring system.
9) Write four advantages of trunking wiring system.
10) Write four advantages of catenary wiring system.
11) Write names of material which are used for making ducts of ducting wiring system.
12) Which types of cables can be used in under floor ducting system?
13) Which types of cables should not be used in under floor ducting system?
14) Write the names of power/ industrial wiring systems.
15) What is raising main bus bar system and where it is used?
16) Write the names different steel trunking.
17) Writ four sizes of steel trunking.
18) Write 04 advantages of tough sheathed wiring system.
19) Write two important precautions during installation of the trunking system.
20) Write 04 advantages of PVC duct (mini plastic trunking) wiring system.
21) Writ four sizes of PVC duct in mm.
22) Write 04 advantages of overhead bus bar system.
23) Write names of faults usually occur in power wiring.
24) What is meant by single phasing and what is its disadvantage.
25) Why earth leakage circuit breaker is not used in power wiring.

Sample Multiple Choice Type Questions (MCQs)

1) This is not a power wiring system
   a. Steel conduit system. b. Trunking system.
   c. PVC Ducting system. d. Catenary system
2) Catenary wiring system is used for
   a. High roof buildings b. Farm houses

c. Very low temperature areas d. All these

3) Power wiring is installed in
   a. Domestic buildings b. Industries
   c. Large commercial buildings d. Both b & c
4) This system is suitable where large number of small or small number of large cables are to be used
   a. Steel conduit system
   b. Trunking system
   c. Catenary system
   d. Concrete ducting system
5) This is not the type of steel trunking
   a. Cable trunking
   b. Multi-Compartment trunking
   c. Bus-bar Trunking
   d. None of these
6) Trunking is generally supplied in the length of
   a. 3 metres b. 5 metres
   c. 10 metres d. All these
7) This fitting is not available for trunking system
   a. Elbows b. Tees
   c. Right-angle turns d. None of these
8) Fire resistant cement is necessary where trunking passes through
   a. Walls b. Floors
   c. Ceilings d. All these
9) This is the advantage of trunking system
   a. Lighter in weight than conduit
   b. Easy to install
   c. Heavy cables above 120mm2 can also be installed
   d. All these
10) The disadvantage of PVC ducting system is
   a. less life
   b. Cannot bear the load of heavy cables
   c. Not water proof
   d. All these
11) The space factor for under floor ducting system is
   a. 35 percent b. 45 percent
   c. 25 percent d. 55 percent
12) The space factor for conduit system is
   a. 35 percent b. 40 percent
   c. 25 percent d. 55 percent
13) The space factor for trunking system is

a. 35 percent b. 45 percent
c. 25 percent d. 55 percent

14) In trunking system, different cables can be accommodated having different
a. Size b. Voltage grade
c. Current rating d. All these

15) Trunking system can be erected
a. quickly b. easily
c. With less skill d. Both a & b

16) Trunking system can be
a. Screwed direct to walls b. Suspended across trusses
c. Buried under floor d. All these

17) Trunking system is a
a. Fire proof system
b. Damp proof system
c. Costly than conduit system
d. Both a & b

18) Laying of cables is easy in this wiring system
a. Trunking system
b. Surface type steel conduit system
c. Concealed type PVC conduit system
d. Both b & c

19) PVC duct wiring system as compared to steel conduit system
a. Easy to install
b. Easy to draw cables
c. Can be used at temperature less 0°C
d. Both a & b

20) Steel conduit system as compared to PVC duct wiring system
a. Difficult to install
b. Difficult to draw cables
c. Can be used at high temperatures
d. All these

21) PVC non-sheathed cables are not permitted in system
a. Concrete ducting system
b. Trunking system
c. Steel conduit system
d. All these

22) This fault can occur in power wiring system
a. Single phasing b. Open circuit
c. Short circuit d. All these

ANSWER KEY

1	**c**	7	**d**	13	**b**	19	**d**
2	**a**	8	**d**	14	**d**	20	**d**
3	**d**	9	**d**	15	**d**	21	**a**
4	**b**	10	**d**	16	**d**	22	**d**
5	**d**	11	**a**	17	**c**		
6	**a**	12	**b**	18	**a**		

Ch-8: Motor Installation and Wiring

Main Topics in this chapter

(1) Power wiring for motors (2) Cable and fuse / circuit breaker size for motor (3) Study and use of magnetic contactors, push buttons, and thermal overload relay and E.O.R (electronic over current relay) (4) To install motor with DOL,3 point & star-Delta starter.

Important points regarding motor installation & cable and fuse size

The nature of motor load is different from that of lighting load and even other power loads (heater, cookers etc.) in the sense that starting current of motors is much higher than their full load running current. The starting current of motors depends upon the type and size of motor and also on their starting method. Therefore special regulations have been developed for circuits feeding the motors. The brief of all these is given below.

- All motors either ac or dc of any horse power must have suitable means of starting and stopping. (IEE Regulation 315)
- An isolating device (an isolator or switch fuse) should also be provided to isolate the motor and its controls from the supply. (IEE Regulation 315)
- Above ½ horse power(367.8 W), all motors must have:
  - Under voltage protection and means of limiting the starting current (IEE Regulation 315)
  - Maximum voltage drop from MDB to motor terminals should not be more than 2.5 % of the supply voltage.
  - Motors having full load current above 20A should be wired direct from MDB with all necessary controls near the motor.
  - Only one motor should be installed on final sub circuit if its current rating is 15A or above. (IEE Regulation 114-A).
  - All motors above 5HP must be started with suitable type of starter.
  - Minimum cross sectional area of conductor feeding the motors is $4.0mm^2$.
  - The current rating of cables for motors should not be less than half the rating of fuse used for its protection.
  - Voltage drop calculation is necessary if length of motor cable from main distribution board to motor terminals is more than 33 meter.
  - Any number of motors can be installed on a 15A final sub circuit, if their total current is not more than 15 Amperes.
- All equipment related to motor control /circuits should be iron clad type and wood should not be used in the installation of control gear.

- Cables of motor circuits should be run in rigid metal conduits or should be of armoured type.
- A piece of flexible metal conduit not longer than 1.25m, should be used between starter and motor terminals.
- HBC fuse should be preferred for motor overload protection & their rating should not be more than 4 times the full load current of motor.
- Current rating of cables should not be less than half the rating of fuse that is installed for its protection.
- For heavy starting currents, circuit breakers should be used instead of fuses. (or increase the size of cable).

Cable & fuse size for motors

Although the starting current of motors is much higher than their full load current, but this current is only for a short time (and above 5HP, starting current is also limited by the use of suitable starters). *So current rating of cables for motors is determined as per full load current of the motor*. For example a 2HP, 230V, single phase ac motor has input current of 11.4 Ampere. Then its cable size will be selected according to this full load current. *The rating of fuse wire is selected according to the starting current of motors.*

In no case, the rating of fuse should be greater than twice the rating of cable of motor.

In case of motors having their starting current less than twice the full load current of motor, then rating of fuse is selected according to the full load current of motor, however if the starting current is higher than twice the full load current of motor, then rating of fuse should be based upon the motor starting current and the cable rating should not be less than half the rating of fuse. So fuse rating is selected before finding the rating of cable.

Size of cable and circuit breaker for motors

Size of circuit breaker and cable for motors is selected 1.2 and 1.3 times the full load current of motor respectively.

Calculating the size of fuse and cable for motors

It is almost impossible to prepare a table showing the correct size of and type of cable to use for every motor, because there are many types of motors and condition of installation may different for each motor. Their fore each motor must be considered separately for calculating its fuse/CB and cable size.

First of all, the correct type and size of fuse is calculated. The rating of fuse for particular motor circuit depends upon the type of motor, type of fuse and starting method of motor as shown in the table below.

i. Find the full load current of motor (either note from the name plate, from manufacturer's table or calculate from the given data according to the formulae given in the box).Find the rating of motor fuse by multiplying its full load current with the factor given in the table.

ii. Find the nearest fuse rating from the table.

Type of motor	Type of starter	Sub circuit fuse rating= F.L current of motor x factor given below	
		HBC Fuse	Rewire-able fuse
3 Phase ac squirrel cage induction motor	Star-Delta	2	2.5 to 3
	Resistance or auto transformer	2.5	3
	Direct on line	3	4
3 Phase ac slip ring induction motor	Rotor resistance	2	2.5 to 3
Single Phase ac squirrel cage induction motor	Direct on line	3	4
D.C motor	Resistance	2	3
	Direct on line	3	4

iii. Halve the value of fuse rating to determine the minimum current rating of cable. For example the found value of fuse rating is 24A, then the minimum current rating will be 24/2= 12A.

iv. Select the size of cable from table for the nearest higher current rating.

v. Multiply the current rating of cable with other factors which can affect the rating of cable (to find the actual current rating in given conditions) such as temperature or any other.

Motors are usually rated in BHP (Break Horse Power) or KWs in S.I units.

One horse power (metric) = 735.5 watts.

Motor input power = $\frac{\text{output in watts}}{\text{motor efficiency}} = \frac{\text{rated BHP x 735.5}}{\text{efficiency of motor}}$

Motor current

In case of dc motors (I) = $\frac{\text{BHP x 735.5}}{\text{rated voltage x efficiency of motor}}$

In case of single phase ac motors (I) $= \frac{BHP \times 735.5}{V \cos\phi \times \eta}$

In case of three phase ac motors (I) $= \frac{BHP \times 735.5}{\sqrt{3} VL \times \cos\phi \times \eta}$

vi. Calculate the value of voltage drop, if the length of cable is more than 33 meters (or area of cable conductor is less than 4.52mm^2). If the calculated value of voltage drop is more than 2.5 % of the supply voltage, then next size is selected and again checked for permissible voltage drop.

Current rating and fusing current of tinned copper wires

Sr. No.	Current rating of fuse in Amps.	Approx. Fusing current in Amps.	Dia. of fuse wire in mm	Size of fuse wire in SWG
1	1.5	3	0.122	40
2	2.5	4	0.132	39
3	3.0	5	0.152	38
4	3.5	6	0.173	37
5	4.5	7	0.193	36
6	5.0	8	0.213	35
7	5.5	9	0.234	34
8	6.0	10	0.254	33
9	7.0	11	0.274	32
10	8.0	12	0.295	31
11	8.5	13	0.315	30
12	1.0	16	0.355	29
13	12.0	18	0.387	28
14	13.0	23	.417	27
15	14.0	28	0.457	26
16	15.0	30	0.508	25
17	17.0	33	0.559	24
18	20.0	38	0.610	23
19	24.0	48	0.711	22
20	29.0	58	0.813	21
21	34.0	70	0.914	20
22	38.0	81	1.016	19
23	45.0	106	1.218	18
24	65.0	135	1.420	17
25	73.0	166	1.624	16
26	78.0	197	1.827	15
27	102.0	230	2.032	14
28	130.0	295	2.337	13

Cable sizes & (HBC) fuse rating for motors

It is just approximation, because the rating of fuse depends upon type & size of motor, its starting method and installation conditions

Motor HP	Full load current	HRC fuse rating	Cable size
1.0	1.9 A	6.0	2.5
1.5	2.5 A	10.0	2.5
2.0	3.4 A	15.0	2.5
3.0	4.8 A	15.0	4.0
4.0	6.4 A	20.0	4.0
5.0	7.8 A	20.0	4.0
7.5	11.6 A	30.0	4.0
10.0	14.4 A	35.0	6.0
12.5	17.3 A	50.0	6.0
15.0	21.0 A	30.0	6.0
20.0	28.0 A	35.0	10.0
25.0	35.0 A	50.0	16.0
30.0	41.0 A	50.0	16.0
40.0	55.0 A	60.0	25.0
50.0	69.0 A	80.0	35.0
60.0	83.0 A	100.0	50.0
70.0	97.0 A	100.0	70.0
80.0	110.0 A	125.0	70.0
90.0	123.0 A	125.0	70.0
100.0	136.0 A	150.0	70.0
125.0	171.0 A	200.0	95.0
150.0	200.0 A	250.0	120.0
175.0	231.0 A	300.0	150.0
200.0	263.0 A	350.0	185.0
250.0	-	-	240.0
300.0	-	-	300.0

Courtesy: *FAST CABLES. Lahore*

Example: *A split phase single phase ac induction motor of 1.5 BHP (metric) having efficiency 85% and pf. 0.8 lagging has to be installed 15 meter away from main distribution board. Twin core PVC insulated copper conductor cable will be used in steel conduit for supply. The declared supply voltage is 230V and ambient temperature 35oC. The motor will be protected by HBC fuse and started with DOL (direct on line)starter. Find the rating of proper*

fuse and cable for this motor.

Solution:

Full load current of motor (I) $= \frac{\text{BHP x 735.5}}{\text{V cos}\phi \text{ x } \eta} = = \frac{\text{1.5 x 735.5}}{\text{230x 0.85 x 0.8}} = = \frac{1103.25}{156.4} =$ 7.05A.

Rating of fuse = **f**ull load current x rating factor of given fuse

= 7.05 x 3 = 33.15A

The nearest fuse rating available (above this rating) is 34A.

So minimum current rating of cable is $\frac{34}{2} = 17$A

Nearest higher rating in the table (9) is 18A and size of cable (of the given type) for this current rating is 2.5mm^2(1/1.78mm) and voltage drop/amp/meter of this cable is 16mV.

The current rating of selected cable at 35^{o}C = 18 x 0.94 = 16.92A

This rating is less than the full load current of motor, so next higher size has to be select, which is 4.0mm^2 (7/0.85)

Rating of this cable is 24A, 600/1000V with voltage drop (per amp per meter) of 10mV.

The current rating of this cable at 35^{o}C = 24 x 0.94 = 22.56A

This rating is more than the full load current of the motor, so selected cable size (4.0mm^2) (7/0.85) is correct.

Calculation of voltage drop is not necessary because length of cable is less than 33m.

Example: *The continuous current rating of 3 phase slip ring a.c induction motor of 35 BHP (metric) is 44A has to be installed7 meter away from main distribution board. Three core PVC insulated, PVC sheathed, non armoured, copper conductor cable will be used in steel conduit for supply. The declared supply voltage is 440V and ambient temperature 45oC. The motor has close access current protection by circuit breaker and rotor resistance starter will be used for starting purpose. Find the rating of cable and CB for this motor.*

Solution:

Full load current of motor (I) = 44A.

Average summer temperature = 45^{o}C.

Length of cable in conduit = 07 meter.

Rating of circuit breaker is =1.2 times x F.L current of motor.

=1.2x44= 52.8A or 53A

Rating of three core cable =1.3 times x F.L current of motor.

=1.3x44= 57.2A

The nearest available rating of CB (above this rating) is 60A.

And the nearest available rating of given type of cable (above 53A) is 65A. The size of cable for this current rating is (35mm^2) (19/1.53) and voltage drop per ampere per meter of this cable is 1000mV (Ref. Column 5& 6 of table 11)

Current rating of this cable at 45^{o}C = F.L current x temperature factor for close access current protection

= 65x0.79 = 48.75A

This current rating is more than the full load current of the motor (which is 44A), so selected cable size (35mm^2) (19/1.53) is correct for give length of cable.

However if the length of cable is more than 33m, then voltage drop is needed to calculate.

Components of motor starters

A typical motor starter consists of a set of 'start' and 'stop' push buttons with associated contacts, thermal or electronics overload relay, low or no voltage release coil and a magnetic contactor.

- Thermal or Electronic Overload Relay
- Push Buttons
- Magnetic contactor
- Low or No voltage release coil

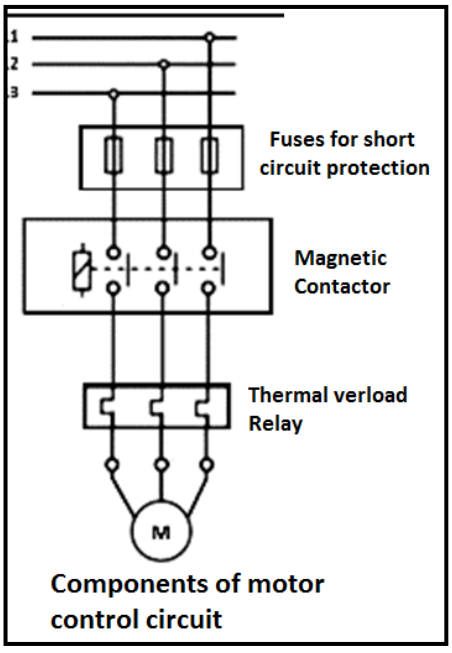


Fig 8.1: A typical motor control circuit sequence

Overload relays can be classified as being thermal, magnetic, or electronic:

Thermal over load relay

A **thermal overload relay works** on the heat produced by the excessive overload current. The function of a thermal overload relay, used in motor starter circuits is to prevent the motor from drawing excessive current which is harmful to motor insulation. Thermal over load relay is usually used for the protection of low-voltage squirrel cage induction motors or DC motors of lower output rating.

Thermal over load relay consists of bimetallic strips which are connected in series of motor winding either directly to motor lines or indirectly through current transformers.

Under normal operating condition the strip remains straight but under sustained overload condition, the strip is heated and bent and the relay contacts get separated which de-energizes the motor control circuit.

The force required to bend the bimetallic strips can be adjusted by an adjuster. In other words, it can be adjusted to operate at different overload currents.

*A small overload current would take much longer for relay to trip the contactors compared to a high overload current where the heating is fast and much less time is taken to trip.

The thermal overload relay **does not provide short circuit protection** as it takes sufficient time to open the contacts. Therefore, this type of relay is used in conjunction with fuses to provide overload and short circuit protection to the circuit. See fig. 8.1. thermal overload relay has inverse time characteristics*.

Thermal overload relays have a fixed trip class because of the fixed thermal element. Unless you change the element, trip class cannot be altered. These are rated in **trip class***. The trip class specifies the period of time it will take to operate in an overload condition. The most common classes are 5, 10, 20 & 30. Class 30, 20, 10 and 5 overload relays will trip within 30, 20, 10 and 5 seconds respectively at 600% of motor full load amps.

As seen in the figure below, both thermal overload relays by ABB and Siemens indicate a fixed trip class 10. Change in ambient temperature may lead to either false-triggering at normal currents or not triggering at all even at abnormally high currents. To overcome this problem, modern thermal overload relays are compensated for ambient temperature but only for a specified temperature range.

Fig 8.2: ABB & SEIMENS thermal over load relays

Electronic overload relay

An electronic over load relay depends upon the strength of the magnetic field produced by the over current instead of depending on heat as is in thermal over load relay. Relays utilizing this principle are not responsive to ambient temperature variation which is a plus point. A " C.T " can provide an electrical measure of the magnetic field of the main current. The response from C.T. is forwarded to electronic circuit whose job is to trip the contacts. These are called solid-state/electronic overload relays. The purpose of thermal and electronic over load relay is same, only the sensing mechanism of EOR differs from thermal over load relay. EOR are more accurate than thermal overload relays.

Fig 8.3: SEIMENS electronic over load relays

In EOR (as seen in figure above by coloured encircling), the trip-class can be chosen. The lower the trip class, the lesser the trip time. During start-up if machine is accelerating slowly, the inrush current will be several times the FLA and will persist for a longer time. Hence the trip class setting would have to be higher so as to avoid tripping during the start-up itself. Variable trip class, broader current range and protection from single-phasing are pretty impressive features of these relays. Because of the solid-state technology involved, digitized data collection and communication is made possible through addition of communication modules. Electronic overload relays offer reliable and precise protection for motors in the event of overload or phase failure. The electronic overload relay can make up a compact starting solution together with contactors.

Main features of EOR

- Selectable trip class (10E, 20E, 30E)
- Adjustable current setting ranges
- Overload protection with phase loss sensitivity
- Temperature compensation up to +70°C and self-supply
- Automatic or manual reset, sealable
- Stop and test function

Benefits of EOR

- Cost effective
- High Performance
- Reliable protection for motors
- Easy to create starters
- Reduced logistic costs and improved designed by three trip classes in one device
- Single mounting kits and wire reset for remote control available for specific applications.

However, *the relay may trip in certain circumstances*

Advanced version of electronic relays are monitoring relays that are capable of

- Over and under-voltage monitoring
- Over and under-current monitoring
- Phase failure detection
- Phase unbalance monitoring
- Phase sequence monitoring

Push buttons: A push button is a small, sealed mechanism that open or close an electric circuit when you press it. Usually, the motor starters are provided with two push buttons (start and stop buttons) in order to energise and de-energise the coil so that contacts will be operated. These electrically operated

starters will not restart after a power failure until the start button is pressed again. There are several types of push buttons, however in motor starters, push on push off type push buttons are used. These are “NC” type and “NO” type. In motor starters usually two push buttons with green and red colour are used. Green button (“NO” type) is used for starting the motor and red button (“NC” type)is used to stop the motor. Yellow coloured push button is provided if motor direction is to be revered.

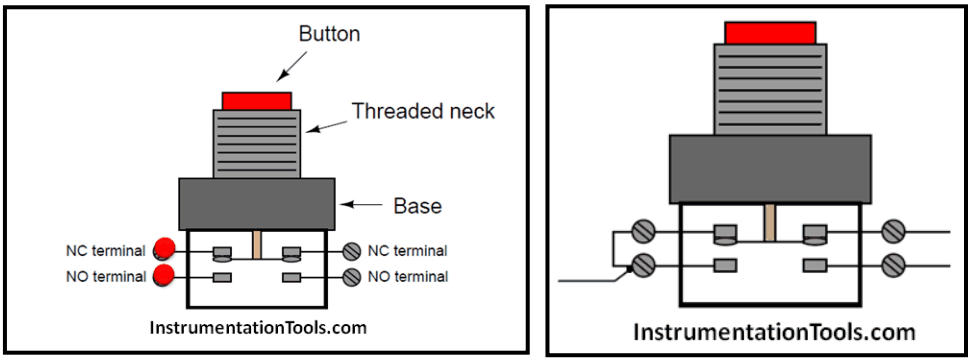


Fig 8.4: NO & NC Push Buttons

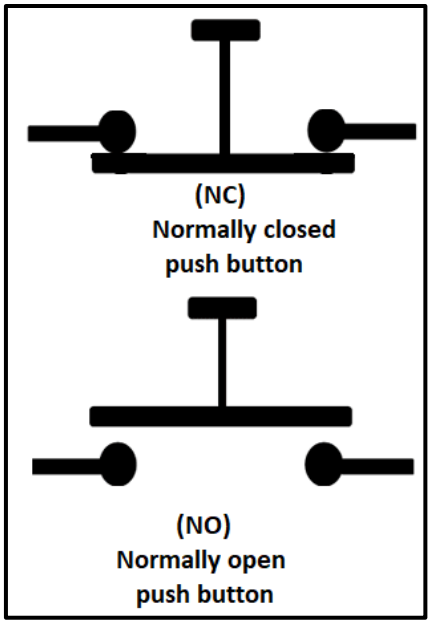


Fig 8.5: NO & NC Push Buttons symbols

Fig 8.6: Push Buttons on a DOL starter

Magnetic Contactor: A magnetic contactor is an electrically-controlled switch used for switching an electrical power circuit. A contactor is typically controlled by a circuit which has a much lower power level than the switched circuit, such as a 24-volt coil electromagnet controlling a 230-volt motor switch .Contactors are mainly used to control machinery which uses electric motors. It consists of a coil (230V for single phase and 400V coils are used). The contactor has three main NO contacts and low power auxiliary contacts(both NO and NC type) used for the control circuit. Contactors range from those having a breaking current of several amperes to thousands of amperes and 24 V DC to many kilovolts. The physical size of contactors ranges from a device small enough to pick up with one hand, to large devices approximately a meter (yard) on a side. Contactors come in many forms with varying capacities and features. Unlike a circuit breaker, a contractor is not intended to interrupt a short circuit current.

Unlike general-purpose relays, contactors are designed to be directly connected to high-current load devices. Switching devices used for more than 15 amperes are usually contactors. Contactors are designed to control and suppress the arc produced when interrupting heavy motor currents.

The electromagnet consists of a coil of wire placed on an iron core. When a current flow through the coil, the iron of the magnet becomes magnetized, attracting an iron bar called the armature. An interruption of the current flow through the coil of wire causes the armature to drop out due to the presence of spring.

Components of a magnetic contactor

- Power circuit
- Control Circuit
- Relay
- Armature
- Electromagnet
- Spring
- Main Contacts (Stationary and Moveable)
- Auxiliary contacts ("NC" & "NO" type)
- Coil

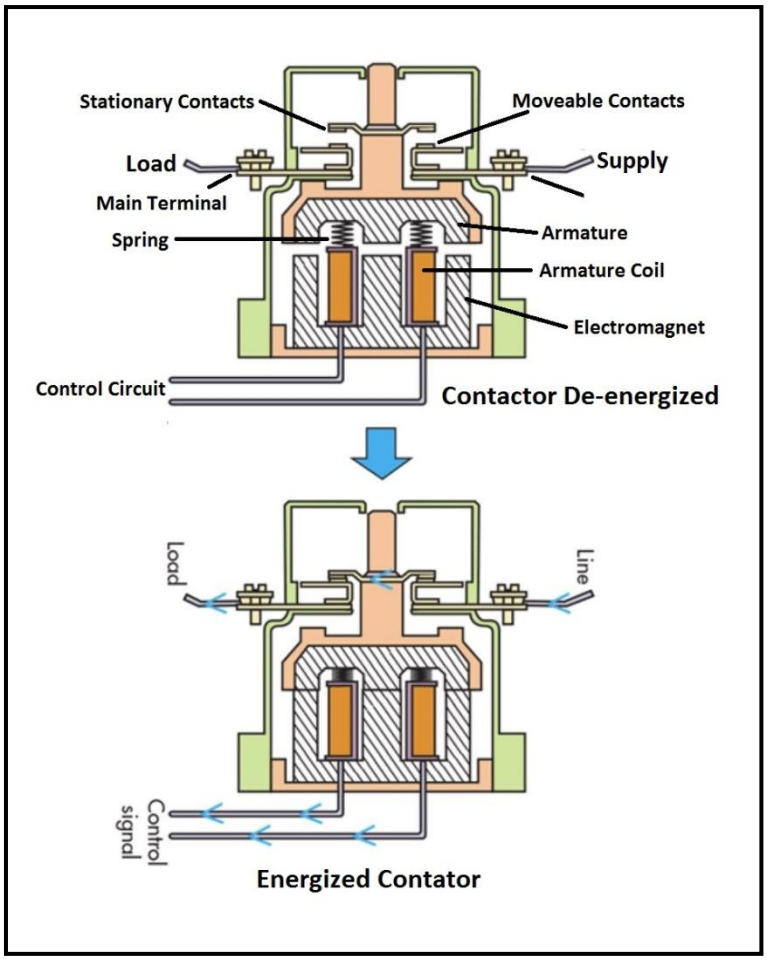


Fig 8.7: Constructional parts of a simple magnetic contactor

Difference between contactor and relay

The contactor is used for high voltage switching applications and the relay is used for low voltage switching applications. Generally, if the load current is more than 15A, the contactors are used and if the load current is less than 15A, the relay is used.

Difference between contactor and CB

Contactor is an electrically-controlled switch used for switching an electrical power circuits allowing the load to be controlled by a control system such as a start-stop push buttons, or an automated controller (PLC).

Contactors are used on low and medium voltages. These are not designed to interrupt a short circuit current. Contactors can break current from few amperes to hundreds of thousand amperes. These are designed for 10000 to 100000 tripping to break normal load currents. **Circuit breaker** is a protective device. Its job is to protect the electrical installation from a fault, so that the fault. It has limited tripping life.

Installing the motor with DOL, 3 Point and star delta starter

Motor Starter:

A motor Starter is a device that is used to start the large electric motors safely and stop when required (or automatically disconnect the motor from supply in case of over load or supply failure). Functions of motor starters can be summarized as below.

i. Start the motor safely
ii. Stop the motor when required
iii. Protect the motor from burning due to over loads
iv. Reverse the direction of motor
v. Disconnect the motor from supply in case of low voltage or voltage failure

Starters are made from two building basic parts, Contactor and Overload Protection. Contactor is used to repeatedly make and break the electrical power circuit. Overload Protection protects motors from drawing too much current, overheating, and from literally "burning out".

A typical motor control circuit consists of the following items.

1. Motor protection devices such as fuse (for low currents) or circuit breaker (for heavy currents).
2. An isolating device (an isolator or main switch or main switch fuse if isolator is not available).
3. A motor starter of suitable type and size.

Sequence and height standards of motor control gears are same for all types of motors.

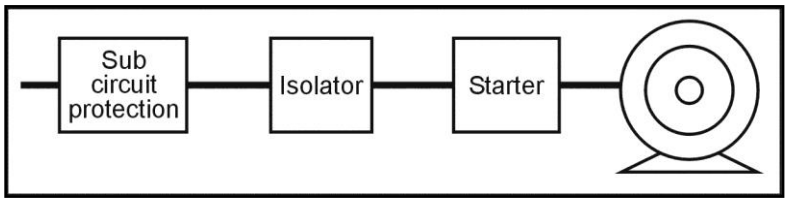


Fig. 8.8: Block diagram of a typical motor control circuit

The DOL starter

A direct online starter consists of two buttons, a GREEN button for starting and a RED for stopping purpose of the motor. The **DOL starter** comprises of an MCCB or circuit breaker, contactor and an overload relay for protection. These two buttons, i.e. Green and Red or start and stop buttons control the contacts.

Since the DOL starter connects the motor directly to the main supply line, the motor draws a very high inrush current compared to the full load current of the motor (up to 5-8 times higher). The value of this large current decreases as the motor reaches its rated speed.

A direct on line starter is used to start low power motors up to 5 horse power.

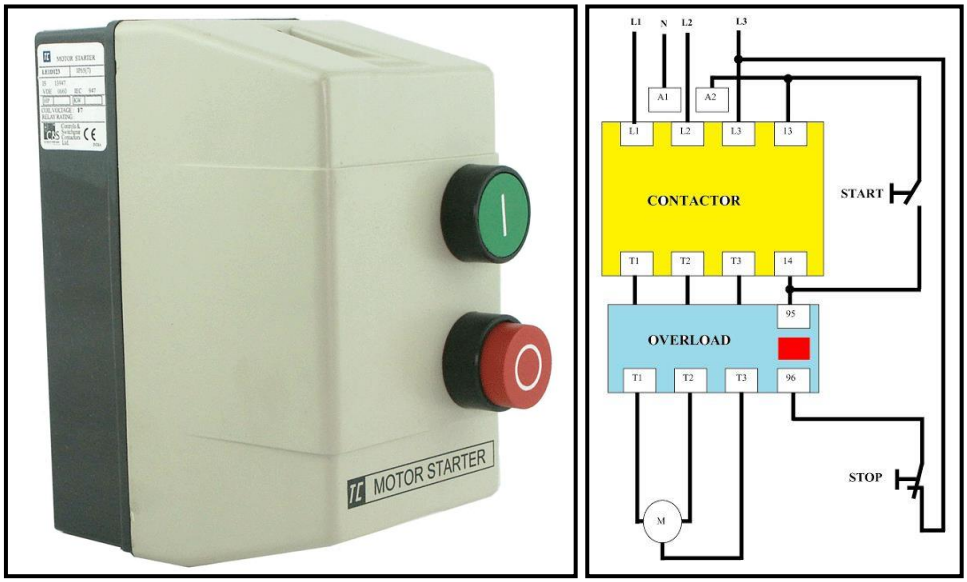


Fig. 8.9: A typical DOL motor starter and its connection diagram

Installing a motor with DOL Starter

Material required for installation of motor with DOL starter

i. Metal clad main board.
ii. 3 way fuse box.
iii. Isolating switch/ isolator/main switch.
iv. DOL starter of suitable rating (with built in over load and under voltage protections).
v. Rawal bolts.
vi. 4 Pieces of 38 mm dia. metal conduits of required length.
vii. Draw wire.
viii. Conduit fittings (such as smooth bore brass bushes, lock nuts and saddles etc.).

Installation procedure

1. Select the proper location to install the main board.
2. Select the main board according to the apparatus to be fixed on it.(for DOL starter a 3 way fuse board and isolating switch will be fixed on this board)
3. Mark the lower height line of main board (1.5 meter from floor surface) and then mark the dots on wall for fixing holes of main board.
4. Drill the holes with suitable bit size (depending on the weight of main board and equipment to be installed on it).
5. Hammer the rawal bolts in the drilled holes.
6. Fit the main board on fixed rawal bolts and tight the nuts.
7. Fit the fuse board on main board.
8. Now fit the DOL starter with same procedure as mentioned above for main board.
9. Connect a piece of steel conduit between the main board and starter using proper fittings (smooth bore bushes, lock nuts etc.)
10. Fix a piece of steel conduit of 38mm diameter on wall between the the starter and motor foundation, passing its horizontal part through the 0.2 m deep trench.
11. A piece of steel conduit is again brought from ground up to motor junction box.
12. Now fit a piece of 38mm dia. flexible steel conduit between motor junction box and motor terminal box.
13. Draw cables from main distribution board to the motor terminals and make connection.

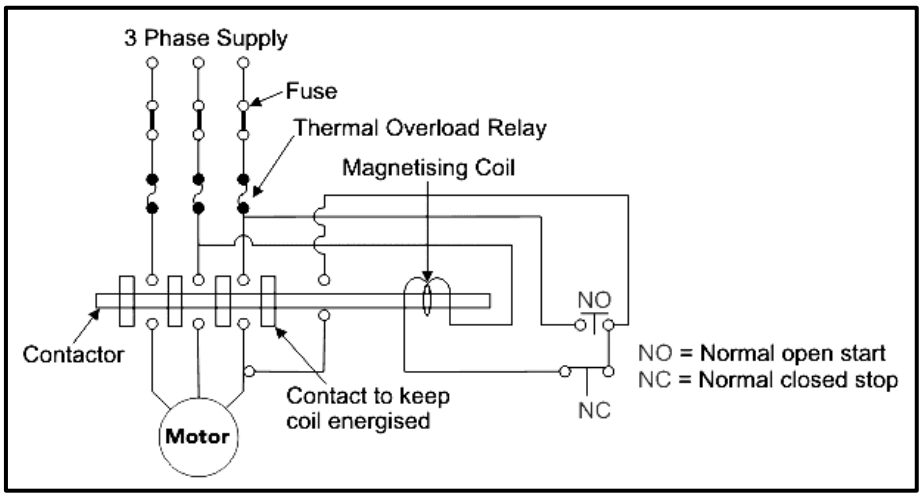


Fig. 8.10: Circuit arrangement of DOL starter of 3 phase motor

Star Delta Starter:

A **star delta starter** is the most commonly used method for the starting of large (from 6- 35 HP) 3 phase induction motors having low starting torque. In star- delta starter, initially the motor is connected in star connection. Then once the motor reaches the required about 70-80 % of the full load speed, the motor is connected in a delta connection.

Star Delta starter may be of following type.

1) Manual with handle operation or push button operation
2) Semi-automatic star –Delta starter
3) Automatic star –Delta starter

Fig. 8.11: Automatic and hand manual star delta starters

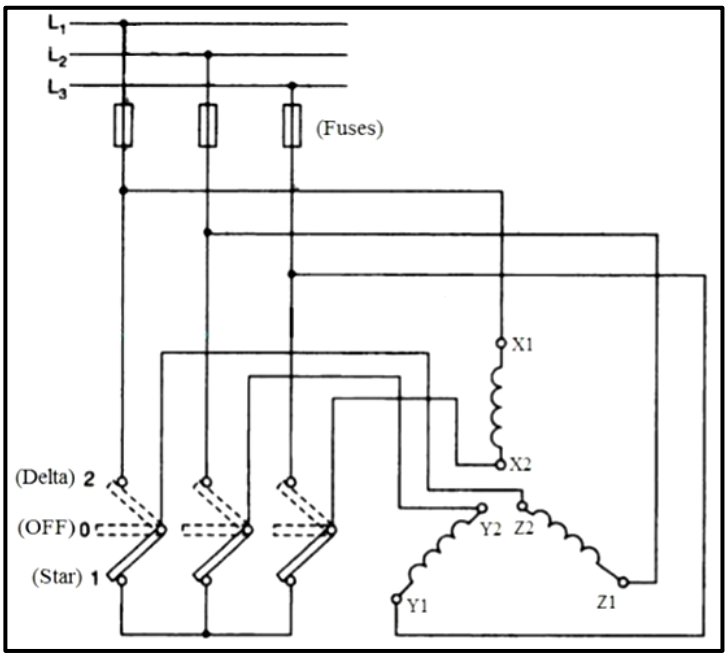


Fig. 8.12: Connection diagram of star delta starter

Installing a motor with Star Delta Starter

Material required for installation of motor with DOL starter

i. Metal clad main board.
ii. 3 way fuse box.
iii. Isolating switch/ isolator/main switch.
iv. Drum type manual star delta starter of suitable rating (with built in over load and under voltage protections).
v. Rawal bolts.
vi. 2 Pieces of 38 mm dia. metal conduits and 2 Pieces of 50 mm dia. metal conduits of required length.
vii. Draw wire.
viii. Conduit fittings (such as smooth bore brass bushes, lock nuts and saddles etc.).

Installation procedure

1. Select the proper location to install the main board.
2. Select the main board according to the apparatus to be fixed on it.(for star delta starter a 3 way fuse board and isolating switch will be fixed on this board).
3. Mark the lower height line of main board (1.5 meter from floor surface) and then mark the dots on wall for fixing holes of main board.
4. Drill the holes with suitable bit size (depending on the weight of main

board and equipment to be installed on it).

5. Hammer the rawal bolts in the marked holes.
6. Fit the main board on fixed rawal bolts and tight the nuts.
7. Fit the fuse board on main board.
8. Now fit the star delta starter with same procedure as mentioned above for main board.
9. Connect a piece of steel conduit between the main board and starter using proper fittings (smooth bore bushes, lock nuts etc).
10. Fix a piece of steel conduit of 50mm dia. on wall between the starter and motor foundation, passing its horizontal part through a 0.2 m deep underground trench.
11. A piece of steel conduit of 50mm dia. is again brought from ground up to motor junction box and is fixed with it.
12. Now fit a piece of 50 mm dia. flexible steel conduit between motor junction box and motor terminal box.
13. Draw cables from main distribution board to the motor terminals and make connection.

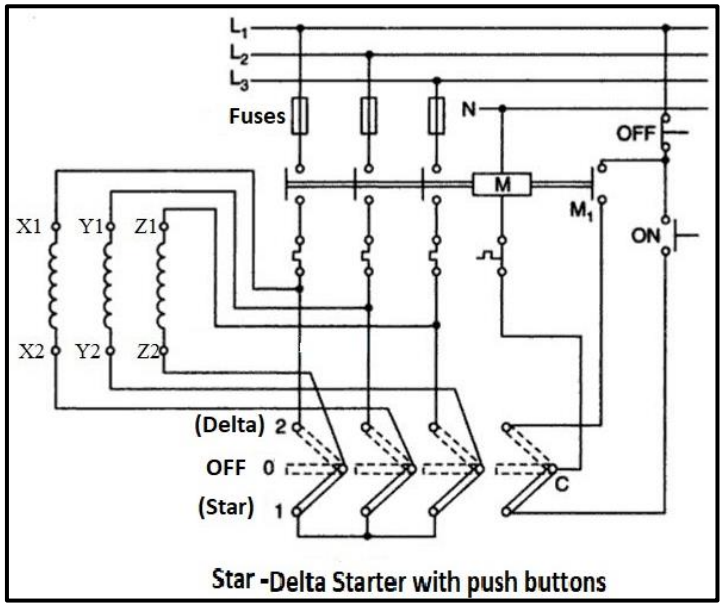


Fig. 8.13: Diagram of push button operated star delta starter

Three-point starter

A three-point starter is an electrical device, used for starting as well as maintaining the DC shunt motor speed. The connection of resistance in this circuit is in series which decreases the initial high current and guards the equipment against any electrical failures.

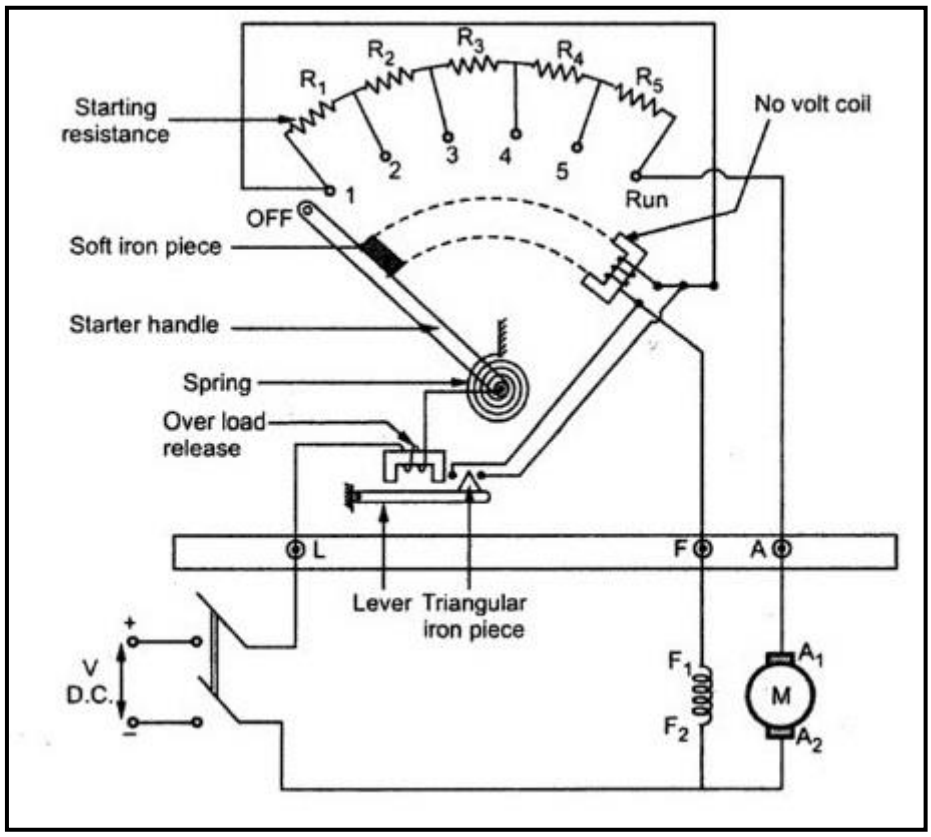


Fig. 8.14: A 3-point starter diagram

Installing a motor with three point starter

Material required for installation of motor with DOL starter

i. Metal clad main board.
ii. 2 way fuse box.
iii. Isolating switch/ isolator/main switch.
iv. Three point DC motor starter of suitable rating (with built in over load and under voltage protections).
v. Rawal bolts.
vi. 3 Pieces of 38 mm dia. metal conduits of required length.
vii. Draw wire.
viii. Conduit fittings (such as smooth bore brass bushes, lock nuts and saddles etc).

Installation procedure

Installation procedure of DC motors is same as described above except that, for DC motors three and four point starters are used. The diagram of three point starter is shown to understand the working of the starter.

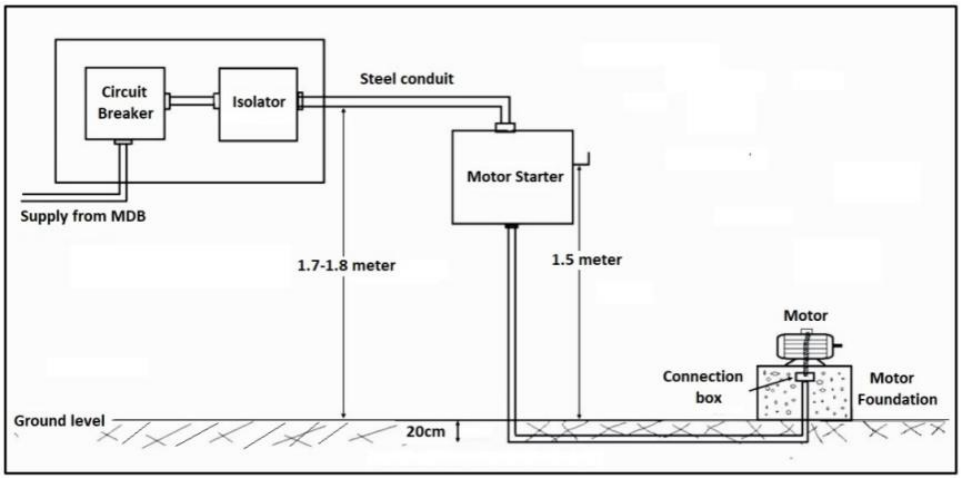


Fig. 8.15: General arrangement of motor installation

Dismantling and assembling of single and three phase motors

An electric machine must be dismantled with care in order to avoid damaging the parts or losing them. No chisel should be used to pry apart mating components. Heavy blows and excessive force must also be avoided.

If screws and bolts are difficult to unscrew, they should be wetted with kerosene and the parts put aside for several hours to allow the kerosene to penetrate between the threads. The screws and bolts will then come loose easily.

After a part is taken off, a marked tag should be attached to it to identify it with the machine to which it belongs.

Small parts should be laid in a box and stored until required. The best way to keep bolts to, nuts and studs from getting lost is to screw them back in the place after the parts have been dismantled.

When dismantling the complicated parts of a motor/machine, (winding for instance) it is necessary to draw sketches, wiring and connection diagrams, and sometimes to take a certain number of measurements.

Bellows are some of the effective ways of dismantling of machines. They are carried out in a definite sequence.

Removing a pulley or half coupling:

Either the set screw or the gib-head key locking the pulley on the shaft must be removed. Kerosene should be poured on the shaft where the pulley is seated. If the fit is not tight, the pulley can be driven off the shaft by light blows of a hammer on a block of wood placed against the hub of the pulley.

When the pulley fits very tight on the shaft, a screw puller is required as shown in the fig below.

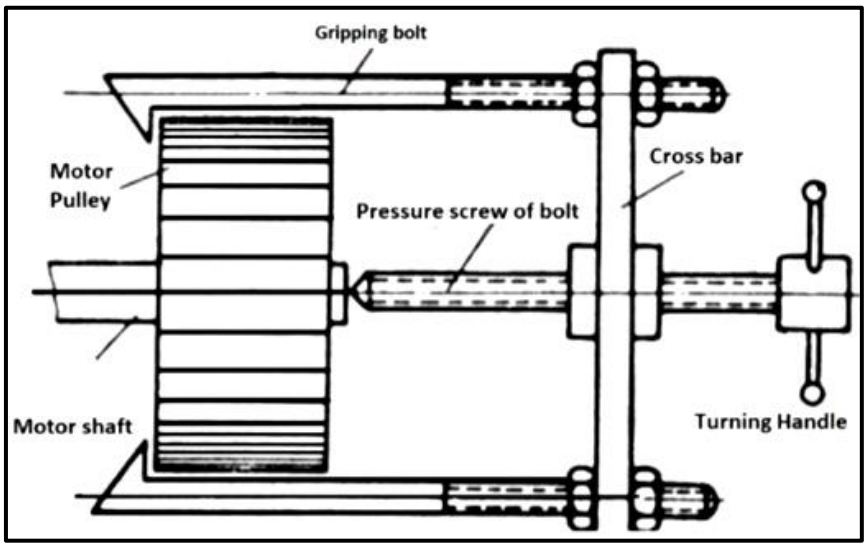


Fig. 8.16: Removing of motor pulley

The puller must always have the axis of its pressure screw aligned with the axis of the shaft. As pressure is applied by turning the handle of the screw and preventing the crossbar from revolving, the pulley will gradually slide along the shaft until it pulled free.

Removing the end cover:

Three to four common horizontal lines are marked, starting from stator body to end cover before pulling out the end covers**.** The screws securing the cover or flanges fixing the bearing in position are unscrewed and the covers or flanges are taken off. Then the brush gear is removed as a whole, the oil is drained from the bearing.

To remove the end covers properly, the fixing bolts are unscrewed and taken off. With light blows of a hammer on a block of wood placed against the lugs of the end covers, the latter is driven out of its seat in the frame.

The rotor must be protected before the end cover is driven out of its seat in the frame. For this, the rotor is held suspended by a sling attached to the hook of a lifting device (electric hoist, chain hoist, single beam overhead crane).

After the cover has come out of its seat in the frame, , it can slide along the shaft of the machine but before this is done a sheet of hard press board should be inserted in the bottom air gap between rotor and the stator core to protect the core steel and the insulation of the windings. The rotor can then be lowered on the stator core with the risk of damage when the end cover is pulled off.

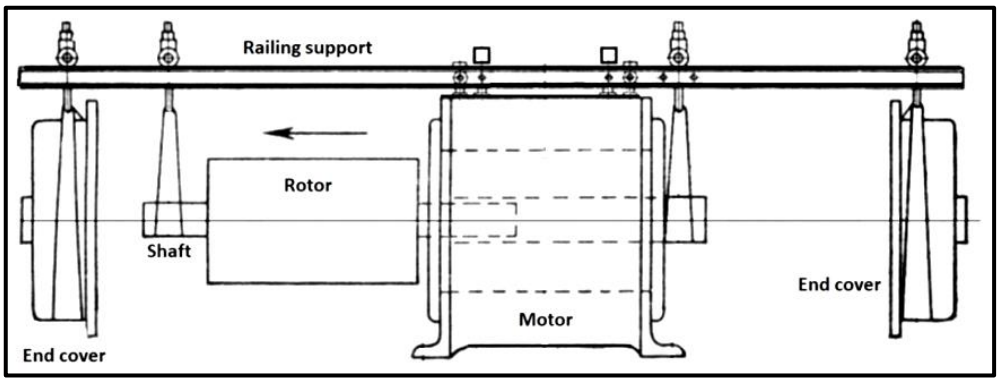


Fig. 8.17: Pulling out of heavy rotor of a large motor

Pulling out a rotor:

In small machines, the rotor is pulled out by hand after the end cover is removed. This is done by carefully raising it 01 or 02mm off the pressboard. Heavy rotors of large machines are pulled out at the motor site by some form of lifting device. *When the rotor is being pulled out, care must be taken to keep it in line with the axis of the machine.* See the centre line of figure 8.15

Pulling out the Bearings:

Ball and roller bearings are removed from the shaft in the same way as the pulleys or couplings, by means of special bearing pullers. The jaws of the puller arms in this case must be engaged with the inner race of the bearing. Before pulling, hot oil should be poured on the bearings to loosen the fit. Sleeve bearing bushes and liners can be driven out of end covers with light blows on a wood driving block held against the end face of the bush or liner. This is done with the end cover lying on a wooden support with an opening large enough for the bush to pass through. Before the bush or liner is driven out, the oil ring should be removed or positioned so that it will not interfere.

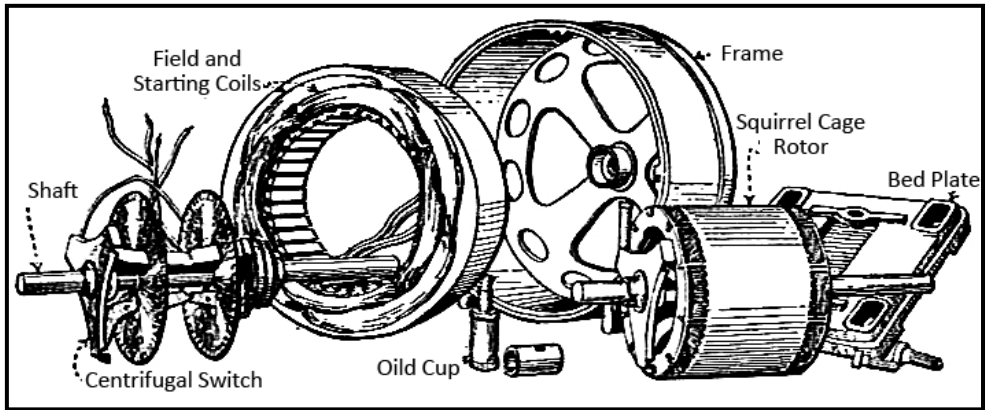


Fig. 8.18: Dismantled parts of single phase ac induction motor

After a machine is dismantled, its main parts such as the end cover, bearings, rocker ring or yoke, bushes, lubrication fittings, and seals should be washed in kerosene or petrol oil. All parts should be examined carefully for repair or replacement. After repair, motors are assembled in proper way. The methods and cares are given below.

Assembling of motors:

Each motor must be assembled in a clean, dry work area free from all unrelated objects. All the parts should be gathered and looked that no part is missing. All the assembling procedure should be carried out in a proper sequence.

Step 1: Fitting of sleeve bearings. The sleeve bearing liners or bushes are usually pressed into their seats or bores in the end covers by means of a screws or hydraulic press. In certain cases it is permissible to use a hammer. The bush is driven in with light blows of the hammer on a block of wood placed on the end of the bush. When the work is done in a press, care must always be taken to keep the bush coaxial with the bore into which it is being pressed.

Step 2: Rotor assembly. First the rotor sub assembly is slide into the shaft and fixed in place. Then the cooling fan is slipped over the shaft and secured in. If the machine is fitted with ball bearings, the later requires preliminary heating in an oil bath to a temperature of 75^{o}C to 85^{o}C, following which they can be pressed into their seating place in the shaft. Bearings must be suspended for heating in the bath. They must not be laid on the bottom of the bath or be heated with a blow torch because of the danger of uneven temperature rise and loss of temperature. The bearings are driven into their seats with light blows of hammer on a block of wood held against a piece of pipe pressed to the inner race of the bearing. The outside diameter of the pipe should not exceed that of the inner race of the bearing.

Step 3: inserting the rotor into the stator and fixing the end covers. The rotor must be inserted into the stator with special care because winding or core may very easily be injured. Method of inserting the rotor into the stator is just opposite to the method of removing the rotor as described above. A light weight rotor can easily be inserted manually by hand. However heavy weight rotors require the use of lifting device and a crane. For protection, a sheet of pressboard should be inserted in the bottom air gap between the rotor and stator. When the rotor is resting exactly in its correct axial position, the back (drive end) end cover is slipped into place. It is in the correct position when the marks made on it and the frame during dismantling is matched. Now, to hold it, the bolts are loosely run in. The temporary pressboard padding is next

pulled out and the front end cover is mounted and also loosely held in place with its bolts. End cover bolts should be taken up gradually and approximately, across a diameter, each bolt being given only half a turn each time.

Step 4: Complete assembly. Before the end covers bolts are completely tightened the shaft should be turned by hand. If there is nothing wrong, the shaft will turn easily without any obstruction. If the shaft is difficult to turn, there may be any of the following reasons.

a. There may be chips or dirt.
b. Thickened lubricant in a bearing.
c. Misalignment of the shaft.
d. Some foreign object left in the air gap.
e. Tight fit between the bearings and shaft.
f. Incorrect tolerance.
g. And some other causes.

After removing the fault, the end covers can be fully tightened. The end cover flanges or bearing covers are now put in place, the oil wells in sleeve bearings are filled with oil and the rest of the components and parts are assembled on the machine. The air gaps are checked with feeler gauge, and end play of the shaft is checked by measuring the clearance between the inner bearing end face and the corresponding shaft journal shoulder (it should not exceed 1 or 2 mm).All bolts and screws are again checked to see that they are tight. Now motor is routed to testing stand.

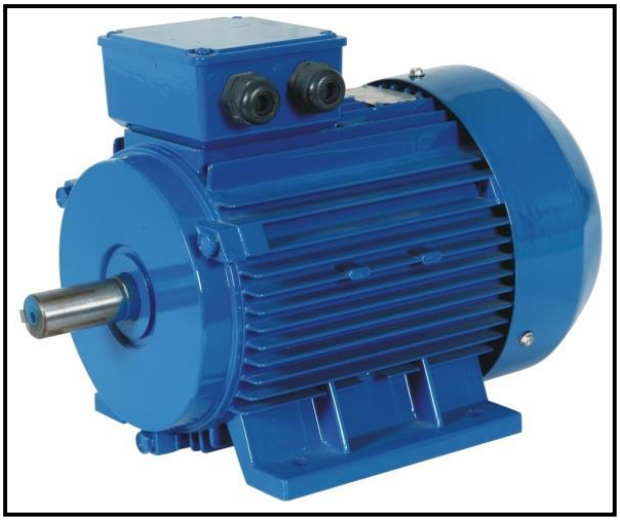


Fig. 8.19: Assembled form of ac induction motor

Preparing motor foundation and its levelling

All motors (except fraction horse power motors and motors of portable appliances) must be used after installing on a properly designed concrete foundation. Otherwise there will be a continuous trouble and may lead to early wear and tear of motor.

Definition: A cubical structure of concrete (or supporting frame) in rectangular or square shape which provides a rigid base to the motor/machine is called foundation.

The size, shape, depth and strength of foundation for any motor depends upon the size, weight, nature of load to be coupled and vibration of the machine along with the nature of soil where the foundation has to be made.

A proper foundation smooth up the motor operation, increases its life and reduces wear and tear.

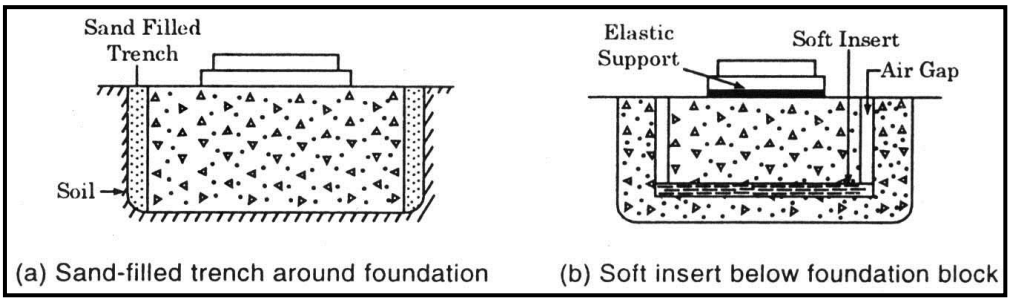


Fig. 8.20: Two methods to block transmission of vibration to nearby walls and apparatus

Purpose of foundation:

i. It provides levelled and firm base for motor.
ii. Support the weight of motor.
iii. Absorb the vibration of motor/ machine.
iv. Confine the motor vibration within the foundation area.
v. Maintain the alignment of motor with coupled or connected machines.

Designing the concrete foundation:

A foundation has to bear two types of loads, which are:

1. **Static** (dead) **load** of motor (or mass of motor).
2. **Dynamic load** (vibration of motor and pull on it).

For calculating the strength of motor foundation, both the loads are taken into account. Vibration and pull is also converted into dead load. Instead of doing complicated calculations, a general rule is adopted in which motor's dead load is doubled to include its vibration and pull. Size of foundation is kept larger than motor dimensions up to 15cm on all sides. To avoid

transmission of vibration to other adjoining parts of the building or other foundations, a layer of sand is filled around the foundation pit or a soft rubber pad is inserted beneath the foundation. If another machine is to be coupled with motor on the same foundation at same level, alignment of both the machines should be checked and adjusted carefully.

Following points are considered to prepare a good motor foundation.

i. Length (including motor shaft) and width of motor.
ii. Dead load of motor.
iii. Level of vibration and pull on motor (in the form of dead load).
iv. Condition of soil.
v. Depth of motor foundation. (It depends upon size and total weight of motor and soil conditions).

Following is the general guideline for foundation depth.

Motor horse power	Depth of foundation in cm
10-25	15-20
25-50	20-25
50-75	25-38
75-100	38-60

Connection of conduit and supply with motor through foundation

Cables of motor circuits are run in surface type rigid metal conduits but the supply from starter wall to motor foundation and up to motor junction box is brought through underground G.I pipe (buried 0.2meter deep in trench) of suitable size, and a flexible conduit (having length not more than 1.25m) is used from motor junction box to motor connection terminal as shown in the figure (general arrangement of motor installation).

Before making the foundation

- Fix the main board on the wall (to hold the circuit breaker and isolator or switch fuse board on it) 1.7 to 1.8 meter high and starter board 1.5 meter high from the ground level.
- Connect all the metal gears by a suitable size of G.I pipe.
- Connect a piece of G.I pipe on lower side of motor starter 2.5 long (and 38mm dia. for DOL starter and three point starter and of 50mm dia. for star delta starter). It will go 0.2 meter deep in ground.
- A horizontal piece of G.I pipe is now connected at the lower end of this pipe up to the centre of foundation and 10cm from pit wall.
- An upward vertical piece of 50mm dia. G.I pipe is again connected at the end of horizontal pipe.
- At the top of this vertical pipe, a metal junction box is fitted.

Steps for preparing a motor foundation

An example is being given to prepare motor foundation for a three phase a.c induction motor of 40HP whose length along with pulley and shaft is 68.6cm and with is 46.75cm.

1. Select the proper location for motor foundation.
2. Dig a rectangular pit 30cm deep in the ground of size about 115cm x 75cm.
3. Spread a 15cm thick layer of broken pieces of bricks in the base of pit.
4. Fill the uneven surface by spreading a thin layer of sand on broken pieces of bricks.
5. Prepare a net of steel rods (with a space of about 15cm between steel rods) and put it in the bed of pit.
6. Prepare a loosely connected rectangular wooden frame (mould), empty from upper and lower sides and put this mould in the pit bed.
7. Measure the distance of holes in the base of motor length wise and width wise.
8. Fix the vertical foundation anchor bolts in the pit with anchor side downward and threaded side upward. The length of anchor bolts shall be so selected that their upper ends come out about 5cm from the foundation.
9. Now prepare a dry concrete mix of cement, sand and crushed stone in the ratio of 1:3:6.
10. Pour water in the dry concrete mix and make a semi solid paste.
11. Pour this concrete in the wood mould continuously up to the desire height. There should not be air bubbles in the foundation block during pouring process. For heavy foundations, mechanical vibration is arranged to remove the air bubbles from the foundation block
12. Now re-check the distance of foundation bolts and adjust them exactly before setting the concrete if some difference is found.
13. Check the upper level of foundation with sprit level and level it if necessary.
14. Now let the concrete to be set for three to four days.
15. Shower the water time to time during setting period and take care that there is no crack seen in the foundation during this time.
16. After the setting of foundation block, put the motor on the foundation and tighten fix the nuts on the threaded head of foundation bolts.
17. Pull through the cables in the pipe and make connections with motor and control gear.

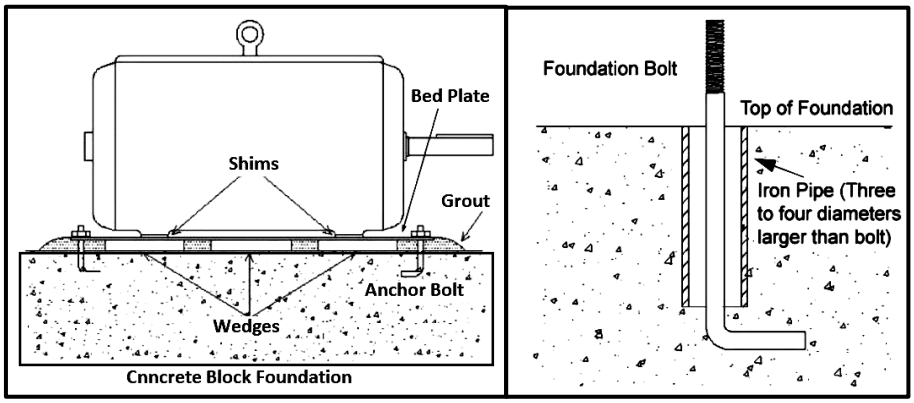


Fig 8.21: Motor fitted on concrete block foundation (left) and a foundation anchor bolt in place (right)

Exercise

Part-1: Subjective type Questions

Sample Long Answer type questions

1) A 10 BHP (metric) continuous rating, three phase ac squirrel cage induction motor has efficiency of 80% and pf. 0.85 lagging. The 400V supply to motor has been provided through three single cores PVC insulated, PVC sheathed, non-armoured copper conductor cables run in conduit from main distribution board, 20 meter away from MDB. Average summer temperature in the installation is 40°C. The motor will be protected by HBC fuse and started with star delta starter. Find the proper rating of fuse and cable for this motor.
2) Write important points regarding the selection of cable and fuse size for motors.
3) Write step wise procedure to calculate the size of fuse and cable for any given motor.
4) A split phase single phase ac induction motor of 2.0 BHP (metric) having efficiency 80% and pf 0.85 lagging has to be installed 40 meter away from main distribution board. Twin core PVC insulated copper conductor cable will be used in steel conduit for supply. The declared supply voltage is 230V and ambient temperature 40°C. The motor will be protected by HBC fuse and started with DOL (direct on line) starter. Find the rating of proper fuse and cable for this motor.
5) A split phase single phase ac induction motor of 3 BHP (metric) having efficiency 80% and pf. 0.5 lagging has to be installed 30 meter away

from main distribution board. Twin core PVC insulated copper conductor cable will be used in steel conduit for supply. The declared supply voltage is 230V and ambient temperature 45°C. The motor will be protected by HBC fuse and started with DOL (direct on line) starter. Find the rating of proper fuse and cable for this motor.

6) Which equipment is necessary for the installation of a 10HP motor?
7) Write function of each in brief.
8) Make list of materials required for the installation of motor with DOL starter.
9) Make list of materials required for the installation of motor with star delta starter.
10) Write all steps to install an electric motor.
11) Write all steps in sequence to dismantle a single phase ac motors.
12) Write all steps in sequence to assemble an electric motor.
13) Which points are considered to prepare a good concrete block motor foundation?
14) Write steps wise procedure to prepare concrete foundation for a motor.

Part-2: Objective type Questions

Sample Short Answer type Questions

1) State IEE Regulation 315 about motor installation.
2) How many motors can be installed on a final sub circuit?
3) For which size of motor, starter is essential.
4) Describe the relation between the size of cable and the size of fuse for a motor.
5) Which type of wiring is recommended for motor installation?
6) Which protective device should be chosen if starting current of a motor is high.
7) On which factors, the rating of a motor fuse depends.
8) What should be the rating of cable, if a 30A fuse has been used for a motor?
9) Define magnetic contactor.
10) Write the sequence of equipment used for motor control.
11) Write the names of parts of a magnetic contactor.
12) Write difference between magnetic contactor and circuit breaker.
13) What is difference between magnetic contactor and starter?
14) How much current can be interrupted by a contactor?
15) What method should be adopted if screws and bolts of a motor are difficult to unscrew.
16) Define the motor starter.

17) What is the function of thermal relay in motor starters?
18) What is the minimum size of cable for a motor circuit?
19) Why starters are necessary for motor starting.
20) Write the names of motor starters.
21) Why motor should be installed on foundation.
22) Write 04 Purposes of foundation.
23) Which types of load, a motor foundation has to bear?
24) Define static and dynamic load of motor
25) What ratio of cement, sand and crushed stone is used to prepare concrete for motor foundation.
26) Write four advantages of installing a motor on a concrete foundation

Sample Multiple Choice Type Questions (MCQs)

1) Above ½ horse power(367.8 W), all motors must have
   a. Under voltage protection
   b. Means of limiting the starting current
   c. Over voltage protection
   d. Both a & b
2) Motors having full load current above 20A, should be wired direct from
   a. Sub distribution board b. Main distribution board
   c. Energy meter d. Service pole
3) Only one motor should be installed on final sub circuit if its current rating is
   a. 15A or above b. 25A or above
   c. 30A or above d. 50A or above
4) All motors above this horse power must be started with suitable type of starter
   a. 5 H.P b. 15 H.P
   c. 25 H.P d. 20 H.P
5) Minimum cross sectional area of conductor feeding the motors is
   a. 4.0 mm2 b. 2.5 mm2
   c. 10 mm2 d. 16 mm2
6) Voltage drop calculation is necessary if length of motor cable from main distribution board to motor terminals is more than
   a. 33 meter b. 10 meter
   c. 23 meter d. Any of these
7) If total current of some motors is not more than 15 Amperes, then No of motors that can be installed on a sub circuit may be.
   a. 3 b. 5
   c. 10 d. Any number

8) All equipment related to motor control/circuits should be of
   a. Iron clad type b. Three phase type
   c. Single phase type d. None of these
9) The rating of HBC fuse should not be more than----------of the full load current of motor
   a. 4 times b. 2 times
   c. 2.5 times d. 5 times
10) In no case, the rating of fuse should be greater than -----the rating of cable of motor
   a. Twice b. Three times
   c. 04 times d. 2.5 times
11) Motors having their starting current less than twice the full load current of motor, then rating of fuse is selected according to the
   a. Full load current of motor
   b. Starting current of motor
   c. Half the full load current of motor
   d. Half the starting current of motor
12) Following equipment is needed for motors above 5HP
   a. Motor protection device(fuse or circuit breaker)
   b. An isolating device
   c. A motor starter of suitable type and size
   d. All these
13) This is not needed for motors less than 5 horse power
   a. Motor protection device(fuse or circuit breaker)
   b. An isolating device
   c. A motor starter of suitable type
   d. All these
14) This is installed in star delta starter
   a. No voltage release b. Over load relay
   c. Under voltage release d. All these
15) Star delta starter is used to start
   a. Single phase induction motor
   b. Three phase squirrel cage induction motor
   c. Three phase slip ring induction motor
   d. Any of these
16) The simplest form of motor starter for the induction motors is
   a. Direct on line starter b. Star delta starter
   c. Resistance starter d. Autotransformer starter
17) The Direct On Line starter consists of
   a. A MCCB or MCB
   b. Thermal over load relay

c. Magnetic contactor
d. Both (b) & (c)

18) Over load relay of motor starter may be of this type
a. Thermal type b. Magnetic type
c. Electronic type d. Any of these

19) Type of wiring recommended to install an electric motor
a. Surface type steel conduit
b. Concealed type PVC conduit
c. PVC duct
d. Both a & b

20) This tool should not be used for dismantling a motor
a. Screw drive b. Cold chisel
c. Hammer d. Lock pliers

21) Minimum current rating of cable for a motor than its fuse is
a. Half b. Double
c. Equal d. 3 times

22) If screws and bolts of a motor are difficult to unscrew, then use
a. Kerosene oil b. Cold chisel & hammer
c. Grip plier & hammer d. Lubricating oil

23) This starter is used to start D.C motors
a. Four point starter b. Three point starter
c. Five point starter d. Both a & b

24) Motor starters should be installed at a height of -------meter from floor.
a. 0.5 m b. 1.5 m
c. 2.5 m d. 03 m

25) Concrete foundation of a motor.
a. Provide firm levelled platform for motor
b. Support the weight of motor
c. Confine the vibration of motor to foundation area only
d. All these

ANSWER KEY

1	**d**	8	**a**	15	**b**	22	**a**
2	**b**	9	**a**	16	**a**	23	**a**
3	**a**	10	**a**	17	**d**	24	**b**
4	**a**	11	**a**	18	**d**	25	**d**
5	**a**	12	**d**	19	**a**		
6	**a**	13	**c**	20	**b**		
7	**d**	14	**d**	21	**a**		

Section-2
ELECTRICITY RULES AND REGULATIONS

Unit 1: Electricity Rules and Regulations

Topics included in this unit:

(Pakistan electricity rules 1973, I.E.E Regulation for Building)

Ch- 9: Electricity Rules and Regulations

Topics: Pakistan electricity rules 1973 (No 25, 28, 29, 32, 40, 49, 51,52, 58, 60, 62, 64.). I.E.E Regulation for building installation (A-1, A-3, A-26, B-4, B-12, C-4, C-6, D-1, D-22)

Pakistan electricity rules 1937.

1) Condition of supply by licensee (Rule No. 25, 28, 29, 32, 40)

Rule No 25: Precaution against leakage before connection

i. A licensee shall not connect with his works the apparatus on the premises of any applicant for supply unless he is reasonable satisfied that the connection will not at the time of making the connection cause a leakage from that apparatus exceeding are five thousandth part of the maximum supply demand on the applicant's premises.
ii. If a licensee declines to make a connection in accordance with sub-rule (i), he shall serve upon the applicant a notice stating reason for so declining.

Rule No 28: Declared pressures of supply to consumers

Before commencing to supply energy to a consumer, a licensee shall declare to the consumer the pressure at which he undertakes to supply energy and he shall not, without the written consent of the consumer or the precious sanction of the Provincial Government, permit the pressure to vary there from by more than 5 per cent in the case of low or medium pressure, or by more than 12 ½ per cent in the case of high pressure:

Provided that, for the purposes of testing or for any other purposes connected with the efficient working of the undertaking, the supply of the energy may be discontinued by the licensee for such period as may be necessary subject (expect in cases of emergency) to not less than twenty-four hours' notice being given by the licensee to all consumers likely to be affected by such discontinuance; and in the event of any such consumer objecting, the supply of energy shall not be discontinued (expect in cases of emergency) without the consent of the Provincial Government and subject to such conditions as it may impose.

Rule No 29: Declared frequency of supply to consumer

From the time of commencing the supply of energy to a consumer by means

Declared frequency of supply to consumers by means of an alternating current a licensee shall declare to the consumer the frequency at which he

undertakes to supply energy and the licensee shall not, without the written consent of the consumer or the previous sanction of the Provincial Government, permit the frequency to vary there from by more than 4 per cent.

Rule No 32: Limits of errors in the meters

The limits of error permissible, in a meter placed upon a consumer's premises in accordance with the section 26 are for the purpose of that sanction the following, namely:-

(a) Where the meter is of a type included the "British Standard Specification for Electricity Meters. No. 37" dated 1930, the limits of error laid down in the specification.
(b) Where the meter is of any other type, it shall not register more than 3 per cent, above or below absolute accuracy at tall loads in excess of one fifth of full load and up to full load.
(c) No meter shall register at no load.

Rule No 40: Cut-out (fuse) on consumer's premises.

A licensee shall provide a suitable cut-out in each conductor of every service-line (other than an earthed neutral conductor or the earthed external conductor of a concentric cable) within a consumer's premises, in an accessible position as close as possible to the point of entry. Such cut-out shall be contained within an adequately enclosed fire-proof receptacle:

Provided that where more than one consumer is supplied through a common service-line, each such consumer who so requires shall be provided with an independent cut-out at the point of junction to the common service.

Rule No 46: Instruction for restoration of persons suffering from electric shock.

(1) Instructions, both the English and in the vernacular (language) of the district, for the restoration of persons suffering from electric shock, shall be affixed by the owner in a conspicuous (visible) place in every generating station and sub-station, and in every factory as defined in clause (j) of section 2 of the Factories Act, 1934 (XXV) of 1934), in which electricity is used as the inspector may, by notice served on the owner, direct.

(2) Copies of the instructions shall be supplied on demand by every Inspector at the price to be fixed by the Provincial Government.

2) General precaution for safety of public (Rule 49, 51, 52, 58)

Rule No 49: Construction, insulation and earthing of apparatus.

(1) All apparatus shall be sufficient in power and size and of sufficient mechanical strength for the work it may be required to do, and so for as is practicable, shall be so constructed, installed, protected, worked and maintained as to prevent danger.

(2) All insulating material shall be chosen with special regard to the circumstances of its proposed use. It shall be of mechanical strength sufficient for its purpose, an so far as is practicable, shall be of such a character or so protected as fully to maintain its insulating properties under working conditions of temperature and moisture.
(3) No live parts shall be exposed as to be capable of being touched by persons not intended to have access to them.
(4) Every part of a system shall be kept efficiently insulting from earth expect that:-
(i) The neutral point of a ploy phase system may be earthed at one point only.
(ii) The mid-voltage point of any system, other than a concentric system, may be earthed at one point only.

Rule No 51: Identification of earth and earthed neutral conductors and cut-outs there in.

In any case where the conductors include an earthed conductor of a two-wire system, or an earthed neutral conductor of multi-wire system or a conductor which is to be connected thereto, the supply of energy shall not be commenced until and unless the following provisions have been or are complied with namely:-

(1) An indication of a permanent neutral 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 conductor to be distinguished from any live conductor. Such indication shall be provided:

(a) Where the earthed or earthed neutral conductor is property of the licensee at or learned the point of commencement of supply.
(b) Where a conductor forming part of a consumer's system is to be connected to the licensee's earthed or earthed neutral conductor at the point where such connection is to be made; and
(c) In all other cases, at the point corresponding to the point of commencement of the supply or at such other point as may be approved by an inspector.

(2) No cut-out, link or switch other than a linked switch arranged to operate simultaneously on the earthed conductor and live conductor shall be inserted or remain inserted any earthed conductor of two-wire system or in any earthed neutral conductor of a multi-wire system or in any conductor connected thereto, with the following exceptions:

(i) A link for testing purposes, or
(ii) A switch for use in controlling a generator or transformer, or
(iii) A switch or link in the connection between the earthed conductor or the earthed neutral conductor and earth at a generating station or sub-station for use in the testing and emergencies only:

Provided that in the case of system in use prior to the 23rd December, 1932, no penalty shall attached to any breach of this Rule occurring before 23rd December, 1940.

Rule No 52: Crossing metallic substances

(1) Where an electric supply-line crosses, or is in proximity to, any metallic substance the owner of the supply-line shall take such precautions as an inspector may approve against the possibility of the metallic substance becoming charged.

(2) Where such metallic substance is introduced after the electric supply-line has been laid or erected, the cost incurred in taking such precautions shall be refunded to the owner of the electric supply-line by the owner of the metallic substance.

Rule No 57: (not in new course) **Connection with earth of frames of generators, etc.** 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 regulating of controlling apparatus connected with the supply, shall be earthed by the owner by two separate and distinct connection with earth.

Rule No 58: Connection with earth of a multi-wire system. In every distributing system in which there is a neutral conductor, where the pressure between the neutral conductor and an outer or phase conductor exceeds 125 volts, the neutral conductor shall be connected with earth by two separate and distinct connections from the neutral bus-bar and in accordance with the following provisions, namely:

(a) The connection shall be made at one point only on each distinct system, namely, at the generating station or sub-station, or both as the case may be, and the insulation of the system shall be maintained at all other parts.

(b) The connection shall not be made by the aid of, nor shall it be in contact which any water-main, gas-main or similar main not belonging to the consent of the owner thereof, and of the inspector; a resistance, not exceeding 20 ohms may be inserted between the neutral bus-bar and earth, and if so inserted, it shall be of sufficient cross-sectional area to carry the current which would pass should an outer or phase conductor become accidentally connected with earth.

(c) The connection shall not be removed except for the purpose of testing in which case it shall be made good again as soon as such test is finished, and a record of any such disconnection shall be kept by the licensee or non-licensee, as the case may be;

(d) The connection shall not be removed in a licensee's system except between 1am to 3am and in a non-licensee's system, while the generator is in operation and energy is being used.

(e) The current from the neutral conductor to earth shall in the case of a licensee's direct current distributing system, be continuously recorded, and, if at any time it exceeds one-thousandth part of the maximum supply current, steps shall immediately be taken to improve the insulation of the system.

3) Electrical supply line and apparatus (Rule 60, 62, 64)

Rule No 60: General precautions applicable to supply at medium or high pressure.

Where a licensee proposed to supply or use energy at medium or high pressure, he shall give notice to an inspector and shall not commence or continue the supply unless and until he has complied with the following provisions, namely:-

(a) All live parts of apparatus shall, unless accessible only to, and under the control of an authorized person, be protected by mechanically strong metal casings or metallic coverings securely fastened throughout.

(b) Suitable lined switch, of requisite capacity to carry and break the current, shall be inserted in each conductor, near the point of origin on the consumer's premises.

(c) Every conductor, unless accessible only to an authorized person shall be, as far as is practicable, completely enclosed in a mechanically strong metal casing or metallic covering, securely fastened throughout or fixed in such other manner as may be approved in writing by an inspector; and

(d) The supply to very apparatus shall be efficiently controlled by suitable linked switched, of requisite capacity to carry and break the current in each conductor, placed near the apparatus in such a position as to be readily handled by the operator, so that by their means all pressure can be cut-off from the apparatus concerned and from any device in connection therewith:

[Provided that this clause shall not supply in the case of transformers, motors and other apparatus where these are controlled by remotely operated switchgear and where suitable arrangements are made for preventing the remote switch from being closed while men are working on the transformer, motor or other apparatus controlled by the switch, or in cases where compliance with this clause would render inoperative the previsions of sub-rules (2) and (3) of Rule 62;]

(e) The word "Caution", both in English and in the vernacular, shall be affixed permanently in a conspicuous position, where possible, on every

generator and every motor and every controlling, or regulating apparatus in connection with such generator or motor.

Provided that, where it is not possible to affix them on the generator motor, or apparatus, they shall be affixed as near as possible.

Provided also that, where the generator, motor, controlling or regulating apparatus, is within an enclosure accessible only to an authorized person, one notice affixed to the enclosure shall be sufficient for the purpose of this sub-rule.

Rule No 61: Main switchboard. (not in new course)The owner of every main switchboard connected with a supply of energy at medium or high pressure shall comply with the following provisions, namely;

(a) A clear space of not less than 3 feet in width shall be provided in front of the switchboard.

(b) If there are attachments or bare connections at the back of the switchboard, the space (if any) behind the switchboard shall be either less than 9 or more than 30 inches in width, measured from the farthest outstanding part of nay attachment from conductor.

(c) If the space behind the switchboard exceeds 30 inches in width, there shall be passage-way clear to the height of not less than 6 feet, save as regards any horizontal supports of the switchboard, which may be placed at the height of not less than 4 feet 6 inches.

Rule No 62: Approval of high pressure supply

No licensee or non-licensee shall deliver a high pressure to any person, other than distributing licensee, except with the approval in writing of an inspector, and subject to such conditions (if any) as such inspector may think reasonable and proper in the circumstances, and the owner shall not bring the installation into use until it has been inspected by an inspector.

(3) A consumer supplied with energy at high pressure shall provide and maintain a locked weather-proof and fire-proof enclosure of agreed design and location for the purposes of housing the licensee's terminal high pressure apparatus and metering equipment. This enclosure should preferable be in a separate building to the consumer's sub-station or installation but where this is not feasible, the licensee's terminal high pressure apparatus and metering equipment shall be completely segregated from any other part of the consumer's apparatus by fireproof walls. The licensee shall, at all times, have access to the enclosure for the purposes of inspecting his apparatus.

Provided that in case of disagreement between the licensee and the consumer in regard to the design and the location of the enclosure party may appeal to the inspector.

Provided further that installations connected to the licensee's high pressure supply before the 4th December, 1943, not fulfilling the conditions of the sub-rule need not comply therewith before the 5th December, 1944.

(3) Where energy is proposed to be used at high tension be the owner or occupier not being a licensee at high pressure, he shall not bring the installation into use except with the approval, in writing, of the inspector, and such approval shall not be given until the following conditions have been complied with namely:-

(a) Every oil-field switch or switch-board, or static condenser or transformer having an oil capacity exceeding 50 gallons shall be segregated from all other apparatus by suitable fire-proof wall, and suitable oil drains and soak-pits shall be provided so as to prevent the spread of oil fires form any part to any other part of the installation.

(b) cable trenches inside sub-stations land containing cables shall be filled with sand, pebbles or similar non-inflammable materials or covered with non-inflammable slabs; and

(c) Such other conditions (if any) as the inspector may think fit to impose;

Provided that installations brought into use before the 4th December, 1943, and not fulfilling the conditions of this sub-rule, need not comply therewith before the 4th December, 1944.

(4) When the position of a high pressure motor or other apparatus is changed, notice shall forthwith be given to the inspector showing the extent and nature of the change of position.

(5) The owner of any high pressure installation (who makes any such alternation in or additions to the installation) as affect the supply shall not utilize the alternations or additions for the purposes of supply unless and until they have been approved by the inspector.

Rule No 64: High pressure electric supply-lines and apparatus placed above ground.

(1) All owners of high pressure apparatus, including every portion of anything pressure electric supply-line) other than an aerial line) placed above the surface of the ground, unless it is in a sub-station, or in a compartment specially arranged for the purpose and accessible only to authorized persons, shall ensure that is completely enclosed in, or protected by a mechanically strong metal casing or metallic covering securely fastened throughout.

Provided that this sub-rule shall not apply to neon-signs and X-rays apparatus which are operated in accordance with instructions issued by the inspector.

(2) All owners of circuits and apparatus connected with any high pressure apparatus to which sub-rule (1) is applicable shall ensure that they are marked at frequency intervals with the word "Caution" both in English

and in the Urdu. All supports of high pressure aerial lines shall be similarly marked at frequent intervals.

I.E.E Regulation for Building installation.

(Institute of Electrical Engineers, London)

Section-A

A-1: Control of supply to consumer's installation.

Every consumer's installation shall be adequately controlled by switch gear readily accessible to the consumer which shall incorporate.

i. Means of isolation, and
ii. Means of excess-current protection, and
iii. Means of earth-leakage protection.

A-3: Excess current protection

The means of excess-current protection required by regulation A-1 (ii) shall comprise either a fuse inserted in each live conductor of the supply or a circuit-breaker having an excess-current release, fitted in each live conductor of the supply.

Exemption: The means of excess-current protection referred to in Regulation A-1 (ii) May be omitted provided that:

i. The rating of all cable connected between the supply undertaking's fuse or circuit-breaker and the consumer's sub-circuit fuses or circuit-breakers is not less than the rating of the supply undertaking's fuse or circuit-breaker, and
ii. The excess-current devices protecting all circuits controlled by the switchgear are located within the same enclosure as the switchgear or alternatively are fixed immediately adjacent to it.

A-26: Final Sub-circuits of rating exceeding 15 A

A final sub-circuit having a rating exceeding 15 amperes shall not supply more than one point except as specifically admitted in regulations A-27-29, or A-30-42, or A-43-55. For the purpose of this regulation, a cooker control unit incorporating a socket-outlet is regarded as one point.

Section-B

B-4: Type of flexible cables and flexible cords

Every flexible cable and flexible cord for use at low or medium voltage shall be selected from one of the following types and shall comply

with the appropriate British Standard Specification referred to below so for as this is applicable. This regulation does not apply to a flexible cord forming part of a portable appliance which complies as a whole with a British Standard Cited in Section F of this regulation, or to special flexible cables and flexible cords for combined power and telecommunication wiring:

i. P.V.C insulate flexible cords (B.S.2004)
ii. Vulcanized rubber-insulated flexible cables and flexible cord (B.S.7).The cable may incorporate a flexible armour of galvanized steel or phosphor-bronze, or a screen of tinned copper-wire braid.
iii. Butyl-rubber insulated or ethylene-propylene rubber-insulated flexible cables and flexible cords (B.S.4180). The cable may incorporate a flexible armour of galvanized steel or phosphor-bronze, or a screen of tinned copper-wire braid.
iv. Varnished PTP fabric insulated flexible cables(B.S.3765)
v. Silicon-rubber insulated flexible cables and flexible cords(B.S.3258)
vi. Flexible cables and flexible cords insulated with varnished cambric and heat- resisting fiber (B.S.3249)
vii. Flexible cords insulated with glass fiber (B.S.4217)
viii. Trailing Cables (primarily for mining and/or quarrying) (B.S. 708 or B.S. 1116)
ix. Travelling Cable for lifts (B.S. 977)

B-12: Choice of types of insulation and protective covering of flexible conductor sizes.

Every flexible cable and flexible cord shall be one of the following types:

i. Braided circular
ii. Un-kinable
iii. Circular sheathed
iv. Flat-twin sheathed
v. Parallel twin; provided that this type shall be used only for wiring of fixed lighting fitting or where the cord ids not subject to abrasion or undue flexing.
vi. Twisted twin non-sheathed, insulated with rubber or general-purpose P.V.C; provided that this type shall be used only for fixed lighting fitting or for pendants which are wholly open to view, or for other applications where the cord is not subject to abrasion.
vii. Twisted twin non-sheathed, insulated with transparent P.V.C.; provided that this type shall be used only for pendants which are wholly open to view.

viii. Single-Core, twisted twin and three core, and circular twin and three core, insulated with glass fiber; provided that these types shall be used only in dry situations for lighting fittings or for other applications where the cord is not subject to abrasion or undue flexing.

Section-C

C-4: Selection for situation

All apparatus shall be of a design appropriate to the situation in which it is to be used and its mode of installation shall take account of the conditions likely to be encountered. Apparatus intended to run unattended, shall be suitable for such operation having in mind the risk of excessive temperature rise.

C-6: Damp situation

In damp situations, every item of apparatus shall be of the damp-and-dust proof type, and cable entries shall be provided with glands or bushings, or be suitable to receive screwed conduit. For lamp holders for a bayonet-cap lamp in any damp situation shall be earthed.

Section-D

D-1: Methods of protection

Every item of apparatus and every conductor operating at a voltage exceeding extra-low voltage shall be effectively prevented, by one of the methods described in item (i) to (iv) below, from giving rise to danger from earth-leakage currents:

i. Enclosure in insulation which is durable and substantially continuous, i.e. "all-insulated" construction.

ii. For an appliance or a lighting fitting, double insulation where the use of this means is provided for in an appropriate British Standard.

iii. Earthing of exposed metal parts in accordance with the requirements of this section.

iv. Isolation of metal in such a way that is not liable to come into contact with live parts or with earthed metal.

Exemption: Regulation D-1 need not to be observed for apparatus and conductor which operate from a dc supply at a voltage not exceeding 110 volts, derived from a battery or dc generator, or from a double wound three phase transformer and rectifier with a suitable smoothing circuit.

D-22: Protection by fuse and current circuit Breaker for excess current

Earth-leakage protection may be afforded by means of fuses or excess-current circuit-breakers provided that the earth fault current available to operate the protective device and so make the faulty circuit dead exceeds:

i. 3 times the current rating of any semi-enclosed fuse, or any cartridge fuse having a fusing factor exceeding 1.5, used to protect the circuit, or
ii. 2.4 times the rating of any cartridge fuse having a fusing factor exceeding 1.5, used to protect the circuit, or
iii. 1.5 times the tripping current of any excess-current circuit-breaker used to protect the circuit.

Exercise

Part-1: Subjective type Questions

Sample Long Answer type questions

1) Write Pakistan electricity rules No. 25, 28, 29, 32, 40 & 46.
2) Write Pakistan electricity rules No. 49,51,52,57 & 58
3) Write Pakistan electricity rules No. 60, 61, 62 & 64
4) Write Pakistan electricity rules No. 65, 66, 67 & 69
5) Write Pakistan electricity rules No. 72, 73 & 74
6) Write IEE regulation A-1, A-3 & A-26
7) Write IEE regulation B-4, B-12 & B-23
8) Write IEE regulation C-4, C-6 & C-8
9) Write IEE regulation D-1 & D-22

Part-2: Objective type Questions

Sample Short Answer type Questions

1) When Pakistan electricity rules were imposed and to which these are applicable?
2) Write Pakistan electricity rule No. 25
3) Write Pakistan electricity rule No. 28
4) Write Pakistan electricity rule No. 40
5) What type of instructions has been given in Pakistan electricity rule No.46?
6) Write Pakistan electricity rule No. 51
7) Write Pakistan electricity rule No. 57
8) Write Pakistan electricity rule about neutral earthing.
9) Write Pakistan electricity rule No. 62
10) Write Pakistan electricity rule No. 64

11) What should be the distance between poles of areal (overhead) lines as per electricity rule No. 66?
12) Write Pakistan electricity rule No. 67
13) As per Pakistan electricity rule No. 69, what should be the distance of areal line from roof and walls of a building?
14) Write Pakistan electricity rule No. 73
15) About what IEE Regulation A-1 speaks out?
16) About what IEE Regulation A-3 speaks out
17) Write IEE Regulation A-1
18) Write IEE Regulation A-3
19) Write IEE Regulation A-26
20) About what IEE Regulation B-4 speaks out
21) About what IEE Regulation B-12 speaks out
22) Write IEE Regulation B-4
23) Write briefly the IEE Regulation No B-12
24) About what, the section "C" of IEE Regulations speaks out.
25) About what, the IEE Regulations No C-6 speaks out.
26) Write four methods of protection against leakage current given in the IEE regulation D-1.
27) About what, the IEE Regulations No D-22 speaks out
28) Write the IEE Regulation No C-4.

Sample Multiple Choice Type Questions (MCQs)

1) Pakistan electricity rules apply on
   a. Power producing public companies
   b. Power producing private companies
   c. Persons related to electricity
   d. All these
2) Electricity rules do not apply on
   a. Power producing public companies
   b. Power producing private companies
   c. Persons related to electricity
   d. None of these
3) Pakistan electricity rules 1-24 are related to
   a. Basic Principles
   b. About getting a licence
   c. About inspector d. All these
4) Total No of Rules of "Pakistan electricity rules" are
   a. 27 b. 39 c. 79 d. 125
5) Pakistan electricity rules 25-80 are related to

a. Electric vehicles
b. Electrical transmission and distribution
c. Provide electricity
d. Both b & c

6) According to Pakistan electricity rules, this job can be completed without licence holder contractor
a. Installing a new wiring
b. Make changes in existing wiring
c. Change any switch or fuse in wiring
d. None of these

7) Pakistan electricity rules 81-125 are related to
a. Electric vehicles and mining
b. Electrical transmission and distribution
c. Getting licence of electricity
d. Basic principles

8) According to Pakistan electricity rule No 28, the max allowable change in medium voltage of the declared voltage is
a. 2.5% b. 5 %
c. 10% d. 12.5%

9) According to Pakistan electricity rules, max allowable change in high voltage of the declared voltage is
a. 2.5% b. 5%
c. 10% d. 12.5%

10) According to Pakistan electricity rules, allowable change in declared frequency of AC supply is
a. 2% b. 4%
c. 3% d. 5%

11) Limit of error in energy meters according to electricity rules is
a. 1.5% b. 2%
c. 3% d. 5%

12) According to Pakistan electricity rule No 40, supply company will provide this on the +ve (phase) wire in the premises of consumer.
a. Fire proof cut out(fuse) b. Energy meter
c. Main switch d. All these

13) Condition of supply by licensee is given in electricity rule No
a. 25 & 28 b. 29 & 32
c. 40 &46 d. All these

14) According to Pakistan electricity rules, electrical equipment should be made in such a way that
a. All the consumers could buy them easily
b. Their insulation should be strong and non absorbent of moisture and heat

c. Their live parts should not be bare and should be non touchable
d. Both b & c

15) According to electricity rule, this can not be connected on
a. Single pole switch b. Fuse
c. Joint d. Both a & b

16) According to electricity rule, the neutral of a system should be
a. Below the phases b. Earthed
c. Between the phases d. Above the phases

17) According to electricity rule ,this voltage & higher is called "high voltage"
a. 220V b. 440V
c. 650V d. 1100V

18) Permission from electrical inspector in necessary to change the location of a machine, if its voltage is above this level
a. 125V b. 230V
c. 400V d. 650V

19) For testing purpose or in case of emergency, supply company can shut down the supply
a. At any time
b. On 24 hours notice
c. With the permission of government
d. Both b & c

20) According to Pakistan electricity rules, these lines must be protect from lighting
a. Guard wires
b. Arial line (over head lines)
c. Barrier wires
d. All these

21) As per electricity rules No 67, the stay wires of metallic poles should be
a. Buried in ground from one end
b. Earthed
c. Six feet away from pole in the ground
d. All these

22) The IEE regulation A-1 speaks about
a. Treatment of electric shock
b. Control of supply to consumer's installation
c. Catenary wiring
d. None of these

23) The IEE regulation A-3 speaks about
a. Control of supply to consumer's installation
b. Rating of final sub circuit

c. Excess current protection
d. Types of flexible cords and cables

24) According to the IEE regulation No A-26, a final sub circuit whose current rating exceeds 15 A, shall not supply more than.
a. One point b. Two points
c. ten points d. 15 points

25) According to the IEE regulation No A-1, every consumer installation shall be controlled by switch gear having
a. Means of isolation
b. Means of excess current protection
c. Means of earth leakage protection
d. All these

26) According to IEE regulation B-23, the limit of voltage drop from consumer's point to any load point is
a. 2.5 % of the supply voltage b. 2.5V
c. 5% d. 4%

27) The IEE regulation related to excess(over) current protection is
a. A-1 b. A-3
c. A-26 d. B-23

28) This IEE regulation states about the voltage drop in consumer premises
a. A-1 b. B-23
c. B-12 d. B-4

29) This IEE regulation discuss about the flexible cables and cords
a. B-4 b. B-12
c. A-26 d. A-1

30) According to the IEE regulation B-4, flexible cables and cords may be this type
a. Braided circular b. Un-kinable
c. Flat twin sheathed d. Any of these

31) This flexible cable shall be used only for pendant, and should be open to eye
a. Single core non flexible b. Braided circular
c. Twisted twin non sheathed d. Any of these

32) Silicon rubber insulated cables/cords are manufactured according to this British standard specification
a. BS-2004 b. BS-4217
c. BS-3249 d. BS-3258

33) BS 2004 states the specifications of this cable/cord
a. PVC insulated flexible cords
b. Silicon rubber insulated flexible cords
c. Varnished cambric insulated flexible cords
d. Butyl rubber insulated flexible cords

34) IEE regulation C-6 speaks about
   a. Damp situations
   b. Dry places
   c. Fuse and breaker ratings
   d. Excess current protection

35) Section D of IEE regulations explains about the
   a. Protection from Earth leakage current
   b. Protection from high voltage
   c. Protection against electric shock
   d. Protection against over load

36) According to IEE regulation, electrical apparatus operating above extra low voltage shall be protected against leakage current by this method
   a. By enclosing it in durable insulation
   b. By providing double insulation
   c. By earthing the exposed metal parts
   d. All these

37) According to IEE regulation D-22, the faulty current for cartridge fuse than the rated current is
   a. 2.4 times b. 2.5 times
   c. 1.5 times d. 3 times

ANSWER KEY

1	**d**	11	**d**	21	**b**	31	**c**
2	**d**	12	**a**	22	**b**	32	**d**
3	**d**	13	**d**	23	**c**	33	**a**
4	**d**	14	**d**	24	**a**	34	**a**
5	**d**	15	**d**	25	**d**	35	**a**
6	**c**	16	**d**	26	**a**	36	**d**
7	**a**	17	**c**	27	**b**	37	**a**
8	**a**	18	**d**	28	**b**		
9	**d**	19	**d**	29	**a**		
10	**a**	20	**d**	30	**d**		

Section-3
FIRE PROTECTION AND SAFETY

Unit 1: Safety from fire and Electricity

Topics included in this unit:

(Fire, Classes of fire, Causes of fire and its prevention, Safety in electrical shops, General safety precaution, Electric shock its prevention and treatment)

Ch-10: Safety from Fire and Electricity

Main Topics in this chapter

(1) Fire, Classes of fire, Causes of fire and its prevention.
(2) Safety in electrical shops (Safety Belt, Gloves, clothing and shoes)
(3) General safety precaution (Machine Guards, tools & ladders)
(4) Electric shock its prevention and treatment

Fire: The Process of burning in which substances combine chemically with oxygen that gives out heat, light, smoke and produces flame is called fire. Fire is combination of fuel, oxygen (or air) and heat.

Causes of Fire:

Following are the reasons of fire.

Smoking, Faulty Wiring, Discharge of static electricity, Sparking, Over loading of electric Machines, Welding spark or soldering apparatus, Lightening, Explosives, Open light and flames, Fire catching/Flammable liquids, Burning Material near electric heater, Hot Ash, Gas and gas apparatus, Oil stove, Gas cylinder, Fireworks, Hot smoke of chimney, Discharge of gases from the furnace, Discharge of heat from chemical reaction , Chemical vapours from chemical plants, Match box in children hands, Poor housekeeping.

The Fire Triangle: Fire is composed of some burning material (fuel), oxygen (or air) and heat as shown in triangle below.

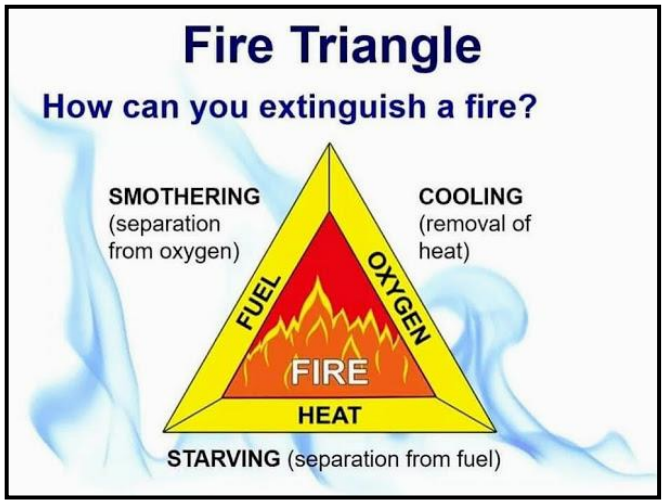


Fig 10.1: The fire triangle and fire fighting principle

Classes of fire

1. **Class A fire** - fires involving combustible carbon-based solid materials such as wood, paper or textiles, trash or anything else that leaves an ash.
2. **Class B fire** - fires involving flammable liquids such as paraffin, gasoline, petrol, diesel or oils (but not cooking oil).
3. **Class C fire**-flammable gases, e.g. butane, propane or methane.
4. **Class D fire**- Burning metals, e.g. aluminium, lithium, magnesium and Titanium.
5. **Class E(⚡)fire**–fire caused by live electrical apparatus.
6. **Class F (K in USA) fire -**fire due to fats, grease and cooking oils or animal fat

Fire fighting Principle

The basic theory of fire fighting is to limit or eliminate/remove any one, two or all the three fire elements (fuel, fire catching material and heat).
These principles are:

a. Cooling: by removing the heat from burning place. Water is used for this purpose.
b. Smothering: stopping the supply of air (or Oxygen)is called smothering. This can be achieved by using sand, blanketing, and foam application or by the use of chemical extinguishers.
c. Starvation: this can be achieved by removing of fuel from burning place. Or by cutting off the supply of gas or liquid fuel.

Fire fighting equipment

The main firefighter equipment used to extinguish fires, including fire fighting hose, portable fire pumps, fire hose reels, fire monitors and fire fighting nozzles.

- Fire extinguishers
- Fire hose reel system
- Fire hydrant systems
- portable fire pumps
- Automatic sprinkler systems

1. Fire extinguishers

A **fire extinguisher** is a fire protection device used to control small fires, often in emergency situations. It is not intended for use on an out-of-control fire, such as one which has reached the ceiling, endangers the user. Typically, a fire extinguisher consists of a hand-held cylindrical pressure vessel containing an agent which can be discharged to extinguish a fire.

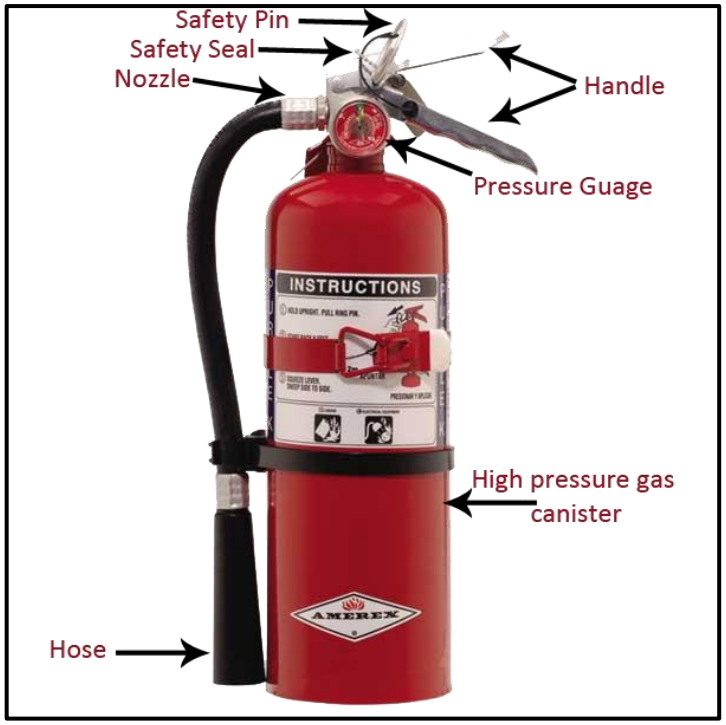


Fig 10.2: Parts of a typical fire extinguisher

Types of fire extinguishers

1. Water, water mist or water spray type fire extinguisher
2. Foam type fire extinguisher
3. Dry Powder – standard or specialist type fire extinguisher
4. Carbon Dioxide ('CO_2) type fire extinguisher
5. Wet Chemical type fire extinguisher

Use of different fire extinguishers

Water Fire Extinguishers (Red label)

The cheapest and most widely used fire extinguishers. Used **for Class "A "**fires. Not suitable for Class B (Liquid) fires, or where electricity is involved.

Foam Fire Extinguishers (Cream labeled)

Expensive than water fire extinguisher. Used for Classes A& B fires. Foam spray extinguishers are not recommended for fires involving electricity.

Dry Powder Fire Extinguishers (Blue labeled)

Often termed the 'multi-purpose' or ABC extinguisher, as it can be used on classes A, B & C fires. Best for Class B fires. It will efficiently extinguish Class C gas fires also. Special powders (L2 for lithium and M28 for all other flammable metals) are available for class D metal fires.

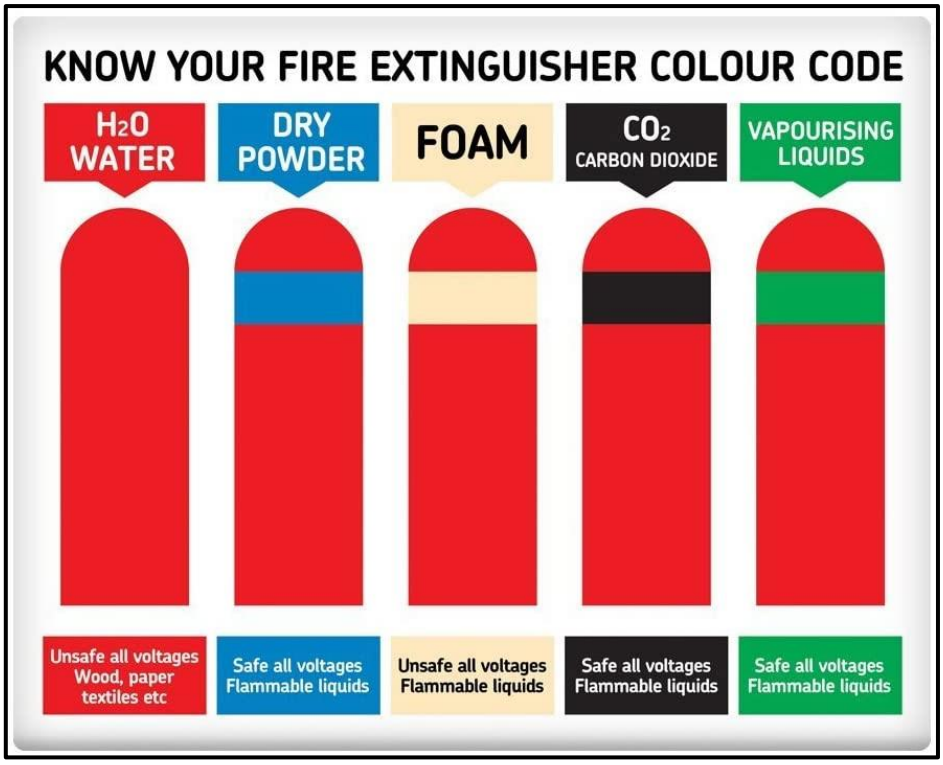


Fig 10.3: Colour codes of different types of fire extinguisher

BUT BEWARE; IT CAN BE DANGEROUS TO EXTINGUISH A GAS FIRE WITHOUT FIRST ISOLATING THE GAS SUPPLY.

Warning: W*hen used indoors, powder can obscure vision or damage goods and machinery.*

CO2 Fire Extinguishers (Black labeled)

Carbon Dioxide is ideal for fires involving electrical apparatus, and will also extinguish class B liquid fires, but has NO POST FIRE SECURITY and the fire could re-ignite.

Wet chemical Fire Extinguisher: Specialist extinguisher for class F fires but can also be used on Class A fires.

2. Fire hose reel systems

Fire hose reel systems consist of pumps, pipes, water supply and hose reels located purposely in a building, ensuring proper coverage of water to fighting a fire. The system is manually operated and activated by opening a valve enabling the water to flow into the hose that is typically 30 meters away.

Using the Fire Hose Reel System

Like fire extinguishers hose reels are used as a "first attack" appliance used during the early stages of a fire and can be used by building owners, occupiers, tenants and the fire brigade

1. Anti-tamper seal is broken.
2. The water supply at the stop valve is turned on.
3. The hose is pulled out up to the required fire point.
4. Water is turned on at the nozzle.
5. The water stream is directed at the base of the fire.

3. Fire hose reel systems

A fire hydrant system is a safety measure or emergency equipment required in some buildings that comprises a series of components that when assembled together provide a source of water to assist fire authorities in a fire. The components include piping, fitting, Hose reels, Hose cabinets, hydrants & pumps.

4. Portable Fire Pumps

Portable Fire Pumps are an essential tool for professionally equipped fire and rescue services and departments, they are used to pump water from a water source for fire fighting.

5. Automatic fire sprinkler systems (wet or dry)

A fire sprinkler system is an active fire protection method, consisting of a water supply system, distribution piping system, and fire sprinkler. Automatic fire sprinkler system (also known as a wet pipe system) is the most effective method of controlling fires. Sprinkler systems can automatically detect a fire, transmit an alarm and control the fire. Fires. Today's automatic fire sprinkler systems offer state of the art protection of life and property from the effects of fire. Sprinkler heads are now available which are twenty times more sensitive to fire than they were ten years ago.

Fire class and fire extinguishers

Extinguishers for Class A Fires:

- Multipurpose dry chemical
- Foam extinguishers
- Loaded stream extinguishers

Extinguishers for Class B Fires:

- Multipurpose dry chemical
- Foam
- Carbon dioxide (CO_2)
- Dry chemicals Loaded stream extinguishers
- Bromotrifluoromethane - Halon 1301

Extinguishers for Class C Fires:

- Multipurpose dry chemical
- Bromotrifluoromethane
- Halon 1301
- Carbon dioxide (CO2)
- Dry chemicals

Extinguishers for Class D Fires:

- Extinguishers or extinguishing agents for class D fires shall be types approved for use on the specific combustible metal.

How to use a fire extinguisher

Remember the acronym (abbreviation) "PASS" to operate a fire extinguisher.

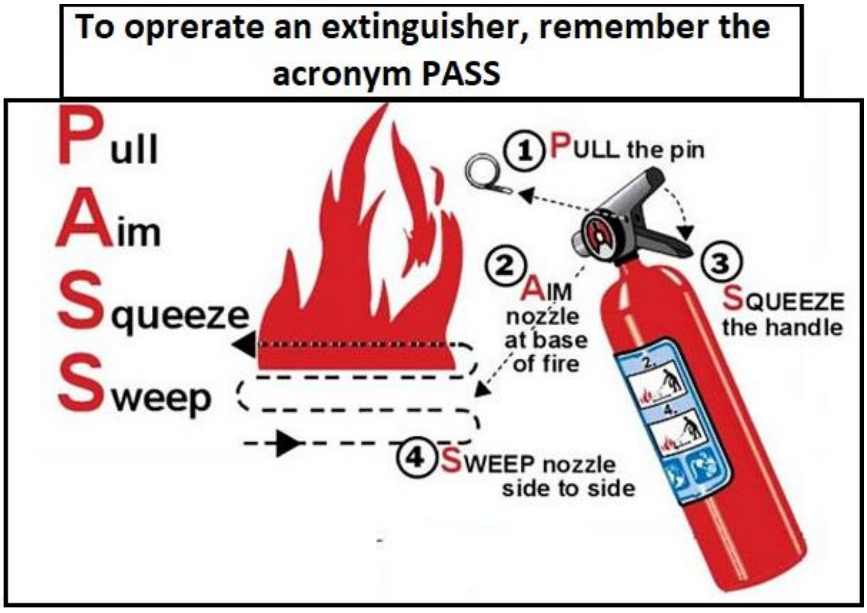


Fig 10.4: Use of a fire extinguisher with PASS formula

The acronym PASS stands for!

Pull the pin to unlock the extinguisher

Aim to the base of the fire and stand 6-10 meter away

Squeeze the lever to discharge the fire extinguishing agent.

Sweep the spray from left to right until fire extinguished

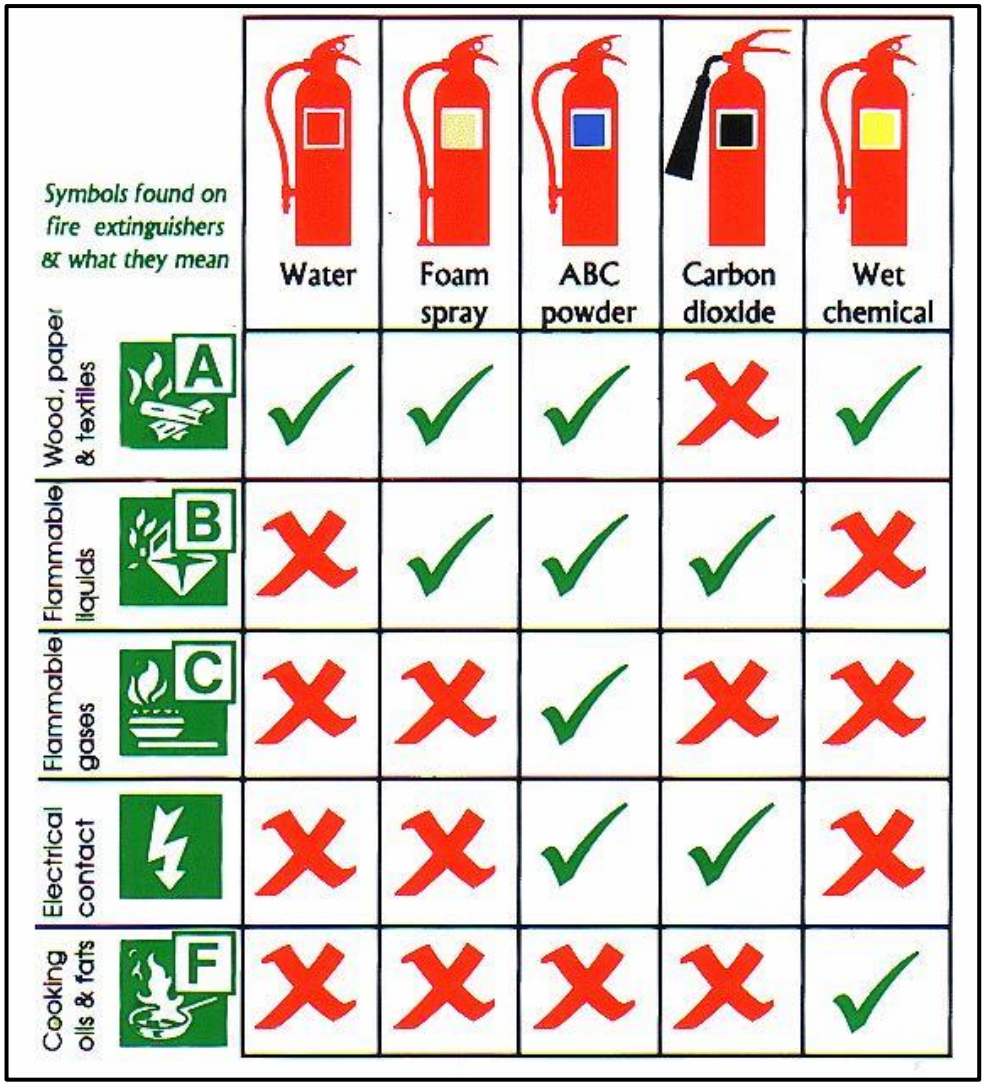


Fig 10.5: Types of firefighting cylinder and their use

Nature of Electrical Accidents

There are many causes of electrical accidents, but these can be summarize into three main and common root causes.

1. Working on *unsafe equipment and installations*.
2. *Unsafe Environment* (i.e. wet environment / presence of flammable vapours).
3. *Unsafe work performance*

So electrical accidents can be minimized to observe the above three main points while working with electricity.

SOME GENERAL SAFETY RULES FOR ELECTRICAL SHOPS

1) Wear suitable PPEs. (Overall, safety shoes, goggles and gloves etc.).
2) Avoid contact with energized electrical circuits.
3) Never use metallic pencils or rulers, or wear rings or metal watchbands.
4) Never touch or try repairing any electrical equipment or circuits with wet hands.
5) Work with only one hand (if it is safe to do so), keeping the other hand at your side or in your pocket.
6) Never use equipment with worn cords, damaged insulation or broken plugs.
7) If an individual comes in contact with a live electrical conductor, do not touch the equipment, cord or person.
8) Turn the power off when working on any circuit, and put up a sign on the control panel so that nobody turns the supply ON by mistake and never try to repair energized equipment.
9) Always use good quality electrical tools with appropriate insulated handles while working with electrical machines/circuits.
10) Treat all electrical devices as if they are live or energized.
11) Never try repairing energized equipment.
12) Never use an aluminium or steel ladder if you are working on any circuit at height.
13) Discharge capacitors before working near them and keep the short circuit on the terminals during the work to prevent electrical shock.
14) Always work in proper light.
15) Do not store highly flammable liquids near electrical equipment.
16) The floor of workplace must be free (clean) from oil, water and grease.
17) Don't wear too tight or too loose cloths, loose necktie or open button sleeves.
18) Always use suitable type and size of cables according to the load.
19) Make sure every electrical installation have effective earthing.
20) Any addition of circuit must be avoided unless there is permission from officer in charge.
21) After using electrical machines/equipment, it must be switched off.

Safety apparel

General - Electrical workers must wear appropriate personal protective (PPE) equipment while working on electrical circuits. Type of PPE depends upon the nature of job and danger involved. PPE for the electric power industry generally includes safety glasses, face shields, hard hats, safety shoes,

insulating (rubber) gloves with leather protectors, insulating sleeves, and flame-resistant (FR) clothing.

Use of safety goggles (eye Protection): Use safety goggles while doing soldering, cutting and grinding work and using hand cutting tools. Safety goggles should be worn over prescription glasses. Eye protection should be worn when working with hazardous fluids, particularly mineral oil, to prevent splashes into the eye. They should always be worn when washing down the internal parts of oil circuit breakers.

Fig 10.6: Safety Goggles for electrical work

Safety Gloves: Rubber gloves tested on high voltage (at least double the working voltage) should be used when working on live electrical circuits/equipment**.** Any sharp burr or wire strand can enter in rubber gloves. To avoid this leather gloves are used over the rubber gloves.

Fig 10.7: High Voltage Leather Protector Gloves for Use with Rubber Electrical Insulating Gloves

Safety Shoes (Footwear): Shoes or boots having rubber sole should be worn in routine, especially when working on electrical poles. These are especially designed to safe guard from leakage currents and mechanical injuries. These have a steel plate located over the toe and are designed to resist impact. Some safety shoes also have an instep guard.

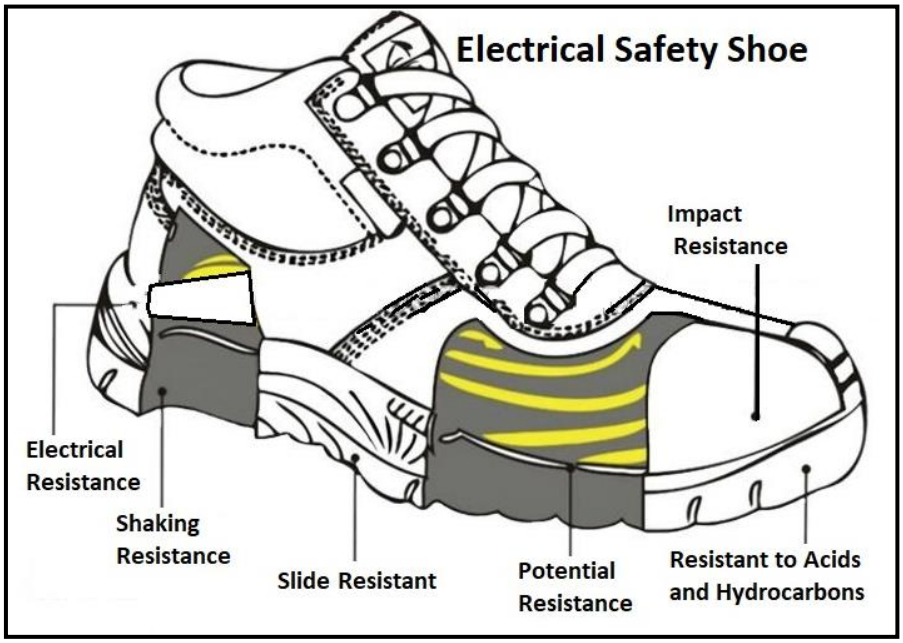


Fig 10.8: Safety Shoes

Safety Belt and safety helmet: Safety harness should be worn when working at any height greater than 1.5 m above ground level and a full harness equipped with a connector is preferred. Fall arrest equipment may be necessary when working at high level. Harnesses should be chosen that are suitable for their intended application and should be of a design that will support the user in the correct position. A harness should be comfortable, allowing adequate movement of the user and the unhindered operation of other devices within the system. Safety belts and harnesses must be checked each time before use. Carefully check buckles, rings, hooks clips and webbing.

Safety helmets normally need be worn only when working on outdoor switchgear, where they serve to protect against falling objects and collisions with solid objects at head height.

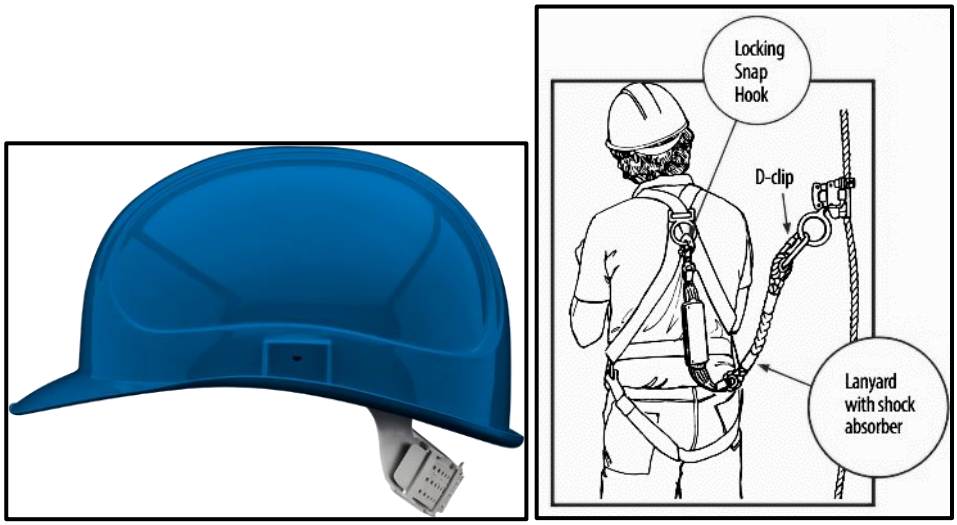


Fig 10.9: Safety helmet and belt

Noise Protection: Noise hazards are very common in thermal power stations and many industries. High intensity noise can cause accidents, reduction in personal efficiency and loss of hearing. Although noise hazards cannot always be eliminated, hearing loss is avoidable with ear muffs, ear plugs, or both. Ear plugs must be properly fitted by qualified personnel.

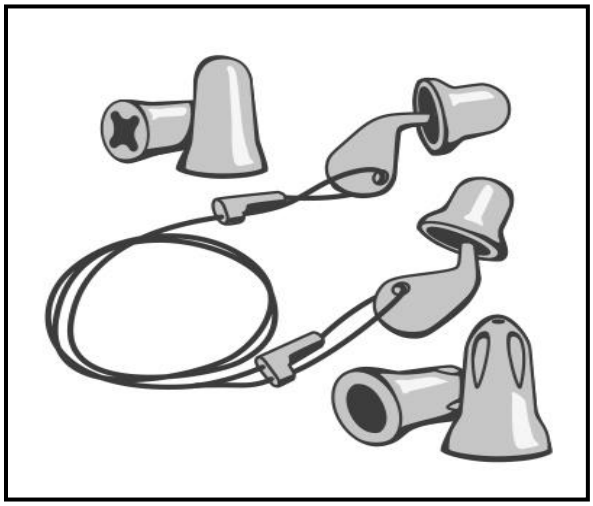


Fig 10.10: Noise protector

Safety Clothing: Special clothings are required for electrical work. Its requirements are!

1. Non flammable

2. Not too tight or too loose
3. Clothing should cover the full body (including arms and legs).
4. Free from conductive material (buttons, clips, zips should be non-metallic).

It is strongly recommended that bracelets, rings, neck chains, exposed metal zips ,watches, metal spectacle frames, etc., are not worn whilst performing electrical work in the vicinity of live electrical equipment, however, where these are worn, they should be suitably insulated.

Fig 10.11: Safety clothing

Hazards to life from rotating electric machinery

Crushed hands and arms, severed fingers, blindness -- the list of possible machinery-related injuries is as long as it is shocking. There seem to be as many hazards created by moving machine parts as there are types of machines.

Preventive methods

Rotating machinery can be some of the riskiest equipment you work with. Keep everyone safe around dangerous machinery with these three tips:

1. Limit time close to rotating machinery.
2. Know what machinery is faulty before a hazardous condition occurs.
3. Increase preventive maintenance

Use of machine safe guards

Safeguards are essential for protecting workers from needless and preventable injuries. A good rule to remember is: *Any machine part, function, or process which can cause injury must be safeguarded.* Safe guards are necessary on following three points!

(1). the point of operation (2)**.** Power transmission apparatus (3). Other moving parts.

> When working near rotating machinery, always be careful of moving shafts and other components and whenever possible work away from potential dangers. Adding wireless tools to your arsenal is also a good way to distance yourself from rotating machinery.

Tools:

All tools are dangerous if used improperly or casually. Working safely is the first point the operator should learn. A person learning to operate tools must first learn the safety regulations and precautions for each tool. Most accidents are caused by not following prescribed procedures.

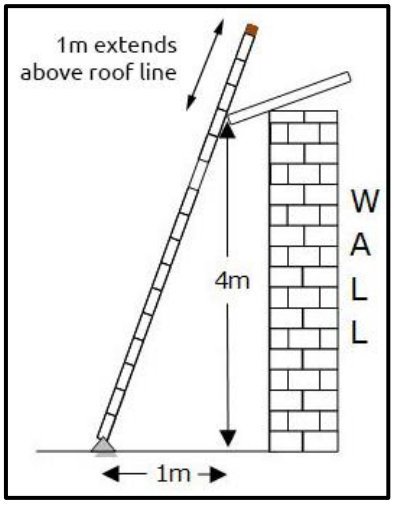
Using ladders safely

When working with electricity or an electrical circuit or equipment, ladder safety should be observed. There are many different types of ladders, and they are made of different materials. Metal ladders should never be used when dealing with electricity. Always choose a nonconductive ladder made of wood or fiberglass.

Also check the condition of ladder before use.

- ✓ **Never work above the safe standing height**, which should be marked or indicated on the ladder.
- ✓ The **general rule of thumb** is don't stand or work above the second step from the top on a step ladder, or above the fourth step from the top on an extension or straight ladder).

- ✓ **Always work within easy arm's reach**. Never stretch out too far. The most common accident with ladders is caused by ladders tipping due to people reaching out too far.



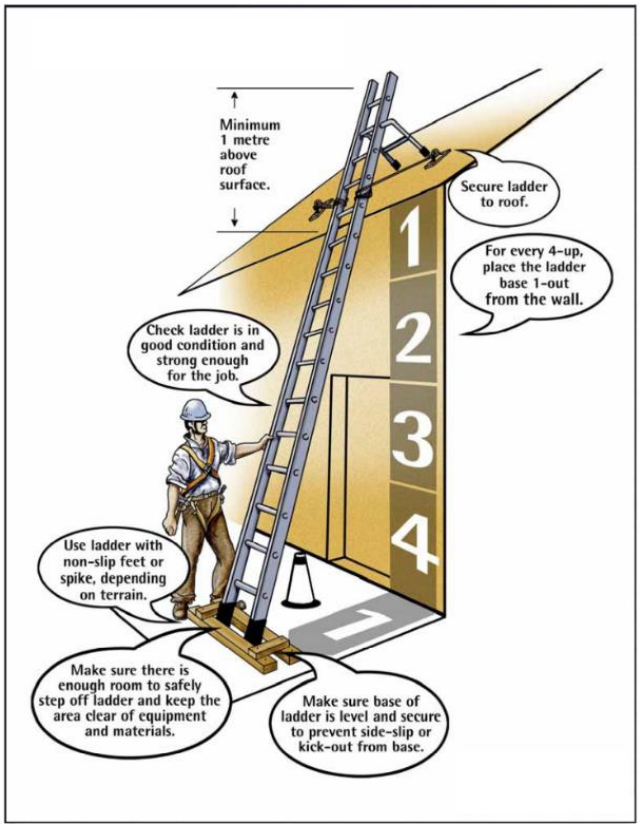


Fig 10.12: Safe use of ladder

- ✓ **Avoid pushing, pulling, twisting or otherwise exerting large forces** while working on a ladder. The sudden movement caused if you are pulling or pushing hard on something and it lets go could be enough to topple the ladder or knock you off.
- ✓ **Never carry anything more than 5kg** in weight up or down the ladder - have it passed up to you.
- ✓ Wear correct non-slip footwear to ensure stable footing on the rungs of the ladder.
- ✓ **The rule of thumb for resting the ladder is "Four Up, One Out"** - for every four feet/meters up from the ground to where the ladder is resting, the base should be one foot/meter out from the vertical surface (see the diagram). If the base is too far out, there is a risk it could slip out. If the base is too far in, the ladder could tip backwards.

Electric Shock, its prevention and treatment

Electric Shock

An electric shock occurs when a person comes into contact with an electrical energy source. Electrical current flows through a portion of the body causing an electric shock. It may result in no injury at all or may result in upsetting damage or even death. Electric current passing through the body, particularly **alternating current** at power frequency of 50 Hz, may disturb the nervous system, causing muscular reaction and the painful sensation.
The most common reaction is to be thrown off the conductor as a result of the muscular contraction.

Fig 10.13: A man after fatal electric shock

Level of current	Effect
0.5-3mA	Tingling sensation
3-10mA	Painful muscle contraction
10-40mA	Respiratory paralysis(possibly fatal)
30-75mA	Ventricular fibrillation (likely fatal)
100-200mA	Heart Clamps tight

General Circuit breakers (MCBs or MCCBs) are designed to protect equipment and not the people

200-500mA	Tissue and organs begin to burn

Treatment of electric shock:

Immediate actions to be taken

If someone get electric shock, promptly do the following

1. Turn off the source of electricity, if possible.

If you can't turn off the power:

2. Stand on something dry and non-conductive board and try to separate the person from current source using non-conductive object such as wood or plastic brush handle, chair, or rubber doormat. Caution: Don't touch the person with your bare hands).
3. Lay the person down and, if possible, position the head slightly lower than the trunk with the legs elevated.
4. Begin CPR* if the person shows no signs of circulation, such as breathing, coughing or movement.
5. Try to keep the injured person warm.
6. Call 1122
7. If the person is not breathing, immediately start artificial respiration until the medical aid arrives.

*CPR is short of ***cardiopulmonary resuscitation***. It is an emergency procedure that can help save a person's life if their breathing or heart stops. When a person's heart stops beating, they are in cardiac arrest. During cardiac arrest, the heart cannot pump blood to the rest of the body, including the brain and lungs.

Severity of electric shock, depends upon many factors which include level of voltage, impedance of the body, length of time in contact with the source, overall health of the victim, path of current through the body, type of current (an alternating current is often more harmful than a direct current because it causes muscle spasms that make it harder to drop the source of electricity).

As a general rule, at an applied voltage of 230 V, 50 Hz the total body impedance for a hand-to-feet path will be in the range 1000 Ω to 2500 Ω and around 750 Ω at voltages in exceeding 1000 V. Any one or more of the following symptoms may arise due electric shock.

- Cardiac arrest
- Heart rhythm problems (arrhythmias)
- Respiratory failure
- Muscle pain and contractions
- Burns
- Seizures
- Numbness and tingling
- Unconsciousness

Call 1122 or local emergency number immediately if any of the above signs or symptoms occurs:

Restoration of breath: There are several methods of restoration of breathing. Two of them are given below.

Method -1

1. Lay the victim on ground keeping his stomach downward with his face one side.
2. Open the buttons of his shirt near the neck and loose the shirt so that he does not feel any difficulty in breathing. Lay the victim in such a way that body pressure does not affect his burns on the body.
3. Sit on ground facing towards the head of victim with feet figures and knees on ground. Kneel over the person's back and. Place both your hands on his back in such a way that your both thumbs touch the spine and other figures spread outward.
4. Now press the victim slowly for about three seconds. Bowing you forward. Keep the person warm.
5. Now remove the pressure slowly any come to the original position for about two seconds without lifting your hands from person.
6. Repeat the process 12-15 times in a minute till the breathing to the victim is resorted.
7. Don't give any type of liquid until the patient is mindful.

Method -2

This method is particularly used where the chest of the victim is suffered and he cannot be laid as stated in above method-1.

1. Victim is laid on his back towards the ground and is ensured that nothing is in the mouth of the victim which would block passage of air.
2. Put on hands under victim's neck and with other hand lift his chin upward.
3. Shut the nostrils of the victim by your thumb and Index finger; put your mouth tightly over the mouth of the victim and blow forcefully so as to expand the chest of the victim.
4. Remove your mouth to let the air to back escape from the chest of the victim.
5. Repeat this process every 3-4 seconds. To avoid direct contact with the mouth of the victim, make use of handkerchief.
6. This method supplies 10-12 times more volume of air into the patient lungs than any other method.
7. Even after apparent recovery, send the victim to the hospital to ensure that person is quite well.

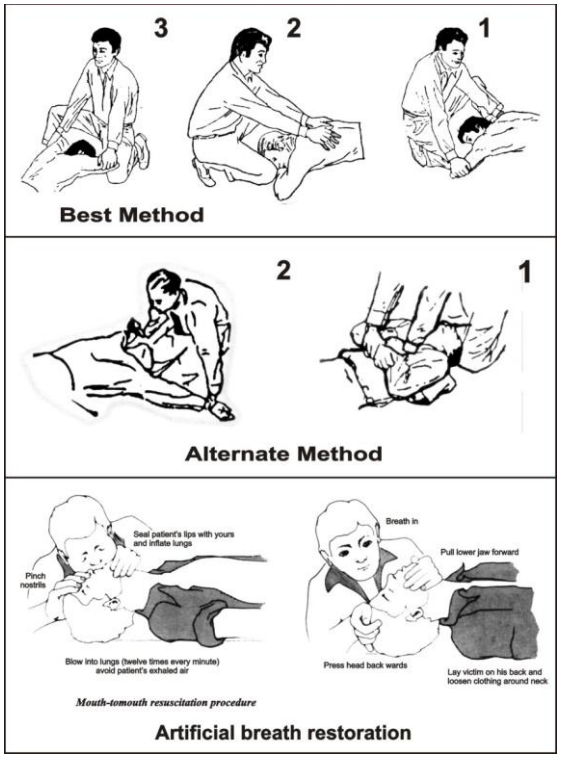


Fig 10.14: Restoration of breathing

Exercise

Part-1: Subjective type Questions

Sample Long Answer type questions

1) What are the methods to prevent the fire? Explain.
2) What are the types of fire fighting equipment? Explain.
3) What is meant by electric shock? How can be avoided from it?
4) How a person should be treated effected by an electric shock? Explain.
5) What are the hazards from rotating electric machines for human life? Also write their preventive methods.
6) Write types of fires. Which method is used to extinguish each type?
7) Write reasons of fire.
8) Write detail note on safety apparel & equipment.
9) Write note on safe use of ladder.
10) Write note on following electrical safety apparatus.
11) (1) Cloths (2) Shoes (3) Gloves
12) Write fire fighting principle and its method in detail.

Part-2: Objective type Questions

Sample Short Answer type Questions

1) Define fire?
2) What are basic combined factors of fire?
3) Make a list of some important causes of fire?
4) What are the types of fire, write down the names?
5) What is meant by class "A" fire? Which method is used to extinguish this fire?
6) What is class "B "fire? Which method is used to extinguish this fire?
7) What is class " C " fire ?Which method is used to extinguish this fire ?
8) What is class " D " fire ?What are the agent to extinguish this fire?
9) Which things catch class "E "fire? How this fire is controlled?
10) What is meant by prevention of fire?
11) What is meant by fire fighting? Write down its purpose?
12) What is the use of ladder in electric work?
13) What is meant by electric shock?
14) Write down five important steps to avoid an electric shock?
15) Write down two methods of protection from rotating electric machines?
16) Write down five important safety measures while working on electrical work?

Sample Multiple Choice Type Questions (MCQs)

1) Basic factors of fire are
   a. Fuel b. Oxygen (air)
   c. Heat d. All
2) To stop the process of burning , should be kept away from air
   a. Fuel or Flammable material
   b. Sources of heat
   c. Both a &b
   d. Light
3) Cause of fire is
   a. Fire work b. Smoking
   c. Poor wiring d. All
4) Burning of electric apparatus and circuits is called class of fire
   a. A b. B
   c. C d. D
5) The type of fire which is related to specific metals e.g magnesium and titanium
   a. A b. B.
   c. C d. D
6) Class E fire can be controlled by
   a. Starvation b. Cooling
   c. Smoothening d. All these
7) Water fire extinguisher is used for this class of fire
   a. A b. B.
   c. C d. D
8) Total capacity of soda acid type water extinguisher is
   a. 5 liter b. 9 liter
   c. 10 liter d. 20 liter
9) During manufacturing, soda acid type water extinguisher is tested at pressure of ------- Kg/cm2
   a. 15 b. 20
   c. 25 d. 50
10) Function of foam on fire is
   a. Cooling b. Smothering
   c. Starvation d. Both b & c
11) Fire of diesel, petrol, varnish, paints, lubricants oil is a class of fire
   a. A b. B
   c. C d. D
12) Dry powder fire extinguisher is used for class of fire
   a. A b. B
   c. C d. D

13) It is used as agent in carbon dioxide fire extinguisher
   a. CO b. O
   c. HO d. None
14) Carbon dioxide reduces the level of oxygen in air
   a. 10 to 11% b. 11 to 12%
   c. 12 to13% d. 13 to15 %
15) While working on pole, safety belt should be fastened on pole at least below
   a. 30 cm b. 40 cm
   c. 50 cm d. 60 cm
16) Linemen should not use the dress
   a. Loose
   b. Dongrie
   c. Dress having metallic buttons or buckles
   d. All these
17) Linemen should use such caps in which
   a. There is no metallic button
   b. There is no metallic ornament
   c. Both a & b
   d. None of these
18) Linemen should use shoes, having
   a. Leather sole b. Insulated material
   c. Both a & b d. Any of these
19) Gloves of linemen should be made of
   a. Good flexible rubber b. Hard rubber
   c. Both a & b d. None of these
20) Linemen should use a ladder
   a. Strong b. Reliable
   c. Both a & b d. Long
21) Top end of ladder should have
   a. Rope b. Hook
   c. Both a & b d. None of these
22) The reason of receiving electric shock is
   a. Short circuit
   b. Leakage of current
   c. Passing of current from human body
   d. Melting of fuse
23) Cause of electric shock is
   a. Touching a bare conductor
   b. Poor earthing
   c. Fuse not proper
   d. All these

24) First step in case of electric shock
   a. Disconnect the supply
   b. Separate the patient
   c. Serve water
   d. Restoration of breathing

25) While working on rotating machines, dress should be
   a. Loose b. Tight
   c. Coloured d. None of these

26) While working on moving machines never do
   a. Oiling b. Cleaning
   c. Repair d. All these

27) While working on machine, keep attention at
   a. Work b. Hands
   c. Clothing d. class

ANSWER KEY

1	**d**	8	**b**	15	**a**	22	**c**
2	**c**	9	**c**	16	**d**	23	**d**
3	**d**	10	**b**	17	**c**	24	**d**
4	**d**	11	**b**	18	**c**	25	**b**
5	**d**	12	**d**	19	**a**	26	**d**
6	**a**	13	**a**	20	**c**	27	**a**
7	**a**	14	**c**	21	**a**		