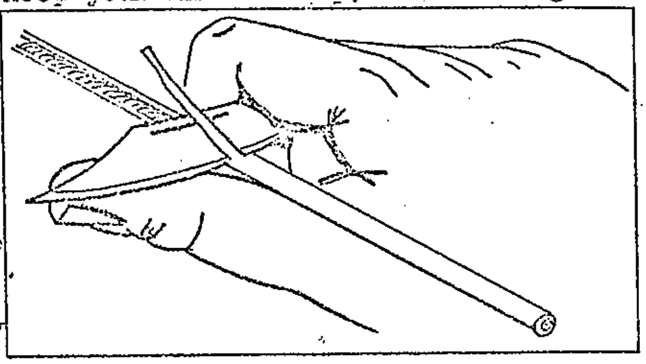
TITLE:- ELECTRICAL WIRING TOOLS AND THEIR USES

LECTURER:-

DATE:-

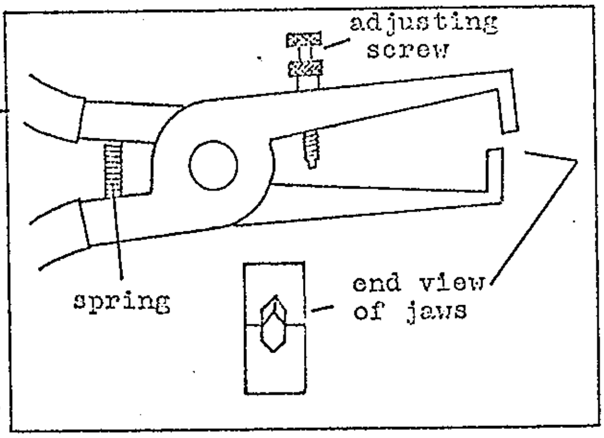
EQUIPMENT:- Knife, stripper, pliers, diagonal cutters, round nose pliers, screwdriver/spanner, crimping tool - 00, 20, Utilux combination, WZ11, WZ12, WZ13, cable cutter.

Knife
Not only a tool, but also a weapon. One of the tools that needs no explanation.
Use When using a knife always cut away from the body and any by-standers.
A blunt knife is more likely to cause accidents than a sharp one, besides making hard work. To keep your knife sharp, hone it regularly on an oil stone.



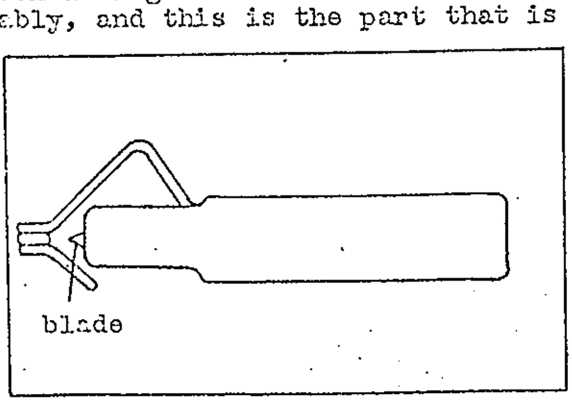
To strip the insulation from cables, hold the cable in the left hand. Hold the body and base of the knife in the palm of the right hand with the blade lying flat against the index finger, sharp edge toward the wrist. Put the blade behind the cable and almost flat to it. Draw the knife along using the thumb to apply pressure to the front of the cable. To cut off the insulation, bend it back, hold the bottom against the cable and cut off the loop thus formed.
Do not leave open knives lying around, especially with the sharp edge uppermost. Don't throw or lark about with knives; remember, in the eyes of the law, they are an offensive weapon.

Stripper Type 1 Plier Type
This is another type of plier.
It consists of a plier type construction with a lockable adjusting screw which sets the closing of the jaws to any desired setting.
The jaws are at right angles to the handles with overlapping V-shaped blades.

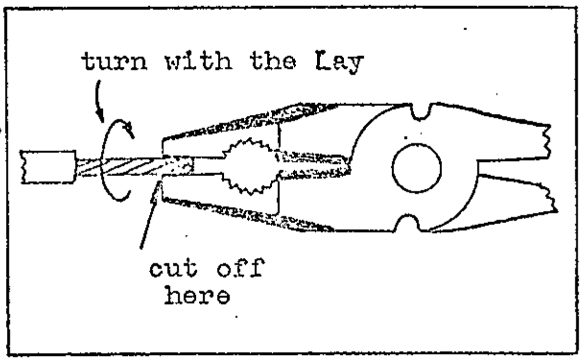


Operation Set the blades so that they cut part way through the insulation, open pliers, turn slightly, and pull off.
Examine the conductors. If they have been nicked at all, cut off, reset the jaws and start again. Even a slight nick reduces the conductor's pliable strength considerably, and this is the part that is bent most.

Type 2 Spring Loaded Type
This consists of a square handle with a spring loaded metal strip with a small blade in the handle: see diagram. To adjust, a screw at the base of the handle screws the blade in and out to give a deeper or shallower cut.
Very safe to use, but can do damage to the cores. Used mainly for stripping outer braiding.

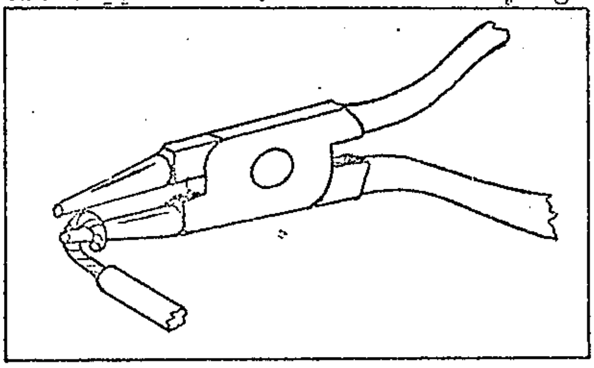


Pliers
Previously described in detail.
Electrical Use - Used in electrical work as cutters and to grip objects, previously described. To twist conductors into shape for entry into connectors.
To do this correctly, grip the end of the conductors with the centre of the flat jaws, with the pliers in line with the conductor. Twist the strands by turning the pliers in the hand, in the same direction as the lay of the cable and pulling at the same time. Then snip off the end bit.



Diagonal Cutters These were previously described.
Electrical Use - To snip off the conductor ends as described in "Pliers". Also for cutting any soft copper wire. Beware of flying ends.

Round Nose Pliers are normal plier action, but are made with tapered, rounded conical shaped jaws.
Use - these are used to make bends, loops and other shapes in conductors.

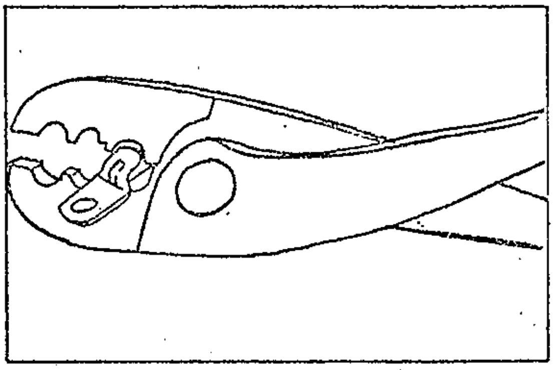


Screwdrivers Previously described, but in electrical work, where small parts are involved, care must be taken not to pierce the hand. Put parts onto the bench to screw them, rather than hold in the hand.

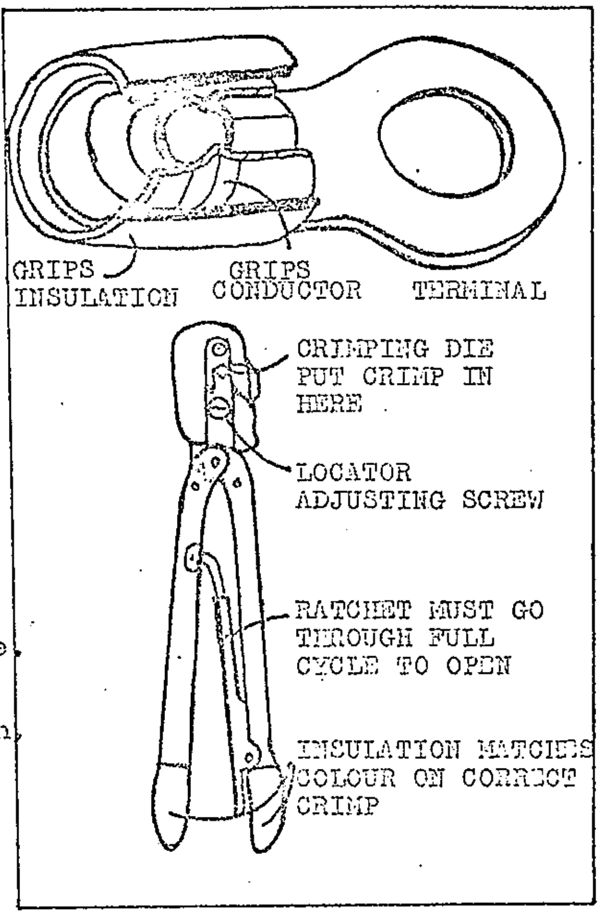
Spanners Previously described. In electrical work care must be taken that nuts and bolts, made more to cater for their conductive properties than strength, are not sheared off.

Crimping Tools Used for securing "crimp-lugs" to the ends of cables, to ensure a secure electrical and mechanical termination.
Use the correct size and type of crimp-lug (see Safety Handbook).
Use the correct size and type of crimp tool, and ensure that it is used in the proper manner with the proper pressure.

Plain Crimping Tools & Lugs
Utilux type used on non-insulated lugs - several sizes covered by each size set of pliers. Straightforward pliers action.
The crimp lugs are provided with small holes at the opposite end to the cable entry hole. Push the lug onto the wire until you can see the end of the wire through the hole; this will be the correct position.
Sizes - The size of crimp-lugs are given by the size of lug and hole diameter.



Insulated Crimp Lugs and Crimping Tools



Insulated Crimp Lugs have 3 sections instead of 2. The top portion fits onto the terminal. The second portion grips the conductor and the third portion grips the insulation. An insulation sleeve is around the cable entry section, the colour of which corresponds to the colour of similar sleeving on the handles of the crimping tool.

Crimping Tools This type of tool is much more complex than the plain type. They are double pivoted to give more leverage. To ensure correct crimping pressure, they are fitted with a ratchet so that the lug cannot be removed from the tool until the crimping cycle is complete. The crimping jaws for the insulation part can be adjusted for 3 different settings by removing a pin in each section and positioning it in a separate hole. The conductor jaws are set and, cannot be adjusted. A spring loaded positioning anvil is often, but not always fitted.

To operate - Put the cable into the lug so that the conductor or conductors protrude through the hole at the terminal end and the insulation is upto the narrow section. Cut off excess conductor. Put the lug and conductor into the crimping tool so that the terminal end goes through the anvil and the conductor part butts up to it. Close the handles.

Make sure you don't trap a portion of skin in any part of the tool, because to get it out, the crimpers have to be stripped into pieces or the crimpers pressed through the full cycle.

Cable Cutters

Special cable cutters are available that will cut through even welding cable in one cut. They are straightforward pliers action. These cutters must not be used for any other purpose than cutting standard copper conductors.

Whilst using all these tools, bear in mind the following:-

(a) Avoid cutting or damaging the conductor.
(b) Avoid cutting or damaging the insulation.
(c) Avoid injury to yourself or others.
(d) Use the proper tool for the job.
(e) If in doubt, ask.

TITLE:- WIRING PRACTICE

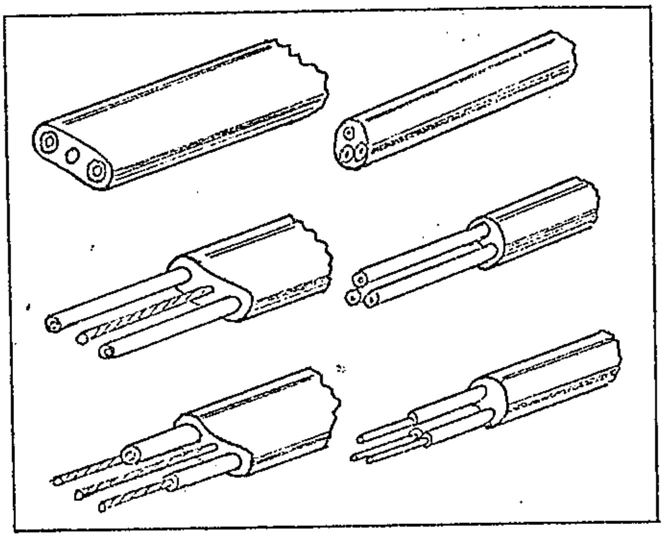
LECTURER:-

DATE:-

EQUIPMENT:- Cable, terminals, crimp lugs, crimp links, crimp tools, claw-washer, shell clamp, rowco strip, blow point, utilux terminal, cable forms.

Once it is learned how to use the electrical tools, the next logical step is to apply the use of these tools into electrical practice, i.e. terminating, jointing, installing of cables, wires, and equipment associated with electrical practice.

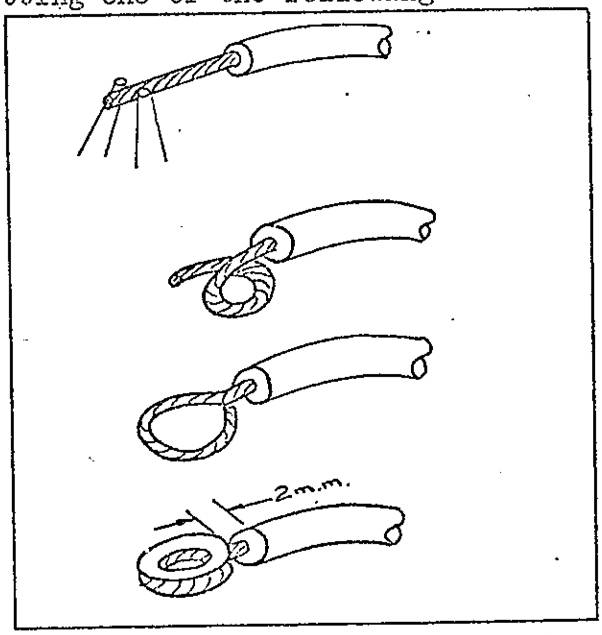
Terminations - a termination is the name given to the connection made between a cable or wire and an item of electrical equipment. Before the termination can be made, the cable end must be properly prepared.



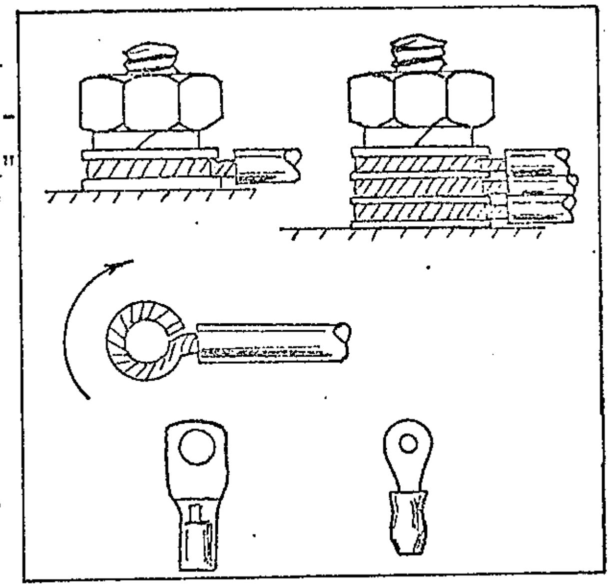
(1) Measure the length of cable required.
(2) Cut off cable leaving approx. 1" extra length to that required.
(3) Remove the cable sheath to the desired length.
(4) Remove cable insulation to required length (use wire stripper on flexible wire, and knife on stranded wire) Do not damage copper conductors.
(5) Twist the strands of wire to tighten the "lay" (Use pliers on stranded wire, and fingers on flexibles).

The cable end is now ready for fitting one of the following terminating devices.

Wire Loop

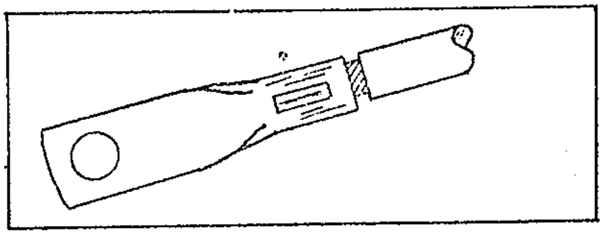


The simplest form of termination is the wire loop. No extra equipment is required, and it is therefore the least expensive. The end of the wire is gripped with the round nosed plier, it is then twisted for approx. half a turn. The pliers are then re-positioned further along the wire. The process is repeated until a full loop or more is formed. The remaining straight part of the wire is then bent in the opposite direction, and excess wire is cut off. The loop must not overlap itself, and sufficient length must be left between the end of the insulation and the loop for washers.
A space of approx. 2mm should exist between the edge of the washer and the insulation.
This type of termination is used where "bolt type" terminals are used.



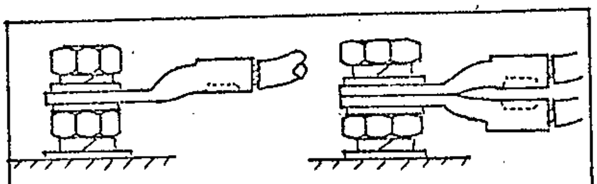
Washers should be placed on each side of the loop, with a spring washer and nut being used to secure the termination.
Where several loops are "stacked" on a bolt, then a washer must be placed between each loop, and the loop must be a snug fit on the bolt. It must be fitted so that as the nut is tightened, the loop will also tighten, i.e. clockwise.

Crimp lug
Two types of crimp lug are available. One is the "Utilux" non-insulated type, the other is the A.M.P. insulated lug. A tool known as a "Crimping Plier" is used for fitting these lugs.
It is extremely important that the proper tool is used on each type and/or size of lug. The table below gives the necessary information.
(See Page M7/2/2A)



Further information on crimp lugs may be found on pages 95 & 96 of the Electrical Safety Handbook.
The method of using the crimp tools is illustrated in the diagram. Note that the Utilux tool is used so that the indentation is on the opposite side to the letters printed on the lug.

mm^2	Cond. Size	Max. Current	No. Cores	Core Colours	Cable Type	A.M.P. lug	Hole Size
.75	24/.2	7.5	1	Bk	Flexible		
"	"	"	"	R	"		
"	"	"	"	Bl	"		
"	"	"	"	W	"		
"	"	"	"	G	"	RED	
"	"	"	3	Bn, Bl, G	Flex.Cord		
"	"	"	2	W, W	Fig. 8	31885	1/8
						31890	5/32
1	32/.2	10	3	Bn, Bl, G	Flex.Cord	31891	3/16
"	"	"	5	Bn,Y,Bk,Bl,G	" "	31894	1/4
"	1/1.13	14	1	Bk	Panel Wire		
"	"	"	"	R	" "		
"	"	"	"	Bl	" "		
"	"	"	"	W	" "		
"	"	16	2	R, Bk	Bldg.Cable		
"	"	13	4	R, W, Bl, G	" "		
1.5	30/.25	15	1	Bk	Flexible		
"	"	"	"	R	"		
"	"	"	"	Bl	"		
"	"	"	"	W	"		
"	"	"	"	G	"		
"	"	"	5	Bn,Y,Bk,Bl,G	Flex.Cord	BLUE	
"	1/1.38	20	2+E	R, Bk	Bldg.Cable		
"	"	17	3+E	R,W,Bl	" "		
"	"	20	2+E	Bk, W	" "	32442	1/8
"	"	"	"	R, W	" "	31901	1/8
2.5	7/.67	23	1	Bk	Panel Wire	31902	5/32
"	"	"	"	R	" "	31903	3/16
"	"	"	"	Bl	" "	31906	1/4
"	"	"	"	W	" "	31907	5/16
"	"	"	"	G	" "		
"	"	28	2	R, Bk	Bldg.Cable		
"	"	"	2+E	R, Bk	" "		
"	"	23	3+E	R,W,Bl	" "		
"	"	"	4+E	R,W,Bl,Bk	" "		
"	50/.25	20	4	Bn,Bl,Bk,G	Flex. Cord		
4	56/.3	25	1	Bk	Flexible		
"	"	"	"	R	"		
						YELLOW	
6	88/.3	44	2	R, Bk	Flex.Cable		
"	"	41	3	R,Bk,G	" "	35109	3/16
"	"	"	4	R,W,Bl,G	" "	35110	1/4
"	7/1.04	39	1	Bk	Panel Wire	35111	5/16
"	"	"	"	R	" "	35112	3/8
"	"	"	"	Bl	" "		
"	"	"	"	W	" "		
"	"	"	"	G	" "		
"	"	47	2+E	R, Bk	Bldg.Cable		
"	"	40	3+E	R,W,Bl	" "		

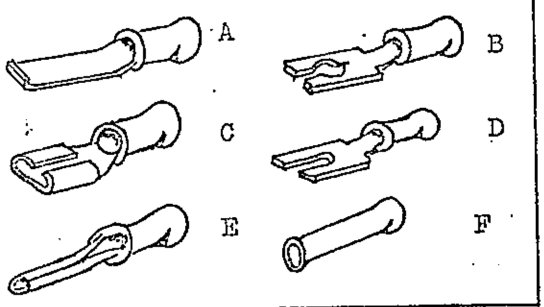


The handles must be squeezed as tightly as possible. The AMP tool has a ratchet to ensure that correct pressure is used. Be sure that the lug is placed in the tool in the proper direction.

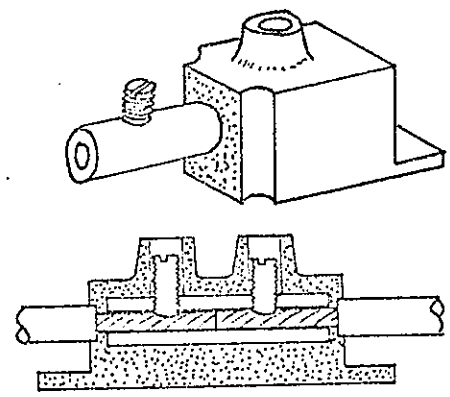
Crimp lugs are usually fitted to bolt type terminals, and should be mounted as illustrated. Other types of lugs are:-

Lip blade - - - - A
Spring blade - - B
Faston - - - - - - C
Spade - - - - - - - D
Pin - - - - - - - - E
Link - - - - - - - F

An example of each is illustrated.



Claw-washer & Shell clamp. These two methods are used in conjunction with the wire loop, and are more secure than the wire loop.
Both types have mostly been replaced by the crimp-lug, but some may still be in use.
Examples of both are illustrated.



Tunnel connectors
This covers a wide range of electrical terminals, and is the type where the wire or wires are inserted into a brass tube and secured by one or more screws. The brass tube is usually covered with p.v.c. or bakelite insulation.
The wire strands must be tightly twisted and pushed as far as possible into the tube or "tunnel" to ensure proper grip. If the wire is small in comparison to the hole in the tunnel, it should be doubled or tripled so that the screw grips properly. This reduces the risk of the screw squashing or cutting the wire.

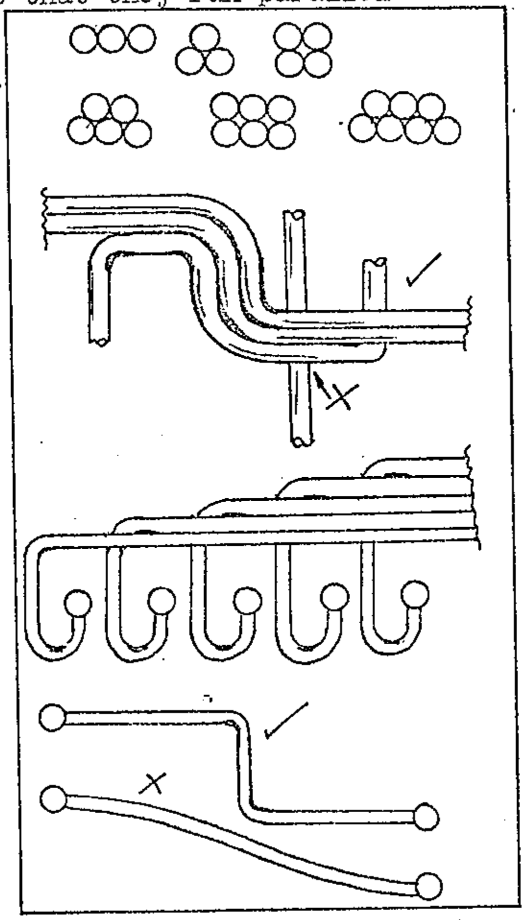
Installation of wiring and cable
Factors which must be considered when an installation is being made are:-

1. The correct circuit
2. Neatness of wiring and cabling
3. Economical planning of wire and cable routes
4. Proper size and colour of wires.

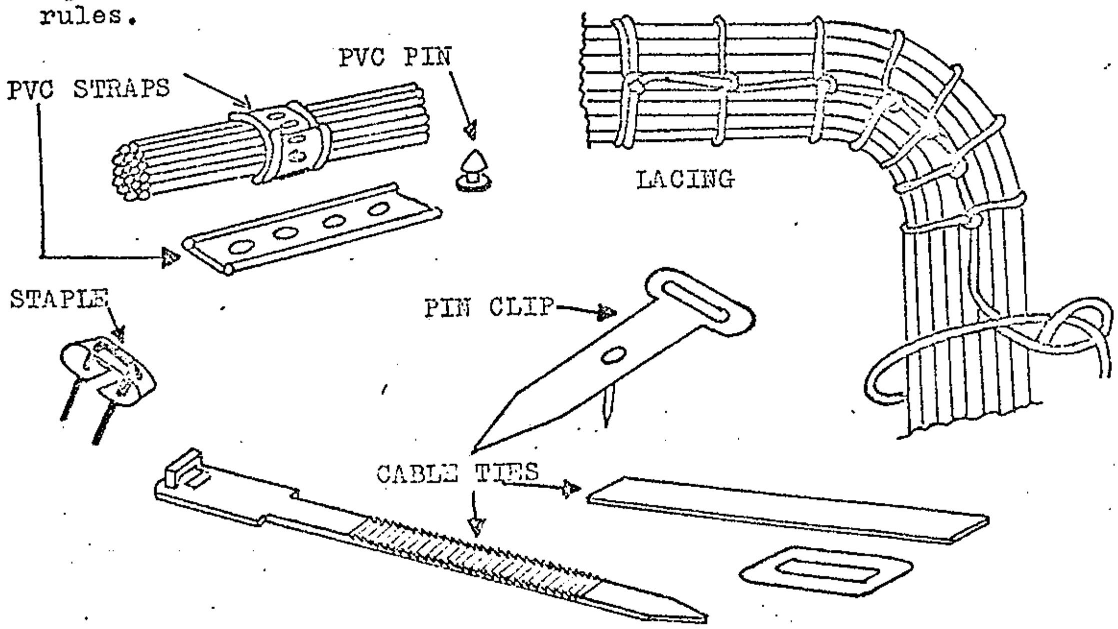
1. The correct circuit may be achieved regardless of its complexity, by approaching the job in a logical manner.
    1) Learn the electrical symbols used.
    2) Obtain or make a "WIRING DIAGRAM".
    3) Study the diagram.
    4) Obtain all materials and equipment before starting.
    5) Use cable markers to identify the ends of each wire as it is installed.
    6) Test each wire for continuity as it is connected.
    7) Ensure that all terminals are FULLY tightened as they are installed.

2. Neatness of wiring & cabling is sometimes difficult to achieve for the apprentice, but with practice, it is possible to achieve the desired standard on every installation. Some factors which go towards a neat installation are:-

1) Install all wires and cables so that they run parallel to each other.
2) Arrange bundles of wires into neat formations as illustrated.
3) Bend single wires over the thumb, not with any tool.
4) Do not allow gaps to appear between adjacent wires - especially on bends.
5) Where wires must cross from one side of a loom of wires to the other, run that wire for a short distance with the loom, and do not make direct cross-over.
6) Leave a small loop at the end of each wire as it is "peeled" off of the loom onto a terminal strip.
7) As each wire is peeled off from the loom, it should be looped underneath the loom, not on top.
8) Where bends are made in wires, endeavour to make 90° changes of direction.
9) Earth wires to individual components must originate at an EARTH BAR, i.e. no looping.
10) Neutral wires to individual components must originate at a NEUTRAL LINK, i.e. no looping.



11) Active wires to individual components may NOT be looped unless the terminal size limits the number of wires originating at that terminal in which case looping is permitted providing that the addition of the load currents and the cable's current carrying capacity are within the limits.
12) Secure the looms of wire using one of the following methods - Lacing, P.V.C. straps and pins, cable ties, pin clips, staples. Whichever method is used, the spacing should be equal and conform with the requirements of the SAA wiring rules.



3. <u>Economy</u> Copper wire is expensive and should not be wasted. The route which wires and cables take should be as short as possible but in a manner which ensures neatness.
Allow sufficient "spare wire" at each end to ensure that the termination can be neatly fitted, and so that it can easily be removed for testing.
Think before installing a wire or cable or cutting the wire or cable as mistakes can prove to be expensive.

4. <u>Size & Colour of Wires</u> The wire size is determined by the current which it must carry and the voltage drop along its length.
Current carrying capacities of cables are tabled in the Safety Handbook. Pages:-
Voltage drop must not exceed 5% (SAA rules).
Wire colours are in the process of being changed to a new standard. So far, flexible cords are covered by the new code, although many are still in use made to the old code.
A comparison is shown below.

		No. of Cores									
	Old Code	1	1	1	2	3	3	4	4	5	5
Active	R	Bn			Bn	Bn	Bn	Bn	Bn	Bn	Bn
Active	Y						Bl	Bl	Blk	Blk	Y
Active	Bl						Blk	Blk	Y	Y	Or
Active											Blk
Neutral	Blk		Bn		Bl	Bl			Bl	Bl	Bl
Earth	Gr			Gr/Y							

R - Red, Y - Yellow, Bl - Blue, Blk - Black,
Gr - Green, Or - Orange, Bn - Brown

All standard cables at present are made to the old code and their colours are as shown in the first column above.

IMPERIAL	METRIC (MM²)	STRANDED	FLEXIBLE	WELDING FLEXIBLES	CURRENT(C
1/.044					8
3/.029					10
3/.036					15
1/.064					15
	1	7/0.4	32/0.2		16
	1.5	7/0.50	30/0.25		19
1/.029					20
	2.5	7/0.67	50/0.25		27
	4		56/0.30		36
7/.036					45
	6	7/1.04	88/0.30		46
7/.044					55
	10		77/0.40		62
7/.052					70
	16	7/1.70	126/0.40	511/0.20	83
7/.064					90
19/.044					105
	25		209/0.40		110
19/.052					120
	35	19/1.53	285/0.40		140
19/.064					165
	50	19/1.78	308/0.40	703/0.3	180
19/.072					190
19/.083					225
	70	19/2.14	203/0.67	988/0.3	230
37/.064					250
	95				280
37/.072					290
	120		336/0.67		320
37/.083					350
	150	37/2.25			370
37/.093					405
	185				435
37/.103					460
	240	61/2.25			510
61/.093					545
	300				600
61/.103					620
	400				680
91/.093					690
	500	61/3.20			790
91/.103					800
127/.093					860
	630	127/2.52			900
127/.103					950

FLEXIBLE CORDS

IMPERIAL	METRIC	IMPERIAL	METRIC	IMPERIAL	METRIC
AREA IN^2	AREA MM^2	STRANDING	STRANDING	CURRENT	CURRENT
.0006	0.5	14/.0076	16/.02	2	3
.001	0.75	23/.0076	24/.02	7.5	7.5
.0017	1.0	40/.0076	32/.02	10	10
.003	1.5	70/.0076	30/.25	15	15
.0048	2.5	110/.0076	50/.25	20	20
.007	4	162/.0076	56/.30	30	25

TITLE: Conduit

LECTURER:

DATE:

EQUIPMENT: Steel and PVC Conduit
Bending Spring
Conduit Benders
Jointing Cement

Conduit is the name given to the tubing used to house and protect cables in electrical installation. Two types of rigid conduit are available:

1. Steel screwed conduit
2. PVC Conduit (Poly Vinal Chloride)

Each type will be used according to the required situation.

Steel Screwed Conduit

This is manufactured in three standard finishes of black-enamelled, galvanised and orange-enamelled.

All steel conduit size is specified by it's outside diameter (0.1).

The range of conduit available is 16.20.25.32.50 mm. With a thread pitch of 1.5 mm.

Welded steel conduit is manufactured from hot rolled carbon steel strip. The strip is first shot blasted to remove all scale. It is then rolled and the edges of the seam are raised to welding temperature (usually by high frequency heating and welding by squeezing the edges together).

The most used steel screwed conduit is the galvanised type.

Steel conduit has approximately ten times the tensile strength of PVC conduit. This allows it's use where exposed to severe mechanical injury and insituations described in S.A.A. Rule 3.25.1.

It is extremely rigid in the allowable distance between support being 2 m (Rule 3.25.10.). It's melting point is about 1341°C which is higher than the temperature at which cable insulation failure occurs

It is not flammable and it's coefficient of expansion is relatively low. If done properly, the threaded joint method of coupling is both electrically and mechanically sound.

Steel conduit also provides an earthed screen for the conductors enclosed.

Conduit should be so installed that it can be readily dismantled and reassembled if alterations or extensions are necessary.

Whether the conduit is used for surface wiring with inspection fittings or for concealed wiring with "draw-in" boxes.

The cables are drawn-in after the conduit has been installed as part of a new installation or replaced at any later time if repairs or alterations are necessary.

Rule 3.25.2. allows the substitution of steel piping for steel conduit provided that the condition listed in the rule are followed.

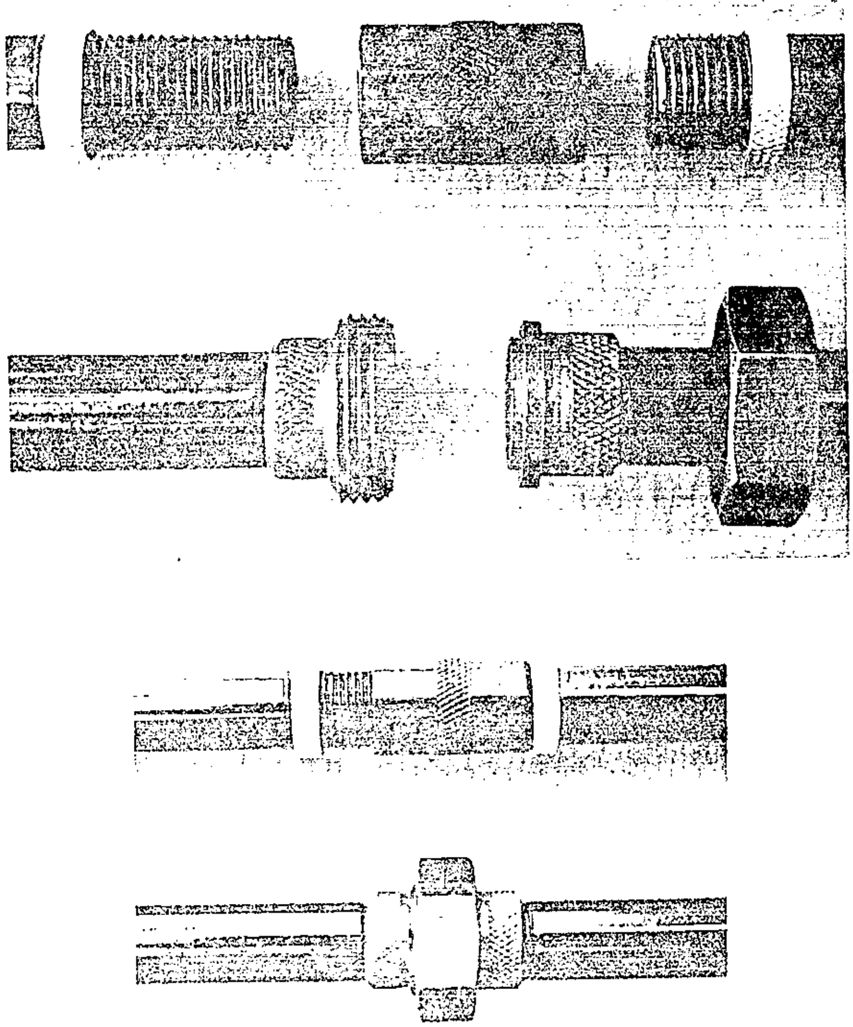
Conduit is cut by holding it firmly, preferably in a "pipe vice" and using a hacksaw with a 32TPI blade.

Threading is effected by holding it firmly in a pipe vice and using a block type stock and die or a stock with four individual adjustable dies. Lubrication must be provided when threading.

After threading, all internal burrs must be removed to prevent damage to cable insullation. A round file or similar tool is used for this purpose.

The thread should be clean, be a firm fit in an accessory and be half the length of a standard coupling.

Ideally, when screwed into an accessory, there should be no exposed thread except where locknuts are used with a "Running Thread".



(a)

(b)

Fig. 8.2 (a) (b) Joining metal conduit using a "running thread" or a manufactured "union"

It is important to realise that where the protective coating of the conduit has been removed, it is necessary to restore this protection by applying some sort of protective coating (Rule 3.25.6), (Lead compound, graphite compound).

Where conduit is used for concealed wiring, use of tees and elbows should be avoided. Change of direction is accomplished by large radius sets or by using conduit bends, thus permitting easy drawing-in of the cables.

On surface work inspection fittings are used. Wherever possible conduit sets should also be used as they are "labour-saving" and make drawing-in easier.

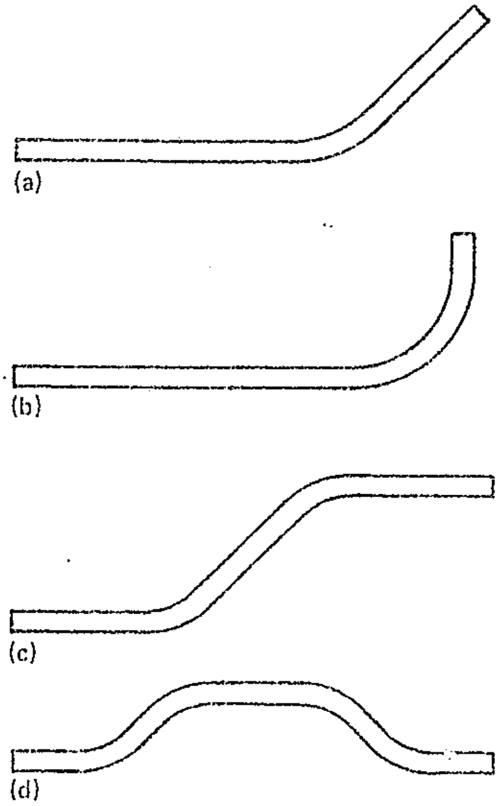


Fig. 8.3 Four sets used commonly in conduit work: (a) Set; (b) 90° set or bend; (c) Double set or offset; (d) Double offset

Bending of conduit must be in such a way that it will not cause distortion of the conduit wall, open a weld or reduce the inside diameter of the conduit (Rule 3.25.8).

Bending can be done using:

1) Setting Block: consisting of a piece of hardwood, with a clearance hole for the conduit near one end with the hole entrance chamfered. The conduit is set in a series of short bends shifting the conduit position in the hole after each bend.

2) A commercial bender

3) Automatic bending machine

4) Any two fixed smooth objects as long as they are not going to be damaged in the process.

Installation

When planning a conduit installation remember these points:

Plan the route

Minimise the number of bends, elbows etc.

Run a draw wire through the conduit

Take care when bending

(No kinks, split conduit, sharp bends)

No burrs

Comply with the S.A.A. rules

1. Continuity
   Rule 5.3.3. 5.4.

2. Corrosive Atmosphere
   Rule 3.25.5.2. 3.25.5.3.

3. Fixing
   Rule 3.25.10. 3.25.11(1.19).

4. Drawing-in Cable
   Rule 3.26.2. 3.26.3.

PVC Conduit

PoliVinyl Chloride is made to an Australian Standard specification as C I73.

Standard colours are grey, orange. This conduit is much lighter and more flexible than steel conduit, but has a very poor mechanical strength and must be supported at a maximum of 1m between fixing (Rule 3.25.3.2.).

Standard sizes are from 20mm to 50mm.

The end of the conduit is belled, thus eliminating the need for a coupling when joining.

The conduit is now used in a wide variety of applications. It's major advantages being that if used with PVC accessories, it forms a double insulated system of wiring.

It will not support combustion, but is highly resistant to chemicals and easily set in a variety of bends. Because of this and the simple method of joining, the labour time for it's installation is considerably less than that required for steel.

All sizes are easily cut by a fine-tooth hacksaw. The conduit being hand-held if possible using the knee as a "steady-rest" for the conduit.

Rule 3.25.3.1. specifies the use of an "abhesive cement" for joints. The liquid used is actually a PVC solvent (normally available from the manufacturer). It is advisable to use only this liquid for joining.

With solvent welding, it is important that both the outside of the conduit and the inside of the fitting are perfectly clean and dry. The solvent must be applied to both surfaces, jointing must be done within one minute of applying the solvent. All excess solvent is wiped off.

Bending

All bending is made with the help of an internal mandrel in the form of a metal spring. A particular spring is available for each size of conduit.

A 20mm PVC conduit may be bent cold if the ambient temperature is not below 16°C. At lower temperatures and for larger sizes, heat must be applied to the conduit:

1) A stream of hot air is ideal if available.
2) A low pressure gas torch. When using a gas torch, care must be taken not to overheat the conduit or to burn it. Keep

the flame clear of the conduit, warming only the air around the bending area. A minimum radius of six times the conduit diameter is recommended.

The following characteristics should be known when using PVC conduit.

1) Expansion fitting must be used (Rule 3.25.3.2)
2) The conduit softening point is approximately 75^{o}C and even at lower temperatures than this it may deform or lose it's rigidity.
3) Rule 3.25.3.3.(d) restricts it's use to temperature below 60^{o}C.
4) It should not be exposed to the following chemicals:
   a) Organic Solvent - Acetone and other ~~ketones~~ Alkanones, amyl acetate and other esters, benzene and aromatic hydrocarbons and their compounds.
      Trichloroethylene and other chlorinated solvents and carbon disulphide.
   b) Oxidising Acids - Concentrated or warm solutions of nitric acid and mixtures of nitric and sulphuric acids.
   c) Never to be used where subject to severe mechanical abuse and cases defined in rule 3.25.3.3.
   d) Use only manufacturer's adhesive cement, Rule 3.25.3.1.
   e) Ultra-violet component of sunlight causes discoloration, and may cause 10% loss in impact strength.
      If PVC conduit is installed outdoors, it should be painted with a protective coat of PVA or acrylic based paint.

It is possible you may encounter a third type of conduit, "Aluminium Tubing". It's uses are very limited.

The manufacturers claim that it has three advantages:

1) Lower transport costs due to lower weight.
2) Ease of handling on site, especially people working on ladders at considerable heights.
3) Ease of threading and cutting.

The Australian Standard Association Book has no provision at this time for this type of conduit. It's acceptance or rejection is left to the inspecting authority.

Flexible Conduit

There are two types of flexible conduit:

1) Steel flexible conduit
2) PVC flexible conduit

Steel Flexible Conduit

This is made from interlocked spirals of pressed metal. It is not normally used as a complete wiring system, but is used in positions where movement could occur, like between the end of a conduit run and a motor where adjustment of the motor position is a requirement.

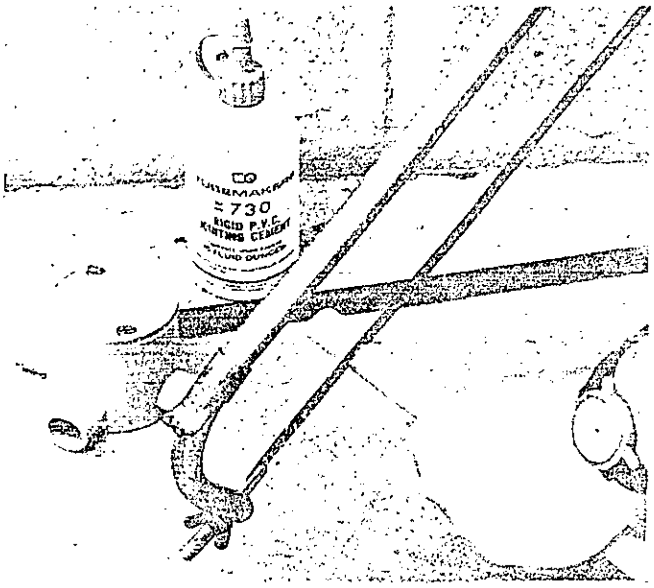
Because the diameter of flexible conduit reduces as it is stretched,a special grip type fitting must be used.

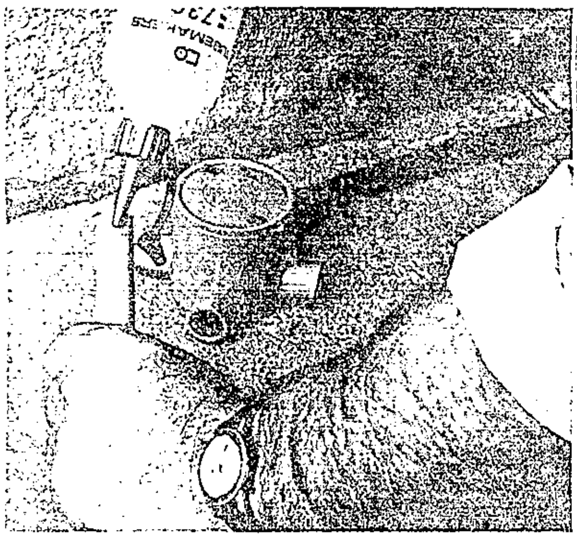
P.V.C. Flexible Conduit

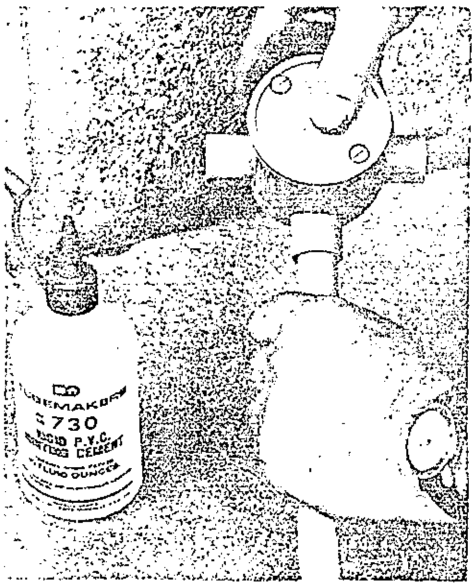
This has superseded flexible metal conduit in similar application, for example, in situations where flexibility is essential to take up movement due to vibration.

Anchoring of PVC flexible conduit must be made according to S.A.A. Rule 3.27.

Neta connectors as well as hose clips are permissible anchors.







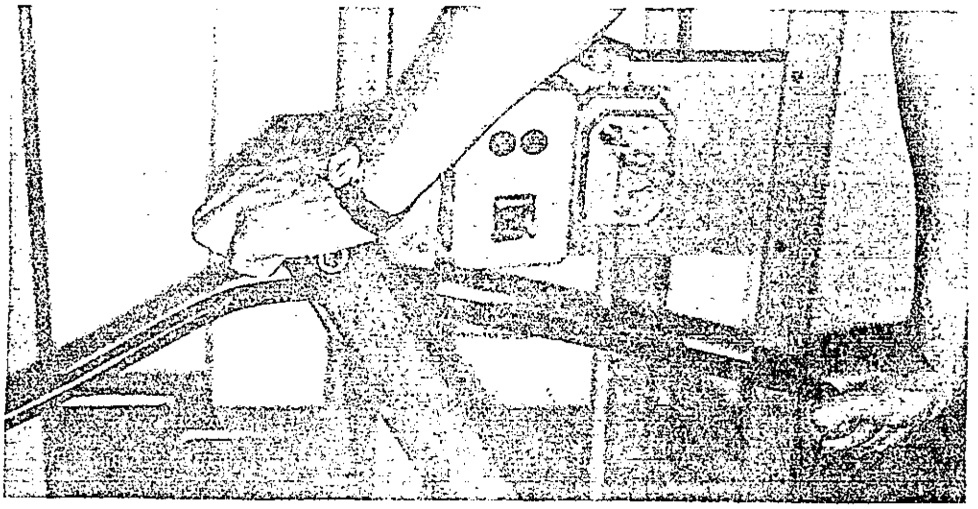
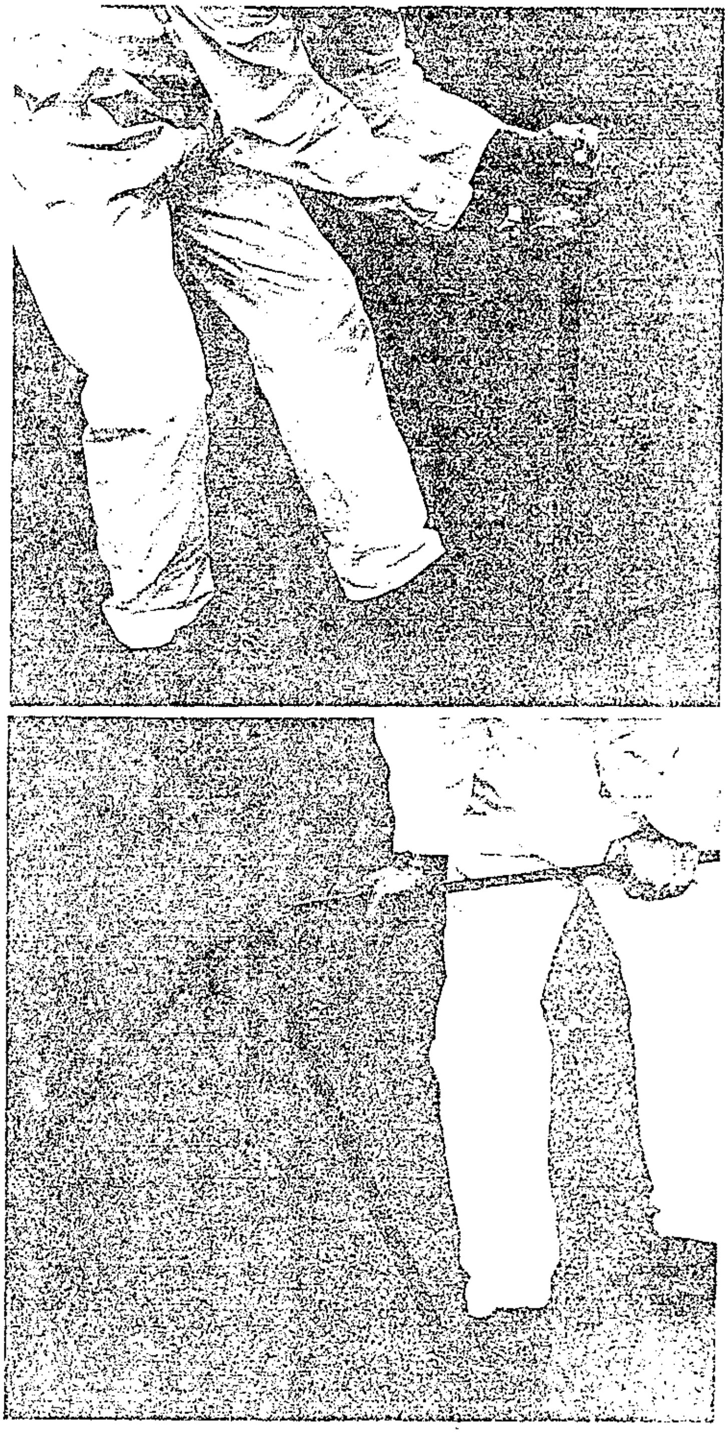


Fig. 8.5 Using a hardwood setting block to set conduit



) A commercial conduit bender being used to set steel conduit

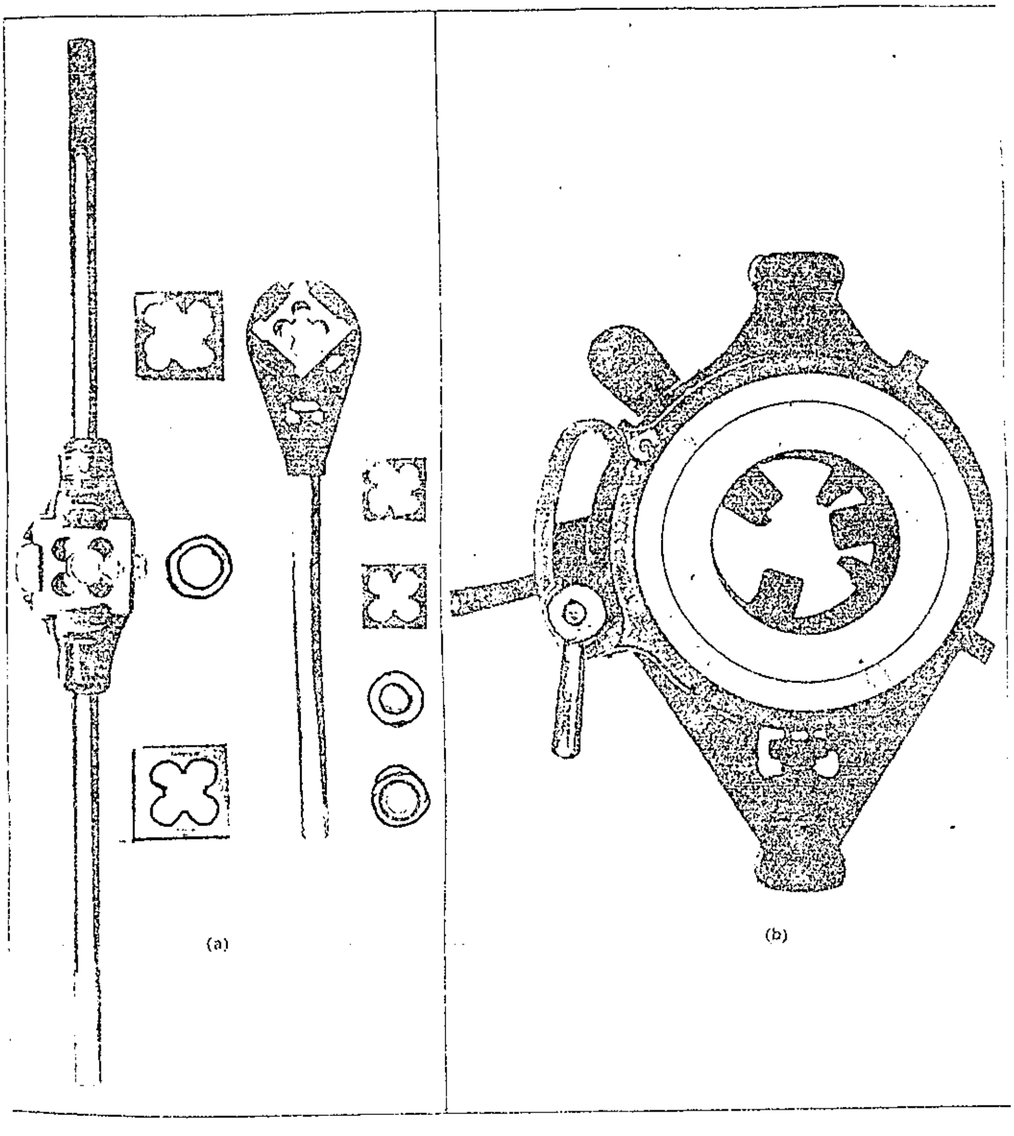
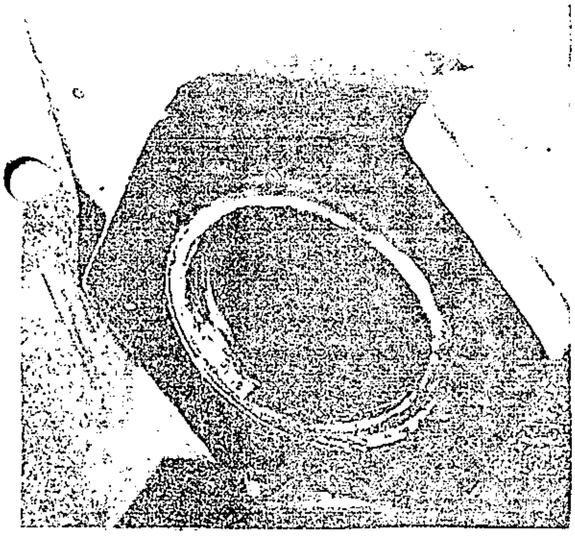
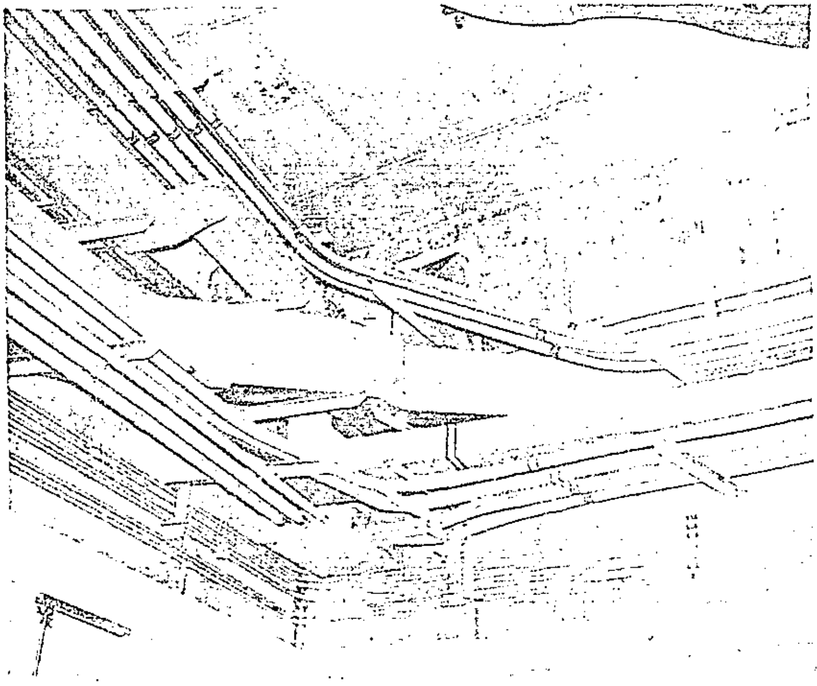


Fig. 8.1 Stock and die sets
(a) "Warragul" single block type; the set on the right has a ratchet stock
(b) "Austec 4R" adjustable type; the one illustrated is suitable for screwing conduit in the range 16 mm to 51 mm (when metrication is complete a metric die of 1.5 mm pitch will be used)
MacPhersons



Termination of steel conduit at an accessory.



The large square draw-in box facilitates installation of cables after the conduit is erected.

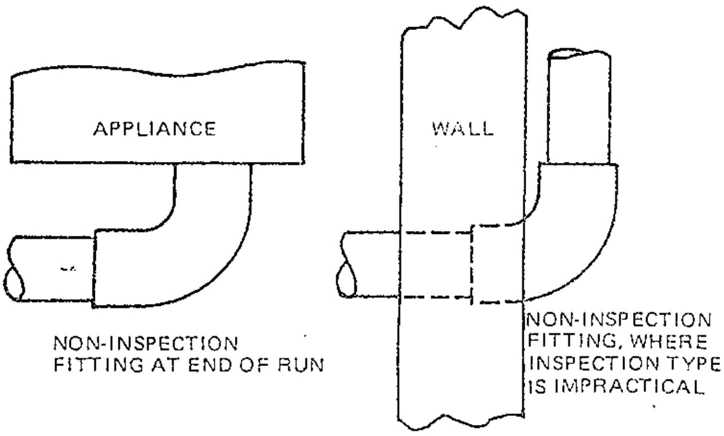
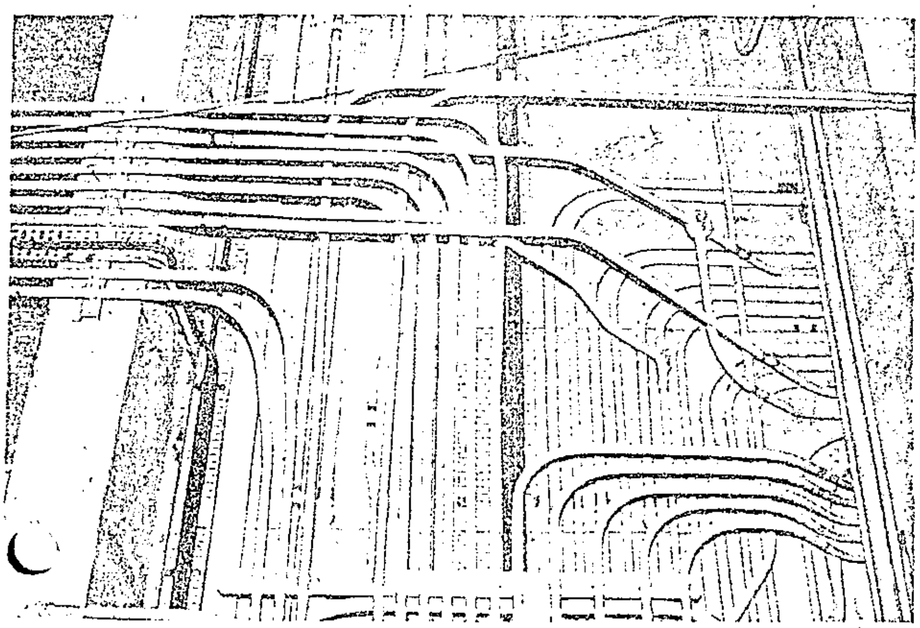


Fig. 8.11 Where non inspection elbows are permitted



.4 Large radius bends and sets have been used in this galvanised conduit work at the Sydney Opera House to facilitate easy drawing-in of cables

TITLE:- SOLDERING ELECTRICAL JOINTS

LECTURER:-

DATE:-

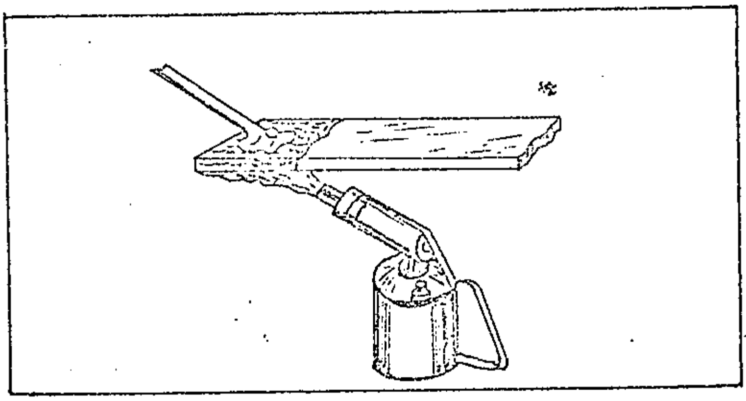
EQUIPMENT:- Copper wire, copper bus bar, resin, methylated spirit, cloth, resin cored solder, stick solder, solder lugs, heat sink.

In electrical work, it is most important that joints in a circuit be of low resistance, and that there is no increase in this resistance, due to oxidisation or tarnishing of the contact surfaces.

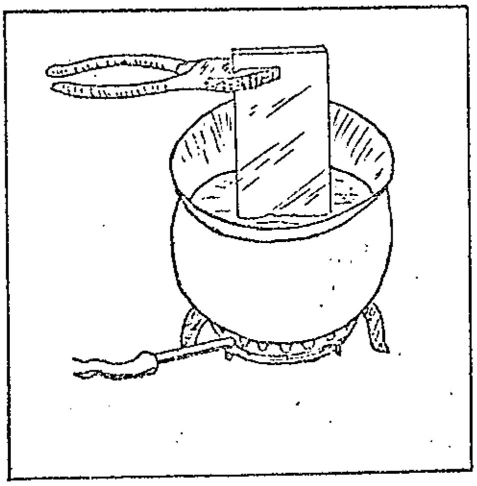
Two clean wires may be twisted together to make a low resistance joint, but after a short period of time, the surfaces will tarnish and the resistance of the joint will increase. This will result in the generation of heat when electricity is passed, since heat is developed proportionally with the square of the current and the resistance (I^2R), and this heat will cause further tarnishing. It is evident that such a joint, will progressively deteriorate and might ultimately start a fire. This type of joint is termed a HIGH RESISTANCE JOINT.

After cleaning a cable, wire, bus-bar etc. in preparation to tinning, remember that touching the material with the fingers imparts a film of grease onto it and prevents proper tinning.

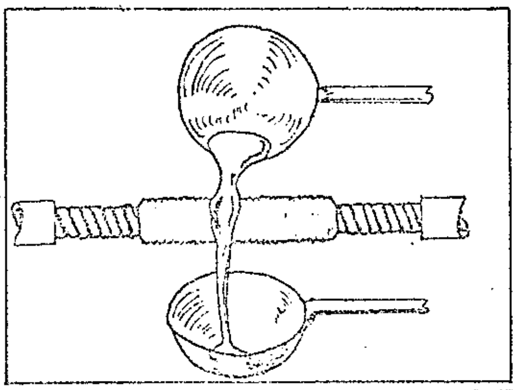
Tinning with an open flame:-
Sometimes it is necessary to tin a surface which conducts heat away too fast for the largest copper bit available, i.e., section wire for armatures, an open flame may be used to heat the job.
The flame is best applied below the surface to be tinned, or back from it if possible. Flux the cleaned surface, apply the heat and melt the solder directly on the fluxed surface - do not let the flame melt the solder. When the surface is properly tinned, re-heat and wipe off the surplus solder with a clean cloth. Do not over-heat the job or the tinning will be burnt off.



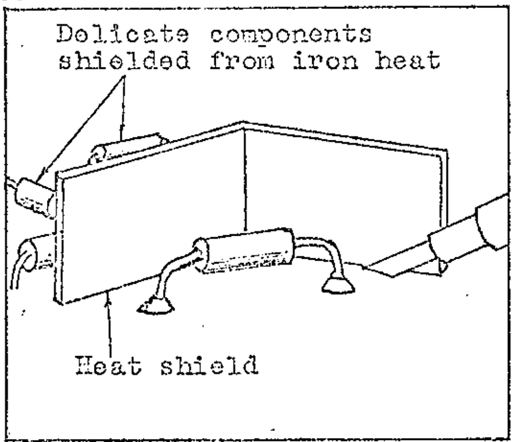
Tinning by immersion:-
Small articles (contacts etc.) may be tinned by immersion in a pot of molten solder, as follows:-
Clean the metal thoroughly, then dip into a flux of resin and methylated spirits; the metal is then dipped into the molten solder and left there for a few seconds. When the metal has been withdrawn, use a clean cloth to wipe off any surplus solder. This must be done while the metal is hot.



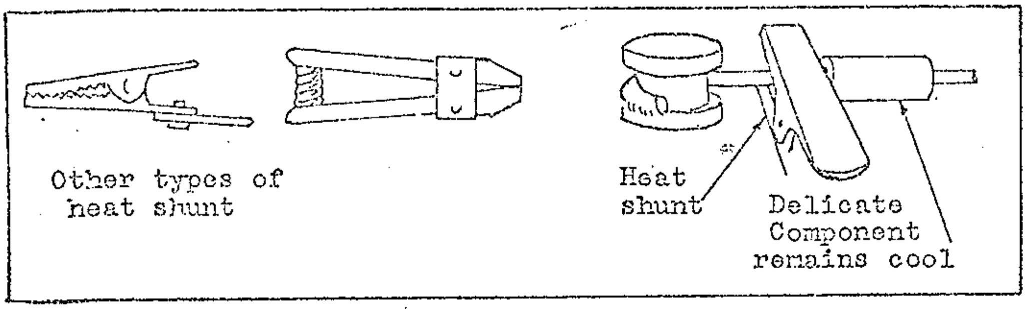
Tinning with ladles:-
Heat can be transferred to a large job, by pouring molten solder over the job. Two ladles are needed, one containing hot solder, and the other heated ladle is used to catch the solder as it flows off the job. By repeated pourings, the job temperature will finally rise to above the melting point of the solder, which will then tin the clean, fluxed surface. This method is often used to solder joints in heavy cables.



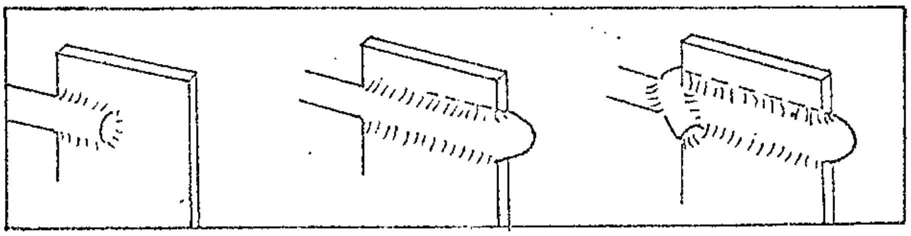
Heat shields:-
Use a heat shield where necessary to shield adjoining components from the heat of the soldering iron.



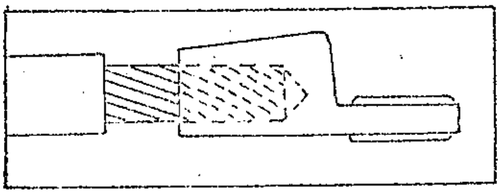
Heat shunt:-
Use a heat shunt to prevent overheating of delicate components being soldered.

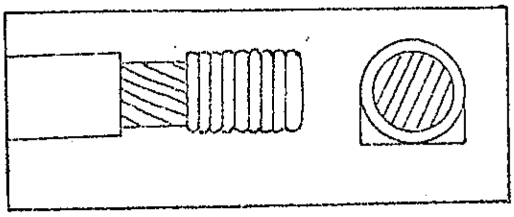


Good joints:-
A good joint is one which has excellent electrical contact between the parts joined, and has good mechanical strength. It should be smooth with no "spikes", bright and shiny, without rough patches. The joint should have a concave surface, and the outline of the wire should be visible, under the surface of the solder.

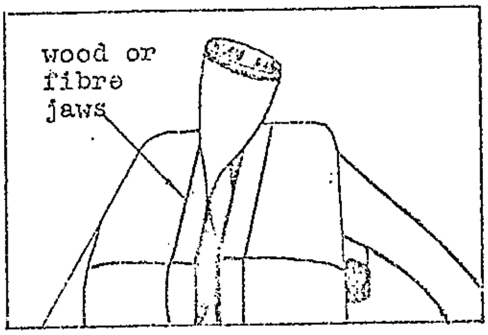


Soldering cable sockets:-
Bare the cable, to allow the conductor to reach the bottom of the socket, with ½" of the conductor showing.

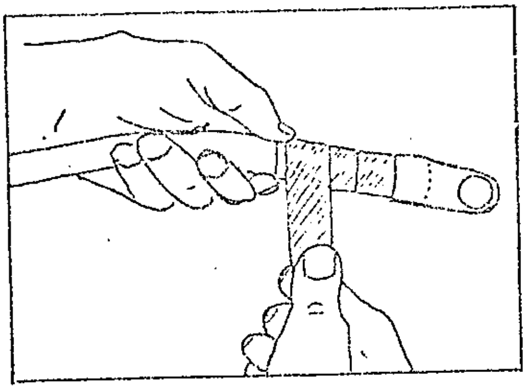


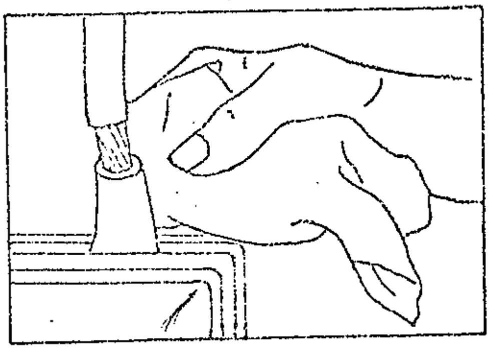


Ensure that the cable conductor fits snugly into the cable socket. (Bind small conductors with copper wire until they fit the socket.)



Clean the cable socket, then place upright in a vice; use wood or fibre jaw inserts to save heat transferring to the vice. Apply resin flux and heat the lug with a copper bit or naked flame. Apply the stick of solder to the inside of the socket and melt sufficient solder to half fill the socket. Apply flux to the cable conductor. Dip the conductor into the socket, apply heat to ensure the solder remains molten, withdraw the tinned cable. Reheat the socket and ¾ fill with solder, insert the cable, wiping away surplus solder from outside the socket. Allow to cool naturally until the solder sets, avoid any movement. Pare away any charred insulation. Wrap the conductor with pure rubber tape, to give the same diameter as the cable insulation. Apply black adhesive tape over the rubber tape.





Safety precautions:-

1. Inspect the soldering iron regularly, for physical damage, especially to the lead.
2. Keep the iron in a stand when not in use.
   Do not subject the iron to rough treatment.
3. Keep the iron away from its lead.
4. Never flick excess solder off the bit. The hot solder may burn someone, or fall into part of the work and cause a short circuit.
5. At all times make sure that the hands cannot be burnt, wear gloves if necessary, hold the job with pliers.
6. Make sure molten solder cannot drip into boots.
7. Have overall sleeves down, and fastened at the wrist, chest covered.
8. Wear a protective face shield. The application of solid metal and a wet flux will often cause the molten solder to explode.

TITLE:- CONDUCTORS

LECTURER:

DATE:-

EQUIPMENT:- COPPER, ALUMINIUM, IRON, NICHROME WIRE, BI-METAL SWITCH, CARBON

The definition of a conductor (S.A.A. 0.5.22) shall mean a wire, cable, or other form of metal suitable for carrying current but shall not include wire cables or other metallic parts directly employed in converting electrical energy into another form of energy.

Generally, any materials that will conduct electricity relatively easily are termed conductors. Conductivity is a word which describes the ease which a current will flow through a conductor.
Silver = 106, Copper = 100, Gold = 72, Aluminium = 62, Lead = 8.
This shows, with copper as a standard, that Silver is 6% better than copper, whereas Aluminium is only 62% as good as copper.

For a material to be accepted, it must have certain properties.

1. High conductivity.
2. Flexibility of use, i.e. as wires, rods, etc.
3. Good all-round mechanical properties i.e. machinability, ductility, malleable etc.
4. Essy to joint.
5. Resistant to corrosion.

Copper, aluminium, and their alloys, ferrous metals, bi-metals, superconductivity, semi-conductors, silicon, carbon, structural materials, and applications.

Copper; although not the best of the conductors listed, is the one which is most widely used as it fulfills almost all the property requirements listed above. Copper, being not so plentiful, has a high market value. This is an advantage as the scrap value is also high. When alloyed with certain other metals, further properties are developed, e.g. Copper and Tin make Phosphor Bronze which is a hard springy metal. Brass being suited for nuts, bolts and castings etc. is an alloy of Copper and Zinc.

Aluminium; is not as good a conductor as copper; it is nevertheless becoming used more as an electrical conductor chiefly because of its weight and reduced costs. Previously its use was limited due to jointing difficulties due to speed of oxidation. This has now been made simpler and it is now possible to fuse aluminium and copper by friction, thereby eliminating electrolytic action.
Its uses include squirrel cages in motor design, aerial conductors (tension is taken by strands of spring steel wire), instruments, power meters etc. Solid strand cables - 2, 3, and 4-core are now being made for general use. These cables generally have larger cores than similar copper cables to compensate for the poorer conductivity, but it is still a lighter cable and requires less man power for installation.
Alloys of aluminium make its electrical and mechanical properties much better.

Ferrous metals:- The greatest part played by ferrous metals is in the magnetic circuits of various pieces of electrical equipment such as:- motors, transformers, relays, lifting magnets, generators etc. All commercial magnetic materials contain iron, other elements such as nickel and cobalt have magnetic properties and it is possible to make non-ferrous magnets.

Permanent or hard magnets retain magnetism, tungsten and chromium steel are the oldest specially manufactured metals for permanent magnets and are sufficiently stable for all purposes.
Cobalt steel alloys have a high efficiency which increases with higher cobalt content. It is used for measuring instruments, telephony, and synchronous motors.

Temporary or soft magnets do not retain magnetism. They are usually laminated to reduce the effects of eddy currents. Nickel-Iron-Cobalt alloys are available for special purposes.

Resistance wire used in electrical heating appliances is usually alloys of Nickel & Chromium (80:20 is Brightray) and Nickel-Chromium-Iron (Glowray - 65:15:20).
Brightray used mostly for temp's between 850°C & 1100°C.
Glowray used for temperatures up to 850°C.

Bi-metals Two metals of dissimilar coefficients of expansion are bonded together and rolled into strips. On heating either directly or indirectly, the bi-metal will bend. This bending can then be used to trip or trigger other equipment.
Bi-metals are available in various shapes and forms - discs, flat, coils, U-shaped etc., each with its own characteristics and rates of bending.

Superconductivity At very low temperatures, most metallic elements lose all trace of electrical resistance. The temperatures are different for each material ranging from 0.35°K to 9.2°K.
Magnetism and its effect on a conductor which is cooled to superconductivity can destroy the properties of superconductivity.
The current flowing in a superconductor flows around the surface of the conductor to a depth of 10-5 cm.
One theory of superconductivity is that the oscillations of the atoms within the structure ceases when superconductivity is achieved.

Semi-conductors:- is a term used to describe certain materials which are neither good conductors, nor good insulators. This can be said about almost all substances. There are, however, some substances which have a peculiar behaviour when used in electrical circuits; mainly their non-linearity of relationship between E.I.& R.

Semi-conductors are classes as (a) NON-METALLIC RESISTANCE MATERIALS, used in the manufacture of certain resistors, or (b) NON-LINEAR ELEMENTS, used in the manufacture of diodes, transistors etc. Silicon and germanium are the two main basic elements used in the manufacture of these solid state devices. The reason for using these elements lies in the structure of its atom which has 4 electrons in the outer (valence) shell which are bound in a crystalline lattice. Some of these electrons can move freely within the lattice, and heat increases the number of free electrons.
It is usually a doped form of silicon used, i.e. a small amount of tri-valent, or pentavalent material is combined with the silicon or germanium to give more free electrons, or less free electrons.

Silicon is a light metal having a specific gravity of 2.34. It is brittle and therefore is limited in industrial use. It is used to alloy with steel for making magnetic stampings because of the fact that it has a high resistivity and therefore reduces eddy currents. It is amaterial that is very resistant to atmospheric corrosion and to attack by many chemicals.

Carbon occurs naturally in 2 forms.. 1. amorphous (charcoal, coal lampblack etc.) 2. crystalline (Diamond, and graphite).
Carbon used for electrical purposes is a compound of powdered carbon and/or graphite with pitch or resin to bind it together. The mixture is baked to 900°C with air excluded, the volatile part of the binding material is driven off and the remainder carbonised.
The peculiarity of carbon is that it has a negative temperature coefficient. i.e. the higher the temp., the lower the resistance. Its greatest use being in brushes for motors and generators, because it is self-lubricating, good conductivity, high contact resistance, high durability. Other uses are for arc lamps, welding electrodes, and for resistance rods in furnaces, bakers ovens etc. (it is silicon carbide, carborundum).

TITLE:- INSULATORS

LECTURER:-

DATE:-

EQUIPMENT:- MICA, VARNISH, P.V.C. BAKELITE, EBONITE, SILK TAPE, ASBESTOS, ZELEMITE

Electrical Insulating Materials are otherwise known as insulators or dielectrics and offer a high resistance to the passage of current.

The base materials used in the manufacture of insulators are cotton, glass, silks, linen, and asbestos which can be used in an untreated condition or can be impregnated or coated with insulating varnish or compound to increase resistance. They can also be in the form of solids, liquids or gases and vary considerably in cost from air to mica and resins.

Physical properties:- Specific gravity is important in varnishes and oils and other liquids. Moisture absorption causes failure of oils and fibrous materials, and can cause corrosion.
The physical properties will influence the choice and application of insulating materials e.g. melting point, coefficient of expansion, viscosity, uniformity of thickness, porosity, and the presence of pinholes in enamel used to insulate wires.

Mechanical properties:- These properties must also be considered when selecting insulating materials, and include tensile, compressive, and shearing strength, machineability (drilling, punching etc.) and resistance to splitting.

Electrical properties:- It must insulate and resist leakage current. Factors which affect dielectric strength are sharp edges on electrodes, increases in voltage, overstressed for long periods, moisture content, location, temperature change and frequency of supply voltage.

Chemical properties:- Resistance to external chemical effects such as attack by acids etc., effect of oils i.e. in transformers, effects of solvents, oxidation, atmospheric conditions especially dampness and direct sunlight and the effects of impurities in the insulation.

Types of Insulating Materials

Gaseous dielectrics:- Air is the most important gas, its dielectric strength varies with atmospheric conditions. Nitrogen is used as a dielectric in gas cooled high voltage cables, capacitors, and transformers. Argon is used in gas filled lamps, and sulphur dioxide for refrigeration etc.

Liquid Dielectrics:- Refined mineral oil and synthetic oils are the only liquids used for insulation purposes. Used as a filling and cooling medium in transformers and cables, as an arc quenching medium in switch-gear and as an impregnating medium.

The most important properties necessary are as follows:-
(a) Dielectric strength
(b) Viscosity
(c) Chemical stability
(d) Flash-point

Other types of oils have quite good insulating properties but are not suitable for general use as insulation.

Varnishes & Paints:- Are used to form solid films for protecting wires etc. The properties depend on the basic materials such as resins and oxiding oils, mostly mixed with driers and plasticisers to improve hardness.
It can be used as an external coating for protection against moisture etc., for impregnation of windings and improvement of electrical and heat properties.

Solid Insulating Materials:- Laminated boards are mostly used and consist of paper fabric bonded together with gums, shellac, synthetic resins etc., under heat and pressure such as bakelite and other laminates.

Asbestos cement boards are good heat resistant materials and are used in switchgear etc. It is also available in the form of rods and tubes.
Vulcanised fibre and pressed boards are used for coils, transformers etc. Principle trade names are Leatheroid, Micatex etc.
Papers are made from cotton, manilla fibre etc. and are used in capacitors, cables, coils.
Cotton cloth ranging from fine to heavy cambric are generally treated with varnish and used in coils. It is a base material of compounds and used in the manufacture of varnished cloths and tapes (empire tape).
Asbestos and glass cloth are used when temperatures become too high for textile materials.

Insulating tapes:- Varnished cloth, silk tapes, rubber adhesive tape, glass fibre, cotton and silk are all used in electrical work. Other well known tapes are based on plastic and cellulose, but have certain limitations of operating temperatures.

Sleeving and Flexible Tubing:- These are made from varnished cambric, cotton, silk, asbestos, glass fibre and P.V.C. The application of each depends on voltage, temperature, and operating conditions etc.

Cable Insulation:- Generally, vulcanised rubber, paper, varnished cloth, bitumen compound, neoprene, are used. The most widely used is p.v.c. because of its longevity, toughness, cost, and it is non-inflammable.

TITLE:- MAGNETIC MATERIALS

LECTURER:-

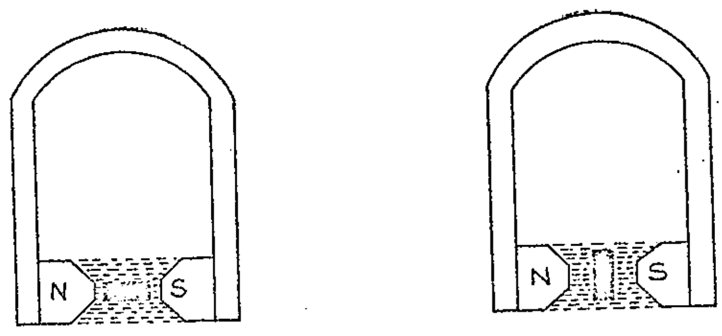
DATE:-

EQUIPMENT:-

Introduction - the first known magnetic material was a lead-coloured stone, called "lodestone", which was discovered by the Chinese. It was found to have certain qualities - e.g. ability to attract iron or similar materials - and it was termed "permanent magnet". However, in regard to modern electro-magnetic equipment, it is very impractical and, consequently, science has discovered other materials which will give the same, and in some cases, better magnetic qualities. "Artificially" made magnets have many distinct advantages in that they are more obtainable, they can be shaped to suit a specific purpose and, due to modern technology, a high degree of permeability and associated qualities are obtained.

Materials - only a few substances are noticeably affected by magnets. Wood, plastics and most metals are examples of those substances which are magnetically "feeble". In these substances, the atomic magnetic forces do not extend beyond the boundaries of the atom - in some cases a very weak magnetic force is detected beyond the boundaries. As a group, they are called non-magnetic materials. However, a few of those substances whose atomic fields extend beyond the atom boundaries can be made to produce very strong magnetic fields, which extend beyond the boundaries of the substance. Such substances are termed magnetic materials.
The materials can be divided into 3 categories -.

(1) Diamagnetic - in a few substances, e.g. copper, gold, zinc and bismuth, the various atomic magnetic fields neutralize each other and no magnetic field exists beyond the atom boundaries. These substances are called dia-magnetic substances. However, their atomic magnetism affects their behaviour when they are placed under the influence of a permanent magnetic field - it causes it to align itself at right angles to the main field (less energy is required to retain it in this position). "Dia" means "across" - diamagnetic materials lie across the direction of the applied field.



PARA-MAGNETIC DIA-MAGNETIC

(2) Paramagnetic - substances which are not dia-magnetic, will set themselves parallel ("para") with the main field and are called paramagnetic substances. The atomic magnetism of para-magnetic materials extends beyond the atom boundaries, although these fields are weak in all but a few substances.

(3) Ferromagnetic - those exceptions are called ferro-magnetic materials, because the strongest paramagnetic material is iron - "ferrum" is the Latin name for iron.
The important ferro-magnetic materials are iron, nickel, cobalt and their alloys. Ferro-magnetic materials may be roughly divided into

two classes, "Hard" and "Soft".
A <u>magnetically hard</u> material is one which, when magnetically induced by a permanent magnet, retains its magnetism after the permanent magnet has been removed. These "hard" materials are used for making permanent magnets for use in electrical equipment such as meters. Generally, materials which are physically hard, such as tempered steel, are magnetically hard.
A <u>magnetically soft</u> material is one which is magnetized readily but loses its magnetic property when magnetising force is removed. A typical example of soft ferro-magnetic material is pure iron. Magnetically soft materials are used in various electrical equipment where it is not desirable to have a permanently "magnetised core" (Contactors etc).

<u>Permeability</u> - <u>all</u> materials allow magnetic flux to pass through them, but in varying degrees. The ease with which a magnetic flux can pass through a substance is called the <u>permeability</u> of the substance. When comparing the permeability of different materials, air is taken as unity.

(a) Dia-magnetic materials oppose magnetic flux and have a permeability <u>less</u> than air i.e. extremely low permeability.
(b) Para-magnetic materials have a permeability <u>equal</u> to, or slightly <u>greater</u> than air.
(c) Ferro-magnetic materials have a permeability <u>appreciably greater</u> than air - it varies with flux density.

TITLE:- CHEMICAL MATERIALS

LECTURER:-

DATE:-

EQUIPMENT:- C.R.C., Bees wax, pitch, silastic, heat-shrink tube, heat gun.

Impregnating and filling compounds (protective & waterproofing):

Two widely different classes of materials are dealt with, viz. (1) The older impregnating and filling compounds, primarily the bitumens and waxes, which are generally melted in place, and which remain permanently heat-softening, and (2) The newer, important synthetic products of polymer chemistry - the "solvent-reactive", or "solventless" resins. The latter, when properly applied, (usually vacuum, or pressure), can be induced to react (polymerize) in situ, and thus provide solid, more "void-free" insulation.
The impregnation and sealing of all forms of porous insulating materials, windings, wire coverings, joints, etc., are essential in securing satisfactory insulation, where appreciable voltage stresses will be encountered.
To achieve intelligent selection, from the many materials available today, attention should be directed to many properties other than initial electrical and physical properties. Some of these considerations, involve voltage endurance (i.e., ability of the insulation system to withstand required voltage stress, throughout the life expectancy of the electrical equipment). No less important, are considerations involving the thermal endurance of electrical insulating systems, which reflect a combination of thermal and oxidative degradation, of the organic materials which make up the impregnant, whether solid or liquid.

Bitumins: The term "bitumin" includes a large number of inflammable mineral substances, consisting mainly of hydrocarbons, and including the hard, solid, brittle varieties termed "asphalt", the semi-solid naphtha and mineral tars, the oily petroleum, and even the light volatile naphthas.

Wax: Is defined as any of a class of natural substances, composed of carbon, hydrogen, and oxygen. In this class are included beeswas, spermaceti, etc. Waxes, when melted, are good impregnating agents, being water-proof but usually not oil-proof.

Bituminous insulating compounds:
Are prepared from a variety of different formulas, but in most cases, their compositions are guarded as manufacturing secrets, and they are marketed under trade names. Semi-solid to solid compounds, capable of melting under heat, are combined in many ways, often with the addition of other substances, including resins, rubber, animal and vegetable oils and fats, animal, vegetable and mineral waxes. Such compounds are resistant to moisture, acids, alkalies, temperature changes, and in many cases, exposure to the weather. They also have reasonably high dielectric strength, ranging from 200 - 1200V (r.m.s.)/mil at 60 cycles.

Filling & sealing compounds:
When these are used to fill voids, and to seal enclosures against the entrance of moisture, they should have a low temp. co-efficient of contraction and expansion, high flash and fire points, low dielectric loss and power factor, high dielectric strength, freedom from volatile matter, very high moisture resistance, and chemical inertness. These compounds should be tested for softening point, evaporation, melting or pouring point, flash point, burning point, chemical activity, and effect of moisture, and electrical properties.

Plastic & hard filling compounds:
Are usually made of asphalt or of pitch derived from asphaltic-base petroleum. Almost all of them are ductile rather than brittle, at operating temperatures.

Most hard compounds form a seal against the admission of moisture or the emission of oil, while the plastic compounds are effective only against moisture, and then only partly so. The hard compounds are therefore well adapted for filling low-voltage pot-heads when it is necessary to seal the end of the cable. They have been used with cable voltages as high as 26 KV, but owing to the danger of voids, they are generally used only for lower voltages.

Epoxy resins:
Epoxy resins are a class of materials, which contain usually more than one epoxide group. They are capable of polymerzing with a number of compounds (called hardeners). The various types of epoxy resins which are available commercially, differ essentially in:
(a) The source and degree of polymerzation of the groups.
(b) The type of catalyst and hardener employed.
(c) The presence or absence of flexibilizing or modifying agents.
Some epoxies can be cured at room temp., others must be cured at higher temp., commonly in the range of 100 to 150°C. Adhesion is usually excellent, which assists greatly in excluding moisture. Chemical resistance is excellent.

Adhesive/Sealants for Electrical/Electronic applications:
A wide use is made of silicone rubber; one type, which has many uses, is a general purpose, flexible, heat resistant adhesive and sealant. It adheres to a wide variety of insulating materials. A few of its many applications are: Sealing joints and lead wire entries - Bonding wires - Sealing connectors - Repair and splicing of cable and lead wire - Dust-proofing and cabinet sealing - Adhesive for thermistor mounting - Weather-strip adhesive and seal, for electrical/electronic housing and enclosures. One such adhesive sealant, is marketed under the trade name - "Silastic 732". Another silicone rubber protective sealant (Dow Corning 1890), is ideal for applying a thin, rubbery overcoat to protect insulated motor windings, which are subjected to such conditions as - Abrasive dust - Moisture - and chemicals. Motor windings which are completely coated, can be readily cleaned by hosing with water.

Heat-shrinkable tubing:
A non-thermoplastic, chemically cross-linked material, (Silastic 1412) this tubing remains flexible and resilient. The tubing shrinks to form a snug fit even over objects of irregular shape, or dissimilar diameters.
Some of the benefits of this tubing are -
Eliminates taping - Handles easily, no special training is needed in application techniques - Needs no new equipment (use existing heat sources; heatgun or lamp etc.) - Can be removed if required, without damaging the part, on which it is shrunk.

Cleaning & Anti-corrosion agents:
These agents have been developed, to satisfy the need created, by the fact that in the course of recent years, the switching elements of electronic gear, were progressively miniaturised, so that it became increasingly difficult to clean the contact points. In aerosol form these agents contain additives that dissolve oxide and sulphide layers, they do not conduct electricity and possess a relatively high insulation resistance. By virtue of this property, and the suitably selected mixture of solvents, no harmful influences, such as current leaks, can intervene, when components in the vicinity of the contacts are hit by the spray.
Other agents i.e., "C.R.C." - "Kontakt 101" - displace moisture, and penetrates under water. In addition to its highly water repellant and anti-corrosive ingredients, it has a unique capacity to penetrate beneath other fluids, thereby lifting moisture from the sprayed component.
It re-establishes immediately, normal electrical constants and resistance values, and can be used successfully in either the electronic or auto-electrical fields.

TITLE: Earthing

LECTURER:

DATE:

EQUIPMENT: S.A.A. Rule Book

Reasons For Earthing

Even when all materials for an installation are carefully selected and then carefully installed to comply with specifications and wiring rules, the possibility of insulation failure in the wiring or equipment is always present. Should such a failure occur, it immediately introduces hazards to life or equipment by:

1. Electric Shock
2. Fire
3. Unstable voltage conditions

In section 'O' of the S.A.A. Wiring Rules, there are terms relative to earthing systems which are covered by definitions and rules.

It is important that these definitions and rules are known by all electricians. "Learnt as soon as entering the trade and never forgotten".

Source of Supply

This refers to the substation or generation station from which electrical energy is supplied.

Earth Connection

This term usually is taken to mean the main earthing connection between the main earthing conductor and the earth electrode (Rule 5.3.1.1.).

Any connection between the earth wire of a final subcircuit and the appliance is also commonly termed as "Earth Connection".

Earth Electrode

The earth electrode is the accessory by means of which final connection is achieved between the general mass of earth and the earthing system. The most common is the driven electrode (Rule 5.7.2.2.) but there are other possible types specified in rule 5.7.2.

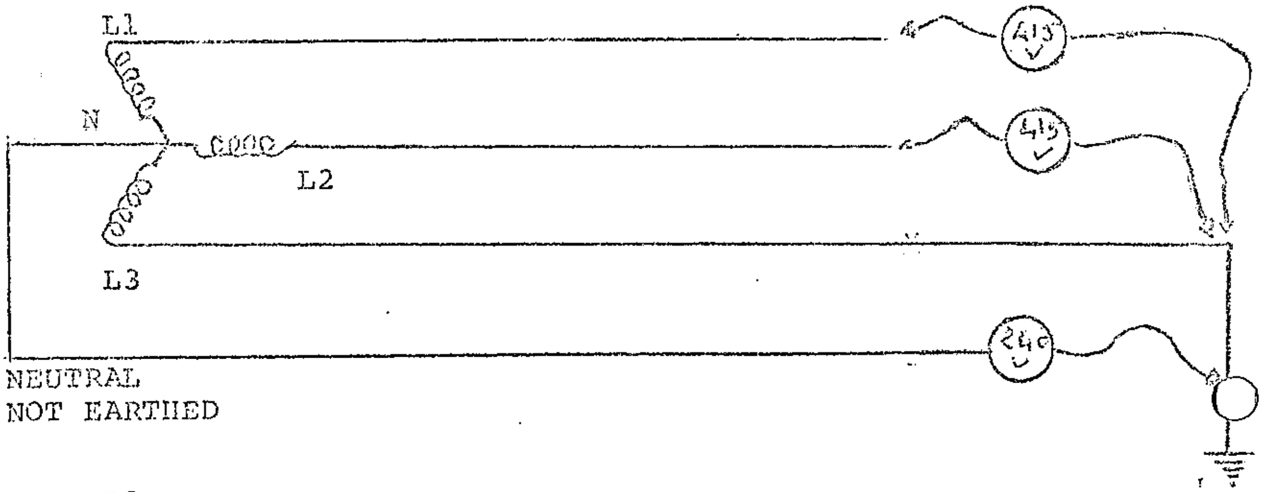
Earth Resistance

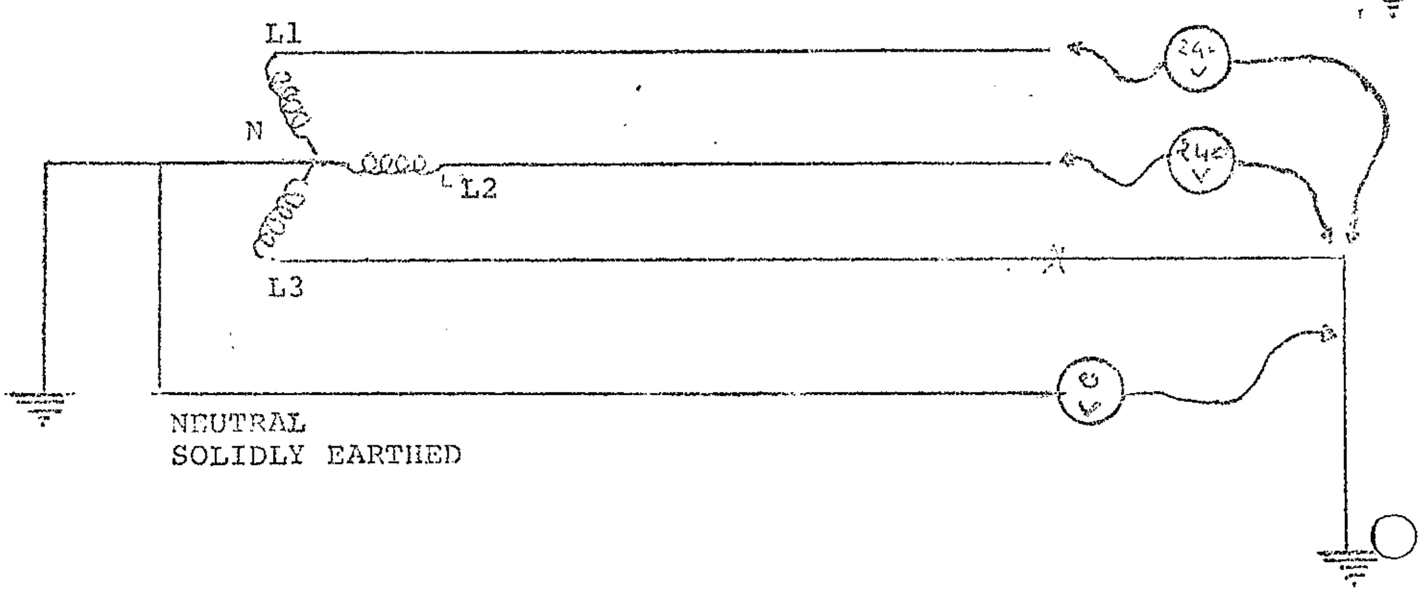
Refers to the resistance existing between the main earth connection (Earth Electrode) and the general mass of earth.

The resistance value is a specified maximum for direct earthing (Rule 5.9.1.) and ELCB (Rule 5.10.1.).

Solidly Earthed

Term used to describe the usual system of earthing where the neutral at the source of supply is connected direct to the earth electrode.





The term "Solidly Earthed" applies to the supply system. It should not be confused with the term "Direct Earthed", also known as Direct Earthing System, which refers to the system of earthing at the consumer's installation.

Earth Bond

This is the connection between two metallic portions of an installation that must be maintained at the same earth potential rules 5.3.1.1. 5.3.8.1.

Earthing Continuity

Refers to the necessity of making metallic cable sheaths or enclosures such as troughing or conduits, both mechanically and electrically continuous so as to provide a low resistance path for any fault current to earth. Sometimes referred to as the earth continuity fault path. (Rules 1.25. 3.25.9. 5.4.).

Short Circuit to Earth

Also called "Short to earth" or "Earth Fault" is one which causes a potential to earth resulting in fault current to earth.

Earth Fault Current

Current present in the earthing system caused by an earth fault.

Earthing Medium

Used to describe the nature of the conductive path to the main earth connection.

See S.A.A. Wiring Rules for permissible and non-permissible earthing medium.

Earthing Bar

Bar or link installed in a switchboard for the purpose of connecting earthing conductors. (Rule 5.3.1.1.).

Laid up Earthing Conductor

An earthing conductor enclosed within the same cable sheath as the associated live conductors.

Twin + Earth $1mm^2$ is a common example.

Earthing Terminal

The seperate terminal provided in accessories or an appliances for the connection of the earthing conductor. (Rules 5.3.2. 5.3.5. 5.3.6.).

Consumer's Earthing Systems

S.A.A. Rules allow 3 types of earthing systems.

1. Direct Earthing System
2. Multiple Earth Neutral System (M.E.N.)
3. Earth Leakage Circuit Breaker (E.L.C.B.).

The most significant feature of these systems of earthing is the solid connection of the neutral star point to the general mass of earth at the source of supply which maintains the supply voltage to earth constant.

On rare occasions, a neutral not solidly earthed system may be encountered (Rule 2.17.). The earthing requirement at the consumer's premises will be the same as those applying to the Direct Earth Syst.

Note: Not solidly earthed refers to the source of supply.

Direct Earthing System

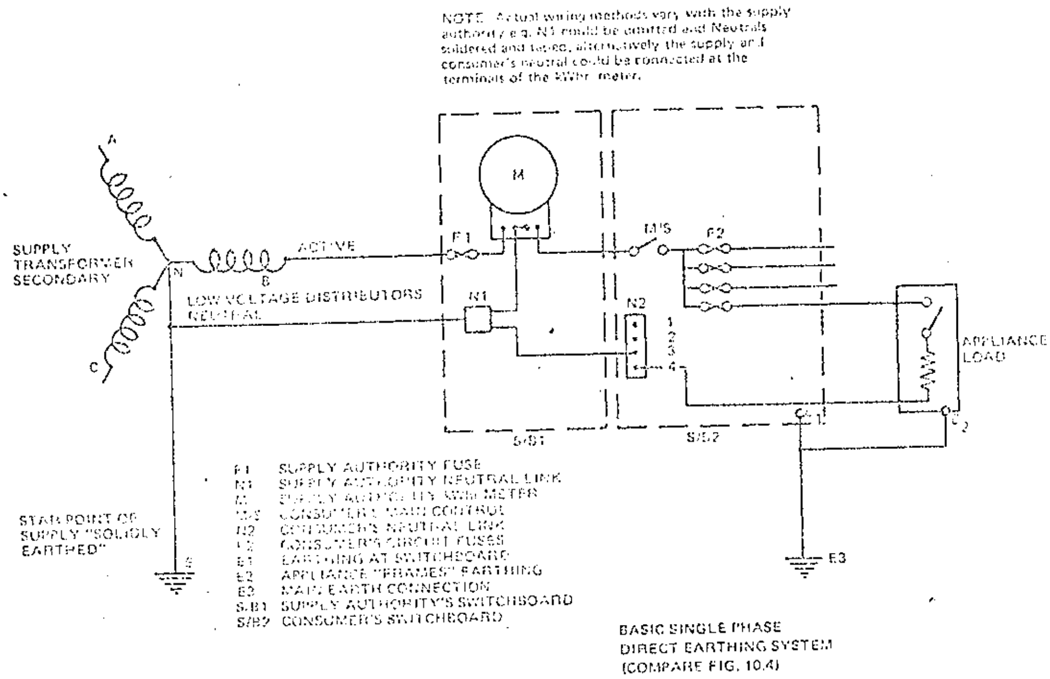


Fig. 10.8 Direct Earthing System

This shows the connections on a small consumer's switchboard for a simple direct earthing system.

There is no connection between the neutral and earth at the consumer's installation.

It is the simplest system but the resistance of the return earth' loop must be kept at low value and for this reason, most supply authorities only maintain the system in areas where a solid water reticulation scheme exists.

M.E.N. System

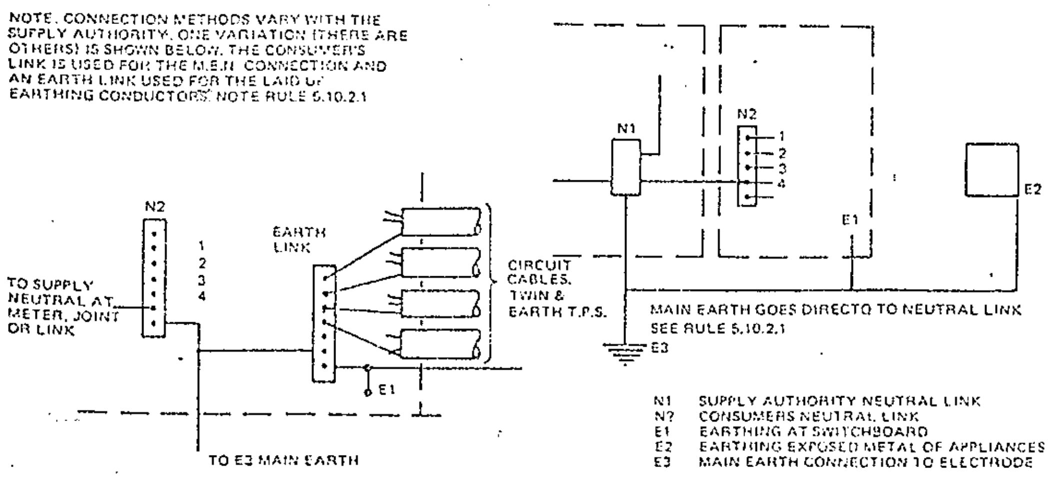


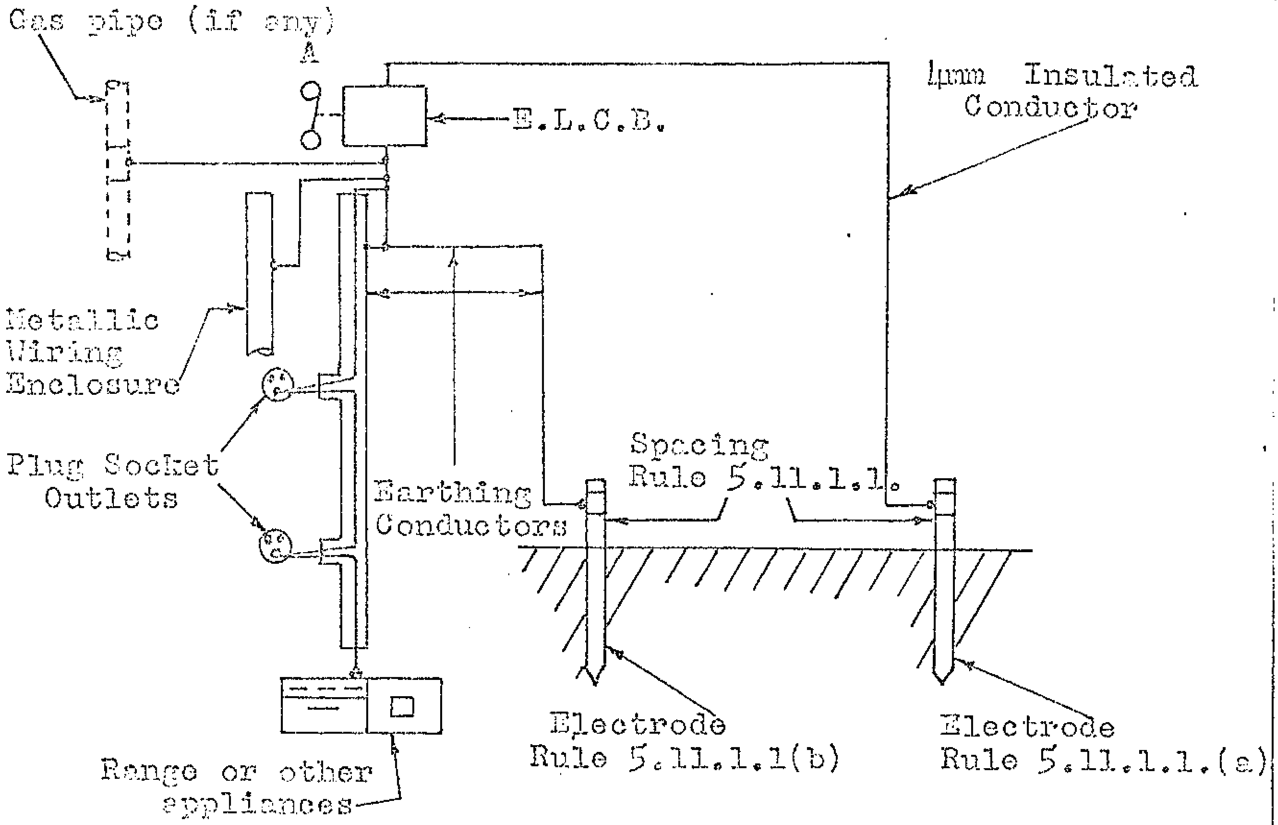
Fig. 10.9 MEN System of Earthing

This is the most widely adopted system. Supply Engineers consider that it's practical advantages outweigh it's disadvantages.

The only difference to the previous system as far as the consumer's installation is concerned, is that the main earthing conductor is taken direct from the earth electrode to the neutral link at the switchboard.

Each consumer's earthing system is connected in the same manner and this mutiple earthing of the neutral together with numerous earthing points on the supply side, gives the system it's name.

E.L.C.B.



CONNECTION OF EARTH LEAKAGE CIRCUIT BREAKER

- SIMPLE INSTALLATION

With either of the previous systems it is necessary for high values of fault current to be present before the protection will operate, hence they are "current-sensitive" systems and neither is effective against voltage rise in the earthing system unless the rise is due to high current, because V=IR low current coupled with high resistance, may cause a high voltage and possible electric shock.

The E.L.C.B. was introduced mainly as a protection against shock, leaving the over load to current devices.

Because of this, it may be considered as supplementary protection added to the direct earthing system.

The diagram shows the additional connections required to add E.L.C.B. protection to a direct earth system.

The trip relay operates between 20 and 26 volts to open the circuit.

This relay is connected between the earthing system and an auxillary earth electrode (Rule 5.11.1.).

Recently another type of Earth Fault Current Protection has been developed. The Core Balance Earth Leakage Protection (Scanelec Permat etc.).

This device has been made to offer protection against accidents which involve contact between a live wire and earth.

Protection is not afforeded against simultaneous contact with active and neutral or two actives.

Installing the Earthing System

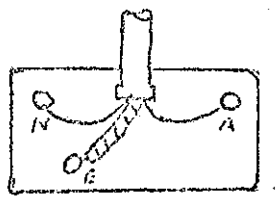
Apprentices should gain a basic understanding of general earthing requirements so that mistakes due to ignorance of these requirements will not occur early in their career.

Section 5 of the S.A.A. Wiring Rules deals with most of the rules relevant to the installation of earthing systems.

Rules 5.9 5.10 and 5.11 are additional rules, particular to each of the three earthing systems.

Observe that:

1. The third pin of all three pins plug sockets must be earthed.
2. All exposed metal as defined by Rule 0.5.44 must be earthed.
3. Metallic parts that have been earthed are not to be used as the earthing medium for other parts of equipment to be earthed.
4. Any bare earthing conductor up to 4mm connected behind a plug socket or switch must be sleeved or insulated (Rule 5.5.2.5.). This also applies to bare earthing conductor at the back of switchboard.



PROTECTION OF BARE EARTHING CONDUCTOR

Supplementary System of Earth Protection

Three methods of achieving isolation of lives parts so that break down to earth is remote are:

1. By the use of all-insulated equipment
2. By the use of double insulating equipment
3. By insulation from supply using an "isolating transformer".

These topics are the subject of later detailed study. They are included here for their basic principles.

1. All Insulated equipment

This type of equipment is designed to ensure that there is no exposed external metal of any description.

2. Double Insulation

This system achieves the isolation of live parts by interposing two separate layers of insulation between the live parts and any external metal.

Both sets of insulation would have to break down to constitute a hazard.

Small appliances such as "Electric drills", "Sewing machines" and "Shavers" are usually double insulated. They are marked:

DO NOT EARTH. DOUBLE INSULATED

On no account should this instruction be disregarded as any earthing of external parts would actually introduce a hazard.

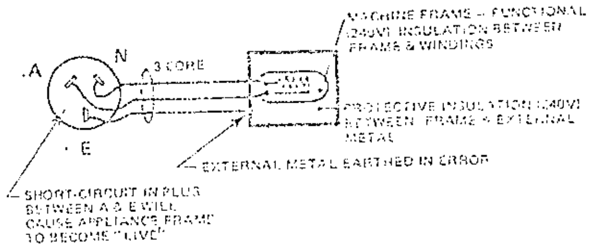


Fig. 10.20 How the earthing of a double-insulated appliance could create a safety hazard

Insolating Transformers

This type of transformer has two electrically separate windings which ensures that there is no potential difference between the secondary supply terminals and earth or the primary supply making shock a hazard.

Only one appliance may be connected to the secondary, not because of over load, but because it could create a safety hazard under certain conditions.

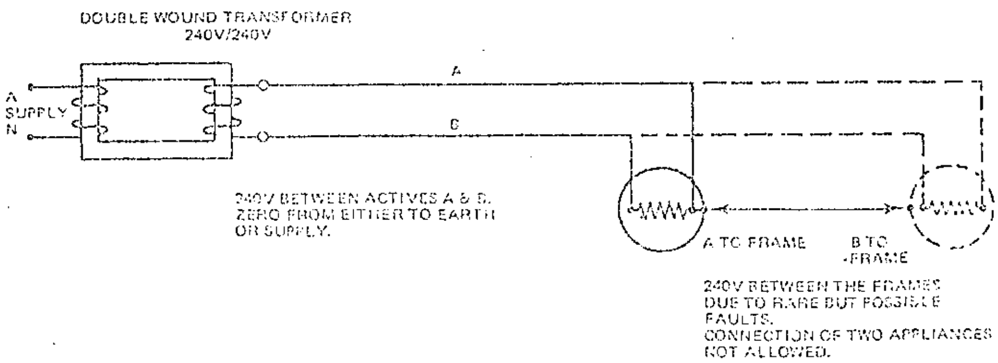


Fig. 10.21 Possible safety hazard created by using more than one unearthed appliance with an isolating transformer

Resistance of Earthing System

The maximum resistance of the earthing system of an installation is specified as 2 OHM by rule 1.25 which also states that it's value must be low enough to permit sufficient fault current to operate the protection.

To ensure that the rule is complied with, the resistance of the earthing system of an installation must be tested. The object of the test is to determine the resistance value of the earthing system between the main earth connection and any part of the system.

For example: The earthing terminal of a three pin plug - the frame of a fluorescent luminair - the frame of a motor.

If an M.E.N. system is employed, then this test is from any part of the earthing system as before to the main earth connection at the NEUTRAL LINK.

In addition, the resistance value from the neutral to the earth electrode must be within 2 OHM.

When carrying out earth resistance tests, the metal frames of all appliances and luminaires should be checked because they are mass produced and it could happen that the resistance between earthing terminal and frame (0.1 OHM or less) is higher than specified by "S.A.A. Rules, part 2 ASC 100".

The process of painting often affects the earth continuity between frames and parts.

Most appliances are handled while in operation, so it is essential to have an effective earthing of the appliance.

Visual inspection of the earthing system should also be made where possible on new and existing installations.

Any apparent high resistance point should be checked and corrected if necessary.

TITLE:- S.A.A. WIRING RULES

LECTURER:- Gerry Heynis

DATE:- 22-6-81

EQUIPMENT:- Figure 8, V.I.R. cable, T.R.S. cable, P.V.C. cable, C.T.S. cable, P.I.L.C. cable, varnished cambric.

CABLE TERMINOLOGY

Conductor-S.A.A. 0.5.24:-
A wire, or other form of conducting material, suitable for carrying current, but not including wire or other metallic parts, directly employed, in converting electrical energy into another form.

Bare conductor-S.A.A. 0.5.25:-
A conductor without covering or insulation.

Active conductor-S.A.A. 0.5.4:-
Any one of those conductors of a supply system, which is maintained at a difference of potential, from the neutral or earthed conductor. In a system which does not include a neutral or earthed conductor, all conductors shall be considered active conductors.

Neutral conductor-S.A.A. 0.5.58:-
The conductor of a 3 wire or multi-wire system, which is maintained at an intermediate, and approximately uniform potential, in respect of the active or outer conductors, or the conductor of a two-wire system, which is earthed at its origin.

Earth conductor-S.A.A. 0.5.38:-
A conductor connecting any portion of the earthing system, to the portion of the installation or apparatus required to be earthed, or, to any other portion of the earthing system.

Cable-S.A.A. 0.5.16:-
One insulated conductor (solid or stranded) or two or more such conductors, laid together either with or without bare conductors, fillings reinforcements, or protective coverings.

Flexible cable - S.A.A. 0.5.19:-
A cable, the conductors, insulation and covering of which, are such as to afford flexibility.

Flexible cord - S.A.A. 0.5.28:-
A flexible cable, no wire of which exceeds 0.30 mm diameter, and no conductor of which exceeds $4mm^2$ cross-sectional area, and having not more than five cores.

COMMON TYPES OF POWER & LIGHTING CABLES

Rubber:- Will withstand temperatures of approximately 50°C, but beyond this it becomes damaged.

Vulcanised India Rubber (V.I.R.):-
Cable becomes damaged at about 60°C, and also by water and oils.

Tough rubber sheathed (T.R.S.):-
These have the conductors laid side by side for twin, or 3 cored flat cables. When the cable contains a bare earthing conductor, it is placed between the insulated cores.

Thermoplastic insulated (P.V.C.):-
Used as an alternative to rubber insulated cable. They have the advantage of being oil and moisture resistant, and are unaffected by corrosive conditions and direct sunlight.

Cab Tyre Sheathed (C.T.S.):-
Are twisted together, to form 2, 3, 4 or 5 core cables. During the process, a jute worming is used to fill the spaces between conductors, and gives a perfectly round surface, the cable is then covered with an outer tough rubber sheath, for mechanical protection.

Varnished cambric:-
Resists oil better than rubber, and will withstand temperatures up to about 70°C. This type of cable has approximately 20% higher current rating than V.I.R. cable, and is mainly used for wiring oil-immersed switch gear, switchboard wiring, and for high voltage cables.

Paper insulated lead covered(P.I.L.C.):-
Most modern power distribution cables are insulated with impregnated paper. As the paper absorbs moisture, and the conductor is required to be screened from external electric fields, the cable is lead sheathed. This lead sheath is earthed. The capacitance between conductor and sheath is appreciable, and care should be taken when handling this type of cable until it has been properly discharged. It will not withstand sharp bending or vibration, without the possibility of fracturing.

Factors to be considered when selecting a cable for a particular job.

(1) Current carrying capacity.(cross sectional area).
(2) Resistance of the run (lead & return, affect voltage drop and power loss).
(3) Insulation resistance (must be able to withstand peak supply voltage).
(4) Mechanical features (strength, flexibility, weight etc.).
(5) Probable future loading requirements.
(6) Initial, and maintenance costs.
(7) Fire and safety risks.
(8) Local conditions i.e., mechanical damage, extreme temperatures, injurious atmosphere.
(9) All relevant S.A.A. and supply authority rules and regulations covering the installation.

DISTINGUISHING CABLE COLOURS: S.A.A. 3.1

General:- The colour GREEN, or a combination of GREEN/YELLOW shall not be used to identify any conductor, other than an EARTHING CONDUCTOR.

The following colour coding of the cores of FLEXIBLE CORDS, is being adopted in several countries (including the U.K.) and accepted for use in Australia -

Sheath: Black
Single Core: Brown (active), Light Blue (Neutral), or, for earthing conductors, Green or Green/Yellow.
2-core: Brown (active), Light Blue (neutral)
3-core: Brown (active), Light Blue (neutral) and for earthing conductors, Green or Green/Yellow.
OR, Brown, Black, Yellow (actives), Light Blue (neutral)
4-core: Brown, Light Blue, (actives) and for earthing conductors, Green or Green/Yellow.
5-core: Brown, Black, Yellow (actives), Light Blue (neutral), Green or Green/Yellow (earth).
OR, Brown, Yellow, Black, (actives) Light Blue (neutral)

Voltage drop - S.A.A. 2.1.3.
This section deals with the fall in voltage, from the commencement of the consumers mains, to any point on an installation. Information on voltage drop, including a method for choosing conductor sizes taking into account voltage drop, is given in Appendix B.

Current rating - S.A.A. 2.1.2.
Except as varied in a particular rule, every conductor shall have a current-carrying capacity, at least equal to the current to be carried by it.

S.A.A. 2.4 - Method of determining maximum demand in mains and sub-mains.

S.A.A. 2.8 - Maximum demands in final sub-circuits.

TITLE:- S.A.A. WIRING RULES (SWITCHBOARD CONSTRUCTION)

LECTURER:-

DATE:-

EQUIPMENT:- Zelemite panel, fuses, neutral link, earth bar, bus-bar, switch board identification tabs.

2.21.1. Spacing of apparatus:-
To ensure safe operation and handling.

2.21.2. Switchgear-mounting:-
Refers to material used for mounting panels.

2.21.3. Switchboard-panels:-
Material used for panels and thickness.

2.21.5. Apparatus-mounting:-
Spacing and fixing apparatus.

2.22.1. Protection of switchboards against spread of fire:-
Wiring enclosures - distance from wooden floors - apertures - flammable material.

2.23.1. Protection against risk of shock:-
Live parts exposed - wire spacing - enclosing live parts.

2.24.1. Accessibility:-
Provision for replacements - doors - distances - clearances.

2.24.2. Switchboards with removable or hinged panels:-
Max. size - clearances - distortion - angle of swing - support.

2.24.4. Fixed switchboards with access from edges:-
Spacing and clearances for safe access.

1	2	3
Distance from any point on the switch-board, to the nearest means of access	Minimum clearance behind switchboards	Minimum space adjacent to point of access
m	m	m
Not exceeding -		
0.3	0.1	0.23
0.45	0.15	0.23
0.6	0.23	0.3
0.75	0.3	0.3

2.24.5. Fixed switchboards with access from rear:-
Spacings - clearances - access - enclosing - locking.

2.25.1. Arrangement of apparatus on switchboards:-
Marking and identifying - links - fuses - switches.

2.25.2 Mounting of fuses:-
Restricted mounting - fuse arrangement - covers.

2.25.3 Fuses on back of switchboard:-

2.25.4 Clearance from bare conductors & live parts:-
Clearances - fixing - busbars - supports - rewirable fuses - manufactured apparatus.

2.25.5. Neutral bars and links:-
Connecting - current carrying capacity - minimum size - terminals - outbuildings - marking under MEN system - enclosing - accessibility - location.

2.26. Wiring of switchboards:-
Enclosure and protection - holes in panels - switchboard covers - arrangement sequence - slack wire - fastoning - pressure on conductors.

2.27. Alterations to switchboards:-
Location - layout - reconstruction.

2.28. Control panels:-
Installation - access to front and roar - protection against spread of fire and risk of shock.

8