

Wire joints - Types - Soldering methods

Objective: At the end of this lesson you shall be able to

- state the different types of wire joints and their uses
- state the necessity of soldering and types of soldering
- state the purpose and types of fluxes
- explain the different method of soldering and techniques of soldering
- explain the type of solder and flux used for soldering aluminium conductor

Joints in electrical conductors are necessary to extend the cables, overhead lines, and also to tap the electricity to other branch loads wherever required.

Definition of joint: A joint in an electrical conductor means connecting/tying or interlacing together of two or more conductors such that the union/junction becomes secured both electrically and mechanically.

Types of joints: In electrical work, different types of joints are used, based on the requirement. The service to be performed by a joint determines the type to be used.

Some joints may require to have good electrical conductivity. They need not necessarily be mechanically strong.

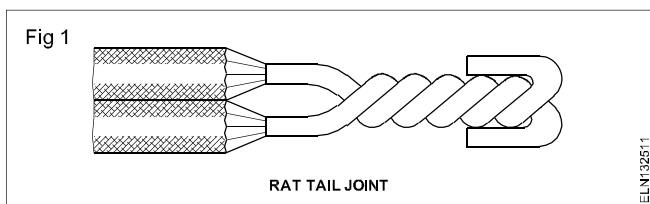
Example : The joints made in junction boxes and conduit accessories.

On the other hand, the joints made in overhead conductors, need to be not only electrically conductive but also mechanically strong to withstand the tensile stress due to the weight of the suspended conductor and wind pressure.

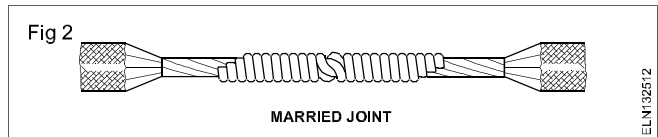
Some of the commonly used joints are listed below.

- Pig-tail or rat-tail
- twisted joints
- Married joint
- Tee joint
- Britannia straight joint
- Britannia tee joint
- Western union joint
- Scarfed joint
- Tap joint in single stranded conductor

Pig-tail/Rat-tail/Twisted joint: (Fig 1) This joint is suitable for pieces where there is no mechanical stress on the conductors, as found in the junction box or conduit accessories box. However, the joint should maintain good electrical conductivity.

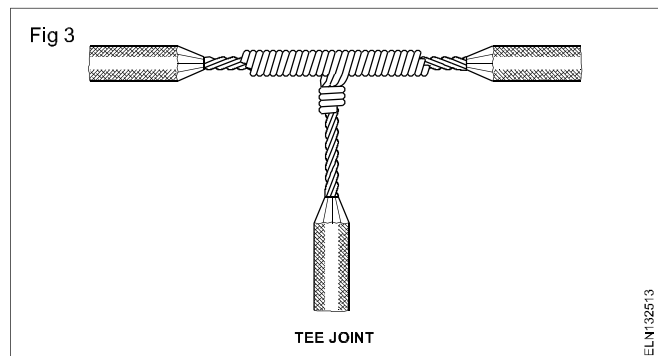


Married joint: (Fig 2) A married joint is used in places where appreciable electrical conductivity is required, along with compactness.

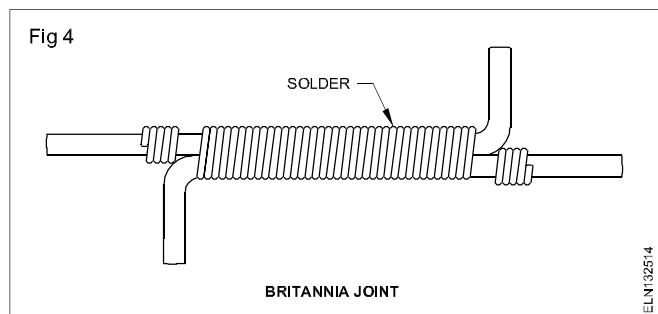


As the mechanical strength is less, this joint could be used at places where the tensile stress is not too great.

Tee joint (Fig 3): This joint could be used in overhead distribution lines where the electrical energy is to be tapped for service connections.

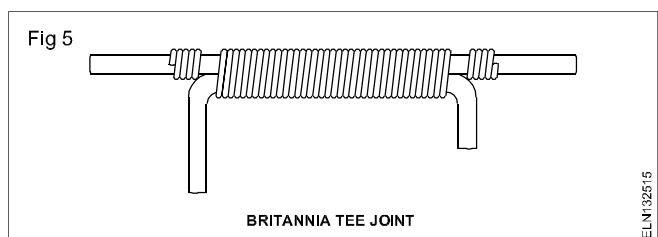


Britannia joint: (Fig 4) This joint is used in overhead lines where considerable tensile strength is required.

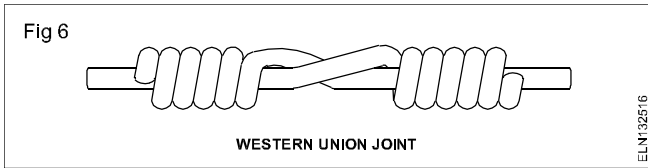


It is also used both for inside and outside wiring where single conductors of diameter 4 mm or more are used.

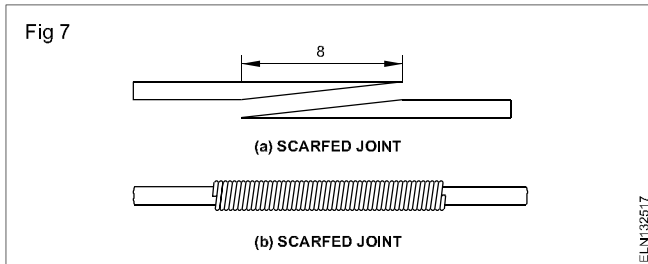
Britannia tee joint: This joint (shown in Fig 5) is used for overhead lines for tapping the electrical energy perpendicular to the service lines.



Western union joint (Fig 6): This joint is used in overhead lines for extending the length of wire where the joint is subjected to considerable tensile stress.



Scarfed joint (Fig 7): This joint is used in large single conductors where good appearance and compactness are the main considerations, and where the joint is not subjected to appreciable tensile stress as in earth conductors used in indoor wiring.



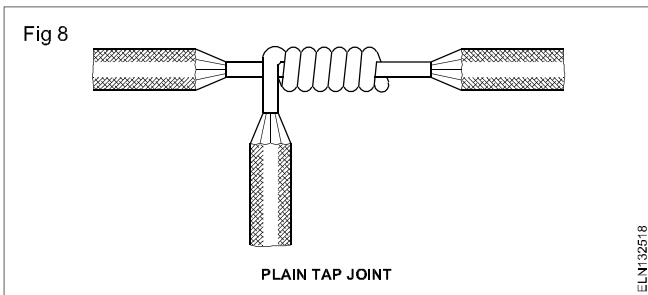
Tap joints in single stranded conductors of diameter 2 mm or less

By definition, a tap is the connection of the end of one wire to some point along the run of another wire.

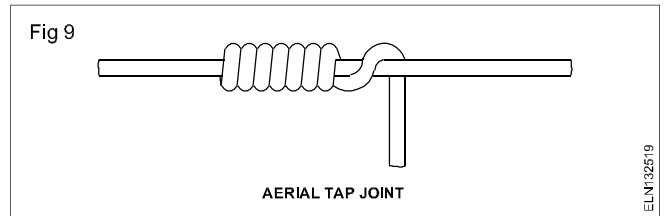
The following types of taps are commonly used.

- Plain
- Aerial
- Knotted
- Cross - Double - Duplex

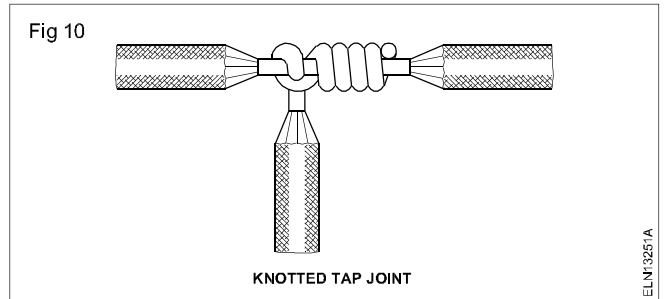
Plain tap joint: (Fig 8) This joint is the most frequently used, and is quickly made. Soldering makes the joint more reliable.



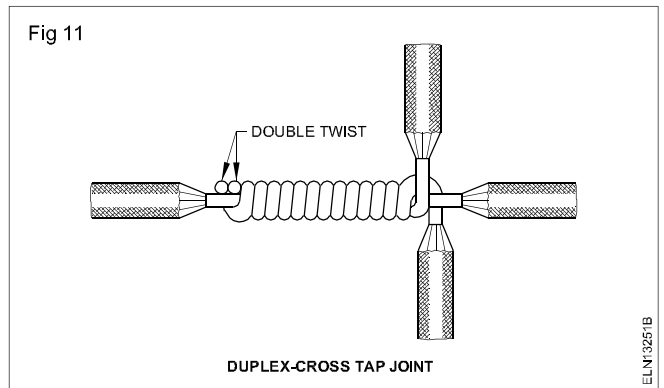
Aerial tap joint : (Fig 9) This joint is intended for wires subjected to considerable movement, and it is left without soldering for this purpose. This joint is suitable for low current circuits only. It is similar to the plain tap joint except that it has a long or easy twist to permit the movement of the tap wire over the main wire.



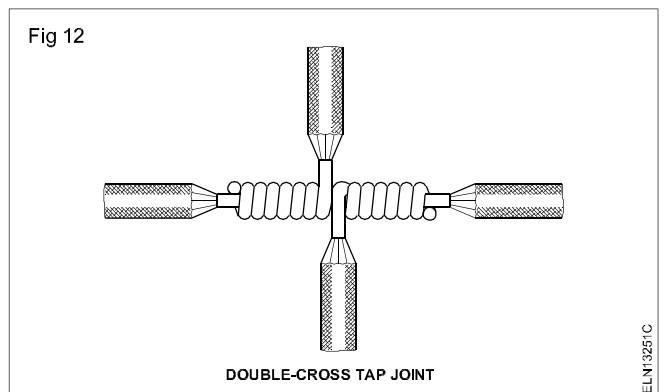
Knotted tap joint : (Fig 10) A knotted tap joint is designed to take considerable tensile stress.



Duplex cross-tap joint: (Fig 11) This joint is used where two wires are to be tapped at the same time. This joint could be made quickly.



Double-cross tap joint: (Fig 12) This joint (shown in Fig 12) is simply a combination of two plain taps.



Soldering - types of solders, flux and methods of soldering

Soldering: Soldering is the process of joining two metal plates or conductors without melting them, with an alloy called solder whose melting point is lower than that of the metals to be soldered. The molten solder is added to the two surfaces to be joined so that they are linked by a thin film of the solder which has penetrated into the surfaces.

Necessity of soldering: Wire and cable joints should have the same electrical conductivity and mechanical strength as that of the parent conductor. This cannot be achieved by a mere mechanical joint. As such cable joints are soldered to have good mechanical strength, electrical conductivity and also to avoid corrosion.

Solders

The following are the general proportions of tin and lead used in the solders.

Designation	Composition	Working temp.	Uses
Plumbing/ Tinman's solder	Tin-50% Lead-50%	212°C.or 413.6°F.	Heavy duty soldering
Electrician's solder	Tin-60% Lead-40%	185°C. or 365°F.	Tinning and soldering electrical joints etc.
Fine solder	Tin-63% Lead-37%	183°C.or 361°F.	Tinning/ Electrical/ Electronic Compound

Solder used for copper: The metal alloy used as a bonding agent in soldering is called a solder. The solders used for soft soldering consist of an alloy (mixture) of mostly tin and lead.

Factors influencing the choice of a solder

The factors that influence the choice of a solder are:

- place of use
- melting point
- solidification range
- strength
- hardness
- sealability
- price.

Flux: Flux is a substance used to dissolve oxides on the surface of conductors and to protect against de-oxidisation during the soldering process.

General properties of flux

The purpose of the flux is to

- dissolve oxides, sulphides etc. thereby making the soldering surface free of oxides and dirt
- prevent re-oxidation during the soldering operation thereby making the solder adhere to the surface to be soldered.
- facilitate the flow of the solder through surface tension so as to make the solder flow into the surface to be soldered.

The state of the flux can be solid or liquid.

The activity of the flux can be weak or strong, and is classified with regard to the corrosive properties, as slightly corrosive or highly corrosive.

The type of solder often determines the flux to be used for soldering.

The following table lists the fluxes used for soldering.

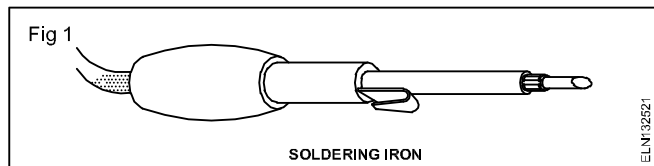
Table

Sl. No.	Suitable flux	Metals/job - used for	Type of solder
1	Zinc chloride (acidic)	Cast iron, wrought iron, mild steel, cast steel, brass, bronze, copper etc. for soldering at low temperature	Tinman's solder Fine solder
2	Hydrochloric acid 10% diluted with water 90%	Zinc Galvanised iron	Coarse solder
3	Sal ammonia rosin (Not fully acid-free)	Copper, brass, tin plate, gun-metal: for clean and finer soldering work.	Coarse solder
4	Rosin	Joining electrical conductors	Electrician's solder
5	Tallow - (turpentine, acid free)	For joining electrical conductors, for soldering.	Electrician's fine solder

Fluxes shown under 1, 2 and 3 are not recommended for electrical purposes as they are highly corrosive, hygroscopic (absorb moisture), and the residues are electricity conductive.

Soldering methods

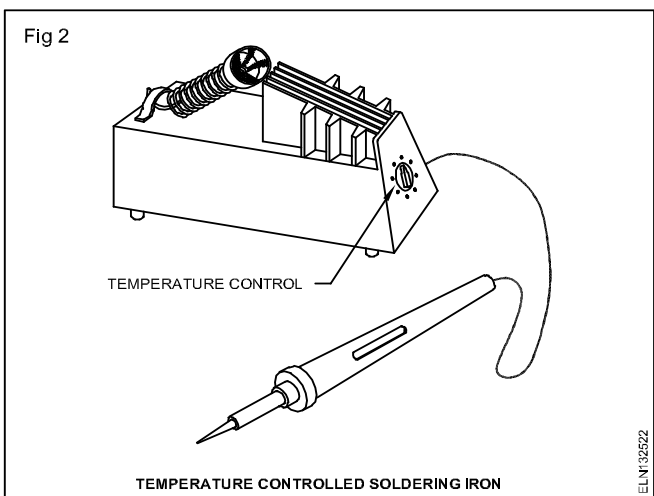
Soldering with a soldering iron: The most common method of soldering is with a soldering iron as shown in Fig 1. This is widely used for most kinds of soft soldering work.



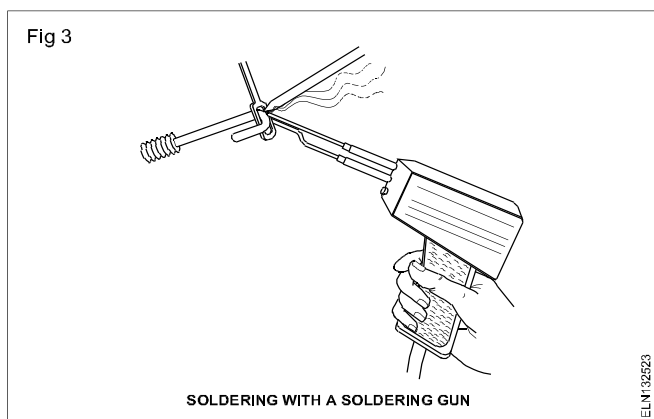
This tool is simple and inexpensive. Soldering irons are available in a wide range of sizes and models. Heating is generally by electrical means, though non-electrical irons are also used.

Temperature controlled soldering

For soldering miniature components on printed circuit boards, a temperature-controlled soldering iron is used as shown in Fig 2. The electrical supply given to the soldering iron is of low voltage, and is completely isolated from the main supply. Low voltage does not endanger the life of the user and will also not spoil the sensitive electronic components. Controlled temperature makes the job easy for the user.



Soldering with a soldering gun: This method, shown in Fig 3, is used for individual soldering, e.g. for servicing and repair work.

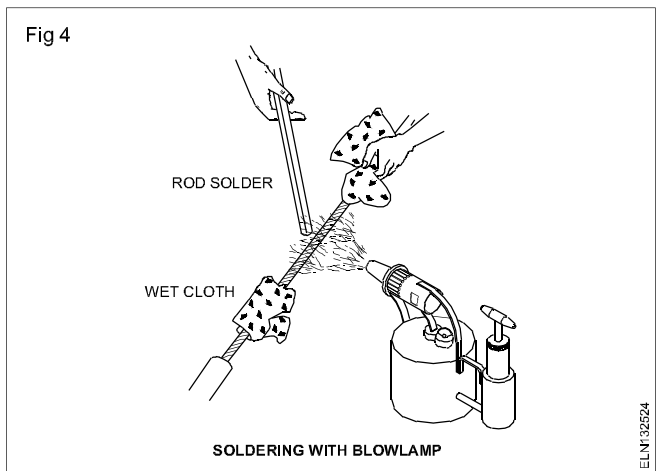


The principle of this method is that an electric current flows through a wire coil heating it. The temperature is difficult to check, and overheating can easily occur. This is the disadvantage.

Soldering with a flame: Soldering with a flame is used when the heat capacity of a soldering iron is insufficient.

This method, shown in Fig 4, permits rapid heating and is used primarily for larger jobs, such as piping and cable work, vehicle body repairs and some applications in the building trade.

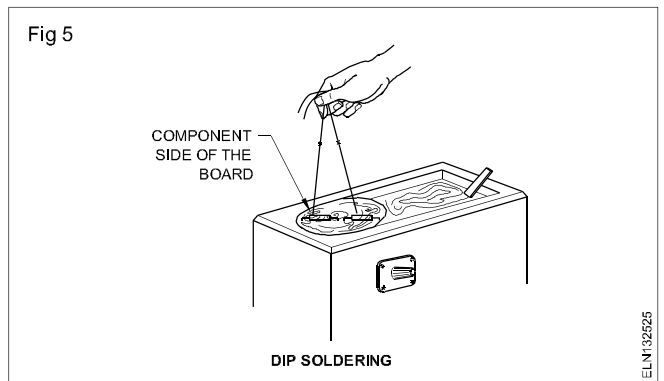
This method requires skilful management of the flame.



Dip soldering: This method, shown in Fig 5, is used for quantity production and for tinning work similar to component soldering on Printed Circuit Boards (P.C.B.). Components to be soldered or tinned are dipped into a bath of molten solder, which is heated electrically.

The solder is kept in motion by an agitator in order to obtain an even temperature and to keep the surface free from oxides. If no agitator is provided, the surface must be protected or skimmed at regular intervals to remove the oxides.

The temperature can be controlled very accurately.



Machine soldering: This method, shown in Fig 6, is used for quantity production, and is based on the principle that molten solder or a mixture of oil and molten solder is set in rapid motion, thus breaking up the oxide film. The solder comes into direct contact with the component ends to be soldered.

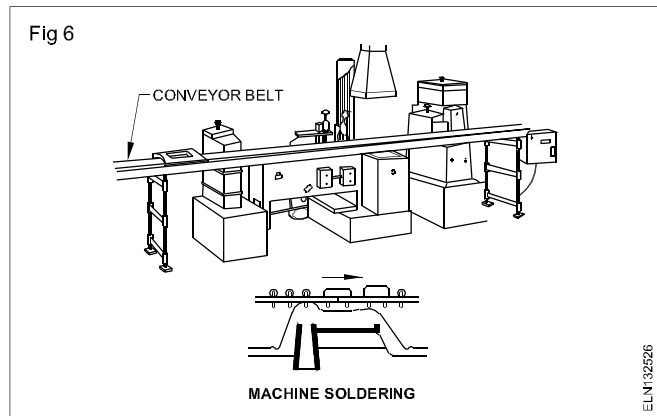
Soldering machines of different designs are used for wave soldering, cascade soldering and jet soldering.

Equipment for machine soldering is expensive and the cost of production is high.

Accurate temperature control can be arranged.

Apart from these, any one of the following methods can also be used for soldering.

- Resistance soldering
- Induction soldering
- Oven soldering
- Soldering in vegetable oil
- Soldering by hot gas



Soldering - Techniques - pot and ladle

Soldering with electric soldering iron: In this method, the joining surface is first cleaned and then the flux is applied over the surface. The joint is then heated, and the solder is kept over the surface to be soldered, and heat is applied by keeping the soldering iron tip over it. The solder melts and spreads on the surface evenly.

The electric soldering iron: The heating element in the iron is heated by an electric current passing through it.

The bit is heated by the heating element.

The face of the bit is the part of the iron, used to make contact with the surfaces to be soldered.

Soldering irons of the following voltages and input power (wattage) are available (I.S.950-1980).

Ratings

Voltage	6	12	24	50	110	230 or 240
Wattage	25	25	25	25	25,75, 250	5,10,25,75, 125,250,500

Select an iron with adequate power to suit the size of the work.

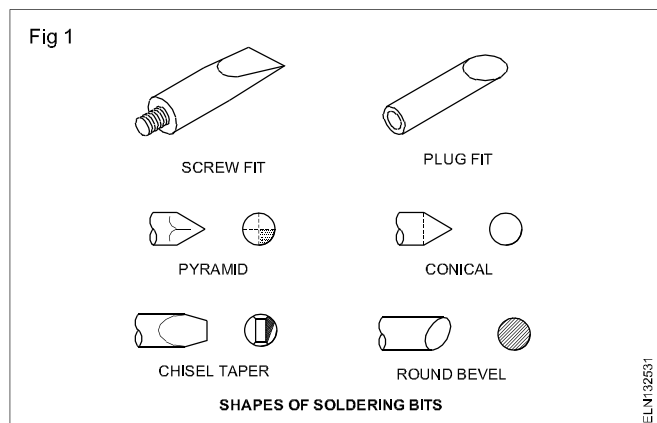
The bit: Most bits are made of copper because it is a good conductor of heat. The face of the bit may be either:

- un-plated or
- iron-plated.

Iron-plated faces do not wear out as rapidly as un-plated faces.

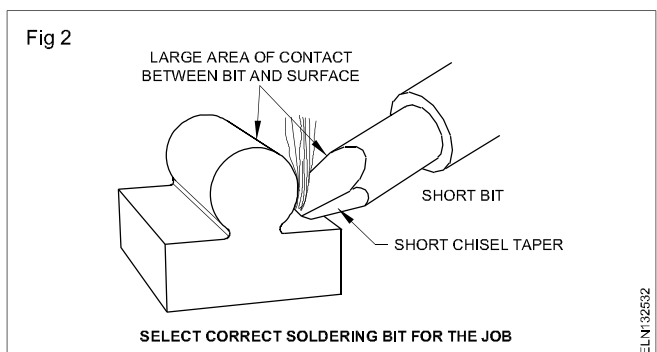
Most irons are so constructed that the bit can be changed.

Different shapes of bits are available as shown in Fig 1.

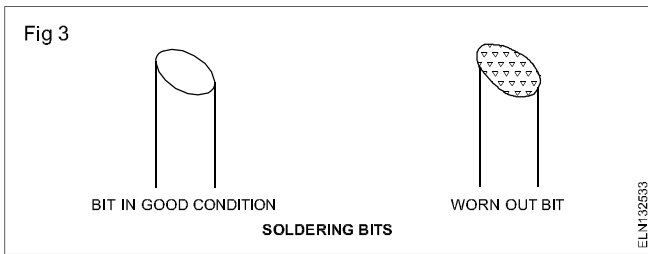


Selecting the bit (Fig 2): Select the bit to give a compromise between:

- the best approach to the work
- the shortest bit and bit taper
- the ideal contact with the surfaces.



Care of the bit (Fig 3): Un-plated bits become pitted quickly and get covered in oxide. If the iron is in constant use, this will occur within a few hours.

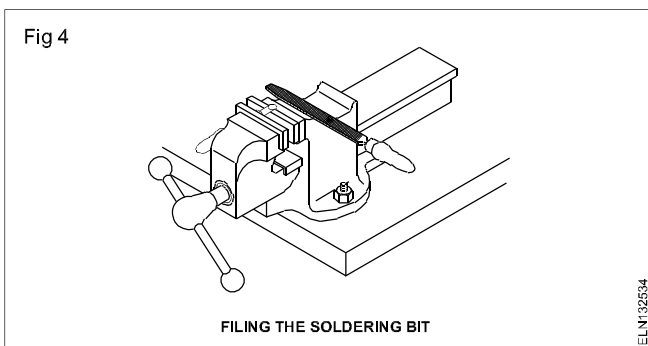


To make a good soldered joint, the bit must be maintained clean, smooth and correctly shaped.

Dressing the bit (Fig 4): To dress an un-plated bit follow the procedure stated below.

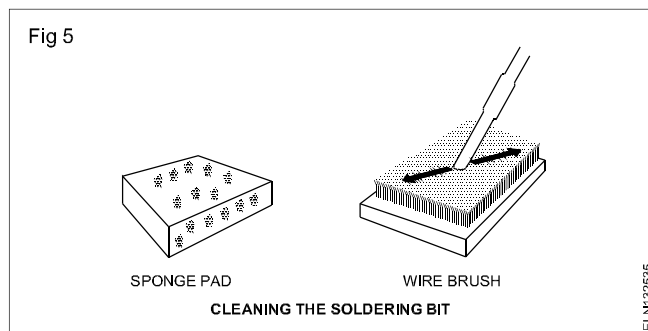
- Switch off, unplug the iron and allow it to cool.
- Remove the bit from the iron, if possible.
- Mount the bit in a vice.
- File to shape.

Do not file the bit in an electronic assembly area. Copper dust from the bit may settle in the equipment and cause a short circuit. Iron-plated bits must not be filed. Renew when worn out.



Cleaning the bit: (Fig 5) The bit should be cleaned frequently. To clean the bit, rub the face of the un-plated bits on a wire brush or special sponge pad when the iron is hot.

Iron-plated bits must not be cleaned on a wire brush. Rub on a sponge pad.



Wetting (soldering): To make a good joint, the solder must flow evenly over and between the surfaces to be soldered. Wetting is a term used to describe the extent to which this occurs.

Good wetting results can be obtained if:

- the surfaces are clean
- sufficient flux of the correct type is used
- the surfaces are hot enough
- the surfaces have been tinned.

Techniques of soldering

Soldering involves the following main operations.

- Tinning the soldering iron
- Cleaning the parts to be soldered
- Applying the solder

Tinning the soldering iron: To make the solder adhere to the tip of the soldering iron, the surface of the tip must be coated with the solder, and this operation is known as tinning.

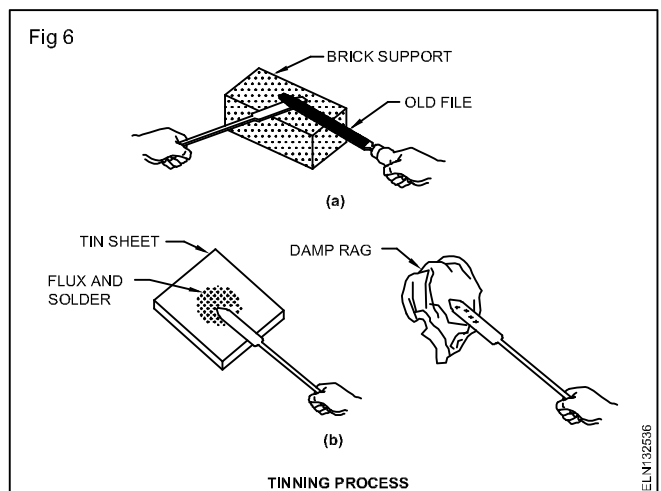
First the tip is cleaned with a cloth and heated either directly or indirectly. The tip is then filed to remove the scales, and is wiped again with a cloth.

The right temperature for tinning could be judged by the change of colour of the tip when heated. If the surface of the copper tip tarnishes immediately, the temperature is high and needs to be cooled slightly by withdrawing the source of heat temporarily. A correctly heated tip tarnishes slowly.

After the soldering iron tip attains the correct temperature, place a small quantity of solder and the flux on a tin plate and rub the bit on the mixture. The solder should stick to the surface of the tip evenly. Wipe out the superfluous solder with a clean damp cloth.

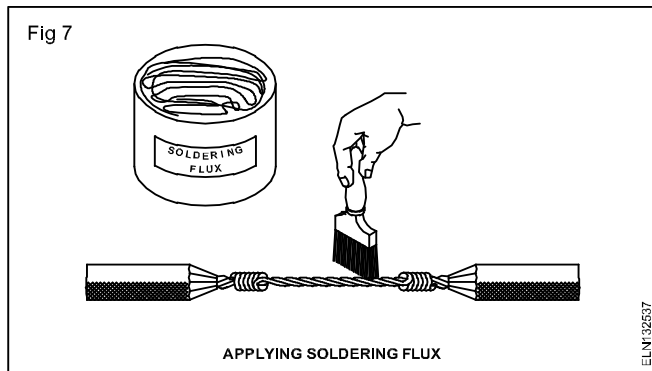
The whole process of tinning is shown in Figures 6a and 6b.

The surface should present a bright silvery appearance when properly tinned.



Cleaning the surface to be soldered: The parts to be soldered should be well cleaned for perfect soldering. The scales, dirt, oil and grease should be completely removed either by wiping or by rubbing with a sandpaper. Immediately after cleaning, the flux should be applied on the surface to avoid oxidization.

Applying the flux: The rosin which is recommended as a flux may be sprinkled over the surface to be soldered or may be applied with a brush as shown in the Fig 7.



Applying the solder: The quantity of the solder to be applied depends upon the size of the job. For small jobs like printed circuit boards soldering or soldering joints in wires of diameter 2 mm or lower, an electric soldering iron is used whereas for soldering joints of large sized cables, pot and ladle are used.

Soldering precautions: Remove the iron as soon as the solder has flowed over the surfaces.

Excessive heating may damage:

- the wire and its insulation
- the component being soldered
- the adjoining components.

Safety

Soldering irons can be dangerous if not maintained or used properly. Follow the directions given below.

Inspect the iron regularly for physical damage, especially the power cord. Replace it, if found damaged.

Keep the iron in a stand when not in use. This prevents burns and fires and protects the iron from damage.

Do not subject the iron to rough treatment.

Keep the iron away from all parts of the body and from its own power cord.

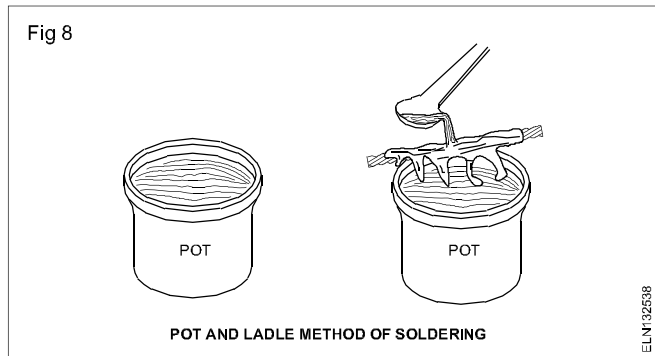
A proper earth connection must be made to all mains-connected irons. If you suspect that an iron is not earthed, do not use the iron.

Never flick excess solder off the bit. The hot solder may cause burns to someone or fall into a part of the work, and cause a short circuit.

Soldering with pot and ladle: (Fig 8) For larger sized jobs like underground cable jointing, a melting pot and ladle are used. The solder is kept in the pot and heated either by a blowlamp or by charcoal. Initially the surface to be soldered is cleaned and a coat of flux is given.

Then the surface to be soldered is heated by pouring molten solder over it in quick succession. The dripping solder is collected in a clean tray. After several pourings, the surface attains the same temperature as that of the molten solder. The flux is again applied and the solder is

slowly poured on the surface as it forms an even layer. Superfluous solder collected in the tray is re-melted in the pot.



Safety

Ensure that the conductor is dry and clean before applying the molten solder, and that it is not allowed to enter the insulation.

Never drop anything, including the metal to be soldered into the bath. Splashes of hot molten solder can cause serious injury. Always wear protective clothing when working with solder baths, like gloves, apron, boots etc. and ensure that no unprotected part of the body touches the pot.

When pouring solder over a joint, keep the ladle low as far as possible to prevent splashing of the molten solder over the sides of the pot.

During the solidification period, the parts of the joint must not be disturbed under any circumstances. If they are disturbed, the strength, conductivity and appearance of the joint will be endangered. The result will be what is often called cold solder and the joint will be defective.

Cooling must not be accelerated. If cooling is accelerated, the solder will assume a crystalline form. This lowers the mechanical strength.

Do not allow the molten solder to fall on to the gas pipe or the electric cables nearby.

Beware of the naked flames to avoid a fire risk.

Reconditioning of solder which is subjected to repeated melting

In practice, when the solder is subjected to repeated melting during the soldering process, the tin content in the solder is considerably reduced due to:

- the slug formation of tin on the molten solder
- oxidization of tin due to its low boiling point.

As such the solder, which is subjected to repeated heating, will have a low percentage of tin as compared with the solder taken from the stores.

To recondition the solder and to bring up the tin percentage, tin is added to the solder at the end of each use. The quantity to be added depends upon the length of time the solder is kept in the molten state.

Soldering aluminium cables

Soldering of aluminium cables: Soldering aluminium conductors is more difficult than soldering copper conductors owing to the highly tenacious, refractory and stable nature of the oxide film which forms immediately on any aluminium exposed to air.

This oxide film does not allow the solder to wet the surface to be soldered, and also prevents the solder from entering the interior surface by capillary action. Hence special solders and fluxes are used for aluminium soldering.

Solder: A special soft solder having a small percentage of zinc is used for joining aluminium conductors. (Soft solders are alloys which have a melting point below 300°C.) IS 5479-1985 gives details of the chemical composition of soft solders and their grades used for soldering aluminium conductors. Details are given in Table 1.

The object of this small zinc content which is a common feature of aluminium solders is to facilitate the alloying of the solder with an aluminium surface. A typical composition of solder with 51% lead, 31% tin, 9 % zinc and 9% cadmium with the brand name 'ALCAP' solder is available in the market for soldering aluminium conductors. In addition a special solder by name Ker-al-lite is also available for soldering aluminium conductors.

Flux: In soldering aluminium conductors, organic fluxes of reaction type, free from chlorides and suitable for soft soldering are used.

The composition of the organic fluxes decomposes at approximately 250°C to effect the removal of the oxide film and also to assist in the spreading of the molten solder to enable tinning the de-oxidised surface immediately.

The major disadvantage of organic flux is that it tends to char at a temp. above 360°C. The charring, thus caused, renders the flux ineffective and gives rise to the danger of creating voids in the joint due to charred flux residues. For this reason, it is essential that the temp. of this solder during the operation is maintained well within 360°C. The commercial name of fluxes used for joining aluminium conductors are Kynal Flux and Eyre No.7.

Procedure of soldering aluminium cables

The procedure of soldering aluminium cables to standard copper lugs employing **Kynal's flux** and **Ker-al-lite** special solder is explained below.

Strip the cable in preparation for jointing in the usual manner.

Spread out the strands so as to effect a general loosening and slight displacement of the wires, and clean the surface preferably with a wire brush.

Apply a small quantity of flux by brushing well into the fanned-out ends of the conductor and baste (moisten) the fluxed conductor with a full ladle of molten solder.

Apply more flux and baste again with the molten solder. Continue to make repeated alternate applications of flux and solder until the wires exhibit a brightly tinned surface free from dull spots.

After the final basting, wipe off the surplus metal from the strands with a clean and dry piece of cloth.

Flux the lug inner surface and fill it with the molten solder.

Insert the tinned end of the cable inside the lug and hold both the cable and the lug firmly without shaking.

Allow the lug to cool and baste the surface quickly with the molten solder to remove the excess solder.

Wipe the lug surface with a clean cloth.

Apply a coating of graphite conducting grease on the lug before using.

Precautions to be followed while soldering aluminium

All surfaces must be scrupulously clean.

When a joint is being made between stranded conductors, the strands must be 'stepped' to increase the surface area.

The surface must be fluxed before the heat is applied.

Safety

During the jointing operation copious fumes are given off when the flux is heated. These fumes contain small quantities of fluorine, and it is, therefore, advisable not to inhale them.

As smoking during the jointing operation results in the inhaling of toxic fumes, smoking during soldering should be avoided.

Table 1

Grade	% of alloying elements			Melting temp. in °C	Flux type	Applications
	Zinc	Lead	Tin			
SnPb53Zn	1.75–2.25	52–54	45.71–45.21	170–215	Organic	Conductors of electrical cables
SnPb58Zn	1.75–2.25	57–59	40.66–40.6	175–220		-do-