

**Making Permanent Joints – Course: Basic Skills and Knowledge of
Electrical Engineering. Trainees' Handbook of Lessons**

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Making Permanent Joints – Course: Basic Skills and Knowledge of Electrical Engineering.

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Introduction

The present handbook is intended for trainees in electrical engineering trades.

It contains a description of the tools and accessories required for the manufacture of permanent joints by soldering, wrapping, notching and pressing.

The individual types of joints are explained in self-contained sections. The necessary knowledge and skills are described in each section in the order of the steps of work required. The illustrations contained shall help to visualize, understand and supplement the text of the individual sections.

To assist the learning process, questions have been included for the trainees to test their knowledge.

1. Types and Meaning of Permanent Joints

Permanent joints are engineering joints of two or more parts (components, conductors) and are made by joining,

	Permanent joints	
material closed	force-closed (non-positive)	form-closed (positive)
soldered joints	pressed joints	wire-wrap joints
welded joints	crimped joints	
glued joints	notched joints	

- Permanent joints are used to join (connect) materials.
- Permanent joints must withstand the same mechanical and electrical stress as the materials to be joined.
- Permanent joints can only be detached by destruction of the joining elements or of the parts joined.

2. Tools for Making Permanent Electrical Joints (Bondings)

Tools for making permanent electrical joints are soldering irons, soldering baths, gasoline or gas blow torches, wrapping, notching and pressing tools. The use of such tools is to be adapted to the relevant application and local conditions.

Soldering irons

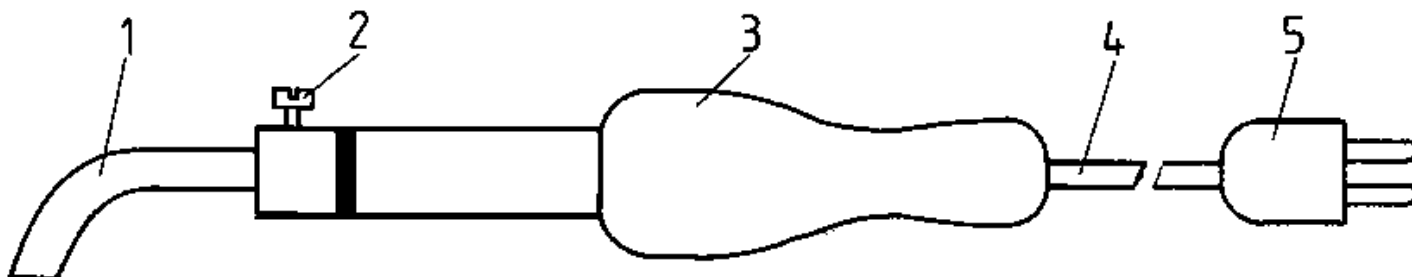


Figure 1 – Construction of an electric soldering iron – 1 bit, 2 fastening screw, 3 handle, 4 lead

Electrically heated by a current-carrying heating wire of a heating coil inside the metal housing of the soldering iron. The proper soldering iron is selected depending on the size of the soldering joint and on the necessary soldering temperature. Soldering irons with a capacity of from 6 to 400 W can be used.

Coordination of soldering iron – wire cross-section – solder diameter

wire cross-section (mm ²)	up to	1.0	1.5 to 6.0	10 to 25	up to 50
capacity of soldering iron (W)	up to	60	100	200	400
solder diameter (mm)	1.0		2.0	2.0	all types

- For soldering work on printed circuit boards soldering irons of maximally 60 W are to be used.
- Soldering irons with a perfect bit are to be used for any soldering work.

Soldering baths

Electrically heated by a current-carrying heating wire of a heating coil in a stationary housing where the solder is molten.

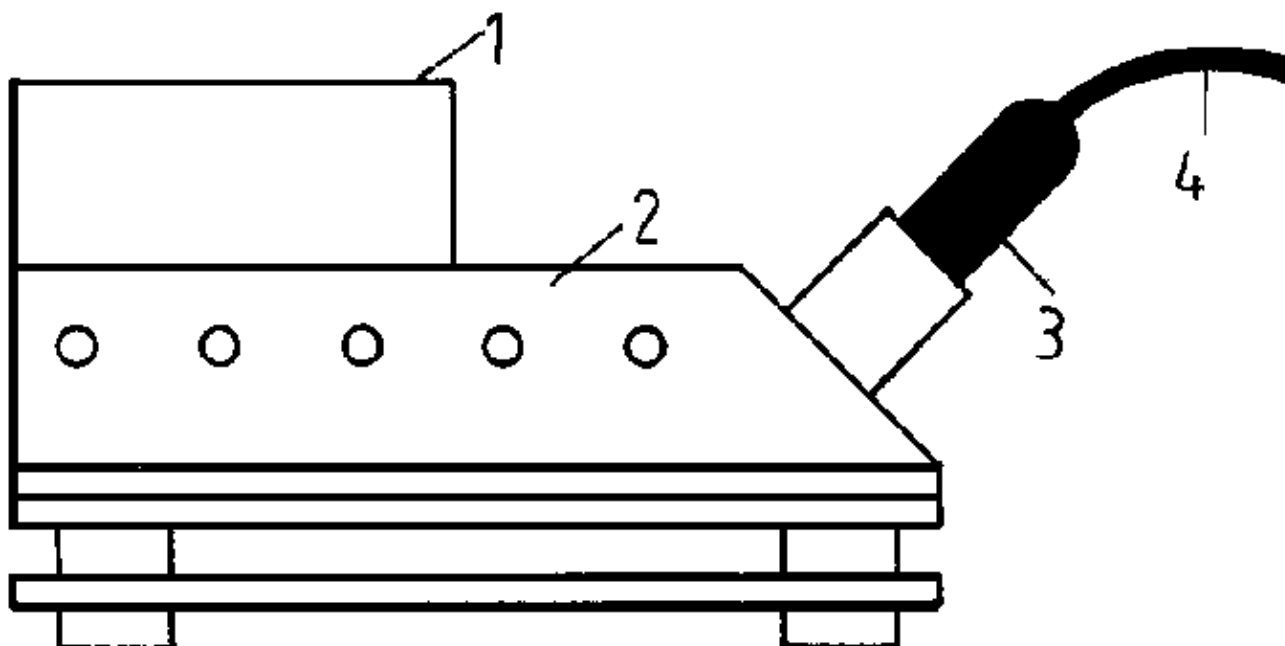


Figure 2 – Schema of a soldering plating bath – 1 soldering tin vessel, 2 electric heating, 3 plug, 4 lead

There are two types of soldering baths:

- Dipping bath for soldering of wires
- Flow–soldering bath for soldering of printed circuit boards.

Gasoline blowtorch

Gasoline blowtorches can be operated independently of the electric mains and are mainly used for soldering large cross–sections.

The following instructions are to be followed when working with the gasoline blowtorch:

- Don't fill the gasoline tank with more than three quarters of its capacity.
- Close the gasoline tank tightly – make sure that the sealing in the screw cap is fitting well.
- Pour the spirit into the preheating bowl and ignite it. By preheating, the gasoline absorbed by the wick is heated and gasified in the gasifier.
- Before the spirit flame extinguishes, let gas from the nozzle into the blow pipe by opening the control knob and ignite the gas. The vent slots in the blow pipe will supply air so that the correct mix of gas and air will be generated.
- Adjust the flame correctly by means of the control knob.
- Use the first third of the flame for soldering.

Gas blowtorch

Gas blowtorches can be used independently of the electric mains and are universal in use by various nozzles and attachable bits. The following instructions are to be followed when working with the gas blowtorch:

- Make sure that all connections are tightly fitting.
- Don't interfere with the pressure relief valve.
- When working in cable shafts etc., place the gas cylinders outside the cable shafts.

Wrapping tools

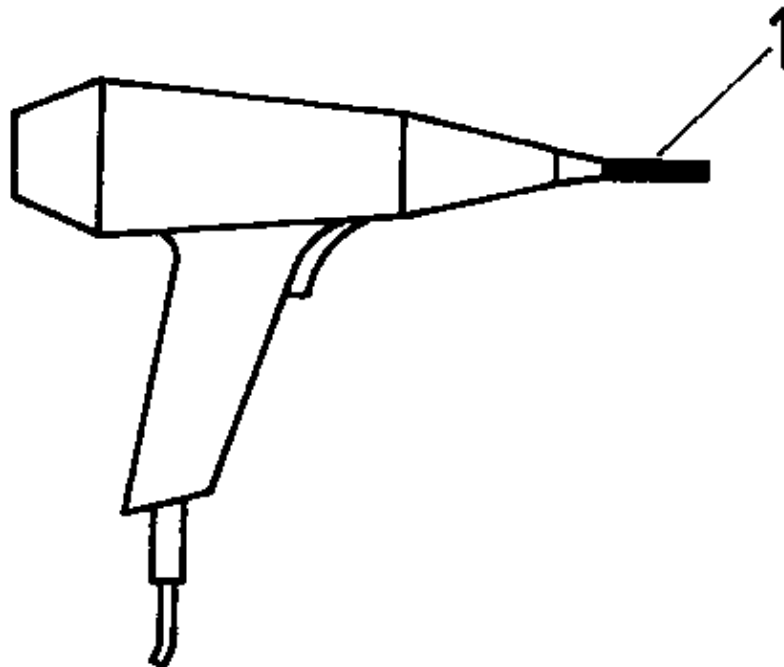


Figure 3 – Wire wrapping tool (wrapping gun) – 1 *wrapping mandrel*

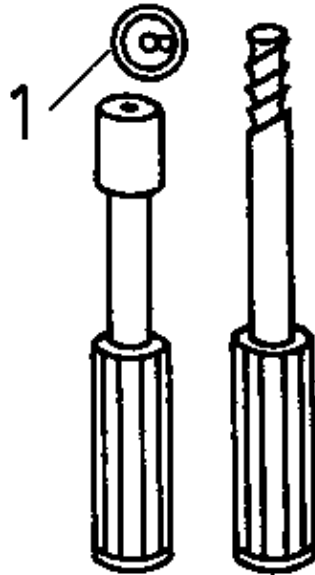


Figure 4 – Wrapping mandrels – 1 front bores

Wrapping tools are required to join one more solid copper conductors of 0.3 mm to 1.0 mm diameter by a tag or to separate them.

The wrapping mandrel is the front pan of the wrapping gun or wrapping needle, i. e. the actual wrapping tool. It is provided with two holes at its front end, one is exactly in the centre and one is off–centre. The centre hole accommodates the wrap pin to be joined with the wire. Because the wrapping mandrel must rotate around the wrap pin, this hole must be 0.1 to 0.2 mm larger than the wrap pin's diagonal. The off–centre hole accommodates the stripped wire. The corkscrew type wrapping needle serves for opening the joint.

Notching tools

Notching pliers are used to join a conductor with a cable eye or several conductors in a sleeve by notching or crimping. In order to be able to handle various conductor cross–sections, two adaptors are required for the notching pliers. The adaptors required for flexible copper conductors, for example, are

0.75... 1.5 mm² and

2.5... 10 mm² cross–section.

For smaller conductor cross–sections the crimping is done with a flat nose plier or adjusting plier.

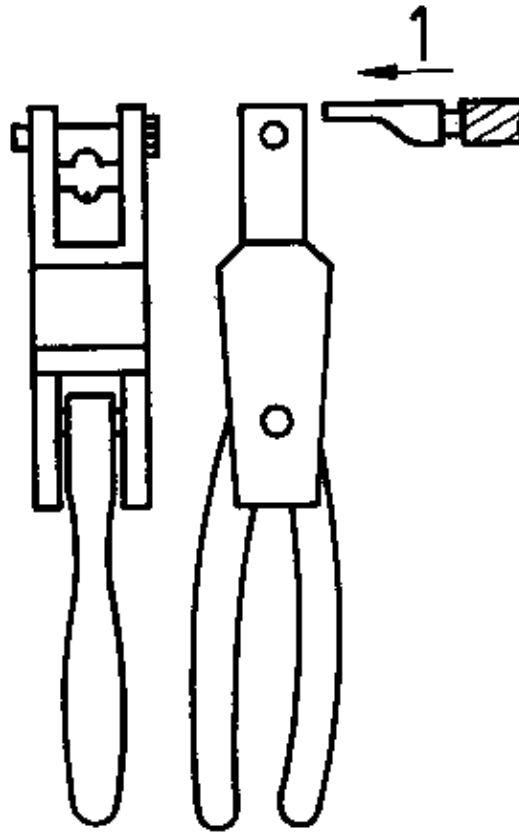


Figure 5 – Notching pliers with tool insert – 1 direction of leading in the cable eye

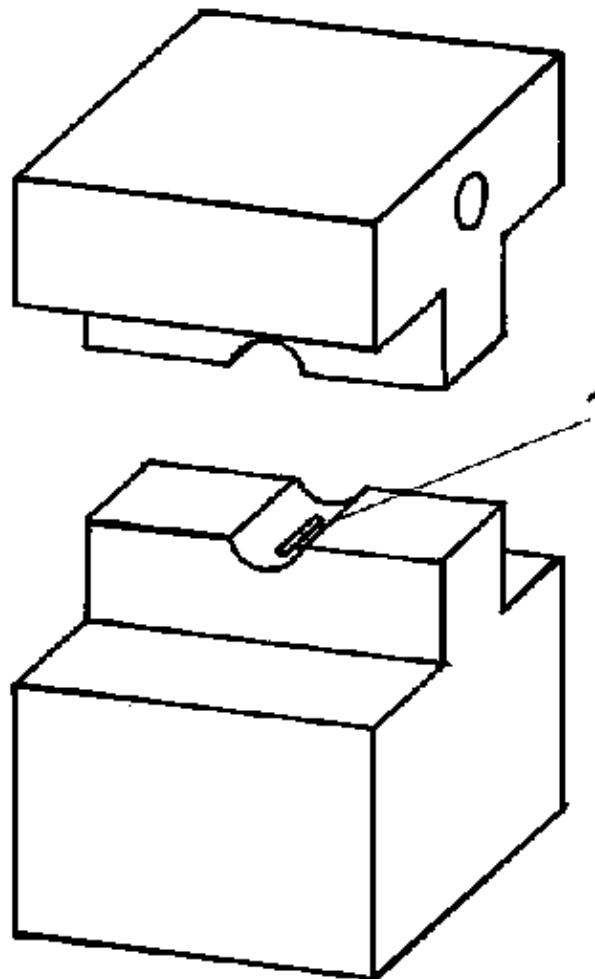


Figure 6 – Tool insert – 1 movable grooved pin

Pressing tools

Pressing pliers are used to join a conductor with a cable eye by pressing. For handling various conductor cross-sections and various conductor materials, different pressing adaptors are required.

The adaptors required for flexible or multi-core conductors, for example, are:

- pressing head with cable shear cutter
- pressing head for copper conductors 0.75... 10 mm²
 10... 120 mm²
- pressing head for aluminium conductors 16... 185 mm²

A hand pressing plier is required for pressed joints of 2.5 mm² aluminium conductors and press-sleeve. The table below is to be completed with the respective tools.

material-closed joints	force-closed joints	form-closed joints

3. Soldered Joints

Soldering is a technique of joining metal by means of molten additional metal (solder). In electrical engineering/electronics, the soft soldering technique (melting point of the solder below 450 °C) is applied.

3.1. Accessories

Soldering fluxes

Soldering fluxes are non-metallic materials preparing the metal surface for soldering. They are important for faultless soldering.

Soldering fluxes have the following properties:

- Removal of unwanted layers from the metal surface.
- Complete moistening of the metal surface to facilitate flowing of the solder.
- Protection of the cleaned metal surface against oxidation.

Soldering fluxes and their behaviour and use:

Soldering fluid	aggressive	for thick multi-core conductors
Soldering paste	aggressive	for thick multi-core conductors or heavily or oxidized conductors
Soldering tincture	conditionally aggressive	for fine soldering
Colophony (rosin), solid or dissolved in spirit	non-aggressive	for manual fine soldering

Solders

Solders are metals with a lower melting point than that of the metals to be joined. Common solders are tin and lead based.

Depending on their use, they are available in different forms:

- Bar solder for soldering baths.
- Thread type solder for manual soldering.
- Strip solder with flux for manual soldering.
- Friction solder for manual soldering of aluminium.

Cleaners

Fluxes, such as soldering tincture or soldering paste, become detrimental to the properties of soldered joints in the course of time. Therefore, it is necessary to remove flux residues after soldering. For cleaning of the soldered joints we use

- spirit or
- naphtha.

3.2. Steps of Work

In practice, there is a variety of forms of soldered joints. The preparation for soldering, however, is always the same.

The following steps are involved:

- Cutting to length and stripping of conductors

The stripping length depends on the relevant use. Stripped conductors must not be notched – risk of breakage!

Tools for stripping of conductors:

Conductor diameter/	conductor cross-section	Tool
Single-wire conductor	0.45... 0.8 mm	
Single-wire conductor	1.0 mm, 1.5... 6 mm ²	
Conductors of more than	6 mm ²	
Wire and tinsel conductors		

- Cleaning of soldering surfaces

Soldering surfaces are stripped conductors, leads (pigtails) of components as well as connections of conductors and components. For making a proper soldered joint it is necessary to clean the surface to be joined by soldering. Depending on the soldering surface, cleaning is done by

- paint stripper (scraper) for small wire diameters and components
- cable stripper for big wire wire diameters
- wire brush
- flame cleaner for enamel-insulated wires (diameter smaller than 0.2 mm)

- Flux-treatment of soldering surfaces

Why must soldering surfaces be treated with flux prior to soldering?

- Tin-coating of soldering surfaces

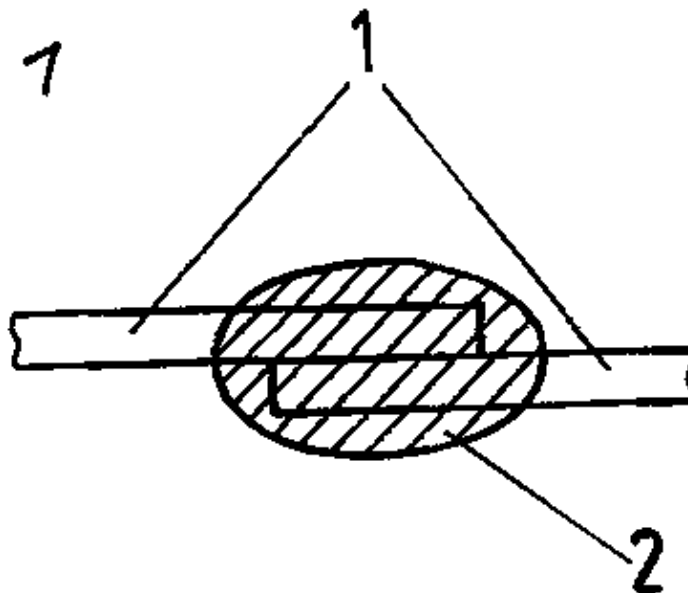
With thin-coating a material-closed joint is made by heating the soldering surface above the melting point temperature of the solder by means of a soldering device and by supplying solder on the soldering surface.

- Making soldered joints

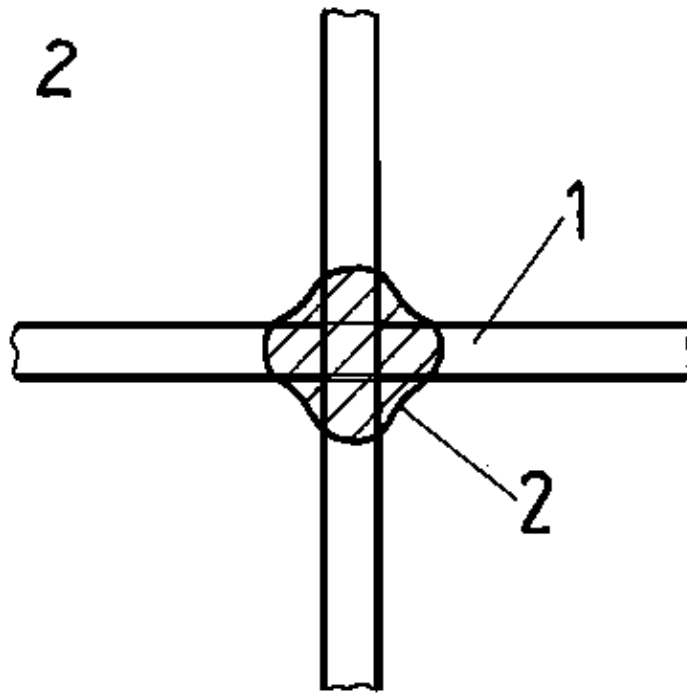
Soldered joints are material-closed joints (bonds) of two solderable metals. There are different forms of soldered joints:

– Wire-to-wire joints as parallel, cross or hook joints as well as soldered joints with twisted wires. Parallel and cross joints are mechanically connected by the solder only and, therefore, can be more easily detached. Hook joints and joints with twisted wires are mechanically stronger and more difficult to detach. The tin-coated wires are put together according to the type of joint. The joint is heated above melting-point temperature of the solder by means of the soldering iron and bonded with soldering tin added. Then the soldered joint must cool down with no displacement of the wires.

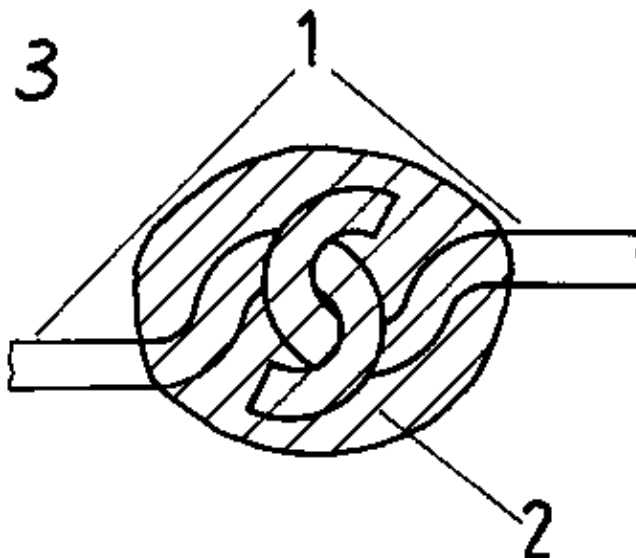
Figure 7 Soldering joints – 1 conductor, 2 soldering joint



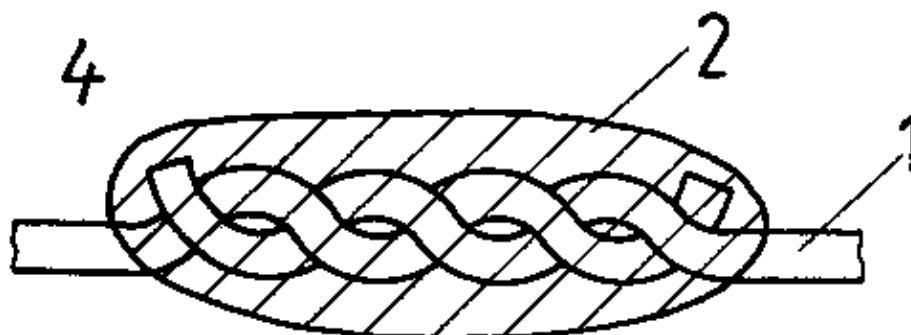
7.1. single or parallel joints



7.2. cross joint



7.3. hook joint



7.4. twisted joint

– Wire and cable eye

The cable eye is to be selected depending on the size of the conductor and to be tin-coated, if necessary. A flexible insulating tube is to be slipped over the conductor and, after soldering, over the cable eye and to be fed into the cable eye. The joint is to be heated by means of a soldering device and when adding solder the

sleeve of the cable eye is filled. It is to be made sure that the wire end and cable eye form a clear end.

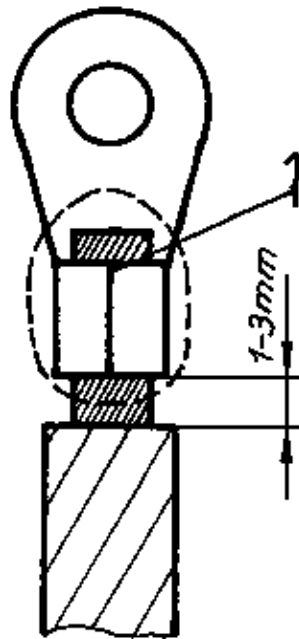
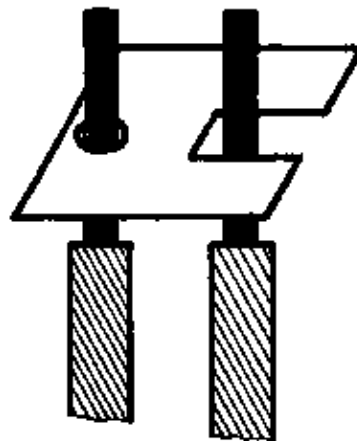


Figure 8 – Wire and cable eye – 1 point to be soldered is to be tin-coated

– Wire and soldering tags



Soldering tags are produced in various forms. The wire is to be led into the respective tag and to be clamped in place by a flat nose plier. Then the soldering tag is heated by means of the soldering iron and by adding soldering tin the joint is made.

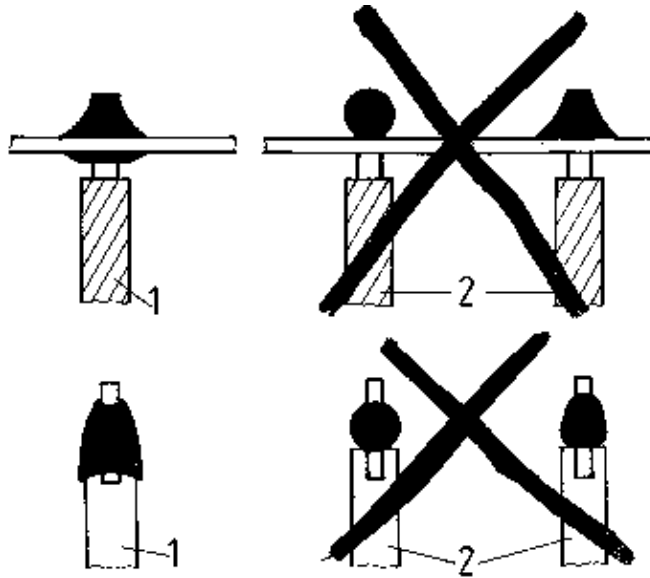


Figure 9 – Wire and soldering tags – 1 correct, 2 incorrect

– Component and soldering tag

What steps are required for joining a component and soldering tag?

– Component and wire

A component–wire–joint is made like a hook type soldered joint.

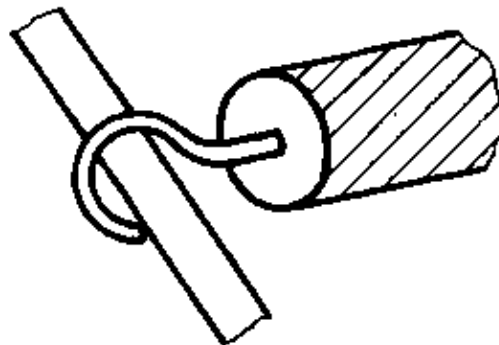


Figure 10 – Component and wire

– Components on printed circuit boards

Soldering on printed circuit boards is to be done quickly and exactly. The soldering iron's capacity should not exceed 60 W so as not to destroy the sensitive semiconductor components by high temperature. The leads of the components are to be bent and cut to length according to the hole spacing on the printed circuit board and to be tin-coated, if required. The component is to be inserted and the soldering eye and the lead are to be heated from the conductor end by means of a soldering iron adding solder.

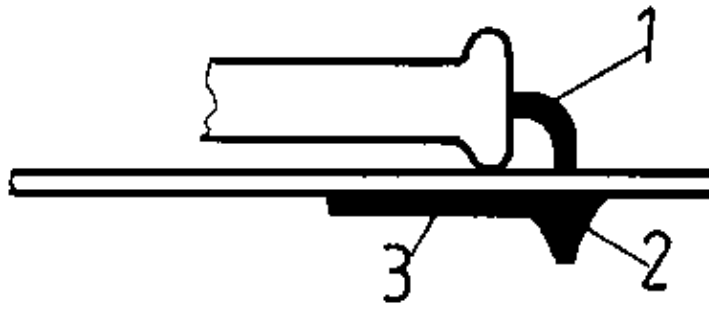


Figure 11 – Components and printed circuit boards – 1 lead, 2 soldering point, 3 printed circuit board trace

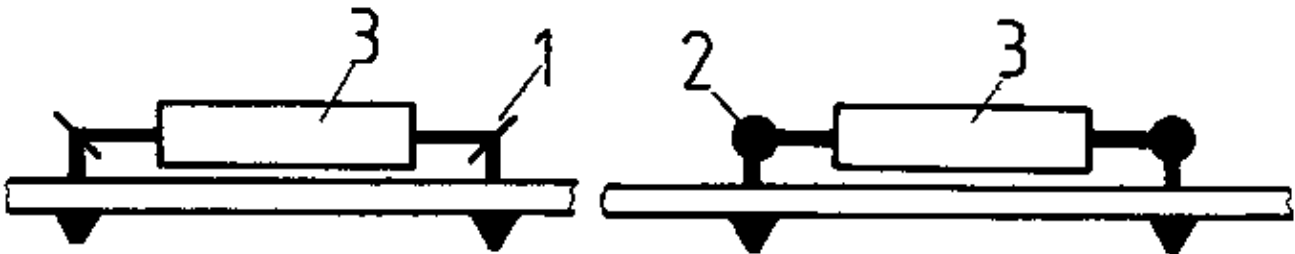


Figure 12 – Replacing a component – 1 separation point of the defect component, 2 soldering point of the new component, 3 component

What steps are required for replacing a component in Figure 12?

• Inspection of the soldered joint

A correct soldered joint features:

- a consistent, bright surface,
- perfect bond between the solder and the parts connected,
- no holes or inclusions in the surface,
- a mechanically strong connection.

What are the causes for a bad soldered joint showing the following faults?

Soldered joint	Cause
Grey surface Bad bond of solder	

4. Wire-wrap Joints

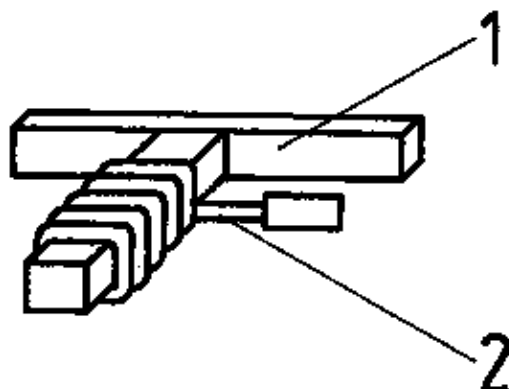


Figure 13 – Wire-wrap joints – 1 wrap pin, 2 wire to be connected

Wire-wrap joints serve to connect solid copper wires of 0.3 mm to 1.0 mm diameter with the respective connecting elements. The wire-wrap joint restricts the electric connection to the two mechanical elements absolutely necessary:

- the wire to be connected
- the wrap pin as connecting element.

Using technological properties of the wire and wrap pin, it is possible to do without solder, flux and heat. Disadvantages of soldered joints are excluded. A maximum of 7 windings is required to achieve a correct joint mechanically and electrically. The joint is generated by plastic flow in the wire at the edges of the wrap pin. The sharp edges of the wrap pin are penetrating into the wire with the oxide layers on the wire and/or wrap pin being removed by scraping and squeezing. Since 7 windings are made, several metallic, clean and gas-proof contact faces are generated. Corrosion on the contact faces is not possible.

Steps of work

- Cutting to length and stripping of conductors

The stripping length results from the number of turns multiplied by the circumference of the wrap pin. As a general rule, a stripping length of approximately 25 mm can be considered for any wire diameter.

Why must stripped wires not be notched?

- Feeding the wire into the wrapping mandrel

The wire is to be fed into the smaller off-centre hole of the wrapping mandrel, to be bent over and held in place.

- Making the wire-wrap joint

The wrapping mandrel is slipped on the wrap pin with the central hole. The wrapping process may start at any point in the wrapping area of the pin. By rotating the wrapping mandrel the wire end is drawn off the hole and firmly wrapped around the wrap pin. In order to ensure that the individual windings are closely fitting, the wrapping mandrel is to be pressed towards the base during wrapping. If several wires are to be connected to one wrap pin, the wires are to be wrapped one after another.

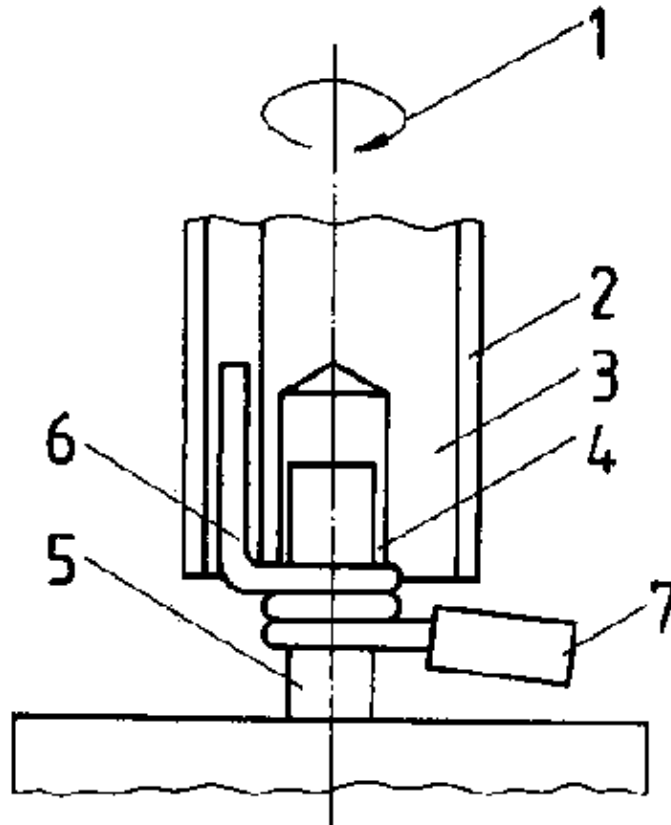


Figure 14 – Making the wire-wrap joint – 1 winding direction, 2 wrapping mandrel, 3 wrapping mandrel part for socket, 4 socket for wrap pin, 5 wrap pin, 6 wire fed into off-centre hole, 7 wire to be connected

• Inspection of the wire-wrap joint

A correct wire-wrap joint features:

- the correct number of turns (windings),
- closely fitting windings,
- no overlapping windings.

The inspection also includes strength testing.

The strength is tested by means of a drawing-off claw and a spring balance.

The joint has the correct strength is not achieved, the joint is to be re-made.

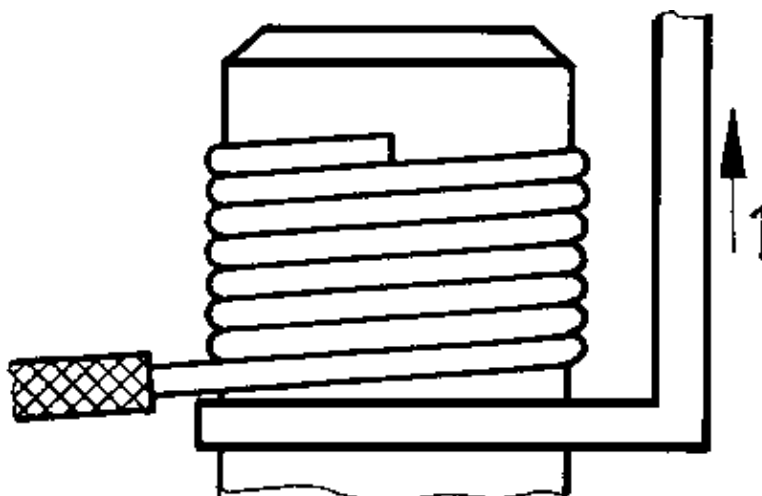


Figure 15 – Strength testing – 1 tensile force direction of the drawing-off claw

Wire diameter	0.3	0.4	0.5	0.6	0.8	1.0	mm
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Required strength	2.0	2.5	3.0	3.5	4.0	4.5	kgf
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• Opening the wire-wrap joint

Any wire-wrap joint can be detached by means of the wrapping needle and then be re-made. The corkscrew type wrapping needle is put on the wrap pin with the hole. By rotation opposite to the wrapping direction of the wire, the wire is lifted and thus the joint is opened. Once used for wrapping, the piece of wire must not be used again for a wire-wrap joint since because of notches there would be a risk of breakage. The wire must be cut off and stripped again.

5. Notched Joints

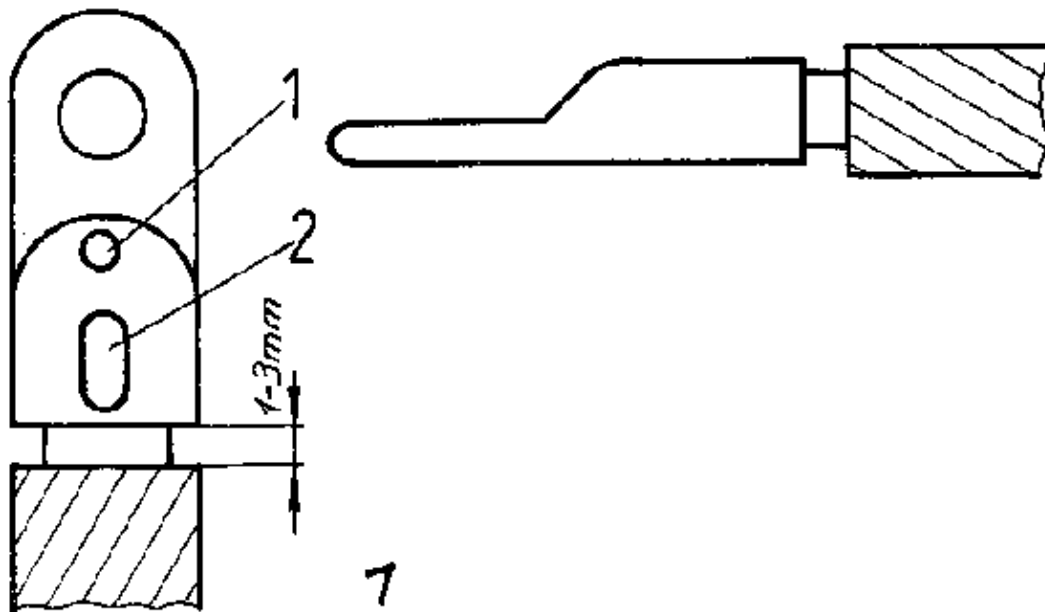
Notched joints are a way of connecting cable eyes with flexible copper conductors or rigid copper or aluminium conductors by means of a sleeve.

Flexible conductors may have a cross-section of 0.02 mm² to 10.0 mm² while for rigid conductors cross-sections of 0.2 mm² to 4.0 mm² are possible.

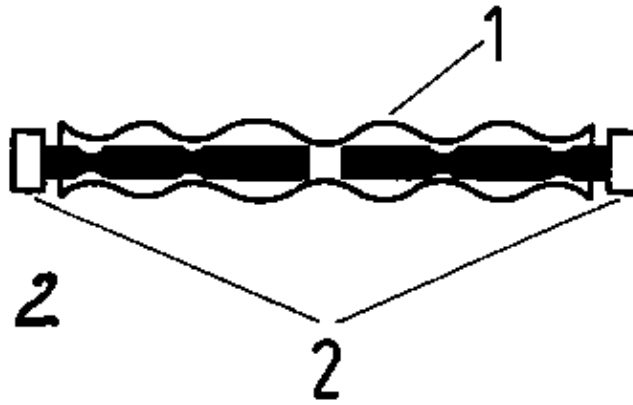
The joints are squeezed together by means of additional metal (cable eye or sleeve).

What are the advantages of notched joints over soldered joints?

Figure 16 – Notched joints



16.1. cable eyes and conductors prepared for notching, – 1 hole for conductor check, 2 pressed mark



16.2. longitudinal notched joint – 1 notch connector, 2 ends of conductor

Steps of work

- Cutting to length and stripping of the conductor The stripping length depends on the required size of the cable eye or sleeve.
- Cleaning of the conductor

In order to achieve good contact of the notched joint the conductors must be free from oxide and/ or varnish.

Which tools are required for cleaning of conductors depending on the cross-section?

- Feeding the conductor into the cable eye or sleeve

When inserting the conductor it is important that the size of the cable eye or of the sleeve is in accordance with the conductor cross-section. The space available in the cable eye or sleeve is to be fully utilized for the conductor.

In the case of flexible conductors with a small cross-section the conductor is to be bent towards the insulation and to be inserted in the cable eye together with the insulation in order to increase the strength of the joint.

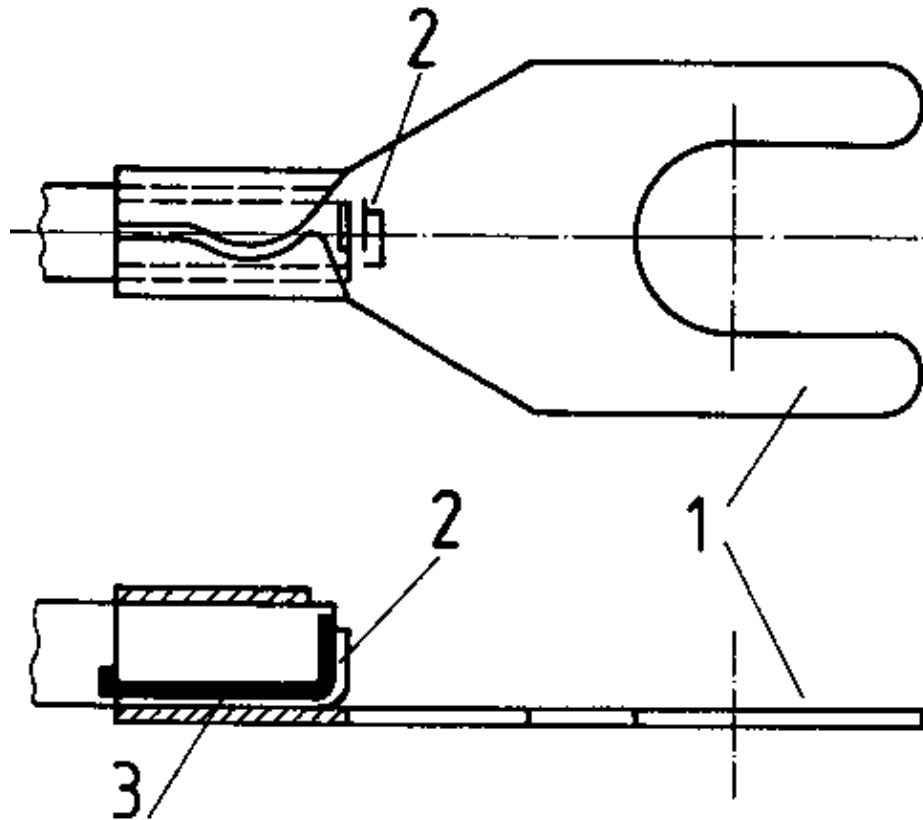


Figure 17 – Notched and crimped joints for flexible cables – 1 cable eye, 2,3 insets

- Making the notched joint

Before the cable eye or sleeve is put into the notching plier it is to be made sure that the correct adaptor is fitted. The cable eye or sleeve is to be put into the notching plier so that notching takes place in the centre. The notching plier is to be pressed down up to the stop and then removed. For joints with cable eyes of less than 0.5 mm² cross-section, flat nose pliers or adjusting pliers may be used. In this case the individual straps are bent over by the plier one after another.

- Inspection of the joint The conductor (s) must be firmly seated in the cable eye or sleeve.

How is a notched joint checked for firm seat?

6. Pressed Joints

Pressed joints are a way of connecting cable eyes with a multiple-wire or flexible conductor. The cable eyes are selected so as to suit the cross section and material of the conductor. Conductor and cable eye must be of the same material. The joint is made by means of a pressing tool.

What cross-sections of copper or aluminium conductors can be pressed?

Steps of work

- Cutting to length and stripping of the conductor
- Cleaning of the conductor
- Feeding the conductor into the cable eye or the conductors into the sleeve

The press-sleeve must be used only for aluminium conductors of 2.5 mm² cross-section.

Three conductors must always be fed into the press-sleeve.

If only two conductors are to be joined, third conductor is to be used as filler.

• Making the pressed joint

The cable eye or the sleeve is to be put into the respective tool with existing marks for fixing the position to be considered. In correct position the pressing process can be performed.

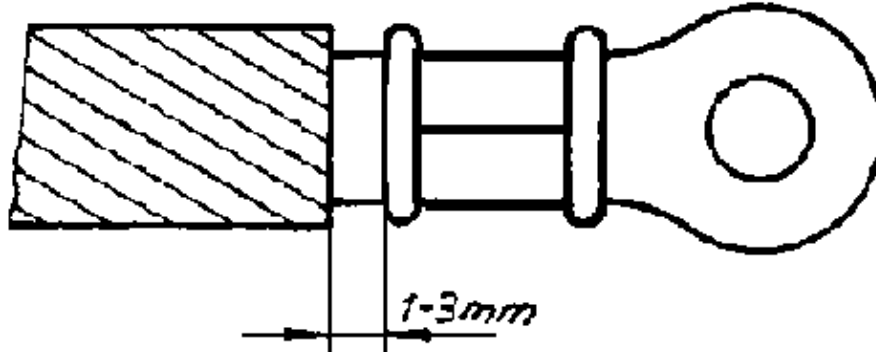


Figure 18 – Marked and fixed cable eye connections

After the pressing process the cable eye or sleeve is to be removed from the pressing tool. The flash produced at the cable eye is to be removed by a side cutting plier or by a file. The insulating sleeve is to be slipped over the press-sleeve until the conical end sticks on the press-sleeve. The pressing tools are to be cleaned after use.

Why must the flash at the cable eye be removed after pressing?

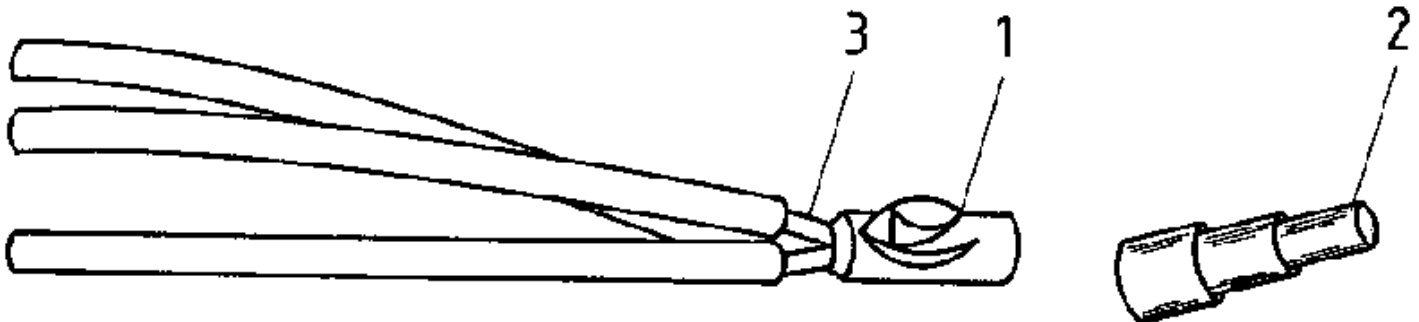


Figure 19 – Sleeve or passed joint – 1 press-sleeve, 2 insulating sleeve, 3 conductors to be connected

• Inspection of the pressed joint

Check gauges are used for checking the proper execution of the pressing

What steps are required for making the various types of joints?

soldered joint wire-wrap joint notched joint pressed joint

- 1
- 2
- 3
- 4

5

6

