

Basic Vocational Knowledge – Electrical Installation

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Introduction

This textbook "Fundamentals of Trade – Electrical Installation" concerns all trainees working as electrical fitters or service electricians in vocations of power installation. It contains a choice of the most important installation technologies resp. techniques to be mastered in the wide working field of installing electrical plants up to 1 kV.

A multiple of illustrations assists in understanding the text. In particular these illustrations serve for easy classification and systematizing of the individual installation activities.

For better finding the important matters "notes on essentials" were introduced being marked by a vertical line in front of the wording. Important hints on labour safety are marked by two vertical lines.

At the end of each section a summary is given being also listed in the table of contents.

This textbook is to contribute to teaching and strengthening of the basic knowledges and basic abilities to be acquired by the trainees.

Explanation of formules, circuit symbols and wiring diagrams was renounced. These may be seen from the current installation instructions.

1. Protective measures against too high a contact voltage and conduct following electrical accidents

1.1. Earthing of electrical systems

An electrical installation is defined as the totality of equipment assembled into a technical unit for the purpose of generating, transferring, distributing, storing or converting electrical power.

In an electrical installation earthing plays an important part for safety and functionality.

Earthing is the totality of all means and measures for connection to earth.

Earthing systems are applied to safely leak lightning, creeping and fault currents via the soil. Moreover, earthing systems are serving to warrant certain operation processes like

- return of fault currents (closing the fault current circuit)
- mastering of line-to-earth faults
- safety in case of defects in transformers.

The following definitions are given:

- lightning currents: currents originating from stroke of lightning into an electrical installation
- creeping currents: currents making current transition possible along the surface of a fixed insulation between parts being under voltage relative to each other
- fault currents: currents flowing due to an insulation fault.

The current flowing via the earthing electrode does not spread itself in the ground, but closes the fault current circuit via the earthed point of the network and the ground.

Earthing electrodes are non-insulated conductors being directly embedded in the ground. Depending on their purpose a difference is made between system earthing electrodes, protective earthing electrodes, control earthing electrodes and auxiliary earthing electrodes.

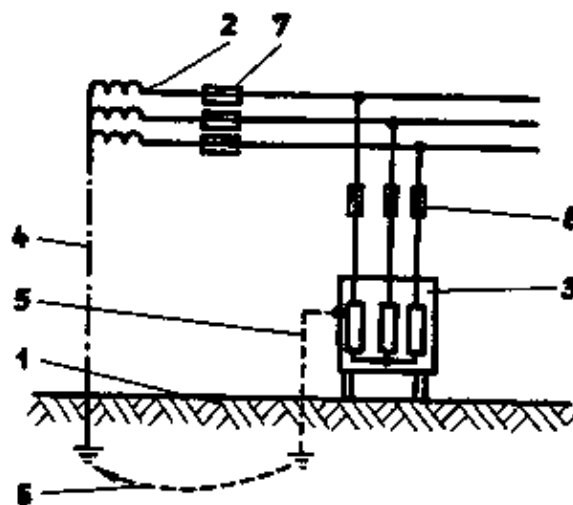


Fig. 1.1. Construction of an earthing system

1 soil, 2 secondary side of feeding transformer, 3 consumer's installation, 4 system earth electrode, 5 protective earth electrode, 6 path of returning fault current in case of fault, 7 main fuses, 8 fuses of consumer's installation.

Earthing systems therefore consist of:

- conductive earthing electrodes connected to each other and
- earthing lines resp. earthing concentration lines being positioned between the electrical equipment and the earthing electrodes.

Earthing is creation of a conductive connection between conductive parts of the equipment and the ground via an earthing system.

System earth electrodes serve to earth one point of the operating circuit (neutral point resp. earthed phase conductor).

Protective earthing electrodes serve to earth conductive parts of the system not belonging to the operating circuit, to which in case of fault voltage may be applied, like e.g. casings of electrical equipment.

Auxiliary earth electrodes serve for monitoring neutral conductors, for taking up measuring currents in case of earth measurements and for connection of the fault voltage circuit breaker at voltage-operated earth-leakage circuit breakers.

Control earth electrodes serve to influence the potential curve in the ground.

For transferring electrical currents into the ground all conductors are suited which have well conductive connections to the ground. Metal constructions, waterpipes or rails are fulfilling – save their actual purpose – their task as earthing electrodes as well as earth electrodes placed in the ground being determined for earthing only.

Contrary to the artificial earth electrodes placed in the ground exclusively for the purpose of earthing, conductors being well suited as earth electrodes, but primarily put into the ground for other tasks, are called natural earth electrodes.

Earthing electrodes are either dug into, driven into or placed in boreholes in the ground. Depending on their depth in the ground they are classified in surface and depth earthing electrodes. In case of a combination of these two types of earth electrodes they are called combination earthing electrodes.

<u>Classification of earth electrodes</u>	<u>Depth in ground</u>
Surface electrodes	up to 3 m
Depth earth electrodes	more than 3 m

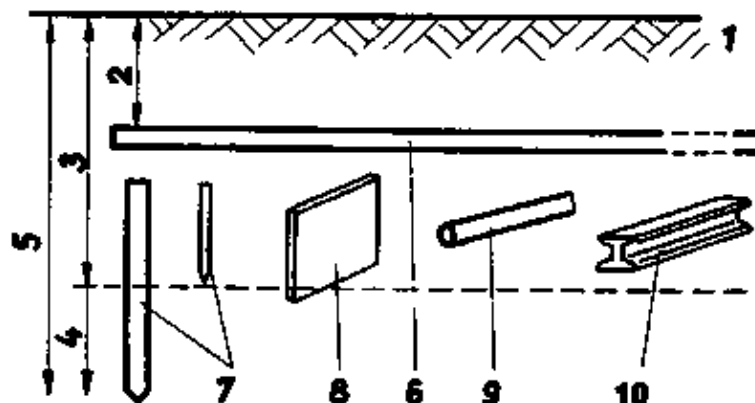


Fig. 1.2. Types of earth electrodes

1 soil, 2 min. depth 0.8 m, 3 surface earth electrode. 4 depth earth electrode, 5 combination earth electrode, 6 strip earth electrode, 7 earthing rod, 8 earthing plate, 9+10 natural earth electrodes: pipeline and metal structure.

The advantage of natural earth electrodes as compared to artificial earth electrodes is avoiding earthwork. Earthing electrodes are named after the material used. Earthing electrodes are discerned according to their depth–position. Earthing electrodes are selected according to the condition of the ground. Hot–dip galvanized round steel being used in lightning arresting engineering since long ago is best suited as surface earthing electrode.

- At the same cross section it exposes a smaller surface for attacks by corrosion.
- Due to its round shape, its bond with the surrounding soil will be better.

When building earthing systems it is not the quality and cross section of the applied earthing material which is decisive, but a good quality of electrical connection with the surrounding soil!

Table 1.1. Materials of earth electrodes

Earth electrode	Material	Min. dimensions
Strip earth electrode (flat earth electrode)	hot–dip galvanized strip or round steel	Cross section 100 mm ² Thickness 3 mm diameter 10 mm
earthing rod	hot–dip galvanized angle	40 mm × 4 mm
	hot–dip galvanized	ext. diameter 24 mm
	steel pipe	wall thickness 3 mm
	hot–dip galvanized round steel	diameter 10 mm to 24 mm
earthing plate	solid or perforated steel plate	

When installing earthing electrodes the following principles are to be observed.

- For protecting earthing strips from dehumidifying or freezing out of the soil they are to be placed in the ground at least 70 cm under the surface.
- Earthing strips may be placed together with underground cables in cable ditches, but the heat from the cable must not be able to dry out the soil. Considering the resistance of earth they must also not be placed on gravel like underground cable.
- Since earthing electrodes will be damaged by corrosion they are not to be placed in aggressive soil, in the vicinity of rubbish or in running waters. Placing earthing electrodes beneath streets (roads) is also prohibited.
- Earthing electrodes placed in the ground are to be arranged in such a way as to prevent them from affecting each other. The distance to foundations of buildings must be 1 m at least.
- After installation the soil surrounding the earthing electrode is to be carefully stamped or to be jetted in layers in case of dry, not bonding soil.
- Earthing electrodes must not be contaminated. Besides appearance of corrosion also tar, paint etc. are to be considered as contaminations.
- In order to keep the user informed about the exact position of the earthing system a precise layout plan of the earthing equipment has to be drawn.

Connection of earthing electrodes among each other are being made by keyed joints, welded joints or bolted joints. Welded joints are to be preferred.

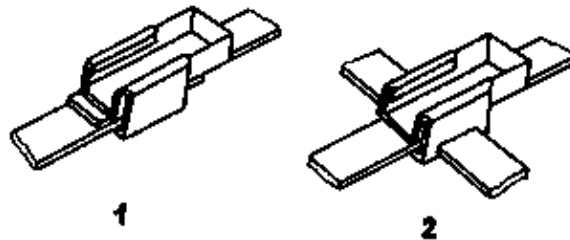


Fig. 1.3. Keyed joint of a strip earth conductor

1 passage, 2 junction.

In case of bolted joints a bolt M 10 has to be taken at least. For joining the earth lead to the auxiliary earthing electrode in case of applying the protective measure "voltage-operated earth-leakage protection" a bolt M 6 will suffice (Always hardened and tempered bolts with hexagonal head are to be used).

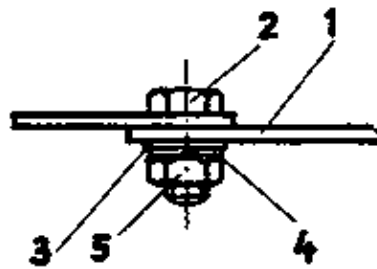


Fig. 1.4. Bolted joint of an earth lead

1 earth lead, 2 hex. head bolt, 3 washer, 4 spring washer, 5 nut.

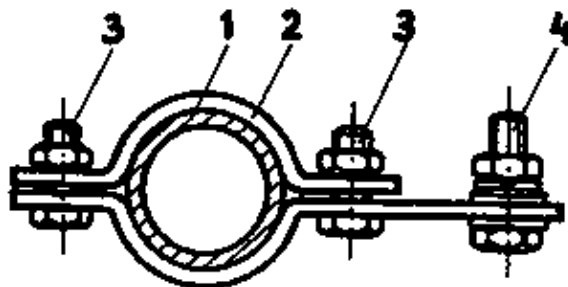


Fig. 1.5. Pipe clip for earthing connection to strip steel

1 pipeline, 2 pipe clip, 3 bolt M 8, 4 bolt M 10 for strip steel joint.

Connections to natural earthing electrodes are preferably to be made outside the soil. At points where this is impossible and at joining faces being not metallic-bright, toothed lock-washers are to be used. At joining faces being metallic-bright, joints between earthing electrodes may be made by applying spring lockwashers resp. plain lockwashers. At the joints of earthing electrodes protection against corrosion is of utmost importance. It must be durable and fully effective. By welding and drilling the zinc layer on the steel is damaged leading to stronger corrosion at the defective points. Protection against corrosion is safely warranted by application of anti-corrosive tape being wound firmly and semi-overlapping, in case of aggressive soils twice semi-overlapping, around and approx. 100 mm beyond the joint. In case of aggressive soils it is recommended to seal the anti-corrosive tape by sealing compound.

Welded joints are to be thoroughly cleaned from scale by means of a welder's hammer prior to applying the anti-corrosive tape. Earthing connections to pipes are sealed by a plastic sealing compound against humidity prior to applying the anti-corrosive tape.

Before connecting natural earthing electrodes they are to be checked for their usability.

Using gas pipes as earthing electrodes is generally forbidden due to the very high transition resistances of the sealing materials and the hazards of explosion.

On the other hand, lead sheaths of underground cables, reinforcing steels in concrete, rail track systems and waterpipe networks may be used for earthing. However, tracks used in earthing must not serve for operation of vehicles driven by direct current.

Prior to using the waterpipe network for earthing purposes the approval of the water supply utility will have to be obtained. This is important, because water meters and locking valves must reliably be bridged. These bridges must under no circumstances be removed when repairing waterpipe networks.

The material for bridges at water meters and locking valves is to be min. 10 mm² Cu, 25 mm² Al or 50 mm² hot-dip galvanized strip steel!

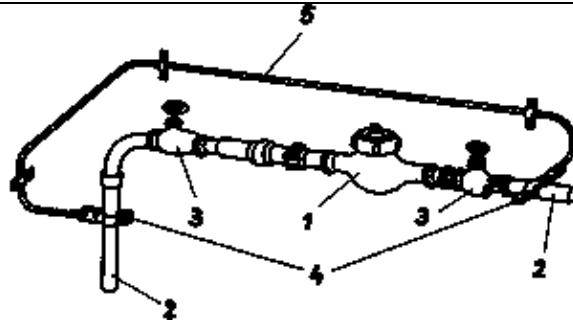


Fig. 1.6. Bridging of a water meter

1 water meter, 2 water pipeline. 3 stop valves, 4 pipe clips according to fig. 1.5, 5 bridging.

Lines connecting parts of the plant to the earthing electrode are called earth leads. When preparing earth leads care has to be taken to cut hot-dip galvanized materials by shears or saw only.

Hot-dip galvanized strip steel is aligned on simple straightening machines or on a parallel by hammer. Processed ends of hot-dip galvanized strip steel are to be deburred by filing. Bores are to be deburred properly by a countersink or bigsize drill.

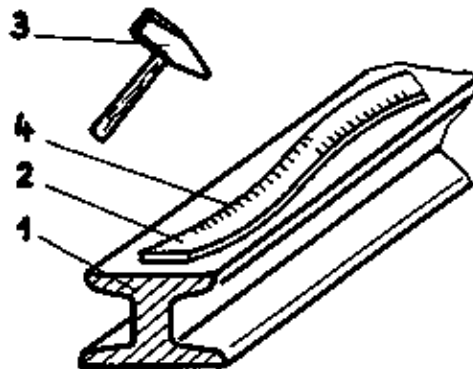


Fig. 1.7. Aligning hot-dip galvanized strip steel by hammer

1 straightening rail, 2 hot-dip galvanized strip steel, 3 hammer, 4 blow points for alignment in case of horizontal (lateral) bends.

For installing earth leads on walls, special clamps are employed. They firmly accommodate the earth leads and are easily mounted. They are directly inserted in the wall or screwed to the wall. Joints and junctions of earth leads and earthing concentration leads are to warrant a durable, safe and electrically well conductive connection.

Permitted are: bolted, welded and pressed joints, but also soldered and notched joints to stranded conductors. Also in this case welded joints are being preferred. Joints must be protected from corrosion!

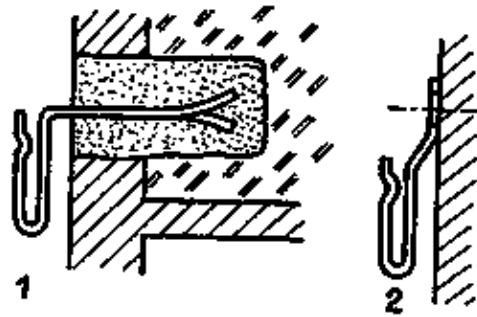


Fig. 1.8. Holders for earth leads of flat steel

1 directly to be inserted into wall, 2 screwable to wall.

The earth resistance of an earthing system may be ascertained by different methods with varying precision. The expert will select from a multiple of available measuring methods that one, supplying him with the most exact result possible, while saving time and expense and applying as little equipment as possible. Fig. 1.9. shows such a measuring arrangement at which the earth resistance may be directly read on the earthing measuring instrument fed by alternating current. It has, however, to be observed that the auxiliary earthing electrodes, earthing electrodes and sensing probe must at least be in a distance of 20 m from each other.

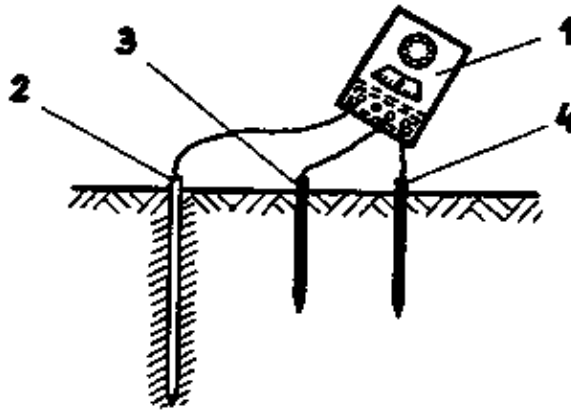


Fig. 1.9. Measuring arrangement for ascertaining earth resistance

1 earthing measuring instrument, 2 earth electrode, 3 probe, 4 auxiliary earth electrode.

The system and protective earth leads are marked by black transverse stripes at all ends and junctions. Blank earth leads in installations like e.g. copper conductors et socket outlets with earthing contact need not be marked. Insulated earth leads are to be marked green–yellow like protective conductors.

1.2. Marking of conductors and designation of networks

Practically there are three different basic types of networks:

- TN–networks with directly earthed netpoint (system earthing electrode) and protective conductor (fig. 1.10., 1.11., 1.12.)
- TT–networks with directly earthed netpoint and protective earthing electrodes at the connected parts of the system (fig. 1.13.)
- IT–networks without earthed netpoint, however, with earthed electrical appliances and parts of the system (fig. 1.14.)

In TN–networks three types may occur:

- networks with combined neutral and protective conductors are called TN-C-networks (fig. 1.10.)
- networks with separate neutral and protective conductors are called TN-S-networks (fig. 1.11.)
- networks with combined neutral and protective conductors in the first part of the network and with separate neutral and protective conductors in the second part of the network are called TN-C-S-networks (fig. 1.12.).

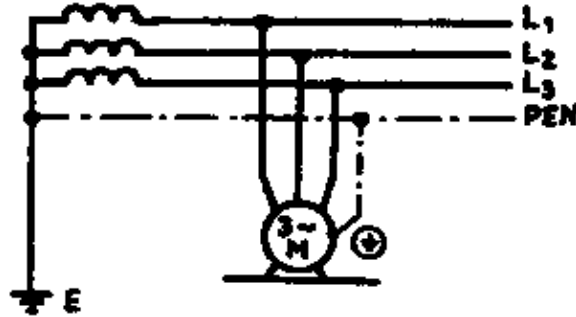


Fig. 1.10. TN-C-network

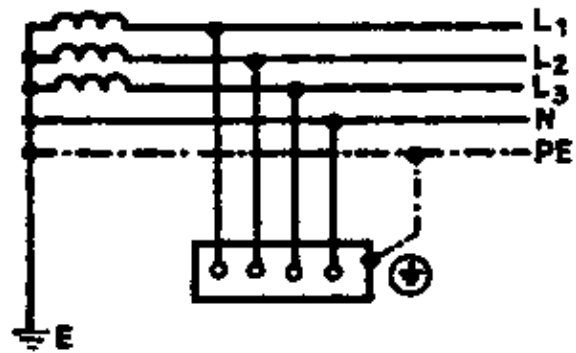


Fig. 1.11. TN-S-network

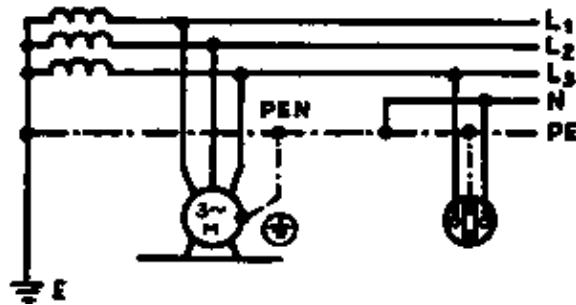


Fig. 1.12. TN-C-S-network

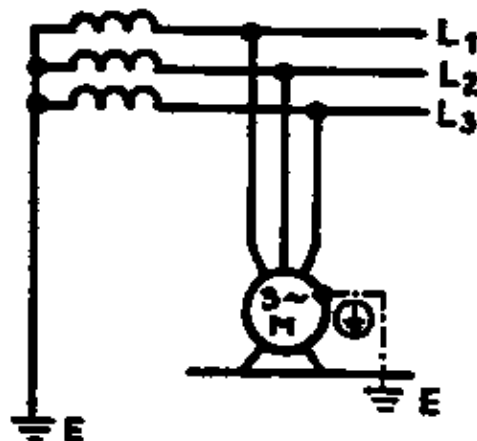


Fig. 1.13. TT-network

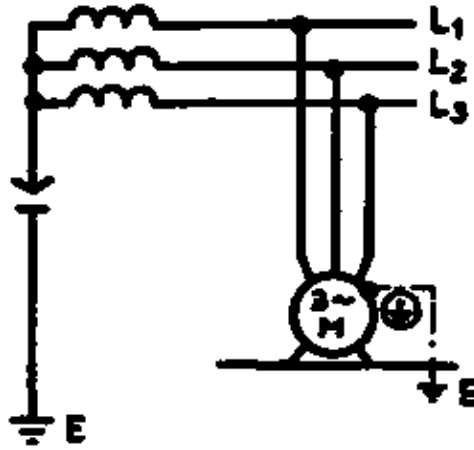





Fig. 1.14. IT-network

The letters for designation of the networks and conductors mean the following:

- T direct connection to an earthing electrode (French: terre)
- I insulation
- N neutral conductor (French: neutre)
- C combination (French: combiné)
- S separate (French: séparé)
- P protection
- E earth
- TE trouble-free earth lead (French: terre électronique).

Table 1.2. Special connection and conductor designations

System	Conductor	designation of connection		designation of conductor
		designation	circuit symbol	
ac current	any phase conductor ¹⁾			L
	1. phase conductor	U		L1
	2. phase conductor	V		L2
	3. phase conductor neutral conductor	W		L3
	without protective function	N		N
dc current	any phase conductor ¹⁾	preferably first half of alphabet		L
	positive phase conductor		+	L+
	negative phase conductor		-	L-
	centre conductor			
	without			
	protective function	M		M
protective conductor, earthed				PE

protective conductor, earthed with neutral or centre conductor function		PEN
protective conductor, not earthed		PU
potential equalization line		PA
earth lead		E
troublefree earth lead		TE

1) for designation of conductor only

1.3. Protective conductors

Protective conductors are an important basic element of protective measures against electrical shocks. Protective conductors connect conductive parts of casings in electrical appliances, conductive parts of buildings and constructions etc. to earthing electrodes.

Protective conductors are meant for protection against too high contact voltages by leaking fault currents!

In almost any case interruptions of protective conductors will result in the concerned protective measure remaining without effect. If the protective measure is not applied properly great sources of danger will be created. Therefore the expert has to take utmost care to correct dimensioning, careful installation, appropriate marking and proper connection of the protective conductors.

1.3.1. Designation of protective conductors

For preventing a mix-up with the phase conductors, protective conductors are marked by colours.

By the work of CEE and IEC the obligatory characteristic colour green–yellow was adopted for protective conductors worldwide. The colour–marking of protective conductors in cables is to be guaranteed by the maker along the overall length of the conductor. Marking of a conductor afterwards by sliding on insulating tubing on or wrapping around the ends of the protective conductor is not permissible. If no protective conductor is required this conductor will remain unused resp. cable without a protective conductor will be taken.

Conductors marked as protective conductors must be used as protective conductors, auxiliary earth leads or potential equalization lines only, i.e. for protection purposes!

1.3.2. Minimum cross sections of protective conductors

The cross section of a protective conductor is determined by its current load and type of installation. Therefore the cross section of a protective conductor being installed in a protected way may be less than the one of a protective conductor being installed unprotected.

Table 1.3. Minimum cross sections of protective conductors

rated cross section of phase conductor mm ²	min. cross section of protective conductor in mm ²			
	protective conductor insulated and against mechanical damage		protective conductor, not insulated and against mechanical damage	
	protected	not protected	protected	

				not protected
0,5	0,5 ¹⁾	4	1,0 ¹⁾	
0,75	0,75 ¹⁾			
1,0	1,0 ¹⁾			
1,5	1,5			
2,5	2,5		1,5	
4	4		2,5	
6	6			4
10	10			6
16	16			10
25	16			16
35	16			16
50	25			25
70	35			35
95	50			50
120	70			
150	70			
185	95			
240	120			
300	150			
400	135			
500	240			

¹⁾ Not permitted for fixed installation

Protective conductors of aluminium are to have a minimum cross section of 2.5 mm² if installed in a mechanically protected way. e.g. if placing cables or wires in a tube. In case of mechanically unprotected installation, e.g. insulated wires laid on the surface, however, the cross section concerned will have already to be 10 mm² at least. If insulated protective conductors with a conductor cross section below 10 mm² are laid underground they will have to be placed in a cable or sheathed line. For insulated protective conductors to be connected to earthing electrodes and therefore to be placed in the ground, only copper conductors from 10 mm² upwards are to be taken. Non-insulated conductors put into the ground will act as earthing electrodes. Due to this reason their minimum cross sections will have to be adapted to those of the earthing electrodes.

From table 1.3. the minimum cross sections of protective conductors in relation to the cross sections of phase conductors are to be seen. They are valid for conductors of copper.

1.3.3. Connection of protective conductors

The functionality of the protective measure depends on the expert connection of the protective conductor. It has to be made with the same care as for phase conductors. All electrical appliances with connection for protective conductors have protective conductor's connection points to which the protective conductor is to be

connected.

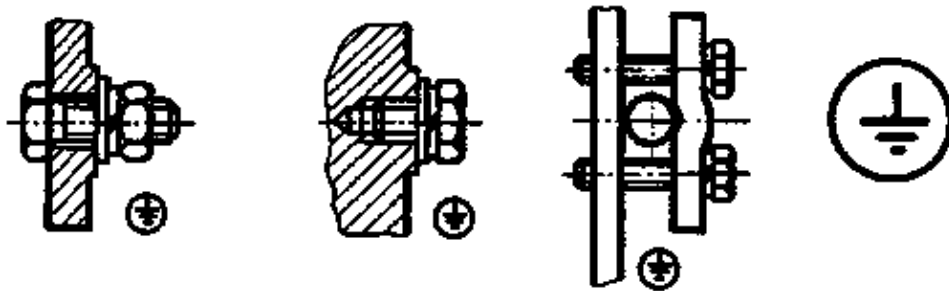


Fig. 1.15. Construction and marking of connection points for protective conductors.

If the protective conductor is passed through an electrical device to be included into the protective measure, e.g. a motor protection switch, then it will not be permissible to connect the lead-in and lead-out of the protective conductor to different points on the device's casing. The protective conductor for lead-in and lead-out (to the motor) is to be connected to a common protective conductor's connection point.

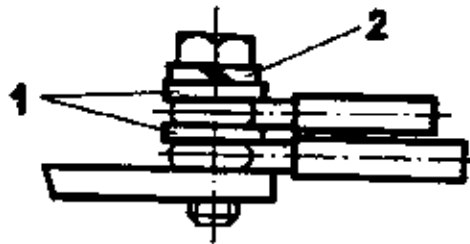


Fig. 1.16. Joining two protective conductors by one bolt

1 washers, 2 spring washer.

Flexible conductors are, prior to connection, to be protected against fanning out of individual conductor wires by soldering, by means of terminal sleeves or by cable terminals. Protective conductors of a cross section below 1 mm² may only be connected to each other by soldering.

For connection of two-pole socket outlets with earthing contact the following will hold:

- When applying the protective measure neutralization and using two-core cable the neutral conductor with the protective function will first be connected to the terminal of the protective conductor and thereafter guided to the terminal of the neutral conductor in uncut condition.
- When using three-core cable the phase and neutral conductors are being connected to one each of the voltage carrying terminals and the protective conductor to the protective conductor's terminal.

For increasing the safety of the protective measure neutralization the second method of connection is being applied. In that instance the neutral conductor and the protective conductor are connected to each other in the distribution or at the socket outlet with earthing contact. Both variants of connection serve to warrant the function of the protective measure even if there is an interruption at the terminal of the neutral conductor.

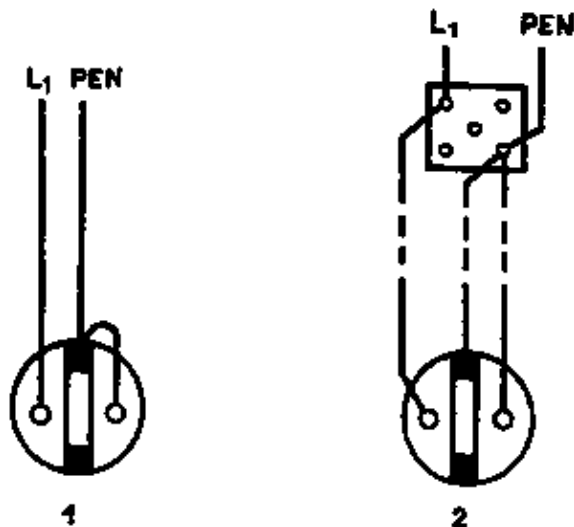


Fig. 1.17. Connection of fixed two-pole socket outlets with earthing contact on application of neutralization

- 1 connection of two-core cable,
- 2 connection of three-core cable

For connection of electrical equipment the following principle is valid:

Protection first, then function!

This means that in the wiring space of electrical equipment the protective conductor should be somewhat longer than the phase conductors, so that in case of failure or overstressing of the pull relief, first the phase conductors and then only the protective conductor are torn off their connection points. Thus the protective measure will also be effective in case of failure. When connecting portable electrical equipment having a connection point for a protective conductor, in the lead-in a separate protective conductor should be provided and connected.

Two-core flexible cables for connection of protective conductors are prohibited for safety reasons!

In the same way operating portable electrical equipment with protective conductors via sockets without earthing contact will be dangerous. On the other hand, socket outlets with earthing contacts may be used for operation of portable electrical equipment without protective conductor's connection. The commercially made plugs which are put together by vulcanizing have such a shape as to enable using a socket outlet with earthing contact.

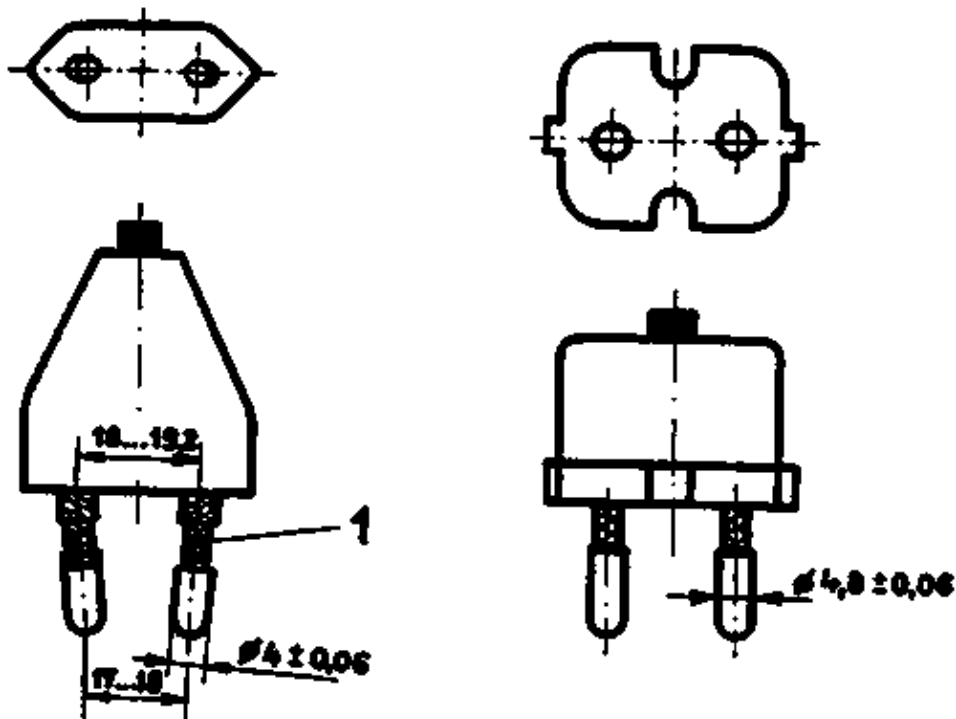


Fig. 1.18. Example for two-pole appliance plugs of portable electrical devices without protective conductor

1.3.4. Lines for potential equalization

Within buildings, as a matter of principle, potential equalization is performed, in order to prevent accidents due to displacement of voltage.

Via potential equalization lines

- all pipelines of metal (gas, water, heating),
 - cohesive building structures of metal (steel girders, window and door frames),
 - reinforcements of steel in concrete,
 - earthing systems for lightning arrest and information installations as well as
 - protective conductors when applying the protective measures protective earthing and neutralization
- are connected together on a potential equalization bar.

This potential equalization bar is to be accommodated at a well accessible location of the building, e.g. in the building's service room. The great benefit of potential equalization is the displacement of the fault potential to all available metallic parts of the building in case of failure until the nearest fuse connected in series responds, avoiding as such to a great extent the risk of accident by bridging a fault potential. The potential equalization bar may be made of hot-dip galvanized strip steel of min. dimensions 30 × 3 mm. The minimum cross sections of potential equalization lines may be taken from table 1.4.

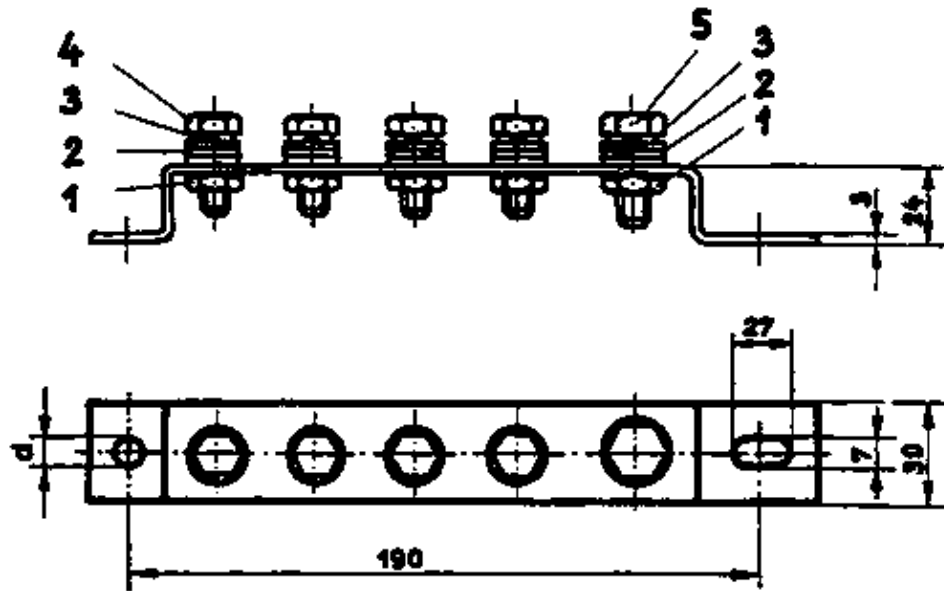


Fig. 1.19. Potential equalization bar

1 hex. nut, 2 washer, 3 spring washer, 4 hex. bolt M8, 5 hex. bolt M10.

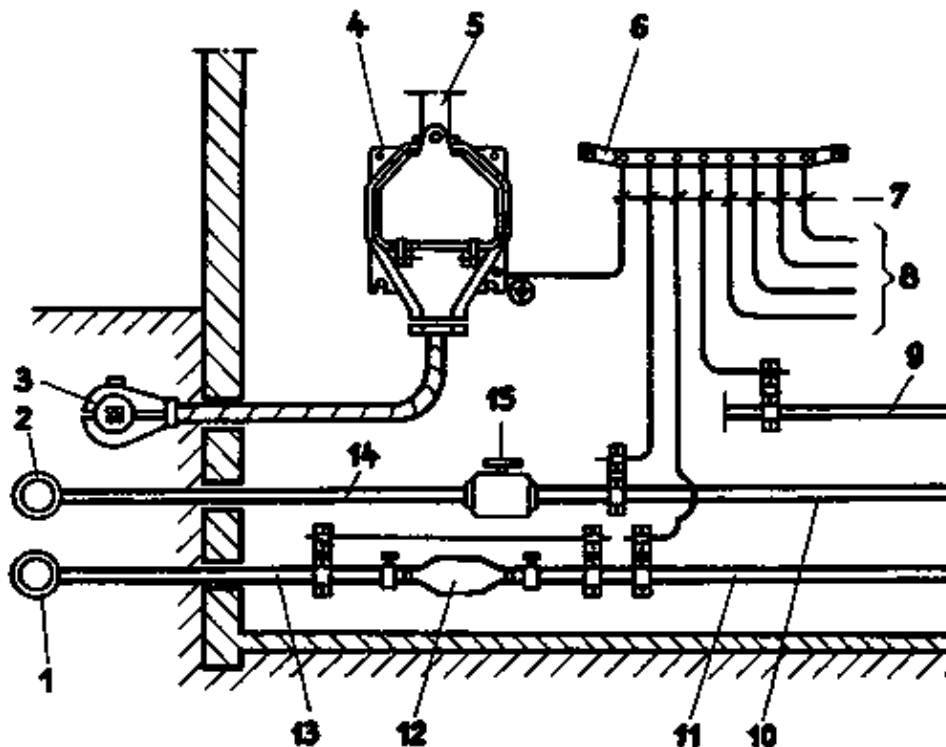


Fig. 1.20. Potential equalization for service tap via cable

1 main water pipeline, 2 main gas pipe, 3 service sleeve, 4 service box, 5 main distribution line, 6 potential equalization bar, 7 potential equalization lines, 8 to further components to be included in potential equalization, 9 heating pipe, 10 gas pipe, 11 water pipe, 12 water meter, 13 water connection pipe, 14 gas connection pipe, 15 main stop valve.

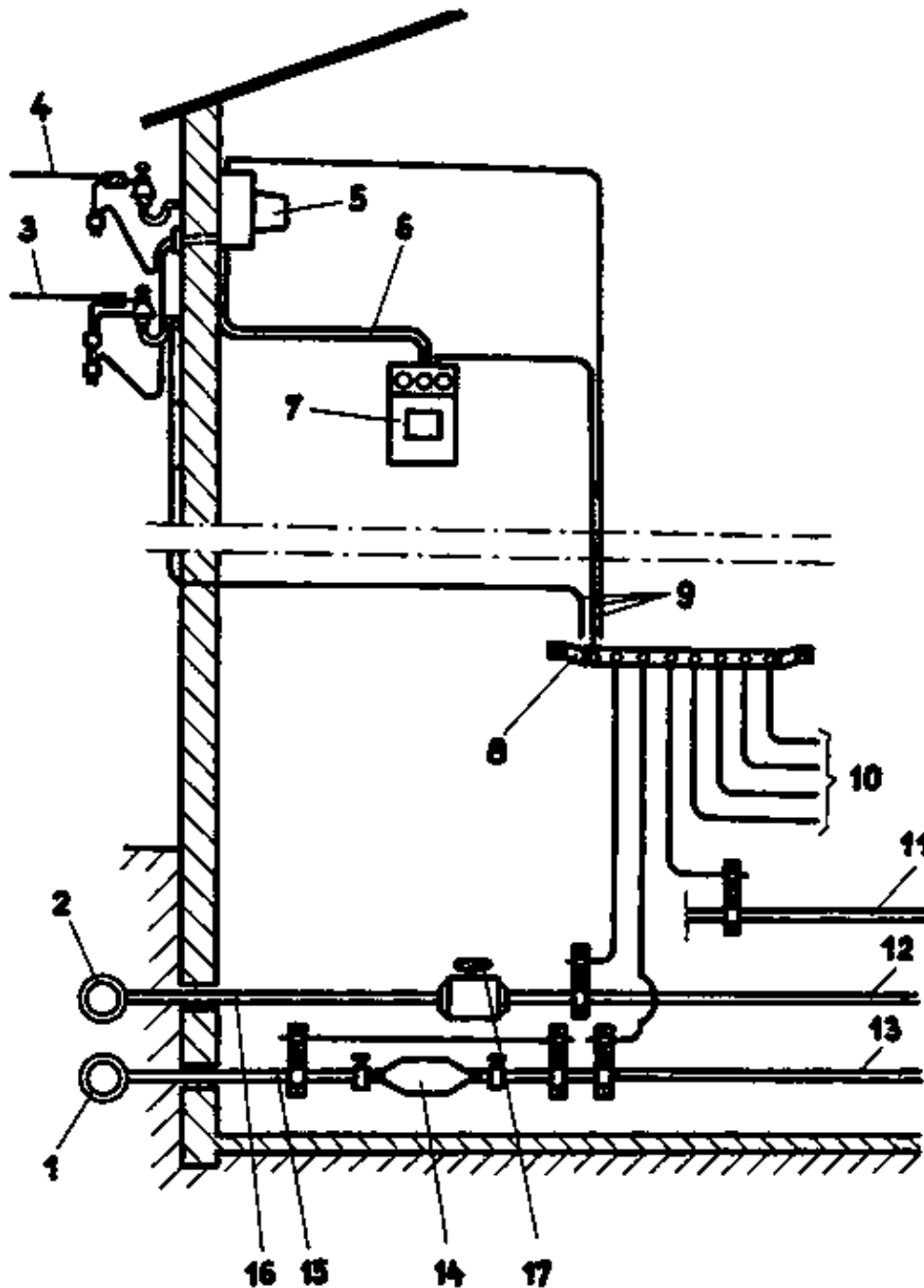


Fig. 1.21. Potential equalization in case of service tap via overhead line

1 main water pipe, 2 main gas pipe, 3 neutral conductor, 4 phase conductor, 5 service box, 6 lead-in to current meter, 7 meter panel, 8 potential equalization bar, 9 connections at choice, 10 towards further components to be included in potential equalization, 11 heating pipe, 12 gas pipe, 13 water pipe, 14 water connection pipe, 15 water connection pipe, 16 gas connection pipe, 17 main stop valve.

Table 1.4. Minimum cross sections for potential equalization lines

	copper	aluminium	hot-dip galvanized steel
in mm ²	10	25	50

1.4. Mode of action, conditions and application of protective measures against too high a contact voltage

When applying a protective measure all electrically conductive parts of the system not pertaining to the operating circuit are to be included, which

- may be touched during operation of the plant or appliance,
- may adopt voltage in case of fault.

Applying several protective measures within a system must not result in their cancelling each other. Protective measures are to be introduced at rated voltages of more than

- 50 V ac voltage
- 120 V dc voltage

These limits for max. permitted contact voltages were ascertained by scientific research. Contact voltages beyond these values may be mortal to the human organism.

Protective measures including and excluding protective conductors are being discerned:
Protective measures without protective conductors are:

- protective insulation,
- protective low voltage,
- protective isolation.

Protective measures with protective conductors are:

- a system of protective conductors,
- neutralization,
- protective earthing
- current-operated earth-leakage protection,
- voltage-operated earth-leakage protection,
- isolating current-operated earth-leakage protection.

Table 1.5. Distinguishing features of protective measures

protective measure	accessory units	result of protective measure
1. with protective conductor		Preventing <u>continuation</u> of too high contact voltages
voltage operated earth-leakage protection	protective switch	
current-operated earth-leakage protection		
isolating current – operated earth –leakage protection	protective switch <u>and</u> internal voltage generation (transformer)	
protective earthing neutralization	without accessory units	
protective conductor system	without accessory units (in case of an overvoltage protector of a live conductor a monitoring or breaking device will be required)	Preventing <u>occurrence</u> of too high contact

		voltages
2. without protective conductor		
protective isolation	internal voltage generator (transformer) without	
protective low voltage	protective switch	
protective insulation	without accessory units	

Every electrical plant and all electrical equipment within the low voltage range up to 1000 V ac voltage or 1500 V dc voltage is to be provided with one of the above mentioned protective measures. In the following the types, conditions and application of the protective measures will be referred to more in detail.

1.4.1. Protective insulation

The protective insulation of electrical equipment consists of protective insulation in addition to the service insulation or of reinforcement of the service insulation.

Even the site-insulation, meaning the insulation of a human being against earth, is a kind of protective insulation. The protective measure protective insulation is distinguished by high efficiency at low maintenance cost. The makers of electrical equipment are obliged to apply it to their products.

There are three versions of protective insulation:

- protective insulation sheathing,
- protective intermediate insulation,
- reinforced insulation.

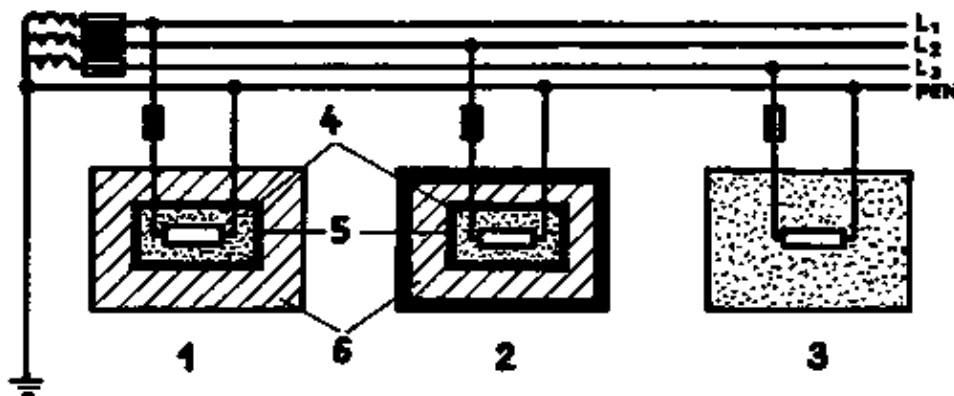


Fig. 1.22. Basic representation of protective insulation

1 envelope of protective insulation, 2 protective intermediate insulation, 3 reinforced insulation, 4 service insulation, 5 metallic sheathing, 6 protective insulation

In case of the protective insulation sheathing all parts exposed to voltage in the instance of fault are firmly enveloped by insulation material, the insulating material being at no place interrupted. Protective insulation sheathing is primarily used for home appliances of low power like hair dryers or vacuum cleaners.

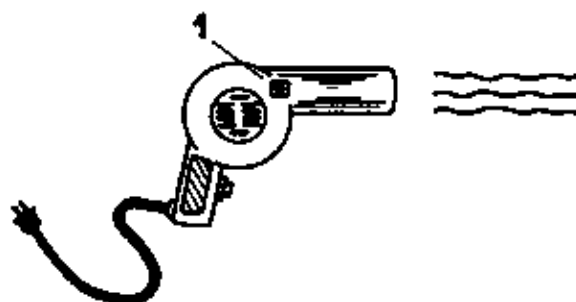


Fig. 1.23. Hair dryer

1 impressed marking for appliances with protective insulation

In case of protective intermediate insulation the external, touchable, conductive parts of electrical appliances are separated by fixed insulating pieces in the interior of the devices from the parts exposed to voltage in case of fault.

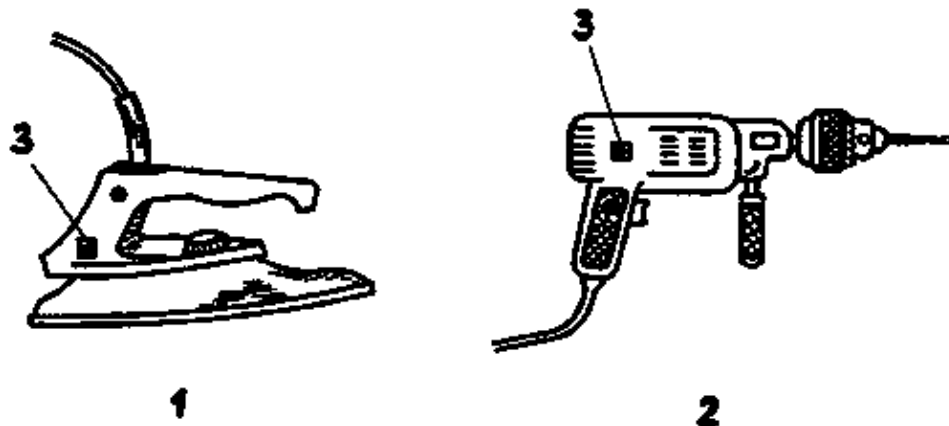


Fig. 1.24. Electric iron (1) and electric hand drilling machine (2)

3 impressed marking for appliances with protective insulation.

In case of reinforced insulation an additional protective insulation is applied directly onto the service insulation or the service insulation is being reinforced by the share of the protective insulation.

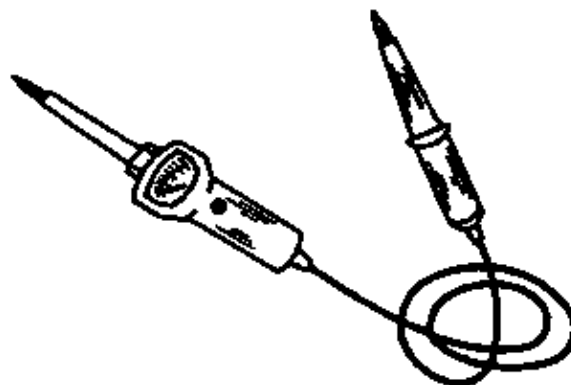


Fig. 1.25. Reinforced insulation at two-pole voltage tester

The insulation material used for protective insulation must have a sufficient breaking strength, high insulating capacity and ageing resistance. There are further high requirements on dimensional stability and corrosion as well as flame resistance. If due to overloading the protective insulation should be damaged, repairs will have to be done with original material only. Patching up the protective insulation provisionally is not permitted.

To protectively insulated electrical equipment no protective conductors are being connected, and there must be no connection points for protective conductors. The connecting flexible lines must not be provided with a protective conductor.

Electrical appliances with protective insulation are recognized by two squares placed one inside the other on the rating plate or being well visibly impressed on casing parts of these appliances.

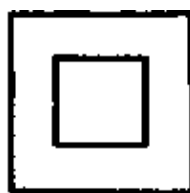


Fig. 1.26. Marking of electrical appliances with protective insulation

1.4.2. Protective low voltage

The protective low voltage is the most effective and safest protective measure against too high a contact voltage. It offers protection even on touching live parts. Its effectivity is based on reducing the service voltage to values being not dangerous to the human body:

– for contact with active parts,	25 V ac volt.
i.e. non–insulated live parts	50 V dc volt.
– for contact voltages on conductive	50 V ac volt.
parts in case of fault	120 V dc volt.

These voltages are too low to harm a human's health. For maintaining the full efficiency of the protective measure the requirements put up for its application must be met.

The most important demand on devices used for generating protective low voltages is:

These devices are to have windings being separated from each other on the primary and secondary side (transformers with galvanically separated windings).

For generating protective low voltages

- short circuit–proof transformers with windings electrically separated from each other,
- motor–generators,
- converters with electrically separated windings,
- accumulator plants and galvanic cells

are being used.

On the other hand, autotransformers have tapped windings and must therefore never be used for generating a protective low voltage. The danger caused for equipment and persons in case of a defect at the autotransformer is illustrated by fig. 1.27. In partial fig. 1 the incandescent lamps will blow due to inter–turn–short–circuit in the autotransformer.

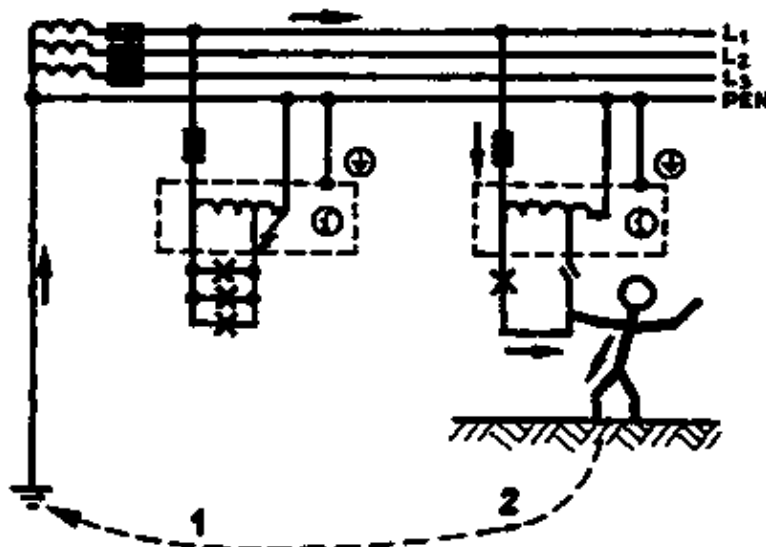


Fig. 1.27. Consequences of wrongly employing an autotransformer in generation of low protective voltage

1 on inter–turn short–circuit blowing of lamps, 2 on rupture of conductor there will be mortal danger

In partial fig. 2 there is mortal danger to the person shown, if the total mains voltage will be bridged by conductor rupture and contact to live parts.

Electrical equipment operated by protective low voltage has neither got connection points for protective conductors, nor must protective conductors be connected. Likewise earthing of conductors within circuits of protective low voltage will not be permitted. Under no conditions must conductors of the protective low voltage circuit be connected to conductors of other circuits or be placed together with them into a common sheath (e.g. a cable). Possible consequences would be dangerous voltage transfers into the circuits of protective low voltage.

For avoiding a mix–up with systems of higher rated voltages, electrical hand devices with protective low voltage (e.g. drilling machines or hand–lamps) have got special plugs. These do not fit into sockets for systems of higher rated voltage.

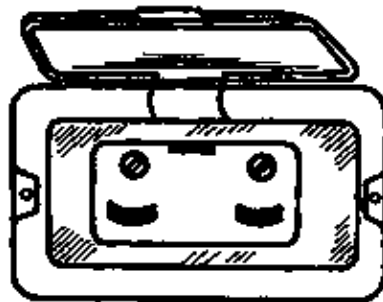


Fig. 1.28. Two–pole socket for protective low voltage.

This protective measure is applied where the existence of too high a contact voltage would result in a mortal current, e.g. for lighting or operation of electrical hand devices in erection pits and in locations consisting of conductive materials like boilers, big containers or pipelines.

Although protective low voltage is considered to be the safest protective measure, its application is limited. Caused by the reduced rated voltage the operating currents are about 5 to 10 times higher than e.g. for 220 ac voltage. This results in considerably higher conductor cross sections for protective low voltage systems and their electrical devices. That is why protective low voltage systems are only operated for outputs of about 4 kVA. As in case of protective insulation, electrical appliances for protective low voltage are marked by symbols. A general marking of all electrical equipment on the rating plate is not required.

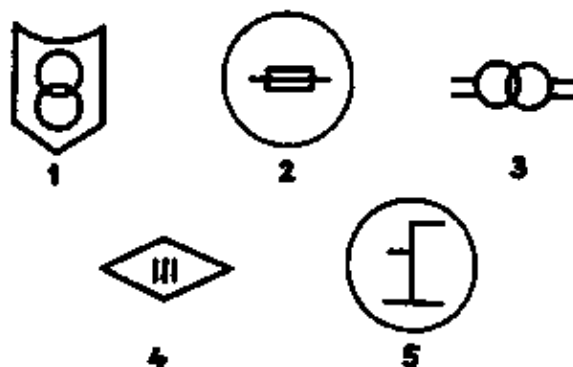


Fig. 1.29. Marking of electrical appliances for protective low voltage

1 protective transformer, 2 short–circuit–proof protective transformer, 3 limited short–circuit–proof protective transformer, 4 appliances for protective low voltage, 5 autotransformer

1.4.3. Protective isolation

Protective isolation holds an eminent position among the protective measures. It has much in common with protective low voltage. As in case of protective low voltage the transformer must have windings which are electrically separated from each other, and the service circuit must not be earthed either.

The important difference is that the protectively isolated circuit may be operated at any rated voltage up to 380 V three-phase current, but only one electrical device must be connected.

Exemptions from this rule are permitted only, if the connected electrical devices are operated with potential equalization lines and are placed on a base.

The mode of action of protective isolation is that in the case of the electrical isolation of a non-earthed circuit from the feeding lines (mains) the fault current circuit cannot close.

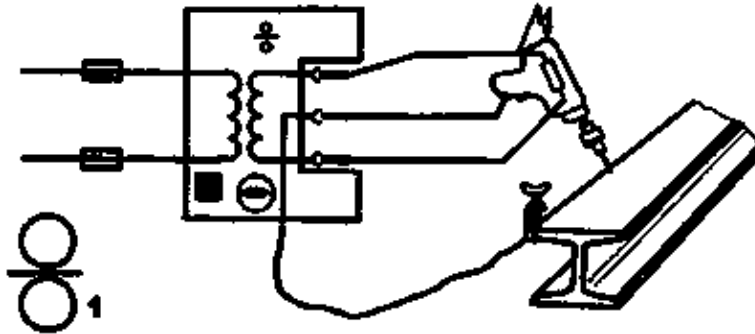


Fig. 1.30. Effective protection by protective isolation with connection of a potential equalization line to the socket's earthing contact and to the metallic location

1 Marking on the rating plate of an isolating transformer

A condition for voltage generation in case of the protective measure protective isolation is use of a

- protectively insulated isolating transformer with electrically separated windings on the primary and secondary side,
- motor-generator,
- converter with windings being also separated from each other.

When working with portable electrical devices in metallic environments a potential equalization line between equipment and location must be installed as shown in fig. 1.30. If this potential equalization line in being installed without mechanical protection, then copper wire of a minimum cross section of 4 mm² will have to be taken.

For connecting electrical appliances to the isolating transformer, lines as short as possible will have to be used. These lines are especially to be protected against damage to their insulation. This holds e.g. for passing lines through doors with metallic frame, since the lines could be damaged when closing the door.

Lack of potential equalization lines and the occurrence of two faults at different conductors of the lead-in may result in a dangerous contact voltage. Protectively isolated circuits must never be connected to conductors of other circuits.

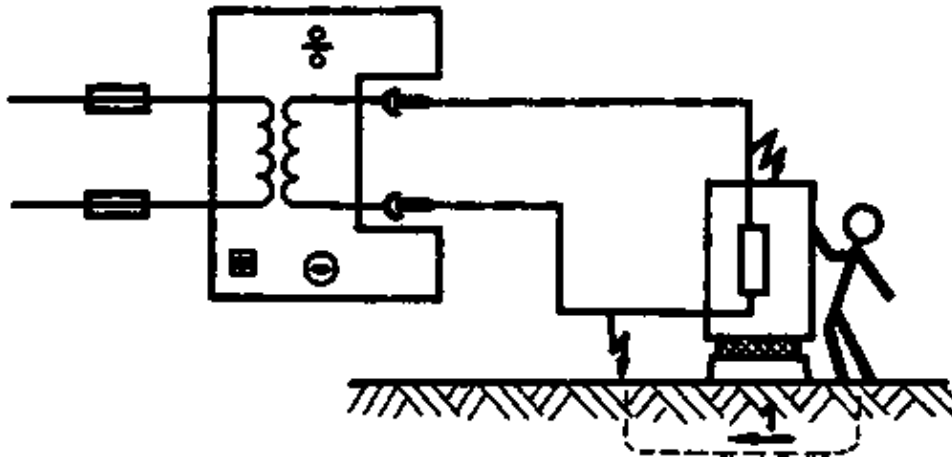


Fig. 1.31. Uneffective protective isolation in case of missing potential equalization

1 path of fault current via the fault current circuit: faulty appliance–person–ground, to faulty second conductor.

The main field of applying the protective isolation is working with electrical tools in zones of conductive construction materials. Further this protective measure is successfully employed for operation of physiotherapeutical appliances in medical care as well as razor socket outlets in lavatories of passenger trains.

1.4.4. The protective conductor system

There are instances when the occurrence of a fault in the plant must not have consequences or lead to disconnection of the faulty phase conductor. This can be the case in electrical systems of mines, chemical industries with continuous processes or of electromedical machinery in operation theatres of hospitals.

Also in case of a line-to-earth fault or fault of frame there is an interest to continue the operation without compromising as to labour safety.

This is possible only by applying the protective measure protective conductor system.

The interconnection of all conductive parts of the plant causes potential equalization among the parts of the plant and the natural earthing electrodes.

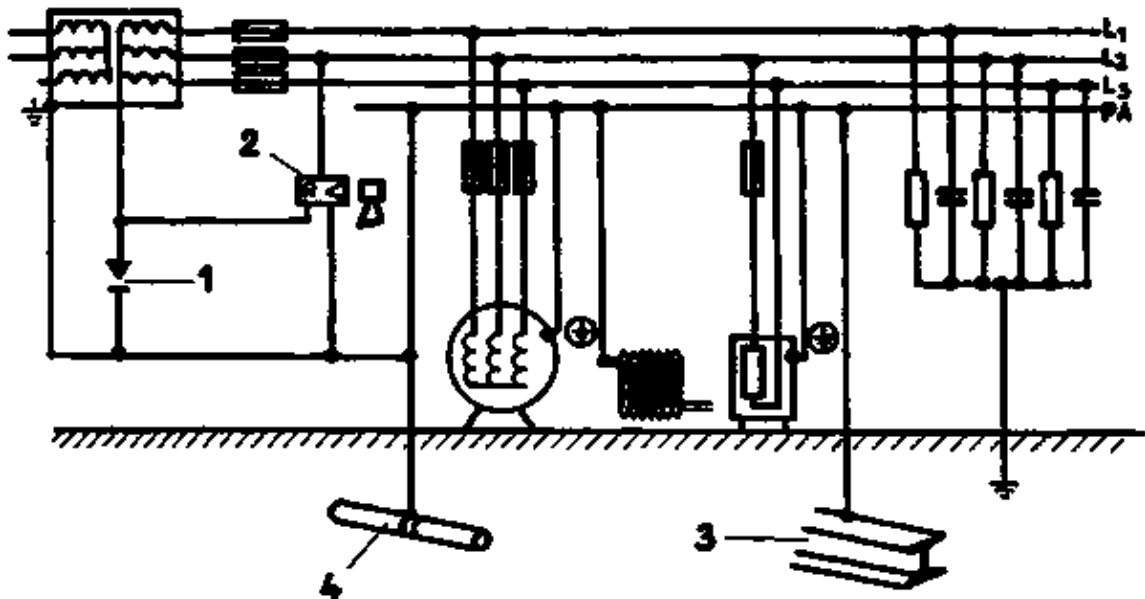


Fig. 1.32. Mode of action of protective conductor system

1 overvoltage protector, 2 monitoring device, 3 construction parts, 4 pipeline systems

If an insulation fault appears the resulting fault potential will spread to the overall system. Since there is no direct system earthing the fault circuit cannot close. The direct earthing of a point of the network is prevented by installing a so called overvoltage protector. This is called an IT-network. No contact voltage can occur. In case of the line-to-earth fault of one conductor the electrical system continues to operate.

However, if a second insulation fault arises in another phase conductor, both faulty conductors will be shortcircuited. Now the protective conductor system will work like the protective measure neutralization, i.e. the fuse in the fault circuit with the lowest rated amperage will respond. The system can continue to operate.

For keeping the operator of the electrical plant informed at all times a monitoring system is connected to the protective conductor system. By optical or acoustic signals it will indicate existing insulation faults. The defect arisen must be searched for and eliminated without delay.

A condition for this protective system to work is that any earthing in the system circuit is to be avoided. On the other hand all electrically conductive parts of the plant (casings) not pertaining to the operation circuit are connected to the touchable metal parts of the plant like pipeline systems, metal doors, plate ducts. This interconnection of all touchable conductive parts is called potential equalization as will be known from section 1.3.4.

It is also important that the protective conductor is not connected to the system's neutral conductor. In this case the protective measure would not function.

For effecting faults on two phase conductors to cause short-circuits no individual earthing of the system must be performed. The max. value of the protective conductor's earth resistance is 20 Ω . This value warrants proper spreading of the fault potential to the overall plant.

The insulation condition will be monitored by the monitoring device. At a minimum value of 255 Ω/V of the insulation the monitoring device will respond.

The point of the network earthed via an overvoltage protector is very important for the function of this protective measure. The electrode insert of the overvoltage protector interrupts the system earth at the earthed point of the network.

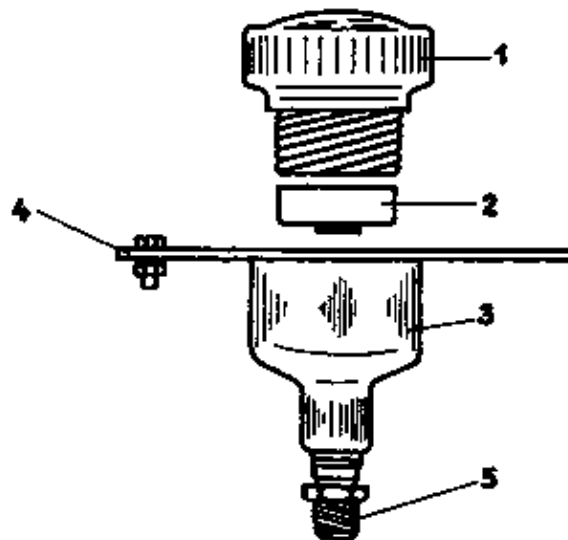


Fig. 1.33. Overvoltage protector

1 screw cap, 2 electrode insert, 3 base. 4 earth connection by means of bolt M6, 5 connection of neutral conductor

The electrode insert will break down only, when a high voltage is transferred to the low voltage side (lightning stroke or defect in transformer). Then the electrode insert of the over-voltage protector will become conductive. This is recognized by the change in colour of the colour-ring at the identification label of the

overvoltage protector. After the electrode insert has responded, the protective conductor system will work like the protective measure neutralization.

1.4.5. Protective earthing

The protective measure protective earthing is really the oldest protective measure. Its effectiveness is based on all electrically conductive parts of the system which may come under voltage in case of fault and which do not pertain to the operating circuit being connected to the earthed protective conductor. In case of a fault, a fault current flows via the lead-in, point of fault, protective earth electrode, ground to the system earth of the voltage generator or transformer. The faulty phase conductor or circuit will be interrupted if the fault current exceeds the interrupting current of the next back-up fuse.

For protection of persons in stationary electrical systems the clearing time may be max. 5 seconds. At portable electrical equipment the fuse must respond within 0.2 seconds in case of fault!

A clearing time of 0.2 seconds in case of fault requires relatively high interrupting currents. They should be at

- instantaneous fuses at least the 4–6 fold
- time–delay fuses at least the 6–8 fold

of the rated fuse current.

Basically two versions of the protective measure protective earthing are being discerned:

- protective earthing with return of the fault current via the ground,
- protective earthing with return of the fault current via metallic conductors like waterpipe networks or cable sheaths.

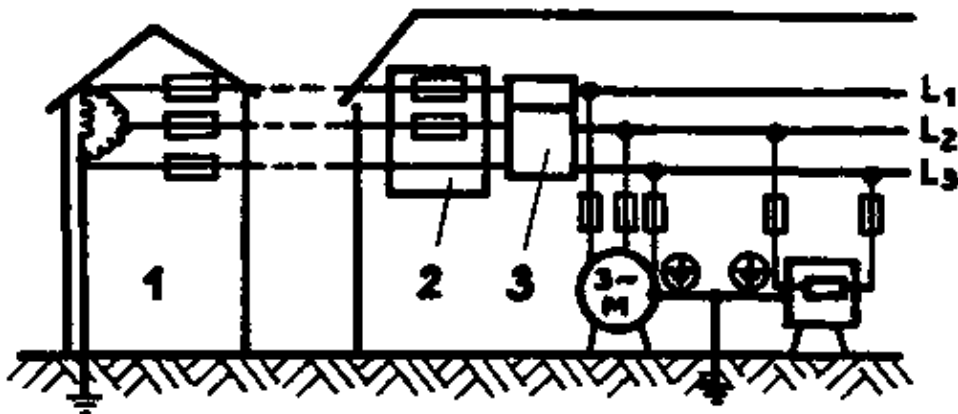


Fig. 1.34. Protective earthing with return of fault current via the ground in a three-phase three-wire system (TT-network)

1 transformer station, 2 main fuses, 3 current meter

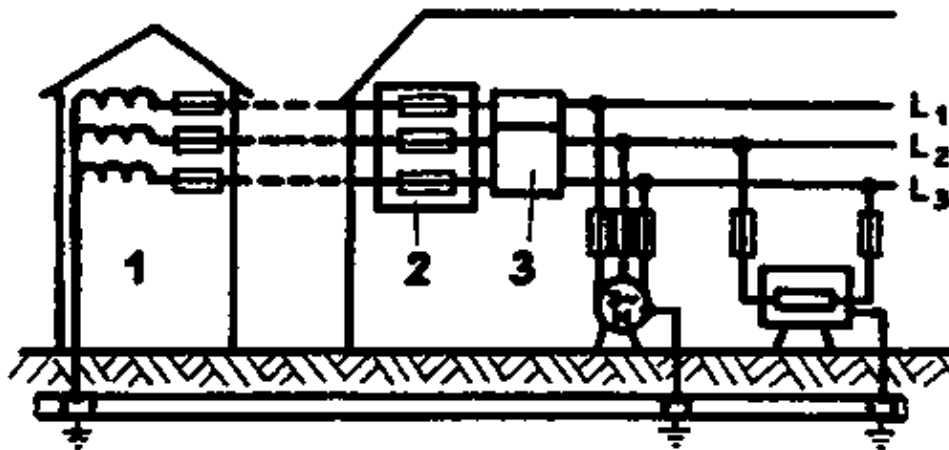


Fig. 1.35. Protective earthing with return of fault current via metallic conductors (TT-network)

1 transformer station, 2 main fuses, 3 current meter

In case of applying protective earthing with return of the fault current via the ground, several electrical appliances may be connected to a common earthing electrode. For this type of protective earthing it is not permissible to use the protective measure neutralization in part of the electrical system for safety reasons. Protective earthing with return of the fault current via metallic conductors may be applied only if adhering to the legal regulations. Otherwise the same conditions are valid for using metallic conductors as for application of natural earthing electrodes according to section 1.1.

A particularity will be found when applying protective earthing to three-phase networks with three conductors. In this case one of the phase conductors will be earthed. Therefore the ground obtains the potential of the earthed phase conductor.

The earthed phase conductor will have no main fuse. Applying protective earthing is quite simple. The protective conductor is connected to the protective conductor's terminal at the electrical equipment. The cross section of the protective conductor depends on its method of installation. The minimum cross sections are as per table 1.3.

Protective earthing is widely used in systems being not suited for neutralization. However it is more and more replaced by the protective measure current-operated earth-leakage protection. Moreover, protective earthing has some considerable disadvantages:

- the earth transition resistance is subject to variations due to climatic effects,
- the required earth transition resistances can be achieved at great expense only,
- by one-pole switching off of three-phase current consumers' installations electrical equipment may be damaged, e.g. windings of motors.

1.4.6. Neutralization

Neutralization is an "onward development" of protective earthing. Instead of via the ground the fault current is returned via the neutral conductor with protective function (PEN), in the following called neutral conductor.

The mode of action of neutralization is similar to protective earthing. A fault of frame occurring in case of fault is being converted into a one-pole short-circuit by the connection casing-neutral conductor. The next back-up fuse will respond interrupting the faulty phase conductor. The faulty electrical equipment will be one-pole interrupted.

For reducing the resistance of the neutral conductor, foremost in the instance of large conductor lengths, the neutral conductor will be earthed at the spur lines. By this, moreover, a limited protection in case of the neutral conductor's rupture is achieved.

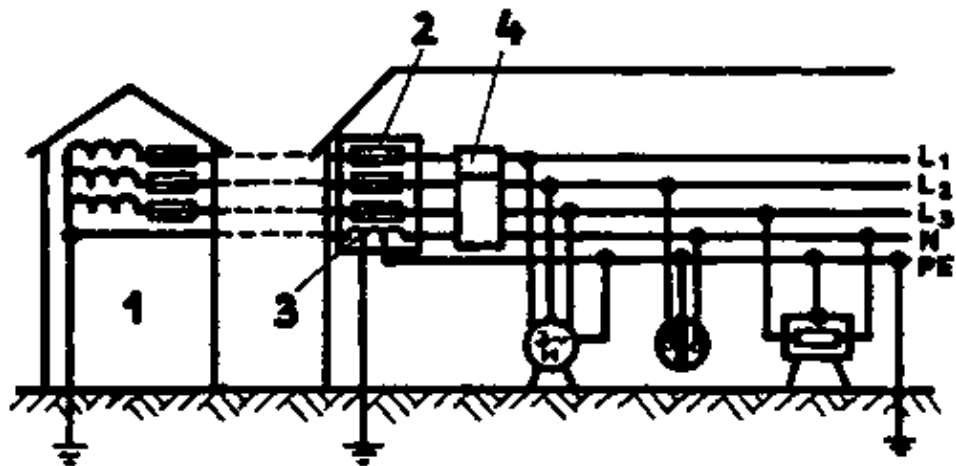


Fig. 1.36. Neutralization in a three-phase four-wire network (TN-S-network)

1 transformer station, 2 main fuses, 3 neutralization bar, 4 current meter

The protective measure neutralization will be rendered ineffective if too powerful fuses are inserted. Thereby the faulty phase conductor will not be interrupted quickly enough and the fault voltage will continue to be applied to the faulty equipment. The neutral conductor must under no conditions be fused or be separately switchable. If the neutral conductor is switched together with the phase conductors the protective contact will have to close first and to open last. This must be warranted, e.g. in case of connectors with earthing contact.

There will be great danger in the instance of a rupture of the neutral conductor behind the last system earthing. Then the part of the electrical equipment to be protected will adopt the full mains voltage against earth.

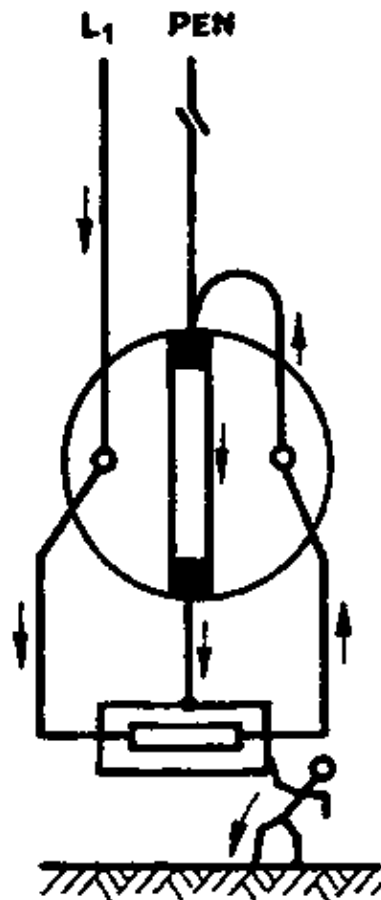


Fig. 1.37. Rupture of neutral conductor in front of a socket with earthing contact

This risk is best avoided by applying a TN-C-S-network according to fig. 1.12.

The neutral conductor is placed in a common sheath together with the phase conductors, e.g. in a cable or tube. When connecting the neutral conductor to electrical equipment, first the protective function has to be accomplished, and only thereafter it will be connected to the operating contact.

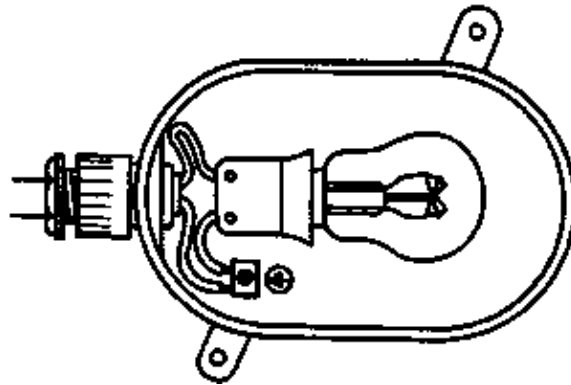


Fig. 1.38. Loops of the neutral conductor at a lighting fitting

At the electrical equipment the neutral conductor must be bridged uncut from the protective contact to the operating contact!

Due to its simplicity and cheapness the protective measure neutralization is employed in all fields of electrical current. Its protective value is undoubted.

1.4.7. Current-operated earth-leakage protection

The current-operated earth-leakage circuit breaker is highly sensitive. It responds to release current intensities in the mA-range independent on the size of the fault voltage. The mode of action of the current-operated earth-leakage protection rests on H. Kirchhoff's first current law.

$$I_1 + I_2 + I_3 + I_N = 0 \quad (\hat{=} \text{ geometrial addition})$$

If the operating current of a consumer's installation is directed via the cumulative current transformer of the current-operated earth-leakage circuit breaker the sum of the currents flowing in both directions will be zero. No voltage is induced in the cumulative current transformer of the current-operated earth-leakage circuit breaker.

In case of a fault of frame the arising fault current will leak via the ground. The flow balance in the cumulative current transformer will be disturbed. In the transformer's core a magnetic alternating field will appear. In the secondary winding of the transformer a voltage will be induced resulting in a current flow via the release coil of the current-operated earth-leakage circuit breaker. After having reached the rated fault current of the current-operated earth-leakage circuit breaker it will disconnect the faulty plant within fractions of a second ($\ll 0.2$ seconds) at all poles.

Current-operated earth-leakage circuit breakers are manufactured for the rated fault current intensities 15 mA, 30 mA, 80 mA, 100 mA, 200 mA, 300 mA and 500 mA. In case of very small rated fault current intensities current-operated earth-leakage circuit breakers will offer a limited protection on contact to parts carrying voltage under operation. Application of the current-operated earth-leakage protection is even possible to insulated networks (IT-networks) of great extension. In this instance the fault current circuit will close via the conductor-to-earth capacitance. The current-operated earth-leakage circuit breaker may happen not to respond in such networks. However, this will not be dangerous since no fault current will flow.

To 4-pole current-operated earth-leakage circuit breakers alternating current as well as three-phase current consumer's installations may be connected. The neutral conductor must also be led via the current-operated earth-leakage circuit breaker. All parts of the plant to be protected are being connected to and earthed by a separate protective conductor (PE) which is installed throughout the electrical system.

The protective conductor (PE) is to be insulated against the neutral conductor (N) behind the current-operated earth-leakage circuit breaker!

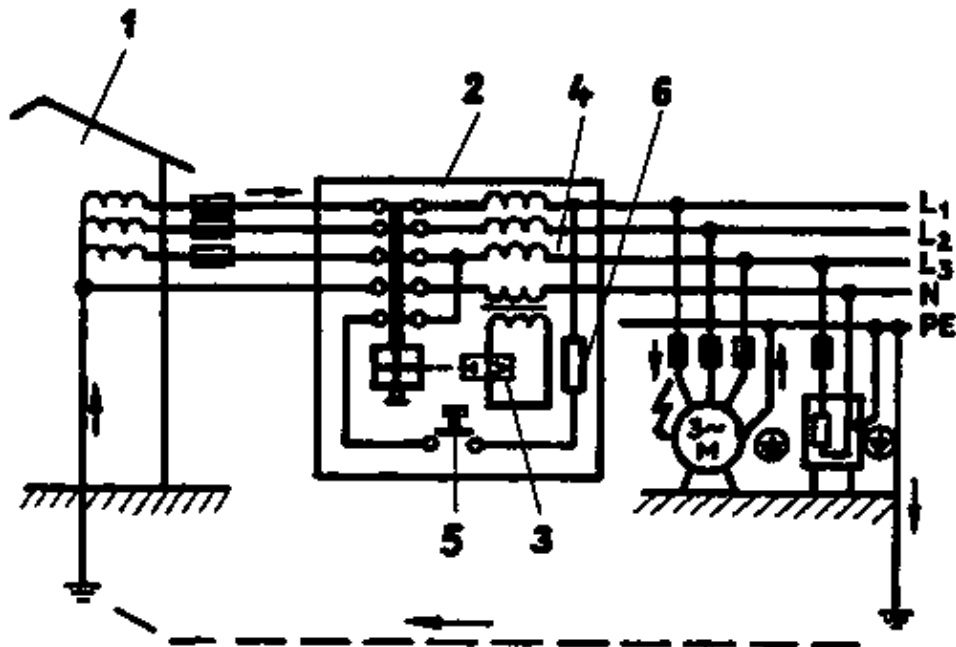


Fig. 1.39. Application of current-operated earth-leakage protection in a three-phase four-wire network (TN-C-network)

1 transformer station, 2 current-operated earth-leakage circuit breaker, 3 fault current release, 4 cumulative current converter, 5 test key, 6 test resistor.

In IT-networks the parts of the plant to be protected are also to be earthed together. Otherwise the occurrence of two faults of frame in different phase conductors may cause a precariously high contact voltage.

The resistance of the earthing system of the current-operated earth-leakage protection must not exceed the value

$$R_s = \frac{\text{max. permissible contact voltage}}{\text{rated fault current of current-operated earth-leakage circuit breaker}}$$

As a future protective measure "quick neutralization" is to be considered. Its protective value is supposed to be very high. By combining the two protective measures "neutralization" and "current-operated earth-leakage protection" extremely short breaking times will be achieved. Foremost this is important for electrical systems with long spur lines, for which maintaining the neutral conductor's required max. resistance offers great problems. This is also valid for electrical systems in which a sufficiently high interrupting current cannot flow in the instance of a one-pole fault.

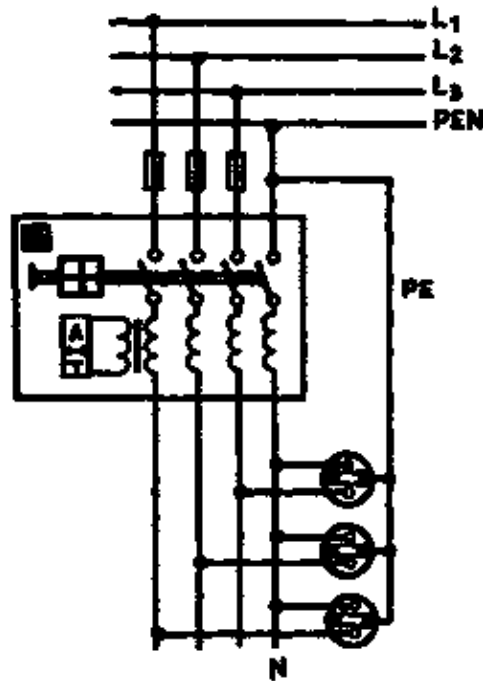


Fig. 1.40. Application of "quick neutralization"

Attention has to be paid that the current-operated earth-leakage circuit breaker will only respond in case of faults of frame, but not in case of short-circuit.

The current-operated earth-leakage protection is employed in all alternating current and three-phase networks independent of the network type.

The current-operated earth-leakage protection can also be applied to three-phase networks without earthed network point!

1.4.8. Voltage-operated earth-leakage protection

This protective measure has become much less important since introduction of the current-operated earth-leakage protection. In favour of current-operated earth-leakage protection it is not any longer employed in electrical plants to be newly constructed. However, it is still working in some older systems.

This protective measure is similar to protective earthing, but its release in case of fault is not directly taking place via the connection between the parts of the plant to be protected and the ground, but at all poles via a release coil.

Its mode of action is based on a voltage-operated earth-leakage circuit breaker monitoring the circuit between the parts of the plant to be protected and an auxiliary earthing electrode. In the instance of a fault of frame voltage will be applied to the voltage-operated earth-leakage circuit breaker. If the fault potential exceeds a certain minimum value the voltage-operated earth-leakage circuit breaker will respond, interrupting the circuit on all poles.

This protective measure will become ineffective when bridging the voltage-operated earth-leakage circuit breaker. Therefore, at the electrical equipment to be protected by voltage-operated earth-leakage circuit breaker compulsory isolations against the earth potential are to be provided. At electrical water heaters e.g. plastic connections are fitted to the waterpipes.

The protective conductor and the auxiliary earth lead must be installed in a protected way, the protective conductor being well insulated against earth!

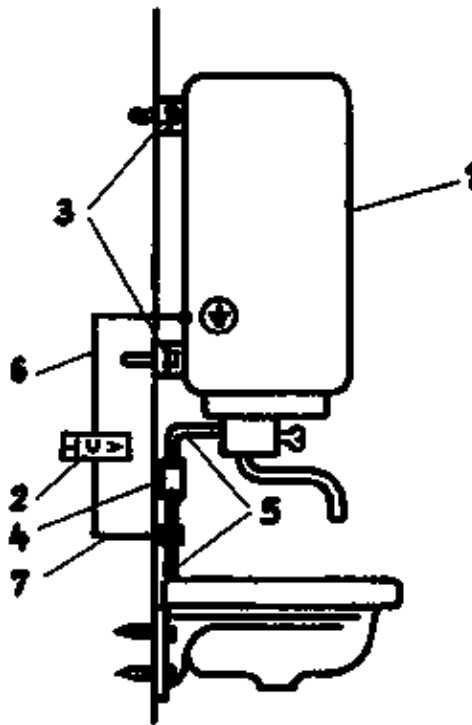


Fig. 1.41. Application of voltage-operated earth-leakage protection at an electrical storage water heater

1 metal case, 2 fault voltage circuit breaker, 3 insulation spacer, 4 insulation pipe, 5 water pipeline, 6 protective conductor, 7 auxiliary earth lead

The waterpipe network may be used as an auxiliary earthing electrode. Connection of auxiliary earth leads to lightning arrester systems is not permitted.

When installing voltage-operated earth-leakage circuit breakers the monitoring instruction of the makers will have to be adhered to. Lead-in and lead-out must not be mixed up.

The resistance of the auxiliary earth lead may be max. 800 Ω .

1.4.9. The isolating current-operated earth-leakage protection

This protective measure is mostly applied in ship-building. It works similarly to the current-operated earth-leakage protection, the difference being in principle that the system is operated via an isolation transformer, the neutral point of the transformer's secondary side being earthed via a coil.

This coil is connected as a voltage divider limiting the fault current to 7 mA.

In case of fault, the fault current will flow via the current coil of the isolating current-operated earth-leakage circuit breaker which will be excited thereby and disconnect the system. The circuit breaker will disconnect the system at a fault current of 6 mA alternating current and 10 mA direct current resp. on all poles.

Live service conductors must not be earthed when applying this protective circuitry.

On the other hand, all conductive parts of the plant not pertaining to the operating circuit via which a fault current can flow are to be connected to protective earthing.

The protective conductor is to be earthed in the vicinity of the supply unit. For systems on ships it is to be connected to the metallic hull of the ship.

In principle the protective conductor is to be isolated from the lines in front of the isolation transformer!

In case of this protective circuit attention has to be paid further to

- the resistance of the protective earthing is not to exceed 500 ohms
- the insulation resistance between a conductor and the protective conductor must not be less than 20 kOhms and
- the capacitance between conductor and earth is not to exceed 100 Nanofarad.

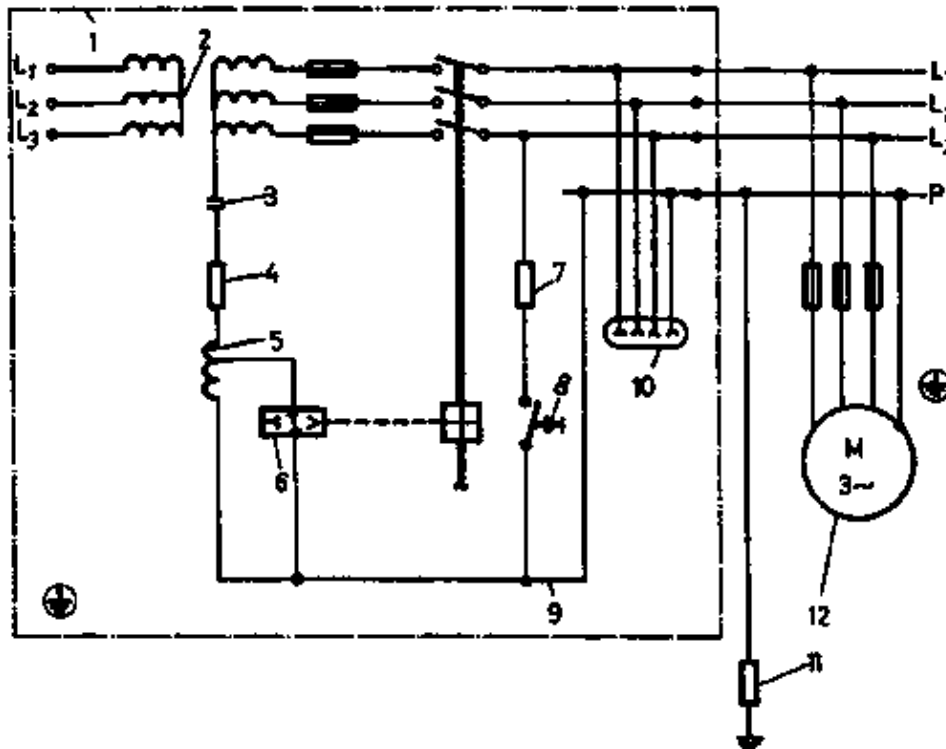


Fig. 1.42. Isolating current-operated earth-leakage protection

1 supply unit, 2 isolating transformer, 3 capacitance, 4 resistor, 5 voltage dividing coil, 6 current coil of the isolating current-operated earth-leakage circuit breaker, 7 test resistor, 8 test key, 9 protective conductor, 10 socket for testing purposes, 11 earth resistance, 12 motor.

1.5. Conduct after electrical accidents

In spite of instructions and extensive measures ever again electrical accidents are happening caused by absent-mindedness and thoughtlessness.

Though in accident-statistics the share of electrical accidents is one of the smallest, the number of mortal accidents caused by electrical current is very high due to the dangerousness of electricity. It should be understood by everyone that any contact to live parts of installations in switchgear and other electrical installations – even at home – can mean serious harm to the health of the person concerned.

After an electrical accident should have happened, immediately steps are to be taken to keep the consequences of the accident at a minimum. The first step is to free the person met with an accident from the circuit. For that purpose it will be necessary to break the accidental circuit:

- switch-off the light or machinery switch
- unscrew the concerned fuse or main fuse
- break the master switch
- in an emergency, cause a short-circuit between the place of accident and the supply point.

If disconnecting the switchgear is not possible within the shortest time, the person concerned will have to be dragged from the location of accident. The person met with an accident will not be able any more to save

himself as already a current of 20 mA will suffice to cramp the muscles in such a way as to make it impossible for him to perform coordinated movements. The saver has to bear in mind to insulate himself against live parts

The person met with an accident must never be touched with bare hands since thereby the saver himself will be exposed to the highest mortal danger at once!

After saving the person concerned and bedding him, the extent of the accident will have to be ascertained and immediately first aid will have to be given.

Serious accidents will frequently cause unconsciousness. Therefore the breathing activity and heart function are to be examined at once. Even if these important indications of life cannot be traced, death of the person met with an accident must not be assumed. Immediately steps for reanimation like artificial respiration and heart massage have to be started.

Additional helpers will have to organize medical aid and transport.

If need be, reanimation must be continued for hours. It may be abandoned only in case there are signs of returning life or if a physician orders abandonment of the reanimation endeavours!

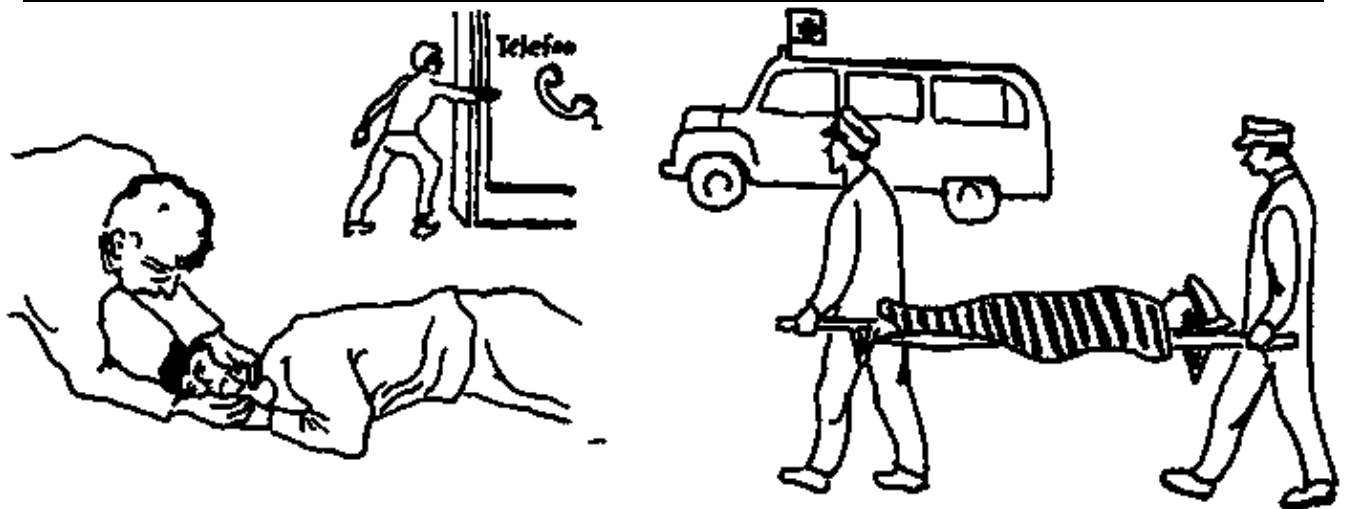


Fig. 1.43. Calling for medical aid and preparing transportation

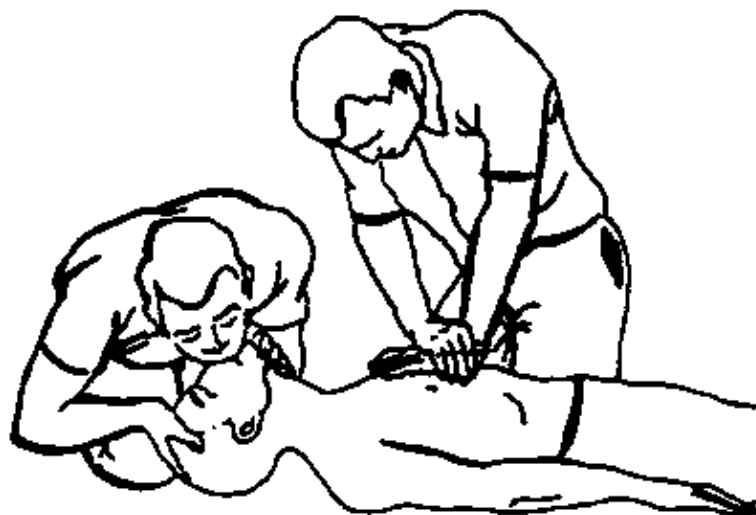


Fig. 1.44. Heart massage and simultaneous mouth-to-nose respiration

Even if the person met with an accident has not become unconscious he must obtain medical care at once. The person shall rest in a sitting or lying position until the ambulance car arrives. Never must the person met with an accident be left alone or walk himself to a physician. This is not permitted, because even after hours have passed the person concerned may become unconscious due to the shock effect of the electrical current, or the highly dangerous trembling of the heart ventricles may arise leading to the stop of the blood circulation.

Besides treatment of the primary effects of the electrical current on the body, of course, the secondary injuries like burns and bone fractures are to be looked after, too.

After the person met with an accident has been taken care of, the place of accident has to be made safe, i.e. will have to be blocked. This is essential, partly to prevent spectators from entering the area of accident and partly to ease the work of enquiry into the accident which is to ascertain the causes of the accident.

From the variety of relief steps to be taken after an electrical accident has occurred it is to be deduced that a fitter must be instructed about the emergency measures to be taken immediately after an electrical accident. The instructions on labour safety to be performed in regular intervals will offer an excellent occasion for that purposes. Further each fitter must know the telephone number of the physician on duty for emergencies resp. where this number can be obtained, where the next stretcher and first aid kit can be found and which workmate has got a training in first aid. The fitter should also be instructed about how to extinguish fires in electrical plants, because many serious accidents are accompanied by fire in electrical plants.

The know-how of the helper about emergency measures to be taken after an electrical accident is determining the success of relief measures in a decisive way!

1.6. Summary

By earthing systems the current is leaked via the ground. According to function there will be discerned:

- system earthing electrodes
- protective earthing electrodes
- auxiliary earthing electrodes
- control earthing electrodes.

For warranting good conductivity between earthing electrode and ground the following principles are to be observed:

- the earthing electrode must be placed 0.70 m into the ground at least
- the soil around the earthing electrode is to be stamped resp. to be jetted
- the earthing electrodes are to be cleaned from all contaminations.

Protective conductors will form the connection between conductive parts of the plant not pertaining to the operating circuit which may become voltage-carrying in case of fault and the earthed point of the system resp. the earthing electrode. Protective conductors are marked green-yellow.

Protective measures against too high a contact voltage are to be applied under all conditions if the rated voltage exceeds 50 V alternating voltage, or 100 V direct voltage.

The following protective measures against too high a contact voltage are discerned:

- protective measures without a protective conductor (protective insulation, protective low voltage, protective isolation),
- protective measures with protective conductor (protective conductor system, neutralization, protective earthing, current-operated, voltage-operated, isolating current-operated earth-leakage systems).

After an electrical accident has occurred steps are to be taken at once to keep the consequences of an accident at a minimum. Persons met with an electrical accident are to be considered as being seriously injured.

Also in case of persons being apparently lifeless they are not assumed to be dead. Reanimation measures (artificial respiration and heart massage) must be continued until there are clear signs of returning life, or until a physician orders the reanimation measures to be terminated.

The helper will have to conduct himself as not to be hit by the impacts of the electrical current.

The following emergency measures may be called for after an electrical accident and should be mastered:

- finding and saving the person met with the accident,
- giving first aid and calling medical help,
- artificial respiration of the person concerned,
- carrying out heart massage
- preparing a person met with the accident for transportation.

2. Power overhead–line systems

Conductors mounted to insulators are being called overhead lines. Conductors and insulator are supported by towers or poles. By means of overhead lines electrical power is led to consumer's installations over large distances. Overhead lines are employed where, for economic reasons, cables are not laid. Overhead lines are offering considerable advantages as compared to underground cables as they do not require insulating sheaths. Their greatest advantage is, however, avoidance of earthworks.

Before erection of the overhead–line system can be commenced building permission for crossing traffic structures and properties will have to be obtained from the proprietors resp. from the trustees.

The route of the overhead line will be set out by means of wooden pegs. The run of the poles' location should be along the boundaries of properties if possible as to easier obtain the proprietors' or trustees' permission.

2.1. Conductor materials and minimum cross sections

For conductor materials in overhead–line construction single–wire conductors of copper or bronze resp. stranded conductors of copper, aluminium as well as aluminium alloys, steel–core aluminium and bronze are being used. Single–wire copper or bronze conductors are permissible up to a cross section of 16 mm² and a span of 80 m. For multiple–wire conductors the minimum cross sections as per table 2.1. will be valid.

The min. cross section for copper may be reduced to 6 mm² and for aluminium to 16 mm² if the span from pole to pole will be less than 35 m!

The span for overhead lines within the low voltage range is between 35 and 80 m!

Table 2.1. Permissible minimum cross sections of stranded conductors

conductor	minimum cross sections
copper and bronze	2 10 mm
steel, hot–dip galvanized	2 16 mm
aluminium and its alloys	25 mm ²
steel–core aluminium	16/2.5 mm ²

2.2. Supports of overhead lines

Poles resp. towers of timber, steel or reinforced concrete are serving to support overhead lines.

Overhead lines are installed on buildings by roof poles on the roof and side arms at the gable resp.

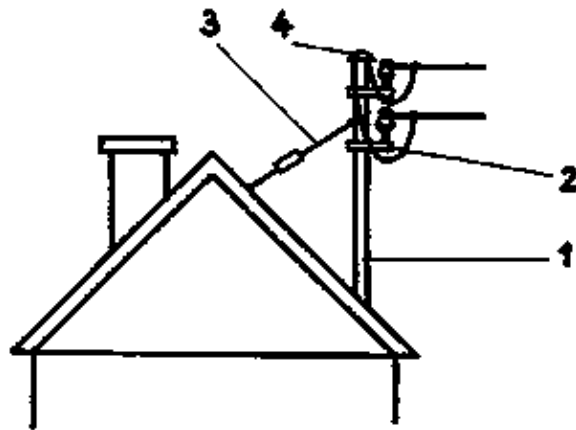


Fig. 2.1. Roof pole for an overhead line

1 steel pipe, 2 cross bar, 3 guying, 4 protective cap.

Poles for overhead lines are discerned according to their application and purpose:

- supporting poles are used on straight lines only and serve but to support the conductors,
- angle poles support the conductors at angular points,
- terminal poles constitute the fixed points of the overhead lines at their ends,
- branching and distribution poles serve for branching and distributing lines into various directions.

The choice of the materials for overhead-line poles is determined by economic and engineering points of view:

- cost of installation and maintenance,
- life of overhead-line systems,
- possibility of disconnecting the line for repair or replacement,
- application of pole (supporting pole, terminal pole etc.).

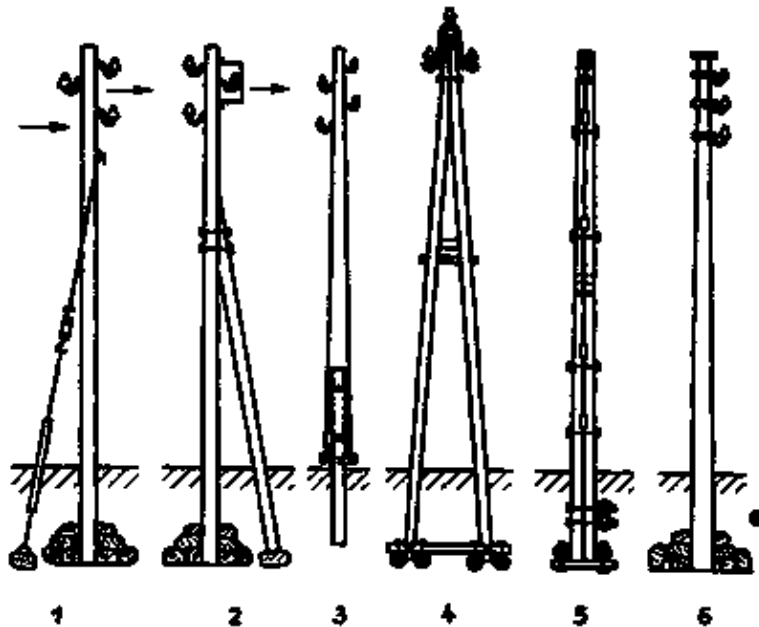


Fig. 2.2. Types of poles

1 wooden pole with anchor, 2 pole with tie, 3 supporting pole with footing of reinforced concrete, 4 A-pole for large loads, 5 double A-pole, 6 concrete pole

2.3. Protection against contact in overhead lines

Insulators and overhead lines are being installed in such a way as to make contact by persons without special auxiliaries impossible, either from the ground or from windows, roofs or other structures.

The distance between conductor and ground must be 5 m at least at the maximum sag. In case of service lines this distance may be reduced to 4 m if the overhead line is to be connected to the building on the plot and no vehicles can pass beneath the overhead line.

The distance between overhead line and trees which are positioned below or laterally of the overhead line and which are to be climbed for harvesting or maintenance purposes is to be min. 1 m. Further min. distances are to be seen from table 2.2.

Table 2.2. Minimum distance when routing lines across country, over streets, buildings and plants

Line route via	vertical minimum distance (in m)
Open country with little unevenness as well as over open land in settlements	5
Expressways, highways, roads, roadways	6
Trees in open country or in settlements	1
Dwelling houses and business premises	2.5
Tramways, trolley bus lines	1.5
Power lines up to 1 kV	0.35
Railways for public traffic without contact lines	7
with contact lines	12.5
Waterways of coastal and inland navigation at highest navigable water level	12.5
Coastal rivers	17.5
Cableways for transport of goods	2
Drag-lift systems	3
Information installations of mail and railroads	1.5

2.4. Erection of poles

The pole's resp. tower's foundation is of utmost importance for the stability of overhead-line poles resp. towers. For poles of wood or reinforced concrete no special foundations are required. However, for giving the concrete mast or steel tower increased stability, e.g. as anchor tower, the base of the tower may be concreted. This holds for wooden poles' concrete pole butts too.

Concreting of wooden poles is not permitted!

According to the pegged out route of the overhead line pits for the poles are dug or holes are drilled. Wherever possible the work is to be done by machines.

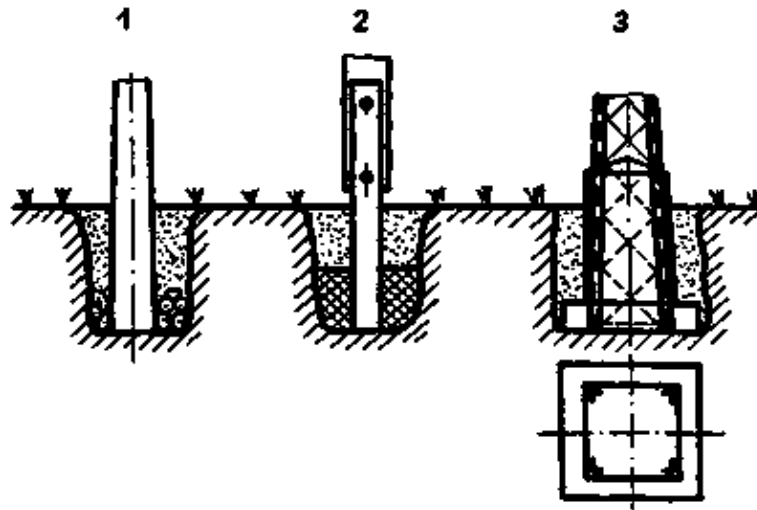


Fig. 2.3. Foundations of poles

1 pole without special foundation, 2 concreted pole footing of a wooden pole, 3 concreted foundation for a steel tower.

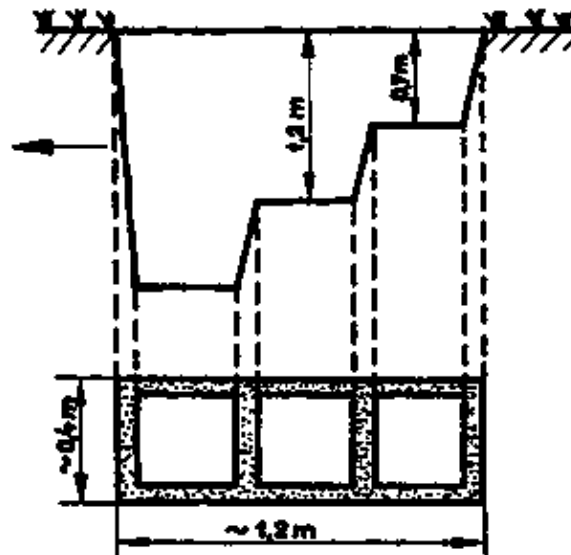


Fig. 2.4. Pits for poles without special foundation.

The base of the pole's pit must at least have the diameter of the pole!

Prior to excavating the pole's pit the corner points are to be pegged out. The excavated soil stays beside the pit of the pole serving for back-filling of the remaining hole after erection of the pole.

Prior to erecting the poles the insulators are screwed to the pole resp. bolted to the cross arms.

The insulators employed are:

- shackle insulators for angular branchings of more than 25° and on terminal bindings,
- insulators with straight insulator spindle: such insulators are mounted to cross bars and are provided with threaded shank, nut and washer,
- insulators with swan-neck insulator spindles: for wooden poles standing in line with wood screw threading or with provision for being concreted into brickwork. For further types of poles there are supports with through bolts, threaded shank and nut.

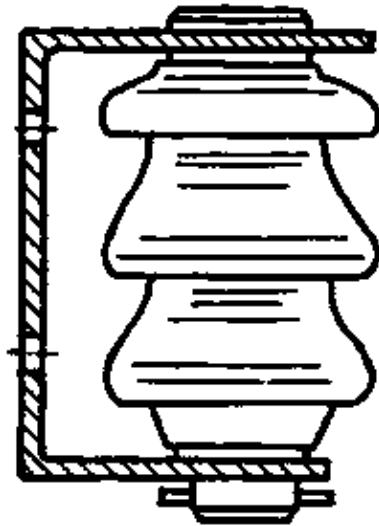


Fig. 2.5. Shackle insulator with straight spindle

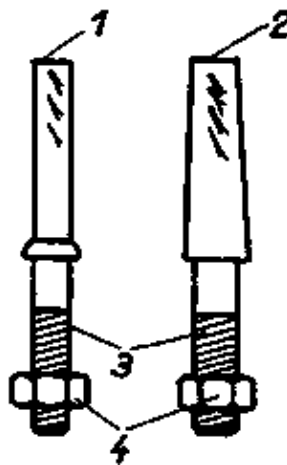


Fig. 2.6. Straight insulator spindle

1 standard spindle, 2 reinforced spindle, 3 threaded shaft, 4 nut



Fig. 2.7. Insulator with swan-neck spindle

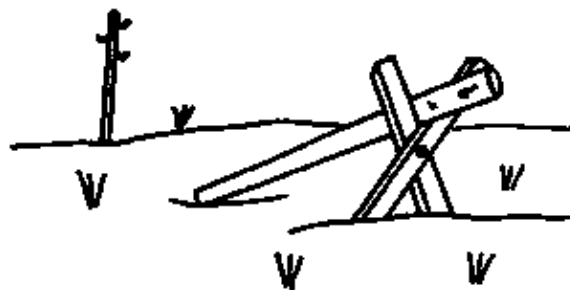


Fig. 2.8. Putting a pole on a forked trestle

For mounting insulators to the pole, application of a forked trestle is being recommended.

When mounting insulators to a wooden pole the distances according to fig. 2.9. are to be adhered to.

In steel resp. concrete towers the mounting holes for the insulators will have already be provided by the maker.

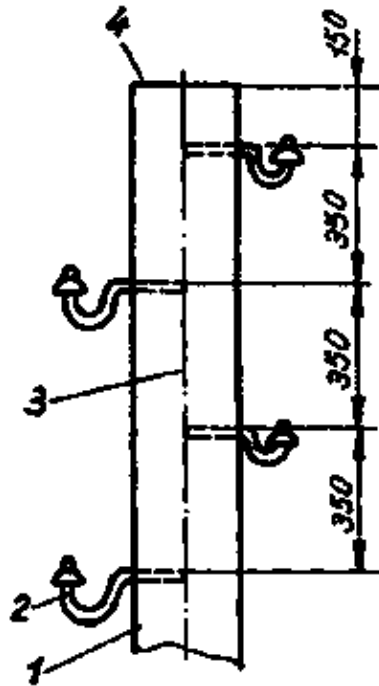


Fig. 2.9. Minimum distances for mounting insulators to the pole

1 pole, 2 insulator, 3 axis of pole, 4 end of pole

A particular problem when erecting towers resp. poles is observation of bird protection. Cross arms, insulator supports and other structures are to be designed and mounted as to prevent creation of resting places for birds adjacent to live conductors.

If in difficult territory it will be impossible to put up the poles by means of truck-mounted crane the poles may be erected aided by wooden rods being bound together in the shape of shears.

For easing sliding of the poles into their pit, a sliding board or plank is placed vertically to the front wall of the pole's pit.

The vertical position of the pole is to be checked by means of a plummet or other measuring device.

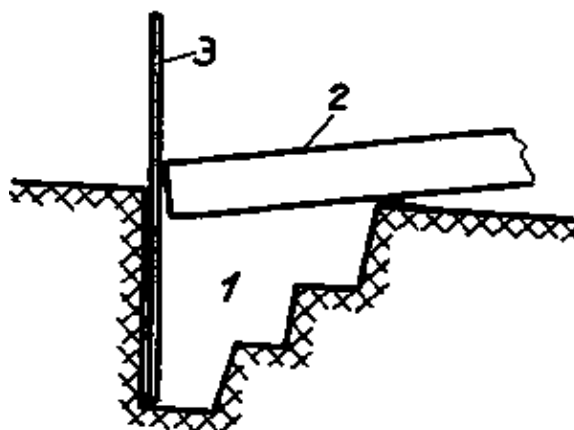


Fig. 2.10. Pole's pit with sliding plank

1 pole's pit, 2 pole, 3 sliding plank

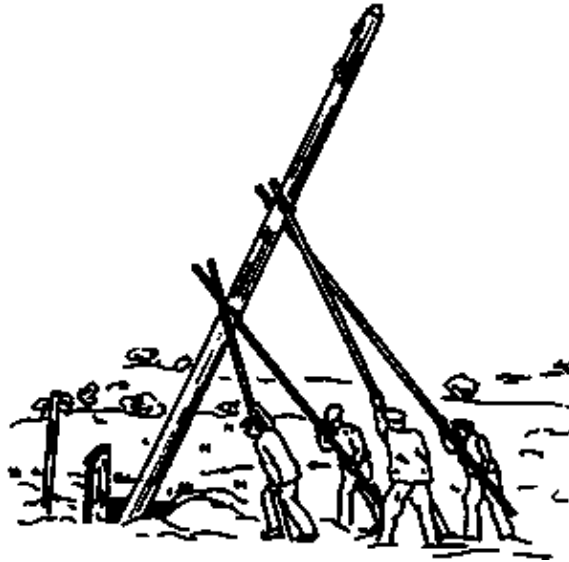


Fig. 2.11. Erecting of a wooden pole

The hollow spaces in the pole's pit surrounding the pole are to be back-filled with soil and stones. The soil is to be stamped for giving good stability to the pole.

2.5. Stringing the conductors

Installation of conductors can be commenced only after the poles have been placed and completely mounted. The foundations must be hardened and ropes resp. ties be ready.

As a rule, the stranded conductors are supplied on drums to the erection site, or in case of small cross sections and quantities in coils and pulled off the reel.

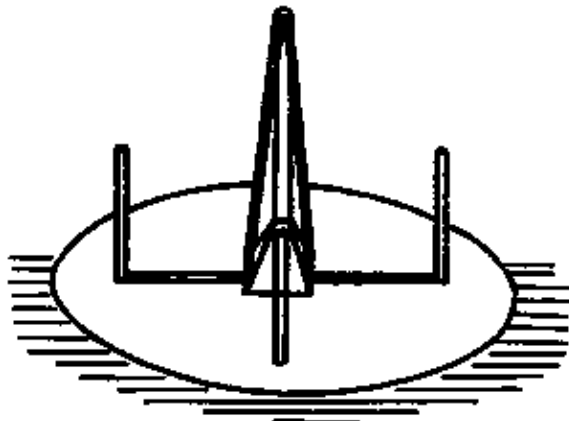


Fig. 2.12. Reel

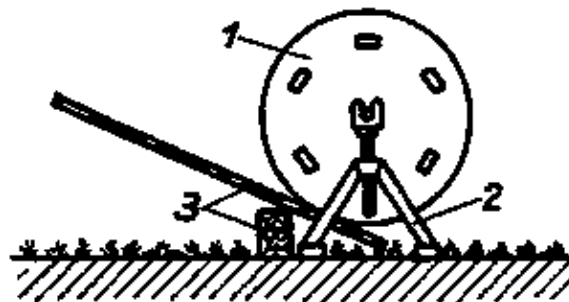


Fig. 2.13. Jacked up rope drum with leverage brake

1 rope drum, 2 adjustable jack, 3 leverage brake

The rope drums are being jacked up, and the stranded conductors are pulled off the drum.

For jacking up the rope drums jacks being adjustable in height and a solid steel axle are being employed. For better rotation of the drum on the axle the axle is well greased at both bearing points of the drum. The jacks are put up as high as to have the drum placed in exactly horizontal position (some centimeters above the ground).

For pulling the stranded conductors off, two methods are applicable:

- laying the stranded conductors on the ground,
- pulling the stranded conductors off, clear of the ground.

Stranded conductors of steel or copper may be dragged over the ground, while for stranded conductors the outer layers of which consist of aluminium this is not permitted. The stranded conductors could be damaged thereby.

Small cross sections are pulled off manually. In long–distance stringing systems fish ropes and rope winches are employed. When paying out the stranded conductors on the ground, care will have to be taken to avoid damage to the stranded conductors by pointed objects like stones, barbed wire etc.

When pulling off clear of the ground the stranded conductors will be guided via pulleys.

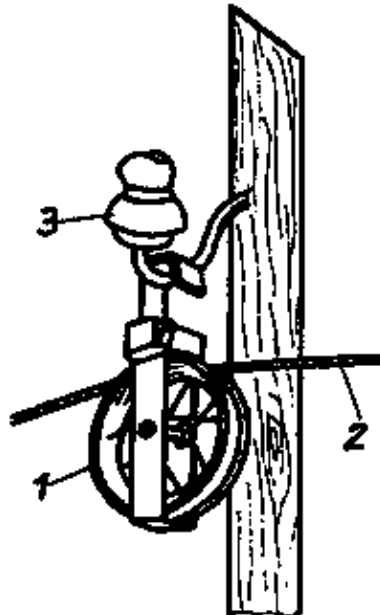


Fig. 2.14. Suspended rope pulley at pole

1 rope pulley, 2 rope, 3 insulator

At crossings of streets, roads or other traffic lanes the stranded conductors are under all circumstances to be protected against damage. Simple horses are used in this case over which the stranded conductors are being laid.

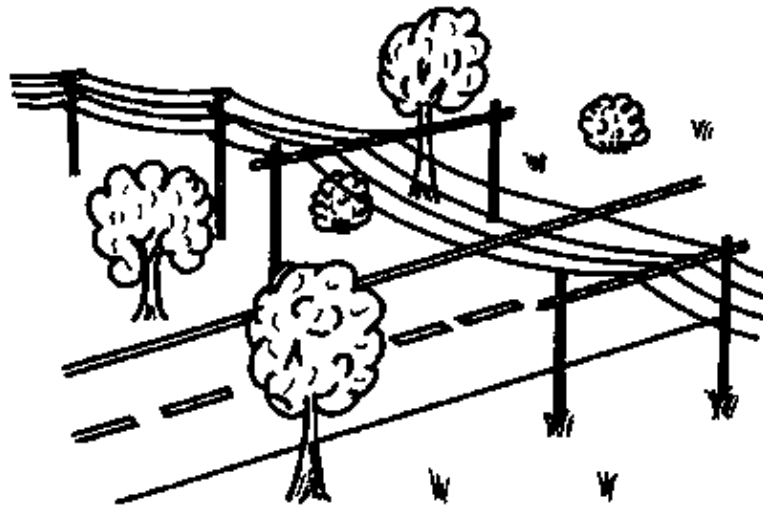


Fig. 2.15. Sliding horse at a roadside

After the stranded conductor has been run out, one end is fixed to the insulator or pole.

For adjusting the sag, the stranded conductor is pulled back in direction of the rope drum.

Prior to adjusting the sag all temporary conductor joints are to be disassembled and to be replaced by proper conductor joints!

For pulling back the stranded conductors special draw-vices are employed which do not damage the stranded conductors' surface. In particular this is important for aluminium conductors.

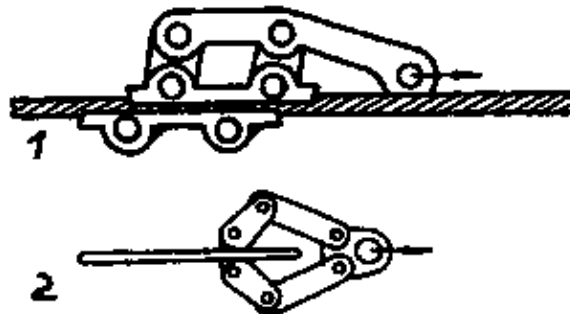


Fig. 2.16. Draw vices

1 draw vice for stranded aluminium conductors, 2 draw vice for stranded copper conductors

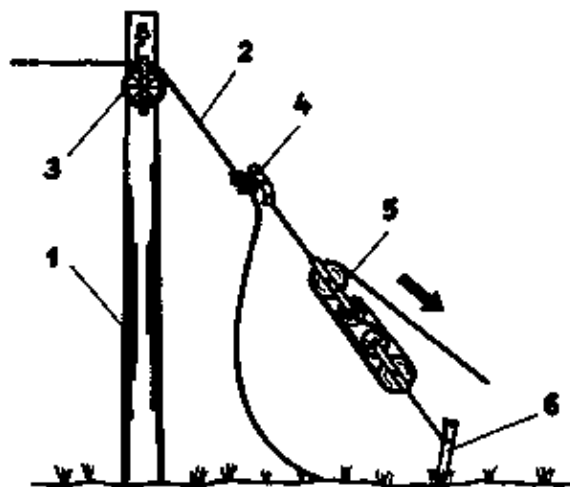


Fig. 2.17. Tensioning the stranded conductor

1 pole, 2 stranded conductor, 3 rope pulley, 4 draw vice, 5 pulley, 6 anchorage

The permissible sag is to be taken from corresponding tables. By slow slackening the stranded conductor the

sag is created. In case of long spans the stranded conductor will be sagging more than in case of short ones.

The sag to be adjusted will depend on the distance between support points (span), on the cross section and material of the stranded conductor and on the temperature!

Adherence to the sag may be checked optically by simple auxiliaries.

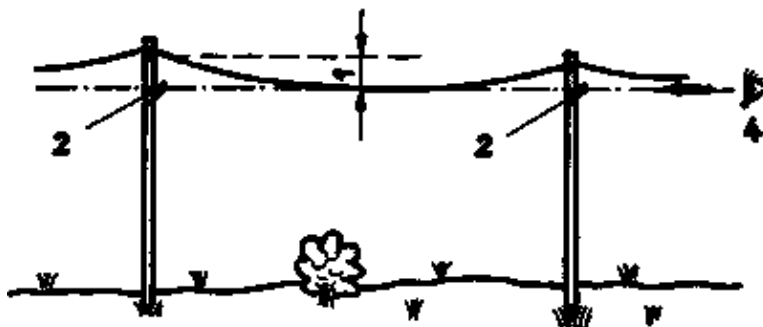


Fig. 2.18. Checking the sag of the stranded conductor

1 sag. 2 adjusting batten, 3 line of sight, 4 eye.

Table 2.3. Technical data of simple wooden poles with stranded copper conductors

conductor cross section mm ²	span m	length of pole m	dig-in depth m	sag at + 40 °C m
25	35	9	1,6	0,43
	40			0,51
	45			0,64
	50			0,78
	55			0,94
	60			1,12
	65			1,28
35	35	9	1,6	0,50
	40			0,62
	45			0,76
	50			0,91
	55			1,07
	60			1,25
50	35	10	1,8	0,55
	40			0,67
	45			0,82
	50			0,96
	55			1,14

	60			1,33
	65			1,52
70	30	10	1,8	0,45
	40			0,65
	50			0,91

2.6. Mounting conductor joints

Already prior to adjusting the sag all provisional conductor joints are to be replaced by the permanent connectors.

The points of conductor joints are the weakest spots in the overhead–lines system. Special attention has to be paid to their mechanical strength and to warrant lowest possible transition resistance!

In overhead–line systems rivet connectors, crimp connectors and bolted connectors are being employed for joining stranded conductors. Moreover cone–type connectors can be found.

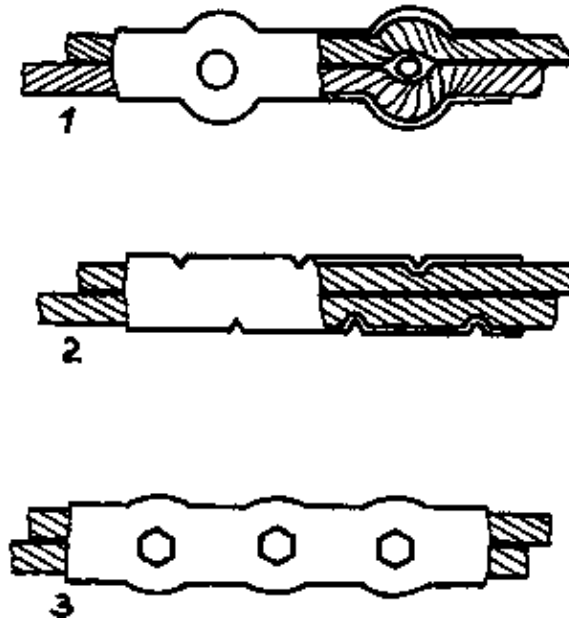


Fig. 2.19. Types of conductor joints

1 rivet connector, 2 crimp connector, 3 bolt connector

Where tension joints occur in the span line, connections are normally made by means of crimp connectors.

The crimp connectors are being mounted by means of crimpers together with crimping inserts to which also a crimping gauge pertains.

Prior to their utilization stranded conductors are being tied off, sawed off and straightened.

Stranded, conductors are on principle not to be sheared off or cut off by chisel!

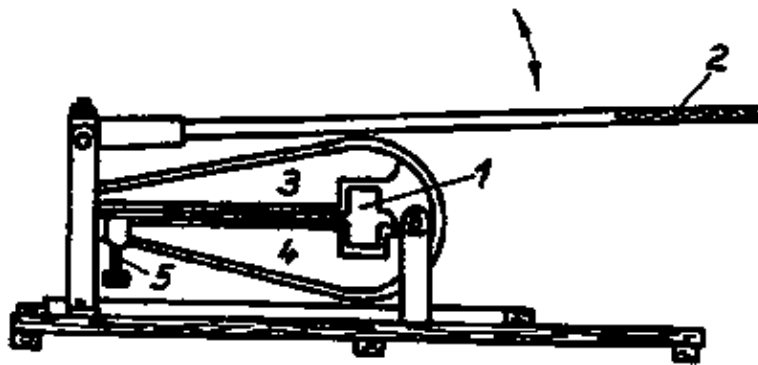


Fig. 2.20. Simple crimper

1 space for crimping inserts and crimp connectors, 2 lever arm, 3 movable part of crimper, 4 fixed part of crimper, 5 set screw

At first the stranded conductors are to be cleaned of adhering dirt and oxide films by a steel brush. Then a very thin film of non-acid technical grease is to be applied to the conductors' ends, and these are slid into the joining sleeve so much as to have them project 3 – 5 mm out of the sleeve.

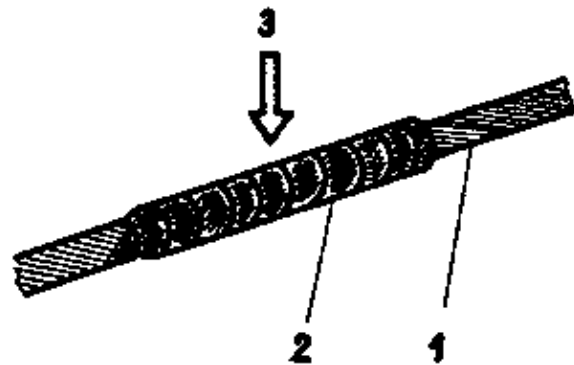


Fig. 2.21. Preparing a stranded conductor for cutting

1 stranded conductor, 2 insulation tape, 3 cutting point

In the case of steel-cored aluminium conductors a sectional or plate inset is slid between sleeve and stranded conductors in such a way as to have their ends evenly protrude from the sleeve on both sides.

Crimping is started from the centre of the sleeve first to one side of the connector and thereafter to the other side.

Proper crimping inserts are to be used in the crimper. On the crimping inserts the designation of the conductor material and the cross section will be found!

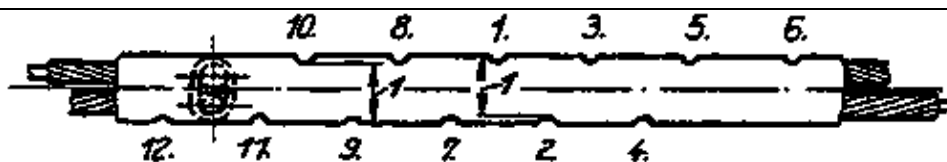


Fig. 2.22. Crimped connection at a steel core aluminium stranded conductor

1 crimping dimension, 1 to 12 sequence of crimping

During crimping the crimper should be kept closed for approx. half a minute after reaching the stop. After each crimping process the correct crimping depth is to be checked by the crimping gauge.

Notches not being sufficiently deep must be recrimped under all circumstances.

When using bolt connectors on stranded aluminium conductors under all conditions care will have to be taken to retighten the clamping points due to the aluminium yielding under the effect of pressure!

Table 2.4. Depth and number of notches for crimped connectors

notching depth for (mm)	cross sections of stranded conductors mm ²									
	25	35	50	70	95	120	150	L85	210	240
Cu–strands	11,6	14,5	16,5	20	24	26	31	35	–	39
steel–II–strands	13,5	16	19	21,5	–	–	–	–	–	–
Al–strands steel core	11	13	17,5	19	24	27	30	33	–	37
Al–strands	15	17,5	20	25	29	33	36	39	41	–
number of notches for										
Cu, steel–II–and Al–strands steel core	2×3	2×3	2×4	2×4	2×5	2×5	2×5	2×5		2×6
Al–strands and short connectors	2×3	2×3	2×4	2×4	2×5	2×6	2×6	2×7	2×7	2×7
ditto for long connectors	2×7	2×7	2×8	2×8	2×10	2×12	2×12	2×12	2×14	–

2.7. Mounting the stranded conductors to the insulators

After adjusting the sag of the stranded conductors these are fixed to the insulators. This takes place by means of binding joints.

The mainly applied binding joints are:

- reinforced cross binding joints
- clamped binding joints
- tie binding joints.

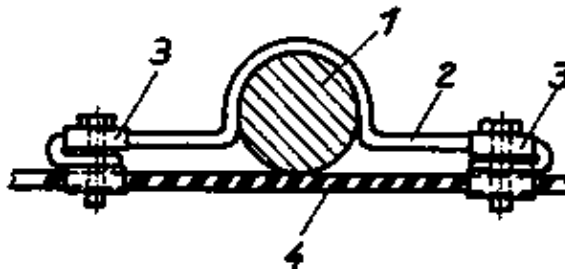


Fig. 2.23. Tie binding joint at a stranded aluminium conductor

1 insulator, 2 tie, 3 s-shaped clamps, 4 wrapped stranded conductor

In case of continuous lines the stranded conductors are preferably fixed by reinforced cross binding joints.

When using stranded conductors of aluminium they must be mechanically protected from the insulators. This will be achieved by wrapping aluminium strip around the stranded conductors. At the contact point with the insulator the aluminium strip is wrapped firmly around the stranded conductor for approx. 13 cm to both sides in each case. Fixing the stranded conductor to the insulator is done by means of binding wire which has to be of the same material as the stranded conductor.

Every reinforced cross binding joint will have to be greased with non–acid technical grease.

How to make a reinforced cross binding joint may be seen from fig. 2.24. For better illustration the turns of the binding wire on the insulator are shown one upon the other. Pay attention, that the stranded conductor should be fixed by 12 turns binding wire at least.

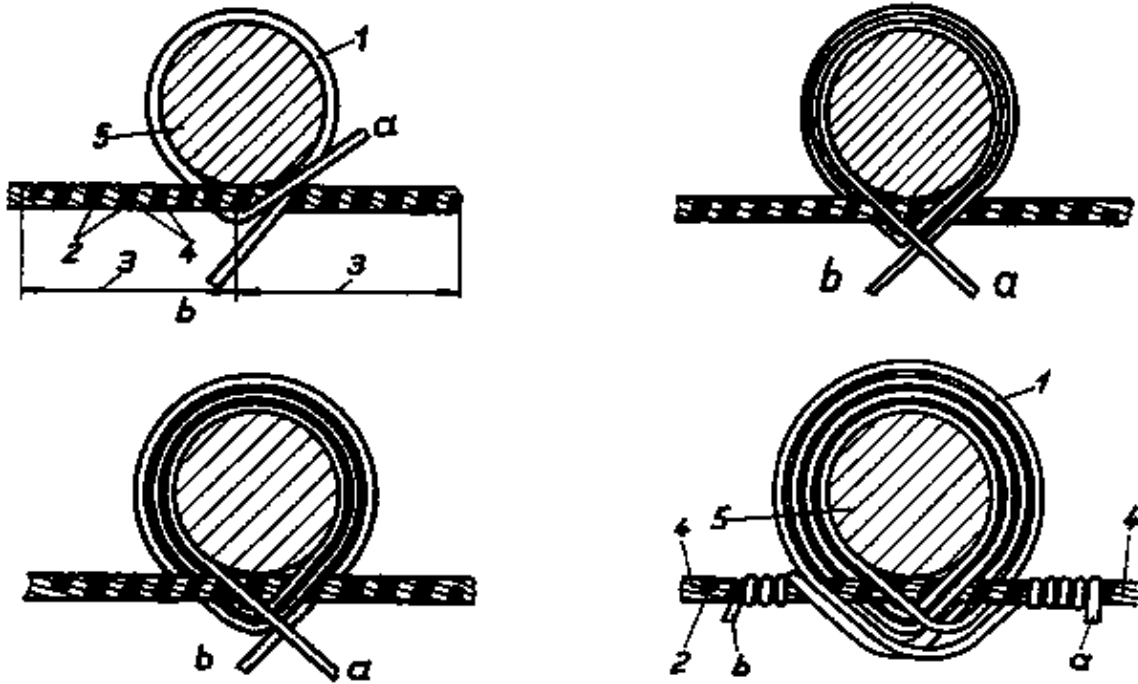


Fig. 2.24. Lashing a reinforced cross binding joint

1 binding wire, 2 aluminium strip, 3 length of wrapping 13 cm, 4 stranded conductor, 5 insulator, a/b ends of binding wire

When making terminal binding joints at stranded conductors of aluminium similarly as in case of the reinforced binding joint an aluminium strip will have to be wrapped around the stranded conductor for protection of the conductor.

Except by terminal clamps, terminal binding joints are also made by using connectors.

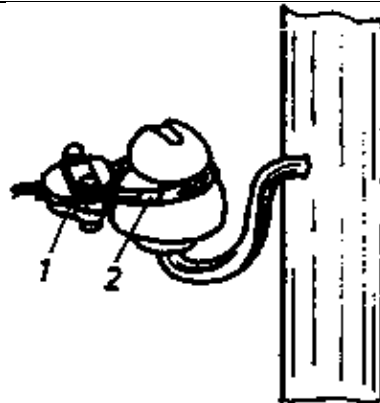


Fig. 2.25. Terminal binding joint with terminal clamp

1 terminal clamp, 2 aluminium strip



Fig. 2.26. Terminal binding joint by bolt connector

1 bolt connector

2.8. Making service taps

For making service taps there is the possibility of directly leading the overhead-line system to the building or to branch off a cable from the overhead line to the building.

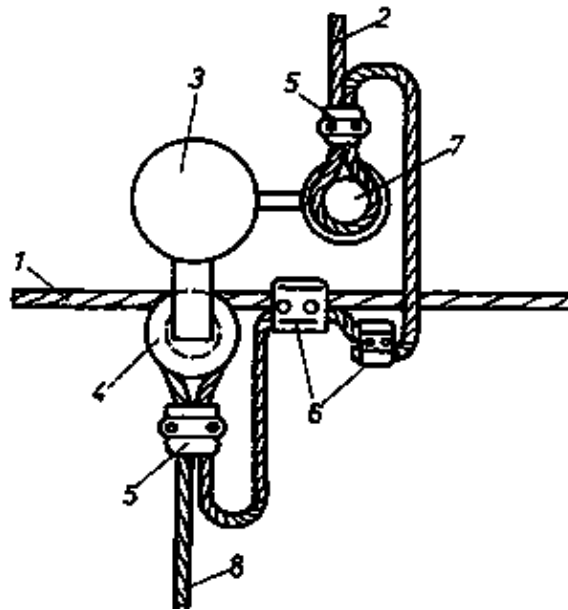


Fig. 2.27. Branching an overhead line from pole

1 main line (lower groove at insulator), 2 branch of service tap, 3 pole, 4 shackle insulator, 5 clamps for terminal binding joint, 6 tapping clamps, 7 pin insulator, 8 further branch

For branching off conductors of small cross section from the overhead line claw-type clamps are being used.

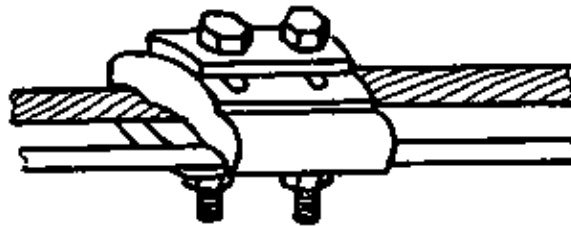


Fig. 2.28. Claw-type clamps

To connect a copper conductor to an aluminium stranded conductor has got its problems. Due to the different metals, copper and aluminium, at the clamping point an electrochemical cell will be created resulting in unfavourable oxidation particularly of the aluminium conductor and thus in a reduction of the cross section. Moreover, by this the clamped connection will become loose.

In this case special aluminium-copper clamps are being employed. Often the overhead lines are directly led to buildings.

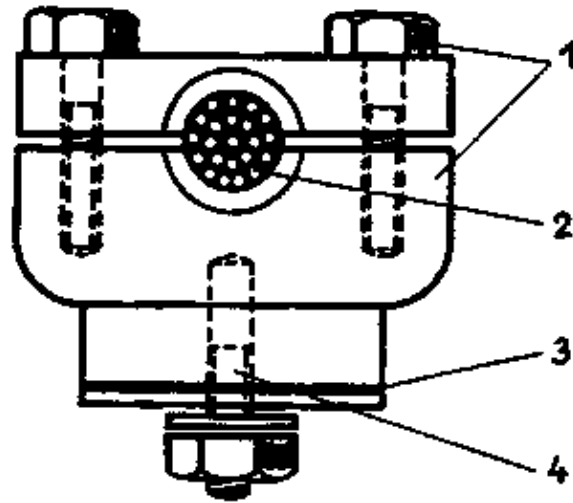


Fig. 2.29. Aluminium-copper clamp

1 aluminium, 2 stranded aluminium, conductor, 3 insulation, 4 electrolytic copper

In this case the insulators are to be mounted as demonstrated in fig. 2.30.



Fig. 2.30. Arrangement of insulators at buildings

1 mounting of two insulators, 2 mounting of three insulators, 4 mounting of four insulators

At building the insulators must be placed into the brickwork as deeply and firmly as to withstand the tensile forces to be expected. When mounting insulators or cross bars to walls of a thickness up to 250 mm they will have to be fixed on the inside to wall reinforcements like e.g. angle iron. This will prevent the insulators from being torn out of the wall.

Water is prevented from ingressing into the building by forming a bend on the cable for dripping off the water before passing the cable through. In passages through walls the cable is laid into protective tubes of 1.5 the diameter of the cable. The protective tube is to be installed slightly inclined towards the outer side in order to prevent ingress of water also in this case.

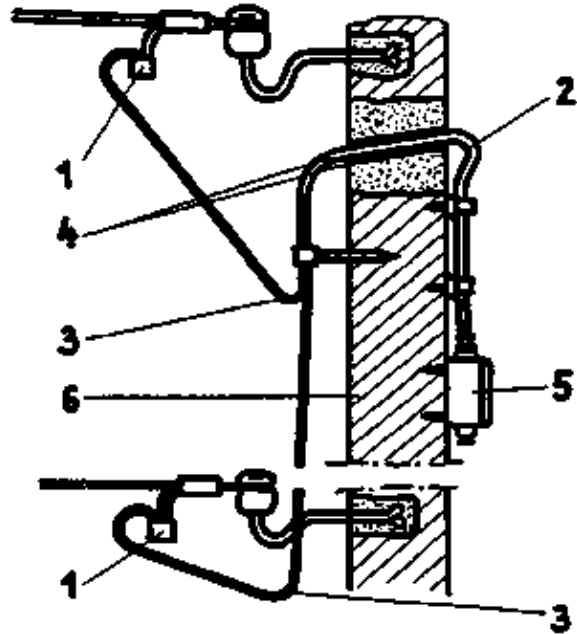


Fig. 2.31. Wall passage

1 clamp, 2 cable, 3 dripping-off bend, 4 passage with tube, 5 junction box, 6 wall

Maintaining the minimum distances between insulators is very important. This is to avoid mutual contact of the stranded conductors with each other in case of wind.

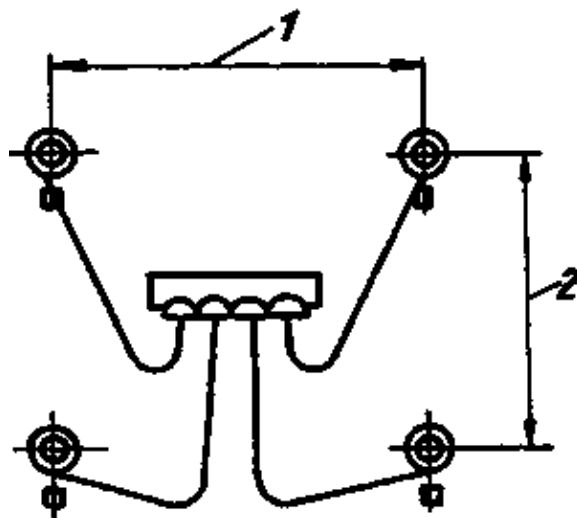


Fig. 2.32. Minimum distances between insulators

1 and 2 distance between insulators 350 mm in each case

Frequently pole cross bars are also mounted to buildings. By transition heads on the pole cross bars the change-over from stranded conductor to cable is accomplished.

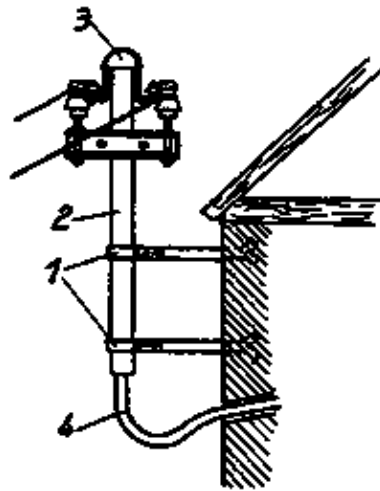


Fig. 2.33. Cross bar

1 support arrangement, 2 steel pipe, 3 transition head, 4 cable

2.9. Work at existing overhead lines

In principle work at existing overhead-line systems is to be performed in dead condition only. Before climbing on poles, in particular wooden poles, their stability is to be checked. The stability of a wooden pole can be verified by simple means:

- sound test: by knocking with a hammer on to the wooden pole just above ground. In case of a high tone the pole may be climbed;
- test drilling: the pole is uncovered for about 50 cm. The pole is to be drilled into by means of a test drill to its centre. The chips sticking to the test drill will give information about the pole's condition. The chips must be dry.

If a safe stability of the pole is not existing any more and its replacement is not possible at once, then the pole will be marked by a red circle.

When this pole must be climbed for urgent reasons, prior to doing so the pole will have to be supported from three sides.

Towers resp. poles of existing overhead-line systems are to be effectively protected against corrosion, rot and pests. Painting coats without penetrative effect, in particular on wooden poles, are not deemed to be protective coats. All cut faces and screw holes are to be protected by a timber preservative (coal-tar oil).

On wooden poles which are to be reattended, bandings are frequently being applied against rot and pests as shown in fig. 2.34. For this purpose the pole is to be uncovered and guyed. The banding is formally wound in clockwise direction around the pole with overlap and nailed on both ends. Steel towers are to be protected against corrosion over the total length by a penetrative primer. Also to the steel ends of concrete mast's reinforcement a protective coat is to be applied, e.g. a bituminous coat.

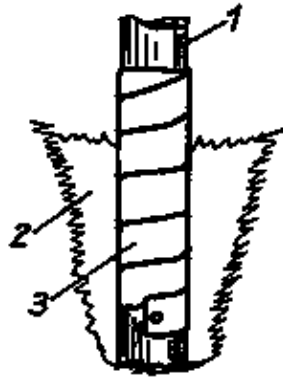


Fig. 2.34. Applying a banding to a wooden pole

1 pole, 2 bared pole, 3 banding applied, 4 banding

Observing labour safety during work at overhead-line systems is of utmost importance. Besides checking the stability of a pole, generally a safety belt is to be fastened and a crash helmet has to be worn when climbing poles. For climbing wooden poles the fitter fixes climbing irons to his shoes. The climbing irons must be fastened firmly to the shoes. For avoiding accidents walking with climbing irons fastened to the shoes is not permitted.

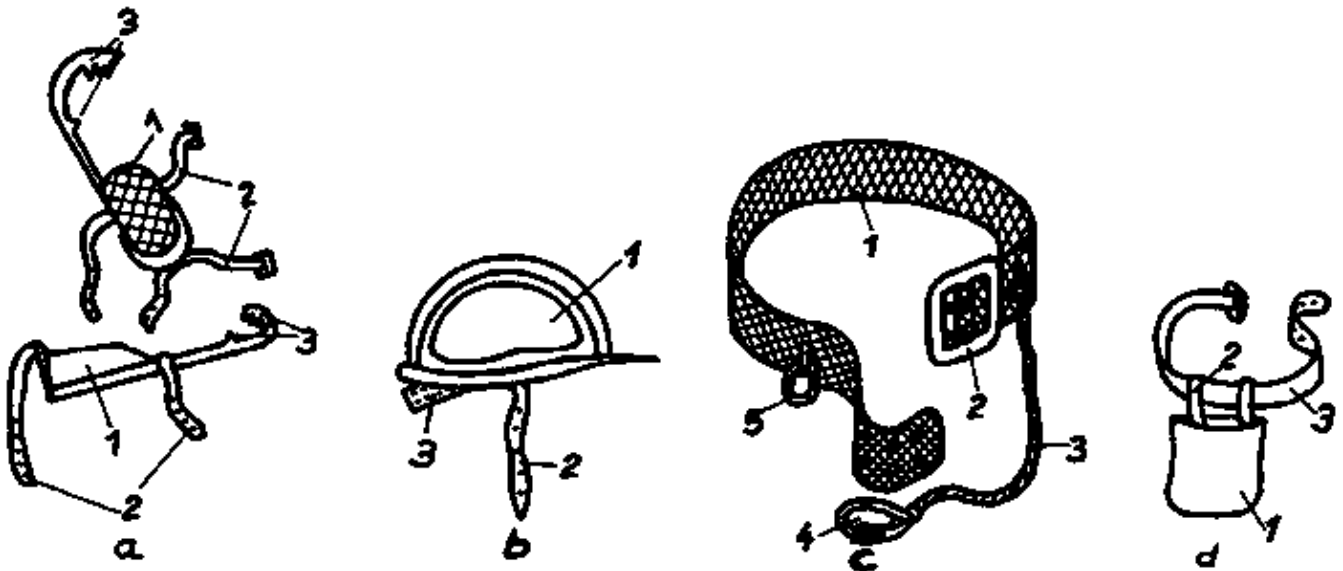


Fig. 2.35. Climbing irons, crash helmet, safety belt and tool-bag

a) climbing iron: 1 foot support, 2 fixing straps, 3 holding tip

b) protective helmet: 1 helmet, 2 chinstrap, 3 neck support

c) safety belt: 1 belt with high breaking strength, 2 double buckle, 3 safety line, 4 securing the snap hooks

d) tool bag: 1 tool-bag, 2 straps, 3 belt

Rubber boots must not be provided with climbing irons, since rubber boots do not fit firmly to the feet!

Work at overhead-line systems is made easier by using collapsible ladders and elevating platforms. They must be entered only if being in an unobjectionable condition and if the devices are firmly and safely based.

When moving on elevating platforms or collapsible ladders no person must be on them. Moreover the cantilever or ladder must be retracted.

Work at live overhead–line systems is to be performed by fitters with a special professional qualification only. Furthermore, an insulated location, special tools and special working apparel will also be required.

Such operations are to be carried out in exceptional cases only, e.g. in case of breakdown repairs.

Great care must be taken if an overhead line is broken. Then the area of danger around the overhead line dropped down is to be blocked at once as not to endanger passer–bys or laymen. The pendant overhead line must be assumed to be voltage–carrying.

Pendant overhead lines must never be touched. This will mean direct mortal danger!

2.10. Summary

The great advantage of overhead lines as compared to cables is the omission of insulating sheaths and earthworks.

As conductor material for stranded conductors copper, aluminium as well as aluminium alloys and bronze are being taken.

The span of overhead lines varies between 35 and 80 m.

Poles for overhead lines in the low voltage range need no particular foundations as a rule.

The sag to be adjusted is to be seen from corresponding tables. It depends on the distance between poles, on the conductor's cross section and on the prevailing ambient temperature.

Conductor joints are the weak spots in the overhead–line system.

They are to be mounted firmly. Rivet connectors, bolt connectors and crimp connectors are applied in overhead–line systems.

The most frequently used connector is the crimp connector.

Fitting the crimp connectors is done by means of crimpers.

By means of the crimp gauge pertaining to the equipment the depth of the notches is checked. The proper crimping inserts will have to be employed.

Stranded conductors are fixed to the insulators mainly by reinforced cross binding joints.

The minimum distance between insulators on poles and walls of buildings is to be maintained under all circumstances. Insulator supports and cross bars of poles are to be anchored in the brickwork in such a way as to resist the tensile forces to be expected. At cable branches from overhead lines each core of the cable is bent downwards in order to have the water drip off.

For passing through walls the cable is to be placed into a protective tube of 1.5 times its diameter.

Prior to climbing poles, in particular wooden poles, their stability has to be tested.

3. Laying of underground cables

Consumers' installations in the low–voltage range are very frequently connected to the power supply networks by underground cables. In this, the traditional paper–insulated compound–impregnated cable is more and more replaced by plastic–insulated dry cable.

At almost the same current-carrying capacity several advantages are offered by plastic-insulated underground cables as compared to compound-impregnated cables:

- omission of the expensive lead sheathing,
- the insulation value will not be reduced due to loss of compound,
- considerably lower weight,
- simpler preparation,
- no problems in overcoming differences in height.

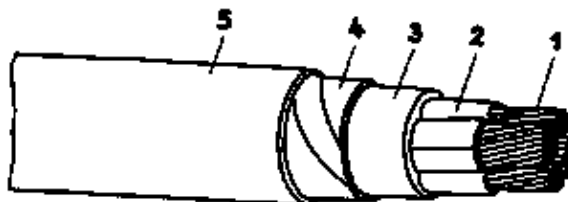


Fig. 3.1. Plastic sheathed cable with copper conductor

1 copper conductor, 2 plastic insulation, 3 common conductor covering, 4 armoring of steel strip, plastic sheath

The concentric conductor of the plastic cable in fig. 3.2. may be used as centre conductor or protective conductor.

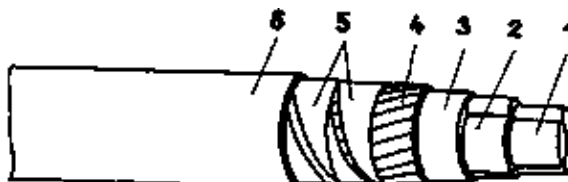


Fig. 3.2. Plastic cable with solid aluminium conductors

1 aluminium conductors, 2 plastic insulation, 3 common conductor cover, 4 concentric conductor of aluminium flat wires (armouring), 5 protection against corrosion, 6 plastic sheath

In lieu of the conductor material copper, becoming ever more expensive and scarcer, more and more underground cable the conductor material of which consists of aluminium is being applied.

Power cables have standardized designations from which the construction and type of cable may be seen!

3.1. Preparing cable laying

The first thing to be done before starting to lay the cable is to fix the cable route under consideration the tracts of land and rights of ownership and utilization. On principle the same is valid here as when fixing the route of an overhead line.

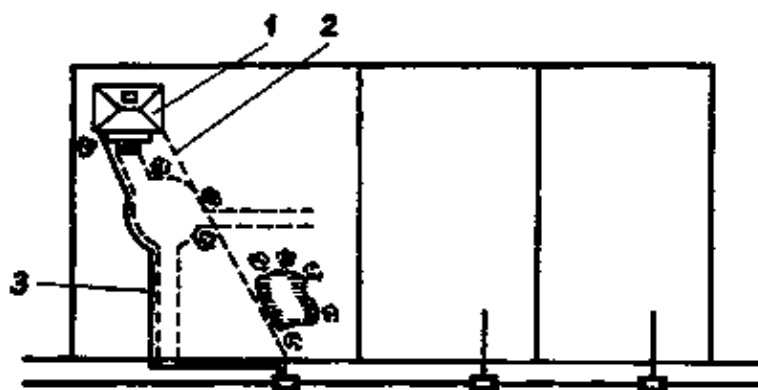


Fig. 3.3. Fixing the cable route prior to running out the cable

1 building to be connected, 2 improper cable route since damage will be caused to ways, ornamental shrubs and banks of waters, 3 proper cable route along a way without mentionable damages to the property

Underground cables are laid in cable ditches. Depending on the properties of the soil and the degree of danger to damaging the cables these cable ditches are from 70 to 120 cm deep. The base of the cable ditch must be so wide as to offer sufficient space for the cables to be laid. The distance between cables is to be approx. 20 cm. In order to prevent damage to the cables they are placed on sand, fine gravel or screened soil. The excavated soil stays beside the cable ditch. After completion of cable laying it will serve to back-fill the remaining ditch.

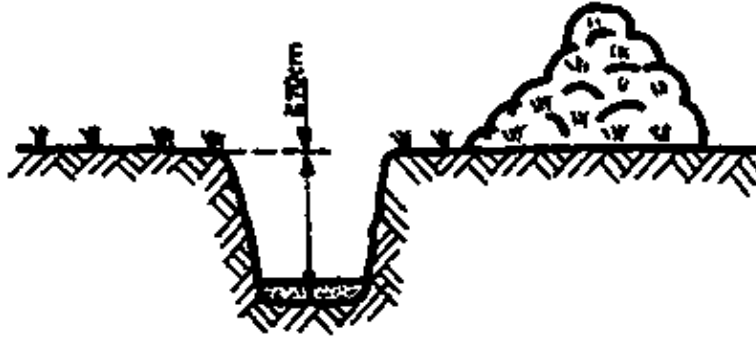


Fig. 3.4. Cross section of a cable ditch

Prior to laying the cable the required cable and auxiliaries for this activity will have to be provided. During this, special attention will have to be paid to the transport of the cable drums. Unloading the cable drums is preferably to be done by mobile crane or from a special trailer. Under no circumstances must cable drums be dropped from a transport vehicle.

In difficult terrain a provisional ramp may serve as an auxiliary. By allowing the cable drums to drop down damages to the cables and cable drums may be caused.

Cable drums are to be moved only in rolling direction. The rolling direction is marked on the cable drum.

Prior to processing, the cable is to be tested for current flow!

In case of the cables showing damages to the insulation, in particular the external insulation, such cables must not be used. If necessary a sleeve will have to be fitted to the faulty point.

3.2. Underground laying of power cables

The cable drum is firmly placed on cable jacks or a cable car. Care has to be taken to position the cable drum horizontally only a few centimeters above the ground. This will prevent the cable drum from slipping off laterally during the cable is run out. A braking device is to be provided at the cable drum.

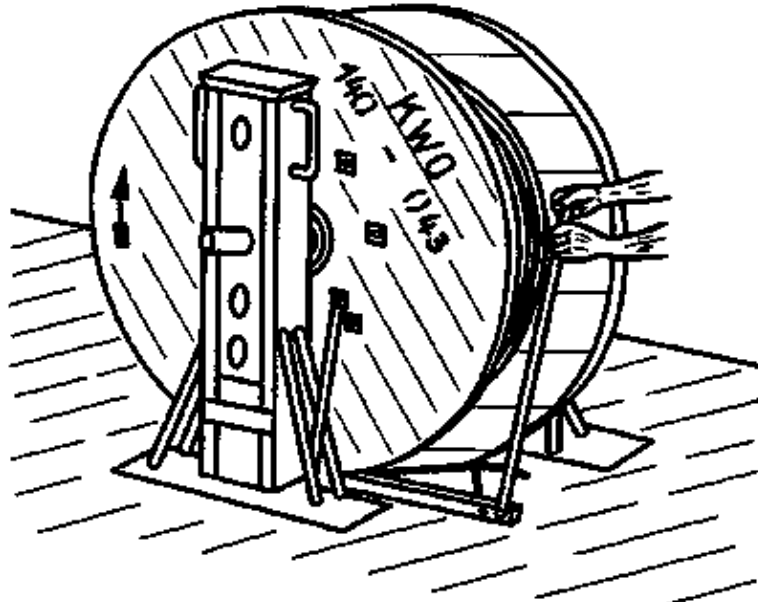


Fig. 3.5. Jacked-up cable drum with braking arrangement

During reeling off the cable should continuously run out under tension from above

The cable has to be pulled off the drum opposite to the rolling direction indicated on the cable drum. The cable must neither be kinked, nor must there be formed loops or curls!

When laying cable, preferably devices for mechanical cable laying will have to be employed. For that purpose winches and cable handling machinery are to be taken.

Cable handling machinery is to be employed in case of long and winding routes.

When laying cable by means of a winch the cable will be joined to a pulling rope by means of a cable stocking of metal.

The pulling speed is to be slowly and flexibly adapted to the tensile force of the cable, in which case

the permissible tensile forces must not be exceeded!

In distances of 5 m idlers are to be positioned on which the cable runs. In curves angular idlers will have to be arranged. If application of machinery for cable laying is not feasible the cable will have to be pulled off manually. The cable is carried with the arms spread downwards.

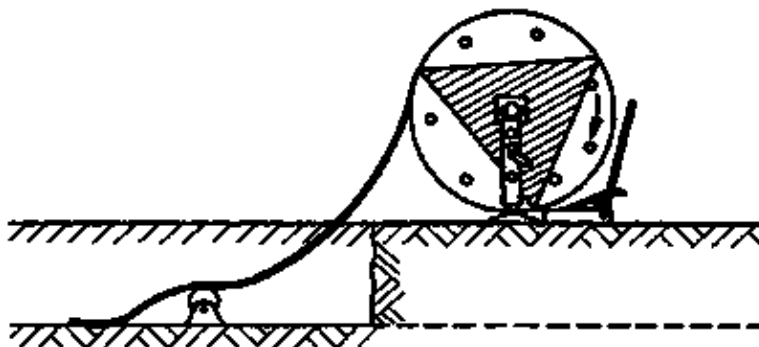


Fig. 3.6. Support by idlers of cable being run out

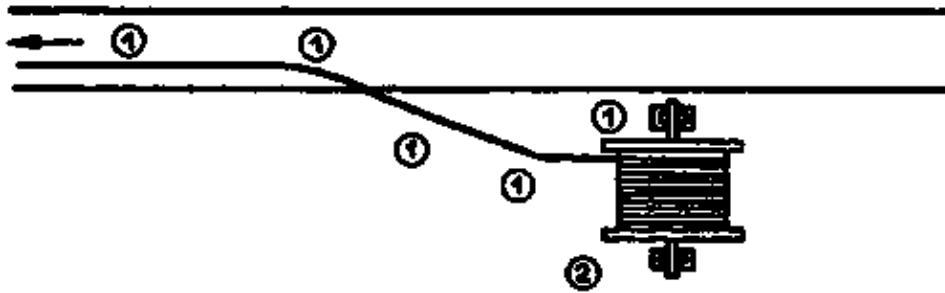


Fig. 3.7. Position of workmen during running out the cable

1 workmen, 2 supervisor

Cables must not be carried on the shoulder because the permissible minimum bending radius may be exceeded resulting possibly in ruptures of cable or insulation. Cables must not be dragged over the ground or other obstacles!

During cable laying the permissible minimum bending radius will have to be observed.

The minimum bending radius is to be related to the external diameter of the cable!

Table 3.1. Permissible bending radii (da) of cables

Type of cable	during laying or bending	final position
lead-sheathed cable	20 da	10 da
smooth aluminium sheath	25 da	20 da
plastic-sheathed cable	15 da	10 da

da: external diameter of cable

At temperatures below 4°C cable is not to be laid any longer. Cables will become brittle at low temperatures and will be easily broken. In urgent cases also at low temperatures cable may be run out, if the cable is warmed up beforehand, e.g. by means of a heater fan.

Cables will be covered in cable ditches by bricks or concrete ducts resp. cable covering hoods. Cables may also be laid into cable ditches embedded in sand without cover. However, in this instance the route of the cable must be marked by an approx. 10 cm wide yellow plastic tape, placed 30 cm above the cable. This exemption holds, however, for cables with a concentric conductor only.

Cables being laid into the ground without cover must be dug in at least 1 m deep!

If cable covering hoods are being employed the cable will have to be surrounded by sand. Existing cavities between cable and covering hood will obstruct heat dissipation from the cable to the soil.

Beneath streets resp. roads cables are being passed, laid in cement ducts. There are cement ducts for 1 to 4 draughts. They are made of concrete and are to be put together without a gap between them.

Beneath railway tracks cables are to be laid in tubes 1.50 m deep.

Alongside gas pipelines cables are being laid in a distance of approx. 25 cm.



Fig. 3.8. Cement duct with 3 draughts

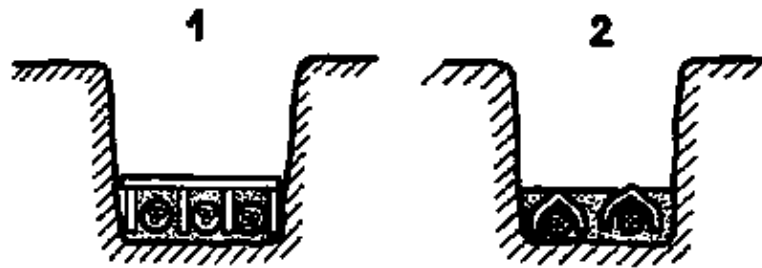


Fig. 3.9. Cable covers

1 bricks, 2 cable covering hoods

Also in the instance of crossing other cables, e.g. telecommunication cables, both cables are to be protected mechanically. Each 3 to 5 m the laid cables will be marked. For that purpose plastic cable marking tape is being used.

Colour and printing on the cable marking tape will inform about

- voltage
- cable type and number of cable as well as
- cross section.

Before cutting sheathed cable, the sheath of the cable will be tied on both sides of the cut. For that purpose "endless bindings" are made of firmly wound twine. The principle of such a binding may be seen from fig. 3.10. For cutting hand hack saws or strength-saving cable shears are being employed.

Within buildings the outer jute cover of cables is to be completely removed for reasons of fire protection!

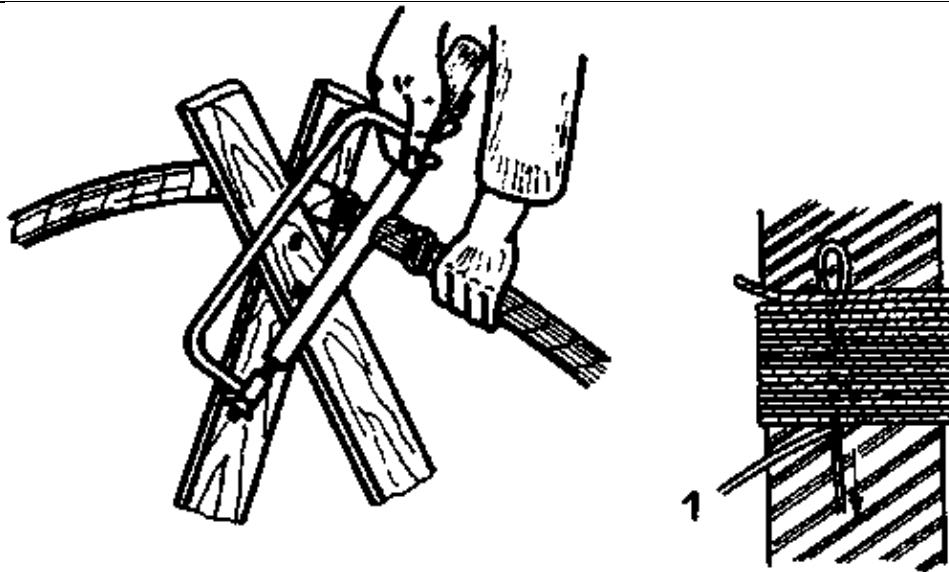


Fig. 3.10. Cutting of a lead-sheathed cable with jute envelope and representation of an endless binding at the cable

1 pull twine by flat pliers until the twine's upper end is in the binding, thereafter cut end at the binding

For drawing or correcting the cable layout plan, cables, cable joints, underpasses as well as particular crossings and exposures will have to be surveyed prior to back-filling the cable ditch. The cable ditch will be back-filled by 30 cm thick layers of soil. Each layer will have to be compacted.

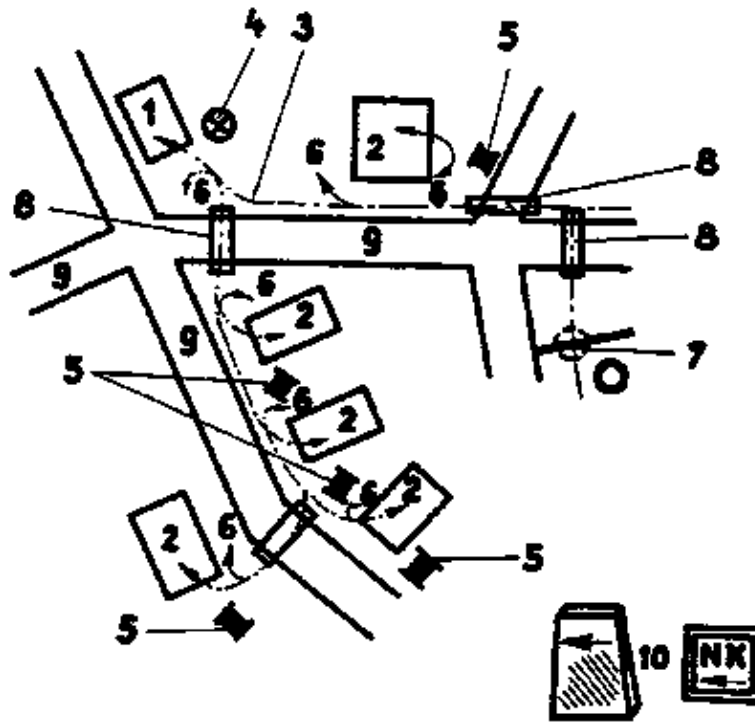


Fig. 3.11. Simplified segment of a cable layout plan and cable marker with information on longitudinal extension

1 switchgear, 2 consumer's installation, 3 cable, 4 site of cable laying machine, 5 sites for placing cable drums along the route, 6 direction of earth excavation, 7 crossing with pipeline, 8 street underpasses, 9 streets, 10 cable marker

The position of cables in ground without fixed reference points is marked by cable markers.

They consist of ashlar or concrete and bear an abbreviation.

3.3. Removal of insulation layers from cable

Prior to making conductive connections at the cable, the individual insulation layers will have to be removed. Processing plastic insulated cable is quite simple. For a cable according to fig. 3.2. the following working steps will be taken:

1. Removal of plastic sheath

Take measurements; by dismantling device make longitudinal incision in plastic sheath; make the circular cut; pull off sheath.

2. Bringing out the concentric conductor

Deflect the individual armouring wires and bunch the wires

3. Cutting of sheet

Nick the sheet by triangular file just above the deflected armouring and tear off

4. Removal of the common conductor cover

Make longitudinal incision by dismantling device; make circular cut; fan out conductor; tear off common conductor cover; clean conductor's plastic insulation from adhering residues of plastic material.

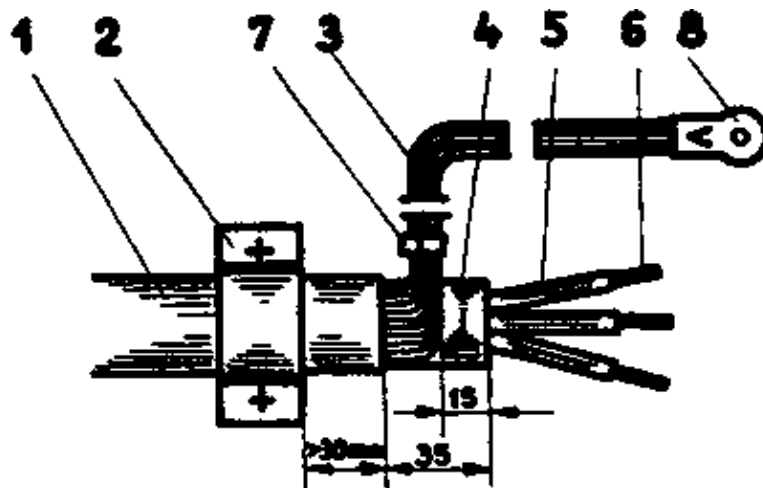


Fig. 3.12. Removal of insulation layers from a cable with concentric conductor

1 plastic sheath, 2 cable fixing clamp, 3 concentric conductor, 4 common conductor cover, 5 plastic insulation, 6 conductor, 7 clip 10 × 1 mm in a distance of approx. 120 mm, 8 cable terminal

For removal of the insulation layers from paper-insulated compound-impregnated lead-sheathed cable the following working steps are to be taken: (see fig. 3.13.)

1. Make tie and remove the external jute cover.
2. Fit collar out of a piece of armouring sheet, cut the armouring by filing and remove same.
3. Remove cushioning layer.
4. Clean lead sheathing by a non-inflammable dissolvent.
5. Solder on copper strand to lead sheath.
6. Make circular incision on lead sheath; make parallel incision in lead sheath; roll-back the loose strip by flat pliers; tear off lead sheath along circular cut; slightly widen the upper edge of the remaining lead sheath.
7. Tie off the belt insulation; unwind and tear off belt insulation.
8. Spread conductors and cut off fillers.
9. Tie off conductor insulation; remove conductor insulation; clean conductors; finally deflect conductors.

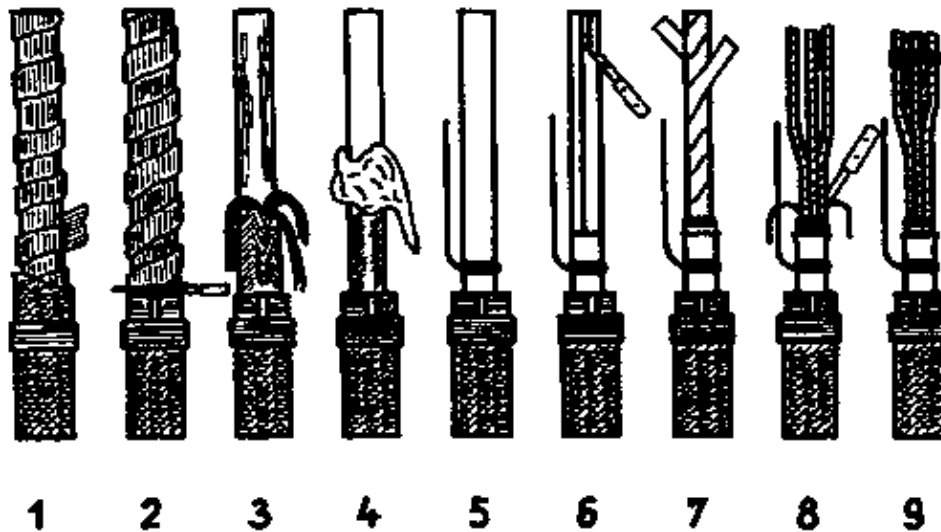


Fig. 3.13. Working steps on removal of insulation layers at paper-insulated lead-sheathed cable

Special care has to be taken in soldering on the earthing strand. For this purpose propane gas soldering devices or a blow lamp for soldering are being employed. The lead sheath and the copper strand to be soldered on are to be cleaned from all oxides. The lead sheath may be cleaned by scraping with a stripper. The copper strand is to be tautly placed around the lead sheath and the soldering surface to be wetted by soldering flux. Solder tin stick is to be laid on in pieces and to be shaped like a bulb by means of a dampened rag after thoroughly warming the soldering surface.

Caution! In case of too much warming of the lead sheath at one point, perforations of the lead sheath may result!

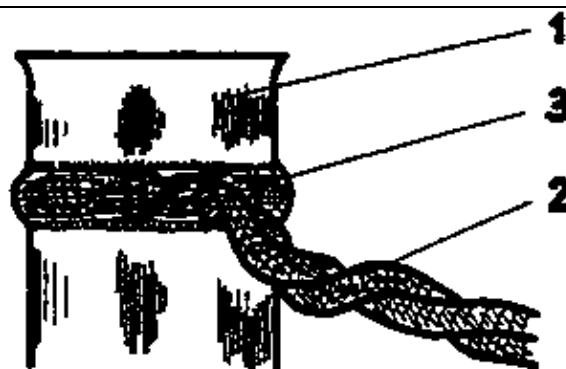


Fig. 3.14. Copper strand soldered onto lead sheath

1 lead sheath, 2 copper strand, 3 soldering surface

3.4. Cable joints and terminations

For protecting cables from ingress of humidity into the insulation, for mechanical protection as well as for preventing cable impregnating compound to emerge from compound-impregnated cables, conductor connections at cables are being made by means of sleeves and cable terminations.

Sleeves serve for connecting cables to each other. Connecting sleeves and tee joints are discerned.

Cable terminations are being installed at points of the cable where transition from cables to open-ended line systems, e.g. bus bars takes place.

There are differences in respect to the construction of sleeves and terminations. Practically sleeves and cable terminations of cast iron, plastic and cast resin are being used.

Fitting of cable sleeves takes place in the cable ditch. For easing the work of the cable fitter providing a work pit is recommended.

For making the sleeve joint both ends of the cable must overlap each other for approx. 50 cm and run towards the sleeve's end as an s-shaped load reducing curve.

Sleeve bodies of grey cast iron are split. The upper and lower parts of the sleeve will be bolted together after accommodating the cable.

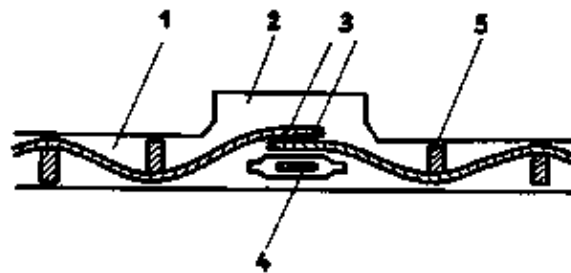


Fig. 3.15. Placement of cable in front of a connecting sleeve

- 1 cable ditch,
- 2 working pit,
- 3 ends of cable,
- 4 cable sleeve,
- 5 flatly placed brick

The outer cover of the cable extends into the inner end of the sleeve's housing. Each opening of the sleeve for entering the cable will be sealed by a bituminous felt batting wrapped around the cable.

The lengths of the lead sheath and of the belt insulation in case of paper-insulated lead-sheathed cables to be stripped are dependent on the cable cross section.

The connection of the conductor ends to each other can be achieved by stamping, soldering, welding or screwing.

Stamped connections can be made in a very simple and firm way by sliding a stamping tube on to the prepared conductor ends which will – similar as in case of stamped terminals – conductively connect both conductor ends after stamping.

Within the sleeve the conductors are insulated and spaced by means of stems.

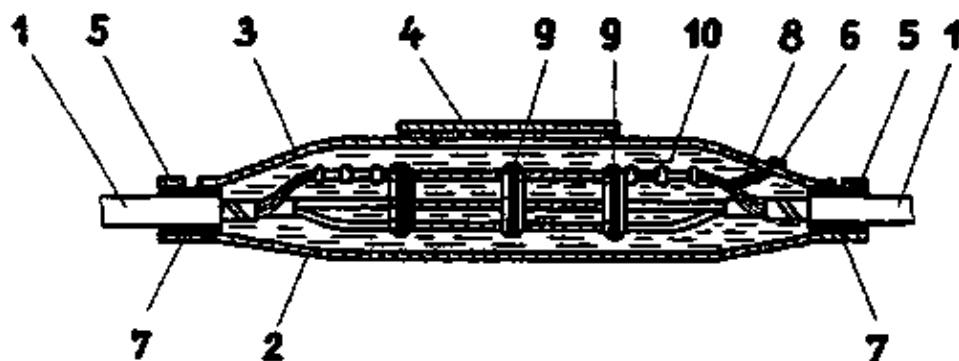


Fig. 3.16. Sectional view of a connecting sleeve at a plastic cable with concentric conductor

- 1 cable, 2 lower portion of sleeve, 3 upper portion of sleeve, 4 lid, 5 compression clamps, 6 earthing socket, 7 bituminous felt batting, 8 flexible earthing strand, 9 steins, 10 sealing compound

The concentric conductors and lead sheath of the cables are being connected to each other.

It is also very important to include the sleeve body into the earthing system.

When installing service tap boxes the main cable needs not be cut!

Cable sealing compound by which the sleeve is completely sealed is easily melted and highly insulating. It will have reached its processing temperature if bubbles do not raise any more in the melting container. Then further heating must be stopped. If during heating the sealing compound foam is created on the surface it will have to be stirred until the foam subsides. Foam means humidity in the sealing compound reducing the insulating capacity of the sealing compound considerably.

After approx. 10 minutes the sealing compound is to be poured carefully through the lid of the sleeve. Since the sealing compound will shrink during the cooling process, refilling will have to be done.

In case of cable terminations to be sealed by sealing compound the same process will be applied as when preparing a cable sleeve.

In the instance of plastic-insulated cable sealing by cable termination is required only if ingress of humidity may take place!

Making cast-resin terminations is simpler than fitting cable terminations sealed by sealing compound.

Also in this case it will be important to seal the cable when working with paper-insulated lead-sheathed cable. This will be achieved if the conductor insulation, the belt insulation and approx. 10 mm of the metal sheathing are being wrapped in two layers of PVC-tape. Each layer of PVC-tape with an overlap of 50 % is provided with a coat of PVC-adhesive. For this termination no box body, but a mould only will be required. Into this mould, being arranged around the cable and sealed, a mixture of synthetic resin and silica sand will be poured.

The mould's concentric position around the cable must be paid attention to!

If strictly observing the mixing ratio and the curing time the casting will be permanently hardened after approx. 24 hours. Then the mould may be removed and the casting be cleaned (de-burring).

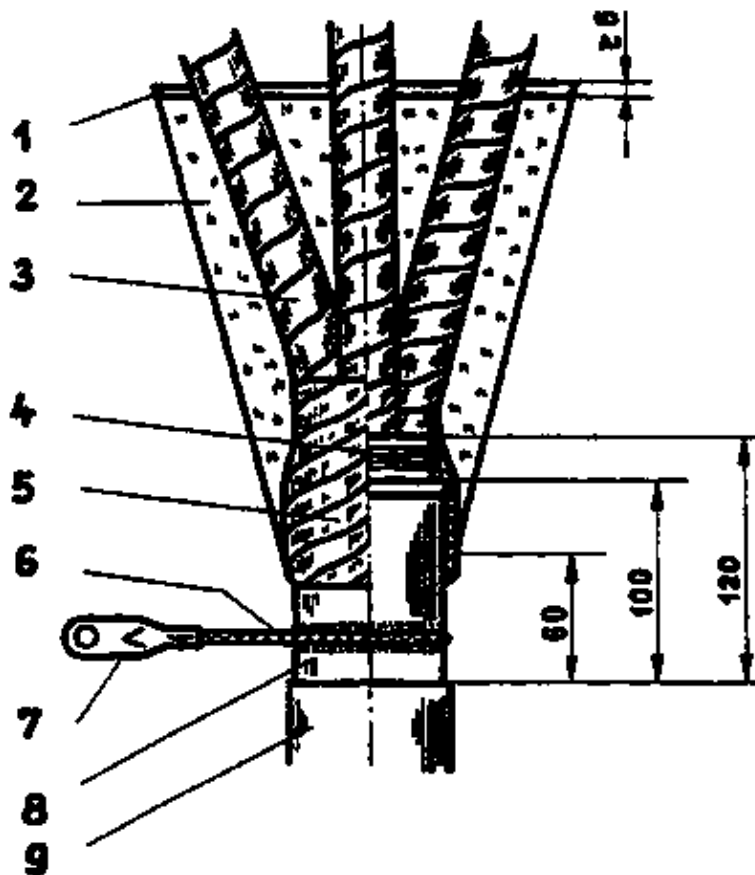


Fig. 3.17. Cable termination of cast resin

1 cast resin, 2 cast resin and silica sand, 3 conductor insulation covered by PVC-tape, 4 belt insulation with binding (4 windings), 5 lower PVC-banding, 6 copper strand, 7 stamped cable terminal, 8 metal sheath, 9 external protective cover

Synthetical resins are chemically aggressive. For protecting the skin and the clothes, protective apparel will have to be worn when making terminations of cast-resin. During this work the eyes are particularly endangered. They are to be protected by safety goggles.

Fitting of cable sleeves and cable terminations is a responsible work. Vocational experience and special knowledge will be required. Due to this, cable sleeves and terminations should in principle be mounted by experts having received special training only! The completed cables will be fixed by a double-tongued mounting clip (see fig. 3.12.) or other mounting elements, e.g. an angle iron, in front of the connection point.

3.5. Making of conductor connections

Conductor connections on cable terminations are quite frequently made via cable terminals.

In case of the traditional methods of connection like soldering, welding or clamping of cable terminals to conductors no absolute safety for an unobjectionable connection will be given.

Stamped connections have replaced these traditional types of connection. Stamping is distinguished by reliability of the procedure, durability of the connection also under unfavourable conditions as well as by uncomplicated handling of the stamping tools. For the stamping of cable terminals mechanical hand stampers, or in case of bigger cross sections, hydraulic stamping devices are being employed.

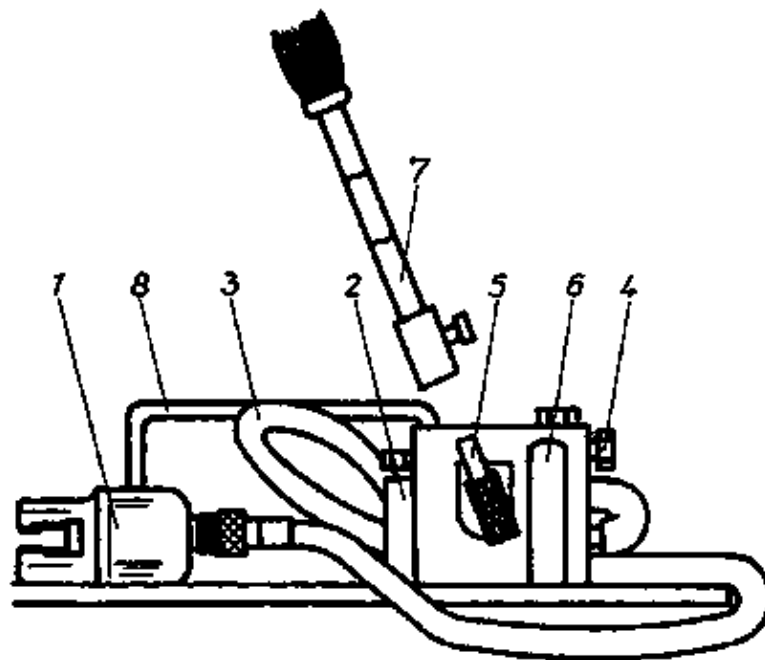


Fig. 3.18. Hydraulic stamping tool

1 stamping head, 2 safety valve, 3 pressure hose, 4 pressure reducing valve, 5 pump lever, 6 pressure tank, 7 pump handle, 8 bearing grip

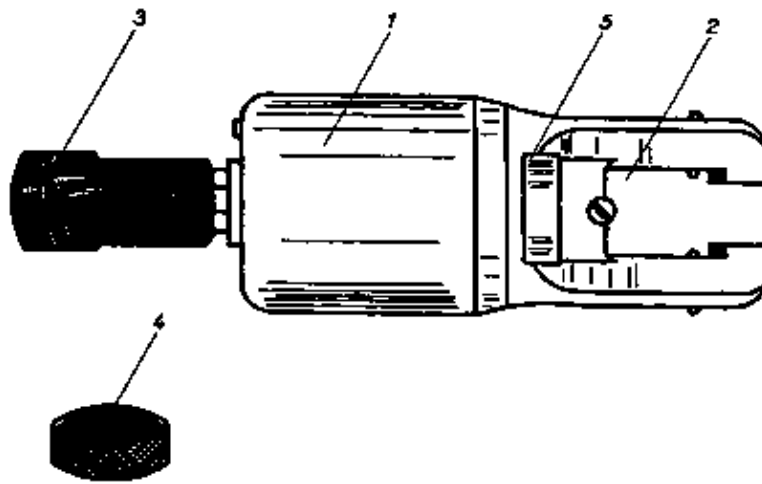


Fig. 3.19. Stamping head of a hydraulic stamping tool

1 Pressure tank of the stamping head, 2 space for stamping inserts, 3 hose connection, 4 screw cap, 5 piston

Stamping inserts being matched to the type of cable and cross section of the conductor will be fitted into the stamping tools.

There are two different types of stamping inserts:

- stamping inserts for V-grooving
- stamping inserts for hexagonal stamping.

V-grooving is on principle applied to copper conductors only!

Cable terminals are marked with information about the size of the diameter of the connecting pin and the conductor's diameter.

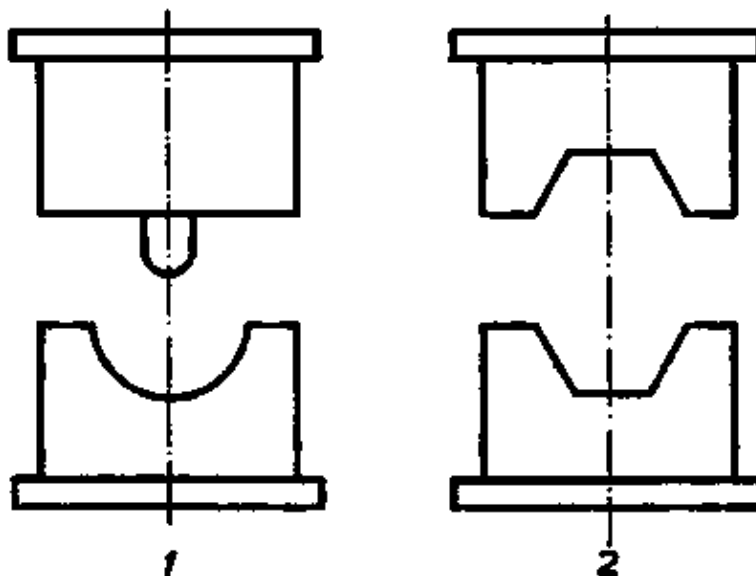


Fig. 3.20. Stamping inserts

1 V-grooving, 2 hexagonal stamping

The stamping inserts for the cable terminal are in any case to match the cable terminal.

The designations of suitable stamping inserts are to be taken from the tables in the valid regulations.

When stamping on cable terminals the following fitting process is to be adhered to:

1. Cutting conductor lengthwise

The conductor is to be matched to the length of the cable terminal up to the connecting pin. It is to fill out the cable terminal. The elongation of the cable terminal's connection during hexagonal stamping has also to be considered. It has to be subtracted from the length of the conductor. Depending on the cross section in question this change of length may be between 3 and 5 mm.

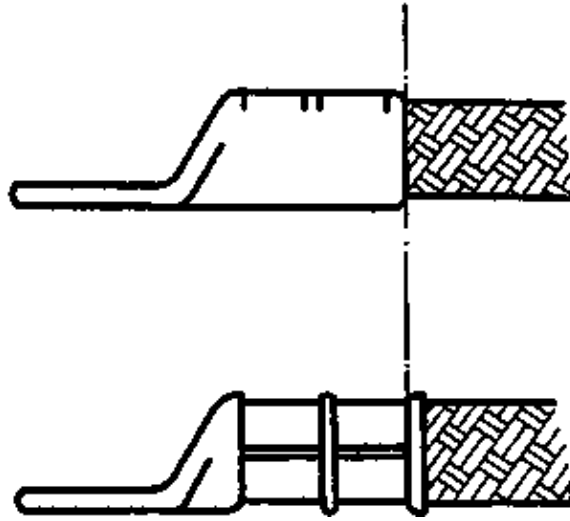


Fig. 3.21. Cable terminal prior to and after stamping

2. Removal of the conductor's insulation and cleaning of the contact surfaces.

The outside of the conductor and the inner contact surfaces of the terminal's barrel must be metallic-bright. Contaminated conductors and barrels of terminals will have to be cleaned from adhering dirt and oxides by wire brush.

Every conductor has to be cleaned only just prior to the stamping process, max. 10 minutes beforehand!

3. Entering the conductor into the barrel of the terminal

Difficulties which may arise in that process are best overcome by chamfering the conductor laterally or by fixing a taut wire binding adjacent to the cut surface which will have to be removed after having entered the conductor into the cable terminal's barrel. Segmental conductors are to be stamped circularly by the corresponding stamping inserts prior to putting on the cable terminal.



Fig. 3.22. Entering the conductor into the cable terminal's barrel by means of a wire binding

4. Stamping on the cable terminal

V-grooving is to be performed so as to have the local impression situated at the upper or lower side of the terminal's barrel approximately in the centre. In particular, maintenance of the required stamping depth has to be observed. This will be achieved when the stamping jaws of the stamping insert will have closed or corresponding markings have been reached.

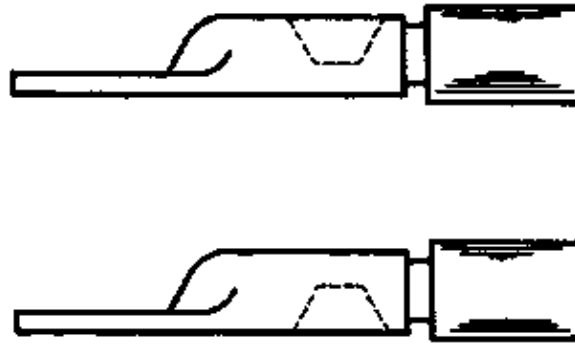


Fig. 3.23. V-grooving of the upper or lower sides

In case of hexagonal stamping of aluminium conductors the stamping insert has to be applied in between the stamping marks on the cable terminal. If two stampings are to be made, stamping will be started at the point nearest to the terminal lug. The burrs resulting from hexagonal stamping at the cable terminal will have to be removed.

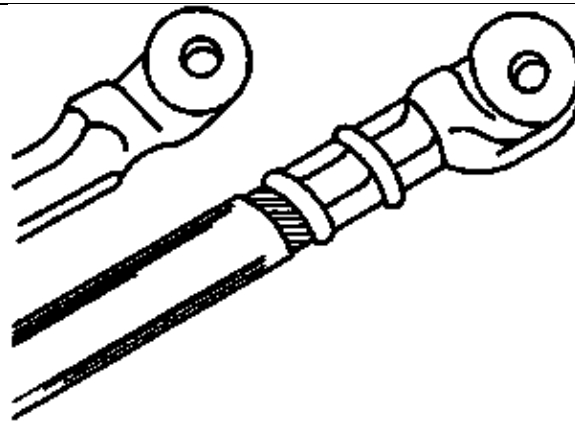


Fig. 3.24. Connection to cable terminal of aluminium conductors with one or two hexagonal stampings

If after closing of the stamp jaws further pressure is exerted on the stamping tool this will unconditionally lead to heavy damage at the stamp inserts or the stamping device itself (risk of accident!!)

Stamp jaws which are not completely closed do not warrant a durable electrical connection (restamping to be done!!)

Lapping the conductors, which has been dealt with in section 3.4. on processing of paper-insulated lead-sheathed cables, takes place after fitting the cable terminals.

For soldering of cable terminals there are some restrictions.

Soldering of cable terminals should be turned to only if stamped terminals cannot be applied.

How to proceed when soldering cable terminal is to be taken from fig. 3.25. and 3.26.

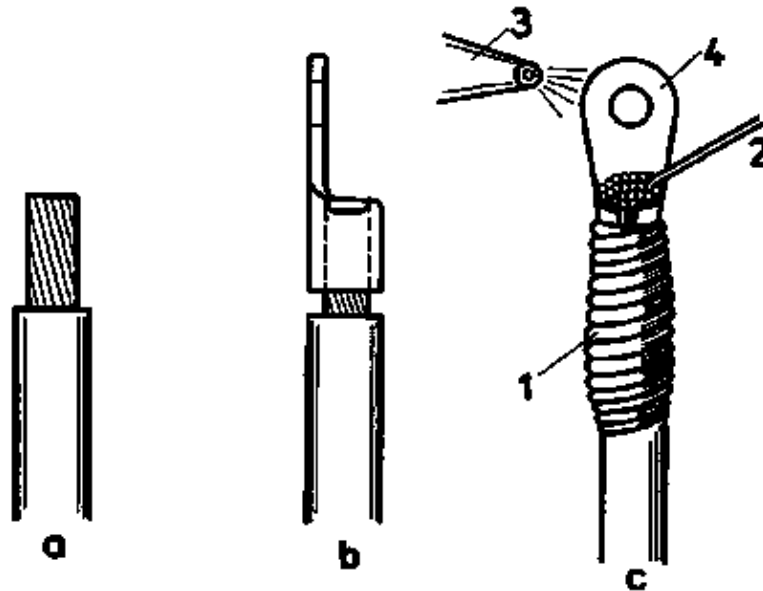


Fig. 3.25. Soldering a cable terminal

a) prepared conductor, b) conductor with cable terminal slid on, c) soldering on the cable terminal: 1 flame-proof batting, 2 solder, 3 heating nozzle, 4 cable terminal

When soldering on cable terminals the connecting area around the lug of the cable terminal is continued to be heated until the soldering tin laid on starts to flow. So much solder is put on to the soldering surface that all parts of the conductor in the total area are covered by tin which must show a mirror reflection.

In no case so much solder is to be brought on the soldering surface resp. heating is continued so long that the solder flows through the cable terminal into the conductor!

Soldering cable terminals requires extensive special skills and is therefore to be carried out by especially qualified experts only.

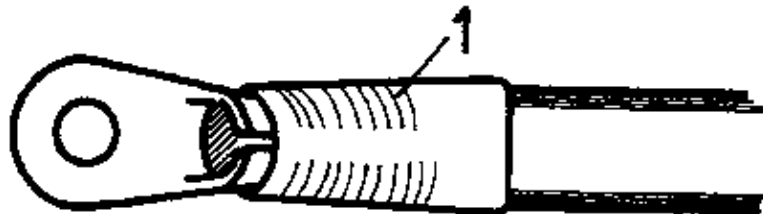


Fig. 3.26. Cable terminal finished by soldering

1 plastic tube or tape

3.6. Testing of cables

Except for the current flow test prior to commencing cable laying the insulation value will be measured after installation of the cable. This test is performed by experts by applying a high voltage for an exactly fixed time unit according to test standards. Within this time no breakdown of the cable insulation must happen. The results of this test are being recorded on a test certificate. The cable may be put into operation after successful testing only.

3.7. Summary

The cable marking informs about:

- type of cable,
- construction of cable
- material and shape of conductors
- cross section of cable.

Cables are being supplied on cable drums in case of larger quantities.

Laying of underground cables is done from the cable drum into cable ditches.

Underground cables are placed 0.70 m deep into the ground at least.

The distance between two underground cables is to be approx. 0.20 m.

Below temperatures of $+4^{\circ}\text{C}$ underground cable is to be laid in warmed up condition in urgent cases only.

When running out cable the following points of emphasis are to be observed:

- the minimum bending radius must not be undercut,
- cables must not be dragged on the ground when being laid,
- underground cables are to be covered. Cables without coverage will have to be dug-in 1.00 m if these cables have a concentric phase conductor,
- every 3 to 5 m underground cables are to be provided with marking tape.

When removing the insulation from underground cables, the individual, insulation layers of the cable are to be removed. Minimum insulation lengths which must remain after stripping are to be adhered to. Cable joints are being made by sleeves and by means of cable terminations. In practical use are sleeves resp. cable terminations of cast iron, plastic or cast-resin.

Conductor connections are mainly made via cable terminals. For this, stamped cable terminals are being preferred to screwed, soldered and welded cable terminals. Stamped cable terminals are stamped on by means of hydraulic or mechanical stamping tools. In this tools matching stamp inserts are to be used.

After laying, the underground cables are tested for adherence to the required insulation resistance. The fixed minimum insulation values are to be kept.

Preparation of the underground cable will be decisive for its life.

4. Low-voltage switchgear and distribution systems

Low-voltage switchgear and distribution systems are an essential part of electrical supply. These are operated by consumer's voltages up to 1 kV ac voltage or 1.5 kV dc voltage.

Low-voltage distribution systems serve to supply all consumer's installations the connection of which to the low voltage network is customary. Except for the station service installations of power plants and transformer stations these are individual consumer groups in industrial plants, in craftman's businesses as well as the public network with its many consumers like dwelling and public buildings as well as offices. Such systems are operated foremost in centres of consumption. This is already required due to the necessity to keep cable lengths as short as possible for limiting the power losses arising from the high currents in the low-voltage network to a reasonable quantity.

The basic purpose of low-voltage distribution systems is therefore to feed the electrical power supplied by a feeder to bus bars and from there via many taps to the individual consumers. According to the requirements, the load necessities, the place of operation, the switching necessities and accessibility there are different types of low-voltage distribution systems.

4.1. Low-voltage distribution systems

In accordance with local and spatial conditions low-voltage distribution systems are classified in

- indoor systems,
- outdoor systems.

Grouping the distribution systems according to their design

- open-type switchgear,
- enclosed switchgear (factory-finished switchgear),
- encapsulated switchgear,
- installation distribution systems

are being discerned.

4.1.1. Open-type switchgear

This is preferably applied in case of higher operating currents. Its advantage is to be easily accessible and well arranged making work with it convenient. Its disadvantage is, however, that it can only be installed in enclosed electrical operation rooms to which authorized staff has got access only. Due to that, it will need more space.

These assemblies generally consist of frameworks of rolled steel sections which may be put up free-standing.

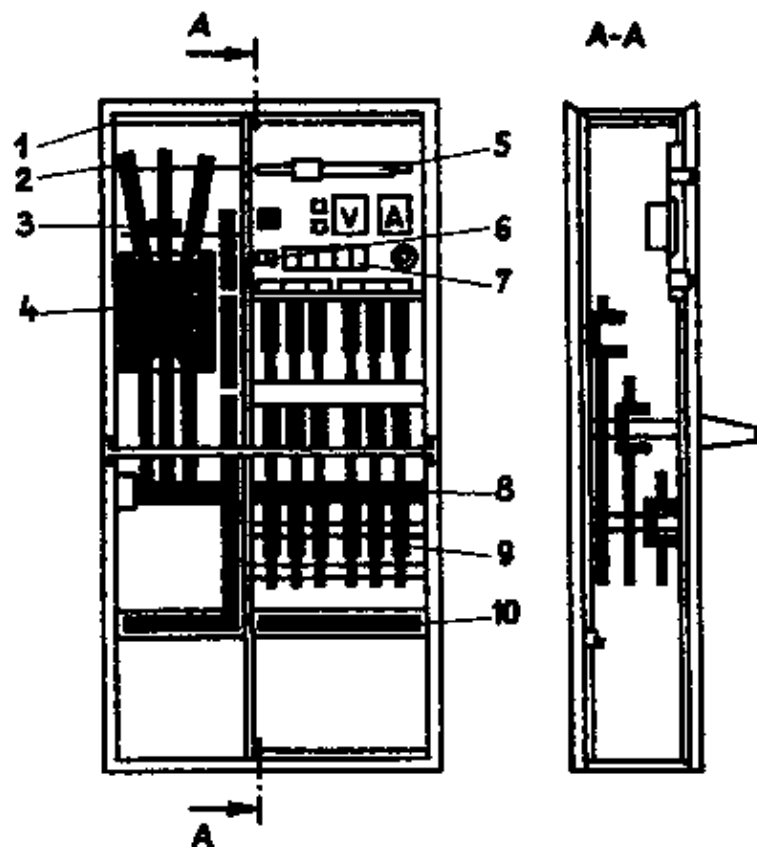


Fig. 4.1. Schematic representation of an open-type switchgear

1 frame, 2 feeding bars, 3 current converters, 4 power switch, 5 terminal board, 6 auxiliary relays, 7 fuses 8 bus bars, 9 lower parts of low-voltage high-power fuses, 10 bar for protective conductors

4.1.2. Enclosed switchgear (factory-finished switchgear)

This means standardized switchgear for indoor use. In case of this type of switchgear panels with different insertions may be arranged together without problems.

Due to factory-finished supply there will be but little installation work required. The switch cubicles are being bolted to each other and connected at the bus bars only. These systems are distinguished by good connecting and extension facilities. All cable connections are performed from below in wiring spaces provided for this purpose. Application of the plug-in method enables quick replacement of modules. The connections of the plug-in units are being made by run-in contacts. The bus bars are screened from the devices. Because of the shape of the switch-gear the installation room will be well utilized.

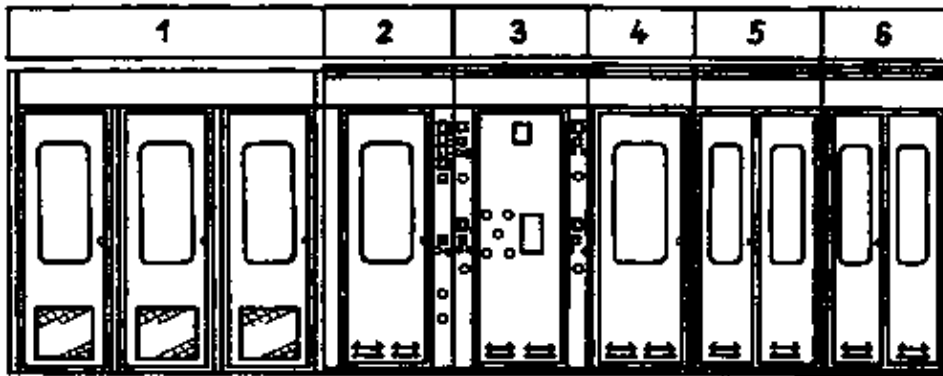


Fig. 4.2. View of a factory-finished heavy-duty station

1 transformer box, 2 supply panel, 3 output panel, 4 capacitor panel, 5/6 contactor panel

Enclosed switchgear (factory-finished switchgear) and open-type switchgear are placed and fixed above openings through which the cables are passed into the switching system. The cubicles are being aligned and bolted to each other.

4.1.3. Encapsulated switchgear

Encapsulated switchgear may be used indoors as well as outdoors. It will always operate there, where high demands are put to protection against humidity, dust, mechanical damage and explosion. The encapsulation may consist of cast iron, weather-resistant steel sheet or plastic.

Encapsulated switchgear has rubber sealing preventing penetration of foreign matter, humidity and explosive matter into the interior of the switchgear.

The switchgear consists of switch boxes assembled like modules containing all required equipment including bus bars. They are mounted to framework or directly to the wall.

The design of the encapsulation depends on the purpose of the switchgear.

When using encapsulated switchgear in explosion-prone rooms the special design of the encapsulation will prevent the switchgear from causing an explosion.

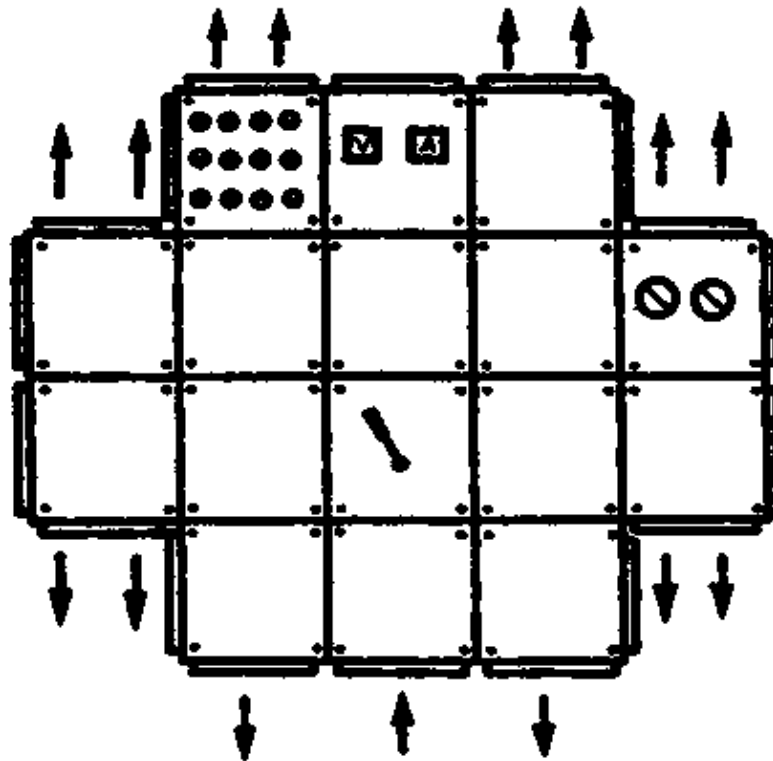
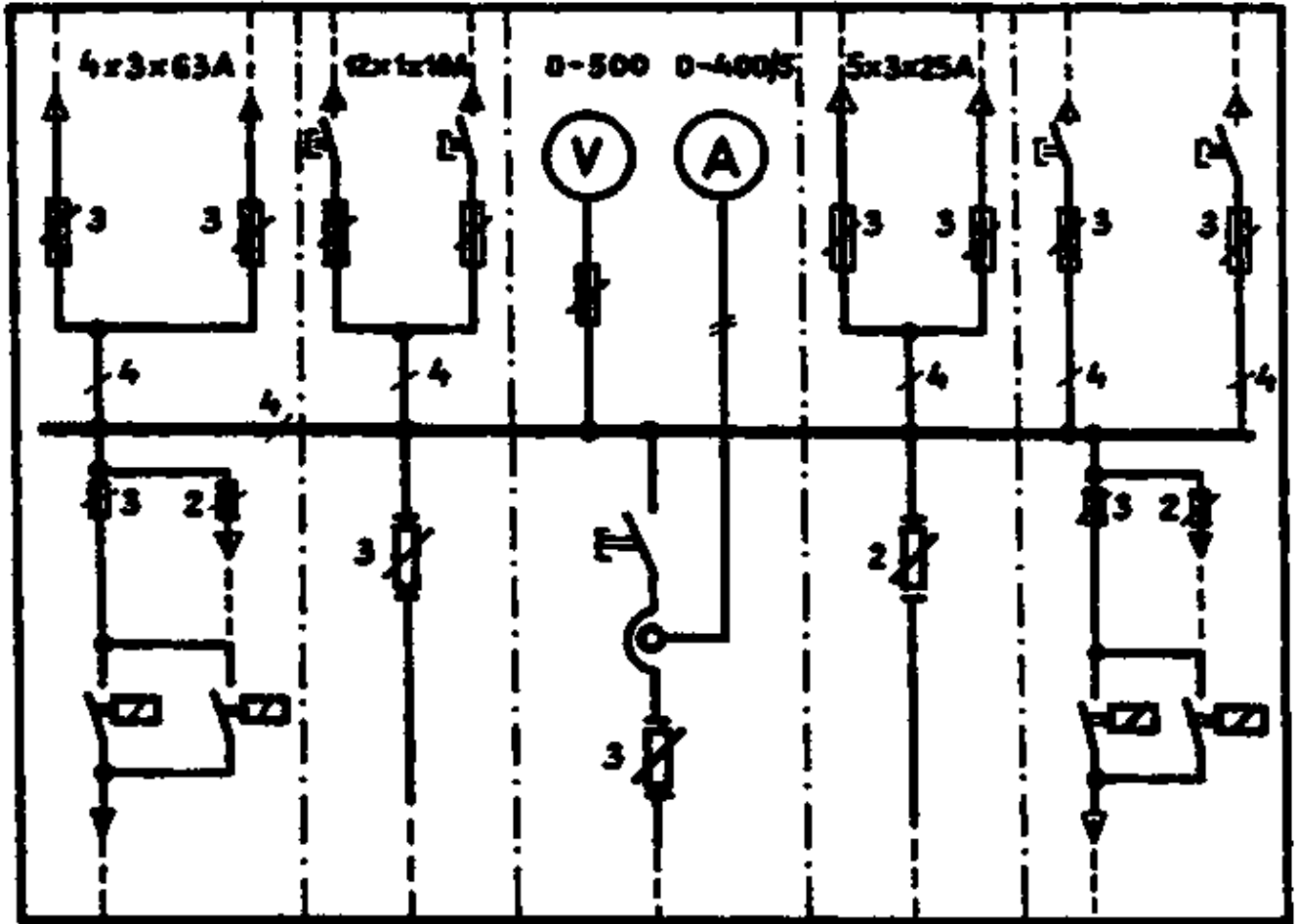


Fig. 4.3. Schematic representation of an encapsulated switchgear

4.1.4. Installation distributions

Installation distributions are foremost employed to supply power to dwelling and public buildings, offices and in a limited scope also to industrial establishments (lighting distributions). They are the simplest form of low-voltage distribution systems. In this case a difference is made between cabinet distributors, switch distributions for underplaster and surface installations as well as central distributors (distribution of fuses in dwelling buildings).

Generally the distributions consist of a frame or framework and a sheet resp. plastic cover. Decorative coverings by wooden or glass doors in niches may be made.

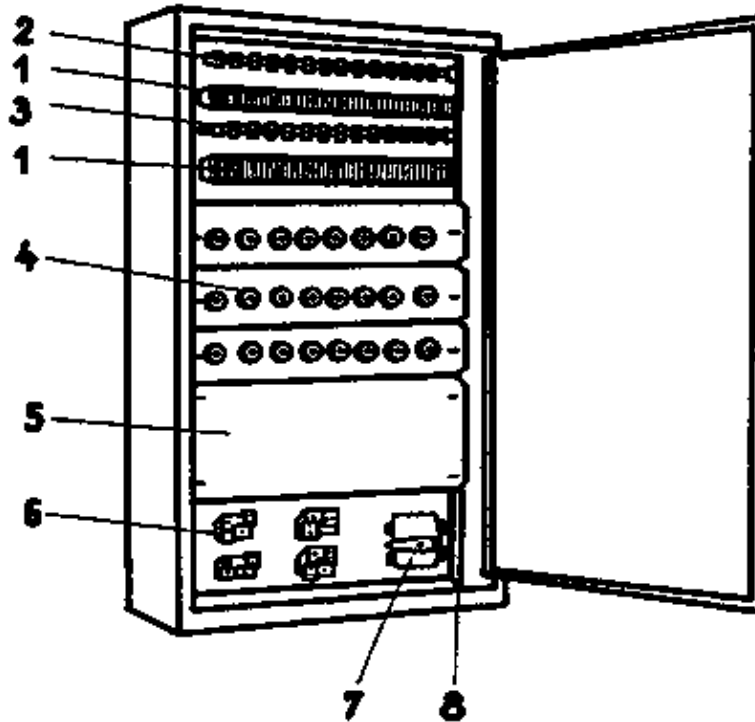


Fig. 4.4. Distribution cubicle

1 terminal strip, 2 terminal strip of protective conductors, 3 terminal strip for neutral conductors, 4 fuses, 5 screening sheet for electrical devices (protection against contact), 6 connecting terminals of feed line, 7 master switch, 8 mounting framework

4.2. Cable connections to switch and distribution systems

The connection cables are entered into the wiring space of the switchgear and distribution system and connected after removing the insulation. In front of the wiring space the connection cables are to be secured by pull relief against being torn off.

For that purpose a part of the switch and distribution systems has got rails to which relieving clamps may be fitted.

By wiring space that part of the switchgear is meant, in which the cables will be connected to the switching devices of the switchgear.

As relieving clamps double-tongued clips or clamps (quick-fixing cable clamps) are being used.

If cables are to be fixed by double-tongued clips the cables will have to be lapped with cable paper for cushioning purposes.

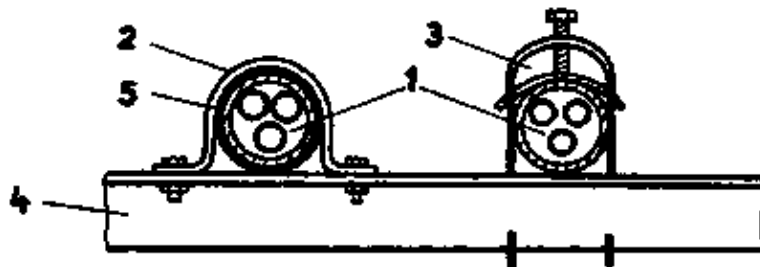


Fig. 4.5. Relieving clamps for cable

1 cable, 2 double-tongued clip, 3 clamp (quick fixing cable clamp), 4 mounting angle, 5 cable paper

Depending on the type of connection points and according to the conductors' cross sections the cable will be connected as described in section 3.

Maintaining the required degree of protection in case of encapsulated switchgear is important. Screwable cable entries are to be tightened and sealed by putty. Conductors which must be installed along or mounted to metal parts, in particular edges, are to be protected at the exposed point, e.g. by plastic tape or hose.

4.3. Preparation and installation of bus bars

In switch and distribution systems bus bars as main current conductors will distribute the electrical power supplied by the feeder. They are therefore an important component of switch and distribution systems.

Solid, non-insulated conductors are called bus bars!

The conductor material of bus bars will be rolled aluminium or copper.

For low-voltage switch and distribution systems mainly flats are being used. Besides them, further sections, e.g. rounds or channels are being taken.

Prior to processing the bus bars will be cleaned from dirt and adhering oxide residues which may have come on to the metallic bright surface during shipment or storage.

If the bus bars are distorted they will have to be straightened on a parallel or straightening machine. When straightening bus bars on a parallel a rubber mallet will be used in order not to damage the bus bar's surface. Distortions on the wide side are being eliminated by short and strong blows of the rubber mallet. Distorting of the narrow side of the bus bars are more difficult to remove. For straightening the bus bars the inner edges of the distortions are to be worked by the rubber mallet until the bends vanish.

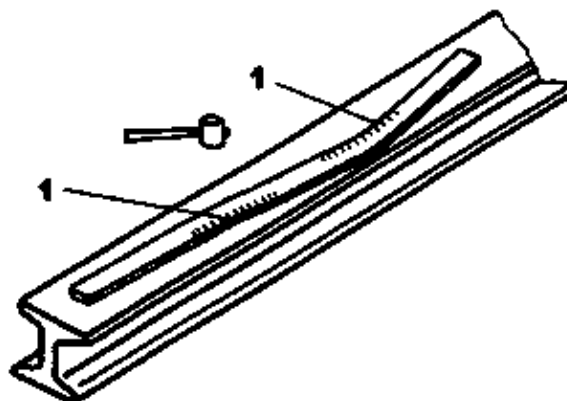


Fig. 4.6. Straightening a bus bar by rubber mallet

1 edges of the bus bar to be worked on

For marking of bus bars pencils or copying pencils are to be used. Scribes are generally not permitted for marking busbars, the reason being that on bending points marked by scribe the material will start to crack and may break.

Bus bars are sawed to length and are not to be sheared. When sawing bus bars clamped in a vice they are to be protected against impressions by the inserts. The sawed off surfaces of bus bars are to be deburred. If it becomes necessary to bend bus bars, bending devices will have to be employed.

In order to avoid cracking of the bus bars, a bending radius of 1 d (bar thickness) must not be undercut. The max. bending angle of bus bars will be 90°. If the bus bar is to be bent beyond this angle, bending will have to be done in two sections.

The bending angle on bending flats around the narrow side will be max. 30°!

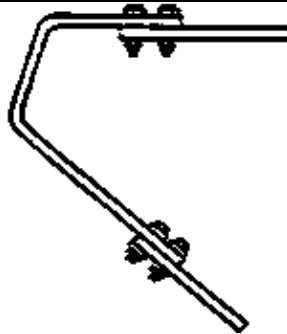


Fig. 4.7. Bus bar bent in two sections

Mounting holes are punched or drilled into bus bars, oblong holes are to be punched into bus bars. It is not permitted to file oblong holes into bus bars. The edges of the mounting holes must be well deburred.

The climatic conditions may require to paint the bus bars on their overall length and to tin the connection points of copper bars. Moreover, by painting bus bars the heat dissipation from the bus bars to the environment will be improved.

Care has to be taken to have the connecting faces completely plane for obtaining the largest contact area possible.

The type of bolted mounting depends on the bars' thickness and their cross sections.

Bus bars will be mounted sliding, not rigid. Due to warming-up caused by the current flow the bus bars must be allowed to extend in length. For that purpose it will be mounted to bar holders of insulating material and supporting insulators. Fig. 4.8. represents a bus bar mounting. For avoiding strain due to extension in length each section of the bus bar is fitted by a fixed support, the other supports being sliding supports. Also by fitting so called expansion strips the elongation of bus bars may be compensated. The expansion strips will serve further to absorb possible shocks caused e.g. by operation of power switches. They consist of strips of metal foil put one upon each other being welded on both sides to solid pieces of the bus bar.

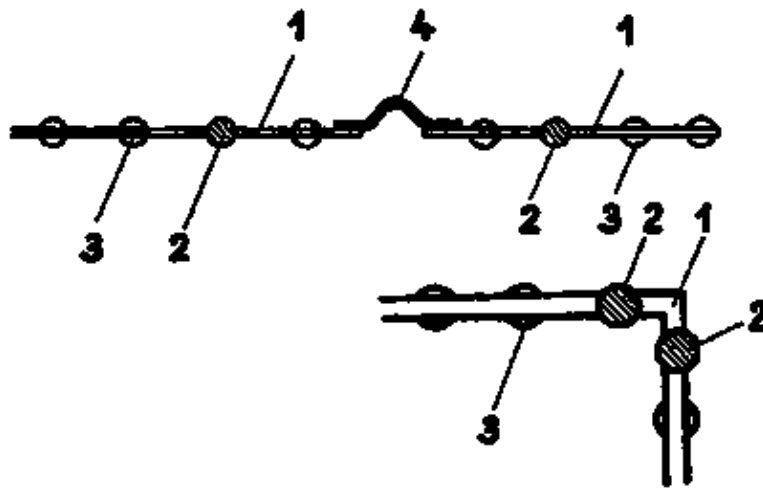


Fig. 4.8. Examples for installation of bus bars

1 bus bars, 2 fixed supports, 3 sliding supports, 4 expansion strip

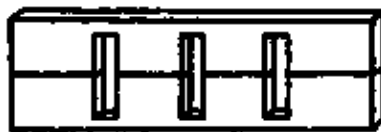


Fig. 4.9. Bar support of insulating material



Fig. 4.10. Expansion strip

1 expanding portion, 2 connecting portion

The bus bars are to be mounted at the cubicles resp. switch panels in such a way as to have the sequence of conductors L1, L2, L3, PEN (PE, N) fixed

- from left to right
- or from above to below
- or from front to rear.

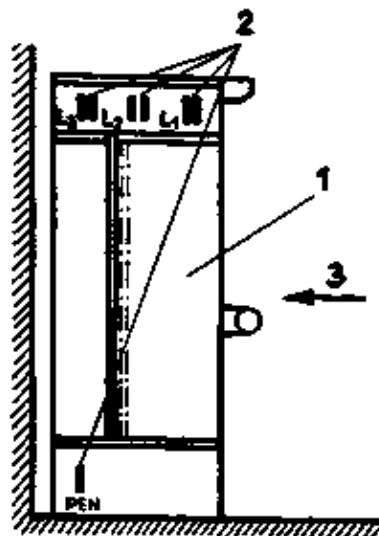


Fig. 4.11. Arrangement of bus bars in a cubicle

1 cubicle, 2 bus bars, 3 operation side

Bus bars for protective conductors will be installed on insulators in the lower portion of the cubicles. Mounting the protective conductors' bars in this location will be favourable due to the protective conductors of the connection cables being connected at this place of the cubicles.

Connection of bus bars to each other can be made by the following methods:

Bar's outgoing: connection between bus bars and electrical devices.

Overlap (unilaterally offset): connection of the same bus bars in each case, e.g. from one cubicle to the next one.

Strap connection: for same purpose, however, to be applied if overlap will not be possible for design reasons.

Connection of joining faces via oblong holes in both parts of the bus bars is not permissible!

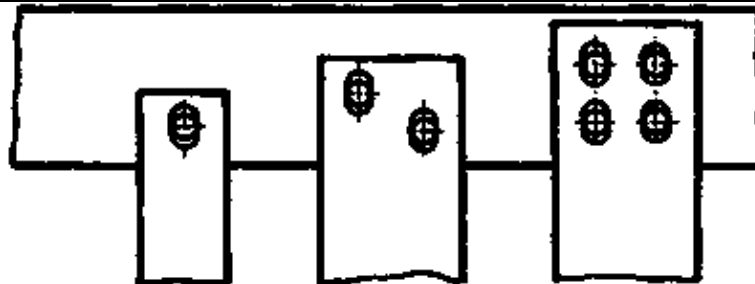


Fig. 4.12. Representation of bars' outgoings

For bolting bus bars galvanized or cadmium plated steel bolts are being used. The bolt heads may be painted with a temper colour. In case of a dangerously high temperature increase at the joining points of the bus bars the temper colour will change to another one.

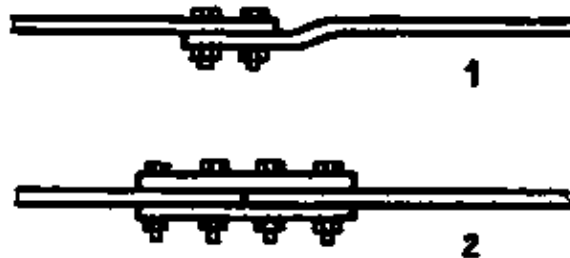


Fig. 4.13. Connections between bus bars

1 unilaterally offset overlap, 2 strap connection

The bolted joints are to be fitted in such a way as to have the bolt heads visible. The nuts are to be tightened by wrench only. Mounting an extension piece on the wrench is prohibited, since the bolt may be overloaded!

4.4. Conduct during working with switchgear

Working on live electrical switchgear is not permitted! By modern working methods this will be actually possible, however, specially insulated tools and a special working apparel, but in any case extensive vocational qualification will be required for that.

For protecting the electricians working at the switchgear from possible accident caused by the electrical current, prior to starting work measures will have to be taken as described in the following.

Disconnection of working site

The switching action – disconnection of the switchgear resp. a portion of same – must be performed only by an expert authorized by the management. The fitters employed in the work have to be instructed regarding possible risks which may arise in the switchgear installation as well as regarding a special code of conduct. One of the electricians, generally an experienced expert with a long–time standing, will be appointed to manage the work as responsible expert.

The user will have to confirm disconnection of the switchgear or part thereof in writing. The form resp. certificate, also called clearance report in writing, is to contain a.o. the following information:

- place and time as well as start and end of the work to be performed,
- type and scope of work,
- scope of disconnection,
- special hints and instructions,
- name and signature of the participating fitters.

All concerned fitters have to sign the clearance report prior to commencement of work and to resign after completion of work or the working day.

Thereby the user – to whom the written clearance report is to be returned – can be sure that no fitter is staying any more in the switchgear installation.

Never must a fitter work alone in a switchgear installation being partly alive. Always a second person must be present in the visual or audible range!

Safeguarding against reclosing

Safeguarding the switchgear against unintentional or self–acting reclosing is an important safety measure.

In case of power drives the driving power (compressed air, spring force, control voltage) will have to be cancelled. Manually operated switchgear can be mechanically locked if such a device has been provided.

Other voltage–carrying parts of the switchgear installation being alive are to be screened for avoiding contact to live parts of the installation.

By switching off circuit breakers, disconnection in the lower voltage range will not yet be finalized. By removing the fuses (screw–type fuses or low–voltage high–power fuses) a visible isolation will be achieved, and work safety will increase.

The removed fuses are to be safely stored. Under no condition they are to remain at the switching point or even left there just slackened!

At the switching elements by which the switchgear was disconnected a caution board must be reliably fixed for the duration of the work, its contents should read as follows:

Do not switch on!
work is going on!
place.....
Board to be removed only by: (name of the fitter)

This is particularly important if the working site is located at a distance from the switching point.

Except for overhead–line systems, earthing and short–circuiting of bus bars at the incoming feeder may be renounced. On earthing and shortcircuiting the sequence mentioned will have to be kept under all circumstances!

Ascertaining dead condition

The dead condition of the disconnected switchgear will have to be ascertained by means of a two–pole voltage tester. Prior to and after application its functionality is to be checked.

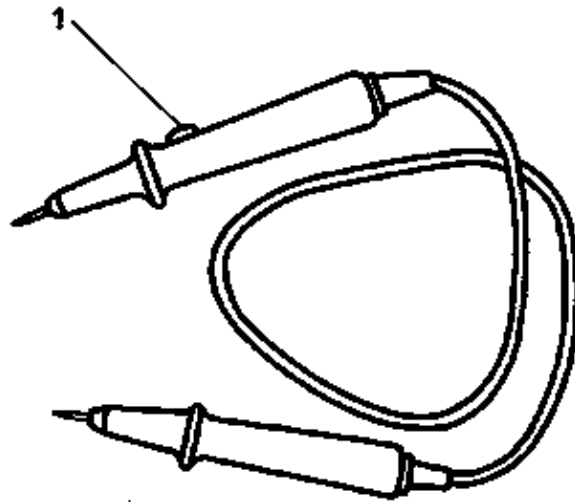


Fig. 4.14. Two-pole voltage tester with load testing button (1)

After the above mentioned steps have been taken, the work may be started.

On completion of the assembly work, tools and materials not required any more are to be removed. All dispensable hands may be drawn back. Now the protective measures can be cancelled. Only thereafter the plant may be reconnected to voltage. After these measures have been completed, the overall plant is considered to be alive.

4.5. Summary

Low-voltage switchgear and distribution systems are being operated in centres of power consumption with consumers' voltages up to 1 kV ac voltage and 1.5 kV dc voltage.

Low-voltage switchgear and distribution systems serve to distribute electrical power. They may be installed outdoors and within buildings. Their design determines the place of installation.

A distinction is made between:

- open-type switchgear systems
- enclosed (factory-finished) switchgear systems
- encapsulated switchgear systems and
- installation distributions.

Cables are connected to the switchgear in the wiring space of the switchgear and distribution systems.

Bus bars serve as main current conductors within switchgear and distribution systems.

Bus bars are solid, non-insulated conductors. They are made in different shapes and with standardized cross sections.

For processing bus bars special attention will have to be paid to:

- Prior to further processing, bus bars are to be cleaned.
- Distortions at bus bars are to be eliminated.
- Bus bars are not to be marked by scribe.
- The bending angle of bus bars is 90°. The minimum bending radius has to be maintained at that.
- Holes are to be drilled or punched into bus bars.
- The contact surfaces of bus bars are to be plane and metallic-bright.

In order to allow bus bars to extend in case of temperature variations they are to be mounted in sliding position. Installation of bus bars in switching panels or cubicles is to be performed according to a fixed

sequence of conductors:

- from left to right
- from above to below
- from front to rear.

Joining bus bars to each other may take place by:

- bar's outgoing
- unilaterally offset overlap
- strap connection.

Prior to commencing assembly work at live switchgear, the parts to be worked on are to be disconnected. For that purpose the following steps will have to be taken:

- disconnecting the working site,
- safeguarding against reclosing
- ascertaining dead condition.

The sequence of the above individual actions has to be observed. After completion of assembly work

- the working sites are to be inspected
- workmen, not required any more, are to be withdrawn
- the protective measures undertaken are to be cancelled
- the system is to be put under voltage again.

5. Fundamentals of installation engineering

Within the low voltage range two groups of installations are being discerned:

- installations within the structure
- installations at the structure.

Besides parts of buildings even machines, constructions and appliances are deemed to be structures.

Installation systems are being installed in the low voltage range up to 1 kV ac voltage and 1.5 kV dc voltage. This does, however, not exclude to call high-voltage lighting and x-ray systems above the voltage ranges mentioned, installations too.

Corresponding to the classification of installation systems the methods of installation are also associated with them. The method of installation is essentially selected according to application and the condition of the rooms, but also in respect to economic and architectural points of view.

Prior to starting installation work, a wiring sketch of the system to be installed will have to be drawn. Thereby switching faults are to be avoided.

Table 5.1. Types of installation

Installation system	
<u>In structure</u>	<u>On structure</u>
• underplaster installation	• surface installation
• inplaster installation	• installation in duct

• underfloor installation	• cable tray installation
• installation in intermediate ceilings	• installation in accessible intermediate ceilings
• installation in cavity and post-and-beam walls	• bracing wire installation

5.1. Fixing and marking the conduction paths

On principle it holds for all methods of installation to install the lines horizontally or vertically resp. parallel to edges, corners etc. at or within the structure. During this, the nominal measurements and minimum distances in force will have to be observed. They are holding for all methods of installation.

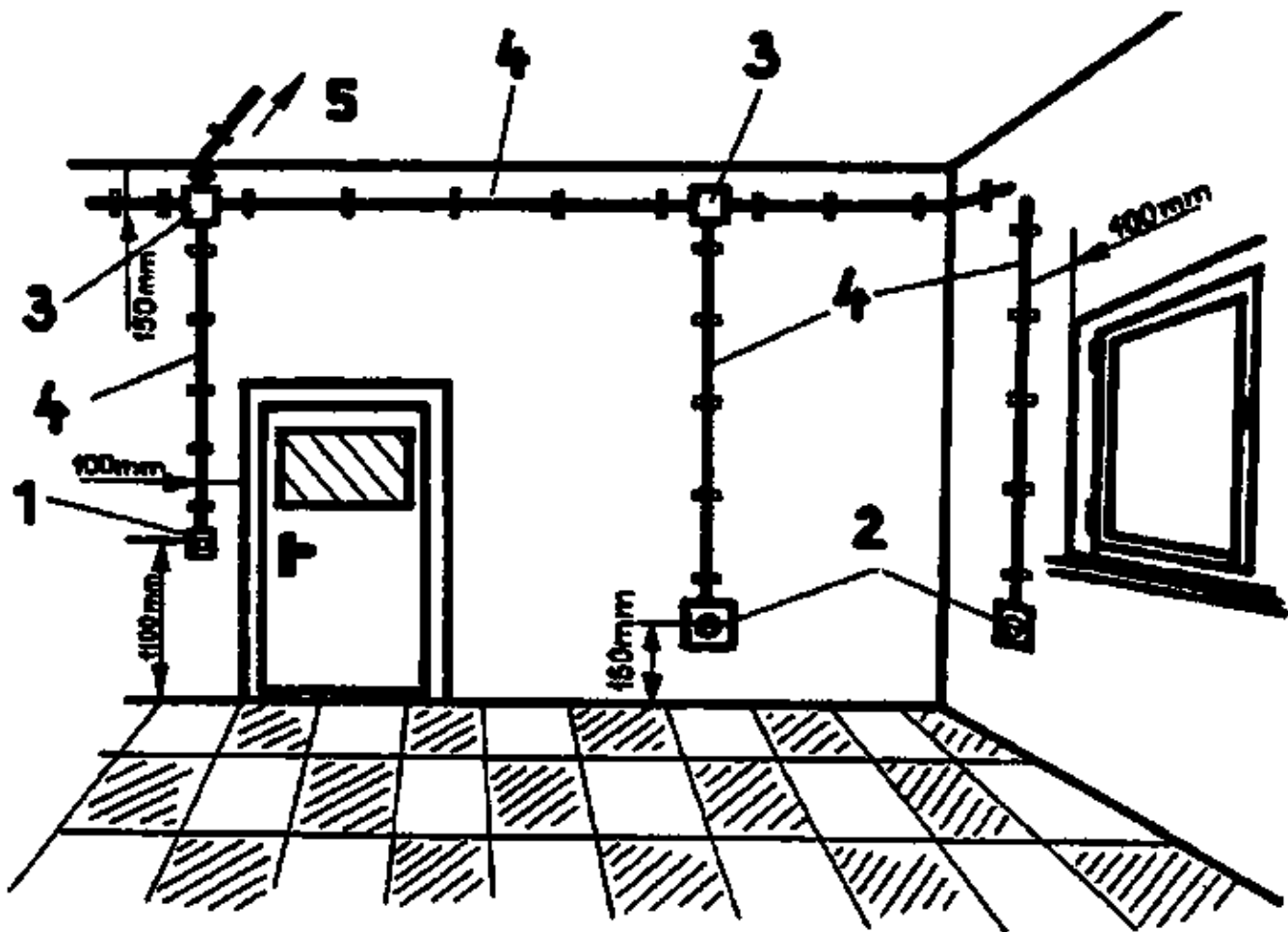


Fig. 5.1. Nominal measurements for fixing installation materials in installation systems demonstrated by a surface installation

1 switch, 2 socket, 3 junction box, 4 cable with fixing clips, 5 feed line to lighting fitting

In order to achieve this requirements, the expert uses simple measuring and auxiliary devices for marking the conduction path.

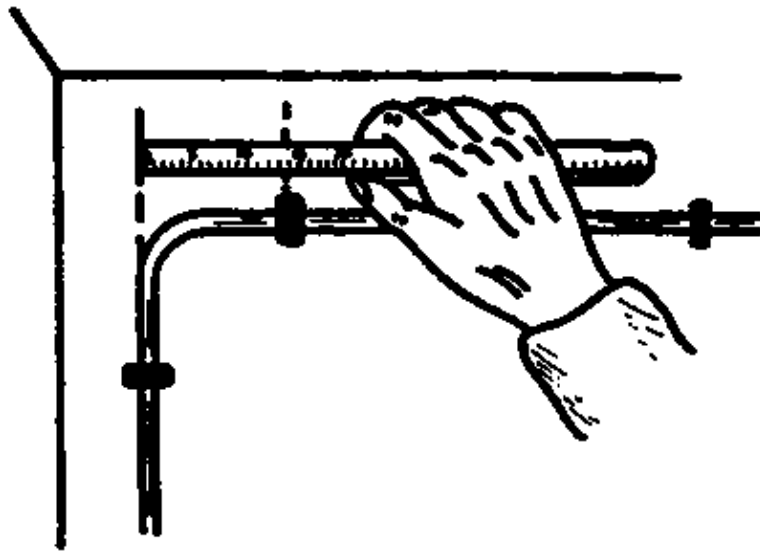


Fig. 5.2. Handling the folding rule

If lines are to be fixed by clips the fixing distances are to be observed. If several lines as a bunch are to be installed by means of clips this is called "bunched installation".

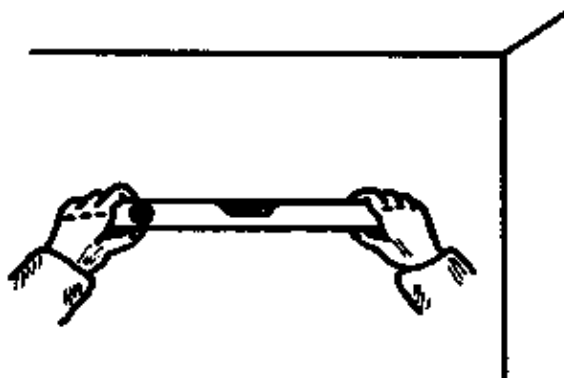


Fig. 5.3. Establishing the horizontal line by water level

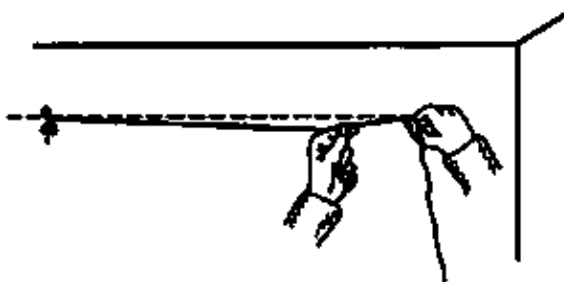


Fig. 5.4. Fixing a cord

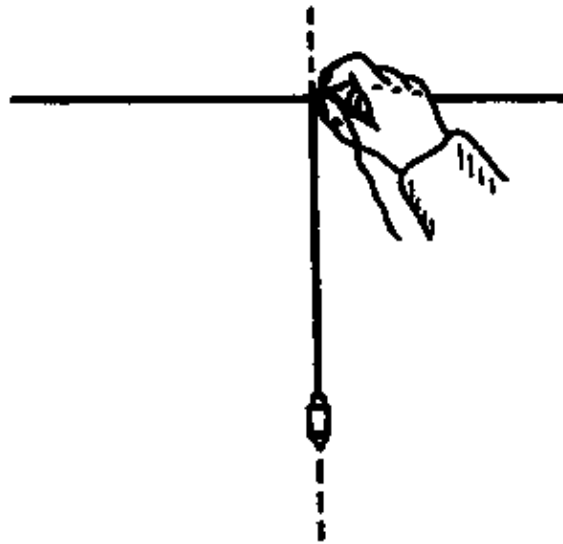


Fig. 5.5. Plummeting

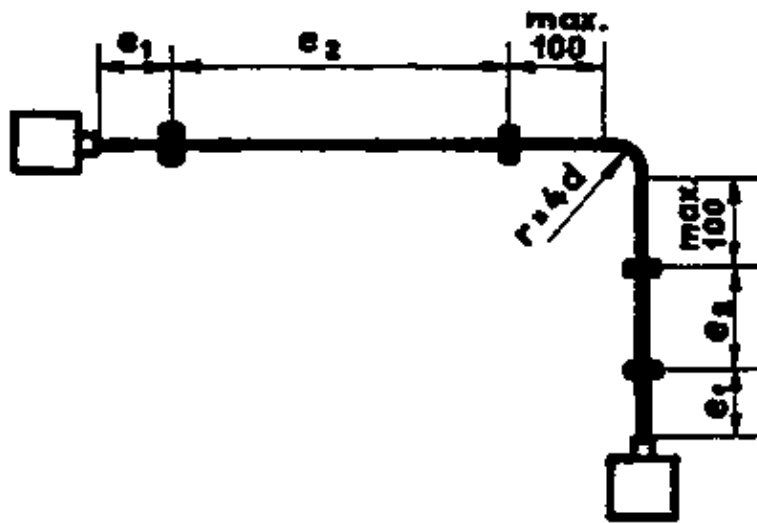


Fig. 5.6. Fixing distances for spacing of cable according to table 5.1.

Table 5.2. Fixing distances for lines

	Recommended value single installation		External diameter of bunch									
			10–15		15–20		20–30		30–50		50–70	
	recommended values for bunched installation											
	e_1	e_2	e_1	e_2	e_1	e_2	e_1	e_2	e_1	e_2	e_1	e_2
horizontal	100	250	150	300	250	350	300	400	400	600	400	900
vertical	100	300	150	400	250	500	300	600	400	800	400	1000

e_1 resp. e_2 see fig. 5.6.

For determination of the fixing points the following steps are to be taken:

- the overall path in which fixing points are to be determined is to be measured, the run of the lines to be marked,
- the first and last fixing point is to be marked according to the recommended values,

- the intermediate space between the first and last fixing point is divided by the nominal measurement being ascertained according to the bunch resp. line diameter. As such, the number of intermediate distances is obtained,
- the number of intermediate distances is rounded off,
- the measured intermediate distance is divided by the number of intermediate distances, thereby obtaining the exact distances between fixing points.

Calculation example 5.1.

The distance between the first and the last fixing point is 4.23 m.

Five lines (diameter of bunch 30 mm) are to be installed horizontally.

How great is the distance between clips?

Given: intermediate distance = 4.23 m

nominal measurement according to table 5.2. = 40 cm

sought for: distance between clips = ?

1. Finding the number of intermediate distances (intermediate distance divided by nominal measurement):

$$423 : 40 = 10.57, \text{ rounded off} = 11 \text{ intermediate distances}$$

2. Determining distance between clips (intermediate distance divided by number of intermediate distances):

$$423 : 11 = 38.45 \text{ cm } 38.4$$

The distance between clips will be 38.4 cm therefore.

Marking is done by pencil, chalk or lime. Never copying pencils or oil chalk are to be used, since these substances will not be covered by coats of paint.

5.2. Dimensioning of conductor cross sections

In the plans of the electrical plant to be erected the conductor cross sections to be adhered to and the conductor materials to be used will be contained.

Observing the listed cross sections resp. the minimum cross sections to be applied according to the tables, is of great importance for the safe function of the electrical plant.

Too large a conductor cross section would not be economical, while too small a conductor cross section would hold the risk of unpermissibly high conductor temperatures, of cable burns and thereby failure of the connected consumers' appliances.

Cable fires were already the cause for catastrophic great fires in the past.

The great importance of observing the prescribed conductor cross sections becomes very clear when evaluating the criteria to be considered for the selection of conductor cross sections:

- Correct determination of load values and fuse amperages considering:

- the material of the conductors,
- the simultaneity factor,
- the number of conductors in the line resp. cable or tube,
- the max. load in kW under attention to the power factor and the length of the line.

– Inclusion of the corresponding impairment factors like:

- conductor's limiting temperature,
- method of installation,
- number of lines in a bunch.

– Maintenance of small transfer losses like:

- voltage loss,
- power loss.

In table 5.3. the minimum conductor cross sections in force for certain fields of application are contained. These conductor cross sections must not be undercut.

Table 5.3. Minimum cross sections of conductors

Line	type of installation/application	Min. conductor cross section	
		Cu (mm ²)	Al
main current line	in installation systems on direct connection to bus	1.5	2.5
	bars or similar main distribution lines	2.5	4
	service taps in front of main fuses	16	25
	main distribution, main and meter feed line (rising line)	6	10
auxiliary current lines	on direct connection to bus bars or similar main distributions	2.5	4
lines for connection of portable appliances	couplers for 16 A rated current	1	–
lines at current converters	general	2.5	4

5.3. Installation of lines

Fixing of the line material is determined by the method of installing the line at or within the structure. In case of underplaster or inplaster installation the line materials are mounted within the structure by

- gypsum binder,
- steel nails or
- adhesive.

Care has to be taken to get the line materials so deeply embedded in the structure as to have them completely covered by the layer of plaster to be provided.

Prior to plastering the walls the boxes should be carefully stuffed with paper after entering the ends of the lines into the boxes. Thereby considerable contamination of the interior of the boxes including the line ends by plaster or paint residues will be prevented.

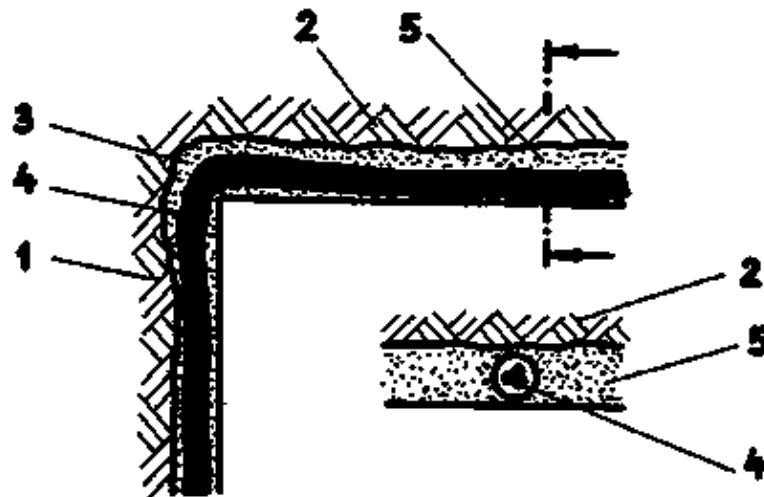


Fig. 5.7. Line path on a corner when applying underplaster installation

1 wall, 2 ceiling, 3 chiselled-out corner, 4 cable, 5 plaster

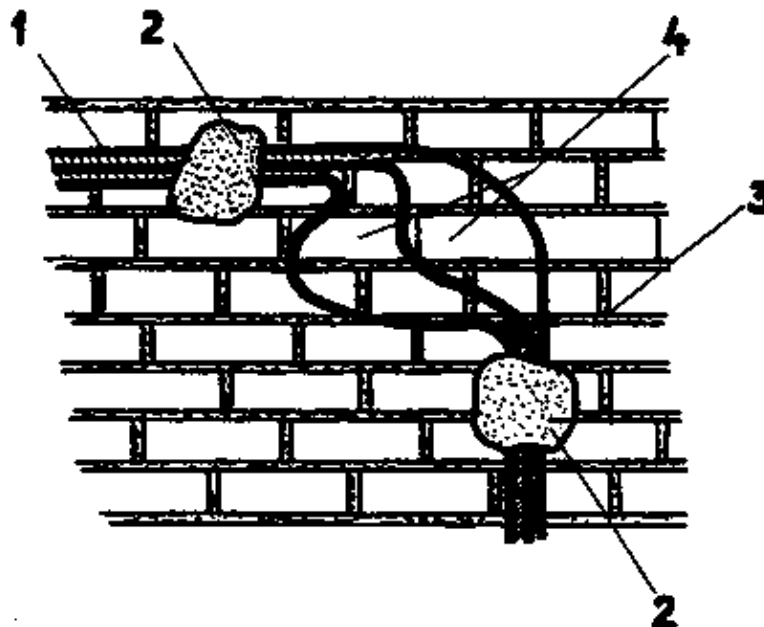


Fig. 5.8. Installing ribbon cable

1 ribbon cable, 2 gypsum binder, 3 brick wall, 4 separated ribbons between ribbon cable conductors for making horizontal bends at ribbon cable

Due to changed techniques in the interior work of buildings, installation engineering had to adapt to these trends, e.g. placement of cavity walls and suspending inserted ceilings of gypsum.

In inserted ceilings lines resp. cables are placed on cable trays, concentrated in bunches or are laid out straight without mounting. Within cavity walls or post-and-beam walls the lines are lead preferably horizontally or vertically to the connection points in question (switch, socket outlet, or junction box). Here, in most cases fixing will not be possible.

In surface installation new fixing methods have replaced the traditional dowelling technique.

The glueing method is very economical. The underside of the clips is glued to the structure. This method can, however, be applied only on roughly cleaned walls (concrete, brickwork, steel) and on lean plaster for preserving the durability and load-carrying capacity of the adhesive joint. Moreover, it is recommended to

employ the glueing method within buildings only. The processing instructions given by the makers of the adhesive are to be observed under all circumstances.

Plastic expander dowels are universally applicable. They are not only useful in fastening the lower portions of clips for installing lines, but also lighting fitting and other supporting elements may be mounted to them.

For drilling mounting holes of expander dowels electrical percussion drills with carbide tipped twist drills are used. Only in rare exceptional cases hand drills are being applied. Carbide tipped twist drills have soldered on tips suitable for all wall types. Only when hitting metal, e.g. reinforcements in concrete, drilling will have to be interrupted at once, since the drill's tip would be spoiled.

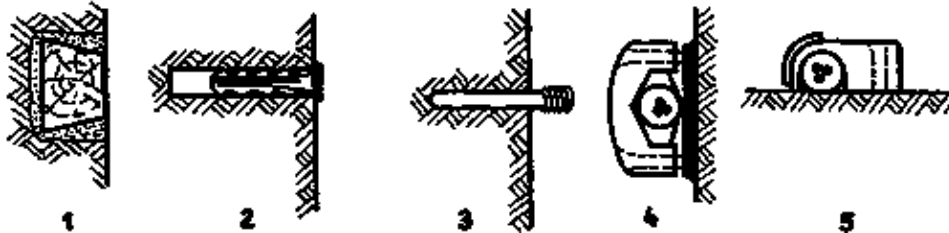


Fig. 5.9. Fixing methods in surface installation

1 dowelling method, 2 bore hole with expansion dowel, 3 shooting device with external thread, 4 glued spacing clip for damp rooms, 5 nailed clip

(The hand drill is to be turned in the bore hole after each blow of the hammer for preventing it from getting stuck in the hole). The lower portions of the clips are to be placed exactly along the marked line paths. This can be achieved by means of a string stretched between two lower portions of clips.

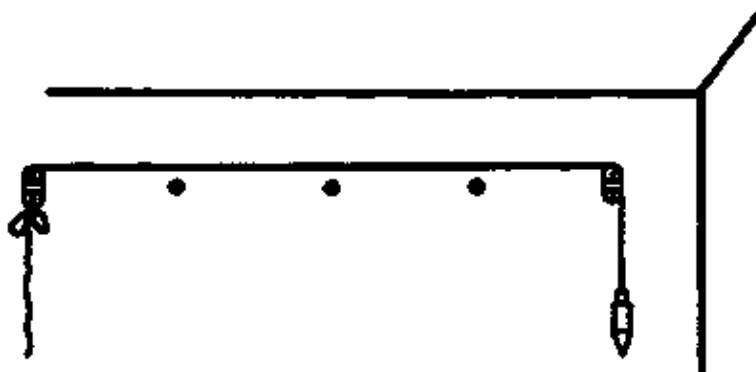


Fig. 5.10. Placing the lower parts of spacing clips for damp rooms aided by a cord

Because of a great number of wires resp. cables in industrial buildings these are frequently put on cable trays. If they are placed horizontally on the cable tray fixing them will not be required. Only if information and power wires resp. cables are laid together on a cable tray they will have to be separated from each other so far as to render it impossible for the power wires resp. cables to interfere with the information wires resp. cables. In case of vertical installation of wires resp. cables on cable trays they must be fixed by clips or suitable binding materials.

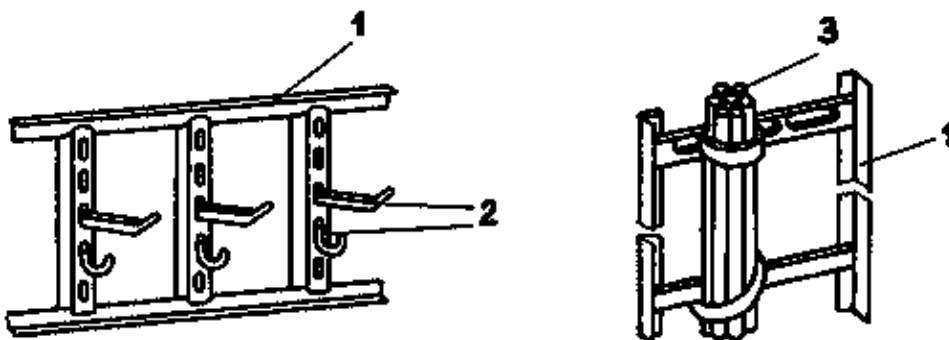


Fig. 5.11. Installation of cables on cable trays

1 cable tray, 2 supporting elements, 3 cable

Prior to installing lines they are rolled off their coils. This has got the advantage of avoiding twist in the length. Such twist can hardly be eliminated any more and will reduce the quality of the installation.

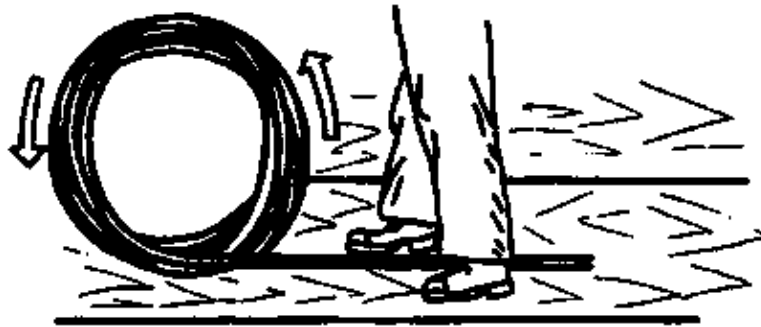


Fig. 5.12. Uncoiling cable by hand

Before cutting lines, the length required is to be measured for keeping waste as low as possible.

For aesthetical reasons the lines are to be run straight-lined in the clips. In case of installing individual or bunched lines by damp-proof clips this will be achieved by observing the following working steps:

1. The lines to be installed are to be laid out parallelly.
2. Either the upper portions of the clips will be loosely mounted over the bunched cable or the wires are to be tied temporarily at the level of the clips.
3. The upper portions of the clips will be systematically fitted from one side. Possible twist in the lines is to be eliminated during this.
4. The bunch will be tied between the clips.

In case of installing single lines in damp-proof clips, on straight runs all upper portions of the clips will be loosely mounted on the line. Thereafter the first 2–3 clips are fastened. When the line is then pulled tautly from the other side in the clips and the last 2–3 clips have been tightened, all other upper portions of clips may be fixed. The line will then be positioned straight-lined in the clips.

In case of bunched installation the lines will have to be placed parallelly in the bunch. After some upper portions of clips have been loosely mounted on the run of the line path and the bunch has been fixed temporarily, straightening the bunch and fixing the clips is to be started from one side.

Junction boxes which are to branch lines from bunches are to be mounted on pedestals above the bunch. The line will be bent to the shape of a tier and entered into the box. Unnecessary bends should be avoided.

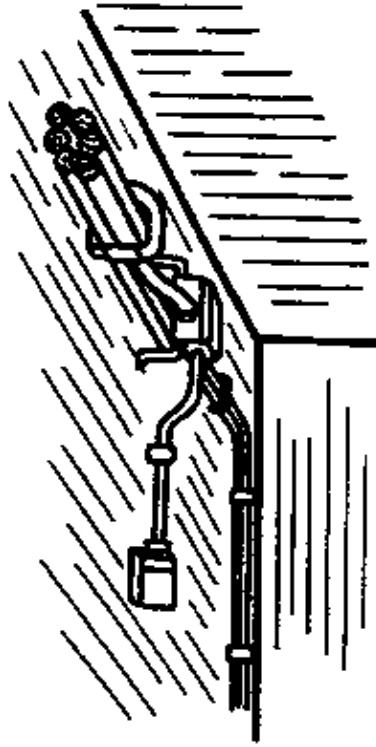


Fig. 5.13. Bunched installation

If lines are to be brought out from the bunch this will be done preferably from the rear for the sake of good look. When concentrating lines in bunches for installation, load impairment factors will have to be considered. The values of current-carrying capacity and coordination of overcurrent protective devices (fuses) as well as the load impairment factors to be considered are to be taken from tables 5 to 10 of the textbook "Circuits, Formulae and Tables of Electrical Engineering".

Within the hand range all electrical devices must be locked in such a way as not to be opened without tools.

Hand range means the spatial range which can be reached by a person's hand without using auxiliary means. It extends from the standing point 2.50 m in height, and in horizontal direction as well as downwards it will be 1.25 m to all sides!

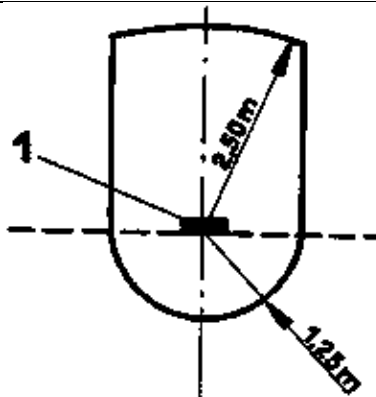


Fig. 5.14. Demonstrating the hand range

1 standing area

Underfloor installation systems are mainly applied in business premises, where in large rooms many consumer's installations are positioned in the central areas of the room and are frequently shifted, like e.g. in open plan offices for connection of electrical typewriters, telephones, desk computers etc.

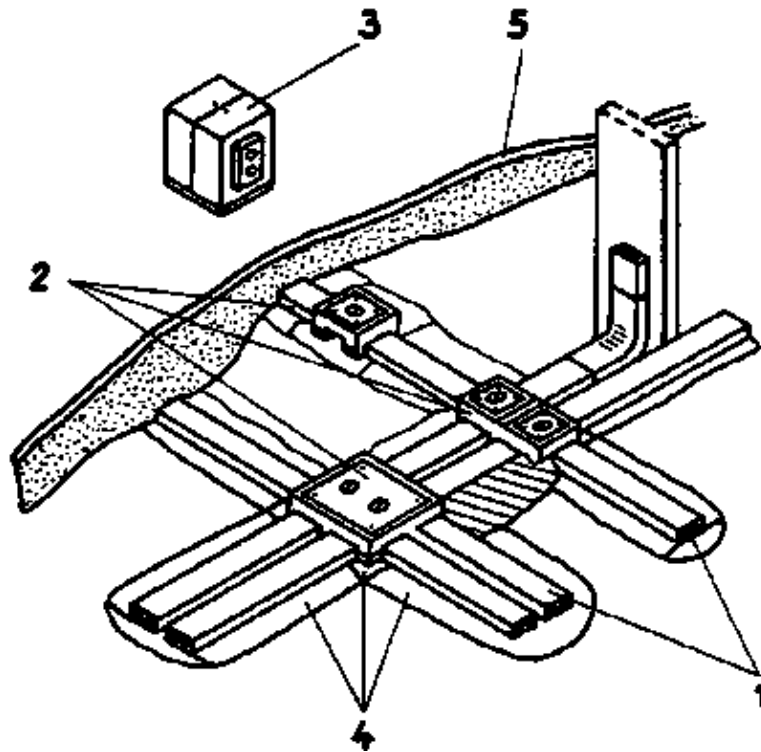


Fig. 5.15. Schematic representation of underfloor-installation

1 cable duct, 2 pull-through box, 3 terminal box for electrical appliances, 4 sub-floor, 5 finished floor

As an installation type outdoors the bracing wire-suspension is known besides the moisture-proof installation. In this case the lines will be tied to a bracing wire. However, care has to be taken not to affect the structural safety of buildings by the required bracing.

Between ground and lower edge of components a minimum clearance of 2.50 m, at crossings of streets, roads and squares a minimum clearance of 3.50 m will have to be observed.

As bracing wire a max. 5 mm thick steel rope (or steel wire) will be used which is to consist of one piece within a span section. One span section must not exceed 50 m.

Within a span section the bracing wire is stayed by supports and thereby subdivided into subsections.

When installing luminous rows the bracing wire must be supported e.g. every 3-6 m.

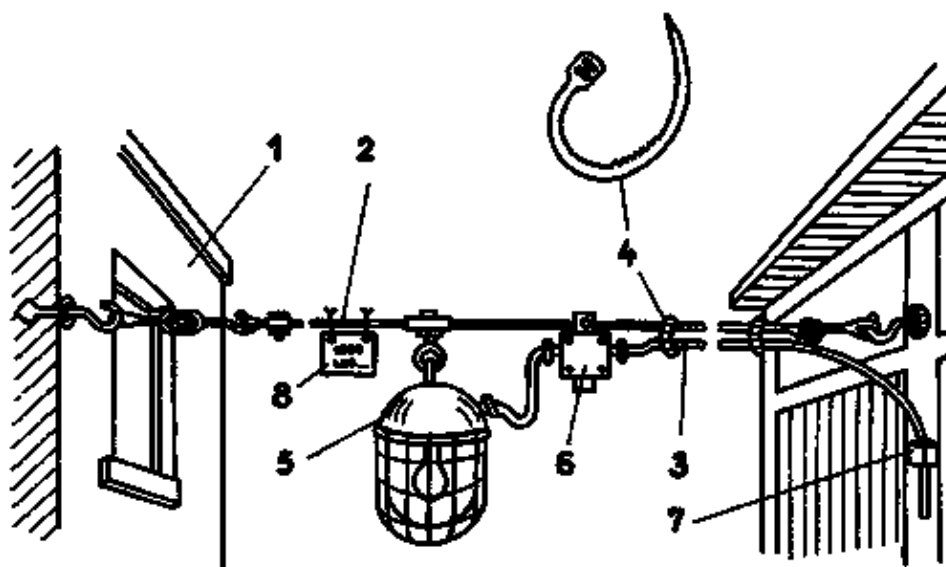


Fig. 5.16. Bridging a yard by bracing-wire installation

1 screw shackle, 2 bracing wire, 3 cable, 4 modular line, 5 lighting fitting, 6 junction box, 7 spacing clip, 8 board rendering information on year of erection and rope load

5.4. Preparing lines for fixed installation

For cutting lines and removing the insulation at the lines' ends suitable tools will be employed like side cutting pliers, cable strippers, stripping tools or automatic wire stripping pliers.

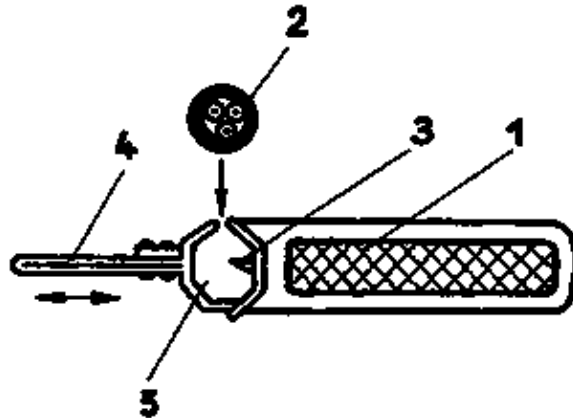


Fig. 5.17. Removal of insulation at a plastic cable by stripping device

1 handle of stripping device, 2 cable, 3 edge, 4 knife, 5 space for cable

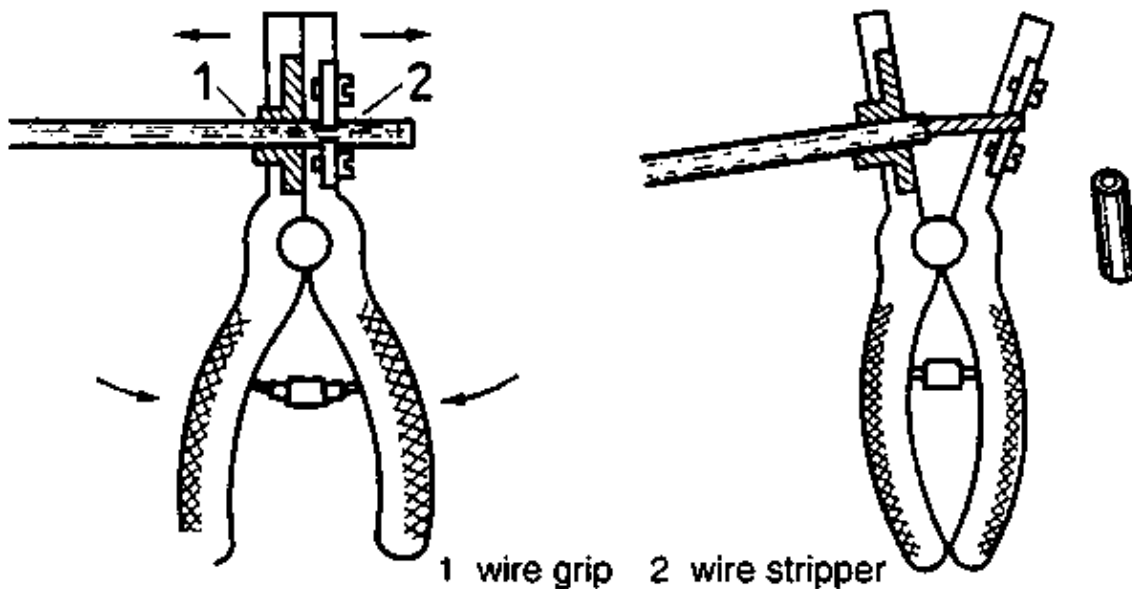


Figure 5.18. Stripping a Cable using automatic wire strippers

Connections are generally made by clamping the electrical materials. In principle the wires are clamped in insulated terminals (connection cell) provided in the electrical equipment.

Loose terminals that are not firmly fixed in the electrical equipment may not be used for this purpose. The only exception to this rule applies to the porcelain or plastic lamp connecting blocks mounted on ceilings or walls.

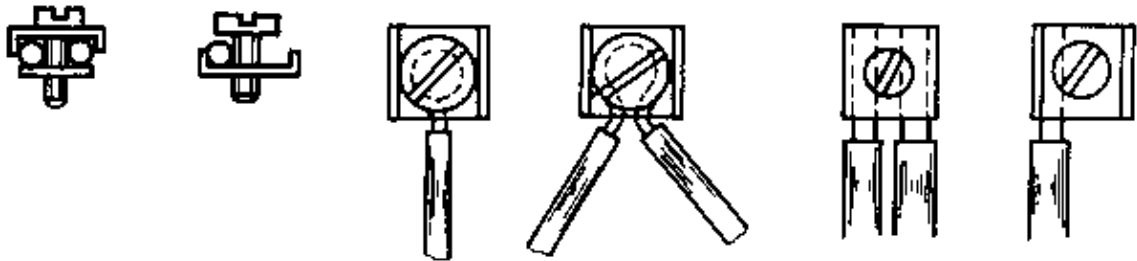


Figure 5.19. Connections executed by fastening

There are three main rules for making fastening connections:

The ends of the conductor must be sufficiently long for you to repeat the connection with the terminal about three times if the conductor deteriorates later. Conductors that are not used remain in place and serve as a reserve.

Fix the ends of the conductor you are connecting to the terminal in the direction of rotation of the fixing screw.

Do not pass an insulated conductor just above a connection terminal of another conductor.

Special attention should be paid to the method of connecting a copper conductor and an aluminium conductor. Do not place the copper and the aluminium directly against each other at the point of contact; make sure they neither join each other nor run parallel with each other.

When you make a connection between an aluminium conductor and a copper conductor it is important to avoid any direct contact between the two conductors. Furthermore you should conserve the stripped ends of the conductor with a neutral grease to protect them against corrosion.

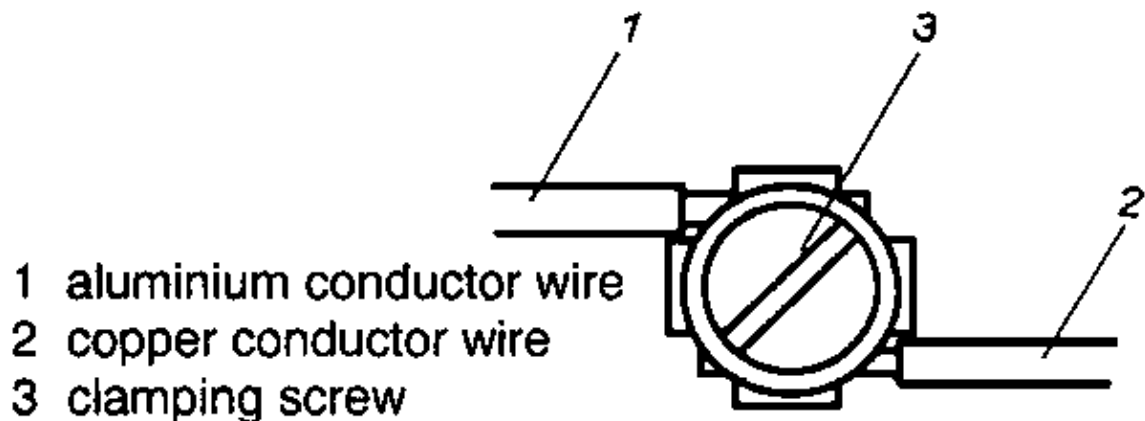


Figure 5.20. Connecting a copper wire and an aluminium wire to a common terminal

When connecting electrical materials it is very important to observe certain conditions that are essential for sound operation and reliability of the electrical installation assembly.

Switches and circuit-breakers may only operate on phase conductors.

Switches and circuit-breakers are connected in such a way that in the open state either the mechanical rocking lever of the control unit comes out at the top, or the change lever is in a down position. In the case of rotary switches it is common practice that when the circuit is open the circuit-breaker switch should be in a horizontal position.

The phase conductor should be connected to the terminal provided for this purpose and which is specially marked.

When connecting a socket the phase conductor must be connected to the terminal on the left and the neutral conductor to the terminal on the right.

If at a socket with earthing contact the protective measure "neutralization" is to be applied, the neutral conductor with the protective function will first be run to the socket's earth contact and then to the plug contact on the right side. The neutral conductor with protective function must not be interrupted in this case, but has to be wired as a loop.

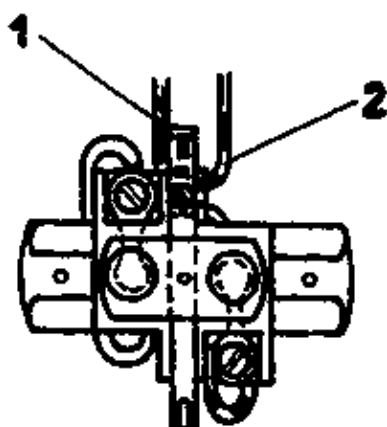


Fig. 5.21. Connecting a socket with earthing contact to a two-core line

1 phase conductor, 2 neutral conductor (looped through the terminal of the protective conductor)

For reasons of clearness in electrical systems a certain wiring order has to be maintained in junction boxes.

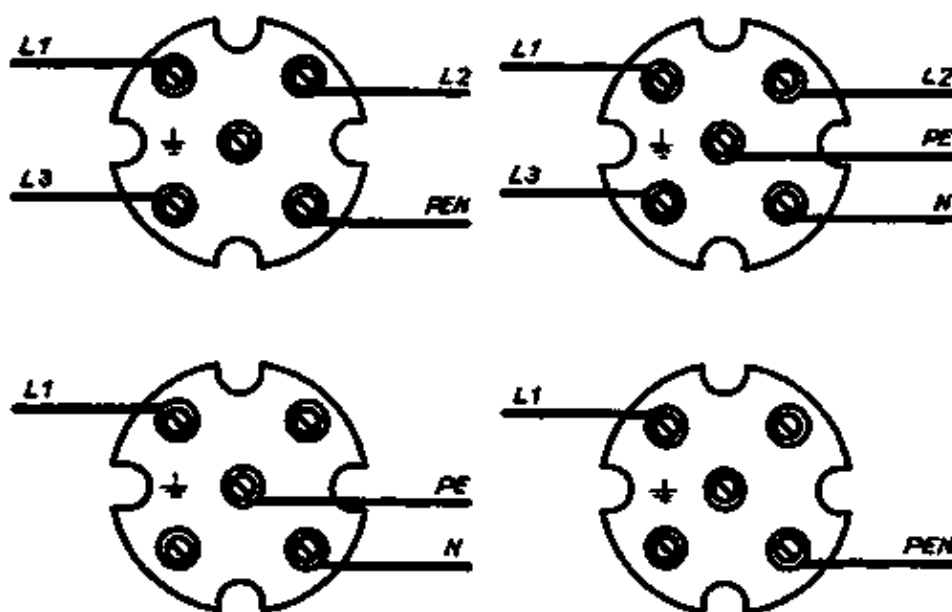


Fig. 5.22. Terminal arrangement in a junction box

Locking and sealing of electrical appliances is of great importance.

Screwings being frequently found on devices working in damp or wet rooms are to be firmly tightened. Sealing elements like reaction rings or rubber seals must not be omitted.

It is very important to observe the required degree of protection.

This will be determined by the kind of room in which the electrical system will be installed;

- dry rooms: dwelling houses, public buildings,
- damp rooms: bakeries, cold storage rooms, outdoor plants, cellars,
- wet rooms: bathrooms, greenhouses, laundries,
- fire-prone rooms: petrol stations, garages, straw storages,
- ship's installations and underwater systems.

The higher the climatic demands on electrical devices to be installed, the higher has to be their protection against intrusion of foreign matter (sand, dust etc.) and protection against contacting their live parts as well as against moisture of any kind. The degree of protection in electrical appliances and equipment is indicated by the makers. It may be read from the casing resp. the rating plate.

In the plans for the installation system the degree of protection will be prescribed, however.

The overall degree of protection in an electrical system is as high as the lowest degree of protection in any of the installed electrical appliances!

Depending on the required degree of protection, between screwing and the device a sealing washer must be inserted.

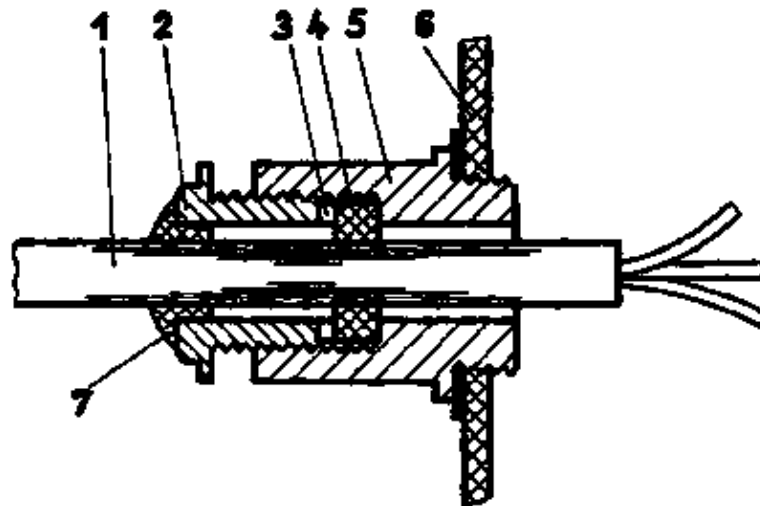


Fig. 5.23. Screw plug on damp room cable in front of an electrical appliance

1 cable, 2 screw bushing, 3 reaction ring, 4 sealing rubber, 5 case, 6 appliance's wall, 7 sealing compound

Besides the traditional clipping of electrical connections to appliances there are further methods of connection which have succeeded in installation engineering. These are stamped connections and plug connections.

Stamped connections are permanent connections in which the conductor ends to be connected are stamped together in compression sleeves by means of stamping pliers. This procedure is similar to stamping on terminals. By applying stamped connections terminal connection pieces in the junction boxes are omitted.

Moreover, such stamped connections may also be used in various electrical appliances like e.g. lighting fittings. The conductor ends will be stripped and properly placed in the wiring space of the electrical device.

By squeezing the hand stamping pliers together up to the stop a durable and well conductive contact will be established.

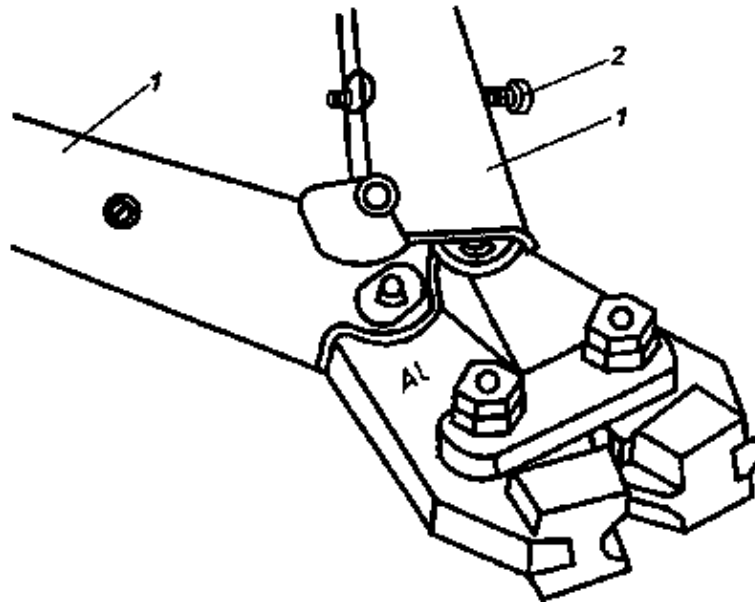


Fig. 5.24. Hand stamping pliers

1 grips, 2 mechanical and stops

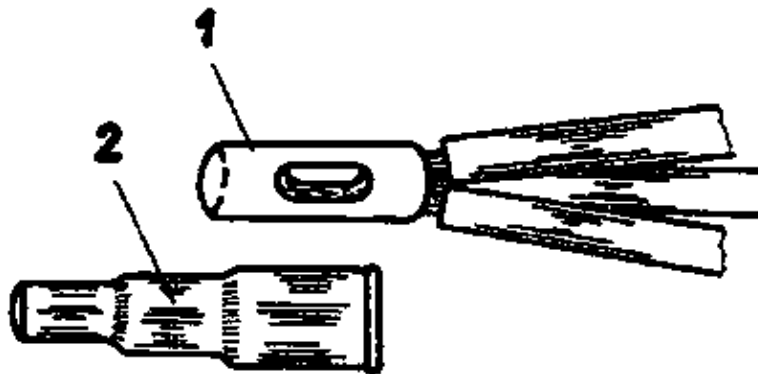


Fig. 5.25. Finished stamped conductor connection

1 compression sleeve, 2 insulating tube

Since the compression sleeve is made of conductive material, an insulation tube is slid over the former in order to avoid short-circuits.

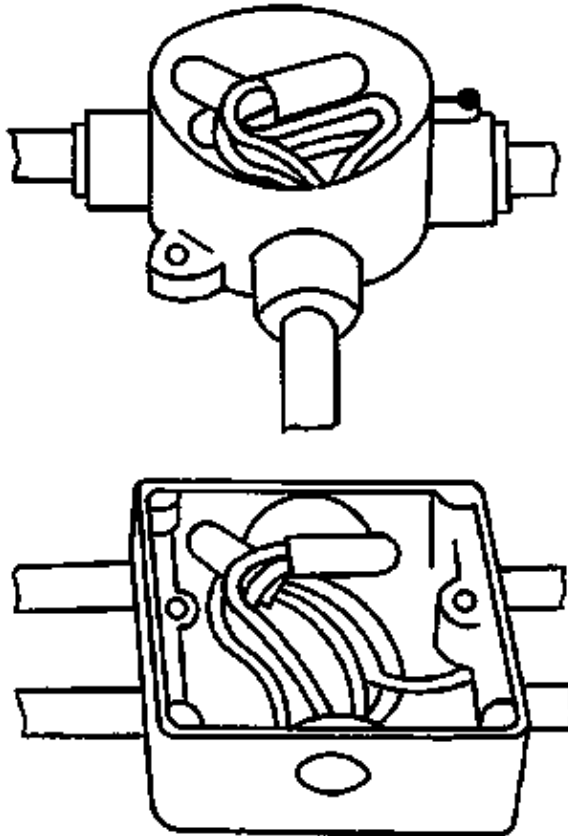


Fig. 5.26. Stamped connections in a junction box

Due to their different electrical and mechanical properties, copper and aluminium must not be connected to each other in one compression sleeve.

Plug connections of different kinds have made their way in electrical engineering, e.g. in the internal wiring of fluorescent lamps or washing machines. But also in junction boxes plugged connections are being employed. They can be made very simply. Depending on the type of plug connector the stripped conductor is entered into same and gripped. If disconnection is required the conductors may be removed from the plug connectors in a simple way.

For this connection method it is foremost required to attach the properly stripped conductors firmly to the plug connectors.

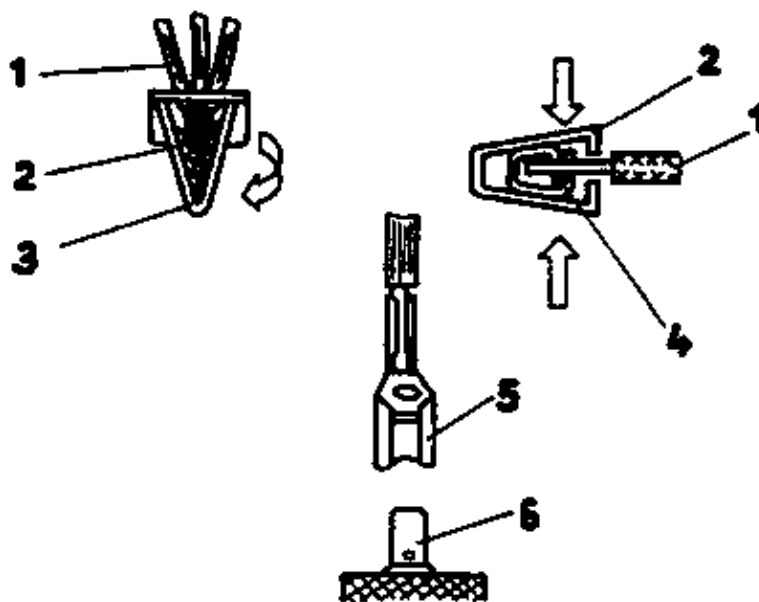


Fig. 5.27. Plugged connections

1 conductor, 2 insulation, 3 conical thread, 4 spring-type clip, 5 plug contact, 6 counter contact

5.5. Connection of lighting fittings

In illuminating engineering there are basically two types of lamps:

- radiant temperature lamps (incandescent lamps),
- discharge lamps.

Incandescent lamps are directly operated by the mains voltage via pertaining lighting fittings and lamp holders. This will not be possible in case of discharge lamps. For their operation corresponding fluorescent lamp ballasts are required.

5.5.1. Incandescent lamps

Radiant temperature lamps as incandescent lamps are being used in various sizes and applications. Most frequently they will be found as general service lamps.

In incandescent lamps the construction of which is shown in fig. 5.28. a thin coiled filament of tungsten is raised by Joule heat to incandescence and thereby caused to light. The share of the power consumed being useful as light is very small. In average the share of the radiation power being effective as light will be approx. 4 %.

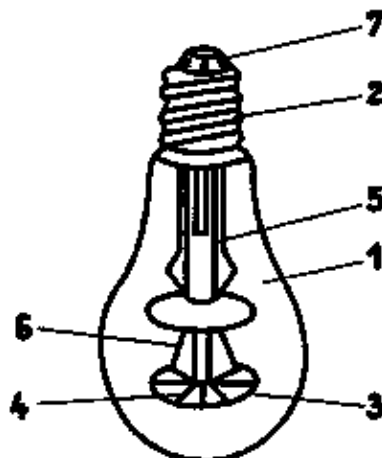


Fig. 5.28. Construction of a general service incandescent lamp

1 bulb, 2 holder, 3 filament, 4 filament support, 5 base wire, 6 electrodes, 7 base contact

The colour of the light in incandescent lamps is similar to daylight, however, the share of red prevails, while the share of blue in the light is small.

For enabling a temperature rise in the tungsten filament the filaments are coiled or coiled coil.

Incandescent lamps will be classified according to their power consumption. Incandescent lamps of 15 and 25 W have got evacuated bulbs. Starting from a wattage of 40 W the bulbs of incandescent lamps will be filled with gas. The gas in the bulb of the incandescent lamp will prevent evaporation of the filament. As filling gas a mixture of argon–nitrogen or krypton–nitrogen is being employed.

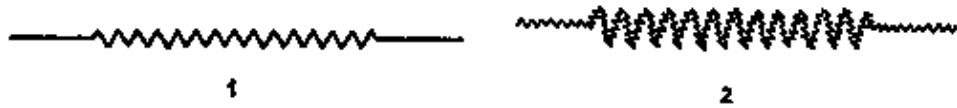


Fig. 5.29. Filament

1 single coil, 2 coiled-coil

A survey containing the essential data on general service lamps of the incandescent type is to be taken from table 5.4.

General service incandescent lamps are being manufactured for operating voltages of 110 V and 220 V.

Table 5.4. General service incandescent lamps

input wattage w	filling of bulb	filament	type of base
15	vacuum	single coil	
25			
...			
40	argon-nitrogen or	coiled-coil	E 27
60			
75			
100			
150			
200	krypton-nitrogen	single coil	E 40
300			
500			
1000			

General service incandescent lamps may be either supplied with clear bulbs or inside-frosted bulbs.

They are also made with inside-mirrored bulbs for decorative purposes. This enables in a simple, but direct way a concentrated lighting of objects to be emphasized in show-windows, exhibition rooms, display boxes etc.

There are special versions of incandescent lamps for different purposes. Among them are miniature lamps (incandescent lamps for scales in wireless sets, bicycle and torch lights), decorative lamps or projection lamps for film projectors.

Incandescent lamps are, besides with a screw cap, also manufactured with a bayonet cap or with festoon bulbs.

Connection to lighting fittings is done in such a way as to always connect the dead conductor to the annular contact and the live conductor to the base contact of the lamp holder.

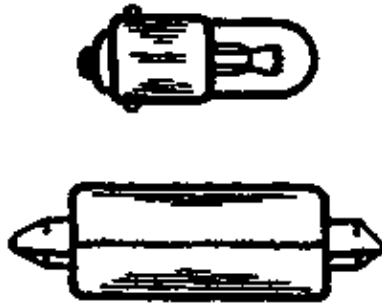


Fig. 5.30. Bayonet cap and festoon bulb

The lighting fittings are to be installed according to the mounting instruction of the maker in question. Usually lighting fittings are suspended on ceiling hooks or screwed to ceilings or walls.

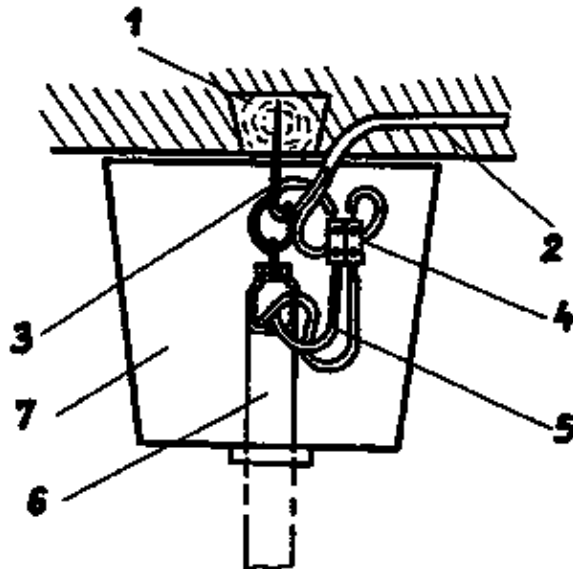


Fig. 5.31. Mounting a ceiling fitting

1 dowel, 2 feed line, 3 ceiling hook, 4 lustre terminal, 5 cable of lighting fitting, 6 pendulum, 7 shade

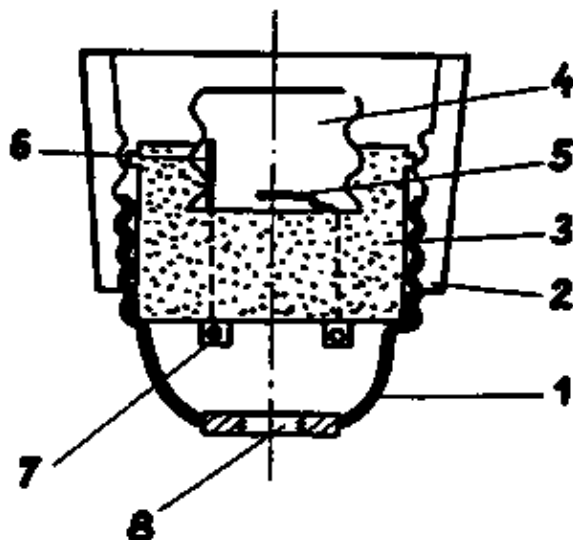


Fig. 5.32. Cross section of a lamp holder

1 and 2 housing of holder, 3 holder support, 4 thread for incandescent lamp, 5 foot contact, 6 lamp base contact, 7 connecting screws, 8 fine thread for pendulum, mount or similar

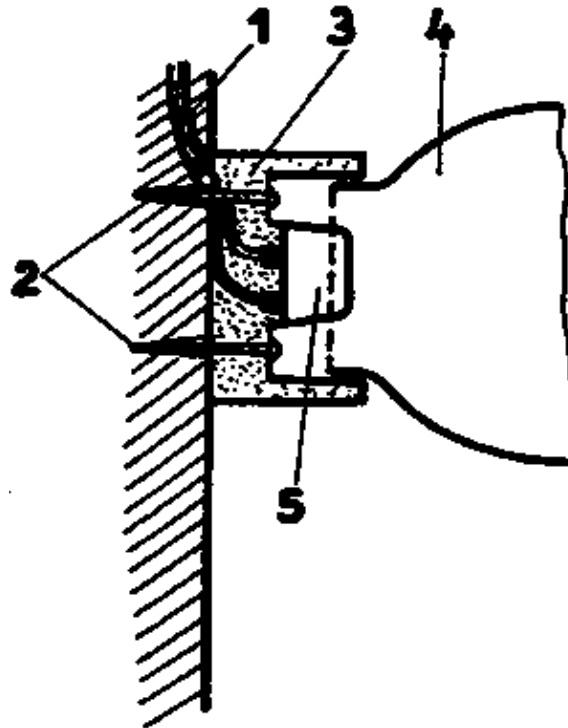


Fig. 5.33. Mounting a wall fitting

1 feed line, 2 expansion dowel, 3 fitting base, 4 glass cover, 5 holder

Metal housings of lighting fittings are to be included in the protective measures against too high a contact voltage!

Incandescent lamps are foremost employed in the lighting of dwelling rooms. In industry and other trades they are primarily applied for lighting work places and as temporary lighting (construction sites).

In rooms to be darkened (cinemas) lighting by incandescent lamps is employed because it may be adjusted via dimming switches to any desired brightness.

5.5.2. Discharge lamps

Discharge lamps in the low voltage range – (high pressure) mercury resp. sodium vapour lamps – are foremost employed in lighting industrial plants, streets and public buildings. The share of blue resp. yellow in the light is quite high. On the other hand, fluorescent lamps are mostly used in workshops, offices, public institutions and dwellings.

Though the purchase price of discharge lamps is considerably higher than that of incandescent lamps, they offer great advantages:

- Depending on the type, the light yield of discharge lamps is 3–4 times higher at the same power consumption.
- The life of discharge lamps is about 5 times higher.

However, the disadvantage of discharge lamps is that they will need (with some exemptions) ballast and accessories like starters, compensating and anti-interference capacitors without which they cannot be operated. It follows thereof that they can be operated by ac voltage only. Furthermore the brightness of discharge lamps can be adjusted but very little. Some makers of discharge lamps accommodate the ballast of their lamps (mercury and sodium vapour lamps) in the base of the bulb in order to avoid separate ballast gear.

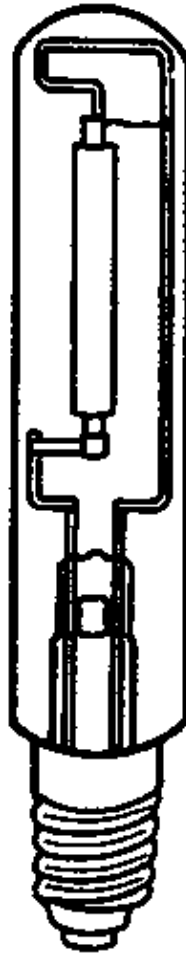


Fig. 5.34. High-pressure sodium vapour lamp

Fluorescent lamps are being manufactured as straight, U-shaped and circular tubes. They have pin contacts.

The shape of mercury and sodium vapour lamps is very similar to that of incandescent lamps.



Fig. 5.35. Straight and U-shaped fluorescent lamp

Fluorescent lamps are made in the range from about 8 W to 120 W. The standard tube diameter will be 32 mm. The most common type of lamps may be seen from table 5.5. Fluorescent lamps are produced to give several light colours. Basic types are daylight white, standard white and warm-tone white as well as several special light colours (blue, red, green, fluorescenting) for decorative purposes.

A fluorescent lamp consists basically of:

- the ballast,
- the starter (standard or tandem starter),
- the fluorescent lamp
- the holder for the fluorescent lamp and starter.

Table 5.5. Input wattage and dimensions of low-voltage fluorescent lamps

Data of fluorescent lamp	straight-shaped			U-shaped			
input wattage (W)	20	25	40	65	20	40	65
length of lamp (m)	0,60	1,00	1,20	1,50	0,32	0,53	0,77

For compensation of the arising inductive reactive current, fluorescent lamps are operated with compensating capacitors. The lamp may subsequently be equipped with compensating capacitors. Care has to be taken to connect the capacitor in parallel to the lamp.

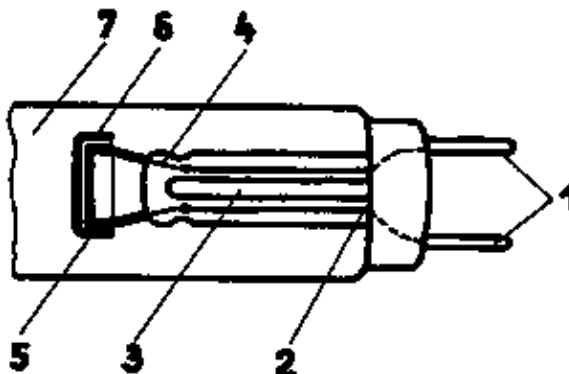


Fig. 5.36. Construction of a fluorescent lamp

1 base contact, 2 feeding wires, 3 support, 4 passing wires, 5 glow cathode, 6 screening, 7 glass bulb

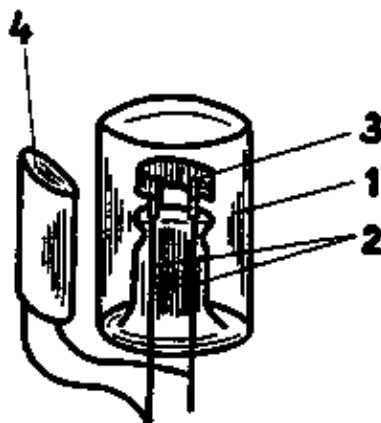


Fig. 5.37. Construction of a starter

1 glass bulb, 2 feeding wires, 3 bimetal with tungsten contacts, 4 anti-interference capacitor

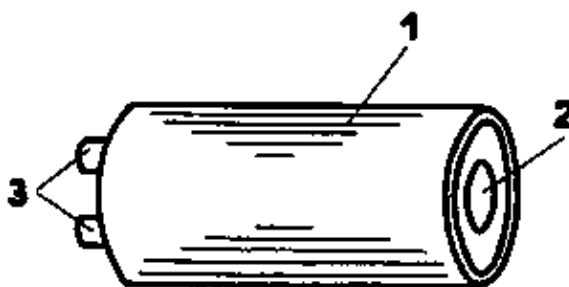


Fig. 5.38. Starter

1 case, 2 viewing glass, 3 contacts

In special cases additionally an anti-interference set may be built into the fluorescent lamp or the control gear of fluorescent lamps may be housed in separately arranged cubicles. This may be required in laboratories, where sensitive measuring instruments may be disturbed by the magnetic fields of the ballast.

A fluorescent lamp of 40 W is compensated by a 4 μF capacitor. For a 65 W fluorescent lamp a 7 μF capacitor will be employed. The compensating capacitor is connected in parallel to the fluorescent lamp.

Fluorescent lamps may be mounted directly to ceilings or walls, suspended from ropes or chains as well as arranged into luminous rows.

When lighting mechanical workshops by fluorescent lamps, these should be distributed among the three phase conductors of the three-phase network for avoiding the stroboscopic effect.

The stroboscopic effect will appear if the discharge lamps are connected to one phase conductor only. Quickly running parts of machines may then appear to be at a standstill or run but very slowly at certain numbers of revolution.

This effect creates a great source of danger. Accidents may take place if workmen are overcome by this optical illusion and reach into machines seeming to be at a standstill.

This effect is, however, used e.g. in spark setting devices for motor vehicles.

Distributing the fluorescent lamps among the three phase conductors of the three-phase network has got further advantages besides avoiding the stroboscopic effect:

- In case of failure of one phase conductor most of the lamps will continue to work.
- An even loading of the phase conductors will be achieved.

By and by fluorescent lamps are spreading into applications hitherto almost exclusively reserved for incandescent lamps, foremost into dwelling rooms.

By introducing a completely new generation of fluorescent lamps with high use-value and low power consumption, replacement of the traditional incandescent lamp is sped up.

5.5.3. Switching-on process of fluorescent lamps

After switching-on the starter, receiving the full voltage via the ballast and the fluorescent lamp's electrodes, will glow at once.

The starter operates like a glow lamp, one electrode of which is provided with a strip of bimetal.

Owing to heating up, the bimetal electrode will be bent and short-circuits the discharge path. The electrodes of the fluorescent lamp will be pre-heated. After quick cooling off the bimetal electrode of the starter returns to its resting position, thereby opening the circuit in which the ballast, the electrodes of the lamp and the starter are connected. The magnetic field in the ballast will collapse. The voltage impulse induced thereby causes the gas path in the fluorescent lamp to break down, and the lamp will light.

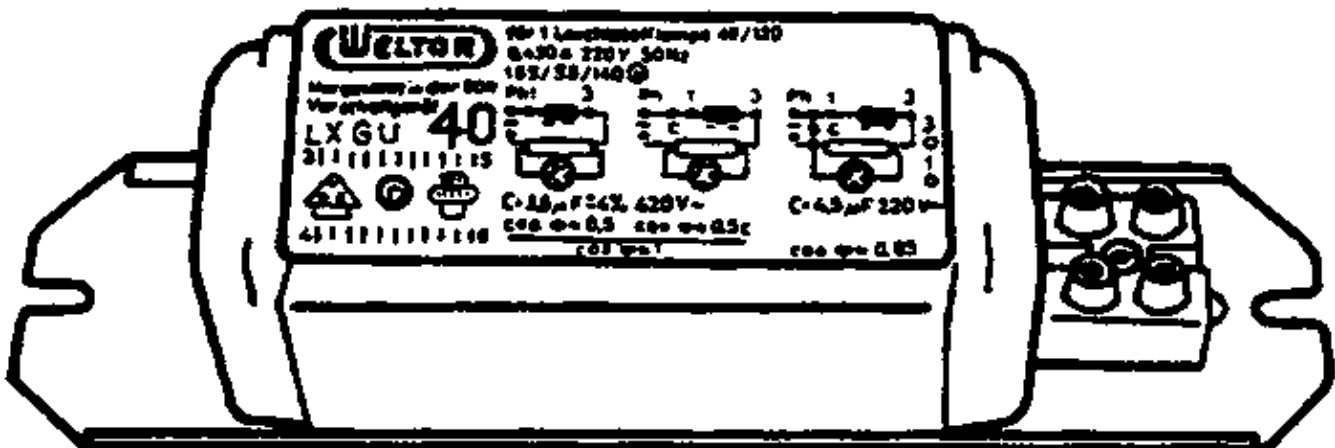


Fig. 5.39. Ballast of a fluorescent lamp

The luminiscent coating being spread over the internal surface of the fluorescent lamp turns to a glowing light due to the ultraviolet radiation being generated in the fluorescent lamp. During operation the ballast serves for limiting the lamp current.

This process of opening and closing the starter circuit will be repeated if the fluorescent lamp does not ignite the first time. Permanent flickering and starting of the lamp points to a defective starter. It may easily be replaced.

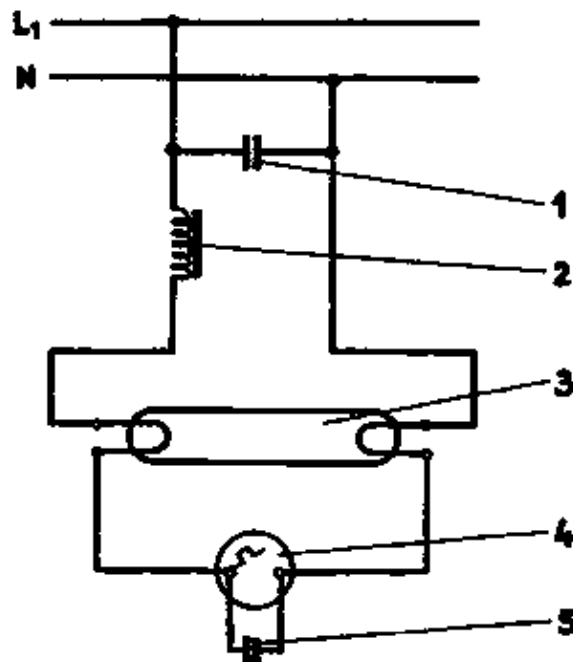


Fig. 5.40. Circuit for operation of a fluorescent lamp

1 compensation capacitor, 2 ballast, 3 fluorescent lamp, 4 starter, 5 anti-interference capacitor

5.5.4. Operation of discharge lamps

Since discharge lamps are consumer's installation with a share of inductive reactive power, there will be interruption arcs at the switching contacts, foremost during switching off.

This will lead to premature wear of the switching contacts.

In order not to overload the contacts of standard installation switches, no more than 8 fluorescent lamps should be installed in one lighting circuit. If a greater number of fluorescent lamps is to be connected, multisection rotary switches will be installed, or the fluorescent lamps will be operated via contactor control.

Mercury or sodium vapour lamps are generally operated via such switching elements.

Contactor control offers the advantage of being switchable from many locations with considerably less expense as is the case for cross connections. Contactors are being operated by means of so called stepping relays.

Stepping relays are switching elements maintaining their switching condition even if the circuit is opened. Since they themselves are only in a position to switch low currents, they serve to actuate the control circuit of the contactor.

Thereby it will become possible to switch the lighting installation on and off by means of a key switch.

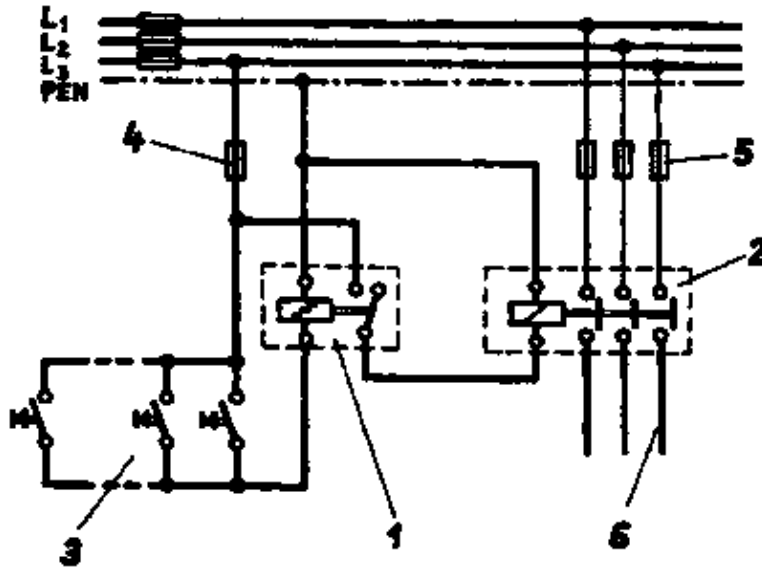


Fig. 5.41. Switching a lighting system by contactor control

1 stepping relay, 2 contactor, 3 key switch (n-fold), 4 control fuse, 5 fuses of lighting system, 6 feed lines to lighting system

The contactors and relays are being housed in the lighting distribution, where also the fuses and a master switch are accommodated.

Lighting installations are not to be protected by fuses of more than 10 A, electrothermal appliances (electrical cookers, water heater etc) by more than 16 A.

5.6. Preparing lines for portable electrical equipment

Portable electrical devices have many applications. Contrary to stationary devices their makers have intended them to change their position during operation.

Some examples of application are:

Domestic field: connection cables for coffee grinders, hair dryers, vacuum cleaners, radio receivers, television sets, washing machines, refrigerators or extension cables.

Trade field: connection cables for hand lamps, portable drills, hammer-drills, connection cables of all kinds for processing machinery.

Lines for connection to portable electrical equipment have got fine-wire copper conductors and are rubber or plastic insulated. By the fine-wire property of the conductors they will become highly flexible.

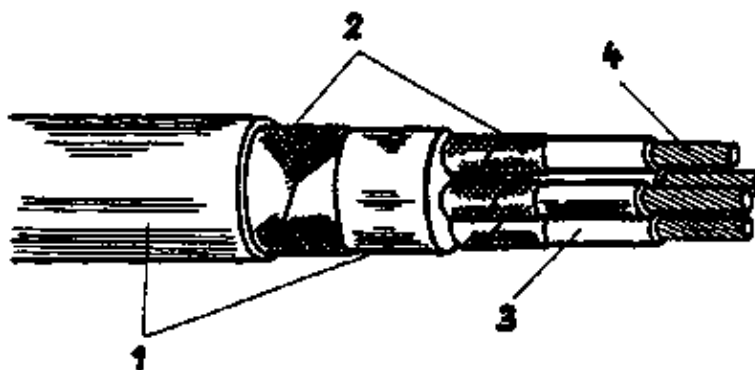


Fig. 5.42. Heavy rubber-sheathed cable

1 rubber sheath, 2 braiding, 3 rubber insulation, 4 fine-wire conductor

Depending on its application in dry, damp or wet rooms or outdoors and its duty, a flexible connection cable of light, medium or strong construction will be used.

Electrothermal appliances are equipped with plastic insulated connection cable only if the max. heating of the device to be connected will be warranted not to exceed + 85 C.

For electrical equipment with plastic cases it is not advisable to use rubber insulated connection cable.

Rubber contains a protective agent against ageing which on contact may come into the plastic material discolouring same under the effect of light.

5.6.1. Removal of insulation layers

When starting to remove the insulation from the conductor ends first the outer common insulation sheathing is to be removed. Thereafter the insulation layers thereunder are being removed.

The conductor insulation of silicone rubber cables will be removed by means of the automatic stripper and not by thermal wire stripping devices due to its heat resistance and the strong smell developing.

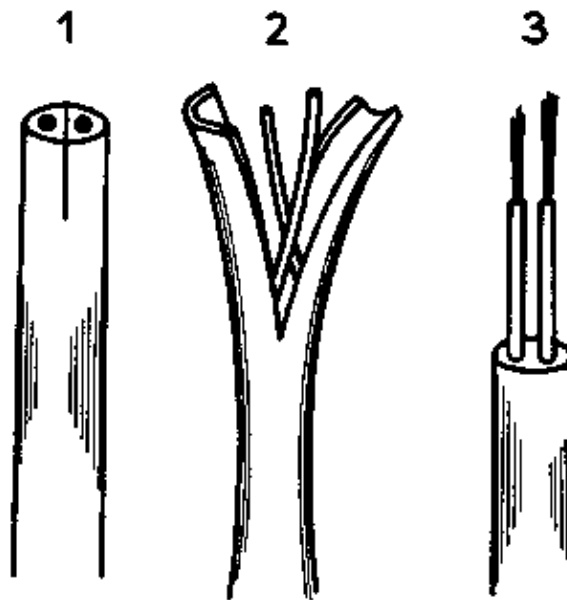


Fig. 5.43. Removing the insulation from a light rubber-sheathed cable

1/2 stripping the external insulation cover. 3 wire with insulation removed

Cross sections exceeding 6 mm² are bared by means of a cable stripping knife. For separating the insulation the knife is put on inclined towards the conductor end, and the conductor insulation will be removed by longitudinal cuts.

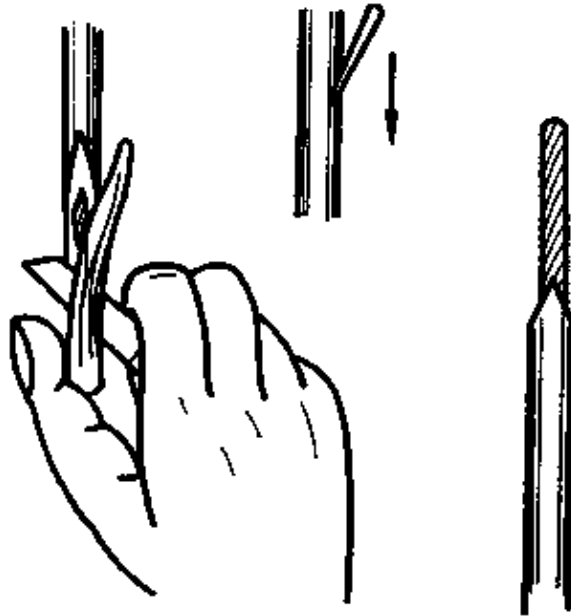


Fig. 5.44. Removing the conductor insulation by cable stripping knife

After stripping, flexible cables will be prepared for connection. The usual procedures for this are:

- tinning of the conductors,
- soldering on cable lugs,
- stamping on terminal sleeves and contact lugs as well as,
- stamping on stamped terminals.

5.6.2. Tinning conductors and bending terminal lugs

Tinning of conductors and using soldered cable lugs should be avoided as far as possible and will be permitted in exceptional cases only, e.g. if lugs are to be bent or stamped terminals cannot be applied.

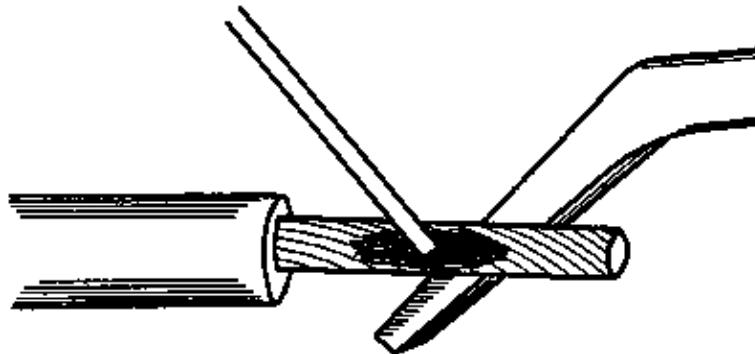


Fig. 5.45. Tinning a conductor

Prior to tinning the conductor ends are to be completely cleaned from adhering oxide residues. These residues will be expediently scraped off by a cable stripping knife. If one fails to do so the tin will not adhere to the conductor.

For tinning, solder with a tin content of 60 % and a non-acid flux (soldering paste or rosin in spirits) will be employed. The cleaned conductor is wetted by flux and tinned by means of a soldering iron or in the tin bath. Attention will have to be paid not to burn the insulation of the conductor and not to let soldering tin enter into the core. Not perfectly tinned conductors are to be reworked.

Lugs may be fitted to the conductor end before tinning. The connecting lug may not be too large. For this, compare also fig. 7.6. and 7.7. as well as table 7.1.

5.6.3. Soldering on cable terminals

For soldering on cable terminals frequently propane gas soldering devices are being employed. During this, the safety regulations are to be observed under all conditions (see fig. 3.25.) for operation. The stripped conductor will be entered into the cable terminal. The insulation of the conductor is to terminate approx. 2 – 3 mm in front of the cable terminal. The cable terminal must be filled. If required, additional bending may take place by means of pliers. Some flux is applied to the conductor end. In order not to burn the conductor's insulation the conductor is lapped with a flame-resistant fabric up to approx. 10 cm. around the conductor to the upper end of the cable terminal.

Now the cable terminal will be cautiously heated around the lug by the flame. So much tin will be applied to the soldering surface as to cover the whole area by tin, and until a mirror image will appear. The soldering surface is never to be heated so much as to have the solder enter through the cable terminal into the conductor. After soldering it is recommended to mantle the lower end of the cable terminal and part of the conductor for 4–5 mm with plastic tape, e.g. in the characteristic colour of the conductor or to pull a piece of plastic hose over the lower end of the cable terminal which was slid onto the conductor beforehand. The plastic tape will be fixed by adhesive. By the plastic tape or plastic hose the protection against contact and the looks of the connection will be improved.

5.6.4. Conductors' terminal sleeves and contact lugs

Conductors up to a cross section of 16 mm² will be provided with terminal sleeves or contact lugs, where no other designs are prescribed.

By their simple and unproblematic attachment working time and auxiliaries (solder, flux, electrical power) will be saved.

Terminal sleeves and contact lugs of tinned brass are manufactured in different sizes for cross sections from 0.75 mm² to 16 mm².

Terminal sleeves are fitted by sliding the matching sleeve onto the conductor. If the terminal sleeve tends to shift on the conductor it is lightly to be pressed on by round nose pliers. The required contact pressure will be achieved by tightening the set-screw.

Some makers of tools manufacture even special pliers for pressing on terminal sleeves which are very suitable.

For stamping on contact lugs specially made stamp pliers will be employed.

Terminal sleeves and contact lugs are foremost applied to the internal wiring of electrical appliances and in standard production of switch cabinets.

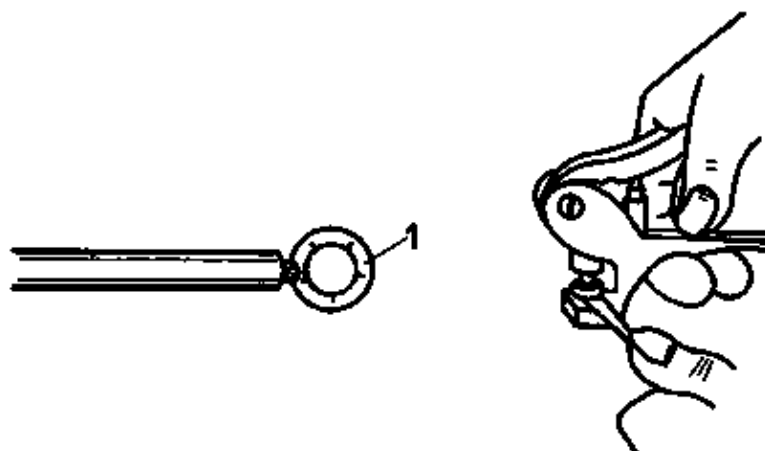


Fig. 5.46. Stamping on contact lugs by pliers

1 finished contact lug

5.6.5. Stamping on cable terminals

Mechanical hand stampers for stamping on cable terminals are suitable for handling cross sections up to approx. 70 mm². Beyond that hydraulic hand stamping devices are being used in practice.

Mechanical hand stampers for conductor cores sections from 0.75 mm² to 6 mm² have got a uniform stamp insert.

For bigger cross sections stamping pliers with replaceable stamp inserts are being employed.

On pressing the stamping pliers by means of the stamp insert a deep notch is stamped into the cable terminal. In any case the size of the stamp inserts must fit the cable terminal. Therefore cable terminals and stamp inserts are provided with corresponding markings. Never cable terminals must be drilled.

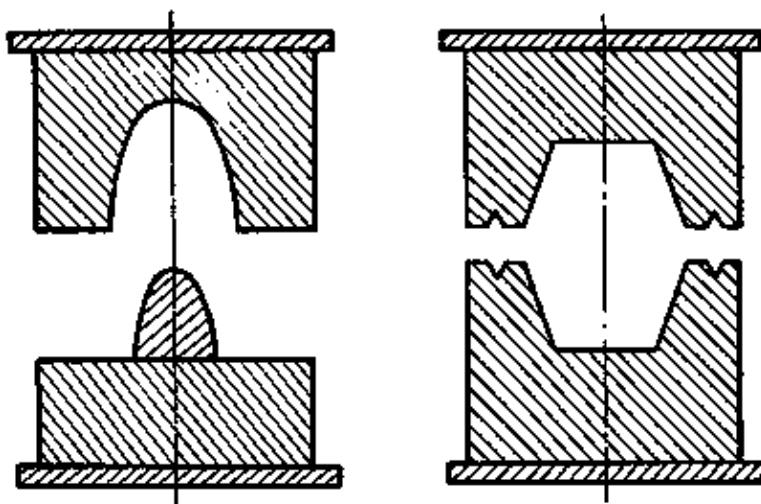


Fig. 5.47. Stamp inserts for stamping on cable terminals

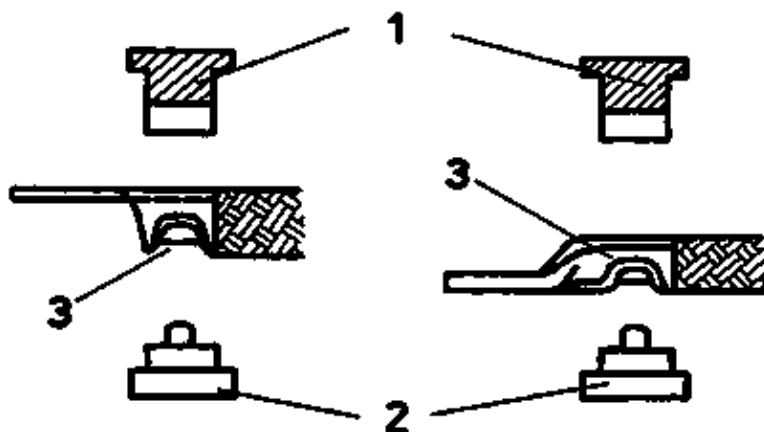


Fig. 5.48. Stamping procedure at the upper resp. lower part of the cable terminal

- 1 upper stamp insert,
- 2 lower stamp insert,
- 3 stamped notch

Only immediately prior to the stamping procedure the conductor is to be cleaned from oxide and contaminations by wire brush. The conductor will then be entered into the cable terminal. It is to fill the cable terminal completely.

Some longitudinal expansion arising from the stamping process will have to be considered.

The conductor insulation is to terminate max. 1–2 mm in front of the cable terminal.

The stamping process will be completed when both pressing jaws are touching each other or when the stamping pliers allow themselves to be reopened.

5.6.6. Connecting portable electrical equipment

Portable electrical equipment will in most cases be operated via a plug connector connected to a flexible cable. Only in rare cases portable electrical equipment will be connected to switches or junction boxes. This is foremost the case for portable electrical devices in a limited sense, e.g. electrical stoves, electrical grinding machines and column-type drilling machines. For connecting portable electrical equipment the following basic rules will hold:

- Flexible cables are to be provided with a pull relief at the connection points. This pull relief has to work directly onto the connecting cable. Cable entries and screwings are not to be used as pull relief.
- Cables are to be handled under installation in such a way as not to cause kinks or curls and are not to be squeezed. If need arises, the equipment will have to be provided with an anti-kink protection.

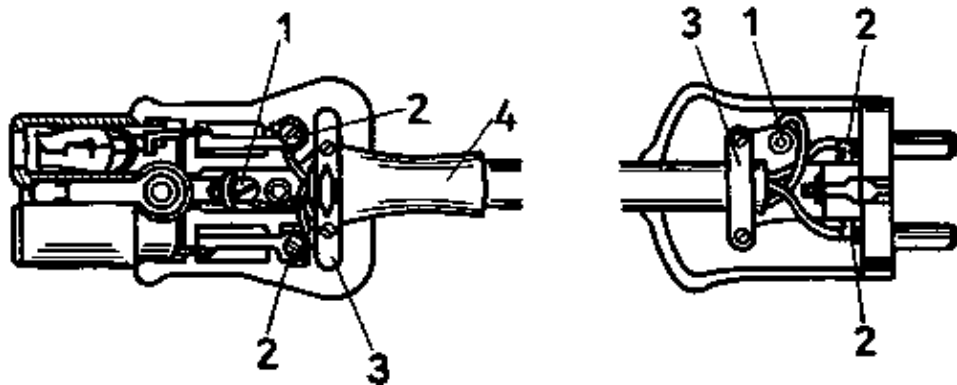


Fig. 5.49. Pull relief of an appliance coupler with earth contact

1 connection of earth contact, 2 phase conductor, 3 pull relief, 4 anti-kink device

- The protective conductor in equipment with protective earthing contact must be longer than the other conductors. It has to be warranted that the protective conductor will be stressed mechanically only after the current-carrying conductors have become loose or been torn off. This will make the protective measure effective to the last.

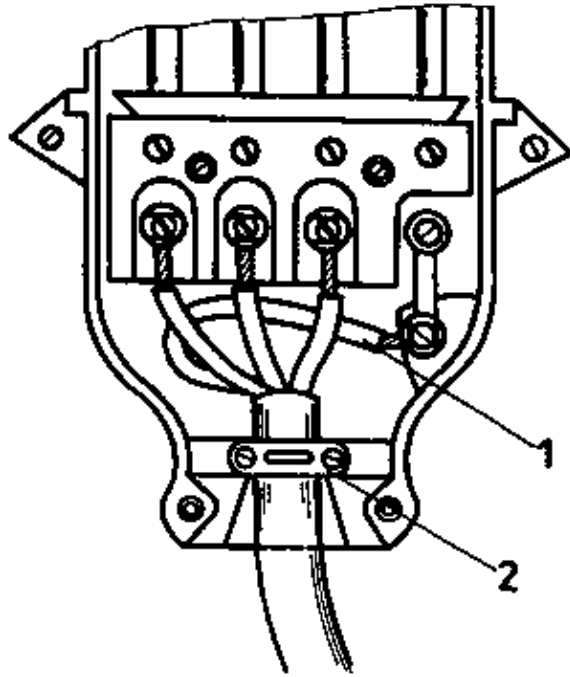


Fig. 5.50. Connection of a three-pole coupler

- 1 protective conductor,
- 2 pull relief

5.7. Preparing tubes

Where high mechanical requirements are put to electrical systems, cables will be laid into tubes individually or in bunches. In electrical engineering

- plastic tubes,
- steel tubes,
- flexible tubes of plastic or steel are being employed.

Steel or plastic conduits are a particularly stable tube material. In steel conduits there is a special cushioning layer.

Due to their weather resistance plastic tubes are to be preferred to steel tubes!

Table 5.6. Fixing distances for plastic and steel tubes

Plastic tube				steel tube				
spacing of fixing points				spacing of fixing points				
nominal bore	straight pipe	before elbows	before sockets, tube ends, wall passages, devices	nominal bore	external diameter	straight pipe	before elbows	before sockets, appliances, tube ends, wall passages
mm	mm	mm	mm	mm	mm	mm	mm	mm
9	800 at max. + 40°C after laying	200	150	11	18.6	1000	200	150

11				13.5	20.4			
13.5				16	22.5			
16				21	28.3			
23								
29	500 at max. + 50°C after laying	400	200	29	37	1500	400	200
36				36	47			
48								

5.7.1. Preparation of plastic tubes

Plastic tubes are to be cut to correct length. Existing burrs are to be removed.

In case of parallel installation of tubes, elbows of the same radius are to be bent for changes of direction. If commercial elbow pieces cannot be used, plastic tubes may be bent to the desired radius by means of bending stoves. For avoiding deformations the tube to be bent is to be filled by a bending spiral fitted to the internal diameter of the plastic tube or with fine sand. On filling the plastic tube with sand both ends of the tube are to be plugged.

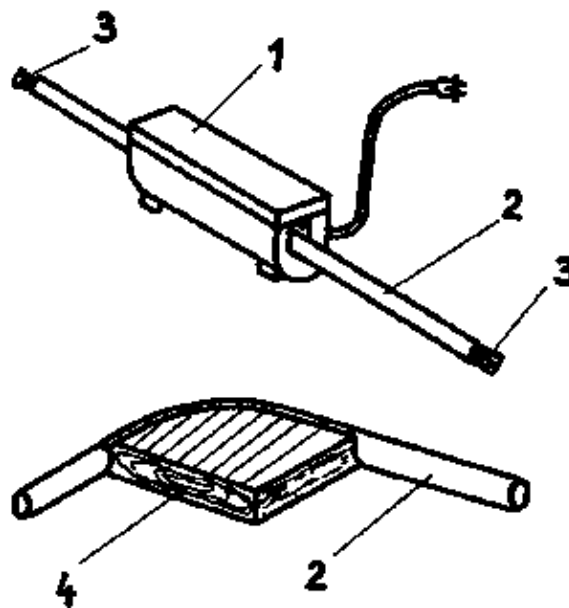


Fig. 5.51. Bending of a plastic tube

1 electric bending stove, 2 plastic tube, 3 locking plug, 4 bending templet

The plastic tube will be well heated in an electric bending stove and bent on a bending templet. For bending, prefabricated bending templets are employed in order to avoid undercutting the prescribed bending radius. The minimum bending radius for plastic tube is approx. $5 \times d$ of the tube.

Plastic tube must never be heated by open flame, since plastic materials are mostly inflammable!

If plastic tubes are to be joined to each other preferably sliding sleeves are to be used for this purpose. At the erection site, however, also plug-in sleeves will have to be made. In that case one end of the tube is to be heated and then slid over the cold end of the next plastic tube.

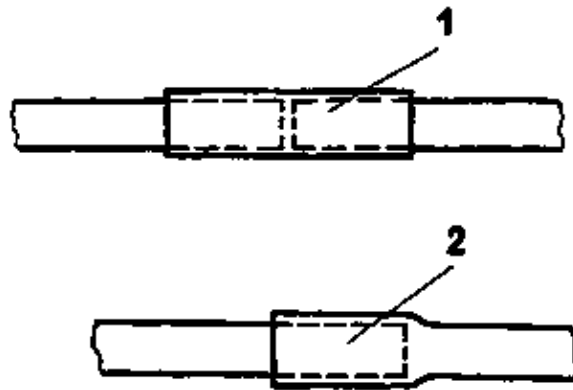


Fig. 5.52. Sleeves of plastic tube

1 sliding sleeve, 2 plug-in sleeve

Plastic tubes will be attached to the structure by clamps.

Damp room spacing clips, but also double-tongued clips of metal may be used for the purpose.

It is also usual to omit sleeves when installing lines in tubes. The pipe ends will then be joined only.

In front of junction boxes, switches and other electrical gear as well as in front of corners the tube may be terminated. The line is then entered into the electrical gear resp. run around corners and edges without the mechanical protection of the tube.

If required, a binding will be provided on the bunched lines or a clamp will be attached.

Plastic tube is supplied in bunches with a length of 3 m.

5.7.2. Preparing steel tubes

Steel tubes can mechanically be stressed more than plastic tubes. Nevertheless, steel tubes should be employed in installations only if the mechanical protection by plastic tube does not suffice.

Steel tubes have got threads on both pipe ends. These threads serve for joining the steel tubes by means of sleeves. Each thread is of about half the length of a sleeve.

Steel tubes may be mounted to the structure by means of clamps. It will, however, also be possible to weld steel tubes directly to the structure of metal. This has, however, to be approved by the customer.

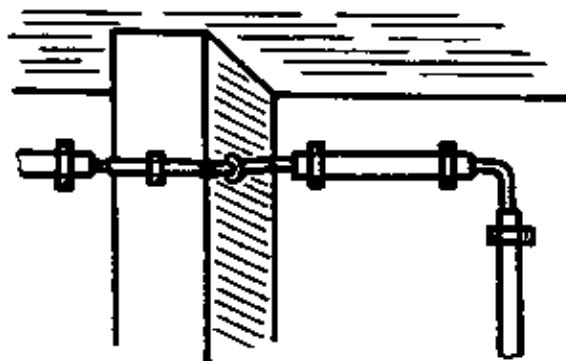


Fig. 5.53. Installation of cable in tube

If steel tubes are cut the arising burrs at the shoulder of the shoulder of the cut are to be removed, in order not to damage the cable insulation. It is also usual to widen the cut tube ends by pushing a strong metal pipe into the tube end and by evenly pressing the pushed-in pipe to all sides to expand the upper edge of the steel tube somewhat. It has, however, to be taken care of not to crack the steel tube during this procedure.

Threads not needed for sleeves should be cut off.

All cut and welded surfaces must be protected from corrosion.

If commercial elbows do not suffice for making bends the steel tube is to be bend. This may be done in cold condition with the help of bending devices or in hot condition by means of a welding flame.

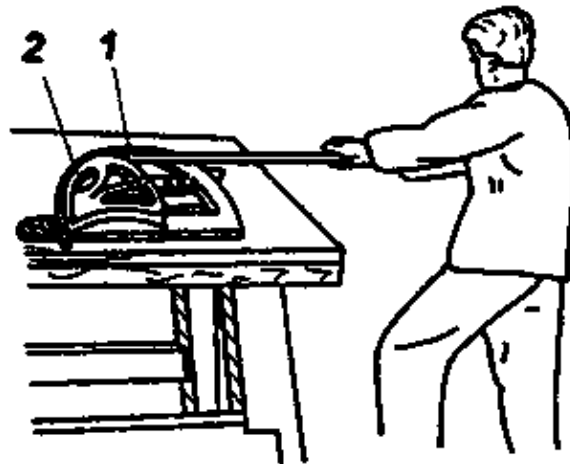


Fig. 5.54. Bending of steel pipe in a bending device

- 1 bending device (base frame).
- 2 templet matched to pipe diameter

Hot bending of steel tubes demand some experience. Similar as in bending of plastic tubes the steel tube to be bend is filled with sand and plugged on both sides.

A wire model is made of the elbow to be bend or the tier to be produced.

Two thirds of the tube's circumference are heated by means of a welding flame just on the side where the steel tube is to be bent.

The cold side of the tube will be the inner side of the elbow.

The steel tube will be heated red-hot. The tube will then be bent on a fire-proof base.

Care has to be taken not to allow the tube to be deformed at the inner edge.

The hot tube will be matched to the wire model. After bending the steel tube will be well cooled.

Never pour the hot sand from the tube. There will be the risk of fire and injury!

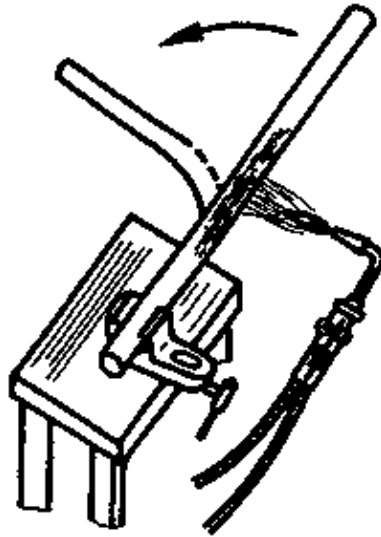


Fig. 5.55. Hot bending of steel pipe

Bending the steel tube by means of a wooden beam in which case the tube to be bent will be put into a matching hole or slot in the wooden beam and then be bent piecewise should remain an exception.

5.8. Installing showers and bathrooms

For electrical installation of stationary showers and bathrooms it does not suffice to maintain a required degree of protection only. Particularities are also to be considered in the arrangement of the electrical equipment.

There is a multiple of dangers which may be created by faulty execution of the electrical installation in such or similar locations. On the other hand damages at the electrical equipment will occur by corroding contacts reducing its life when not observing the degree of protection.

Short-circuits, failures of the equipment and live casings due to creeping currents can be the most extreme consequences of penetrating water.

The same danger will also arise if unsuitable electrical appliances are being installed.

On the other hand there will be mortal danger to persons if it will be possible to approach from the water live parts of the electrical equipment in a dangerous way or if these can be touched. Therefore the following principles for the arrangement of conductors in installing showers and bathrooms are to be observed:

- In showers and bathrooms installation of conductors in plastic tubes, plastic insulated cables or ribbon cable for underplaster or inplaster installation is permissible only.
- Cable and wires for power supply to other rooms must not be run through showers and bathrooms. Exempted are the lines of the socket circuit.
- Within the protected area shown in fig. 5.56. no switches or sockets are to be mounted. Exempted are switches installed in electrical appliances like electrical storage water heaters, boilers and continuous-flow water heaters. These appliances are to be splash-proof in all directions.
- Within the protected area shown in fig. 5.57. wires and cables must not be installed unless they are serving to supply electrical appliances like boilers or electrical storage water heaters.
- Wires and cables within the protected area must be installed in adjacent rooms only if there is a minimum distance of 6 cm between the conducting material and the inside wall of the shower or bathroom. In case of healthy concrete this distance may be 4 cm.

- A supply line to a stationary current consuming device within the protected area must be installed vertically from above.

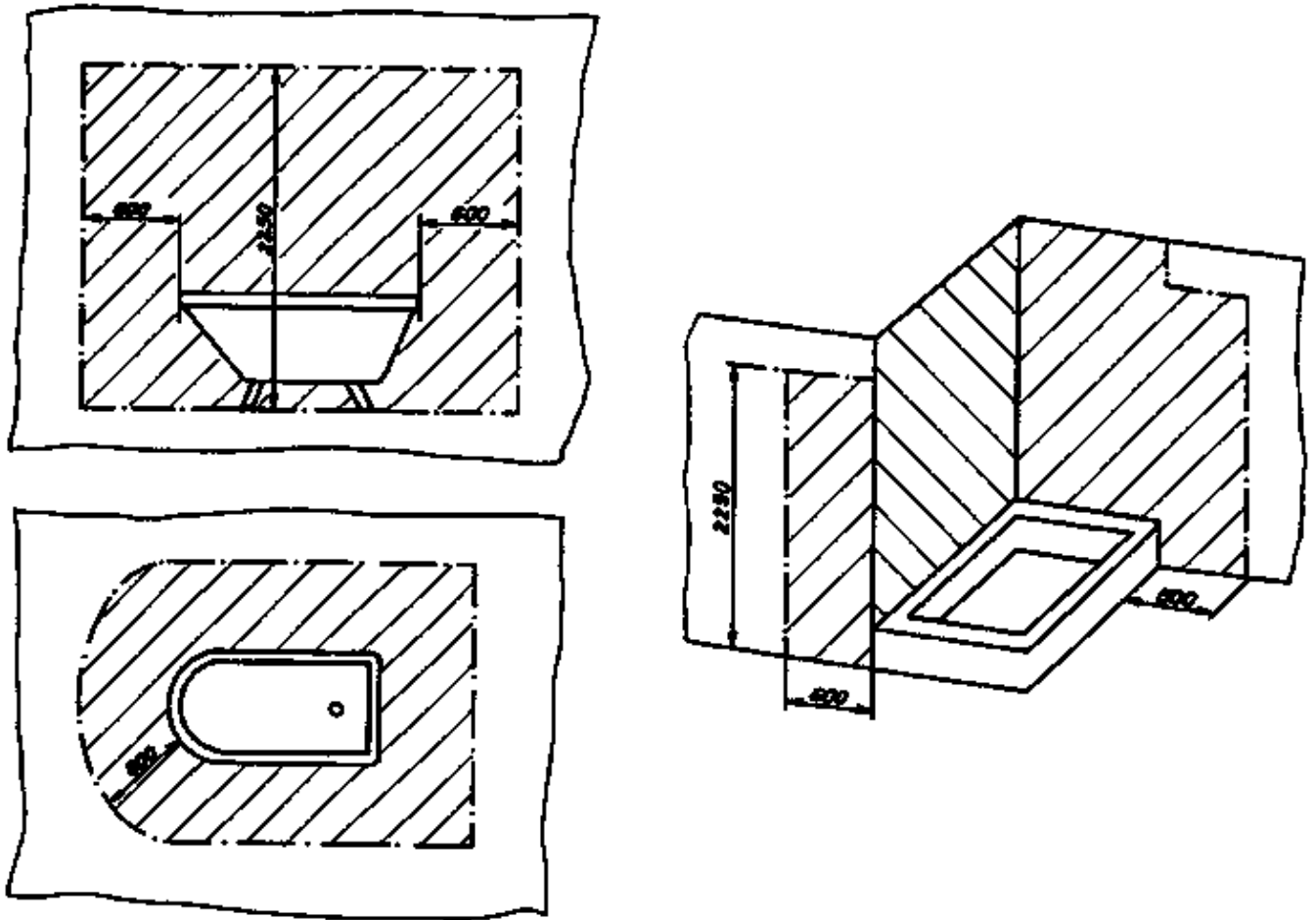


Fig. 5.56. Protected area for installing switches and socket outlets in bathrooms and shower stalls

Installation of cables or wires beneath bath tubs or shower stalls is prohibited!

Switches or sockets must not be installed in shower stalls. In rooms equipped with a shower stall one socket will be permitted if the following conditions are fulfilled:

- The distance of the socket from the boundary of the shower stall is to be 0.60 m at least.
- The socket must be sealed against ingress of vertically falling water.
- There must be a curtain against splash water on the side of the shower stall facing the socket.
- The shower stall must be sufficiently ventilated.

For still making safer shower stalls and bathrooms the pipelines are to be included in the potential equalization. Compare section 1.3.4. in this respect.

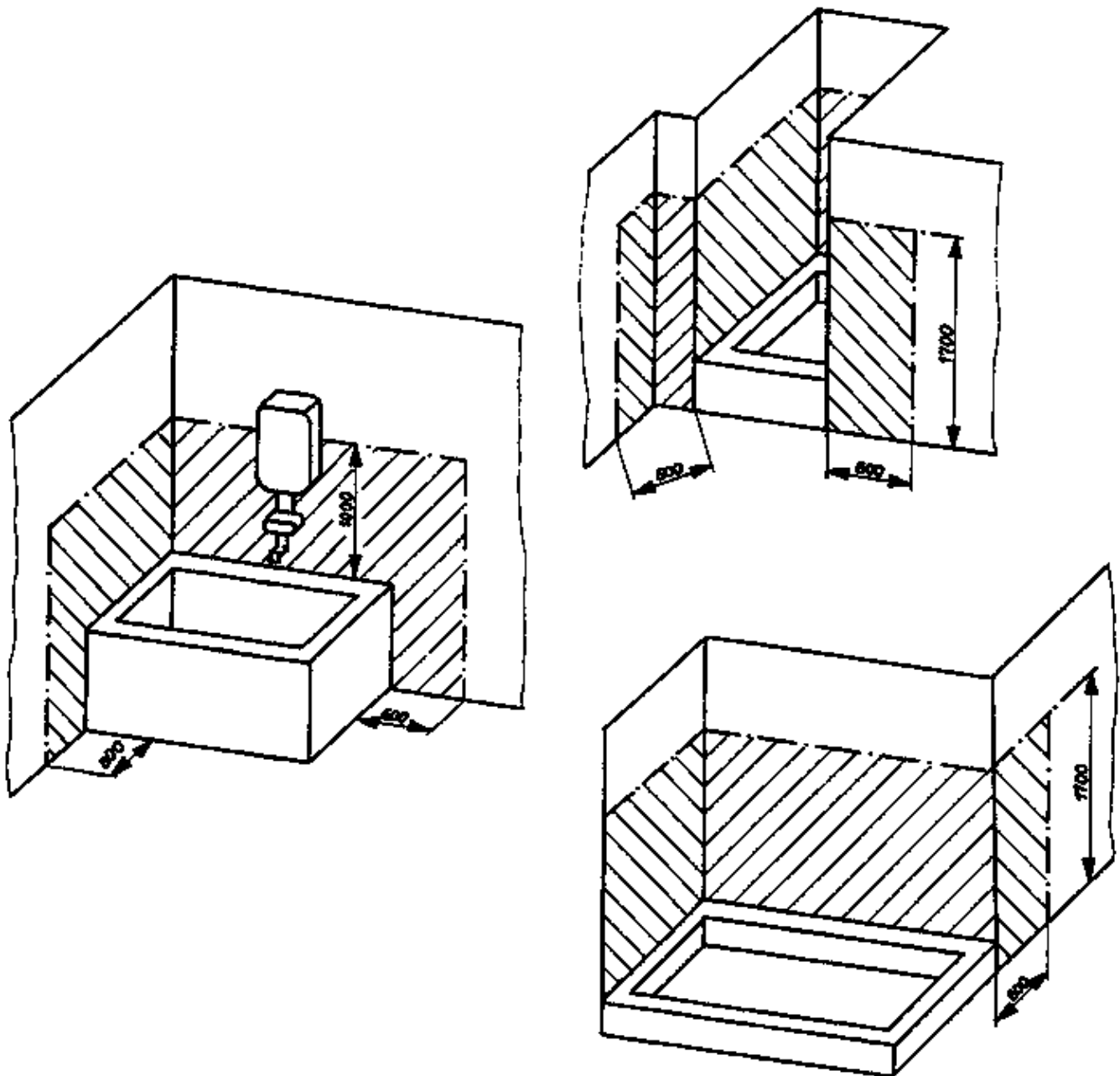


Fig. 5.57. Protected areas for installation of cables

Operating electrical devices (radio receivers, electrical heaters) in the immediate vicinity of the bath tubs or shower will be of mortal danger. The electrical shock which may occur when the electrical appliance comes into contact with water will be mortal with high probability, since the person concerned will not be in a position to free himself from the fault circuit!

5.9. Installation in explosion-prone rooms

In many fields of industry and engineering electrical plants must be installed, although there is the risk of explosive matter gathering there in dangerous quantities. This may be gases, vapours or even dusts.

Under such conditions the electrical plant must be designed in such a way as not to cause a risk for explosion.

The equipment and installation materials are distinguished in this case by a particularly robust design.

Yet, not every explosive matter is equally dangerous. For this reason explosive matters are classified in ignition groups.

Ignition groups are such groups in which explosive gases, vapours or dusts are classified according to their ignition temperatures!

Depending on the ignition group of an explosive matter, such equipment will therefore have to be selected for installation showing special design, electric and thermal features. These special features have been fixed in the protective system of electrical equipment.

Protective systems are the result of design, electrical and thermal measures at electrical equipment which exclude the risk of explosion!

For each installation type and the equipment connected thereto the protective system is to be prescribed in the working documents.

For the safety of the fitter the technical data of explosion-proof electrical equipment are provided on a well visible spot, e.g. on the type plate.

It holds for all explosion-proof electrical equipment to be limited to the most necessary extent only.

Every explosion-proof electrical system must be all-pole disconnectable from a place quickly to be reached and not exposed itself to danger. The breaking device for emergency disconnection will be marked red.

On principle all explosion-prone electrical equipment is to be laid out as a damp-proof installation.

When preparing wires and cables the following points of emphasis are to be observed:

- Aluminium conductors may be used from 6 mm² cross section upwards only, in exceptional cases smaller cross sections can be applied.
- Wires and cables with aluminium conductors being run uncut through explosion-prone rooms may have a cross section of 2.5 mm².
- In battery rooms exclusive copper must be employed as conductor material.
- Wires and cables are being entered into electrical equipment by means of specially explosion-proof bushings or damp proof screwings only.
- The degree of protection in explosion-prone systems is prescribed.
- At the passage of wires and cables into adjacent rooms being without explosion risk the point of passage must be well sealed.
- Electrical equipment in explosion-prone systems must be sealed by special seals.

Special seals are special screwings permitting opening of the explosion-proof electrical devices by special tools only.

This is to assure opening of such electrical appliances but by experts equipped with corresponding tools. Screws with triangular-shaped heads are used for that purpose!

Explosion-proof lighting fittings have got protection covers over the protective glass intended to protect them from damage. Only lighting fittings arranged in such a way as not to be exposed to damage need no protection cover. The protection cover is made of steel.

It is important not to exceed the max. surface temperature of the lighting fitting. Therefore explosion-proof lighting fittings must only be equipped with such lamps for the capacity of which they have been designed. Provision with smaller lamp capacities is permitted.

Sodium vapour lamps must not be used in explosion-prone rooms.

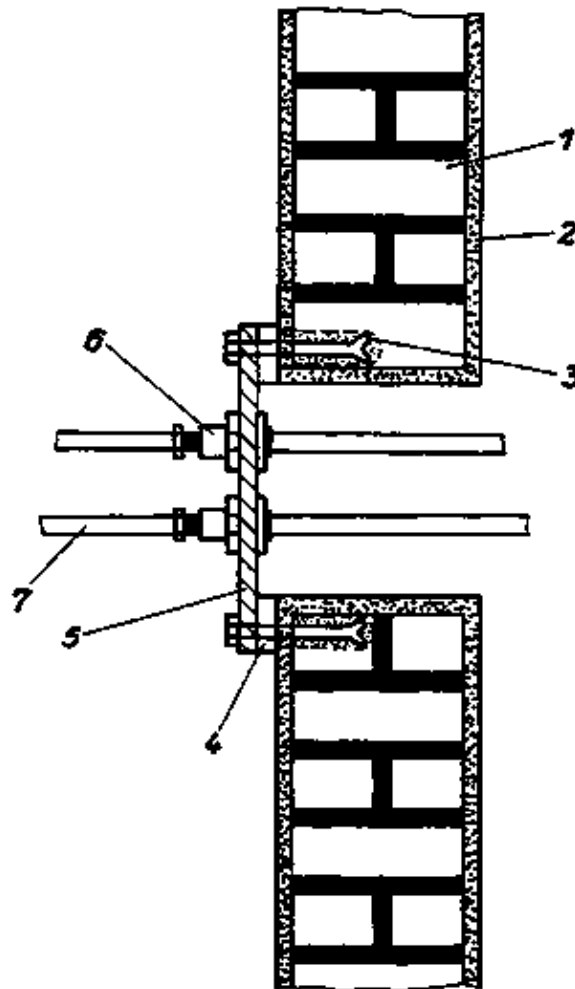


Fig. 5.58. Example for a gas-proof wall passage

1 brickwork, 2 plaster, 3 fixture in brickwork, 4 seal, 5 plate, 6 screwing, 7 cable

If lighting fittings are to be suspended freely swinging they will have to be connected via flexible cables.

In battery rooms lightings are to arrange within the hand range and along the gangways between the batteries.

For repair work in explosion-prone installations electrical hand lamps are also used as working light. It is to be observed to insert shock-proof incandescent lamps into these hand lamps.

Maintenance and repair work in explosion-proof installations must be performed in dead condition of the electrical system only.

When opening appliances and encapsulated switchgear the protection against explosion will be rendered void. An electrical spark would suffice to trigger an explosion. For this reason replacement of faulty fuses and lamps by laymen is not permitted in explosion-prone rooms.

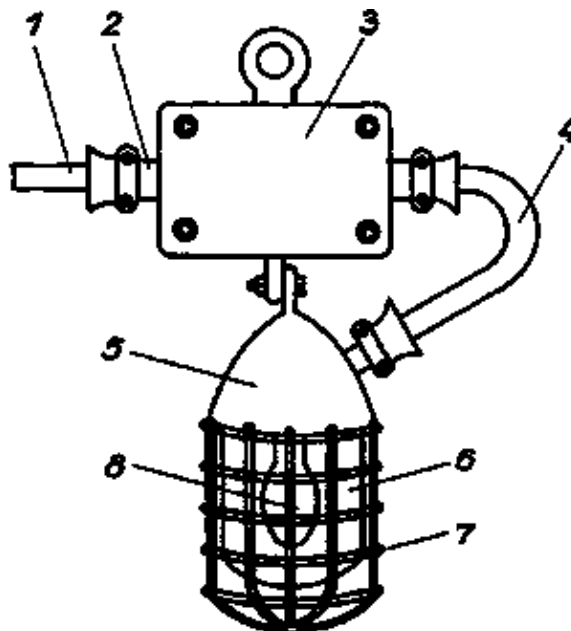


Fig. 5.59. Mounting of an explosion-proof pendant lamp with mercury vapour lamp

1 feed line, 2 entry, 3 casing of ballast, 4 flexible cable, 5 pendant lamp, 6 protective glass, 7 protective cover

Parts of explosion-proof electrical systems are to be opened in dead condition only. They are to be made voltage-carrying again only after the protection against explosion has been reestablished!

The makers of electrical equipment are partly considering these requirements already when designing their devices. For instance, explosion-proof fluorescent lamps have got internally mounted magnetic switches. As soon as the lamp is opened this magnetic switch cuts the fluorescent lamp. This will permit replacement of fluorescent lamps without risk.

5.10. Principles for connecting power-consumer's installations to the mains

Generally the consumer's installation will have to be connected to the mains along the shortest route.

Entries into houses must not terminate in explosion or fire-prone rooms. The service line is to be installed so that the piece of line concerned may burn out in case of an arc-short circuit without spreading the fire. The service line will be mostly a four-core cable.

Rubber sheathed cables are not permitted as service lines!

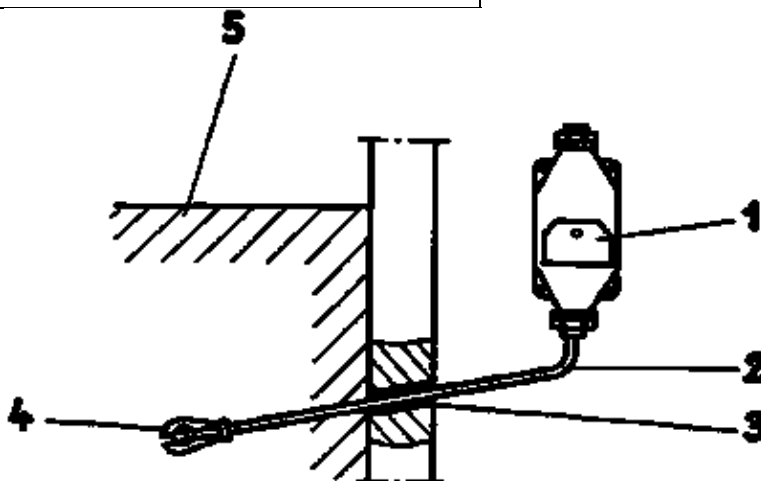


Fig. 5.60. Service entry via power cable

1 service box, 2 service cable, 3 protective tube, 4 services sleeve, 5 ground

All parts of the installation in front of the current meter, like service boxes, main fuses, main junctions and meter panels should be fit for sealing. This is to prevent unauthorized tapping of power.

Service boxes are being installed in a 3–pole version. The bases of the main fuses must be designed for a nominal current of 63 A at least. The mounting height of service boxes is between 500 and 1700 mm above the upper edge of the finished floor.

There is also the possibility to mount the service boxes out–side the building, but for this the approval of the power supplying utility will be required.

Service boxes installed near easily inflammable materials are to have a high degree of protection. This is established in special rules.

For the installation between main fuse and current meter conductor cross sections depending on the max. expected load are prescribed, however, at least

- 10 mm² aluminium or
- 6 mm² copper.

Current meters are being mounted on meter panels. The mounting height of current meters will be 1500 mm from the upper edge of the finished floor. They are to be attached vertically. Such locations are chosen for mounting current meters, in which they are protected from damage, e.g. wall niches. Such locations should also be dry and not dusty and be protected against deposit of moisture. It is to be secured to have the current meter accessible by the power supplying utility at all times. In dwelling houses with several storeys the current meters are therefore being mounted in staircases or anterooms of storeys.

Mounting current meters in flats is to be avoided!

The following mounting places for current meters are generally prohibited:

Garages, stables, kitchens, bathrooms, laundries, lavatories and passages.

5.11. Summary

An installation system is the totality of the electrical equipment being arranged in or on a structure like consumer's installations, wires, cables, mounting materials or switches.

The installation system will be designed according to local requirements and practical and aesthetic points of view.

For all types of installations it holds to run the lines horizontally or vertically resp. parallelly to edges, corners etc. on or in the structure.

Lines are classified in those for connection to portable equipment and those for fixed installation. Cables for connecting portable electrical equipment are to be specially prepared prior to connection.

Connecting conductors to each other and the connection of electrical equipment will have to take place in the wiring space of the electrical appliances.

Application resp. function of the required protective measure against too high a contact voltage is to be warranted under all circumstances.

All electrical equipment mounted within the hand range must be locked so that it cannot be opened without tools. When mounting the installation system the required degree of protection for the rooms concerned has to be observed. The degree of protection of the overall system is as high as the lowest degree of protection of an installed appliance. Fluorescent lamps are to be preferred to incandescent lamps in spite of higher purchase prices. They are many times superior to those as regards light efficiency and life.

Fluorescent lamps are to be compensated for improving the power factor.

Where lines might be damaged they are to be protected by tubes. Plastic tubes are preferable to steel tubes.

If commercial elbows of tubes do not suffice, plastic or steel tubes should be bent. Tubes are being joined to each other by sleeves.

On installation of shower stalls or bathrooms protected areas are to be observed in respect to laying of cables and wires and mounting of switches and sockets.

Installation work in explosion-prone rooms is to be done so as to avoid dangers arising from the electrical system. The electrical equipment must correspond to the demands put on them for explosion-prone areas in terms of design, electrically and thermally.

Aluminium lines are to be installed in explosion-prone rooms from a cross section of 6 mm upwards only. A cross section of 2.5 mm² is permitted in exceptional cases only.

Explosion-proof electrical equipment is to be sealed by special seals. It must be opened in dead condition only and be recommissioned only after having been sealed properly.

Prior to starting installation work a wiring diagram of the system to be installed is to be made. This will prevent faulty connections.

Examples for basic wiring in illumination engineering are to be taken from the textbook "Circuits, Formulae and Tables of Electrical Engineering", section 3.

6. Installation of emergency lighting systems

Power supply for all applications from the mains will be warranted. Nevertheless, failures of the mains may occur. If by failure of the mains voltage human life or material assets are endangered, then an emergency lighting system may be installed.

Emergency lighting is an additional illumination being automatically switched on in case of failure or dimming of the general lighting. For this, additional investment in electrical devices, cables and installation materials will be required.

The power supply for minor emergency lighting systems is made by direct current originating from accumulators. In normal operation the accumulators are being charged by the mains via charging rectifiers.

For emergency current supply of industrial shops, agricultural breeding and hatching plants, protection rooms or operation theatres the capacity of accumulators is too low.

The emergency current in such instances will be supplied by emergency power generating sets with a Diesel engine. These have an almost unlimited application and may be suited to the required wattage and voltage.

Emergency lighting systems may be fed by accumulators or emergency power generating sets. Accumulators are accommodated in battery rooms and supply direct current, standby generation sets mostly three-phase current.

Emergency lighting systems are divided into panic lighting and special lighting!

The panic lighting illuminates rooms and evacuation paths. In case of danger it will enable escape from the corresponding location without accident and danger. Its mean illuminance will be less than that of the general lighting. In average it will be 1 – 3 % of the general lighting's illuminance. Depending on the type of rooms, this is fixed in regulations. Examples for application of panic lighting are:

Meeting rooms, escape ways, stairways and doors in dimmed rooms of public buildings, out-patient departments, shopping centers, multi-storey dwelling houses, museums, restaurants, schools, production rooms.

Contrary to panic lighting, special lighting will render it possible to continue processes the interruption of which would endanger human life, domestic stock or important plants. The illuminance of special lighting may be up to 100 % of the general lighting's illuminance.

Application fields of special lighting are e.g.:

Operation theatres in hospitals, control stations in industrial plants, information centres in mail traffic and telecommunications.

6.1. Demands on construction of emergency lighting systems

The emergency lighting is switched on or prepared for operation by one actuation at the emergency lighting main distribution. In case of mains failure or decrease of the mains voltage below a value of 80 % it will switch automatically if the standby circuit arrangement is employed.

In case of the emergency lighting's permanent circuit arrangement same operates in parallel with the general lighting. Change-over from general to emergency lighting takes place automatically. The change-over is being indicated by optical or acoustic signals at an appropriate place, e.g. at the subdistributions of the emergency lighting system.

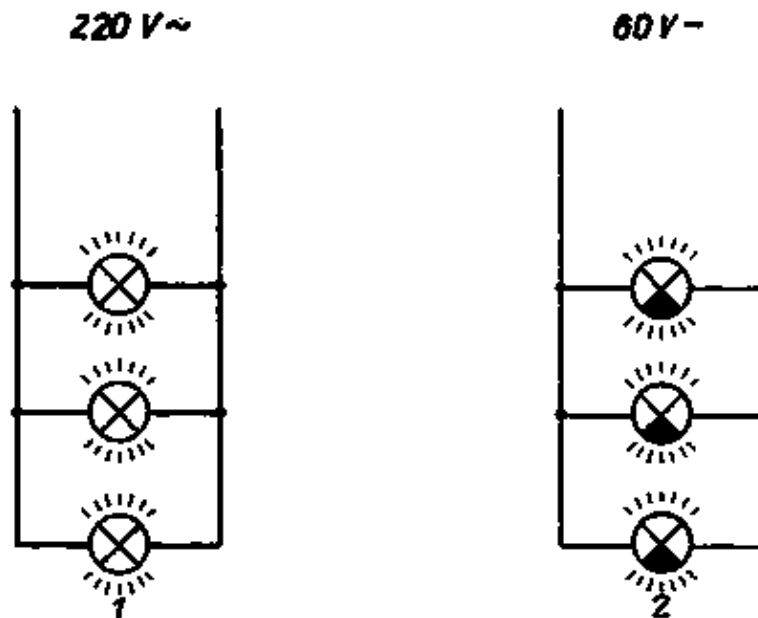


Fig. 6.1. Mode of action of a permanent circuit arrangement

1 general lighting circuit, 2 emergency lighting circuit

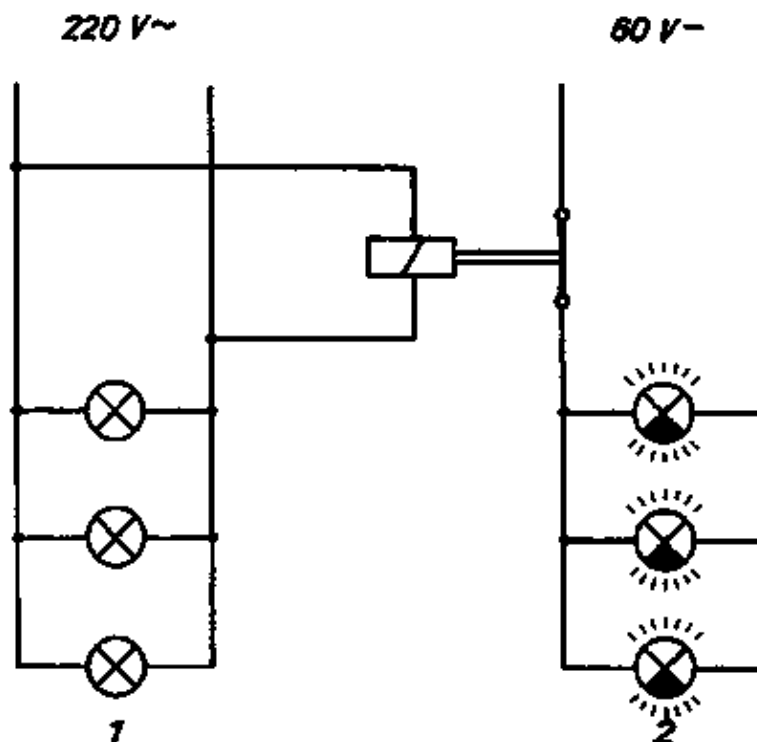


Fig. 6.2. Actual operating diagram of a standby circuit on failure of the mains

1 general lighting circuit, 2 emergency lighting circuit

Emergency power generating sets will be put into operation by an automatic starter after a short time delay. If the Diesel engine does not start after the first starting trial the starting procedure will be repeated until the Diesel set runs or is put out of commission after making a certain number of starting trials in vain. For this reason regular test runs, e.g. weekly ones, are to be performed with emergency power generating sets for keeping them always in operating condition.

After the mains voltage has returned, lighting will again be taken over by the general lighting system through repeated change-over. In this way accumulator systems will be prevented from discharging themselves until exhausted.

An example for emergency lighting dependent on the general lighting is shown in fig. 6.3.

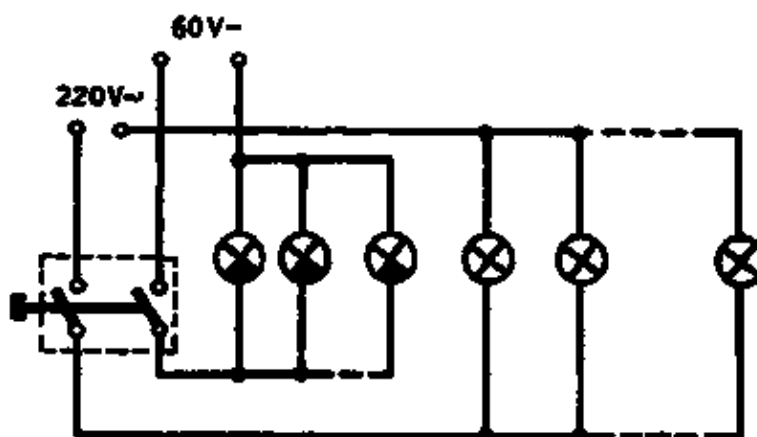


Fig. 6.3. Dependent emergency lighting

This type of emergency lighting will be installed in such rooms which are rarely entered by persons, but which must be lighted also in case of emergency. The particularity in this type of emergency lighting is the actuation of the general lighting and emergency lighting by one and the same switch.

When the general lighting is switched off, the emergency will not be put into operation either in case of mains failure. Only if after switching on the general lighting this illumination should fail, the emergency lighting will be

switched on automatically. Depending on the degree of danger to human beings and material assets switching-on delays are maintained. This serves to avoid unnecessary switching-on of the emergency lighting in case of short-time failures of the mains or great variations in the voltage of the mains. Some switching-on time delays of emergency lighting systems are summarized in table 6.1.

Table 6.1. Turn-on delays in emergency lighting systems

Turn-on delay	Examples for application
0.5 seconds	meeting rooms, cinemas, department stores, hotels, operation theatres, control rooms, pedestrian tunnels
30 seconds	shelters, reception halls, staircases, normal ward units in hospitals, big garages, open plan offices

For some emergency lighting systems there may be further special requirements. For instance, it holds that

- lamps for emergency lighting must not be operated via lighting dimmers,
- the special lighting in operation theatres of medical institutions must also be switched on automatically if the lighting at the place of operation fails due to rupture of the incandescent lamps filament or other defects,
- in systems, for which a master switch is provided (a.o. in explosion-prone rooms) the emergency light is operated by a separate switch.

6.2. Arrangement of distributions, circuits, cables and wires in emergency lighting systems

For installation of emergency lighting systems a lot of principles in designing of the emergency lighting system are to be considered. The designer will have to include these principles into his working documents for the erection staff.

These are first of all

- the installation materials to be used,
- the choice of the type of installation and the arrangement of the emergency system's lighting fittings,
- the arrangement of the emergency lighting system's circuits.

The distributions of the emergency lightings will be arranged according to fire sections. If the emergency lighting distribution in one fire section should fail due to fire, it will be warranted thereby that the emergency lighting continues to function in other fire sections.

For avoiding unauthorized interferences in emergency lighting distributions, those distributions must be locked.

To make work easier when carrying out maintenance and repair work a general wiring diagram in all-pole representation is to be exhibited at the emergency lighting system's main distribution. The installation plans of the emergency lighting system are to be permanently up-dated.

The general wiring diagram is to include the following information:

- description of the distribution in detail up to the last distribution fuse,
- current type and supply voltage,
- type and capacity of the emergency power plant,
- designation of the outgoing circuits,
- rated current of the fuses,

- number of lighting fittings,
- capacity of the individual circuits,
- cross sections and materials of the conductors,
- the protective measure applied against too high a contact voltage.

A number of demands are put to the installation of emergency lighting lamps mentioned in the following:

- Emergency lighting lamps may be accommodated together with general lighting lamps in one lighting fitting.
- For being able to discern emergency lighting lamps from general lighting lamps the lamp bases of emergency lighting lamps will be painted red.
- As already described in section 6.1., the panic lighting is to warrant safe escape from dangerous areas. Max. 12 lamps may be connected to one circuit, loading the circuit up to 6 A. In that case a 10 A fuse will have to be used.
- The lamps of the panic lighting along the escape ways are alternately to be connected to two circuits. This will secure continued illumination of the escape ways on failure of one emergency lighting circuit.
- For panic lighting only lighting fittings of a max capacity of 60 W are to be installed. However, these lighting fittings are to be equipped with lamps of max. 40 W only.
- Adjacent to each emergency lighting fitting a pictogram is to be exhibited in a well visible place.
- The pictogram is to contain the following information:
 - distribution,
 - circuit,
 - lamp's capacity,
 - number of the lighting fitting in the circuit.
- Within a system the lighting fittings are to be marked uniformly.
- The emergency lighting fittings within one circuit are to be numbered in succession.
- For being able to discern junction boxes of the general lighting circuit from junction boxes of the emergency lighting circuit without doubt, the interior of the latter will be marked by green paint. It will not serve the purpose to mark the covers. After repair work they may be mixed up.

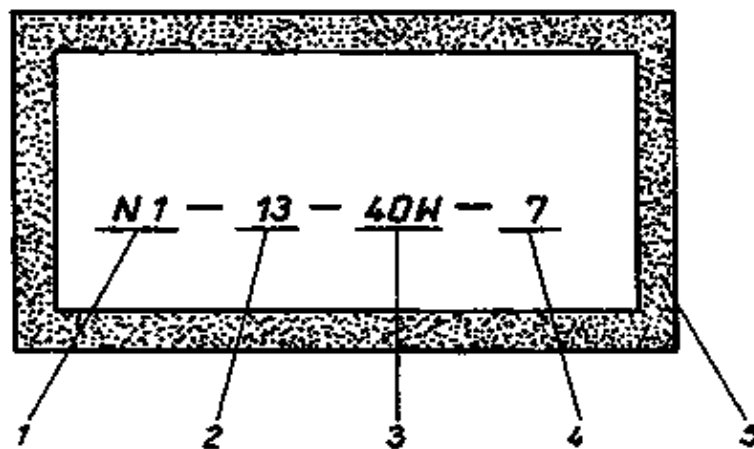
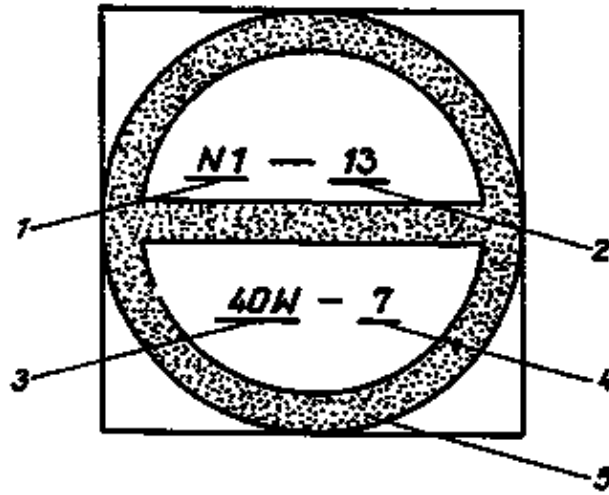


Fig. 6.4. Marking of emergency lighting fittings

1 designation of emergency lighting distribution, 2 number of circuit, 3 lamp wattage, 4 number of lighting fitting in the circuit, 5 bordering of pictogram (green)

– Installing switches in circuits of the panic lighting is not permitted. In the most unfavourable case the emergency lighting may become ineffective on failure of the mains supply thereby!

– On emergency lighting systems selected protective measures against too high a contact voltage will have to be applied, since the emergency lighting system will have to continue to operate in case of failure. Such protective measures are the protective conductor system or protective insulation. Neutralization or protective earthing are unsuitable on the other hand. This is important insofar, as on failure of the mains the emergency lighting will be the only illumination still working.

In emergency lighting systems up to 250 V no protective measure against too high a contact voltage will, be required!

For operating emergency lighting systems, rated voltages have been established. They may be taken from table 6.2.

Table 6.2. Nominal voltages of emergency power plants

Nominal voltage	Application
12 V	In systems up to 200 W for consumer's installations only

24 V	For lamps in operation theatres only
60 V	For industrial control, not for emergency power plants serving for emergency lighting only
110 V	Power distribution systems or remote controlled stations
220 V	Preferred voltage enabling a simple and economic construction of emergency lighting systems. Standard lighting fittings, switches, fuses, motors etc. can be used
380 V	Application for special lighting only, since consumer's installations with great capacity are being operated

6.3. Installation of emergency lighting systems

The emergency lighting system will be installed in accordance with the installation type of the general lighting system. In industrial plants lines of the emergency lighting may be installed bunched together with other lines too. In all other emergency lighting systems the lines of the emergency lighting are to be installed in a distance of 50 mm minimum from all other lines.

In buildings like cinemas, theatres, shopping centres, exhibition halls and rooms, hotels, restaurants and shelters only

With copper conductors having a cross section of min. 1.5 mm² are permissible. This holds also for explosion-prone rooms which are generally to be installed in the damp-proof version.

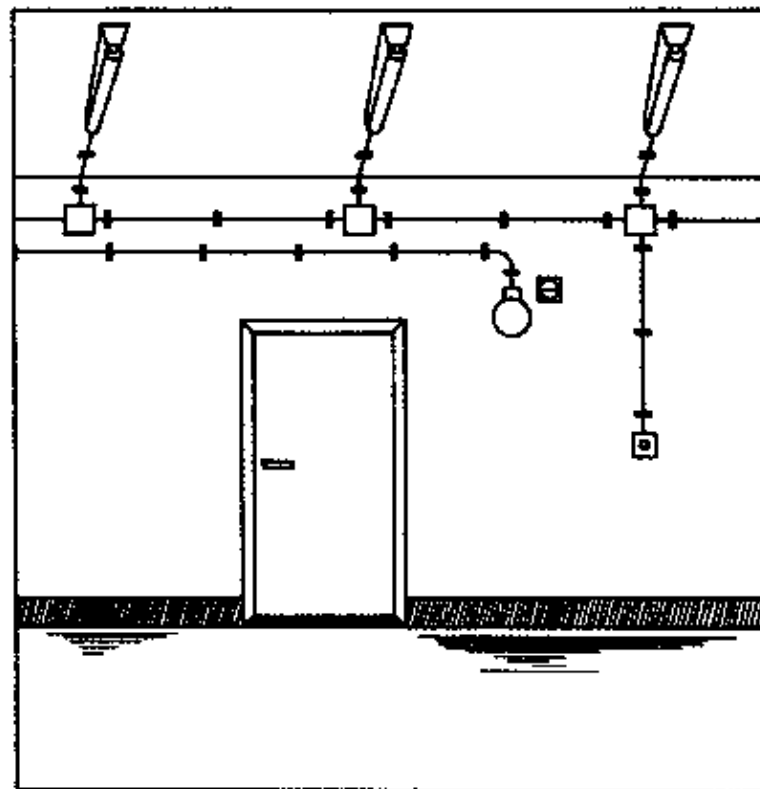


Fig. 6.5. Separated general and emergency lighting in a corridor

6.4. Summary

Emergency lighting is an illumination to be installed at additional investment, turning automatically on in case of the general lighting's failure or too high an undervoltage. Supply of emergency current may take place by batteries or emergency power generating sets.

Emergency lighting systems are classified into panic lighting and special lighting.

The emergency lighting system may be operated as standby circuit or as a permanent circuit. It will also be possible to operate the emergency lighting as an illumination dependent on the switching condition of the general lighting.

The lighting fittings of the emergency lighting are being equipped with lamps of max. 40 W capacity.

The lighting fittings in the emergency lighting circuit are to be marked. They will obtain a designating pictogram containing the distribution, number of circuit, capacity of lamps and number of lighting fittings in the circuit.

Switches are not to be installed in circuits of panic lighting. In emergency lighting systems protective measures against too high a contact voltage are required from a supply voltage of 250 V upwards only.

If protective measures against too high a contact voltage are to be applied, such protective measures are being chosen which will warrant further function of the emergency lighting also on occurrence of a fault to frame.

Circuits along escape routes are divided in such a way as to install the lamps of one circuit alternating with the lamps of the other circuit. Therefore, on failure of one emergency lighting circuit, the escape route will still be illuminated.

In industrial plants lines of the emergency lighting may be installed together with lines of other circuits.

In all other emergency lighting systems a distance of at least 50 mm between the emergency lighting's lines and further line systems must be kept.

In public buildings, protection rooms and explosion-prone rooms copper will have to be exclusively used for conductor material.

7. Mounting and connection of motors

7.1. Placement of electric motors

Prior to mounting an electric motor, by means of the rating plate it will have to be checked, whether the motor is suited for the connection and whether it is not damaged.

In particular it will have to be confirmed, whether the values indicated on the rating plate are in accordance with the necessary values.

Rating plates are predominantly placed on the stator's enclosure. Only in exceptional cases the rating plate will be on the motor's end shield or terminal box resp.

Electric motors are to function for a long time. Therefore it will be important to observe the following principles during erection already:

- Electric motors are to be mounted shock-proof.
- Ventilation openings serving for cooling the motor must be left uncovered.
- No axial pressures must effect the motor's shaft.
- The machine to be driven must be balanced.

When aligning machine sets equipped with couplings the two shaft ends must be positioned axially against each other, i.e. there must not be any deviations in horizontal or vertical direction.

Deviations in direction during mounting of motors must never be compensated by the couplings!

For aligning the motor and the machine, a gauge according to fig. 7.1. has proved to be useful. A water level will not be suited for aligning the coupling.

After both machines have been roughly aligned without special facilities, the gauge according to fig. 7.1. will be put on both shaft ends. The distance between the centres of the gauge is to be small at that. If both shaft ends are turned synchronously to each other the position of the centres relative to each other must not change during a full revolution.

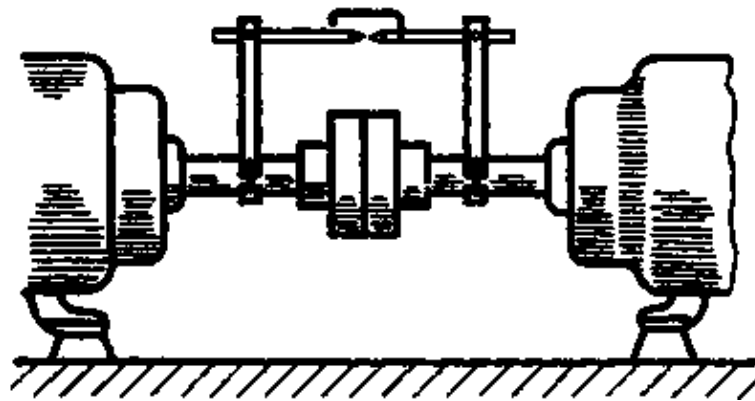


Fig. 7.1. Aligning directly coupled machines by a gauge

The axial play of machines with slide bearings may cause the distance of the gauge's two centres from each other to change permanently. This will be prevented by putting a steel centre into the centre of the shaft of the non-driven shaft end and fixing it to the end shield via a tie,

At flexible couplings the distance required between the two halves, which must be equal in any position of the shaft, is measured by means of spacing gauge.

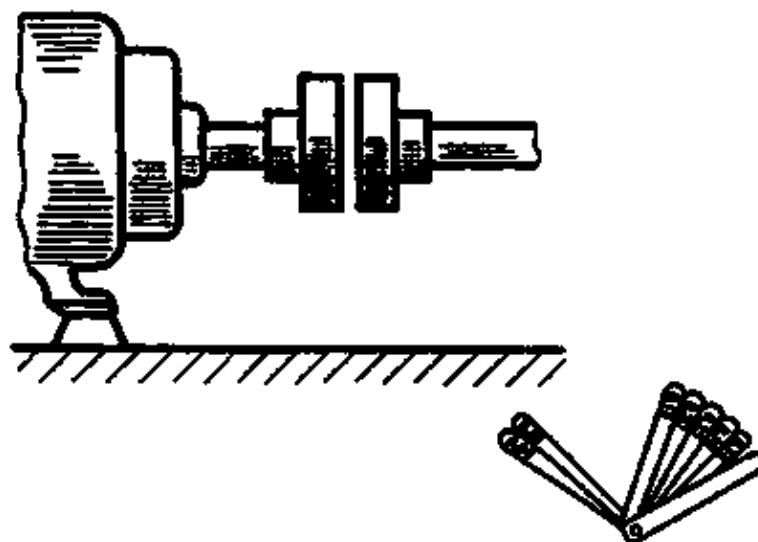


Fig. 7.2. Applying a spacing gauge

In case of rigid couplings the coupling halves must be positioned tightly adjacent to each other.

Only after both machines have been aligned they will be fixed, and the coupling will be bolted.

Prior to aligning motors equipped with transmission devices like couplings, pinions or belt pulleys, the transmission device, e.g. belt pulley, will be mounted onto the shaft end.

For mounting transmission devices, mounting tools are to be employed resp. the part to be mounted is to be heated. For mounting, the shaft ends of the motors have got centrings with threaded bores.

Driving on transmission devices by hammer blows is not permitted, since the shaft, the bearings and other parts of the motor may be damaged!

For pulling off transmission devices a puller is being employed.

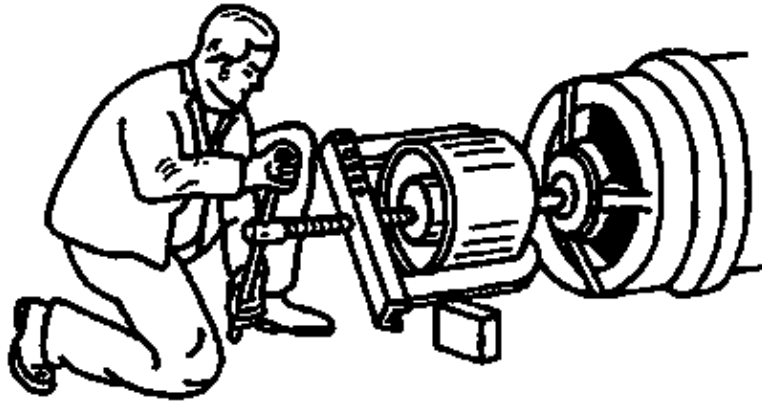


Fig. 7.3. Pulling off a belt pulley

After the transmission device has been mounted onto the shaft, the motor is to be bolted to the holding bars resting in loose condition on their foundation. By water level the motor will now be aligned in longitudinal and transverse direction.

Differences in height are being compensated by placing iron wedges underneath. Wooden wedges are not to be employed since they are easily pressed together resp. are swelling up when the foundation is poured!

Thereafter the motor belt pulley is being aligned with the belt pulley to be driven.

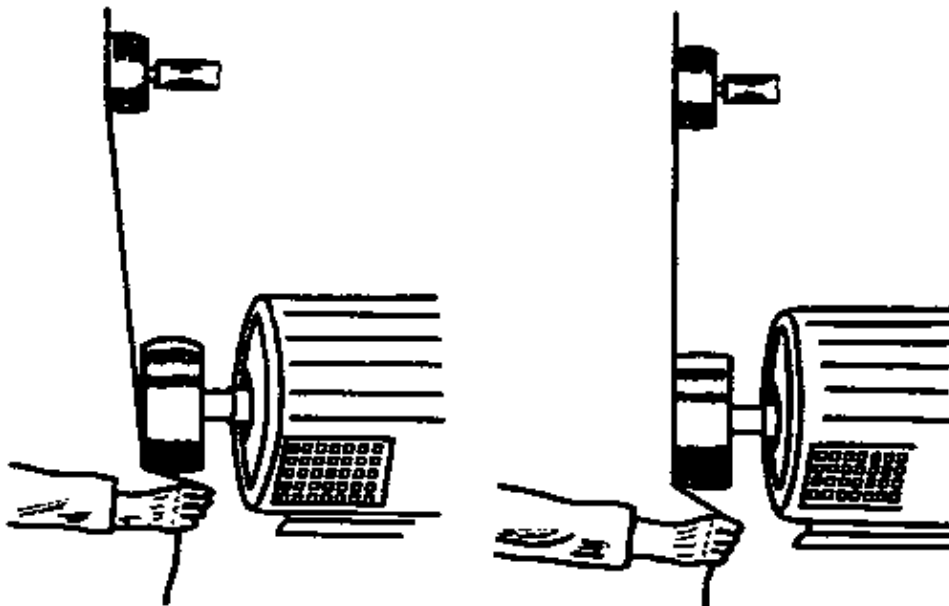


Fig. 7.4. Aligning a belt pulley

The front faces of the belt pulley and the counter pulley must be exactly parallel!

After alignment of the belt pulley the position of the motor will be rechecked in both directions. Only after the motor has been exactly positioned, the foundation may be poured.

7.2. Connection of three-phase motors

Most of the practically used motors are three-phase squirrel-cage motors.

The wiring of the motors takes place under consideration of the designed connections, like

- star connection,
- delta connection,
- star-delta connection to the terminals of the motor terminal board.

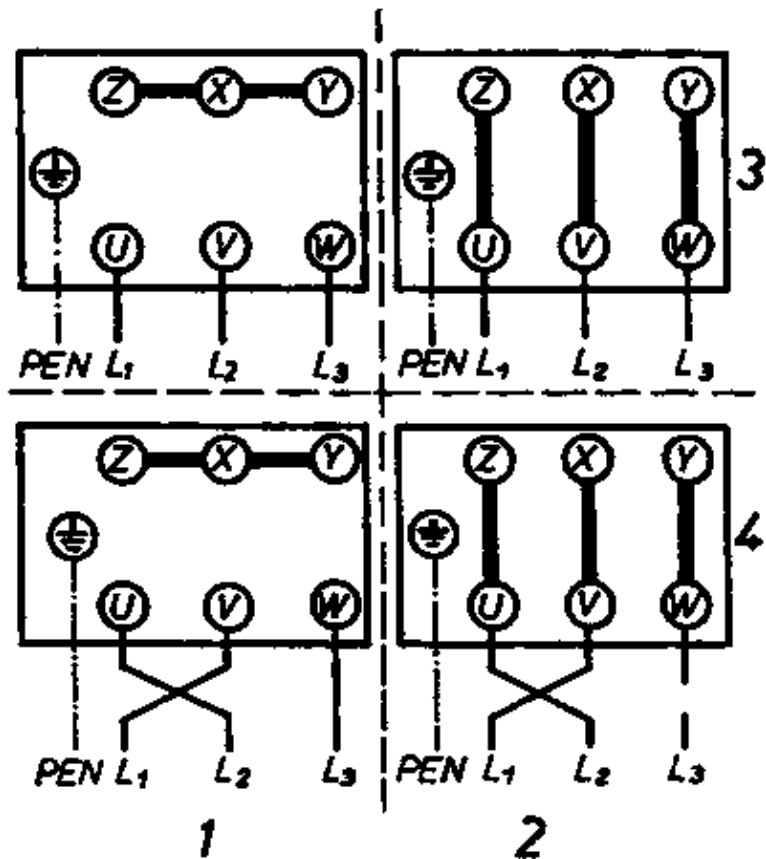


Fig. 7.5. Position of bridges in a three-phase squirrel-cage motor

1 star connection, 2 delta connection, 3 clockwise rotation, 4 anti-clockwise rotation

In case of star connection the bridges are placed via the winding ends z, x, y at the terminal board.

In case of delta connection the bridges are placed via the beginnings and ends of the windings u-z, v-x, w-y at the terminal board.

A reversion of rotation will be achieved by changing of two phase conductors!

If motors are connected via flexible connecting lines the conductors will have to be prepared for connection accordingly. The conductor ends are provided with tinned lugs or cable terminals will be applied in case of larger conductor cross sections.

How to make terminal lugs at flexible conductors may be seen from fig. 7.6.

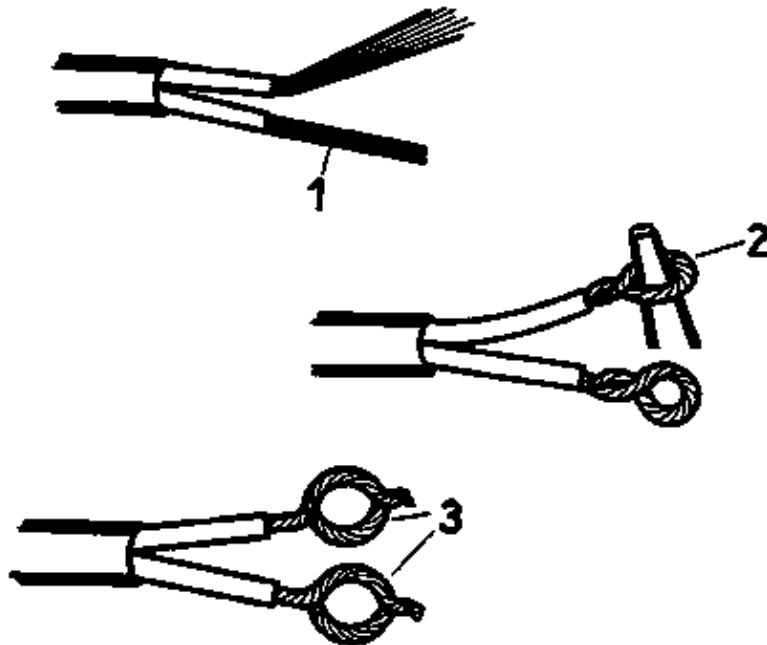


Fig. 7.6. Fitting terminal lugs to flexible conductors

- 1 twisting of the cleaned and prepared conductor end,
- 2 making the lug by means of an arbor,
- 3 making the lug by separating the conductor

If terminal lugs are being bent at solid conductors the following quality requirements will have to be observed:

- The conductor must not be damaged during treatment by round nose pliers.
- The terminal lug must be closed.

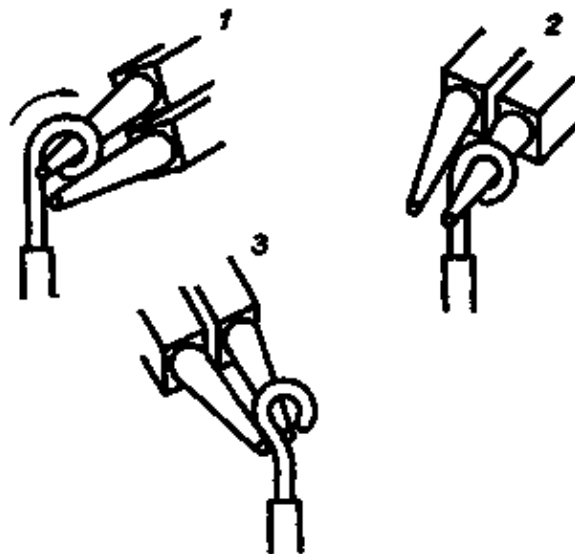


Fig. 7.7. Bending of terminal lugs

- 1 pre-bending the lug,
- 2 repositioning of round nose pliers,
- 3 completing the lug

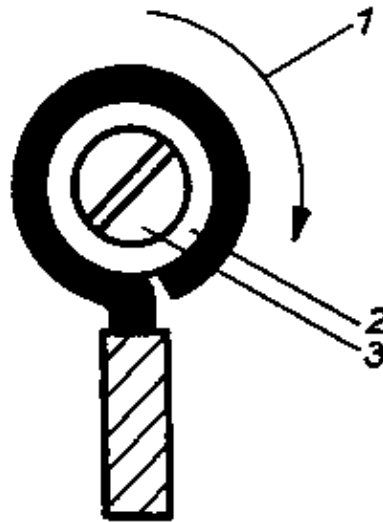


Fig. 7.8. Terminal lug

1 rotational direction, 2 washer, 3 screw

– The terminal lug must be placed on the connecting stud so that the end of the lug is positioned in tightening direction.

Terminal lugs will be bent on conductors up to a cross section of 16 mm². In case of bigger cross sections cable terminals will be fitted!

The functioning of the protective measure employed will be dependent on proper connection of the protective conductor to the marked connection point of the protective conductor.

Table 7.1. Diameter of terminal lugs for metric threading

Size of thread	M4	M5	M6	M8	M10	M12
Diameter of terminal lug mm	4,2	5,2	6,3	8,3	10,5	12,5

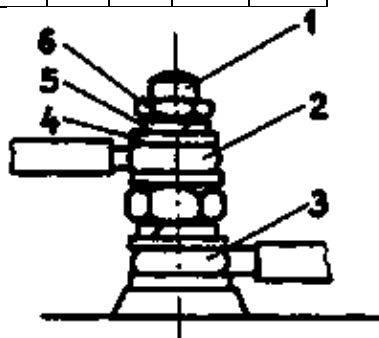


Fig. 7.9. Arrangement of terminal accessories at the stud of the motor

1 stud, 2 terminal lug, 3 end of winding, 4 washer, 5 spring washer, 6 nut

The firm fit of the cable clamping arrangement (pull relief) in front of the motor terminal box is important too. It will prevent the connecting cable from being torn of the connection stud in case of tensile stress.

Motors which vibrate during operation or the position of which will be frequently changed are to be connected via flexible cable.

This flexible cable is to be kept as short as possible. Therefore the fixed connection line will be terminated in a motor transition box, and a flexible cable will then be run from there to the motor.

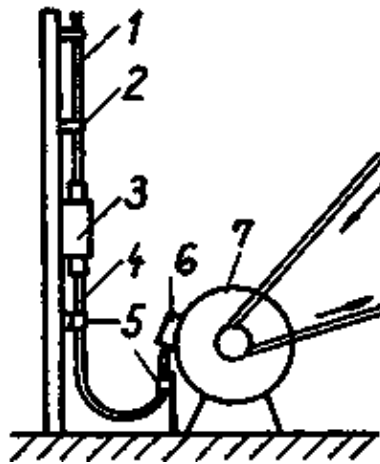


Fig. 7.10. Connecting a motor via a motor transition box

1 motor supply line, 2 damp room spacing clips, 3 motor transition box, 4 flexible connection cable, 5 pull relief clamps, 6 terminal box of motor, 7 motor

7.3. Installation of motor protection switches

Three-phase motors with a power of up to approx. 2.2 kW are generally starting directly.

However, protective arrangements are needed protecting the motor against overload and short-circuits.

This is accomplished by motor protection switches installed in the supply line to the motor. These have got thermal overcurrent releases against overload and a tripping magnet for possibly occurring short-circuits. Series fuses provide protection against short-circuits on motors being not equipped with magnetic instantaneous tripping. So called "sluggish" fuses serve that purpose being able to conduct the expected motor starting current without responding.

Motor protection switches are jack switches and are manufactured in three-pole version. They have got trip-free release, i.e. after release they cannot be kept in turn-on position by retaining the switch knob or button. This is achieved by mechanical uncoupling in the motor protection switch.

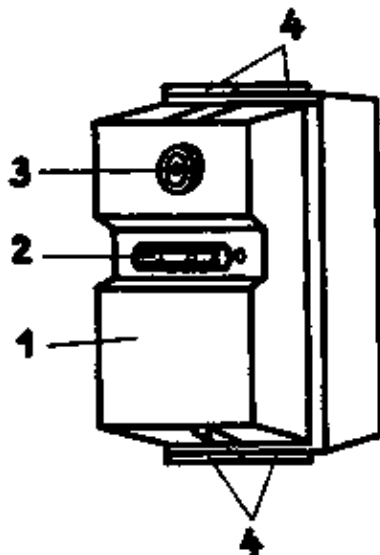


Fig. 7.11. View of a motor protection switch

1 casing, 2 switching device, 3 signal lamp, 4 cable entries

On the switch insert there are the dials for setting the overcurrent and short-circuit releases.

The overcurrent release will be adjusted to the rated motor current.
 The tripping magnet for short-circuit protection will be set according to the data of the project plans.
 The rated motor current may be read on the motor's rating plate!



Fig. 7.12. Setting the thermal overcurrent release at the motor protection switch

The motor protection switch is exactly to be matched to the motor current!

Table 7.2. Coordination of current fuses with setting ranges of overcurrent releases

Setting range of overcurrent release	series fuse	
	instantaneous	time-delayed
(A)	(A)	
0,16 – 0,25	–	–
0,25 – 0,4	2	–
0,4 – 0,6	2	–
0,6 – 1,0	4	–
1,0 – 1,6	6	4
1,6 – 2,5	10	6
2,5 – 4	16	10
4 – 6	20	16
6 – 8	–	16
8 – 10	–	16

7.4. Star-delta start of three-phase motors

When switching on a motor a current will flow through the stator's winding being many times stronger than the rated motor current. This current is called starting current. It will highly stress the electrical network. On increasing rotational speed the starting current will decrease until the rated current is reached at the rated rotational speed.

By star-delta starting a reduction of the starting current will be achieved. This starting connection is the most frequently applied starting method for asynchronous squirrel-cage motors of greater power.

The star-delta starting operation is practically executed via

- automatic star-delta switches,
- star-delta contactor combinations.

The stardelta hand switch (cam switch) is hardly to be met any more in actual operation. Functioning of the star-delta starting necessitates that the motor is suitable for this method of starting, i.e. with a three-phase four-wire system of 380/220 V every winding of the motor must be designed for 380 V.

Table 7.3. Connection of three-phase squirrel cage motors to mains

Voltage stated on rating plate	voltage of feeding mains	motor connection
380/220 V	3 × 220 V 380/220 V	delta connection star connection
380 V (660/380 V)	380/220 V	delta connection star–delta starting
660 V	660 V	delta connection star–delta starting

A star–delta contactor combination consists of the following electrotechnical units:

- 3 contactors (network, star and delta contactors),
- 1 time relay (pull-in delayed),
- 1 three–pole thermal overcurrent release,
- 3 fuse elements or automatic cut–outs for the main circuit,
- 1 fuse element or automatic cut–out for the control circuit,
- 4 signal lamps, e.g. 24 V
- 1 motor 380 V

The mode of function of a star–delta starting circuit is shown as an all–pole representation (circuit diagram) in fig. 7.13. and 7.14. as well as a general wiring diagram in fig. 7.15.

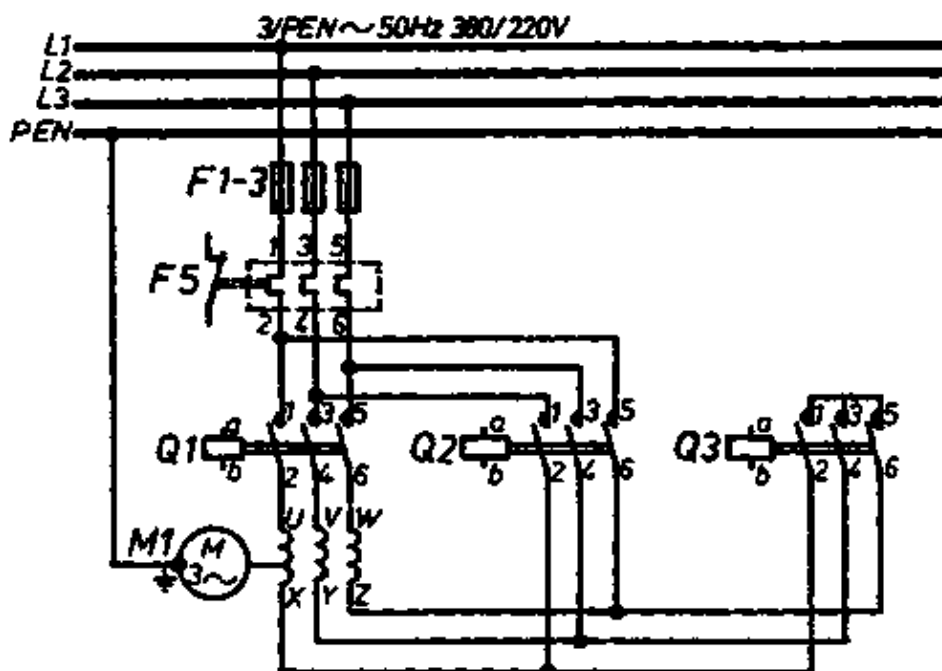


Fig. 7.13. Star–delta connection, all–pole representation of power part (circuit diagram)

F1 ... F3 fuses, F5 thermal overcurrent release, Q1 network contactor, Q2 delta contactor, Q3 star contactor. M1 three–phase motor

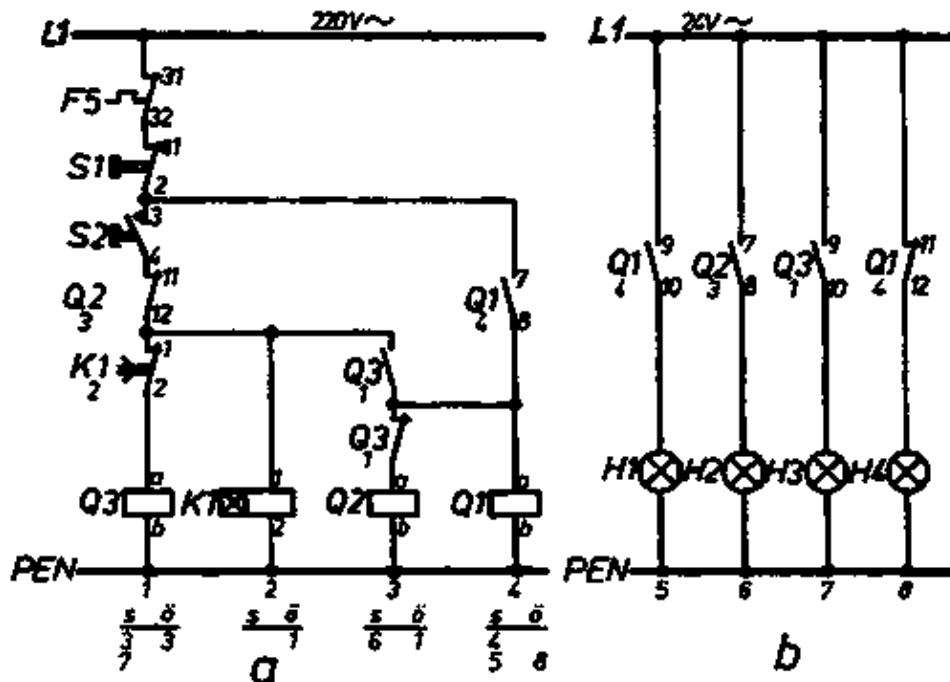




Fig. 7.14. Circuit diagram of an automatic star-delta contactor circuit with indication

a control, b indication (e.g. 24 V~)

S1 OFF key, S2 ON Key, Q1 network contactor in current path 4, Q₁1 normally open contact of Q1; Q2 delta contactor in current path 3, Q₂2 normally open and closed contacts of Q2, Q₃3 star contactor in current path 1, Q₁3 normally open and closed contacts of Q3, K1 pull-in-delayed time relay in current path 2, K₂1 normally closed contact of K1, F5 thermal overcurrent protection, H1 ... H4 signal lamps, 1 ... 8 numbering of current paths,  normally closed contacts,  normally open contacts (to be shown for each contactor in the current paths concerned)

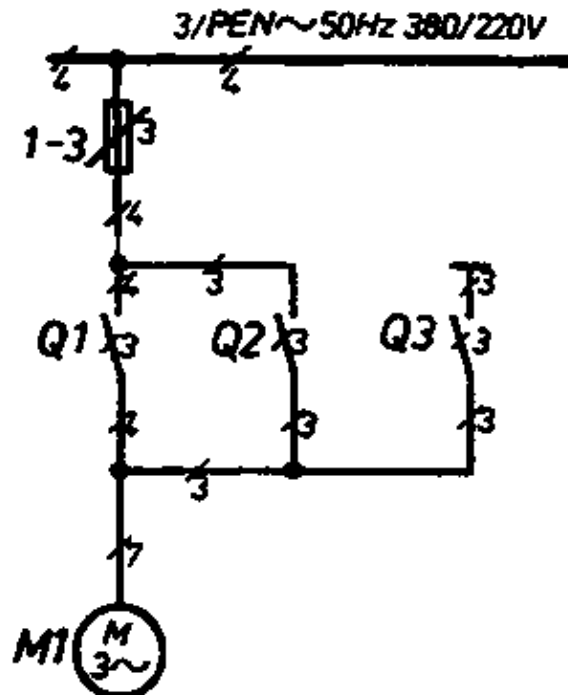


Fig. 7.15. Star-delta connection (general wiring diagram of power part)

Switching sequence for fig. 7.14.

Key S2 is actuated!

Time stage 1

The circuit for Q3 is closed via F5, S1, S2, Q₃, 2, K₂1 and star contactor Q3 in current path 1 responds, closes the normally open contact Q₁3 and opens the normally closed contact Q₁3.

Thereby the circuit to the delta contactor Q2 in current path 3 is interrupted.

Simultaneously the time relay K1 in current path 2 starts operating. Further by the normally open contact Q₁3 in current path 3 the network contactor Q1 in current path 4 is pulled up. In current path 4 the normally open contact Q₄1 is closed and via F5, S1 of the line connection and the normally open contact Q₄1 the network contactor Q1 in current path 4 and the star contactor Q3 in current path 1 are pulled up, and the motor starts in star connection. By switching on star contactor Q3 in current path 1 and the network contactor Q1 in current path 4 the normally open contact Q₄1 in current path 5 and the normally open contact Q₁3 in current path 7 will be closed.

Signal lamp H1 will indicate the network contactor and signal lamp H3 the star contactor to be switched on.

At the same time signal lamp H4 will go out which indicates the star–delta circuit not to be operating.

Time stage 2

When the time set at time relay K1 in current path 2 has elapsed, in current path 1 the normally closed contact K₂1 will open and the circuit to the star contactor Q3 will be interrupted.

The normally closed contact Q₁3 in current path 3 will be re–closed and current is flowing via holding contact Q₄1 of the network contactor in current path 4 and the conductor connection to current path 3 as well as normally closed contact Q₁3, so that the delta contactor Q2 in current path 3 pulls up.

The motor runs in delta connection. Simultaneously the normally closed contact Q₃2 in current path 1 will be opened and star contactor Q3 in current path 1 cannot be switched on via S2.

At the same time of opening of contacts Q₃2 and K₂1 in current path 1 and drop out of star contactor Q3 the normally open contact Q₁3 will be reopened and signal lamp H3 will go out.

By switching on delta contactor Q2 in current path 3, however, the normally open contact Q₃2 in current path 6 will be closed and signal lamp H2 (for the delta connection) will light.

The wiring to the star–delta connection is made according to available drawings resp. the instructions of the maker. In case of star–delta starting of the motor the bridges on the motor terminal board will have to be removed. The motor supply line from network contactor Q1 is to be connected to the beginnings of windings U, V, W. The lines for the star–delta changeover from contactors Q2 and Q3 are to be connected to the ends of winding X, Y, Z. The protective conductor is to be clamped to the point provided and marked for this purpose. The coordination of the motor's accessories is to be taken from table 7.4.

After the motor is wired, it will have to be checked whether it runs in correct rotational direction. If the motor runs opposite to the desired direction of rotation, two phase–conductors will have to be exchanged in the motor supply line. In case the direction of the rotating field cannot be ascertained by test run of the motor, this can be found out also by connecting a phase–sequence indicator to the motor supply line. For switching capacities of more than 10 kW application of an auxiliary contactor for extinguishing the arc of the star contactor will be appropriate. Further examples of switching arrangements of motors are to be taken from the textbook "Circuits. Formulas and Tables of Electrical Engineering", section 4.

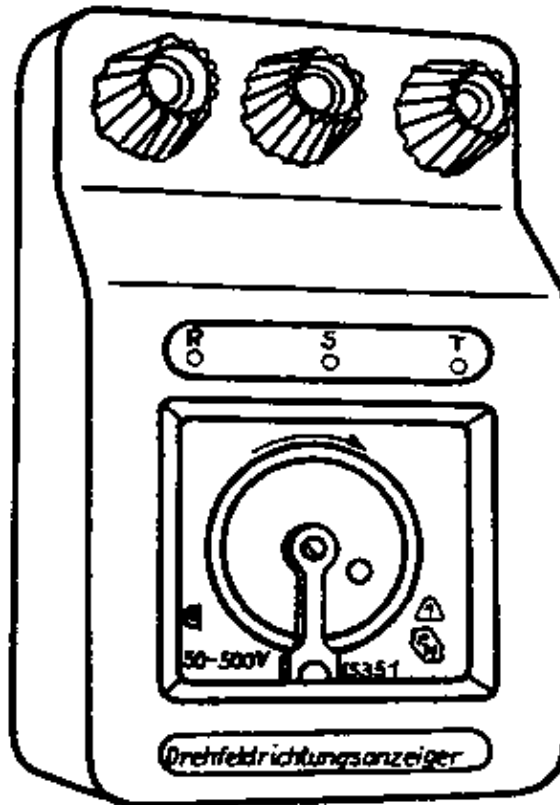


Fig. 7.16. Phase-sequence indicator

Table 7.4. Choice of accessories for three-phase motors with 380 V rated voltage

Motor P_n	I_n	fuse	contactor	temperature relay/type setting range	motor protection switch	flexible connection to motor
(kW)	(A)	(A)	(A)	(A)	(A)	(A)
0,16	0,42–0,68	2	16	0,4...0,68	0,4–0,6	4×1,5
0,25	0,7–1,0	4	16	0,65...1,1	0,6–1,0	4×1,5
0,4	1,0–1,6	4	16	1,0...1,7	1,0–1,6	4×1,5
0,6	1,5–2,0	6	16	1,0...1,7	1,6–2,5	4×1,5
				1,6...2,8		
0,8	1,9–2,4	6	16	1,6...2,8	1,6–2,5	4×1,5
1,1	2,4–3,0	6	16	1,6...2,8	1,6–2,5	4×1,5
				2,6...4,5	2,5–4	
1,5	3,4–4,2	10	16	2,6...4,5	2,5–4	4×1,5
					4–6	
2,2	4,7–5,6	10	16	4,3...7,5	4–6	4×1,5
3,0	6,5–7,5	16	16	4,3...7,5	6–8	4×1,5
4,0	8,4–9,6	20	16	7,2...12,5	8–10	4×1,5
5,5	11,2–12,6	25	16	7,2...12,5	10–16	4×1,5
7,5	15–17	35	25	10–16/16–25	10–16	4×1,5
					16–25	

10	19,8–21,4	50	25	16...25	16–25	4×2,5
13	25,6–27	50	40	25...40	–	4×4
17	33–35	63	40	25...40	–	4×6
22	43–45	80	63	40...60	–	4×6
30	58–61	100	63	40...64	–	4×10
40	78–82	125	100	64...100	–	4×16
55	116–114	160	200	100...140	–	4×25
75	145–155	200	200	140...200	–	4×50
100	193–207	260	250	160...280	–	4×70
125	240–255	300	250	160...280	–	4×95
160	304–328	350	400	280...400	–	4×150
200	370–400	430	400	250...420	–	4×185
250	460–500	500	630	420...600	–	–
320	590–610	600	630	–	–	–

7.5. Summary

Prior to mounting electric motors it has to be checked, whether the motor will be suited for the connection in question and that the motor is not damaged.

The motor and the machine to be driven are to be exactly aligned.

This holds also for transmission devices. Motors for connection to three-phase current up to a power of 2.2 kW are directly started. For starting the motor a multi-section rotary switch is employed to which a motor protection switch is series connected.

The overcurrent release of the motor protection switch is to be set to the rated current of the motor.

Three-phase asynchronous motors with squirrel-cage of bigger power are switched on via a starting circuit. The mostly used starting arrangement is the star-delta connection.

In case of star connection of three-phase motors, bridges are being laid over the ends of the winding.

In case of delta connection bridges are connecting the opposite beginnings and ends of the winding.

If star-delta starting is to be employed, the bridges will have to be removed.

8. Testing of installed plants

After completion of the electrical plant the supplier of the electrical plant will have to test the installed plant prior to handing over to the customer.

By the tests to be performed on the one hand the expert construction of the plant regarding function and on the other hand its safety will have to be established.

The results are to be laid down in a test certificate if so required by the user of the electrical plant. For each system the following tests are to be undertaken:

- visual inspection,
- ascertaining the insulation resistance,
- functional test

During determining the insulation values and when carrying out the functional test special care will have to be taken. These tests are being performed with a test voltage or the mains voltage applied. There is an increased risk of accident.

8.1. Visual inspection

On visual inspection the overall electrical plant will be checked. This is done in dead condition of the plant. By means of suitable tools like screw drivers and wrenches as well as by manual testing it will have to be ascertained that

- all distributions, switches, plug arrangements and the other equipment including lines and line fittings are properly fixed;
- all clampings are tightened;
- the pull reliefs at portable electrical equipment are firmly fitted.

By means of drawings and other design documents it is to be checked whether

- the minimum cross sections prescribed have been observed in the installation, e.g. for conductors and potential equalization lines;
- cables, wires and conductors have been properly marked and, where required, special designations have been provided;
- installation materials have been used expertly, the minimum distances and dimensions have been observed;
- connections have been made in the rotational direction of the terminal screws and multicore conductors have been specially prepared;
- automatic cut-outs, releases and fuses have been correctly dimensioned resp. properly set;
- voltage-carrying parts have been properly covered;
- the correct installation materials have been used resp. have been installed at the place provided for in the design.

8.2. Testing the insulation resistance

A sufficiently strong insulation of the electrical plant is required for its operation.

Short-circuits, line-to-earth faults and faults of frame caused by damages may exist in the electrical installation. They are to be traced by testing the insulation resistance.

For that purpose it will be required to remove all fuses and to disconnect all consumer's installations by unscrewing, disconnecting or pulling out. Switches are, however, to be closed.

By applying a test voltage and sampling the conductors against each other as well as against mass or earth the insulation condition of the installation will be established. For generating the test voltage 3 hand generator or another insulation measuring instrument is being employed.

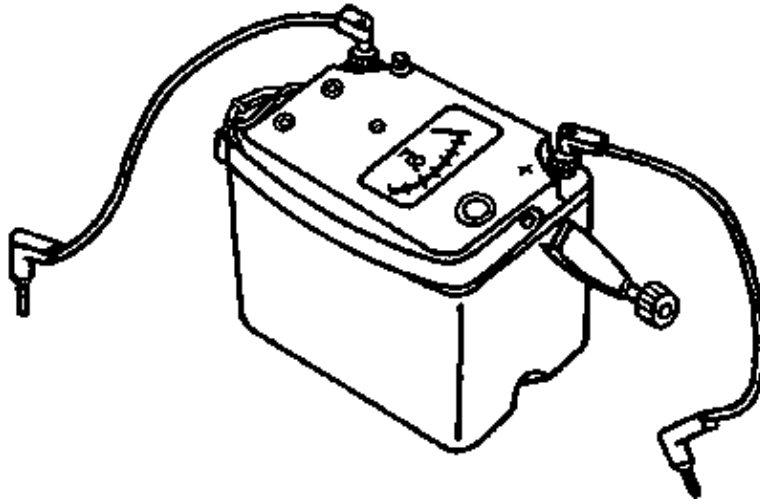


Fig. 8.1. Hand generator with connected test lines

On a three-phase four-wire network the following tests will have to be performed:

- between conductors L1 and L2
- between conductors L1 and L3
- between conductors L2 and L3
- between conductor L1 and PEN
- between conductor L2 and PEN
- between conductor L3 and PEN.

If the rated voltage of the electrical plant is up to 60 V the test voltage of the insulation measuring device will have to be 500 V.

If the rated voltage of the electrical plant is more than 60 V the test voltage of the insulation measuring device will have to be 1000 V.

Cable and wire installations are to be short-circuited after applying the test voltage!

An insulation value of 10 k Ohm/V in newly installed plants is considered to be sufficient. This minimum value must not fall below.

8.3. Functional testing

Part of functional testing is the current flow test being carried out in dead condition. Current flow testers rendering an optical or acoustic signal on the current flow are almost exclusively operated by torch batteries of 1.5 resp. 4.5 V!

Handling of current flow testers is very simple. By means of two test prods the test voltage will be applied to the conductor of the cable to be tested.

If there is no interruption in the conductor the current flow tester will give an optical or acoustic signal.

If there is no signal, there is an interruption in the conductor or in the plant.

By systematic encircling and searching the fault will have to be found and remedied.

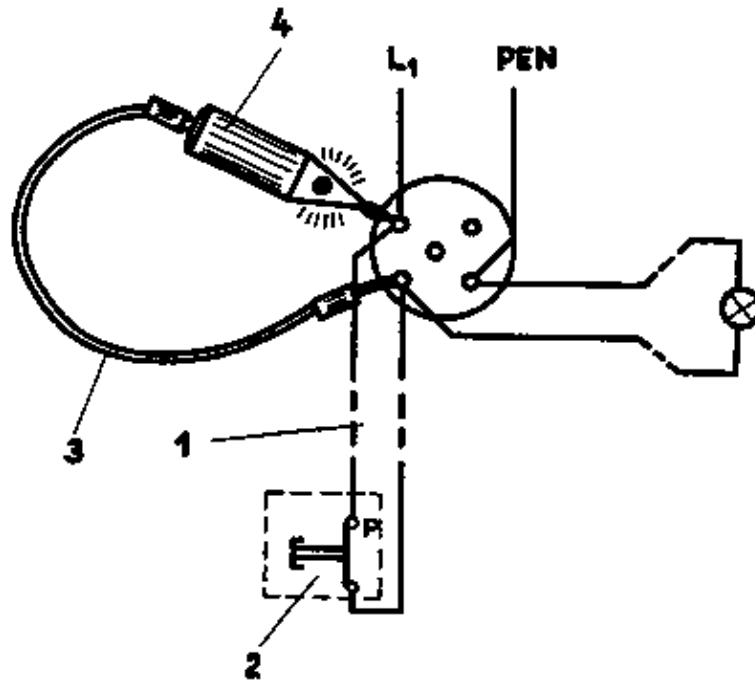


Fig. 8.2. Current flow tester

1 cable (switch line), 2 conductor bridging (switch), 3 test line, 4 current flow tester

After applying the mains voltage the voltage condition of the plant will be established.

For that purpose two-pole voltage testers are employed. During testing the glow lamp will light, warning of the applied voltage. Similarly as in case of the insulation value check, testing by the voltage tester is done subsequently between the phase conductors and then between phase conductors and protective conductor resp. earth. It will be very important to ascertain functioning of the protective measure against too high a contact voltage.

Function of neutralization, protective earthing and current-operated earth-leakage protection is being established by a loop measurement (of the protective conductor's resistance). Also in this case testing is performed in live condition. This measurement is carried out between each phase conductor and the protective conductor. Connecting and disconnecting the measuring lines should, however, take place in dead condition.

Table 8.1. Testing and measuring devices

Current flow tester (bell, buzzer, glow lamp 4,5 V, telephone)	plant to be dead	current flow test
Hand generator	plant to be dead	insulation test
Voltage tester two-pole (load testing button or voltage meter)	plant to be live	functional test ascertaining voltage condition
Phase-sequence indicator	plant to be live	functional test ascertaining sequence of phase conductors
Test plug Loop measuring device	plant to be live	functional test, testing function of protective measure

8.4. Summary

Prior to commissioning the newly erected or expanded electrical plant, three basic testing procedures are to be undertaken:

– Visual inspection

By visual inspection faults are to be found. Test or measuring devices will not be employed.

– Insulation test

Subsequent to visual inspection, insulation testing will be performed. By establishing the insulation capacity proper operation of the electrical plant is to be warranted. Testing devices will be employed.

– Functional test

Functional testing means ascertaining the current flow and the voltage condition. Testing and measuring devices will be employed.