

**Handling and Connection of Cables and Lines for Fixed Laying –
Course: Basic Skills and Knowledge of Electrical Engineering.
Methodical Guide for Instructors**

Table of Contents

<u>Handling and Connection of Cables and Lines for Fixed Laying – Course: Basic Skills and Knowledge of Electrical Engineering. Methodical Guide for Instructors</u>	1
<u>1. Aims and Contents of Practical Vocational Training in “Handling and Connection of Cables and Lines for Fixed Laying”</u>	1
<u>2. Organizational Preparation</u>	1
<u>2.1. Preparation of Labour Safety Instructions</u>	2
<u>2.2. Preparation of Teaching Aids</u>	2
<u>2.3. Preparation of Working Tools and Materials</u>	3
<u>2.4. Time Planning</u>	3
<u>3. Recommendation for the Implementation of the Practical Vocational Training in the Working Techniques of “Handling and Connection of Cables and Lines for Fixed Laying”</u>	3
<u>3.1. The Introductory Instructions, Demonstrations and Exercises</u>	3
<u>3.2. Recommendations for Working with the Instruction Examples for Practical Vocational Training</u>	7
<u>3.3. Examples for Recapitulation and Tests</u>	8

Handling and Connection of Cables and Lines for Fixed Laying – Course: Basic Skills and Knowledge of Electrical Engineering. Methodical Guide for Instructors

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1. Aims and Contents of Practical Vocational Training in “Handling and Connection of Cables and Lines for Fixed Laying”

After having finished their training based on this lesson, the trainees shall have achieved the following aims:

- They have the necessary knowledge and skills for handling and connection of cables and lines for fixed laying.
- They can carry out the operations involved in handling and connection of cables and lines for fixed laying.
- They are able to check the work done.
- They meet the safety requirements.

In order to achieve the above aims, the following knowledge and skills must be taught by the instructor:

Knowledge

- Selection of the right working technique in accordance with the relevant connection and material to be used.
- Criteria for clamped joints in electrical installations.

Skills

- Correct handling of the lines.
- Proper connection of the conductors.
- Checking the work done.

2. Organizational Preparation

In order to ensure that the instructions, demonstrations and exercises go off smoothly, the training must be well prepared. This includes:

2.1. Preparation of Labour Safety Instructions

Prior to the exercises the trainees must be instructed in brief on how to properly handle the working tools and prevent accident.

It is recommended to prepare a book in evidence of the labour safety instructions given to note down in brief outlines all instructions given for preventing accidents and for handling the working tools properly. The trainees should then confirm by their signature that they have been instructed accordingly.

The instructions should include the following:

- For any work in and on electrical installations the installation must be in dead condition.
- The dead condition is to be checked by means of testers.
- The installation is to be secured against re-connection by other persons.
- Proper tools are to be used only. (Defective tools are to be replaced or repaired!)
- When removing insulations with the cable stripper (knife), the knife blades must be sharp. (Sharp blades minimize the risk that the knife might slip off and cause injuries!)
- Cutting with the knife must **always** be directed away from the body.
- Any flash produced with pressed joints is to be removed.
- Soldering iron used for soldered joints
 - must not be unattended in operating condition,
 - are to be deposited only on the stands or supports intended for this purpose,
 - are to be disconnected immediately on completion of the work.

Other labour safety instructions can be given for special local conditions.

2.2. Preparation of Teaching Aids

The theoretical instructions should be given at a place where the trainees are able to make notes, preferably in a room with blackboard, desks and mains supply.

When the instructions are given in the workshop or at the workplace, the tables should be provided with clean supports for the papers etc. to be deposited.

For the demonstrations during the instructions one workplace should be equipped as follows:

- Material and equipment for exercises (cables, lines and electrical equipment).
- Folding rule or steel rule.
- Combination plier, side cutting plier, round nose plier.
- Screwdrivers, hexagon-head wrenches.
- Cable stripper (knife).
- Insulation stripping plier.
- Sheath stripper.
- Pressing tool with accessories.
- Cable eyes.
- Pressing plier.
- Press-sleeves and insulation sleeves.
- Wire wrapping tool.
- Soldering iron and soldering accessories.

- Anti–corrosion grease.

Sufficient copies of the “Trainees’ Handbook of Lessons – Handling and Connection of Cables and Lines for Fixed Laying” are to be made available to provide one copy to each trainee.

Tables etc. are to be written on the blackboard prior to the instructions.

2.3. Preparation of Working Tools and Materials

- Sufficient copies of the “Instruction Examples for Practical Vocational Training – Handling and Connection of Cables and Lines for Fixed Laying” are to be distributed to provide one copy to each trainee as theoretical basis for the exercises to be done.
- The material necessary for the exercises as specified in the “Instruction Examples...” are to be prepared and kept ready in sufficient quantity.
- Each trainee must have a place for carrying out the exercises.

2.4. Time Planning

Based on the total hours available, the times for the individual training sections of this lesson should be planned individually. Time planning is recommended for the following sections:

- Introduction into the relevant working technique in the form of instructions.
- Necessary demonstrations.
- Job–related instructions to prepare the exercises.
- Exercises/practising.
- Recapitulations and tests.

In such time planning the following factors should also be taken into consideration:

- Level of training reached by the trainees,
- training conditions,
- future assignment of the trainees,
- level of difficulty of the relevant training section.

The emphasis in each training section should be on the acquisition of practical skills and abilities by practising. Any waiting times occurring for the trainees in spite of good planning should be bridged by suitable preparatory work, such as preparation of materials to be used for exercises.

3. Recommendation for the Implementation of the Practical Vocational Training in the Working Techniques of “Handling and Connection of Cables and Lines for Fixed Laying”

The following sections contain recommendations on how to organize and implement the instructions, demonstrations, exercises and tests.

3.1. The Introductory Instructions, Demonstrations and Exercises

The introductory instructions for each working technique can be given in a class–room. During the instructions the trainees should be advised to note down necessary additions or answers into the “Trainees’ Handbook of Lessons”.

The arrangement of the contents of the “Trainees’ Handbook of Lessons” is adapted to the introductory instructions and the main points therein contained should be taught. The knowledge of the working techniques of making permanent joints and fastening joints should be repeated and referred to since a good command of those working techniques is a precondition for acquiring the working techniques of “handling and connection of cables and lines for fixed laying”.

The subject of “Connection of Cables and Lines for Fixed Laying to Electrical Equipment”, in particular the criteria for clamped joints in electrical installations, should be taught intensively using all teaching aids available.

Fundamentals for handling and connection of cables and lines for fixed laying

At the beginning the trainees should be informed on the aim to be achieved.

This can be done by showing the trainees finished products and pointing to the many applications of lines for fixed laying in industry, agriculture, public life and, last not least, in households.

Before the demonstrations and exercises the trainees must be made familiar with installation engineering terms not yet known. For this purpose the tables, lists etc. contained in the “Trainees’ Handbook of Lessons” may also be written on the blackboard or be used as transparency.

When explaining the new terms, some typical representatives of lines to be handled or connected should be shown and, if possible, also locations where they are installed.

The criteria for the selection and use of lines for fixed laying should also be dealt with in detail.

Usual working techniques to be applied prior to the connection of lines are to be repeated.

Handling of lines

It is to be made sure that all trainees can watch the demonstrations.

After the demonstrations the trainees should start with the exercises at their workplace.

Attention is to be paid to the fact that all trainees have to keep their workplace always in order and that

- tools are to be deposited in cleaned condition,
- tools are to be deposited so that they cannot be damaged,
- tools and materials are to be supported so that they do not protrude and cannot fall down,
- electrical tools are to be switched off after use with the mains plug to be disconnected.

Before the exercises the necessary material is to be handed out to the trainees.

The demonstration parts should be available to the trainees for comparison.

Any mistakes made in the exercises should be corrected immediately and be evaluated together with the trainees. The instructor should point out again and again that wrong operation of tools may cause waste material or re-working.

Stripping of the insulation

First the instructor should explain how to proceed with stripping of the insulation and what tools are to be used for stripping. The stripping length of the insulation sheath and conductor insulation is to be specified.

- Stripping of the insulation sheath by means of the cable stripper (knife) and by means of the sheath stripper

Here it is important that the cable stripper is applied at the correct angle and moved away from the body. (To avoid damage to the conductor insulation and to prevent accidents!)

- Removal of the filler
- Removal of the conductor insulation

When stripping the conductor insulation, special attention is to be paid to guiding the knife correctly since otherwise faults may be produced which cannot be repaired, such as:

- notching of the conductor
- cutting of the conductor sheathing (conductor insulation)
- injury of the trainee (stabs or cuts).

Vertical guidance of the knife on the conductor is a typical example of wrong guidance!

The use of insulation stripping pliers should also be dealt with since they remove the conductor insulation more quickly and more cleanly.

Insulation stripping pliers normally have several ground-in cutting edges, arranged side by side, and are suitable for cross sections of conductors from 0.75 to 6 mm².

Only use the cutting edge intended and marked for the relevant cross section of the conductor to ensure clean removal of the conductor insulation and to avoid damage to the conductor! To avoid damage to the conductor, the pliers should cut into the conductor insulation no more than 2/3 up to 3/4! The rest is to be torn off.

Conductors with cross sections exceeding 6 mm² are to be stripped by means of the cable stripper!

During the exercises the instructor should repeat again and again

- that the insulation layers are to be separated and removed cleanly and completely from the conductor beneath,
- that the conductor must never be cut.

The trainees must be strongly warned of the risk connected with a cut conductor.

- Reduction of the cross-sectional area at the joint may result in
 - lower capacity,
 - excessive heating,
 - possible destruction of the connection and of the connected equipment.
- Risk of breakage of the stripped conductor (particularly of Al conductors)

This may have the following effects:

- Breakdown of the connected equipment.
- Loss of the protective function of the faulty conductor (short circuit, electrical accident by existing shock-hazard voltage).
- Bending of wire lugs
- Pressing-on of cable eyelets

Since these working techniques are already known to the trainees, it is recommended to repeat the knowledge already acquired based on the “Trainees’ Handbook of Lessons” for the lessons of “Making Fastening Joints” and “Making Permanent Joints”.

Connection of cables and lines for fixed laying to electrical equipment

At the beginning it should be made clear to the trainees that the rules elaborated hereinafter apply to all electrical appliances, devices, machines and other equipment and must be strictly observed. But it should also be pointed out that special installations, such as emergency lighting and explosion-proof installations are subject to special rules which are additionally to be observed. The relevant technological regulations are to be made known to the trainees. The demonstrations and subsequent exercises should start with “simple electrical connections”, such as switches, branch boxes etc.

It is not before the trainees have a good command of these working techniques that more intricate clamped joints can be dealt with, such as terminal boxes, distribution installations, machine and contactor connections.

Colour codes of cores are to be specifically discussed.

Making screw joints

The making of screw joints should be demonstrated to the trainees as vividly as possible.

This can be done by showing practical examples, such as screw joints in sockets, on individual terminals or other electrical equipment.

But it is also possible to prepare and show suitable examples on the blackboard or on transparencies.

When explaining the connection of conductors, the following points should be emphasized:

- The conductor insulation must end 1 mm before the point of clamping.
- One conductor only is to be connected to terminals of installation switches, sockets and lamps.
- The conductor must be put under the clamping screw in the direction of rotation only.
- The conductor must be supported by the whole contact area of the point of connection or joint.
- Cu and Al conductors are to be clamped so that they are not in direct contact.
- Al conductors are to be greased with anti-corrosive grease.
- If several conductors are connected to one connection bolt, it is to be made sure that a washer is inserted between the conductors and a lock washer after every third conductor.
- For connections of protective conductors or middle conductors one conductor per point of connection is admissible only.

(Series connection of the protective conductor is admissible only as “uncut” conductor loop within one unit!)

- When a cable eye and a lug are jointly connected to a connection bolt, they are to be separated.
- When connecting conductors to cap screws without clamping saddle or distributor plate, no more than three conductors, which may differ by up to two cross-sectional steps, must be connected with washers to be inserted between the conductors.
- When connecting conductors to cap screws with clamping saddle, one conductor only must be connected per saddle side and the conductors may differ by one cross-sectional step.
- When connecting conductors to cap screws with distributor plate, one conductor only must be connected per distributor plate and the conductors must have the same cross section.
- Washers used for connection to screws or bolts must cover at least two thirds of the conductor.

Criteria for clamped joints in electrical installations

Clamped joints in electrical installations are subject to special rules which must be quoted and explained to the trainees.

This refers in particular to the following rules:

- The switch–lamp–wire is to be connected to the floor contact and the neutral conductor is to be connected to the ring contact.
- Disconnection through switches is allowed for phase conductors only.
- Connection marks on switches are to be observed.
- For connection of sockets the phase conductor is to be clamped at the left–hand side and the neutral conductor with protective function (PEN) or the neutral conductor and protective conductor at the right–hand side.
- The phase conductor sequence is to be observed when connecting power sockets.

The points of clamping are to be firmly tightened!

Points of clamping of Al conductors, in particular, should be re–tightened after a few days since they might get loose because of “flowing” of the material!

The trainees are also to be made familiar with the TRR rule (TOP, REAR, RIGHT–HAND).

The necessity of having a consistent system of clamped connections is also to be underlined.

During the exercises the trainees should be constantly supervised.

Defective or poor–quality connections should be immediately reworked or repaired.

If certain faults are repeatedly found, the trainees should be called together at one working place and be advised on the causes and effects.

The aim should be to make clear to the trainees the proper relationship between expenditure of work and technology on the one hand and esthetics and effects of the faults on the other hand.

Pressed joints

Here it is essential to point out that pressed joints are “permanent” joints.

Moreover it is necessary to discuss the criteria for connection by means of press–sleeves.

Press–sleeves must be fixed only by means of the pressing pliers intended for this purpose! Perfect pressing is to be ensured!

To avoid short circuit or body contact, perfect fit and vertical position of the insulation sleeves are to be ensured!

During the exercises the trainees should also be controlled and corrected, if necessary.

- Making wire–wrap joints
- Making soldered joints

These two working techniques should be dealt with in the form of a repetition since the trainees should already be familiar with these working techniques.

Here, too, “Trainees’ Handbook of Lessons – Making Permanent Joints” should be used.

3.2. Recommendations for Working with the Instruction Examples for Practical Vocational Training

The “Instruction Examples” describe the sequence of operations and contain a working drawing for carrying out the respective operations.

Moreover, the recommended materials, a list of the necessary working, measuring, testing tools and

accessories as well as the necessary previous knowledge are included for each example. The sequence of operations is supplemented by comments so as to provide the trainees with any information required for carrying out the work properly and in line with the safety regulations.

The following should be considered in the organization of the work:

- The trainees should do themselves any work involved in the instruction example.

This will enable the instructor to watch, correct and justly judge the achievement of each trainee.

3.3. Examples for Recapitulation and Tests

This section contains questions to strengthen and test the knowledge and skills acquired. The answers to the questions are also given. Questions, which are also contained in the “Trainees’ Handbook of Lessons”, are marked with the letter “A”.

1. What is the difference of lines and cables for fixed laying compared to those for connection of non-stationary (mobile) equipment?

“A” (Cables and lines for fixed laying are permanently installed and intended for single bending considering a bending radius. Their location remains unchanged. Lines for non-stationary laying are intended for portable electrical equipment. They are flexible and have fine or finest wires.)

2. What are the criteria for the selection and application of cables and lines for fixed laying?

“A” (Rated voltage, type of mechanical stress, temperature range, location)

3. How is a plastic-sheathed cable constructed?

(From inside to outside: Cu, Al or AlCu conductor, conductor insulation, filler, insulation sheath)

4. What are the risks involved in a conductor which has been damaged when stripping the conductor insulation?

“A” (Reduction of cross-sectional area at the joint: lower capacity, heating of conductor, destruction of the connection and/or connected equipment; breakage of stripped conductor: breakdown of the equipment, loss of the protective function with risk of short circuit or accident by existing shock-hazard voltage)

5. What is to be considered for bending of wire lugs?

“A” (Round-nose plier to be used only. Conductor must not be damaged. Lug must be adapted to the diameter of the thread or bolt.)

6. What is to be considered for making a joint with wire lugs?

“A” (Lug must be placed so that lug end is in direction of rotation when connection screw is tightened.)

7. What is to be considered for pressing-on cable eyelets?

“A” (Cable eye must be in accordance with cross section of conductor. Pressing inserts must comply with cable eye. V-grooves are applied on Cu conductors only. Change in length is to be considered for

hexagonal pressing. Contact faces of cable eye and conductor must be cleaned to remove dirt and oxide layers. If necessary, wire ring is to be applied for feeding-in segmental, multi-wire conductors. Flash produced at cable eye with hexagonal pressing is to be removed.)

8. What do the rules for the connection of cables and lines for fixed laying apply to?

(To all electrical appliances, devices, machines, clamped joints and other equipment.)

9. When are lugs to be bent for clamped connections?

“A” (When connection is made to stay bolts or cap screw terminals without clamping saddle or distributor plate.)

10. Why must neutral or protective conductors be looped at the point of the connection?

(To avoid loss of the protective function when the preceding point of connection is detached or disconnected.)

11. What are the advantages of a consistent system of clamped connections in electrical installations?

“A” (Facilitates fault finding, repairs, extension and connection of equipment depending on the direction of rotation.)

12. What are the advantages of pressed joints over clamped joints?

“A” (Shorter assembly time, no clamping inserts required, longer lasting contact, no risk of short circuit or body contact since points of connection are insulated.)

13. What operations are required for making wire-wrap joints?

“A” (Preparing the wrapping tool, stripping the conductor, inserting the conductor into the wrapping tool, putting the wrapping tool onto the connection lug, carrying out the wrapping process, removing the wrapping tool and switching off, inspection of the wire-wrap joint.)

14. What operations are required for making soldered joints?

“A” (Making the soldering iron ready for operation, stripping the conductor, cleaning the conductor and connection lug to remove dirt and oxide layers, inserting the conductor into or attaching it to the point of connection, treating the point to be soldered with acidless flux, carrying out the soldering process adding soldering tin, inspection of the soldered joint.)

