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BEST PRACTICE

for the installation of medium voltage cable accessories

CONTENTS

1. INTRODUCTION

This document has been written by cable accessory manufacturers to help promote 'best practice' in the installation of their products. It is principally for installers but hopefully will be instructive for all involved in the construction and operation of medium voltage (MV) cable networks.

Cable networks cannot be built without joining cables together and terminating them to equipment or overhead lines. The long-term reliability of the network therefore depends critically on both the cable and the accessories installed on it. A fundamental difference between cables and accessories is that cables are made in factories under closely controlled conditions, whereas accessories have to be installed on site from a kit of components. This puts a heavy responsibility on the accessory installer to do an accurate and skilled job, frequently under unfavourable conditions. It is an unfortunate fact that cable network faults are often located at accessory positions, and in the majority of cases the cause of the fault is inaccurate or poor quality installation.

The text and pictures below highlight the more important aspects of the installation of cable accessories from the point of view of their effect on system reliability.

The writers of this document hope that it will be found both useful and interesting, and that it will contribute to the increasing reliability of medium voltage networks.

2. SCOPE

'Medium voltage' (MV) in this document means power-frequency system voltages from U_m = 7,2 kV to U_m = 42 kV where U_m is the 'highest system voltage' for which the cable and their accessories are designed. Within this range, the common rated voltages of European networks are 10 kV and 11 kV (U_m = 12 kV); 20 kV and 22 kV (U_m = 24 kV); 30 kV and 33 kV (U_m = 36 kV).
International technical specifications (CENELEC and IEC) refer to values of U_m rather than country-specific rated voltages.

This document refers both to modern polymeric insulated cables and to historic paper insulated cables. Though the latter are now rarely installed in Europe, they are common in existing utility networks and there is a continuing need to connect new polymeric cables to them via 'transition joints'.

Accessories mentioned in this document are of the following types:

- Joints for connecting cables of the same design (straight joints) or different design (transition joints), connecting a branch cable to a main cable (branch joint) or insulating a cable end (stop end);
- Terminations making permanent connections between cable and electrical equipment or overhead line,
- Screened separable connectors for terminating cable to equipment via standardised equipment bushings.

The most common MV accessory technologies in use today are heat-shrink, cold-shrink and 'push-on' systems, all based on polymeric materials with specific characteristics according to their function in the accessory. Conductor connectors are compression (crimp) or bolted (mechanical) designs. These technologies, and the important aspects of their installation, will be addressed in the following pages.

3. CABLES

3.1 Paper-insulated cables

Until the 1980s, most of the MV cables installed by utilities and industry were paper-insulated type in which the insulation over the conductor(s) is built up by applying multiple layers of special cellulose paper. This paper insulation has to be impregnated with insulating oil or compound to exclude air and impart good electrical properties. A common feature of all paper cables is a metallic sheath, normally extruded lead or aluminium, enclosing the paper-insulated core(s). The main purpose of the metallic sheath is to give the paper insulated cores complete protection from the environment outside the cable.

Figures 1, 2 and 3 show examples of 3-core cables with lead sheaths and steel tape or wire armour. The three common constructions are:

- 'Belted', with an overall lead or aluminium sheath enclosing the three cores (Figure 1). This construction is common only with cables of rated voltage 12 kV and below,
- 'H' ('screened'), with a metallic foil screen covering each core, and an overall lead or aluminium sheath (Figure 2),
- 'HSL', with a lead sheath covering each core (Figure 3).

These three cable types each require their own accessory designs, **so it is important to identify the cable construction details in order to select the right joint or termination.**

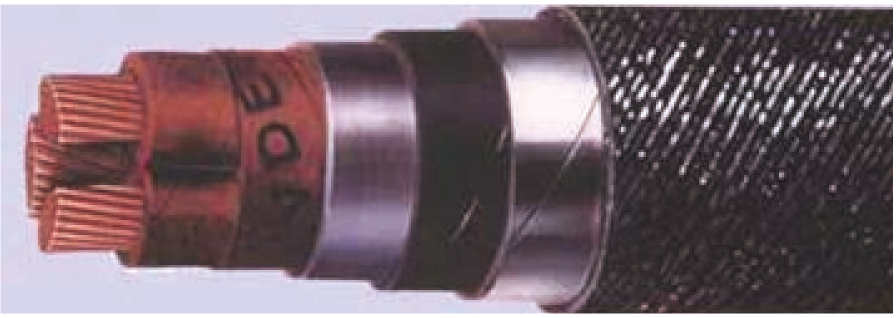

Figure 1 – 12 kV 'belted' paper-insulated cable with overall lead sheath and steel tape armour

Figure 2 – 'H' type or 'screened' 36 kV paper-insulated cable with overall lead sheath and steel wire armour

Figure 3 – 'HSL' 24 kV paper-insulated cable with individual lead sheaths and overall steel tape armour

3.2 Polymeric insulated (extruded) cables

In most European countries, paper insulated cables have been superseded by cables with extruded polymeric (plastic) insulation in place of paper. The insulation material in these modern cables is either crosslinked polyethylene (XLPE) or ethylene propylene rubber (EPR). Figures 4 to 9 show typical single-core polymeric cables, though there are other design variations of cables for special applications. Similar design variety applies to 3-core cables, of which Figure 10 is one example. Figure 11 is an example of a 3-core bundle comprising 3 single-core cables supplied twisted together.

All these cables have an extruded polymeric outer sheath, usually PVC or polyethylene, and some form of metallic screen, typically copper wires or tapes, or longitudinally-applied aluminium or copper foil laminate. In addition, or sometimes in place of these screens, there may be an armour layer comprising steel tape or wire, or aluminium wire. For protection against moisture entry, some cables are made with an extruded lead or aluminium sheath, and there may also be water-swellable tapes (Figure 9) or powder to prevent water passing along the cable under the sheath.

What is important for the installer is that he is aware of the function of each of the cable components and knows, with the help of the installation instruction, what to do with each of them as part of the procedure to prepare the cable ends.

At the heart of all modern MV polymeric cables is a three-layer extrusion comprising:
- Inner conductive layer applied over the conductor (conductor screen);
- Insulation (XLPE or EPR) of defined thickness according to cable rated voltage;
- Outer conductive layer applied over the insulation (insulation screen).

The outer conductive layer is often referred to as the 'semicon screen'.

An alternative insulation screen, typical of earlier designs of polymeric cables, is a conductive (graphite) paint layer covered by a conductive fabric tape (Figures 7 and 8).

The different types of insulation screen; bonded, strippable and paint & tape, each require different methods and different tools for their correct removal as part of the accessory installation procedure. This will be covered in later sections.

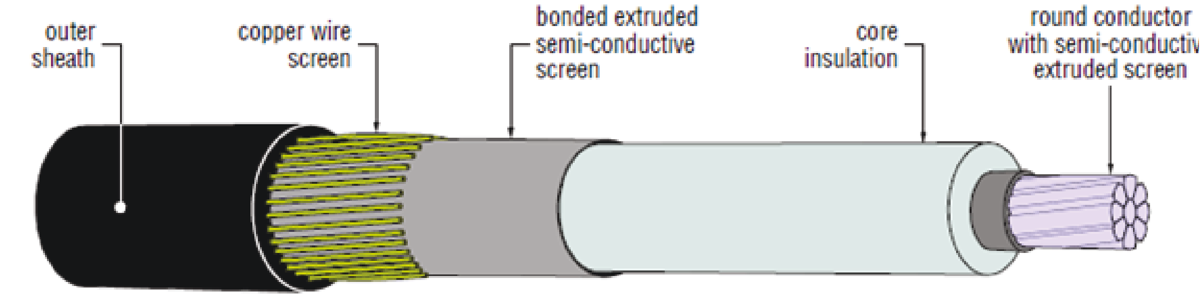

Figure 4 – Single-core cable with bonded or strippable insulation screen and copper wire earth screen

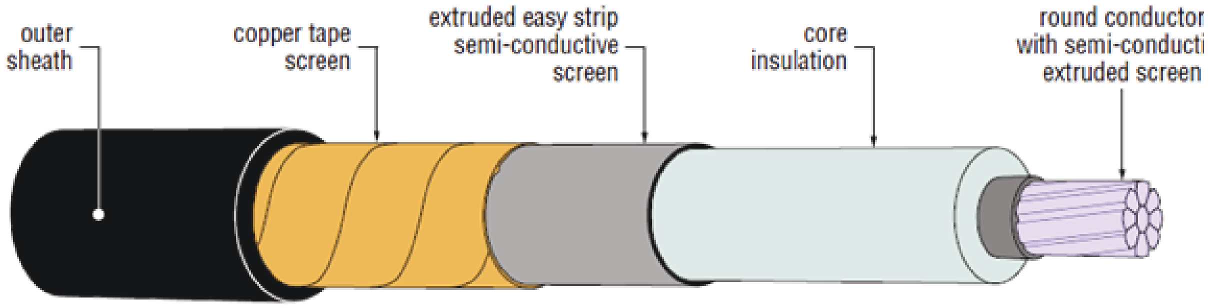

Figure 5 - Single-core cable with bonded or strippable insulation screen and copper tape earth screen

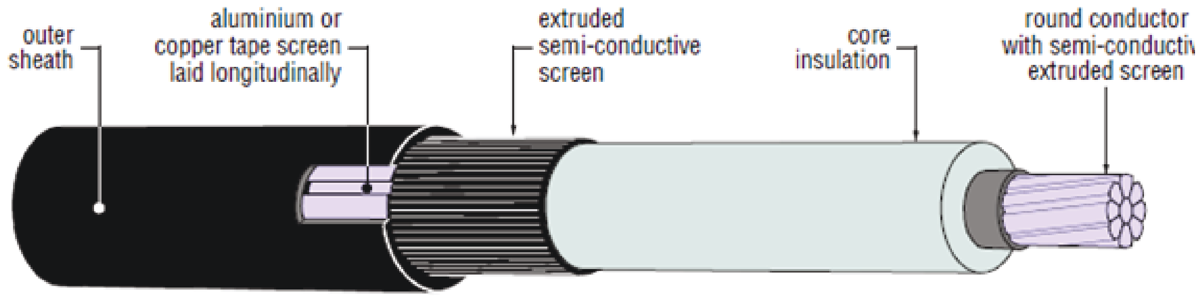

Figure 6 – Single-core cable with aluminium or copper tape laminate earth screen bonded to the outer sheath

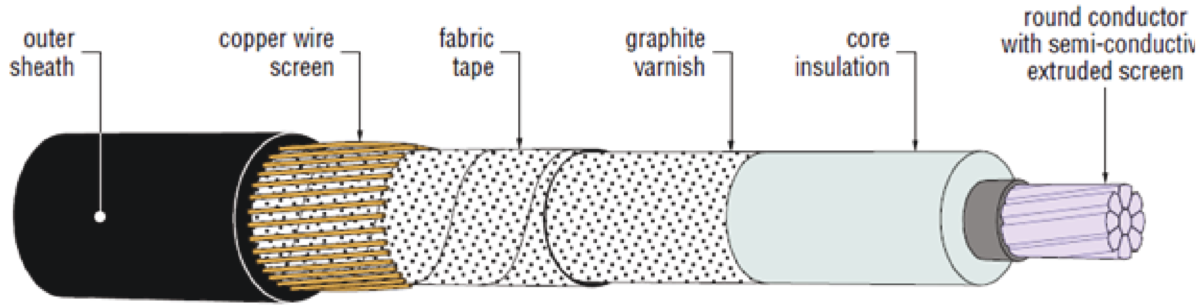

Figure 7 - Single-core cable with conductive paint & tape insulation screen and copper wire earth screen

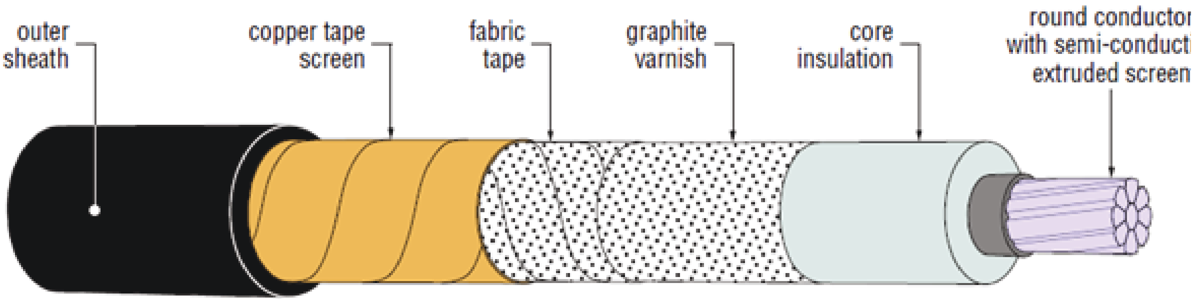

Figure 8 – Single-core cable with conductive paint & tape insulation screen and copper tape earth screen

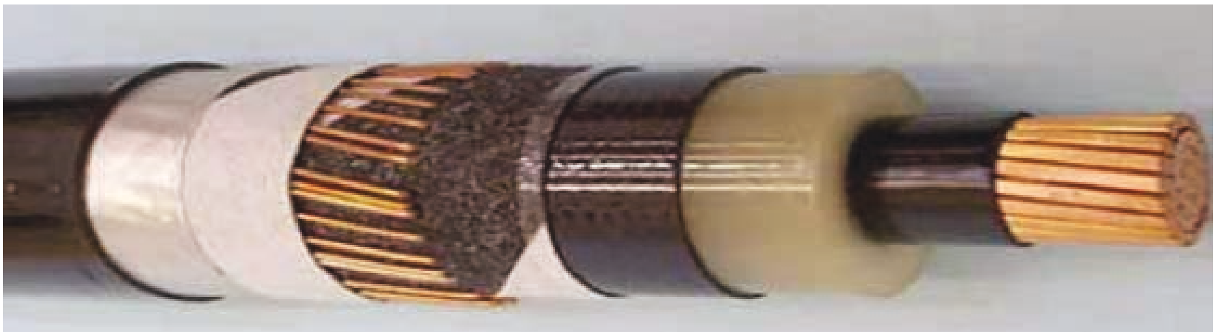
Figure 9 – Single-core 36 kV cable with XLPE insulation, bonded insulation screen, copper wire earth screen, water-swellable tapes and PVC outer sheath

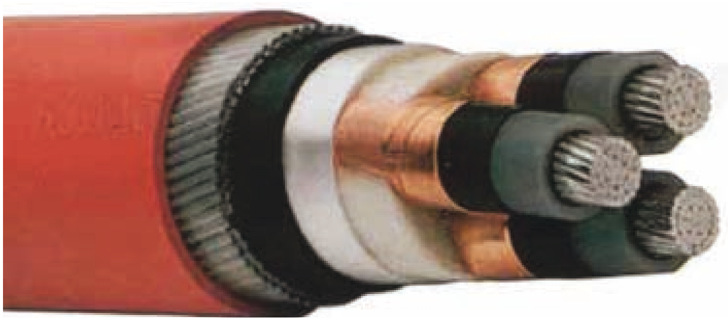
Figure 10 – Typical 3-core 12 kV cable with copper tape earth screens and steel wire armour


Figure 11 – Single-core cables supplied twisted together to form a 3-core bundle

Although it is many years since paper cables were installed as standard, there is still a demand for ‘transition joints’ to connect new polymeric cables into existing paper cable networks owned by electricity utilities.

The requirements for correct handling and preparation of paper cables and polymeric cables are quite different, as will be seen in later sections.

4. THE INSTALLATION SITE

As noted in the Introduction, there is a significant difference between the environment in which a cable is made and the environment in which a joint or termination is installed. Yet both are expected to have the same long-term service reliability.

The accessory arrives at the installation site as a box or bag of components together with an installation instruction and parts list. Modern accessory kits comprise mostly plastic or rubber components together with metallic parts for conductor connection, electrical screening and earth bonding. Once the packaging is opened, the components are vulnerable to damage and contamination with dirt or moisture.

The conditions at the installation site are one of the very important aspects of ‘best practice’. The site, whether in a trench or at ground level should be:

- **a safe working environment**;
- **as dry as possible** with no standing water close to the working area (see Figure 12);
- **sheltered from rain and wind**;
- **free from contamination** whether falling or wind-blown.
- **well lit**, with artificial lighting provided if necessary

In addition, there should be:

- **good all-round access** to the accessory being installed and to the associated cables (see Figures 13 and 14);
- **clean, dry and protected storage** for accessory components, cleaning materials, other consumables and installers’ tools.

Figure 12 – Not a 'dry' environment!

Figure 13 – Crowded road and walk-way services

Figure 14 – Inadequate installation space between substation equipment

5. FIRST STEPS

Before agreeing to do the requested work, **the installer should ask himself if he has received adequate and relevant training** appropriate to:

- the system voltage;
- the cable(s) involved;
- the accessory type and technology.

If the honest answer is 'no', the installer should not continue with the work.

The accessory kit will normally include, in addition to the components to be installed:

- a parts list and
- an installation instruction.

No work on cable preparation should begin until the installer is confident that **all parts and materials are available and are the correct type and size** to complete the installation. These should be checked against the parts list. **Components with an expired 'use by' date should be rejected. Any required special installation tools should be checked to ensure that they are correct for the intended application and are in good working order** (see 6.2).

Accessory manufacturers and suppliers all emphasise that the first and most important step in the installation process is to **read the installation instruction** before doing anything else. This applies even if the installer is familiar with the accessory type, because the manufacturer may have changed a component or a procedure.

Before being delivered to site, **cables to be jointed or terminated should have been fitted with end seals** to prevent moisture and other contaminants entering the cable. This is vital for polymeric cables as well as paper cables. The installer should check that the end seals are intact before starting work. **The cut cable should be checked to make sure that the conductor and other components are dry.**

Cables to be jointed should be positioned so that **the joint will be straight when installed**. Modern joints, though generally made of flexible materials, are not designed to be 'banana-shaped'. **If the cables cannot be set straight with each other, jointing work should not go ahead**.

For terminations into electrical equipment, **it is important that the cable can be set into the appropriate position without over-bending it or damaging the cable sheath against nearby metalwork**.

If possible, **a short length of spare cable should be made available** for trial use of cable preparation tools (see 6.2).

6. CABLE PREPARATION

6.1 General

With every cable accessory, the cable being jointed or terminated forms a vital and integral part of the completed joint or termination.

The early stage of accessory installation is preparation of the cable ends. There is nothing more important than to do this part of the work accurately and skilfully.

Before starting work to prepare the cable ends, **it is essential that an adequate length of cable outer sheath near to the working area is thoroughly cleaned and dried a** d kept in this state throughout the installation procedure. For some types of accessory there is a requirement to 'park' components on the cable prior to installing them in their final position. Even if the cable sheath is clean, **it is good practice to cover the section of sheath where accessory components will be parked**. For this purpose some manufacturers recommend using the plastic bags that components were supplied in.

Techniques involved in the preparation of cables are quite different for paper cables and polymeric cables. The following two sections highlight the most important steps for each cable type.

6.2 Preparation of polymeric cables

Compared with paper cables, polymeric cables appear easy to work with. They have no oily impregnating compound, are generally lighter in weight and more flexible.

The perception that the technology change from paper to polymeric cables has 'de-skilled' the installation process has probably contributed to a more casual approach to training of installers. The result, seen by those who investigate accessory failures, is that **the great majority of failures involving polymeric cables could easily be avoided by accurate and good quality cable preparation**.

Many special tools are available to assist the correct preparation of polymeric cables for jointing and terminating. **The use of special tools will make the job easier, safer and less likely to result in serious error.**

The cable outer sheath will probably have metallic components immediately under it, or may be bonded to a a uminium la inate. **In each case use an appropriate sheath removal tool rather than an unguarded knife**. The appropriate tool will help prevent damage to the underlying component, which may typically be copper wires, copper tape or armour wires. In the case of cables with aluminium laminate sheaths, the special tool should include the capability for preparing the sheath for an earth bonding connection if required.

Figures 15-17 show tools designed to aid the removal of plastic cable sheaths.

Figure 15 – Sheath removal tool

Figure 16 – Using a sheath removal tool

Figure 17 – Sheath removal tool for cables with aluminium laminate sheaths

Depending on the design of cable, whether single-core or 3-core, there may be other layers to remove before the black conductive screen ('semicon') of the phase core is exposed.

Removal of the black conductive screen layer covering the insulation is a critically important stage in the preparation of polymeric cables.

This screen layer is extruded together with the insulation and the inner conductor screen. Its thickness is generally between 0,3 mm and 0,6 mm and there are two types used in modern MV cables. These are:

- 'peelable' (non-bonded) screens which can be peeled away from the insulation to leave a smooth clean surface, and
- 'bonded' screens which, as the term implies, are firmly bonded to the insulation and can only be removed using a tool which cuts off the screen layer but leaves an acceptably smooth insulation surface.

A third type of screen found in some older generation MV cables comprises a conductive paint or 'varnish' applied to the insulation surface and covered with an overlapped conductive fabric tape. Removal of this type of screen is mentioned on a later page.

Techniques and tools for screen removal are quite different for each type, but the important rule for both is

- **NEVER use an unguarded knife**. This includes broken glass and any other object with a sharp unguarded edge.

If an unguarded knife is used, there is a very significant risk of cutting into the insulation at the screen edge. A knife cut may be invisible but will almost certainly become a future failure site, possibly immediately the cable system is energised but certainly after several months or years. The knife cut will likely be a site of partial discharge activity (see section 11.) which would probably be detected if analytical tests were applied to the system before or during service.

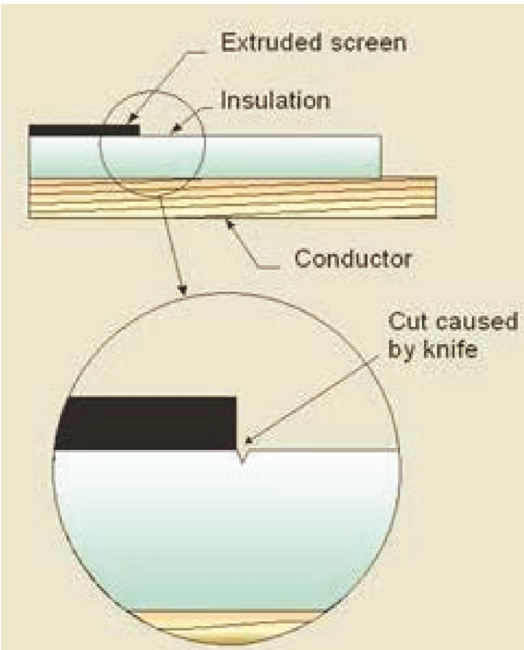

Figure 18 – Knife cut into the insulation surface caused by use of an unguarded knife

For **peelable screens**, the technique is to make spiral or longitudinal cuts into the screen to a depth less than its thickness, allowing the layer to be removed in one or more strips to the dimension given in the installation instruction. Depth-guarded knives made for this application can be adjusted for various cutting depths. **A vital step before using any guarded knife tool is to set the cutting depth appropriate to the thickness of the screen layer.** This is best done by experiment using a spare length of the same cable. The cutting depth must be sufficient to allow the screen to be peeled but must not penetrate the full depth of the layer.
Some accessory manufacturers and users recommend removing a ring of peelable conductive screen material at the screen edge position using a round file. This is done before removing the rest of the screen layer. The file is used carefully and uniformly around the cable until the underlying insulation is just visible (see Figure 19). The claimed advantage is that no knife is involved so there is no danger of cuts in the insulation at the screen edge. The unwanted screen length may then be peeled away after scoring the material with a guarded knife or other suitable tool (see Figures 20 and 21).

Figure 19 – Using a round file to create a screen edge

Figure 20 – Using a depth-guarded knife to score the screen

Figure 21 – Peeling strips of screen

Figure 22 – Finished screen edge and smooth insulation surface

The result should be a clean screen edge and smooth insulation surface, as shown in Figure 22.

For **bonded screens**, many special tools are available. The most popular and successful tools all work on the same principle. After setting up the tool according to the diameter over the screen and the screen depth, the tool is moved in a spiral motion from the cable end to the screen cut position. As in the case of peelable screen tools, **the tool should preferably be correctly set by experiment using a spare length of cable.**

Figures 23-25 show a screen removal tool in use.

Figure 23 – Setting the correct cutting depth etc at the cable end (if no spare cable is available)

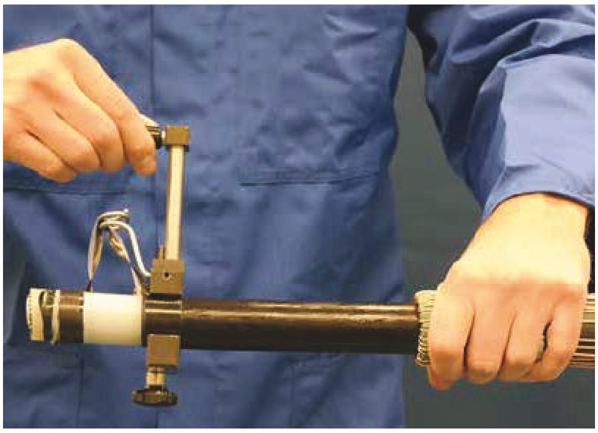

Figure 24 – The tool moves in a spiral motion along the core

In order to remove enough but not too much insulation, a practical guide is to set the removal tool so that the strip being removed shows ⅔ black screen and ⅓ insulation across its width (see Figure 25).

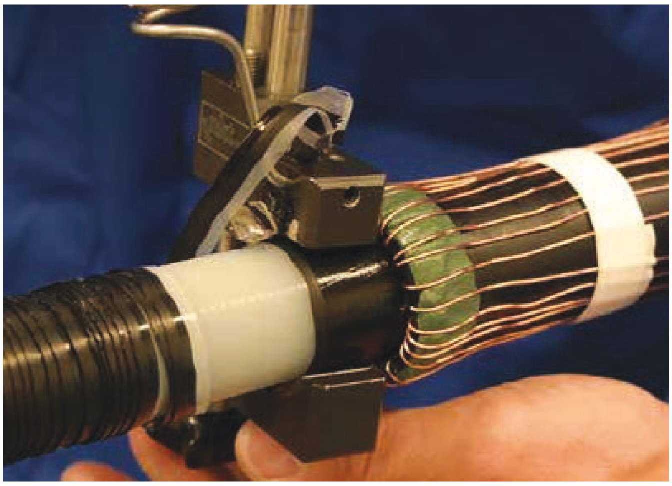

Figure 25 – This cutting tool creates a tapered screen edge at the selected position

Other bonded screen removal tools are shown in Figure 26.

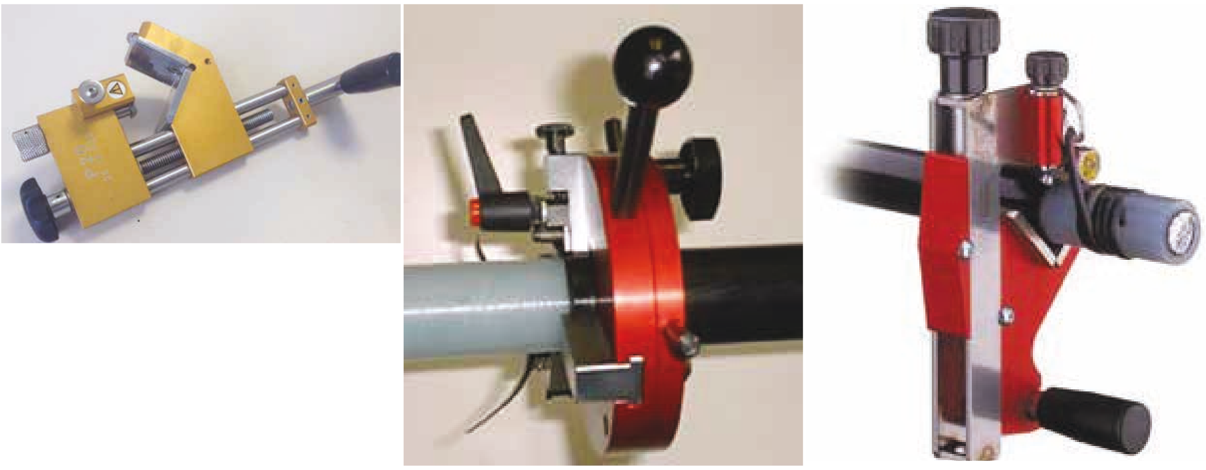

Figure 26 – Spiral cut bonded screen removal tools

The essential result after using the tool is:

- **complete removal of the screen layer without removing more than a very thin layer of insulation;**
- **screen edge free from projections or filaments;**
- **smooth insulation surface with no remaining conductive material.**

Figures 27-29 show three examples of unacceptable screen edge quality resulting from incorrect use of a screen removal tool. In all cases there would be raised electric stress at the irregularities in the screen edge, probably leading to early-life failure of the accessory.

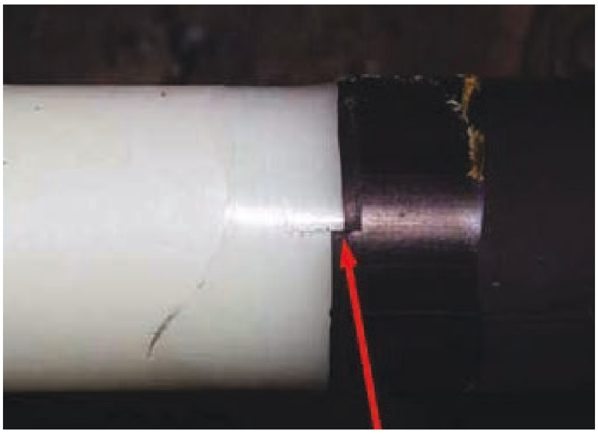

Figure 27 – Irregular conductive screen edge caused by incorrect use of the removal tool

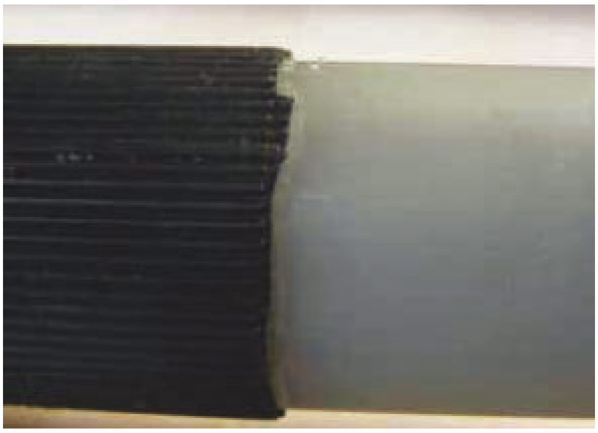

Figure 28 – Irregular edge of peelable screen

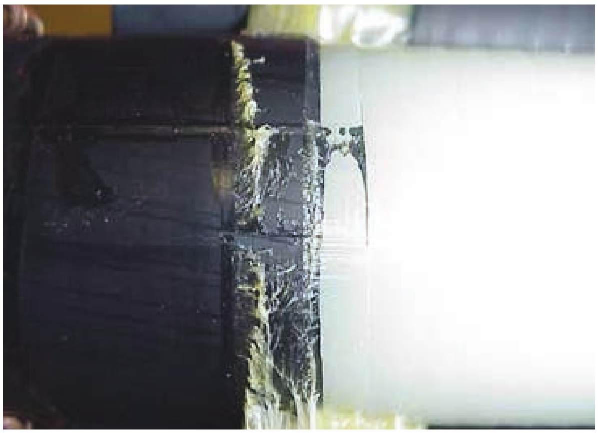

Figure 29 – Incomplete removal of conductive screen material from insulation surface

The quality of the screen edge is vital to the performance of the accessory in service. Irregularities or knife cuts into the insulation are positions of raised electric stress which will inevitably result in early-life failure. Installers must be aware of this and pay great attention to this stage of the accessory installation process.

Figure 30 shows an unacceptably rough insulation surface caused by an incorrectly set screen removal tool or gross misuse of the tool by the installer. **It is good practice to smooth any minor surface roughness using abrasive cloth (preferably aluminium oxide type).** The degree of surface roughness shown in Figure 30 is, however, beyond any reparatory treatment.

Figure 30 – Extremely rough insulation surface resulting from incorrect setting and/or misuse of screen removal tool

It is good practice to make available a short length of 'waste' cable core to adjust and check the tool setting, and become familiar with its use.

After cutting the core (conductor and insulation) to length, **removal of the insulation to fit the connector will be made easier using the appropriate special tool.** If a knife is used, great care should be taken to achieve a straight cut edge and avoid scoring the surface of the conductor. Cutting into XLPE insulation with a knife is made easier if the insulation is warmed. Figure 31 shows spiral cut insulation removal tools in use.

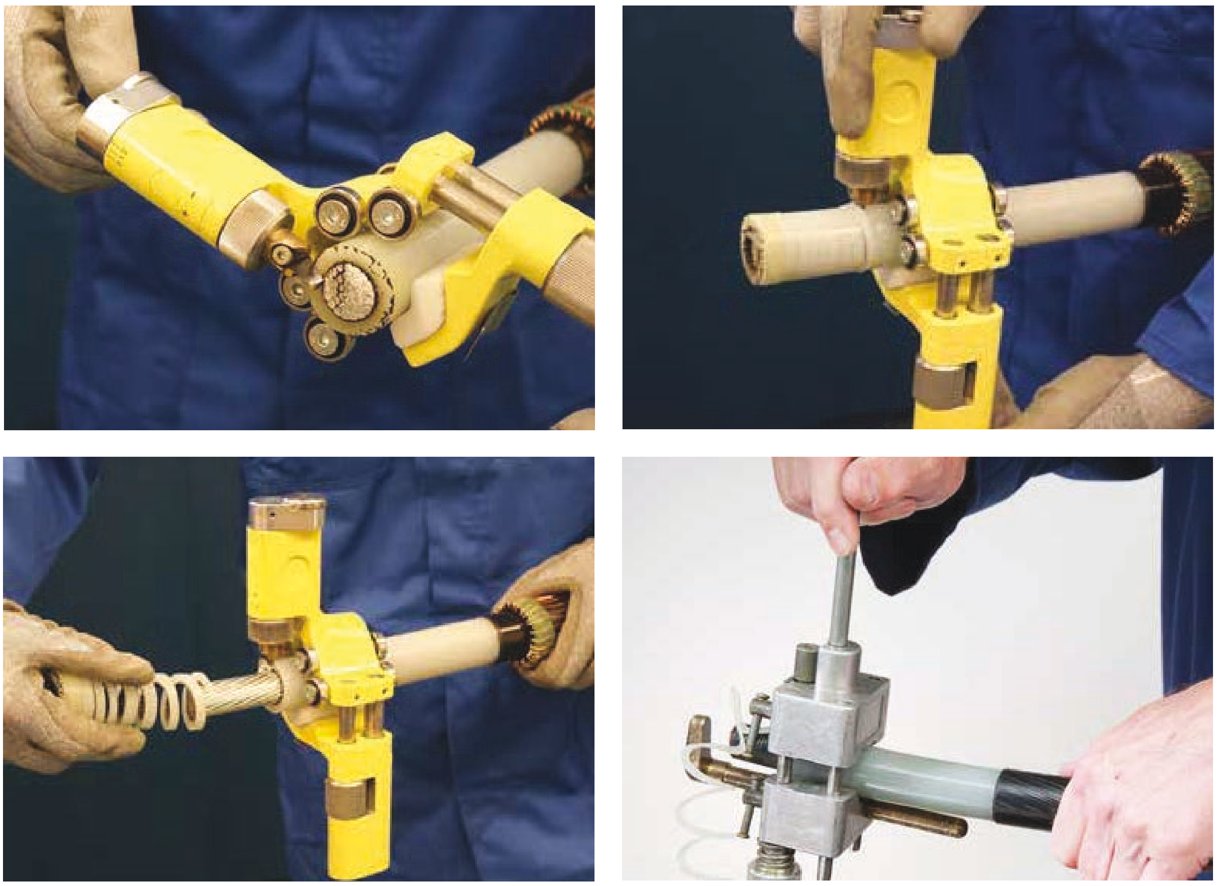

Figure 31 – Spiral-cut insulation removal tools in use

Some accessories, especially for higher voltage cables, may require that the edge of the insulation is chamfered (tapered). Tools such as those shown in Figure 32 are available for this purpose.

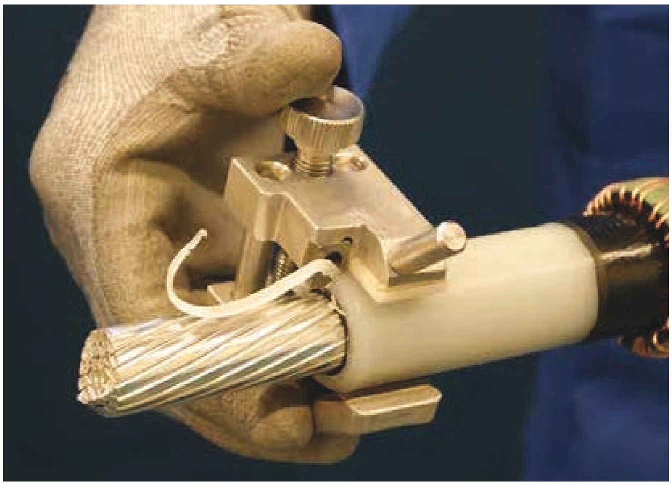

Figure 32 – Tool for chamfering the insulation edge

Before installing components of the joint or termination, **the prepared cable core should be cleaned to remove any dirt or other contaminants.** This should be done using clean cloths and a recommended cleaning agent. **Wiping of the insulation should always be done towards the conductive screen.** A cloth that has been wiped over the screen should be discarded and replaced with a clean one. Similarly, **the connector should be wiped without allowing the wiping cloth to contact the insulation surface.**

Some older polymeric cables do not have an extruded conductive screen. The screen in these cables will probably be a black conductive graphite-based 'paint' covered by a conductive fabric tape (see section 3.2). To prepare a screen edge, the tape is unwound and fixed at an appropriate position back from the screen edge position. The exposed conductive paint is then masked with tape and the conductive paint is removed to the screen edge position using a recommended solvent.

6.3 Preparation of paper cables

Because paper cables are no longer installed as standard in European MV networks, installers will probably only have to work with them when making transition joints to newly-installed polymeric cable.

Installers who are not familiar with paper cables should take special training before working with them.

The paper cable to be jointed may have been in the ground for several decades, working reliably while undisturbed. Paper is a natural material and suffers from ageing as a result of long term exposure to raised temperature during service. The most damaging result of ageing is embrittlement of the paper tapes, making them likely to crack or break when the cable core is moved. Broken insulating papers will significantly weaken the electric strength of the insulation as a whole. The following is best practice when handling paper cables.

- **Handle with care when positioning the cable.** Steel armour layers may have been weakened by long-term corrosion and may not offer mechanical support to the cable.

- **Do not bend the cable any more than is strictly necessary.** Remember that the paper insulation will be more brittle than when the cable was made. Bending the cable imposes mechanical forces on the individual paper layers. If the paper tapes crease or crack, the cable insulation will probably fail during service.
- **Remove the metallic sheath only when necessary.** Once the paper insulation is exposed it will absorb moisture and become electrically weaker. **Beyond this point installation work should proceed without delay.**
- **If possible, do a moisture test on the paper insulation to prove that it has not been exposed to the environment. If the insulation proves to be 'wet', installation work should not proceed. If possible, avoid working with paper cables in very cold temperatures because the paper tapes will be more vulnerable to cracking.**
- **With 3-core cables, support the cable crutch when separating and setting the cores into position.** Support the crutch with a firm hand or wrap it with strong cloth tape. A common mode of failure in 3-core transition joints is electrical breakdown in the paper cable crutch due to over-bending of the cores causing damage (cracking, splitting, creasing) to paper insulation layers.

Figure 33 shows one method for removing a lead sheath. **Whatever sheath removal method is used, it is essential to avoid any damage to the underlying paper insulation. Because the paper surface is likely to be covered with sticky compound it must be thoroughly protected against contamination during the installation process.**

Figure 33 – A technique for removing lead sheaths

7. CONDUCTOR CONNECTORS

7.1 General

Within joints and terminations, conductor connectors are responsible for carrying the electric current between cables or between cable and other electrical equipment such as switchgear, transformers and overhead lines. They are therefore fundamentally important components of electrical networks.

Connectors that are not the right size or type, or not correctly installed, can cause failure of the accessory. Two common types of failure are:

- Overheating or 'burn-out' of the connector and accessory due to high electrical resistance
- Electrical breakdown of a joint if the connector is the wrong shape (causing raised electrical stress)

The original method of making connections to cable conductors was by soldering or brazing. This has now been replaced by two technologies, both of which have proved highly reliable if components are correctly selected and correctly installed. These connector categories are:

- Compression ('crimp') connectors
- Bolted (mechanical) connectors

Whatever the connector type, it is essential to check that **the connector is compatible with the accessory to be installed**. This is vital for all styles of joint and may be similarly important for terminations. It is preferred that connectors are included in the accessory kit because selection of the right connectors has already been done by the accessory manufacturer or supplier. If connectors are not included, the supplier must provide guidance (in the installation instruction or other documentation) as to the types and sizes of connector that are suitable. **Before starting work, the installer should make every effort to check that the connectors have been correctly selected.**

For all connector types, **the correct length of insulation must be removed from the conductor to allow full insertion into the connector body.** Installation instructions will specify any gap, or none, between connector body and insulation cut edge.

Before installing any connector, **the exposed cable conductor must be clean and free from any contamination.** The connector installation instruction may require that the conductor surface is abraded with a wire brush or abrasive cloth. The internal surface of the connector may have a coating of grease or other interface compound, in which case it should not be removed and must be protected from contamination. A connector with a grease coating will normally be supplied in protective packaging and it is good practice to **remove the packaging only immediately before installation.**

Installers should check some general requirements for compression and mechanical connectors used for main conductor connections:

- Connectors for transition joints should be 'blocked' to prevent impregnating compound from the paper cable finding its way across the joint into the polymeric cable, or water in the polymeric cable entering the paper cable.
- Connectors for terminations ('lugs') should not have a 'sight hole' into the connector barrel, which could allow entry of moisture.

7.2 Compression connectors

Compression ('crimp') connectors are installed using special equipment comprising a powered hydraulic or hand-operated press tool together with a die set. There are two main connector types in common use:

- Hexagonal or circumferential compression
- Deep indent compression

For both techniques it is essential that:

- **The connector is the right size and type for the conductor**
- **The die set is correct for the type and brand of connector**
- **The die set is correct for the conductor cross-section (mm^2) or diameter**
- **The press tool and the die set are compatible**
- **The press tool and die set are maintained in good condition.**

Compression connectors for MV applications are not normally range-taking and are each intended for a specific conductor size. A connector is also likely to be specific to the material and construction of the cable conductor (metal type, stranded or solid, round or shaped). **Application details must be thoroughly checked to ensure that the connector and conductor are compatible.**

Installers should be aware that the diameters of modern cable conductors may be smaller than was envisaged when the compression connector was designed. This may result in a connector being a 'loose' fit on the conductor even though it is the correct size for the conductor cross-section. **The installer must not be tempted to select a connector for a smaller conductor cross-section even if it will fit on the conductor.** This is because the smaller connector may not have adequate metal cross-section to suit the conductor size.

Hexagonal compression takes its name from the shape of the die used to compress the connector body on to the conductor (see Figure 34). Connectors have a cylindrical shape and usually have guide marks to show the correct positions of the die for installation. There may be more than one compression position on each side of the connector. **With hexagonal compression connectors, the first compression must be the one nearest to the centre of the connector body.** Subsequent compressions are next to the previous one, moving towards the end of the connector.

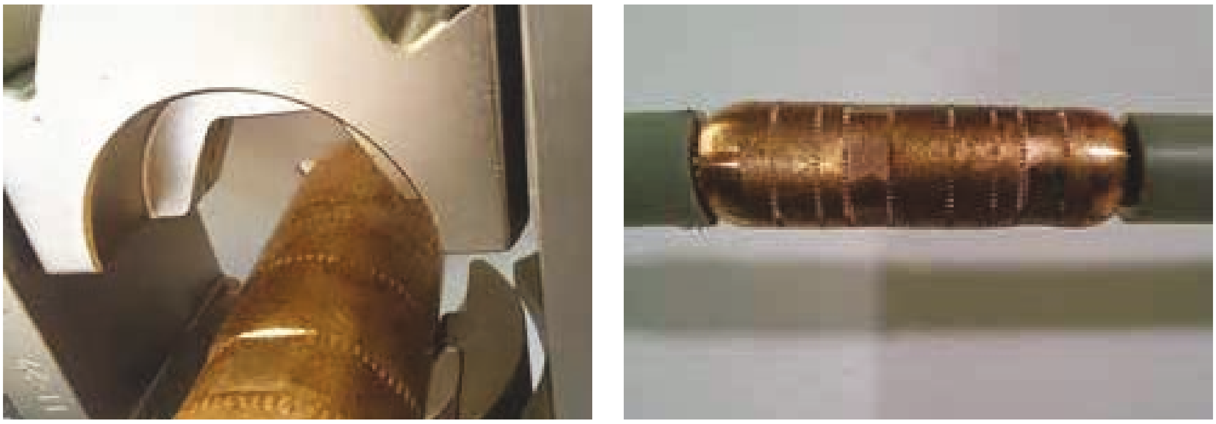

Figure 34 – Hexagonal compression die and copper connector (for stranded copper conductor) showing first compression position

Figure 35 shows a hexagonal compression lug with tool guide marks on the barrel.

Figure 35 – Compression lug showing guide marks for hexagonal compression tool positions

For deep indent compression, as the name implies, an indenting tool is pressed deep into the connector body. Because of the amount of disruption caused by the tool, the connector body must be fully supported in a cage which forms part of the tooling equipment (see Figures 36 a d 37).

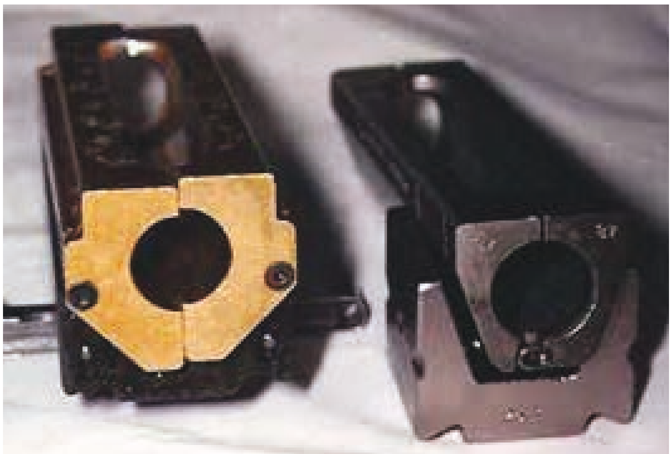

Figure 36 – Die cage for deep indent tool

A very important difference between these two compression technologies is the sequence of compressions. With hexagonal compression the first tool position is nearest to the connector centre, but **with deep indent compression the first tool position is at the end of the connector, working towards the centre.**

Figure 37 – Second deep indent position

After installation, compression connectors should be carefully checked for any sharp edges or points. **It is essential that any sharp edges or points are removed using a file or abrasive cloth.** The installation instruction may include this step. **The connector body and nearby surfaces must then be thoroughly cleaned to remove any metal particles or other contaminants.** Installation instructions may also require the depressions in the body of deep-indent connectors to be filled with a mastic or putty (usually supplied in the kit).

7.3 Bolted connectors

Bolted (or 'mechanical') connectors have screws which are tightened to contact the conductor within the bore of the connector. These connectors are steadily gaining in popularity because they are size range-taking (which is convenient for inclusion in accessory kits) and usually require no special installation tooling. In addition, most of those for MV applications have shear-head screws where the screw head or part of the screw shank breaks away when the correct tightening torque is reached. This takes away requirement on the installer to apply a controlled torque. Sheared screws generally leave a relatively smooth profile over the cylindrical body of the connector. **Any projecting points or edges must be removed using a file or abrasive cloth.**

Bolted connectors may be installed using standard hand wrenches if the screws have hexagonal heads (see Figure 38) or hexagonal sockets (see Figure 39). **The sequence of screw shearing is from the screw nearest the connector end, working towards the centre. It is good practice to tighten screws progressively from one to another until all are tight but not sheared. The first screw should then be further tightened until it shears.**

Figure 38 – Bolted connector with hexagonal head screws

Figure 39 – Bolted connector with hexagonal socket screws

The use of a hand-operated wrench gives maximum control over the tightening and shearing procedure but some connector manufacturers allow the use of power impact wrenches to tighten and shear the screws. **It is essential that the installation method is in accordance with the connector installation instruction or the manufacturer's recommendation.**

Range-taking of bolted connectors may extend to three or more standard conductor sizes. These connectors will probably be fitted with screws having several shear positions (Figure 40 left) or a 'step-less' shear feature making the screw shear flush with the connector surface (Figure 40 right). With most joints and terminations **it is important that the sheared screw thread does not project above the cylindrical profile of the connector body after installation.** The installation instruction may require the use of a file or abrasive paper to remove any projections of the sheared screws. If this is the case, **metallic filings or dust must be completely cleaned from the connector body and nearby surfaces.**

Figure 40 – Multi-shear position (left) and step-less shear (right) screws

Range-taking bolted connectors may include metal inserts (see Figure 38) or plastic centring rings (see Figure 41) intended to position smaller conductors concentric within the bore of the connector. **Centralising inserts must be used (for smaller conductors) or discarded (for larger conductors) according to the installation instruction.**

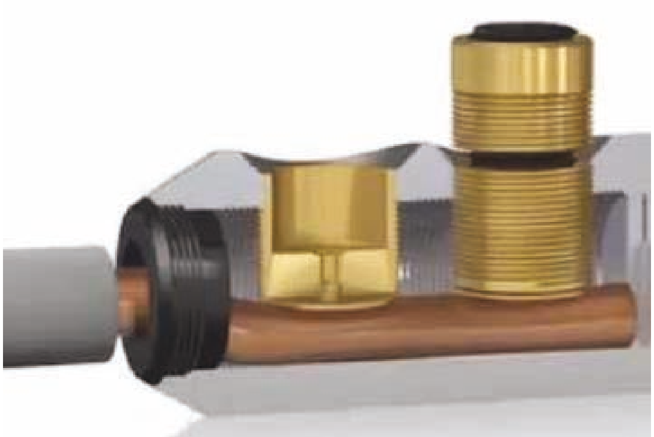

Figure 41 – Plastic insert (black) for centring a small conductor in the connector body

It is good practice to use a connector support tool to prevent twisting of the connector (see Figures 39 and 42). This is particularly necessary when working with small cable conductors to avoid bending of the conductor either side of the connector.

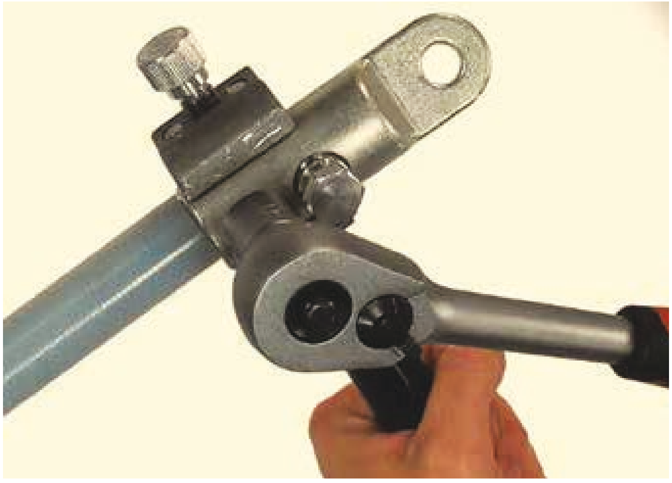

Figure 42 – Use of a support tool for installation of a shear-head mechanical lug

8. EARTH BONDING

Earth bonding across joints and at terminations does not always receive the level of care and attention that it requires. An ineffective earth bond can be just as damaging to accessory performance as inadequate phase conductor connections. It is also possible that **network safety may be compromised if an earth connection is lost or has high resistance.**

A failure mechanism frequently seen in joints and terminations is overheating at positions where the cable metallic screen and/or armour is connected across a joint or to an earth connection at a termination. Overheating results when a high resistance earth bond carries fault current or induced 'circulating current'. The overheating can damage underlying cable insulation and cause insulation failure.

The most frequent cause of earth bond problems is the presence of continuous induced earth circulating currents in single-core circuits. These circulating currents are induced in the metallic earth components of the cable if there is a connection to earth at each end of the cable (referred to as 'solid bonding'). The problem is likely to be worse in circuits with large-conductor cables with aluminium wire armour (AWA). Because of the high conductivity of AWA, the circulating current can be many hundreds of Amps when the cable conductor is heavily loaded.

Unfortunately, accessory suppliers are not always made aware of the possibility of circulating currents when asked to specify products. The installer should be in a good position to know the system earthing arrangements and to **check before installation whether the earth bonds provided with the accessory are adequate.** If there is doubt, installation should not proceed.

9. ACCESSORY TECHNOLOGIES

9.1 General

Installers should always receive training in the accessory technologies that they will work with. Each technology has its own peculiarities and practice will be needed for the installer to become familiar with the individual skills needed. Installation instructions always have detailed information on cable stripping dimensions etc but not necessarily much guidance on techniques relevant to whether the accessory components are heat-shrink, cold shrink, push-on or maybe more than one technology.

The sections below highlight some important considerations for each of the major technologies.

9.2 Heat-shrink accessories

Heat-shrinkable sleeves and moulded parts are made of special crosslinked plastic materials that are heated a d stretched (‘expa ded’) a d then cooled whilst held expa ded. The expa ded state becomes ‘frozen’ into the molecular structure. Extruded tubings and moulded parts are supplied in this state.

The installation process involves positioning and re-heating the expanded parts, usually with a propane or butane gas torch, until the parts shrink (‘recover’) on to whatever they have been placed (Figure 43). Because a naked flame is involved (or perhaps a powerful hot air gun), **an appropriate level of installer skill is required to ensure full recovery, avoiding faults such as voids in the interfaces of insulating layers, or burning of the material surface.**

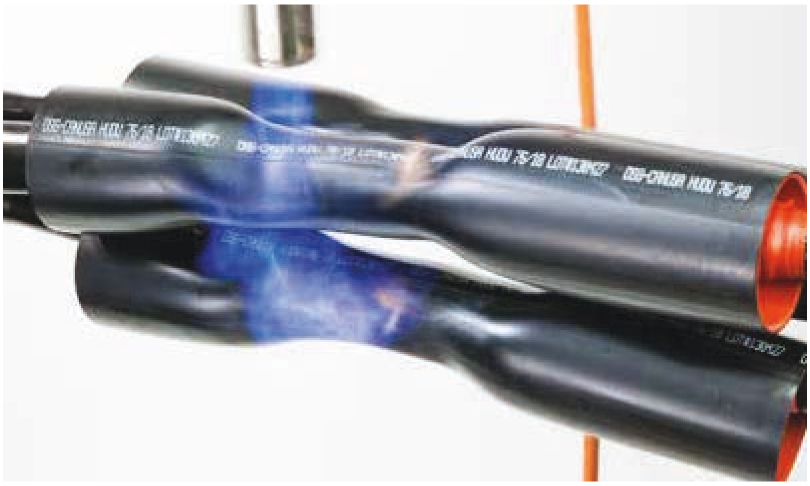

Figure 43 – Shrinking joint insulation/screening tubings

Some important rules for successful installation of heat-shrink components are as follows.

- **Use a gas torch designed for this purpose (not a torch designed for soldering).**
- **Adjust the torch to give a large soft yellow flame.**
- **Position the part accurately because adjustment may not be possible after shrinking starts.**
- **Keep the flame moving around the shrinking component.**
- **Point the flame in the direction of shrinking.**
- **Do not move the accessory until the heat-shrink components have cooled.**

9.3 Cold-shrink accessories

Cold-shrink sleeves and moulded parts are also supplied in an expanded form but in this case on some form of rigid former or ‘hold-out’. The hold-out is removed during installation to allow the stretched part to recover into position on the joint or termination (see Figure 44). Cold-shrink components are usually made from soft flexible materials such as silicone rubber and EPDM.

Some important rules for successful installation of cold-shrink components are as follows.

- **Check that the parts are within their 'use by' date.**
- **Keep the expanded components away from sharp objects.**
- **Use only the specified grease or other lubricant.**
- **Position the component accurately because adjustment may not be possible after recovery starts.**
- **Support the component in position and remove the holdout carefully and slowly without stretching the component.**
- **When removing spiral holdouts, the instruction may require the tape pulling position to be rotated around the cable to avoid snagging or tangling.**

Figure 44 – Installation of a cold-shrink joint sleeve with spiral tape holdout

9.4 Push-on accessories

This is a general term referring to joints, terminations and separable connectors that are not supplied in an expanded form. Each part is sized such that it forms an interference fit with the cable and can be pushed into position, usually without the need for special tooling. These accessories are also referred to as 'slip-on'.

There are many designs of terminations and joints in this technology category. Applications extend well beyond MV up to the highest system voltages. The most well known MV push-on accessories are fully screened separable connectors for connecting cables to electrical equipment via standardised bushings (see Figure 45).

Figure 45 – Screened separable 'T' connectors (or 'elbows')

Some important rules for successful installation of push-on components are as follows.

- **Check that the part is correctly sized for the cable diameter (because range-taking may be restricted).**
- **Apply only the lubricant supplied with the kit or recommended by the manufacturer.**
- **Install each component on to the cable in a single movement (do not stop part-way) into its final position.**

9.5 'Hybrid' accessories

Some accessories comprise a mix of heat-shrink, cold-shrink and push-on components. The recommendations applying to each technology should be followed.
Some utilities favour joints that include a pourable resin. The usual function of the resin is to provide additional mechanical protection and/or moisture sealing. **It is very important to follow closely the instructions for mixing and pouring of resin, including health and safety guidance for personal protection.**

10. SOME CAUSES OF FAILURE

As well as causing disruption to power supply, accessory failures are potentially dangerous especially if they occur in public areas such as under roads or walk-ways. Figure 46 shows the immediate result of electrical breakdown and arcing in a joint installed in a manhole under a wa k-way.

Figure 46 – Failure of a joint installed in a manhole under a walk-way

The following figures illustrate some installation faults that have already resulted in accessory failure or may do so sooner or later.

Figure 47 shows a cross-section cut through a heat-shrink joint. There is a large void at the 7 o'clock position. This was caused by under-heating at this part of the circumference of the joint. The installer applied most heat between 10 o'clock and 4 o'clock positions, no doubt convenient for where he was standing. Electrical stress in the void will result in partial discharges that will probably lead to breakdown of the joint.

Figure 47 – Air void between layers of a heat-shrink joint

Figure 48 shows removal of a strippable screen after spiral scoring. The scoring knife has been set too deep and has cut into the underlying XLPE insulation.

Figure 48 – Cuts into XLPE insulation caused by strippable screen scoring tool blade set too deep

Figure 49 shows a heat-shrink termination that has failed by breakdown between the lug and the insulation screen. Electrical tracks are visible on the insulation surface and the heat-shrink sleeve has split in a number of places due to arcing. The cause of the failure may have been under-shrinking of the tubing and/or entry of moisture at the conductor lug.

Figure 49 – Failure of a termination due to electrical tracking on the insulation surface

Figure 50 shows a termination (push-on or cold-shrink type) where the termination body covers only part of the deep-indent conductor lug. This was probably the result of mis-placement. The termination must seal on to the lug barrel to prevent moisture entry. In this case the seal may have been ineffective.

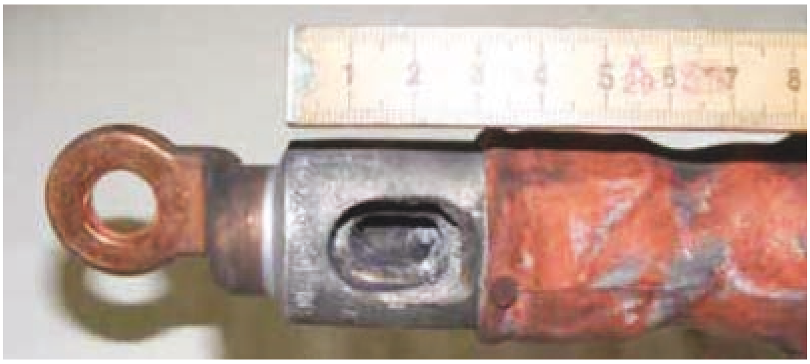

Figure 50 – Incomplete coverage of termination lug possibly allowing moisture entry

Figure 51 shows cable termination bushings on 12 kV switchgear. The centre bushing has failed by surface breakdown after long-term partial discharge activity on its surface. The activity resulted from incomplete sealing of a heat-shrink insulating boot on to the bushing surface. Corrosion of the surrounding steelwork (caused by acidic gases generated by discharge activity) indicates that the electrical activity had been occurring for some time before complete failure.

Figure 51 – Failure of a switchgear bushing after long-term partial discharge activity

Figure 52 shows a heat-shrink termination on 3-core cable. The individual cores may have been made to the correct length but the cable crutch position should be near the base of the cable box. The cores have been severely bent in order to make connections to the bushings. In addition, phase identification sleeves or any other covering should not be on the termination surface as they will interfere with the essential non-tracking function.

Figure 52 – Termination made without regard to dimensional instructions

Figure 53 shows what happens when the installer does not follow the installation instruction and does not remove the insulation screen. Unfortunately this indicates that he not only did not read the instruction but also does not understand the function of the screen and the fact that it is conductive. Electrical failure would have been immediate given that there is only nominal separation between phase voltage (conductor connector) and earth (insulation screen).

Figure 53 – Immediate failure due to insulation screen not being removed during installation

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11. ADDITIONAL INFORMATION

11.1 Electric field and stress control

All cables for MV and higher voltage ratings, whether paper or polymeric insulated, have a metallic screen which is connected to earth. In addition, polymeric cables have a conductive polymeric screen as described in earlier sections. This screen ensures that the electric field generated by the energised phase conductor is wholly contained within the primary insulation.

At the position where a cable is to be jointed or terminated, outer layers of the cable including the conductive screen over the insulation must be cut back according to dimensions given in the installation instruction (see Section 6.2).

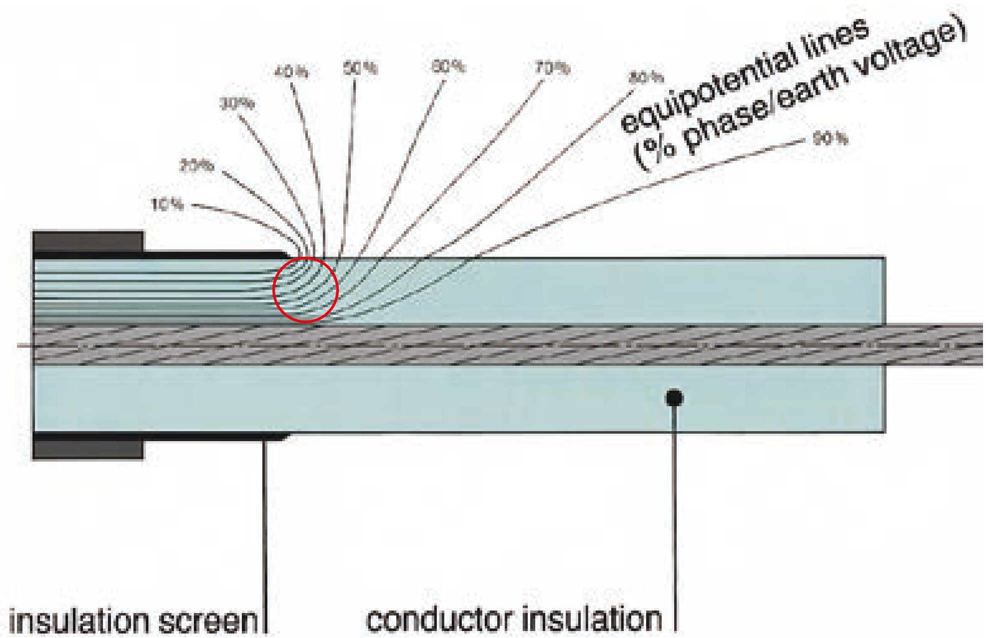

Figure 54 – Electrical equipotential lines indicating strong electric field at the screen edge

Figure 54 shows this situation, with the electric field represented by 'equipotential lines' joining points of equal voltage or 'potential'. Where the equipotential lines are close together the electric field is strong.

This strong electric field at the screen edge (indicated by the red circle) would cause insulation damage and eventual electrical breakdown if nothing were done to reduce the electric stress at this position. This is why all MV joints and terminations have 'stress control' components whose function is to reduce the electric stress at the screen edge (and other positions of high stress) to acceptable levels.

Figure 55 shows the stress control method used from the earliest days of cable accessory development. This is a 'stress cone' which controls stress by positioning a conductive cone-shaped component at the screen edge and thereby forcing the equipotential lines to separate exit the cable insulation more gradually. This is called a 'geometric' method of stress control. Stress cones for polymeric cables are made of flexible rubber and are commonly incorporated in cold-shrink or push-on a cessories

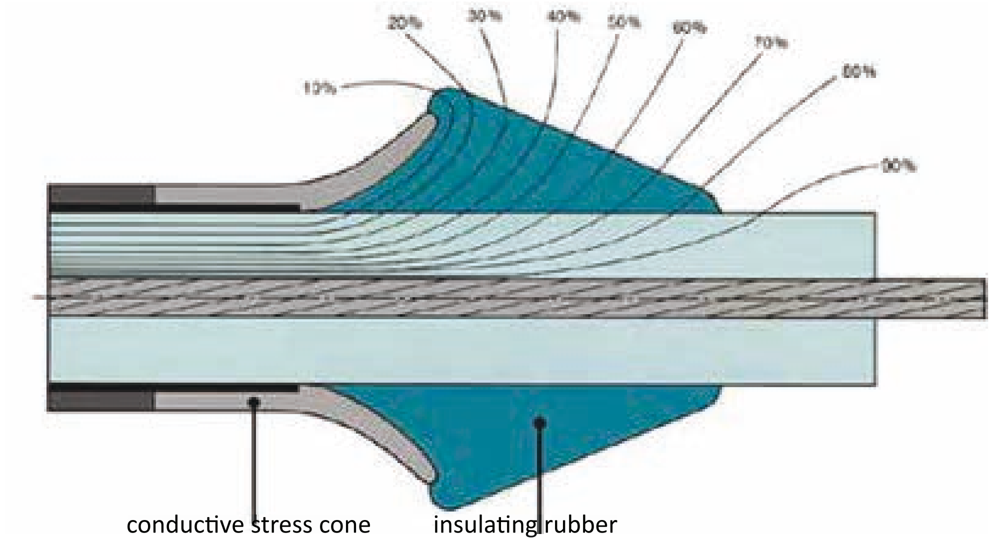

Figure 55 – Control of electric stress by a ‘stress cone’

The common alternative to a geometric stress cone is a layer of material with special electrical impedance characteristics. The stress control function will depend on the resistivity and/or high relative permittivity of the material but the result is similar to that of a stress cone, in that the electric field is graded along the length of the layer and the field strength at the screen edge is reduced. The material may have ‘non-linear’ resistivity properties similar to those of surge arresters.

Figure 56 illustrates this type of electrical stress control. The materials may be in the form of heat-shrink or cold-shrink tubings, mastics or hot-melt compounds.

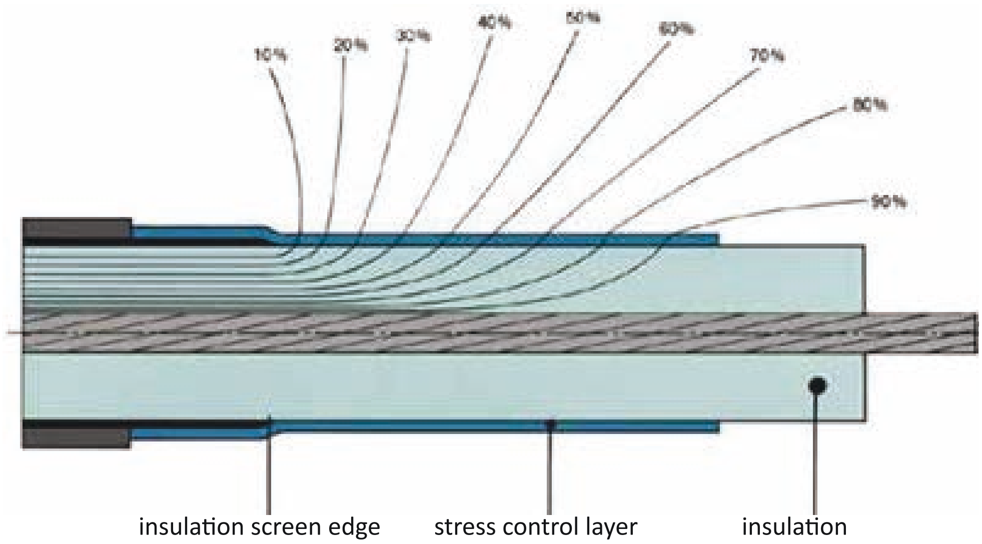

Figure 56 – Control of stress by a material layer with special electrical impedance characteristics

11.2 Partial discharges and their effects

Partial discharges are localised electrical breakdowns, typically occurring in small voids within insulation. When partial discharges happen in free air, for example on the surface of insulators, they are commonly called ‘corona’.

Partial discharges within the polymeric insulation of joints and terminations are likely to result in full breakdown of the accessory at some unpredictable time during service, depending on the size and number of the discharges and the progressive damage done by them.

Effective stress control components and their correct installation will reduce the likelihood of partial discharges occurring at working voltage or test voltages. The essential part to be played by the installer is to ensure that the accessory insulation is as void-free as possible, especially in high stress areas such as near the screen edge. **Best practice will involve close attention to the following.**

- **Ensuring that interfaces, such as those between layers of heat-shrink material, are clean and free from any contamination.**
- **Correctly positioning cold-shrink and push-on components that make contact with the screen edge.**
- **Applying adequate and uniform heating to heat-shrink components.**
- **Applying insulation or stress control tapes exactly as required in the installation instruction (tension, positioning etc).**

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