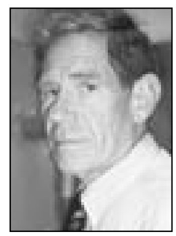
Medium-Voltage Cable Accessories



by Norman Poulter
Shrink Polymer Systems

Power cable installation throughout Europe and the UK until the early 60s exclusively used impregnated paper for the primary insulation of the conductors for both single- and three-core cables.

The UK adopted both aluminium- and lead-sheathed cables with and without steel wire armouring; these are still in use today. In the very early days of paper-insulated cable terminations, dry-type systems were employed along with compound-filled end box designs and cast-iron boxes with hot pour bitumen for joints.

Cold shrink products such as push-on, prestretched tube, and grease-applied slip-on types also became popular in the 1960s and are still specified by specific authorities.

In the early 1970s polymeric (XLPE) cable types began to emerge in Europe and the UK, mainly on three-core cables, while the USA employed the single-core concept at 10 kV, 20 kV, and 35 kV.

The heat shrink concept began to be employed at this period by the utility companies and has now spread internationally as the preferred method of terminating and jointing. There are many advantages of using heat shrinkable techniques, such as:

- There is a large shrink ratio, resulting in one kit assembly to cover numerous cable ranges.
- Heat concept dries out moisture.
- Mastic seals are activated by heat, so sealants are usually visible at sleeve ends.
- They are not size sensitive and can be used on sector-shaped conductors.

The manufacturers of shrink polymer systems also realised the importance of good jointing and terminating instructions. By using pictorial drawings with a minimum of text, non-English speaking countries can identify the important highlighted areas in an easily identified format. Failures are nearly always attributed to poor cable preparation and failure to observe the correct jointing procedures in the areas where the electric cable stresses are prudent.

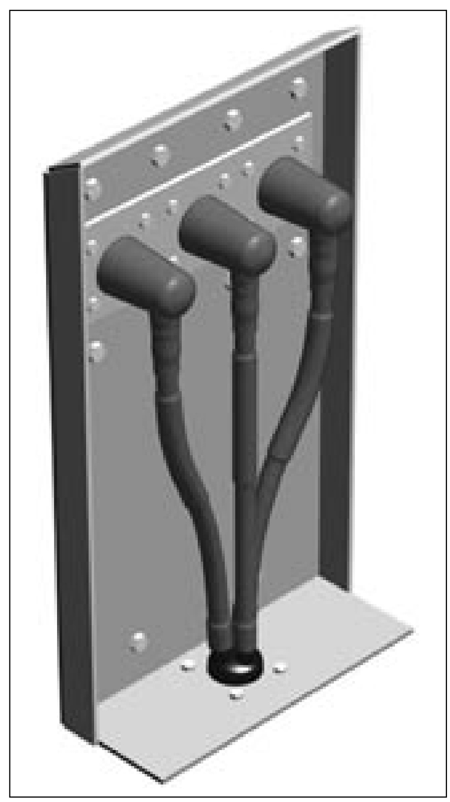


Figure 1

Although the USA shares a language with the UK, there are many differences in the selection of words to describe various things. Below is a list of some terms used in Mr. Poulter's article and the common equivalent used in the United States.

Editor

Core	Conductor
Screen	Shield
Joints, jointing	Splice, splicing
Cable jointers	Cable splicers
Earth, earthing	Ground, grounding
Armour support	Reinforcing
Metal sheaths	Armour
Self-amalgamating	Self-fusing

Terminations

The major switchgear/transformer manufacturers have, for many years, designed dry-air filled boxes, resulting in a much greater demand for shrink-on terminations.

All terminations and joints have to be tested to various international standards, and while cables prepared by experts in perfect laboratory conditions will undoubtedly meet these requirements under test, field experience shows that failures still occur at working voltage due to a variety of reasons.

Typical list of Weakness Resulting in Failures

- Compression lugs fitted to outdoor terminations of the compression tube type with inspection holes allowing moisture to penetrate the conductor cores.
- Failure to eliminate air pockets on paper-insulated, lead covered (PILC) three-core "belted" cables in the crotch area.
- Core crossing resulting in discharge if cores are too close to each other in an unscreened area at the core cross point. This results in the air "breaking down" electrically at approximately 4 kV on an 11 kV cable, 6 kV on a 24 kV cable, and 9 kV on 36 kV cable. The antitrack shrink material then begins to erode due to the ionisation of the air, which over time will inevitably cause failure of the termination.
- Poor cable preparation, in particular on extruded dielectric types where insufficient care is taken on semiconductive screen removal at the crucial area of the screen cutoff. Cable jointers are generally reluctant to purchase engineered screen removal tools and rely on knives, blades, and homemade tools for removal. This can result in cutting through the screen and into the primary insulation, leaving voids which result in the discharge phenomena described in the third item above. Even well-prepared screen removal at the cutoff point can result in a possible void, as the stress control tube may not follow the semiconductive edge profile. (See figure 2.)

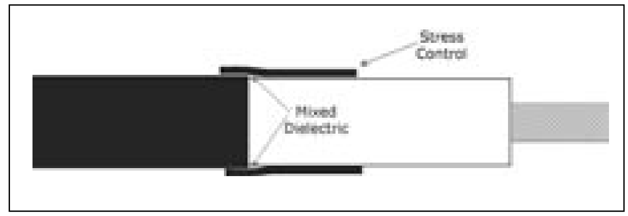


Figure 2

- Moisture penetration due to poor sealing techniques.
- Inadequate phase-to-phase and phase-to-earth clearance.
- Tracking
- Poor jointing instructions.

There are solutions and remedies to these weaknesses which will be described later in the article.

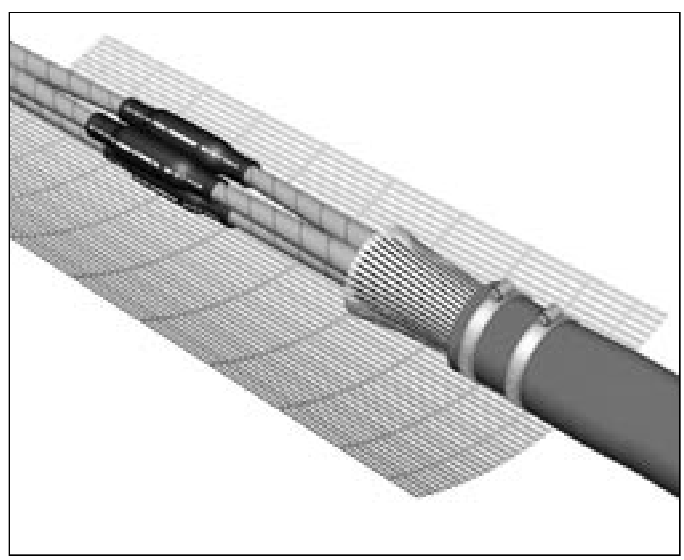


Figure 3

Joints

Many of the points discussed regarding terminations are also relevant to joints. The object of the jointing exercise is to replace all the materials that were removed to joint the conductors and replace them in such a way as to replicate the cable as closely as possible to its original state.

There are many techniques used in conductor jointing from "sweating" the weak-back ferrule (normally associated with the original cast iron paper joints) to compression and the present popular "shear bolt" designs. Connector jointing is a complex subject due to the variety of designs for copper and aluminium conductors in circular-solid, circular-stranded, and sector-shaped styles.

There is also the consideration of copper being jointed to aluminium, cables of unequal cross sectional area being jointed to themselves, and transition jointing where paper is being jointed to polymeric.

Let's look at some of these designs.

Compression Connections

There are a substantial number of manufacturers who claim suitability of their design for voltages up to 36 kV. Caution is needed if the body of the barrel is not smooth and does not have tapered ends. Also, responsible connector manufacturers will be able to manufacture appropriate compression tooling for their designs or confirm the compatibility of other tooling and die combination for their connectors. There are three types of crimp configurations currently in use: hexagonal, oval, and indent.

Oval and hexagonal crimping can leave sharp "ears" if incompatible tooling is used. These "ears" must be filed smooth to avoid a highly stressed area which will be subjected to electrical discharge. Indent crimping will leave void holes which must be filled with high permittivity, stress relief tape.

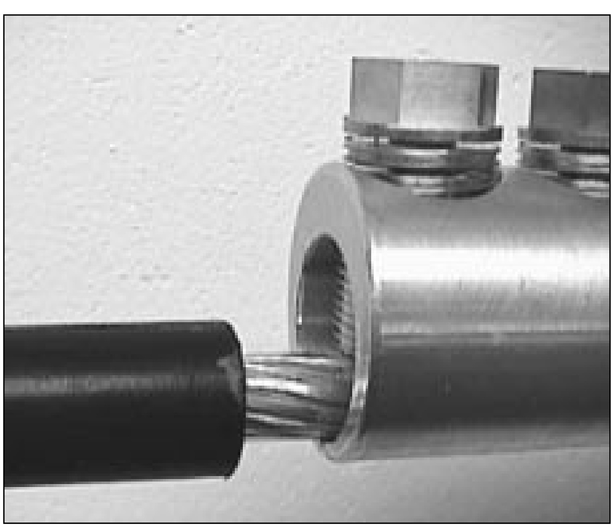


Figure 4

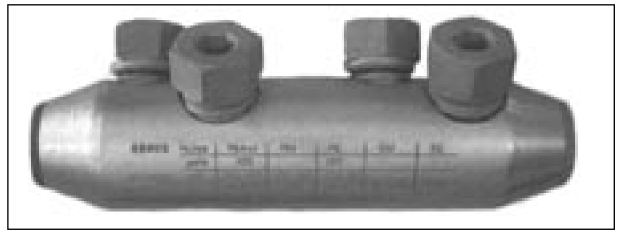


Figure 5

Mechanical Connections

Split types are now very popular in the UK, as this design comes in two halves which are easy to apply to three-core cables where the conductors do not have to be bent. The heads shear off at a given torque; therefore, no compression tooling or die combinations are necessary. As this connector is "blocked," it is also suitable for transition jointing for paper to plastic to stop the migration of the paper oils. There are several disadvantages of this type of connector, however.

The ends of connector are nontapered, resulting in high "step downs", and the conductor insertion is noncentralised. (See figure 4.) These two conditions result in areas of high electrical stresses leading to probable discharge. Shrink polymer systems have now standardised on a shearbolt connector design where these critical areas of high stresses are removed by tapering the ends and centralising the conductor. (See figure 5.)

Stress-Relieving Tapes

This type of tape generally has permittivity values between seven and 13 (test method IEC 250). (See figure 6.) This does not necessarily mean that a value of 13 will perform better than a value of seven, as void-filling characteristics are equally as important. Shrink polymer systems have a yellow stress control tape, reference number TS 31785Y, which possesses high tack, high stretch, and low viscosity void-filling qualities with a permittivity value of minimum nine. Whichever type of connector is selected, stress-relieving tape must be used in conjunction with heat shrinkable installations. This is applied in a half width overlap with stretch and must also be applied to any indents left by the tooling. Gaps between end of primary insulation and connector must also be filled in.

Push-on molded components are also widely used, eliminating the need to fill voids and use stress tapes. They rely on the faraday cage principle, in which conductive rubber-ribbed moldings are in contact with the connector. As the potential difference across the air is very low, discharge should not occur. Push- on molded components have several disadvantages, however. On three-core cables the molded components prove to be very bulky and have no design features to eliminate moisture penetration unless used in conjunction with large diameter shells and resins. On large aluminium conductor sizes the ferrule could possibly be longer than the moulded component. The positioning over the ferrule is critical.

Stress Control Tubing

Shrink polymer systems employ the heat shrinkable, high permittivity, and low resistivity stress control tubing which is shrunk onto the stress relief tape previously applied. This has the effect of achieving a more uniform distribution of the field lines. This tube extends over the ferrule and onto the prepared screen cutoff points. (See figure 2.)

Figure 6

Insulation Thickness

When designing jointing systems, the thickness of the insulation over the bare conductor (i.e., ferrule) should have a safety factor in excess of 15 percent of the original cable. Shrink polymer systems employ a one-piece, combined dual wall (insulation/ semiconductive) tube of appropriate diameter to match this insulation at voltages to 12 kV. At 17.5, 24, and 36 kV additional insulation tubes are added to meet these cable specifications The installer must remember to shrink this material all around the tube to avoid inconsistent wall thicknesses on full recovery.

Typical List of Weaknesses Resulting in Failures

- Incorrect crimping of connector.
- Air trapped in connector (if indent crimps not filled).

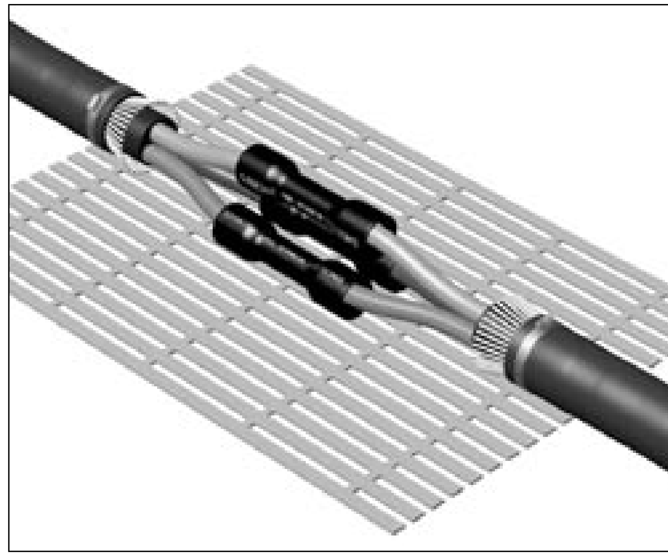


Figure 7

- Air trapped between end of insulation and end of connector.
- Discharge at screen ends caused by poor stress tape application or cuts to primary insulation.
- Moisture ingress entering cable sheathing through poor sealing.
- Inadequate insulation levels over connector.
- Poor jointing instructions.

The solutions and remedies to these weaknesses are described below.

Earthing Terminations

Earthing must be provided to carry any circulating currents to core screens, metal sheaths, and armour wires. It must also have the ability to carry fault current. On indoor terminations the use of tin plated copper, solder-blocked braids, metal canisters, armour support, clamps, and a complete corrosion protection system should be employed.

Earthing Joints

Connecting the earthing components across a joint requires correctly choosing and fitting the components to take care of both circulating currents and the short-circuit requirements. The outer semiconducting layer of the core/connector insulation should be wrapped in a tin copper mesh bandage and connected to the cable earth at each end. There are a great many variations and earthing complexities and such a wide variety of cable types to consider. Once a cable type, size, and voltage are specified it should be left to the manufacturer to supply the correct type of earthing system to meet both the national and local standards.

Remedies and Solutions to Overcome Termination Failures

- Always use one-piece solid lugs for outdoor termination, not squashed tube type.

- Wrap butyl self-amalgamating tape around crotch and under lead cut on three-core belted cables to eliminate air.

Check clearance dimensions on three-core cables.

- Care must be taken in semiconductive screen removal not to nick the primary insulation at the screen cutoff point.

- Ensure that all mastic seals are in place on bushing protection boots, rain sheds, and core tubes.

Remedies and Solutions to Overcome Joint Failures

- Ensure connector is free from "burrs," sharp points, not squashed tube type.

- Fill in all gaps with stress tapes before applying stress control tubing.

- Ensure correct application of stress tape at screen cutoff points. (See figure 2.)

- Fit all seals as supplied, in particular at crotch area, under armour beddings and end of connector insulations.

Jointing and Terminating Instructions

It is the responsibility of cable accessory manufacturers to supply easy-to-read, simplified, pictorial jointing instructions and to avoid heavy reading of text manuals. This point cannot be overstated, as, in the writer's opinion, far too many jointing instructions are not read or understood, resulting in the installer compromising on the areas of importance previously mentioned. This all too often results in that first failure.

Norman Poulter has over 38 years' experience in cable connecting devices, including 14 years with AMP, 12 as General Sales Manager UK with the Sigmaform company, and, from 1990 through present, as senior partner with Shrink Polymer Systems. www.shrinkpolymersystems.co.uk