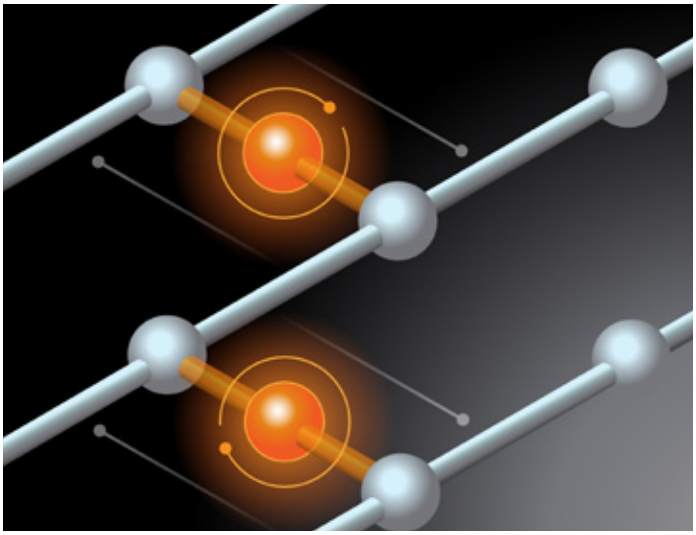
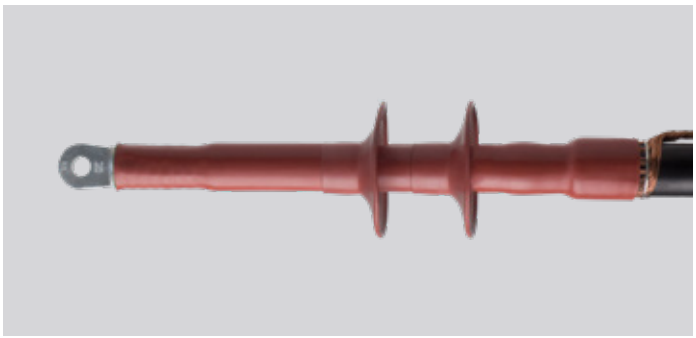
HEAT SHRINK TECHNOLOGY — MAKING ELECTRICAL CONNECTIONS MORE RELIABLE

BASED ON SPECIALLY FORMULATED, CROSS-LINKED THERMOPLASTIC POLYMERS, HEAT SHRINK TUBING AND COMPONENTS CONFORM TIGHTLY TO THE UNDERLYING SUBSTRATE ONCE INSTALLED. AVAILABLE AS TUBING, JOINTS/SPLICES AND TERMINATIONS, HEAT SHRINK PRODUCTS CONNECT, SEAL AND INSULATE ELECTRICAL CABLES AND COMPONENTS, PROTECTING THEM FROM MECHANICAL, FIRE AND CORROSION DAMAGE WHILE ENSURING RELIABLE SERVICE, REDUCED MAINTENANCE AND DOWNTIME.

Dr. Frank Drumm, Senior Director Product Management, Cable Accessories, TE Connectivity (TE)



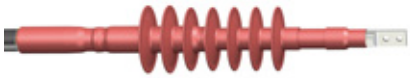


ABSTRACT

For owners and operators of electrical infrastructure systems related to power transmission and distribution, industrial, municipal and military operations, power-generation and distribution systems, wind and solar farms, marine and offshore applications and more, the need to safeguard all electrical cables and their connections and terminations is Job 1. In any electrical network, connections between adjoining electrical cables and between cables and mechanical equipment are always the weakest link.

Such connections can fail for any number of reasons, including poor material or design choices, aging, installation errors and more. During the decades in which such above- and below-ground installations are in service, periodic repairs, upgrades and capacity expansions are routinely carried out to ensure ongoing service and meet growing demand.

EPKT TERMINATION



OHVT TERMINATION

MSXU JOINT/SPLICE

By selecting state-of-the-art engineered components and partnering with a supplier that has a proven track record of success, system operators can invest in upgrades that will pay dividends over time. Specifically, investment in such strategic engineering upgrades can make all the difference between operating reliably as required and experiencing unplanned and unacceptable downtime and service interruptions — some of which could have catastrophic consequences. Strategic investments in the components discussed in this white paper can provide long-term financial savings (and help to avoid negative financial impacts and operational risk).

Meanwhile, proper investment can maximize electric grid reliability and minimize unplanned downtime. This helps business owners and operators to avoid potential penalties and litigation that may be associated with downtime in critical operations.

Similarly, proper investment in heat shrink tubing and components to fortify any electrical infrastructure can help to reduce the total cost of ownership through improved lifecycle cost savings, reduced maintenance needs and lower failure rates. This is especially important for components installed in remote locations and hard-to-reach places (such as underground).

Ideally, when selecting a vendor, owners and operators of electrical assets should look for one that offers:

- A broad and diverse product portfolio
- A deep bench of experience in material science and polymer formulation, cross-linking capabilities, and manufacturing expertise
- A proven track record in various environments and applications
- Strong capabilities in both customer service and the training and certification of field personnel who will install the components in the field

TE Connectivity (TE): Offering Broad and Deep Experience

TE Connectivity's vast portfolio of engineered heat shrink tubing, molded parts and engineered components to safeguard electrical cables and components are manufactured from cross-linked Raychem thermoplastics, which have been leading the market in performance for more than 60 years.

Raychem was the originator of the initial patents related to heat shrink technology. (SIDEBAR 1).

When they are specially formulated using a proprietary blend of chemical additives, these high-performance polymers are able to display functional attributes that are essential to safeguard critical electrical assets and infrastructure. For instance, Raychem thermoplastics can be formulated to deliver improved resistance to mechanical damage and corrosion, increased flame retardancy and fire resistance, radiation resistance for nuclear environments and more.

With the benefit of its broad expertise in both polymer formulation and cross-linking technology that is a key enabling technology for the heat shrink concept, TE Connectivity manufactures components in many shapes and sizes. Its engineered products can be purchased off-the-shelf, or customized options can be developed to meet site specific-needs and constraints.

Today, the range of insulating tubes, sleeves, molded parts and other components that are available to connect and terminate electrical cables and components fall into two general categories — cold-shrink and heat shrink components. Both cold-shrink and heat shrink components have their own strengths and weaknesses, and each plays a role in the universe of options. The cold-shrink technology is discussed in (SIDEBAR 2 ~ PAGE 12).

Paul Cook: The founder of Raychem thermoplastics

Paul Maxwell Cook was a chemical engineer who is credited with many of the pioneering breakthroughs first developed and patented by Raychem (and advanced by TE Connectivity). He also had a hand in the development of heat shrink technology and the crosslinking process that is a fundamental part of it.

Cook graduated from Massachusetts Institute of Technology (MIT) in 1947 with a degree in chemical engineering and began his career as a chemical engineer at SRI International (Menlo Park, California). In 1957, Cook founded Raychem to enable the development and commercialization of applications that would take advantage of a new field — radiation chemistry.

He served as the Chief Executive of the company until 1990. He became Chairman of Raychem's Board of Directors in 1990 and remained on the Board until 1995. During Cook's long tenure with Raychem (later TE Connectivity), the company created more than 200,000 products.

In addition to his many contributions to Raychem's success and to the fields of chemical engineering and material science, Cook received broad professional recognition for his contributions to the field. Among his many career highlights, Cook was:

- Elected to the National Academy of Engineering in 1985
- Elected to the American Academy of Science in 1990
- One of ten Americans to receive the National Medal of Technology from President Ronald Reagan in 1988
- Recipient of the Winthrop-Sears Medal from the Chemical Industry Association in 1986
- Recipient of the Golden Omega Award for contributions to technical progress by the Electrical/Electronic Insulation Conference (EEIC) in 1989

Thanks to Cook's pioneering efforts more than a half century ago and his long-lasting legacy, the broad line of Raychem heat shrink products and other components remain a leading technology solution to protect, insulate and enhance electric wires, cables and components, and remain the leading technology for ensuring reliable connections and terminations in energy networks.

SIDEBAR 1

TE Connectivity's heat shrink tubing, joints/splices, terminations and other accessories are used in low-voltage (LV; <1,000V), medium-voltage (MV; >1,000 to ~52,000 V) and high-voltage (HV; >66,000 V) applications, to connect and terminate electrical cables, wires and connections.

For LV applications, heat shrink tubing and accessories are mainly used to provide electrical insulation and sealing against moisture ingress. For MV and HV applications, heat shrink tubing and accessories are also equipped with electrical stress control. For outdoor applications, the use of materials that are formulated to provide improved tracking and erosion resistant (TERT) capabilities allows them to be used reliably in harsh environments.

TE Connectivity's heat shrink tubing and accessories are available in a wide range of materials, colors, and sizes. Heat shrink tubing is delivered in forms such as spools, discrete lengths and cut pieces. These concepts and more are discussed in greater detail in this White Paper.

What's at stake for owners and operators

Because heat shrink tubing and components are manufactured from cross-linked thermoplastic polymers, they are able to operate reliably at elevated temperatures without risk of melting and are able to withstand a maximum temperature range of 150°C to 250°C, (302°F to 482°F). These premium components are especially well-suited to connect and terminate electric cables and components and ensure long-term system reliability — especially when the stakes are highest. Such applications include:

- Electrical-infrastructure systems in which there is little tolerance for downtime or service interruptions; these include electrical-transmission and distribution grids, power plants, electrical substations, solar and wind farms, hospitals, laboratories, water-treatment plants, universities, stadiums and more.

and

- Environments in which the components must perform reliably in the face of particularly harsh, highly polluted or contaminated operating conditions (such as oil-and-gas recovery systems, mining operations, petroleum refineries and petrochemical plants and other industrial facilities.

Heat shrink tubing and accessories are routinely used to insulate electric cable, to provide reliable terminations and to provide connections between cables and between cables and machinery.

Specifically, TE Connectivity's durable, reliable heat shrink components are able to meet these critical performance expectations:

- Ensure current-carrying capacity and desired electrical performance
- Provide electrical insulation
- Provide electrical stress control (to manage electrical stress and prevent tracking and erosion)
- Prevent potential oil leakage from oil-impregnated-paper cables (OIPC) —which is also called paper-insulated lead cable (PILC) — and avoid moisture ingress
- Provide desired screening and shielding
- Ensure fault-carrying capacity
- Guarantee earthing
- Provide sealing to prevent ingress of moisture and other fluids
- Provide protection against mechanical abrasion, impact damage, chemical abrasion and more
- Improve fire resistance and/or flame retardancy

This White Paper provides an in-depth discussion of the inherent advantages that result when heat shrink components and accessories are selected to terminate and connect electrical cables and connections, in an effort to maximize system reliability, reduce unplanned downtime, streamline field installation and simplify the management of spare parts inventories to support routine maintenance and operation.
With a focus on proper material selection and installation, the use of TE Connectivity heat shrink components intend to give system owners and operators peace of mind, and over the lifecycle of these installations, these premium products strive to pay for themselves, by stability, durability and dependability to perform over an expected service lifetime of 40+ years, in harsh climate conditions.

The broad family of heat shrink product offerings

Owners and operators of systems with complex electrical infrastructures need reliable, proven options to insulate components against heat and electric current, provide strain relief for connectors and joints/splices, and protect and seal electric cable, wiring and components against water ingress, exposure to chemicals and damage from abrasion or bending. Today, heat shrink tubing and components offers a versatile, reliable and cost-effective option to address all of these operational challenges.

In recent years, the development and commercialization of co-extruded and triple-extruded heat shrink components has created additional ways to combine form and function. Specifically, co-extruded heat shrink parts benefit from the marriage of two high-performance materials, by combining an outer heat shrink thermoplastic layer with an inner elastomeric material. Once the single co-extruded tube or part is installed, its inner layer conforms more reliably to irregular surface, while the outer heat shrink layer protects the underlying electrical cable or component from challenges present in the surrounding environment. Co-extruded and triple-extruded heat shrink components are discussed in greater detail on page 8.

Specific heat shrink product options that are available for MV applications include:

MV splices/joints

- All components to complete the splice/joint are available in one pre-engineered kit, which helps to streamline installation and reduce errors in the field
- Triple-extruded splice sleeves, which provide high recovery force for optimal interfacial pressure and visual indicators for safe installation
- Fewer components, which reduces installation time
- Enjoy a slim, space-saving profile
- Available for numerous cable types and applications

MV terminations

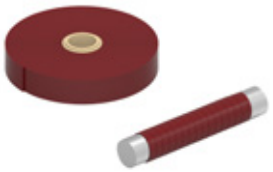
- These cable accessories provide an essential connection between MV electrical cables and transformers, air-insulated substations, overhead lines and busbars
- Co-extruded, one-piece termination provides built-in stress control
- Slim profile and lightweight
- Can be installed upright or inverted
- Non-tracking, maintenance-free material

Wraparound sleeves

- Tough, flexible general-purpose sleeves that provide a secure environmental seal
- Provide a permanent channel-locking system
- Includes integral heat-activated sealant coating
- Access to the cable end is not necessary
- Sleeves have been proven to provide insulation up to 2 kV, and can be used for rejacketing across the entire voltage range
- Available in sheet form, which can be coated on the inside with a heat-activated adhesive
- When wrapped around an assembly and heat shrunk, it conforms to irregularly shaped assemblies being repaired
- Fiberglass-reinforced thermoplastic sheets can provide reinforcement and additional mechanical strength and impact resistance

Tubing

- Heat shrink tubes for insulation and splicing, cable rejacketing, repair and busbar insulation
- Can be formulated to provide added resistance to chemical or mechanical damage (for instance, when electrical cables, harnesses, connections and terminations are dragged along the ground, flexed frequently and subjected to abrasion during installation)
- Sealant or non-sealant coated types available
- Available in thin-wall, medium-wall or heavy-wall configurations
- Nuclear-grade options (Class 1E Qualified)
- Flame-retardant, halogen-free, non-corrosive and lead-freeversions are available



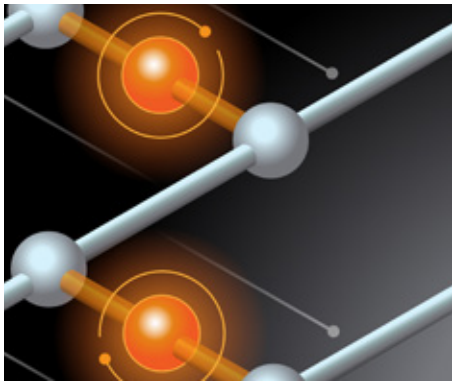
Tape

- Heat shrink, adhesive-coated tape is used to enhance insulation and flashover protection
- Relies on an anti-tracking material to minimize buildup of pollutants
- Suitable for indoor and outdoor use
- Versatile and flexible at extreme temperatures from -40°C to 90°C), (-40°F to 194°F).

With a high expansion ratio (typically three to four times the extruded diameter), heat shrink tubing and components can cover a wide range of applications. This makes it possible to repair and protect the most damaged cable jackets in the field (or in tight spaces) without removing the connectors.

In general, heat shrink tubes, connections and terminations provide a more reliable and cost-effective alternative — and more uniform and reliable performance over the lifetime of the installation — compared to taping, molding or potting.

Cross-linking the thermoplastic — The key enabling technology



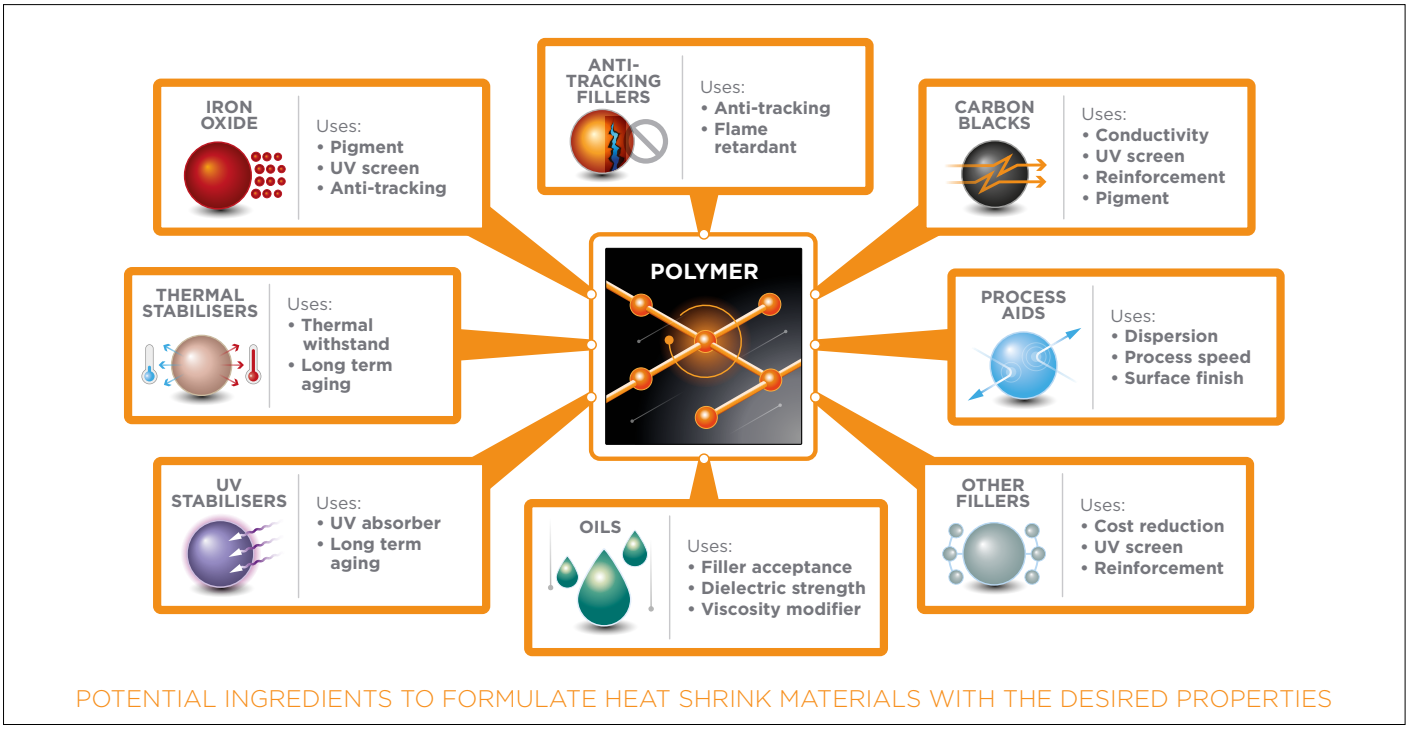
As noted, the ability to manufacture heat shrink tubing and components is predicated on a cross-linking process, which gives both the thermoplastic and the resulting manufactured part desired performance attributes.

Several steps are carried out during the production of the cross-linked thermoplastic and the manufacture of the heat shrink tubing and other components:

1. The formulated polymer is exposed to a high-energy electron beam, which causes permanent modification of the polymer structure via cross-linking.
2. During exposure to the high-energy electrons, hydrogen atoms are removed from the polyethylene chains, and new bonds form between carbon atoms in adjacent chains. Chemical cross-linking is an alternative method for molded components.
3. Once cross-linking is complete, the resulting material has lost its melting properties, so when it is exposed to temperatures above its crystalline melting point (typically ~120°C (248°F) for polyethylene), the cross-linked polymer will soften but not melt.
4. The cross-linked polymer is heated again, softened (without melting) and expanded to its supplied tubing dimension. Sheets and molded parts can be expanded into shapes that will remain intact, even when cooled again.
5. When the heat shrink tubing or components are installed in the field, a certified installation expert heats them using a gas torch. As the heat shrink component softens at elevated temperatures, it shrinks back to its pre-expanded dimensions, any co-extruded hot-melt sealant layer (or standalone sealant tapes) soften and flow into place, helping to anneal the heat shrink component tightly to the surface of the electrical cable or component, thereby creating a hermetic seal against moisture ingress, and a final product that accommodates cable bending, abrasion and vibration and will protect the underlying asset for the next several decades.

Sophisticated process controls are used during extrusion, cross-linking and expansion to ensure uniform wall thickness of the finished products before and after installation.

Today, the family of proprietary, precision-engineered polymers in the Raychem portfolio continues to grow. These exact amounts of chemical additives are blended into a polymer base in precise amounts, the resulting thermoplastics and manufactured parts demonstrates a range of valuable performance advantages.



POTENTIAL INGREDIENTS TO FORMULATE HEAT SHRINK MATERIALS WITH THE DESIRED PROPERTIES

FIGURE A

Heat shrink products help to streamline parts inventories

Interestingly, once heat shrink parts have been extruded, cross-linked, stretched into their desired expanded form and cooled again, they benefit from a "memory effect." This memory effect allows the parts to remain — intact and stable —in this expanded state indefinitely at ambient temperatures.

This gives heat shrink products unlimited shelf life under specific storage and warehouse conditions, without degradation or embrittlement. Decades-long shelf life is a valuable consideration for maintenance, repair and operations staff that need to maintain a stockpile of spare inventory to support routine and emergency maintenance and repairs.

By comparison, cold-shrink tubing and components that have been expanded to enable installation in the field (SIDEBAR 2 - PAGE 12) lose their tension and can become brittle over time if left on the shelf past their expiration date (which typically covers a span of 2–3 years). This more-limited shelf life creates inventory-management challenges for system owners and operators, who may need to closely manage and switch out inventories of cold-shrink components as they are reaching their expiration date. This is an important consideration for applications that are considering whether to use cold-shrink versus heat shrink technology options.

Heat shrink tubing options

When it comes to selecting heat shrink tubing, several categories are available. As the technology has continued to evolve over time, so has the performance of the resulting products.

Single-wall tubing

Single-wall, heat shrink tubing provides insulation, strain relief and protection of the underlying electric cable or component against chemical degradation, mechanical damage and abrasion, and outperforms taping and molding in place over the lifetime of the installation. This option is also widely used for noise reduction, identification and organization (for instance, for bundling wires or assembling cable harnesses).

This flexible, high-performance product has reliably consistent dimensions and physical properties, with shrink ratios from 2:1 to 4:1. Single-wall tubing can be formulated for increased flame retardancy. Flame-retardant types are offered in both standard and low-toxicity zero-halogen versions. Different formulations can be used to produce products that have improved stress control, tracking and erosion-resist, and oil-blocking properties. This is especially important in cable accessories and kits used for terminating and connecting cables.

Multi-layer tubing options

This option involves the use of multiple standalone tubing sleeves to achieve the desired level of functional performance. Specifically, several individual heat shrink tubes are layered consecutively over the electric cable. During installation, each tube is heated to shrink it in place separately before the next tube is added and heated.

When this approach is used, users are able to select the most optimal combination of tubes manufactured from different thermoplastics in order to confer the right mix of performance attributes. However, the need to heat shrink each tubing layer separately increases the cost of installation in terms of time and labor.

Co-extruded tubing options

By comparison, co-extruded heat shrink tubing also combines multiple layers for enhanced performance, but during manufacturing, the layers are co-extruded to produce a single integrated tubing product. This enables a one-step installation process, whereby the field technician is able to heat shrink the entire assembly in the field in one step, saving time and money and streamlining the overall process.

In recent years, TE Connectivity's family of co-extruded heat shrink tubes has grown to include not just dual-layer co-extruded tubing, but triple-layer extruded tubing, as well. Each is discussed next.

Dual-wall, co-extruded heat shrink tubing

Dual-wall heat shrink tubing is a co-extruded product that combines two layers of heat shrink thermoplastic, or an outer layer of heat shrink thermoplastic and an inner layer of hot-melt adhesive. Both layers have a role to play. When combining two layers of heat shrink polymer, the outer conductive layer acts as a kind of electrical screen while the inner layer provides insulation and can help to improve conformity to irregular surfaces. For instance, with co-extruded tubing that has an inner hot-melt adhesive, the inner face provides insulation and protection against the ingress of moisture and other corrosive agents. And the inner hot-melt adhesive can be enhanced with stress control fillers. The outer layer protects the entire assembly from mechanical and chemical attack.

When a heat source (typically a clean-burning gas torch or hot air gun) is used during installation, the inner adhesive layer melts and flows, conforming closely to the irregular surface of the electric cable or component, creating a hermetic seal against the ingress of moisture or other fluids. At the same time, the cross-linked outer layer shrinks in place to provide electrical insulation and mechanical protection.

The outer layer is formulated to provide added electrical resistance, UV resistance, tracking and erosion resistance (TERT) to resist the surface accumulation of pollutants in the field, improved flame resistance and fire retardancy and more. Dual-wall heat shrink tubing products offer shrink ratios ranging from 2:1 to 6:1.

Triple-layer, co-extruded heat shrink tubing

In the early 2000s, TE Connectivity added a triple-extruded tubing product (using three co-extruded layers) to its product portfolio:

- The inside layer consists of an elastomeric material (typically EPDM rubber), which, once the entire assembly has been shrunk to its final size, provides hermetic seal against the cable substrate. This layer provides insulation and prevents the ingress of moisture and other corrosive fluids.
- The middle layer consists of an insulating, heat shrink thermoplastic that can vary in thickness depending on the insulating voltage level.
- The outer layer consists of a conductive heat shrink thermoplastic, whose formulation can be precisely engineered to provide a combination of performance attributes that are dictated by site-specific requirements or constraints.

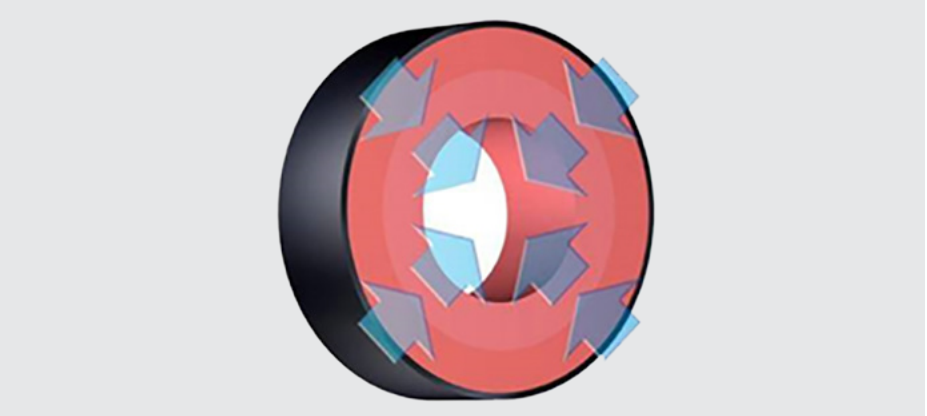


FIGURE B

During operation, electrical cable will experience a cyclic heating and cooling in response to rising and falling load on the network. In the face of the rising temperatures, the cable expands, yet the flexible inner elastomeric layer will retain its void-free hermetic seal against the cable surface, thanks for compressive forces exerted by the stiffer heat shrink layers that make up the outer layer of this co-extruded, multi-layer tubing.

Once the electric cable cools down (for instance, due to lower load in the network), the elastomeric layer is able to relax again and remains hermetically sealed to the cable the entire time. This guarantees optimal insulating behavior at the interface cable and reliable protection against the ingress of moisture or other corrosive agents.

The ability of the inner elastomeric layer to compress and relax, as needed, can also be an advantage for installations that involve joining two cables that have different cross-sectional diameters.

To ensure safe installation in the field, triple-layer co-extruded tubing is manufactured with longitudinal marks in its expanded state. These help to guide the installer, and is discussed in greater detail later on page 10.

Managing the electrical field distribution

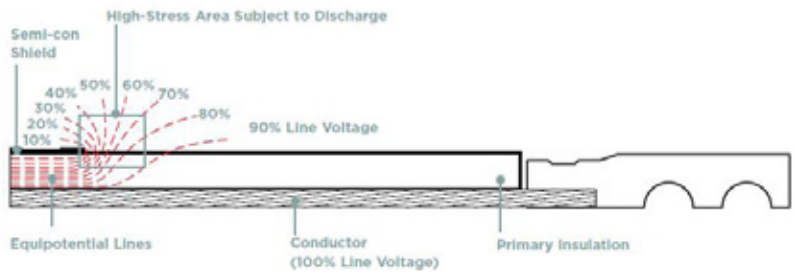
Due to the relatively high voltage and higher electrical field strength in medium-voltage cables (1,000–52,000 V), electrical stress control becomes an additional factor to consider when selecting heat shrink tubing to be installed in MV applications.

Polymeric MV electric cables are based on a coaxial structure, where the insulating layer is covered on both sides with semi-conductive layers to ensure proper radial electrical field distribution. When a cable accessory must be added in the field, the outer semi-conductive layer must be interrupted.

Untreated, this would result in a very inhomogeneous distribution of the electrical field, which, in particular, creates a very high electrical field strength at the end of the semi-conductive layer. As a result, partial discharges can occur in this area. These can lead over time to a failure of the cable accessories (these include a puncture of the cable insulation, flashover along the cable accessory and more).

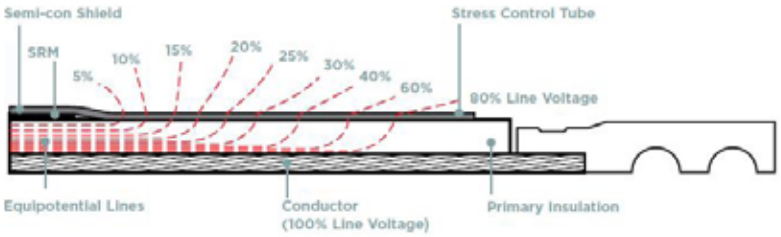
As such, the multilayer construction of a MV cable construction — which consists of a semi-conductive, insulating, semi-conductive, metal screen and outer insulating layer— need to be carefully connected in a similar way for when installing MV joints and splices. To reduce the electrical field strength along the joint area, so-called stress-control sleeves are applied.

They determine the maximum electrical field strength along the joint area. As shown in Figures C and D, this leads to an extraction of the equipotential lines along the joint area, which are perpendicular to the electrical field lines. This prevents electrical stress in the insulating material and potential discharges, which would lead to a failure of the product.



Equipotential lines that can occur in an electric cable without the use of a stress-control sleeve, leading to a less-homogeneous distribution of the electric field over the length of the cable.

FIGURE C



Equipotential lines that occur when a stress-control stress is used, allowing for more homogeneous distribution of the electrical field, as desired.

FIGURE D

The challenge of maintaining oil impregnated electrical cables

As noted, typical electrical infrastructure systems grow over time, with evolving technology options being added here and there, as they are commercialized. Such upgrades typically occur in piecemeal fashion, rather than as a large-scale replacement of an entire system. This creates challenges when it comes to installing reliable, seamless connections in the field between electric cables that have different cross-sectional diameters and use dissimilar or competing cable technologies.

For instance, historically, there has been broad reliance on the use of oil-impregnated-paper cables (OIPC), in combination with a lead cover known as paper-insulated lead covered cables (PILC).

For decades, OIPC/PILC cables have been widely used as the cable technology of choice to establish low, medium- and high-voltage networks underground. Existing networks often remain in service for 40 to 60 years. OIPC/PILC cables consist of multiple layers of oil-impregnated paper as insulating layer. The oil provides reliable insulating behavior, and prevents moisture ingress. In addition, these cables are valued for their “self-healing capabilities” in the field which gives them an extended life-time. Thus, rather than replacing enormous lengths of such cable, system operators tend to replace only individual segments of the cable at a time to rectify failures or address other operational needs.

To prevent the leakage of oil to the surrounding environment, OIPC/PILC electrical cables require hermetically sealed, heat shrink joints and terminations, and the potential for oil leakage over a service life that can last decades could rule out the use of cold-shrink terminations.

Meanwhile, the use of polymeric cables over OIPC/PILC cables has become the preferred norm in modern installations and upgrades. This newer technology option —which involves cables based on cross-linked polyethylene — now comprises the majority of newly installed network cables.

Nonetheless, all over the world, existing infrastructures rely on existing OIPC/PILC cables that are still in service (as they are typically expected to deliver decades of reliable service). And in some regions of the world, OIPC/PILC cables are still being used in the construction of new power-distribution networks. As a result, localized repairs and upgrades in the field are more challenging.

Installing hybrid connections

The ability to create reliable connections and transition joints to join older OIPC/PILC cable with newer polymeric cables in the field calls for specialized MV cable accessories. Heat shrink tubing and connections are ideally suited to meet this challenge. In particular, the proprietary thermoplastic can be specifically formulated to provide enhanced oil-barrier properties.

Special formulated oil-locking, heat shrink tubes can quasi-transform the paper cable into a polymeric cable when applied over the oil-paper impregnated cables. This heat shrink thermoplastic layer provides the required barrier properties to block both oil escape, while it creates a hermetic seal that prevent moisture ingress. An additional conductive heat shrink-tube acting as the semi-conductive layer completes this so-called quasi-transformation.

Once installed, these specialty products can help safeguard connections between OIPC/PILC and polymeric cables, ensuring reliable service for decades.

Proper installation is important — and straightforward

Proper installation is a major factor in ensuring the long-term performance of heat- shrink connections and terminations in order to optimize grid reliability. TE Connectivity works in several ways to ensure proper installation of its heat shrink tubing and components.

To streamline installation in the field and minimize errors, heat shrink tubing and cable accessories are supplied in pre-engineered kits.

Such kits typically include:

- High-performance, heat shrink components
- Ground braids that provide continuity across the splice
- Ground clamps or connectors that provide secure grounding without soldering
- Shielding mesh that surrounds the splice for personnel protection
- Shear bolt connectors for wide application ranges covering multiple conductor constructions

Use of visual indicators

In some cases, the heat shrink tubing itself can be manufactured with visual indications that help guide the field installer and ensure correct installation.

Use of shear bolt connectors and compression cable lugs

TE Connectivity's heat shrink tubing and accessories use shear bolt or compression connectors and lugs. These state-of-the-art mechanical connectors are designed to shear off at the right points. The benefit is that the system owner/operator does not need multiple connectors to install the heat shrink tubing; instead, installation technicians can use this single reliable mechanical connector.

Extensive training of field installation personnel.

TE Connectivity's training programs help stakeholders to meet the highest safety standards, maximize operational lifespan and minimize maintenance costs. The company trains 2,500 installers each year, to use the proper tools and techniques to install heat shrink cable accessories for medium voltage and high voltage installations. Recently the certification of installers has become a trend due to the reduction of installer skill levels across the globe.

Such training and certification is available:

- At five TE training centers in the U.S., China, France, Germany and Russia
- Through TE's distribution partners worldwide
- At the customer's training facilities or in the field at the installation site

Using heat shrink products to safeguard MV joints

The construction of a MV heat shrink joint is carried out in a way that allows each layer of the cable to be rebuilt over the joint area. Figure E shows a typical joint that would be used to create an inline splice for a polymeric cable.

FIGURE E. EXAMPLE OF AN INLINE HEAT SHRINK JOINT WITH A MECHANICAL CONNECTOR FOR A POLYMERIC CABLE.

As shown in the cross-section in Figure E, the inner core is the current-carrying metal conductor. Different cable conductor materials and shapes need to be taken into consideration during the design and manufacture of these MV connectors (for instance, aluminum versus copper, stranded versus solid versus round, and so on).

TE Connectivity's mechanical aluminum connectors with shear bolt technology have been a commonly used option over the past decades. The use of proven shear bolt technology prevents common installation errors that can arise when incorrect connectors are used in the field. This often happens when cable accessory kits do not include the appropriate connector.

Stress-control sleeves, together with void-filler mastic and a conductive patch around the connector, ensure a proper electrical field control for the heat shrink joint. The triple-extruded joint body completes the primary insulation. After completion of the metal screen continuity, the outer heat shrink tube will be applied to seal on both ends of the cable.

Once installed, this outer heat shrink tube is sealed on both ends with a mastic that avoids water ingress along both the interface cable lug / sleeve and on the cable side at the interface cable / sleeve.

MV terminations provide an essential connection between MV electrical cables and transformers, air-insulated substations, overhead lines and busbars. In addition to cable insulation and cable connections, TE Connectivity heat shrink product portfolio based on Raychem thermoplastic also includes a broad array of cable lugs and molded end caps that are used to terminate a cable end.

Key components are stress control sleeves with stress grading void fillers which are applied over the cutback area of the semi-conductive layer. The tracking and erosion resistant is applied over the entire configuration, with adhesive sealing applied over the Lug area and at the cable jacket end to prevent moisture ingress. For outdoor applications additional heat shrink sheds can be applied to extend the creepage distance, depending on the pollution level in the area of installation.

The earthing of the cable screen is accomplished by connecting the copper tape screen of the cable to a braided earth lead, and maintained by a constant force spring. A typical example of such a termination is shown in Figure F.

One alternative design option for the MV termination described above involves using a co-extruded design. The stress-control layer is integrated in the tracking and erosion-resistant, heat shrink outer sleeve. This construction, shown in Figure G, contains a hot-melt adhesive based on zinc-oxide (ZnO), which provides electrical stress control while also providing a hermetic seal to the cable lug and cable. This product requires fewer parts compared to the product shown in Figure F and acts similar like a surge arrestor during operation.

FIGURE F

FIGURE G

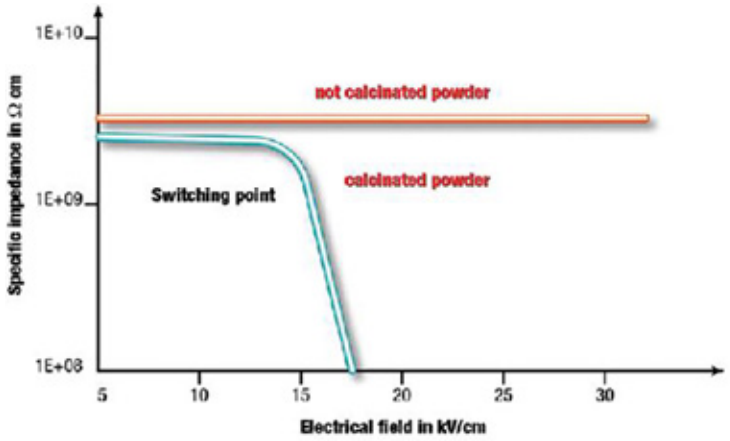


FIGURE H. CONSTRUCTION OF A MV HEAT SHRINK TERMINATION WITH SEPARATE STRESS CONTROL SLEEVE

Figure H. Shown here is an MV termination constructed by co-extruding an internal layer of ZnO hot-melt adhesive (for electrical stress control) with an outer heat shrink outer jacket of specially formulated Raychem thermoplastic.

The ZnO layer has a non-linear resistance characteristic and thus provides insulating behavior up to a certain electrical field strength or applied voltage, as shown. At a determined electrical field strength, the ZnO layer will demonstrate a conductive characteristic and create a voltage drop. A further increase of the applied voltage along the termination will lead to an increased area, where the stress control of the ZnO layer will become active. The maximum electrical field strength on the termination remains the same due to the switching characteristic, a phenomenon that is known from semiconductors.

Cold-shrink technology solutions

While the focus of this in-depth White Paper is on the many advantages of heat shrink technology and products, another option — cold-applied sleeves to protect electric cables and connections — offers a viable option for certain LV, MV and HV applications (up to 245 kV). TE Connectivity is one of the only global providers that produces a complete range of both heat shrink and cold-shrink technology solutions.

Cold-shrink sleeves are pre-expanded in the factory onto a temporary holdout, which allows them to be easily installed in the field. During installation, the holdout is removed and the pre-expanded sleeve recovers, creating a tight seal onto the cable substrate. The most common materials used to produce cold-shrink sleeves and terminations are flexible EPDM rubber and silicone rubber.

This one-piece component is designed to provide reliable product functionality, making it a convenient, affordable option for establishing cable joints in certain applications, especially environmental where the use of a gas torch is restricted due to fire or wildfire risk, as well as installations where there may be constricted physical spaces that would also limit torch use.

One downside associated with cold-shrink tubing and components is that pre-expanded parts can lose their tension and the elastomeric materials can become brittle over time. This gives them a more-limited shelf life, which can create inventory-management issues and challenges for system owners and operators, in terms of the need to closely manage inventories of cold-shrink product to support routine and emergency maintenance and repairs. Typically, cold-shrink components have a reliable shelf life of two to three years. This is an important consideration for applications that are considering whether to use cold-shrink versus heat shrink technology options.

SIDEBAR 2

Closing thoughts

Heat shrink tubing and cable accessories have been used successfully for more than 50 years, to safeguard the performance and reliability of low, medium- and high-voltage electric networks, in the face of challenging conditions across numerous industries.

TE Connectivity's product portfolio has been proven over decades of service and continues to grow to meet the demands of the market. Thanks to the long shelf life of these rugged heat shrink products, and the combination of mechanical (bolted) connectors and lug technology to simplify installation in the field, these essential cable accessories help to meet the challenges faced by today's industrial and utility owners and operators.

Up-front investment in these premium engineered components, based on state-of-the-art Raychem thermoplastic materials, can help provide demonstrable performance advantages and lifecycle cost savings compared to lower-cost options that may be available. The integration of functions into co-extruded and triple-extruded, heat shrink tubes, combined with indicators for safe installation, has significantly increased the reliability of these products.

Such savings result from reduced downtime, reduced expenditures related to maintenance, labor and inventory, and reduction of business risk associated with unplanned downtime (in terms of financial and legal penalties), potential safety issues associated with unplanned electrical outages and more.

Author

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