3M™ Cold Shrink Splices:

Splices to Fit All Electrical Cable Systems

Author: Bill Taylor, Retired 3M Product Development Engineer
Contact Person: Selvakumar, 3M Application Engineering Manager

September 2022

Abstract

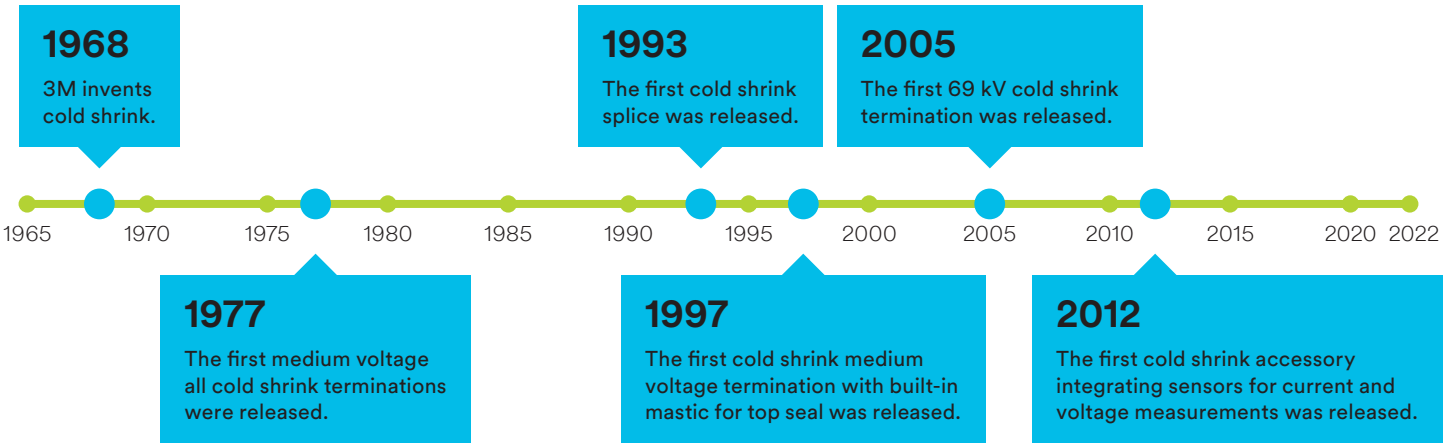
Unlike most splice manufacturers who design and provide one splice for all voltage classes and standards, 3M has many splices that can accommodate the different systems. This paper will discuss each splice in detail so you can choose what works best for your system and needs. Before we get into the specifics of each splice, let's spend a few minutes discussing splice designs and how they work.

Table of Contents

History of 3M™ Cold Shrink Technology

For over 50 years, professional electrical workers have trusted 3M for innovative solutions that enhance safety and productivity. That's why 3M invented cold shrink technology: a revolutionary alternative to traditional tape accessories and heat shrink cable joints and terminations. They can be installed in a fraction of the time, without the need for special equipment or permits.

Since inventing cold shrink with low voltage ethylene propylene diene monomer (EPDM) tubes in 1968 — more than 50 years ago — 3M has had many "firsts" in cold shrink development.



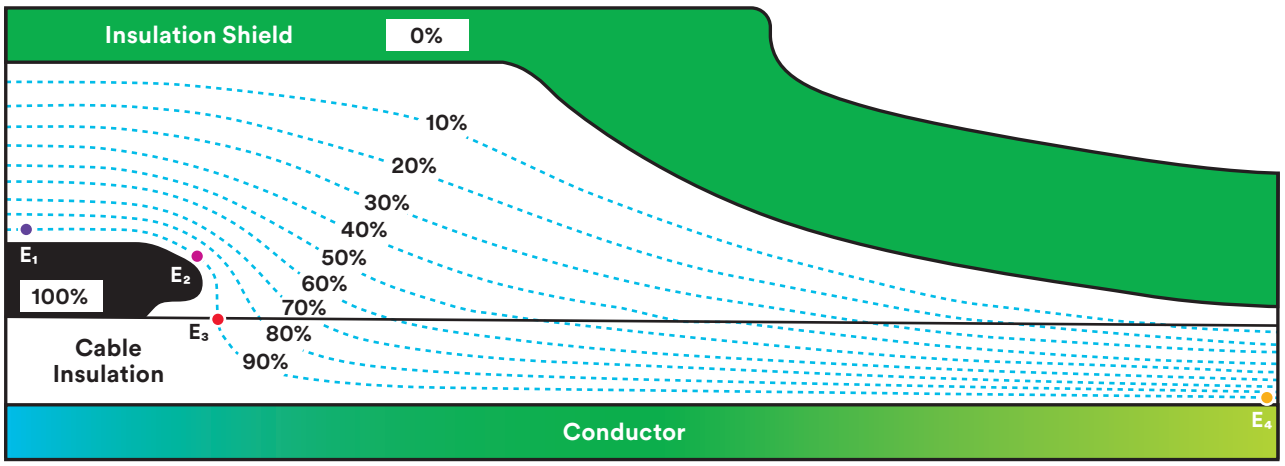
While there are now many companies that have cold shrink products, 3M's long, successful history and experience with cold shrink technology is very valuable when designing new products. Many of our medium voltage cold shrink products have been in service for more than 40 years. We have continuously improved our technology to offer cable accessories that are reliable, safe, and easy to install, with enhanced efficiency and excellent performance.

Many of our medium voltage cold shrink products have been in service for more than 40 years.

Splice Design Theory

The function of a splice is to channel the electrical stress from the cable into the splice and back into the cable so it can withstand surges and stresses without failing. Just as with terminations, the electrical stress at the semi-conductive step of each cable can be controlled with either geometric or high dielectric stress control. In addition to controlling the stress at the semi-conductive step, the air around the connector must be handled so it doesn't ionize from high electrical stress and cause a failure. **Figure 1** shows a splice that uses geometric stress control and regulates the air voids around the connector by using a Faraday cage.

Figure 1: Electrical stress plot of a 15 kV geometric splice



E_1 maximum stress over connector shield	31.1 V/mil
E_2 maximum stress at end of connector shield	36.3 V/mil
E_3 maximum stress along the interface	12.7 V/mil
E_4 maximum stress on the cable insulation	72 V/mil

The Faraday cage is a semi-conductive section of rubber that conducts voltage only (an electrode). It is in contact with the connector and is therefore at the same voltage as the conductor. There is now no potential difference between the conductor and the electrode, which means there is no potential difference across the air, so the air can't ionize and cause failures. All our splices use this Faraday cage for controlling the stress around the connector because we feel it performs the best and is the most reliable. The electrode in all our splices is designed with tolerances to cover the gap between the connector and cable insulation, connector growth from crimping, cable shrink-back over time, and to provide installation tolerance.

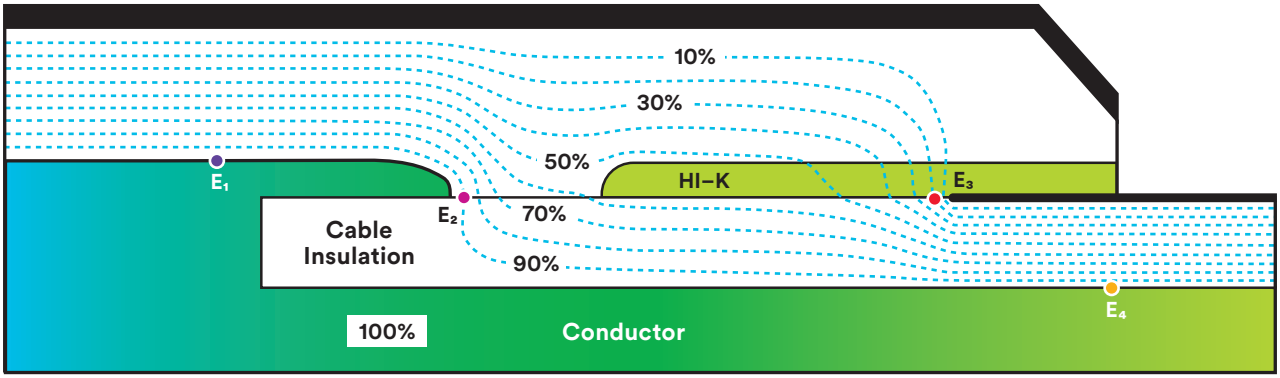
Learn more about nonlinear resistive stress control and why 3M's medium voltage cold shrink terminations use high dielectric stress control in the white paper: "The Benefits of Cold Shrink Technology vs. Heat Shrink Technology."[1]

1. "The Benefits of Cold Shrink Technology vs. Heat Shrink Technology" by Bill Taylor, 3M Retired and George Fofeldea, 3M.

Other splices control the stress in the air around the connector by filling the voids with mastic and covering the connector with high dielectric materials. This method also works, but all the air voids around the connector must be filled in so that none remain, which is more difficult and is the responsibility of the installer.

High dielectric stress control at the semi-conductive step also works very well. A stress plot of this method is shown in **Figure 2**.

Figure 2: Electrical stress plot of a 15 kV high dielectric splice



E_1 maximum stress over the connector shield	46.7 V/mil
E_2 maximum stress along the interface at end of connector shield	18.3 V/mil
E_3 maximum stress along the interface at end of cable insulation shield	7.8 V/mil
E_4 maximum stress in the cable insulation	72 V/mil

3M uses the high dielectric method in some splices and the geometric method in some splices. All splices must also have an insulation shield layer on the outside of the splice.

Important Considerations

Testing and Evaluation

Our splice designs are extensively tested and evaluated by 3M before they are released for sale. They are evaluated to the applicable International Electrotechnical Commission (IEC), European Committee for Electrotechnical Standardization (CENELEC), Institute of Electrical and Electronics Engineers (IEEE), or other standards and test reports that are available. Additional tests are also conducted, such as AC step-to-failure tests, to make sure that the splice design is robust and will provide excellent performance. All the following splices are designed to be installed between -20°C and 50°C and are cold shrink bodies and cold shrink rejacketing tubes. All the splice bodies are silicone rubber and all the rejacketing tubes are EPDM rubber, which provides excellent physical protection and an environmental seal to help keep moisture out of the splice cavity.

Cold Shrink Advantages

Most 3M™ Medium Voltage Cable Accessories are cold shrink because of the many advantages cold shrink has over heat shrink. Cold shrink accessories provide an inward pressure on the cable whereas heat shrink provides no inward pressure. This pressure provides better electrical performance.

Cold shrink products expand and contract with the cable as it goes through load cycles and thermally expands and contracts. Cold shrink accessories are also much easier to install and provide a more uniform installation than heat shrink products. All these advantages are explained in detail in the 3M white paper, “The Benefits of Cold Shrink Technology vs. Heat Shrink Technology.”[1]

Preparation and Training

While splice design plays an important role in splice reliability, there are other factors that are essential such as cable preparation and proper training. 3M offers training on why cable preparation is so important, the significance of all components in the splice kit, and on the best way to install accessories so they are reliable and have a long life.

Reliability and Consistency

To make sure the delivery system is as reliable as the product itself, 3M devotes time and research as well as extensive testing for core designs to make sure they will survive shipping and will install correctly. As splices have increased in size, we have developed cores that support these larger bodies and still install in a reliable and consistent manner.

Use of Proper Grease

Use only the grease supplied with the splice kits from 3M. Grease is a void filler and is specially designed so it won’t be absorbed into the splice. If silicone grease is used instead of the grease supplied with the kit, it will be absorbed into the splice body and there will be no filler at the semi-conductive step, which can lead to a failure. In an experiment, silicone grease was applied under a silicone splice body and the splice body was cut off 24 hours later. During that time, all the silicone grease had been absorbed into the body.

1. “The Benefits of Cold Shrink Technology vs. Heat Shrink Technology” by Bill Taylor, 3M Retired and George Fofeldea, 3M.

Featured Splices

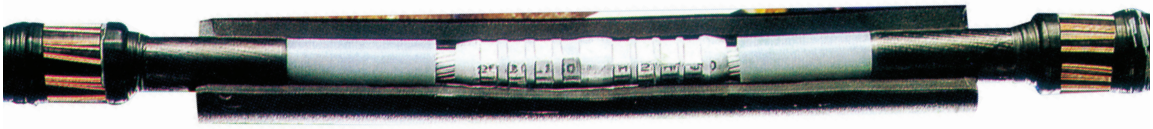
This paper only addresses inline splices that are used for extruded cables. There are kits for all types of metallic-shielded cables, including wire shield, tape shield, aluminum sheath, etc. Kits can also come with connectors, either compression or shearbolt. There are kits for three-core cables as well as single-core cables. All the medium voltage splices come in kits for single- or three-conductor applications. The following splices are described in more detail to help you understand the differences so you can choose the splices that are best for your applications.

3M™ Cold Shrink QS1000 Splice

The 3M QS1000 splice is used for 17.5 kV (max.) systems and below. The unique design performs very well at up to 17.5 kV, but not at higher voltages. **Figure 3** shows a cutaway of the splice.

17.5 kV system

Figure 3: Cutaway of 3M™ Cold Shrink QS1000 Splice body



As seen in **Figure 3**, the splice is one piece and has a molded electrode in the middle to control the air around the connector. The electrode length is designed to cover the maximum published length of connector associated with each body. It also has molded insulation and a molded insulation shield layer.

The unique part of this splice is that its insulation is a high dielectric constant material. This allows the insulation to control the electrical stress at the end of the cable insulation shield and also provide electrical insulation for the splice. This design allows for a shorter splice body, which is very important when used in a three-conductor splice kit. The design of this splice, with only the three integral components molded into it, provides a robust high-performing design at an economical cost.

Installation is simple as the kit comes with everything needed. The splice body, metallic sock, and rejacketing tubes are all parked on the cable after it is prepared. The conductors are joined with connectors, and the supplied grease needs to be applied as specified.

Once the void-filling grease is applied, the splice body is installed followed by the metallic sock and the rejacketing tubes. The metallic sock is connected to the cable metallic shield with constant force springs, which provide a quick and reliable connection with no soldering. In all cases, follow the instruction sheet with the exact instructions for the kit.

There are three different bodies and kits to fit all cable sizes from 70 to 400 mm^2 for 6.35/11(12) kV or 8.7/15(17.5) kV cables.

These splices meet and exceed all IEC and CENELEC standards.

The 3M QS1000 splices are 100% factory tested for partial discharge and AC withstand to ensure reliability.

3M™ Cold Shrink QS2000E Splice

This splice was released in 2007 and is a lower-cost reliable option for utilities. The splice has an excellent reliability record. The splice body is triple-extruded silicone with an outer semi-conductive layer, a middle insulation layer, and an inner high dielectric layer. The electrode is hand applied over the connector by installers. **Figure 4** shows the splice.

12 kV and 24 kV systems

Figure 4: 3M™ Cold Shrink QS2000E Splice

The high dielectric layer of the splice provides the electrical stress control needed at the end of the cable insulation shield. The high dielectric layer also lowers the electrical stress at the end of the electrode enough so that the end shape of the electrode doesn't matter. This allows the electrode to be installed in the field. This splice material also has good thermal conductivity, which helps dissipate heat away from the connector, so it runs cooler and helps extend the life of the system.

Since this is an extruded splice, it can be cut to any length. Leave it longer to accommodate longer connectors or cut to needed length for a repair splice. A long repair splice can be used to replace a failed splice with a longer connector. This longer splice body and connector allows the repair needed to replace the existing connector and damaged cable with one long splice — instead of two standard-length splices with a short piece of cable between them. This allows for only one set of cable preparations (two cable ends) instead of two sets (four cable ends), which reduces the installation time and the chance of errors.

Once the electrode is installed, it is critical that the grease provided with the kit be installed over the electrode, the cable insulation, and filling the step at the cable insulation shield. This grease is a void filler and very important to the performance of the splice. After the grease is applied, the splice body is installed, followed by the metallic shield sock and the rejacketing material. In all cases, follow the instructions that come with the kit being installed.

For 12 kV (max.) and 24 kV (max.) systems, there are splice body sizes to cover all conductors from 50 to 630 mm^2.

The 3M QS2000E splices meet and exceed all CENELEC and IEC standards. These splices are not 100% factory tested, but are approved by our rigorous 3M quality system.

3M™ Cold Shrink QS200 Splice

This splice has an excellent reliability record. The 24 kV splice has a triple-extruded splice body which includes the inner layer of high dielectric material, the middle insulation layer, and the outer layer being semi-conductive rubber. The 36 kV splice has a coextruded two layer construction (the high dielectric inner layer and the insulation layer). The outer semi-conductive layer for the 36 kV splice body is painted. This splice material has good thermal conductivity which helps dissipate heat away from the connector, so it runs cooler and helps extend the life of the system. The inner electrode is painted with semi-conductive paint that bonds to the silicone rubber. The electrode length covers a published maximum connector length. This splice has fewer steps than the 3M™ Cold Shrink QS2000E Splice because the electrode is incorporated into the splice body. **Figure 5** shows the 3M QS200 splice.

12 kV, 24 kV and 36 kV systems

Figure 5: 3M™ Cold Shrink QS200 Splice

Once the cable is prepared, it is critical to apply the grease included with the kit over the cable insulation and fill the step at the cable insulation shield. This grease is a void filler and very important to the performance of the splice. After the grease is applied, the splice body is installed, followed by the metallic shield sock and the rejacketing material. In all cases, follow the instructions that come with the kit.

For 12 kV (max.), 24 kV (max.) and 36 kV (max.) systems, there are splice bodies that cover all conductors from 50 to 1000 mm^2.

The 3M QS200 splices meet and exceed all CENELEC and IEC standards. These splices are not 100% factory tested, but are approved by our rigorous 3M quality system.

3M™ Cold Shrink QS200MB Splice

The 3M QS200MB splice uses the 3M™ Cold Shrink QS200 Splice body and makes installation even easier because the metallic shield and rejacketing materials are all incorporated onto the same core, making it virtually impossible to forget to park any components. Fewer components and steps mean reduced chances for error and a more reliable system. **Figure 6** shows the splice.

24 kV
system

Figure 6: 3M™ Cold Shrink QS200MB Splice

For this splice, each end of the cable is prepared, the body is parked on the cable and a connector is installed. Grease is applied to each cable and then the inner core is removed to install the splice. The metallic shield is then connected, and mastic is applied to the cable jackets as per the instructions. The rejacketing cores are then removed to install the rejacketing tube on each end and the splice installation is complete. In all cases, follow the instructions that come with the kit.

For 24 kV (max.) systems, there are splice bodies that cover all conductors from 50 to 630 mm^2.

The 3M QS200MB splices meet and exceed all CENELEC and IEC standards. These splices are not 100% factory tested, but are approved by our rigorous 3M quality system.

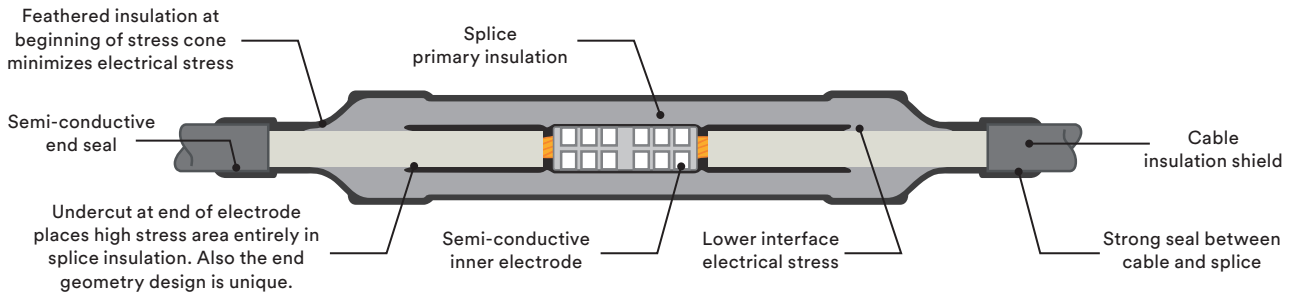
3M™ Cold Shrink QS-III Splice

The 3M QS-III splice line was designed and released in 1997 specifically for the North American market and has a very reliable record. The splice meets the IEEE-404 splice standard test requirements, which are more severe than the IEC and CENELEC standards, especially in the current cycle portion of the standards.

15 kV, 25/28 kV, 35 kV and 46 kV systems

The splice body is molded using silicone rubber. The inner electrode is molded and, for the 25, 35 and 46 kV bodies, has an end geometry that is initially molded into an elliptical shape, but when installed on the maximum size cable turns into a perfect round shape. The electrode length covers a published maximum connector length. The silicone insulation has an additive to make it more thermally conductive, so that heat will be dissipated away from the connector and the splice will pass the thermal cycling in IEEE-404. The insulation shield is also molded and extends beyond the insulation so it will land on the cable insulation shield and provide installation tolerance. **Figure 7** shows a cutaway of a 3M QS-III splice.

Figure 7: Cutaway of a 3M™ Cold Shrink QS-III Splice



Once the cable is prepared, it is critical that the grease provided with the kit be installed over the cable insulation and fill the step at the cable insulation shield. This grease is a void filler and very important to the performance of the splice. After the grease is applied, the splice body is installed, followed by the metallic shield sock and the rejacketing material. In all cases, follow the instructions that come with the kit.

There are four splice bodies each for 15 kV #2 AWG to 1000 kcmil (35 to 500 mm^2) and three for 25/28 kV #1 AWG to 1000 kcmil (50 to 500 mm^2) conductor sizes. There are two splice bodies for 35 kV #1/0 AWG to 1000 kcmil (60 to 500 mm^2) conductor sizes. There is one splice for 46 kV that covers conductor sizes #4/0 AWG to 1000 kcmil (120 to 500 mm^2).

The 3M QS-III splices pass all the IEEE and CENELEC standard requirements.

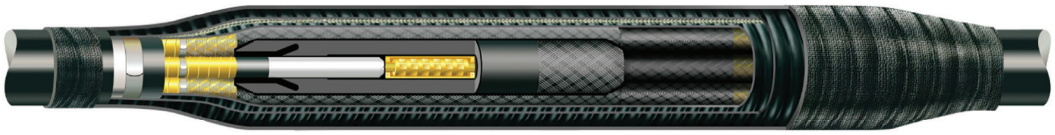
These splices are 100% factory tested for partial discharge and AC withstand to ensure reliability.

3M™ Cold Shrink QS3000 Splice

The 3M QS3000 splice meets the IEC standard and for IEC cables with a maximum system voltage of 72.5 kV. The body is molded with the inner electrode and geometric stress control elements designed to minimize electrical stress. The body exceeds the requirements of IEC-60840 standard. The splice design is robust for these voltages because reliability is of the utmost importance. The splice body is shown in **Figure 8**.

72.5 kV
system

Figure 8: 3M™ Cold Shrink QS3000 Splice



It is recommended, but not required, that a connector be supplied with the body. For this voltage level, the connectors are designed so that the outer diameter is very close to the outer diameter of the cable insulation, which helps to minimize the electrical stress.

The splice covers an application range of 150 to 1200 mm^2 and is used for cables with copper wire screen, copper wire screen with aluminum laminate, lead sheath, and aluminum tube sheath. The kits also come with a screen shield equivalent to either 50 mm^2 or 150 mm^2. If the cable has an aluminum wire screen, there is a supplementary kit for connecting the wires. The splice also has cold shrink EPDM rejacketing tubes. As with all splices, it is critical to follow the instruction sheet that comes with the kit.

These splices are 100% factory tested for partial discharge and AC withstand to ensure reliability.

Summary

Table 1, below, summarizes the splices discussed in this paper.

Key:

R = refractive
G = geometric

M = molded
E = extruded

P = painted
T = taped

3M™ Cold Shrink Splice	Stress Control	Electrode	Outer Layer	Splice Body	Max. Voltage (kV)	Type Tests
3M™ Cold Shrink QS1000 Splice	R	M	M/P	M	17.5	CENELEC HD629.1 S2 IEC 60502-4 GB/T 12706.4
3M™ Cold Shrink QS2000E Splice	R	T	E	E	24	CENELEC HD629.1 S2 IEC 60502-4 GB/T 12706.4
3M™ Cold Shrink QS200 Splice	R	P	M/P	E	36	CENELEC HD629.1 S2
3M™ Cold Shrink QS200MB Splice	R	P	E	E	24	CENELEC HD629.1 S2
3M™ Cold Shrink QS-III Splice	G	M	M	M	46	CENELEC HD629.1 S2 IEEE-404
3M™ Cold Shrink QS3000 Splice	G	M	M/P	M	72.5	CENELEC HD629.1 S2 IEC 60502-4 GB/T 12706.4

The power distribution systems in the U.S. and Europe are significantly different, which is why the standard requirements are also different. Reliable, easy-to-install splices for each system have been developed by 3M so you can obtain splices that help you meet all your needs and range from full-integrated splices to tape splices. Our product will arrive at the job site ready to be installed. Make sure to follow the instructions provided by 3M when installing the product.

Let us help you improve the dependability of your system with our training and reliable products.

3M™ Cold Shrink Shelf Life

3M states that all our cold shrink medium voltage accessories have a three-year shelf life, while most other medium voltage accessories have a two-year shelf life.

Shelf life, as it relates to cold shrink products, means that at the end of the shelf life the product is not guaranteed to shrink to the minimum published application diameter of the product.

Technical Information: The technical information, guidance, and other statements contained in this document or otherwise provided by 3M are based upon records, tests, or experience that 3M believes to be reliable, but the accuracy, completeness, and representative nature of such information is not guaranteed. Such information is intended for people with knowledge and technical skills sufficient to assess and apply their own informed judgment to the information. No license under any 3M or third party intellectual property rights is granted or implied with this information.

Product Selection and Use: Many factors beyond 3M's control and uniquely within user's knowledge and control can affect the use and performance of a 3M product in a particular application. As a result, customer is solely responsible for evaluating the product and determining whether it is appropriate and suitable for customer's application, including conducting a workplace hazard assessment and reviewing all applicable regulations and standards (e.g., OSHA, ANSI, etc.). Failure to properly evaluate, select, and use a 3M product in accordance with all applicable instructions and with appropriate safety equipment, or to meet all applicable safety regulations, may result in injury, sickness, death, and/or harm to property.

Warranty, Limited Remedy, and Disclaimer: Unless a different warranty is specifically stated on the applicable 3M product packaging or product literature (in which case such warranty governs), 3M warrants that each 3M product meets the applicable 3M product specification at the time 3M ships the product. 3M MAKES NO OTHER WARRANTIES OR CONDITIONS, EXPRESS OR IMPLIED, INCLUDING, BUT NOT LIMITED TO, ANY IMPLIED WARRANTY OR CONDITION OF MERCHANTABILITY, FITNESS FOR A PARTICULAR PURPOSE, OR ARISING OUT OF A COURSE OF DEALING, CUSTOM, OR USAGE OF TRADE. If a 3M product does not conform to this warranty, then the sole and exclusive remedy is, at 3M's option, replacement or repair of the 3M product or refund of the purchase price. Warranty claims must be made within one (1) year from the date of 3M's shipment.

Limitation of Liability: Except for the limited remedy stated above, and except to the extent prohibited by applicable law, 3M will not be liable for any loss or damage arising from or related to the 3M product, whether direct, indirect, special, incidental, or consequential (including, but not limited to, lost profits or business opportunity), regardless of the legal or equitable theory asserted, including, but not limited to, warranty, contract, negligence, or strict liability.

Disclaimer: 3M industrial and occupational products are intended, labeled, and packaged for sale to trained industrial and occupational customers for workplace use. Unless specifically stated otherwise on the applicable product packaging or literature, these products are not intended, labeled, or packaged for sale to or use by consumers (e.g., for home, personal, primary or secondary school, recreational/sporting, or other uses not described in the applicable product packaging or literature), and must be selected and used in compliance with applicable health and safety regulations and standards (e.g., U.S. OSHA, ANSI), as well as all product literature, user instructions, warnings, and limitations, and the user must take any action required under any recall, field action or other product use notice. Misuse of 3M industrial and occupational products may result in injury, sickness, or death. For help with product selection and use, consult your on-site safety professional, industrial hygienist, or other subject matter expert. For additional product information, visit www.3M.com.

Content Disclaimer: Bill Taylor, a former 3Mer and a member or officer of IEEE/PES/ICC, has participated and provided information in this white paper. Bill has also received compensation from 3M in connection with his participation and the information that he has provided herein.

Reference:

1. "The Benefits of Cold Shrink Technology vs. Heat Shrink Technology" by Bill Taylor, 3M Retired and George Fofeldea, 3M.

Electrical Markets Division
13011 McCallen Pass, Bldg. C
Austin, TX 78753 USA
800-200-0265
www.3M.com/coldshrink