3M

5600 and 5680 Series

Cold Shrink™
Silicone Rubber Termination Kits 15 kV–35 kV

Product Description

3M™ Cold Shrink™ 5600 and 5680 Series QT II Termination Kits contain one-piece silicone rubber terminations designed for concentric neutral (CN) cable. **They meet the requirements of IEEE 48-1990 for Class I terminations.** In addition, they meet German standard VDE 0278 parts 5 & 100, British standard BS C-89, Spanish standard UNE 21-115-75 and Brazilian standard A-B-N-T-9314. Similar terminations using Cold Shrink technology meet French EdF standards HN 33-E-01 and HN 41-E-01. Data on foreign standards are available upon request.

The 3M termination consists of a high dielectric constant (Hi-K) stress control tube insulated with a molded silicone skirted insulator. There is a four-skirt design rated 15 kV, six-skirt design rated 25/28 kV, and an eight-skirt design rated 35 kV. Cold Shrink QT II terminations are provided in an expanded state, mounted on a removable inner supporting plastic core. As supplied in this prestretched condition the termination is ready for field installation. During installation the core is unwound, allowing the termination to shrink and form a tight seal. Collectively, these termination kits accommodate cable primary insulation diameters from .632″ to 2.75″ (16–70 mm). These kits can be used to terminate the following concentric neutral (CN) power cables:

- #2 AWG to 1250 kcmil at 15 kV
- #2 AWG to 1500 kcmil at 25 kV
- #2 AWG to 2000 kcmil at 35 kV

Stress Control

The QT II controls the electric field stress distribution at the terminated cable insulation shield end with a special high dielectric constant (Hi-K) material which is an integral part of the termination assembly. The Hi-K material has a dielectric constant of about 25. By controlling the electrical field, the stress concentration in the applied termination materials, and at the air interface, is less than 15 volts/mil at rated voltage. In the shielded portion of 15 kV cable, stress concentrations typically vary from 50 volts/mil at the shield to about 70 volts/mil at the conductor. The stress level in the cable beneath an installed Cold Shrink QT II termination is less than it is in the shielded portion of the cable. Figure 1 illustrates an actual computerized stress plot of 3M's termination.

Cold Shrink Insulators

Cold Shrink QT II skirted insulator material is nontracking silicone rubber, which minimizes leakage currents in wetted conditions for three reasons:

1. The smooth surface of this silicone rubber insures that a minimum amount of contamination will adhere to the termination.
2. Silicone rubber has a hydrophobic surface. When water comes in contact with the silicone it beads up and runs off the skirts rather than completely wetting these surfaces. Thus a less conductive path is formed on the silicone and leakage currents are minimized.
3. When leakage currents do increase and arcing occurs on the surface, the ash formed by erosion of the silicone insulator is nonorganic or nonconductive. Continued degradation is thereby deterred.

Under heavy rain conditions, conventional skirted terminations with even-skirt diameter insulators tend to form drip paths or continuous water paths from insulator skirt tip to skirt tip. By comparison, 3M insulators are designed with unique, uneven skirt diameters. This feature allows water dripping from the upper skirt to fall free, avoiding the skirt to skirt conductive path that can develop with even-skirt diameter insulators. This design of the Cold Shrink QT II termination optimizes performance under heavy rain conditions.

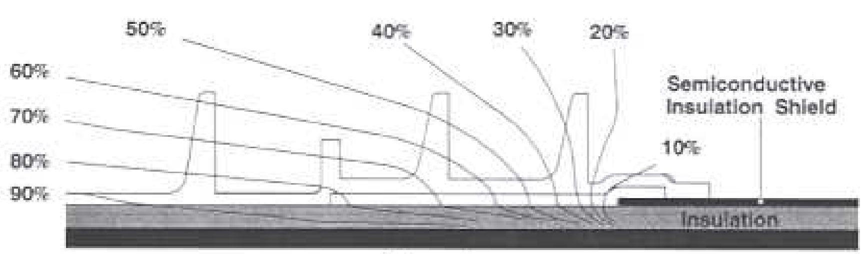


Figure 1

Kit Contents

Each kit contains sufficient quantities of the following materials to make one termination:

- 1 molded rubber silicone termination
- 1 packet of silicone grease
- 2 strips of Scotch™ 70 Silicone Rubber Tape
- Instructions

Applications

5600 and 5680 series Cold Shrink QT II silicone rubber terminations are used to terminate concentric neutral (CN) cables rated 15 kV, 25/28 kV, and 35 kV, having extruded, solid dielectric primary insulations of polyethylene (high and low density), cross-linked polyethylene (XLP) and ethylene propylene rubber (EPR). These terminations are lightweight for either free-hanging or bracket-mounting arrangements. They can be used in both protected and weather-exposed contaminated areas. The amount of airborne contamination determines the operating environment. Operating environments are described as areas having a varying degree of airborne contaminants or a pollution severity that may, or may not, effect the long-term performance of terminations. These operating environments are defined as light, medium, heavy, and extremely heavy variations in pollution severity. The appropriate termination selection depends on the system voltage and operating environment (see tables that follow).

Recommended Application Guide

Termination Kit	System Voltage	Operating Environment			
		Light	Medium	Heavy	Extremely Heavy
(Four Skirt) 5601–5603	15 kV	R	R	R	
(Six Skirt) 5681–5684	15 kV		R	R	R
(Eight Skirt) 5604–5608	15 kV			R	R
(Four Skirt) 5601–5603	25/28 kV	R			
(Six Skirt) 5681–5684	25/28 kV	R	R	R	
(Eight Skirt) 5604–5608	25/28 kV		R	R	R
(Four Skirt) 5601–5603	35 kV				
(Six Skirt) 5681–5684	35 kV	R			
(Eight Skirt) 5604–5608	35 kV	R	R	R	*

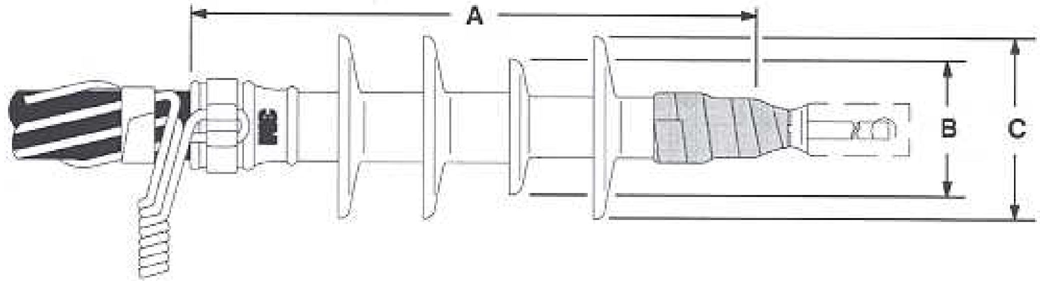
Notes:
1. Recommended operating environments are marked with an R.
2. See your 3M sales representative about environments marked with an *.

Pollution Severity Level Guide

Light*	Heavy
• Areas without industries and with low-density housing.	• High-density industrial areas and some urban areas with high-density housing, especially those with infrequent rainfall.
• Areas subjected to frequent winds and/or rainfall, areas with low-density industry and housing.	• Areas subjected to a moderate concentration of conductive dust, particularly industrial smoke-producing deposits.
• Agricultural areas. Note: Spraying fertilizer or burning crop residues can lead to a higher pollution level due to wind dispersal.	• Areas generally close to the coast and exposed to coastal spray or to strong winds carrying sand and salt, and subjected to regular condensation.
• Mountainous areas.	
Medium	**Extremely Heavy**
• Nonpolluting industrial areas subject to infrequent rainfall and/or with average-density housing.	• Usually very limited areas having extremely heavy pollutants from industrial sites, especially those located near oceans and subjected to prevailing winds from the sea.
• Areas subjected to frequent winds and/or rainfall with high- density industries and/or housing.	• Very small isolated areas where terminations are located immediately adjacent to a pollutant source, such as downwind from a cement plant or paper mill.
• Areas exposed to wind from the coast but generally over two miles from the coast.	

*All of the light pollution regions should be 7 to 15 miles from the coast and should not be exposed to coastal winds. The distance from the coast depends on the topography of the coastal area and on the extreme wind conditions.

Four-Skirt Termination



Typical Dimensions

Product Number	A	B	C	Creepage Distance	Arcing Distance
5601	8.50″ (max.) (216 mm)	1.67″ (42,4 mm)	2.68″ (68,1 mm)	13.75″ (max.) (349 mm)	9.00″ (max.) (229 mm)
5602	8.50″ (max.) (216 mm)	1.82″ (46,2 mm)	2.75″ (69,8 mm)	13.75″ (max.) (349 mm)	9.00″ (max.) (229 mm)
5603	9.50″ (max.) (241 mm)	2.00″ (50,8 mm)	3.25″ (82,6 mm)	15.75″ (max.) (400 mm)	10.00″ (max.) (254 mm)

Termination Selection Table

Product Number	Primary Insulation O.D. Range inches (mm)	Conductor Range (AWG / Kcmil)	
		15 kV	25 kV*
5601	.637 – 1.12 (16,2 – 28,4)	#4 Str or #2 Sol – 4/0	#2 Sol – 2/0
5602	.84 – 1.38 (21,3 – 35,0)	250 – 500	1/0 – 350
5603	1.08 – 1.80 (27,4 – 45,7)	500 – 1250	350 – 750

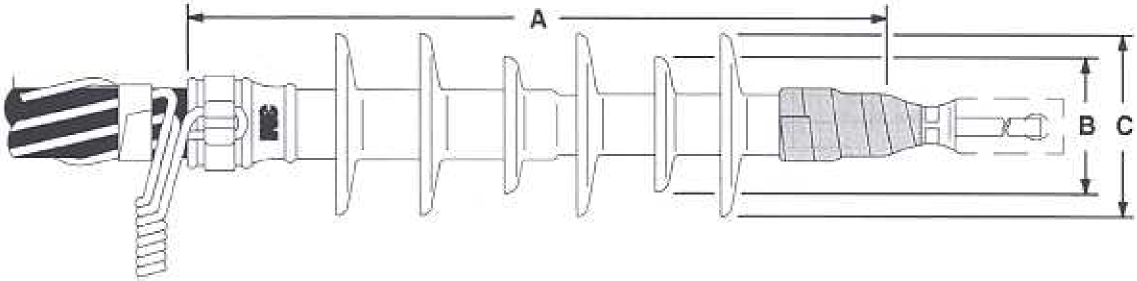
*See recommended application guide on page 2.

Typical Results per IEEE 48-1990 Tests

IEEE STD. 48 Test	15 kV Class		25 kV Class	
	Requirement	Results	Requirement	Results
60 sec. w/s ac	50 kV	70 kV*	65 kV	80 kV*
10 sec. w/s wet ac	45 kV	55 kV*	60 kV	65 kV*
6 hours w/s ac	35 kV	70 kV*	55 kV	75 kV*
Corona @ 3 pc. CSV	—	33 kV	—	36 kV
Corona @ 3 pc. CEV	13 kV	28 kV	21.5 kV	32 kV
15 min. w/s dc	75 kV	Pass 75 kV	105 kV	Pass 105 kV
Impulse w/s	110 kV	+145 kV* −130 kV*	150 kV	+160 kV* −145 kV*
30 day Cyclic Aging @ 130°C w/s ac	28.5 kV	Pass	48 kV	Pass
Corona @ 3 pc. CEV>	13 kV	Pass	21.5 kV	Pass
Impulse +10	+110 kV	Pass	+150 kV	Pass
Impulse −10	−110 kV	Pass	−150 kV	Pass

* At higher voltage, flashovers occur.

Six-Skirt Termination



Typical Dimensions

Product Number	A	B	C	Creepage Distance	Arcing Distance
5681	11.50" max.) (292 mm)	1.67" (42,4 mm)	2.68" (68,1 mm)	19.50" (max.) (495 mm)	12.00" (max.) (305 mm)
5682	11.50" (max.) (292 mm)	1.82" (46,2 mm)	2.75" (69,8 mm)	19.50" (max.) (495 mm)	12.00" (max.) (305 mm)
5683	13.00" (max.) (330 mm)	2.00" (50,8 mm)	3.25" (82,6 mm)	22.25" (max.) (565 mm)	13.50" (max.) (343 mm)
5684	13.25" (max.) (337 mm)	2.00" (50,8 mm)	3.55 " (90,2 mm)	22.50" (max.) (571 mm)	13.75" (max.) (349 mm)

Termination Selection Table

Product Number	Primary Insulation O.D. Range inches (mm)	Conductor Range (AWG / Kcmil)		
		15 kV*	25 kV	35 kV*
5681	.637 – 1.12 (16,2 – 28,4)	#2 – 4/0	#2 – 2/0	
5682	.84 – 1.38 (21,3 – 35,0)	250 – 500	1/0 – 350	#1 – 4/0
5683	1.08 – 1.80 (27,4 – 45,7)	500 – 1250	350 – 750	4/0 – 500
5684	1.31 – 2.10 (33,3 – 53,3)	1000 – 1750	750 – 1500	500 – 1250

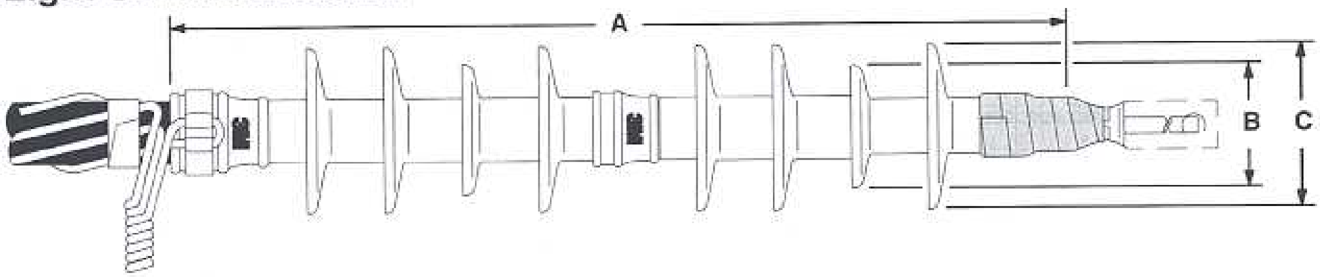
* See recommended application guide, on page 2.

Typical Results per IEEE 48-1990 Tests

IEEE STD. 48 Test	15 kV Class		25 kV Class †		35 kV Class †	
	Requirement	Results	Requirement	Results	Requirement	Results
60 sec. w/s ac	50 kV	90 kV*	65 kV	100 kV*	90 kV	110 kV*
10 sec. w/s wet ac	45 kV	60 kV*	60 kV	70 kV*	80 kV	80 kV*
6 hours w/s ac	35 kV	80 kV*	55 kV	90 kV*	75 kV	100 kV*
Corona @ 3 pc. CSV	—	33 kV	—	36 kV	—	41 kV
Corona @ 3 pc. CEV	13 kV	28 kV	21.5 kV	32 kV	30 kV	39 kV
15 min. w/s dc	75 kV	Pass 75 kV	105 kV	Pass 105 kV	140 kV	Pass 140 kV
Impulse w/s	110 kV	+175 kV* −165 kV*	150 kV	+185 kV* −170 kV*	200 kV	+200 kV* −185 kV*
30 day Cyclic Aging @ 130°C w/s ac	28.5 kV	Pass	48 kV	Pass	66 kV	Pass
Corona @ 3 pc. CEV>	13 kV	Pass	21.5 kV	Pass	30 kV	Pass
Impulse +10	+110 kV	Pass	+150 kV	Pass	+200 kV	Pass
Impulse −10	−110 kV	Pass	−150 kV	Pass	−200 kV	Pass

† 25 kV class QT II terminations will also meet prorated values for 28 kV rated systems.
* At higher voltage, flashovers occur.

Eight-Skirt Termination



Typical Dimensions

Product Number	A	B	C	Creepage Distance	Arcing Distance
5604	16.00″ (max.) (406 mm)	1.67″ (42,4 mm)	2.68″ (68,1 mm)	26.50″ (max.) (673 mm)	16.50″ (max.) (419 mm)
5605	16.00″ (max.) (406 mm)	1.82″ (46,2 mm)	2.75″ (69,8 mm)	26.50″ (max.) (673 mm)	16.50″ (max.) (419 mm)
5606	18.00″ (max.) (457 mm)	2.00″ (50,8 mm)	3.25″ (82,6 mm)	29.50″ (max.) (749 mm)	18.50″ (max.) (470 mm)
5607	18.25″ (max.) (464 mm)	2.00″ (50,8 mm)	3.55″ (90,2 mm)	29.75″ (max.) (756 mm)	18.75″ (max.) (476 mm)
5608	19.50″ (max.) (495 mm)	2.40″ (61,0 mm)	4.00″ (102 mm)	33.50″ (max.) (851 mm)	20.00″ (max.) (508 mm)

Termination Selection Table

Product Number	Primary Insulation O.D. Range inches (mm)	Conductor Range (AWG / Kcmil)		
		15 kV*	25 kV	35 kV*
5604	.637 – 1.12 (16,2 – 28,4)	#2 – 4/0	#2 – 2/0	
5605	.84 – 1.38 (21,3 – 35,0)	250 – 500	1/0 – 350	#1 – 4/0
5606	1.08 – 1.80 (27,4 – 45,7)	500 – 1250	350 – 750	4/0 – 500
5607	1.31 – 2.10 (33,3 – 53,3)	1000 – 1750	750 – 1500	500 – 1250
5608	1.80 – 2.75 (45,7 – 69,8)	1500 – 2000	750 – 1500	500 – 1250

* See recommended application guide on page 2.

Typical Results per IEEE 48-1990 Tests

IEEE STD. 48 Test	15 kV Class		25 kV Class		35 kV Class	
	Requirement	Results	Requirement	Results	Requirement	Results
60 sec. w/s ac	50 kV	100 kV*	65 kV	110 kV*	90 kV	120 kV*
10 sec. w/s wet ac	45 kV	65 kV*	60 kV	75 kV*	80 kV	90 kV*
6 hours w/s ac	35 kV	90 kV*	55 kV	100 kV*	75 kV	110 kV*
Corona @ 3 pc. CSV	—	33 kV	—	36 kV	—	41 kV
Corona @ 3 pc. CEV	13 kV	28 kV	21.5 kV	32 kV	30 kV	39 kV
15 min. w/s dc	75 kV	Pass 75 kV	105 kV	Pass 105 kV	140 kV	Pass 140 kV
Impulse w/s	110 kV	+200 kV* −190 kV*	150 kV	+220 kV* −205 kV*	200 kV	+240 kV* −230 kV*
30 day Cyclic Aging @ 130°C w/s ac	28.5 kV	Pass	48 kV	Pass	66 kV	Pass
Corona @ 3 pc. CEV>	13 kV	Pass	21.5 kV	Pass	30 kV	Pass
Impulse +10	+110 kV	Pass	+150 kV	Pass	+200 kV	Pass
Impulse −10	−110 kV	Pass	−150 kV	Pass	−200 kV	Pass

* At higher voltage, flashovers occur.

Physical and Electrical Properties

5600 and 5680 series Cold Shrink terminations can be used on cables with a rated maximum operating temperature of 90°C and an emergency overload rating of 130°C, (reference: AEIC CS5 and AEIC CS6). These kits meet requirements for a 15 kV, 25 kV, and 35 kV Class I termination in "IEEE Standard Test Procedures and Requirements for High-Voltage Cable Terminations" (IEEE 48-1990) (see Performance Tests). The current rating of the terminations meets and exceeds the current rating of the cables.

Silicone Rubber Insulator

Physical Properties	
Test Method	**Typical Value***
Color	**Munsel Gray**
Permanent Set 22 hours @ 212°F (100°C) 100% elongation 5 minute recovery	8%
Ultimate Tensile Strength (ASTM-D42-68)	1200 psi (8.28 MPa)
Electrical Properties	
Test Method	**Typical Value***
Dielectric Constant (K) (ASTM-D150-70) 73°F (23°C) 194°F (90°C) 266°F (130°C)	 3.4 3.0 2.7
Dissipation Factor (ASTM-D150-70) 73°F (23°C) 194°F (90°C) 266°F (130°C)	 4% 1.3% 1.2%
Dielectric Strength (ASTM-D149-70 75 mil (1.90 mm) gap	 507 V/mil (20 kV/mm)
Track Resistance (ASTM-2303-68) 2.5 kV, 10 k Ohms	 10 hrs

EPDM Rubber Hi-K Stress Control Tube

Physical Properties		
Test Method	**Typical Value***	
Permanent Set 22 hours @ 212°F (100°C) 100% elongation 5 minute recovery	18%	
Ultimate Tensile Strength (ASTM-D42-680)	1394 psi (9.6 MPa)	
Electrical Properties		
Test Method	**Typical Value***	
Dielectric Constant (K) (ASTM-D150-70) 60 Hz; @ 60% strain 73°F (23°C) 149°F (65°C) 194°F (90°C)	 @ 400 V 25.7 24.5 25.2	 @ 3 kV 28.8 27.2 27.7
vs. frequency @ 73°F (23°C) 150 Hz 1,000 Hz 10,000 Hz 100,000 Hz	 35 29 24 20	

EPDM Rubber Hi-K Stress Control Tube (Cont.)

Electrical Properties		
Test Method	**Typical Value***	
Dissipation Factor (ASTM-D150-70) 60 Hz; @ 60% strain 73°F (23°C) 149°F (65°C) 194°F (90°C)	 @ 400 V 0.096 0.093 0.132	 @ 3 kV 0.166 0.165 0.161
vs. frequency @ 73°F (23°C) 150 Hz 1,000 Hz 10,000 Hz 100,000 Hz	 0.16 0.15 0.14 0.12	

*Average values. Not intended for specification purposes.

Specifications

Open Specification

The cable termination must be a one-piece Cold Shrink 15 kV, 25 kV, or 35 kV class device and meet all 15 kV, 25 kV, or 35 kV requirements for Class 1 termination as recorded in IEEE 48-1990. The termination must be a molded rubber unit where the built-in stress relief mechanism uses the concept of high dielectric constant capacitive stress grading. The molded rubber insulator must be made from silicone rubber.

Close Specification

Terminate all 15 kV, 25 kV, and 35 kV class concentric neutral (CN) cable in accordance with the instructions in the 3M 5600 and 5680 series Cold Shrink QT II silicone rubber termination kits.

Performance Tests

Corona Tests

The purpose of the corona tests is to insure that all properly installed terminations operate corona-free at a minimum of 150% of their operating voltage. In this test, phase-to-ground voltage is gradually increased until discharges are displayed on an oscilloscope.

The voltage at which these discharges reach three picocoulombs is recorded as the corona starting voltage (CSV). The voltage is then lowered until the discharges are less than three picocoulombs. This voltage is recorded as the corona extinction voltage (CEV). All QT II terminations conform with the IEEE-48 required minimum CEV level of 150% of operating voltage. Samples installed on 15 kV class cable are typically corona-free at 30 kV. Samples installed on 35 kV class cable are typically corona-free at 40 kV.

Lightning Impulse Tests (BIL)

In this test, nominal 1.2 x 50 microsecond waves, both positive and negative, are used. Ten consecutive impulses at each polarity are applied. All terminations meet BIL requirements as recorded in IEEE 48-1990 with a considerable amount of safety margin. See applicable tables "Typical Results per IEEE 48-1990 Tests."

All terminations meet AC withstand tests as specified in IEEE 48-1990. See applicable tables "Typical Results per IEEE 48-1990 Tests."

The average value of voltage that will arc over the termination surface in air, from the cable connecting lug to the neutral wire at the termination base, is shown in the table below.

Terminations are immersed in SF_6 gas to determine interface dielectric strength. The SF_6 gas, having higher dielectric strength than air, prevents termination flashover. The AC breakdown values are shown in the table below.

AC Flashover and Breakdown Tests						
Product Number	AC Flashover			AC Breakdown in SF_6		
	15 kV Class	25 kV Class	35 kV Class	15 kV Class	25 kV Class	35 kV Class
5601–5603	75 kV	85 kV		130 kV	155 kV	
5681–5684	95 kV	105 kV	115 kV	130 kV	155 kV	197 kV
5604–5608	105 kV	115 kV	130 kV	130 kV	155 kV	197 kV

Environmental Performance

When airborne contaminants are deposited on a termination surface, destructive leakage currents can be initiated when the surface becomes wet. Fog and drizzle are worse than rain. Rain tends to wash the pollutants off the termination, while fog will wet the pollutants, making the surface conductive (to varying degrees) and promoting leakage current formation. This is most typical of hydrophilic surfaces, typified by porcelain (Figure 2).

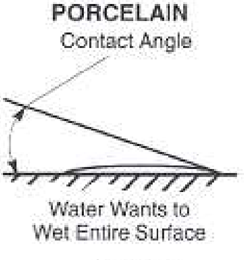


Figure 2

The surface of the 3M silicone insulator is hydrophobic which makes it less likely to erode or track because the surface does not wet readily (Figure 3). This either prevents or minimizes leakage current formation.

Figure 3

On occasion, severe environmental conditions can be sustained for long time periods and cause any polymeric surface to lose its hydrophobicity. Because of this, EPDM polymers tend to lose their hydrophobicity over time, and porcelain surfaces become increasingly hydrophilic with time, resulting in premature failure or flashover. However, the silicone surface will reestablish its hydrophobic surface within 24 hours (Figure 4). This unique ability of 3M silicone is a major factor to insure long service life.

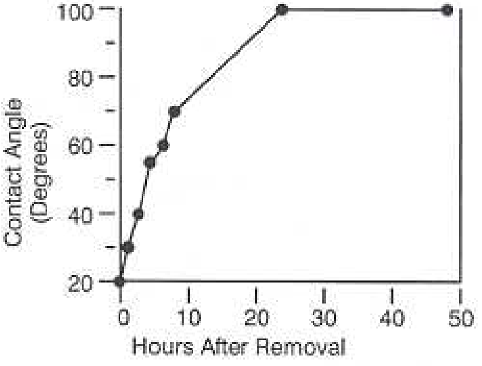


Figure 4

Sealing Tests

Seals on concentric neutral (CN) power cable are obtained when QT II terminations are installed. The rubber termination applies a constant force uniformly around the cable semiconductive insulation shield to create the bottom seal. The top seal on the lug is provided by the additional use of Scotch™ 70 silicone rubber electrical tape.

The seals are tested by immersing the lug end in water and applying air pressure to the conductor. Both seals will withstand internal air pressure test per IEEE 48-1990.

Ultraviolet Resistance

After 1,000 hours of testing in a Weather-O-Meter according to specifications ASTM D750 and ASTM G23, the silicone insulator exhibited no crazing, cracking, or change in surface appearance. Silicone rubber, unlike carbon-based elastomers, is inherently stable under exposure to sunlight. This is because of the silicone molecular backbone (the silicon-oxygen bond) has a bond strength greater than the ultraviolet energy of sunlight, while the carbon-carbon bond of an EPDM elastomer is weaker.

Field Maintenance

Hypotting

These terminations can be tested according to the instructions given in IEEE 400-1991, "Guide for Making High Direct Voltage Tests in the Field."

Surface Cleaning

It is not uncommon in areas of extreme contamination for users to periodically clean terminations and other insulators. Energized or deenergized, established techniques for cleaning cable terminations can be used, such as high-pressure water and pulverized corn cobs. Cold

Shrink QT II terminations, as a rule, do not require such periodic cleaning.

Availability

Cold Shrink 5600 and 5680 series QT II silicone rubber termination kits can be purchased through your local authorized 3M electrical distributor.

Shelf Life

3M Cold Shrink 5600 and 5680 series kits are packaged one termination per carton. As provided in the expanded state, terminations have a shelf storage life of three years.

Maximum recommended storage temperature is 110°F (43°C). Kit components are not affected by freezing storage temperatures. The year and quarter of manufacture is molded into the base of each termination. Proper stock rotation practice is recommended.

Installation Techniques

Instructions regarding proper installation is included in each kit. A brief summary of these procedures is as follows:

1. Prepare cable according to standard procedure (Figure 5).
2. Install lug using appropriate crimp tool (Figure 5).

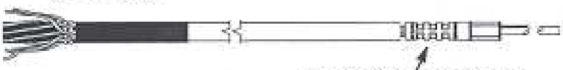


Figure 5

3. Fill in the step at the semiconductor insulation shield cut edge using silicone grease (Figure 6).

Figure 6

4. Place termination over cable and unwind the core allowing the termination to shrink into place (Figures 7 and 8).

Figure 7

5. Install ground clip and Scotch 70 tape top seal (Figure 8).

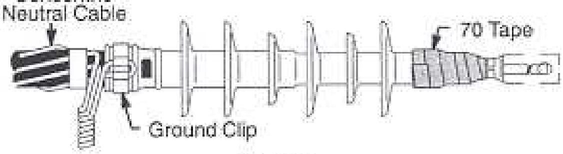


Figure 8

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3M

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