# Data Sheet

# Quick Term II Silicone Rubber Termination Kit 4604 and 4605 • 46 kV

## 1. Product Description

3M 4604 and 4605 Quick Term II Silicone Rubber Termination Kits are three-piece Cold Shrink terminations for Tape Shield, Wire Shield, and LC Shield power cables. **They meet the requirements of IEEE standard 48 – 1990, for class 1 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 Quick Term II technology meet French EdF standards HN 33-E-01 and HN 41-E-01. Data on foreign standards are available upon request. The 3M Quick Term II consists of a high dielectric constant (High-K) stress control tube insulated with a molded silicone skirted insulator. The 4600-series termination is a twelve-skirt design incorporating a one-piece base termination assembly, a four-skirt extension insulator, and a Silicone Rubber Jacket-Sealing Cold Shrink PST Assembly.

Quick Term II terminations are provided in an expanded state; mounted on a removable inner supporting plastic core. As supplied in this pre-stretched 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 cover cables with primary insulation O.D. from 1.31″ to 2.60″ (33 to 66 mm). These kits can be used to terminate 46 kV Shielded Power Cables from: 4/0 AWG to 1500 kcm.

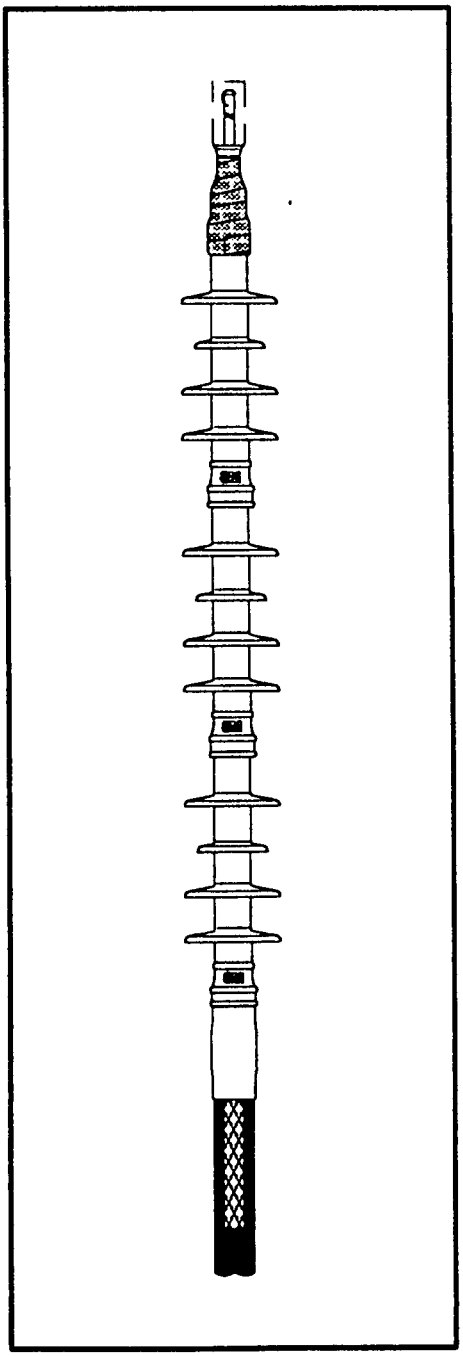
### Stress Control

The 3M Quick Term II controls the electric field surrounding the terminated cable insulation shield end, by use of a special high dielectric constant (High-K) material which is an integral part of the termination. The High-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 46 kV cable, the stress concentrations typically vary from 45 volts/mil at the shield to about 85 volts/mil at the conductor. When terminated with the Quick Term II, the stress in the cable underneath this unit is less than it is in the shielded portion of the cable. *Figure 1* shows an actual computerized stress plot of the Quick Term II.

### Cold Shrink Insulators

3M Quick Term II Skirted Insulators are constructed of non-tracking silicone rubber which minimizes leakage currents in wetted conditions for three reasons:

1. The smooth surface of the 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 lowered.



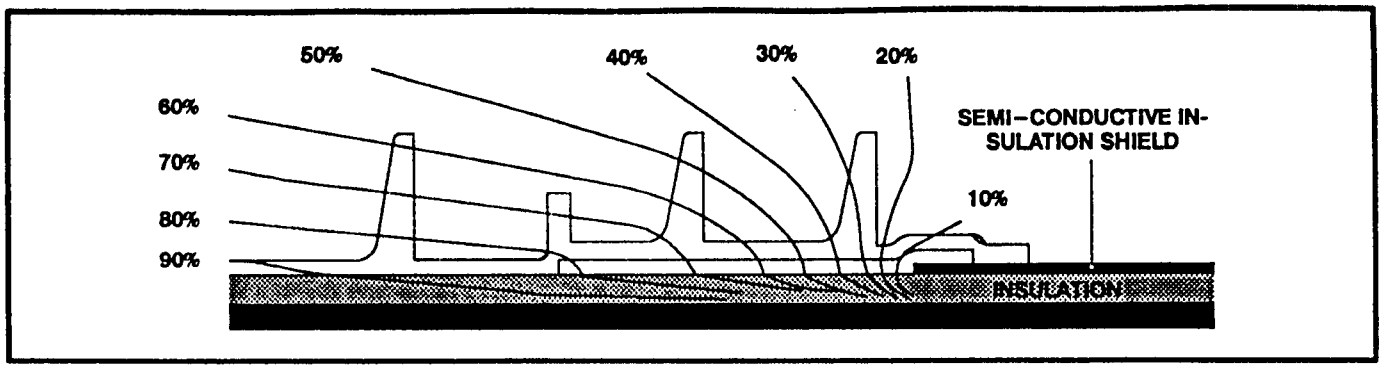



**FIGURE 1**

3. When leakage currents do increase and arcing occurs on the surface, the ash formed by erosion of the silicone insulator is non-organic 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 Quick Term II 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 3M Quick Term II termination optimizes performance under heavy rain conditions.

### Kit Contents

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

- 1 High-K, 8-Skirt Silicone Rubber Termination Assembly.
- 1 Four-Skirt Silicone Rubber Insulator.
- 1 Silicone Rubber Jacket-Seal PST Assembly.
- 1 Pack Silicone Grease.
- 2 Pre-Formed Ground Braids.
- 1 Constant-Force Spring.
- 2 Mastic Seal Strips.
- 1 Roll Scotch™ No. 13 Semi-Conducting Tape.
- 1 Roll Scotch™ No. 70 Silicone Rubber Tape.
- Instruction Sheet.

## 2. Applications

The 4604 and 4605 Quick Term II Silicone Cold Shrink Terminations are used to terminate shielded power cable rated 46 kV, having extruded solid dielectric insulation as follows: Polyethylene (high and low density), cross-linked polyethylene (XLP) and ethylene propylene rubber (EPR). The terminations are light weight for either free-hanging or bracket-mounting arrangements. They can be used in both protected and weather exposed contaminated areas.

## 3. Data: Physical and Electrical Properties

The 4604 and 4605 Quick Term II terminations can be used on cables with a rated operating temperature of 90°C and an emergency overload rating of 130°C, (reference: AEIC CS5 and AEIC CS6). These kits meet the requirements for 46 kV Class 1 terminations in IEEE Standard Test Procedures and Requirements for High-Voltage Cable Terminations (IEEE Standard 48 – 1990). (See Section 5, **"Performance Tests"**). The current rating of Quick Term II terminations exceeds the current rating of the cable installed.

## Typical Physical and Electrical Properties

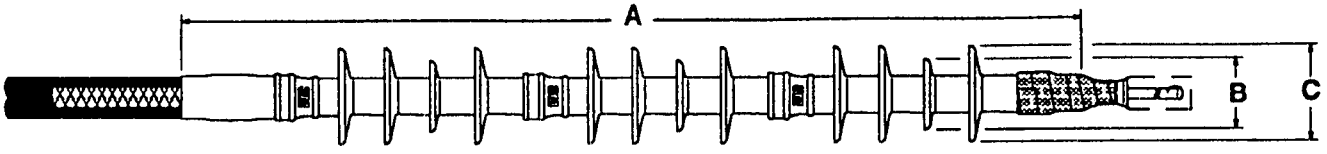
### Silicone Rubber Insulator

#### Physical Properties

| Test Method | Typical Value* |
|---|---|
| • Color | Munsel Gray |
| • Permanent Set<br>22 hours @ 100°C (212°F)<br>100% elongation<br>5 minute recovery | 8% |
| • Ultimate Tensile Strength<br>(ASTM D412-68) | 1200 psi<br>(8.28 MPa) |

#### Electrical Properties

| Test Method | Typical Value* |
|---|---|
| • Dielectric Constant (K)<br>(ASTM D150-70) | |
| 23°C (73°F) | 3.4 |
| 90°C (194°F) | 3.0 |
| 130°C (266°F) | 2.7 |
| • Dissipation Factor<br>(ASTM D150-70) | |
| 23°C (73°F) | .4% |
| 90°C (194°F) | 1.3% |
| 130°C (266°F) | 1.2% |
| • Dielectric Strength<br>(ASTM D149-70)<br>.075" (1.9 mm) gap | 507 volts/mil<br>(20 kV/mm) |
| • Track Resistance<br>(ASTM 2303-68)<br>2.5 kV, 10 k Ohms | 10 hrs. |




TWELVE-SKIRT TERMINATION

## Typical Dimensions

| Product Number | A | B | C | Creepage Distance | Arcing Distance |
|---|---|---|---|---|---|
| 4604 | 28″ (max.) (711 mm) | 2.0″ (51 mm) | 3.55″ (90 mm) | 46″ (max.) (1168 mm) | 30″ (max.) (762 mm) |
| 4605 | 28″ (max.) (711 mm) | 2.4″ (61 mm) | 4.0″ (102 mm) | 46″ (max.) (1168 mm) | 30″ (max.) (762 mm) |

## Termination Selection Table

| Product Number | Primary Insulation O.D. Range Inches (mm) | Conductor Range (AWG / Kcmil) 46 kV |
|---|---|---|
| 4604 | 1.31″ – 2.10″ (33 – 53 mm) | 4/0 – 600 |
| 4605 | 1.80″ – 2.66″ (46 – 66 mm) | 600 – 1500 |

**See Recommended Application Guide, on page 2.

## Typical Results per IEEE STD. 48 – 1990 Tests

| IEEE STD. 48 Test | 46 kV Class | |
|---|---|---|
| | Requirement | Results |
| 60 sec. w/s ac | 120 kV | 150 kV* |
| 10 sec. w/s wet ac | 100 kV | 115 kV* |
| 6 hours w/s ac | 100 kV | 135 kV* |
| Corona @ 3 pc. CSV<br>CEV | —<br>40 kV | 52 kV<br>49 kV |
| 15 min. w/s dc | 170 kV | Pass 170 kV |
| Impulse w/s | 250 kV | +285 kV*<br>–275 kV* |
| 30 day Cyclic Aging @ 130°C w/s ac<br>Corona @ 3 pc. CEV ><br>Impulse +10<br>–10 | 53 kV<br>40 kV<br>+250 kV<br>–250 kV | Pass<br>Pass<br>Pass<br>Pass |

* At higher voltage flashovers occur.

## EPDM Rubber High-K Stress Control Tube

### Physical Properties

| Test Method | Typical Value* |
|---|---|
| • Ultimate Tensile Strength (ASTM D412-68) | 1394 psi (9.6 MPa) |
| • Permanent Set 22 hours @ 100°C (212°F) 100% elongation 5 minute recovery | 18% |

### Electrical Properties

- Dielectric Constant (K) (ASTM D150-70) (60 Hz; @ 60% strain)

| | @ 400 V | @ 3 kV |
|---|---|---|
| 23°C (73°F) | 25.7 | 28.8 |
| 65°C (149°F) | 24.5 | 27.2 |
| 90°C (194°F) | 25.2 | 27.7 |

vs. frequency @ 23°C (73°F)

| | |
|---|---|
| 150 Hz | 35 |
| 1,000 Hz | 29 |
| 10,000 Hz | 24 |
| 100,000 Hz | 20 |

- Dissipation Factor (ASTM D150-70) 60 Hz; @ 60% strain

| | @ 400 V | @ 3 kV |
|---|---|---|
| 23°C (73°F) | 0.096 | 0.166 |
| 65°C (149°F) | 0.093 | 0.165 |
| 90°C (194°F) | 0.132 | 0.161 |

vs. frequency @ 23°C (73°F)

| | |
|---|---|
| 150 Hz | 0.16 |
| 1,000 Hz | 0.15 |
| 10,000 Hz | 0.14 |
| 100,000 Hz | 0.12 |

* Average values, not intended for specification purposes.

# 4. Specification Guide

## Open Specification

The cable termination must be a three-piece Cold Shrink 46 kV Class device and meet all 46 kV requirements for a Class 1 termination as recorded in IEEE Standard 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.

## Closed Specification

Terminate all 46 kV Class Tape Shield, Wire Shield and LC-Shield cable in accordance with the instructions in the 3M Brand 4604 and 4605 Quick Term II Silicone Rubber Termination Kits.

# 5. Performance Tests

## A. Corona Tests

The purpose of corona testing 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 high frequency 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 Quick Term II terminations conform with the IPCEA recommended minimum corona extinction (CEV) level of 150% of operating voltage. Samples installed on 46 kV class cable are typically corona-free at 50 kV.

## B. Impulse Tests (BIL)

In this test a nominal 1.2 × 50 microsecond wave, both positive and negative, is used. Ten consecutive impulses at each polarity are applied. All Quick Term II terminations meet the BIL requirements as recorded in IEEE Standard 48 – 1990 with a considerable amount of safety margin.

## C. Alternating Current Withstand Tests

All terminations meet ac withstand tests as specified in IEEE Standard 48 – 1990. See applicable tables **"Typical Results per IEEE STD. 48 – 1990 Tests."**

The average value of voltage which will arc over the termination surface in air, from the cable connecting lug to the neutral wire at the termination base, is shown in *Figure 2*.

To determine dielectric strength, terminations are immersed in $SF_6$ gas. The $SF_6$ gas, having a higher dielectric strength than air, prevents termination flashover. The ac breakdown values are shown in *Figure 2*.

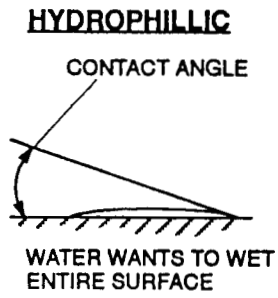
**AC Flashover and Breakdown Tests**

| Product Number | AC Flashover 46 kV Class | AC Breakdown in $SF_6$ 46 kV Class |
|---|---|---|
| 4604 | 165 kV | 210 kV |
| 4605 | 165 kV | 210 kV |

**FIGURE 2**

## D. Environmental Performance

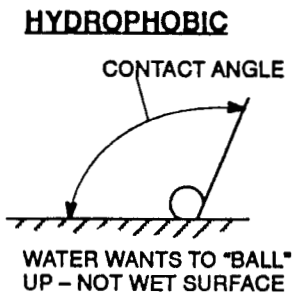
When airborne contaminants are deposited on a termination surface destructive leakage currents can be initiated when the surface becomes wet. Fog and drizzle are worse than rain. Rain tends to wash the pollutants off the termination while fog will wet the pollutants making the surface conductive to varying degrees promoting leakage current formation. This is most typical of hydrophillic surfaces typified by porcelain *(Figure 3)*. The surface of 3M Quick Term II silicone insulator is hydrophobic which makes it less likely to erode or track because the surface does not wet readily *(Figure 4)*. This either prevents or minimizes leakage current formation. 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 hydrophillic with time, which will result in premature failure or flashover. However, the silicone surface will re-establish its hydrophobic surface within 24 hours *(Figure 5)*. This unique ability of the Quick Term II Silicone is a major factor to insure long service life.




HYDROPHILLIC

PORCELAIN

FIGURE 3




HYDROPHOBIC

SILICONE

FIGURE 3

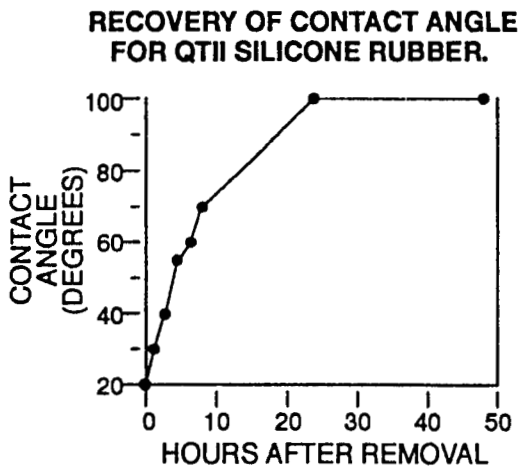



FIGURE 5

## References

L.A. Johnson* and W.C. Osborn*, "Contamination Testing of Distribution Class Cable Terminations", IEEE Underground T and D Conference, Pub. 76 CH 119-7-PWR, 1976.

E.M. Sherif and A.E. Vlastos, "Influence of Aging on the Electrical Properties of Composite Insulators", Fifth International Symposium on High Voltage Engineering, 1987.

S.M. Gubanski and J.G. Wankowicz, "Distribution of Natural Pollution Surface Layers on Silicone Rubber Insulators and Their UV Absorption", IEEE Transactions on Electrical Insulation, Vol. 24 No. 4, 1989.

H.C. Hervig*, "Splices and Terminations for Solid Dielectric Cables — A Comparison of Alternatives", T and D Committee, Electric Council of New England, 1989.

R.S. Gorur, L.A. Johnson* and H.C. Hervig*, "Accelerated Aging of Silicone Rubber Cable Terminations", T and D Conference on Electrical Insulation and Dielectric Phenomena, Leesburg Virginia, 1989.

H.C. Hervig*, "Accelerated Environmental Testing of Distribution Class Silicone Terminations, Non-ceramic Insulators for Outdoor High Voltage Applications", Tutorial Workshop U. of Connecticut, 1989.

L.A. Johnson*, "Polymeric Terminations Present and Future — Cold Shrink Silicone Terminations", IEEE/PES T and D Conference, 1989.

R.S. Gorur, L.A. Johnson* and H.C. Hervig*, "Contamination Performance of Silicone Rubber Cable Terminations", IEEE Winter Power Meeting, Feb. 1990.

* Member of the 3M Electrical Products Division Technical Community.

## E. Sealing Tests

The bottom seal on a shielded power cable is formed with mastic placed under and over the ground braid (solder-block section) which, in turn, is over-wrapped with vinyl tape. The tape wrap compresses the mastic to form a moisture seal around the ground braids. A jacket-sealing Cold Shrink insulator covers the cable jacket end and tape/mastic region to complete the seal.

The top seal on the lug is provided by the 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 Standard 48 – 1990.

## F. Ultraviolet Resistance

After 1,000 hours of testing in a Wether-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 back bone (the silicone-oxygen bond) has a bond strength greater than the ultraviolet energy of sunlight while the carbon-carbon bond of an EPDM elastomer is less than sunlight.

## 6. Installation Techniques

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

A. Prepare cable according to standard procedure *(Figure 1)*.
B. Install ground braids *(Figure 2)*.
C. Install Jacket Seal PST *(Figure 3)*.
D. Apply a liberal coating of silicone grease to the edge of the cable semiconductive insulation shield or Scotch No. 13 Tape.
E. Place termination components over cable and unwind cores allowing assemblies to shrink into place *(Figure 4)*.
F. Apply 70 tape top seal *(Figure 5)*.

## 7. Field Maintenance

### Hypotting

These terminations can be tested according to the instructions given in IEEE Standard 400-1980, "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, e. g. high pressure water and pulverized corn cobs.

## 8. Availability

3M 4604 and 4605 Quick Term II Molded Silicone Rubber Termination Kits can be purchased through your local authorized 3M electrical distributor.

## 9. Shelf Life

3M 4604 and 4605 Quick Term II Silicone Rubber Termination Kits are packaged one termination per carton. As provided in the expanded state, terminations have an on-shelf storage life of three years. Maximum recommended storage temperature is 110°F (43°C). They are not effected by freezing storage temperatures. The year and quarter of manufacture is molded into the base of each Quick Term II termination. Stock rotation practice is recommended.

FIGURE 1

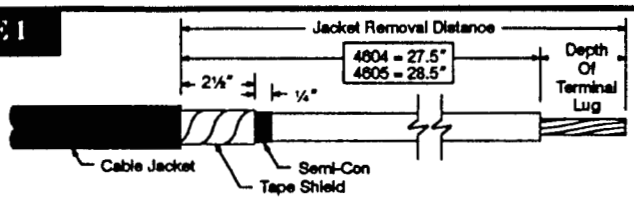



FIGURE 2

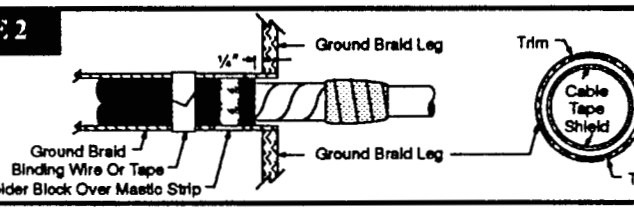



FIGURE 3

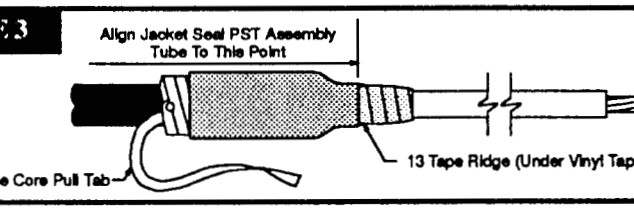



FIGURE 4

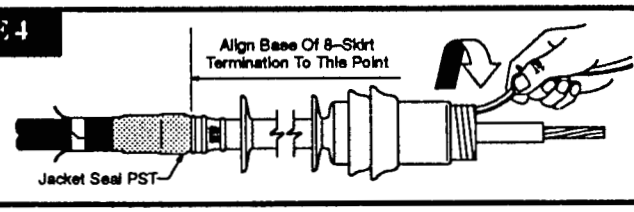
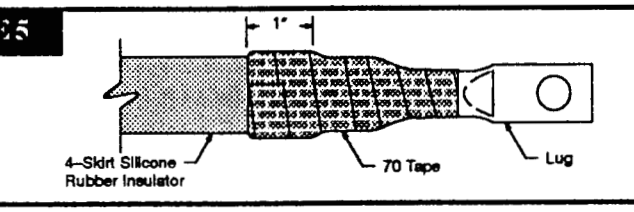



FIGURE 5






80-6106-6163-9



**3M Electrical Products Division**

6801 River Place Blvd.
Austin, Texas 78726 – 9000