

# High Voltage Power Cable, Splicing & Terminating

edited by Robert Goodman and William Osborn

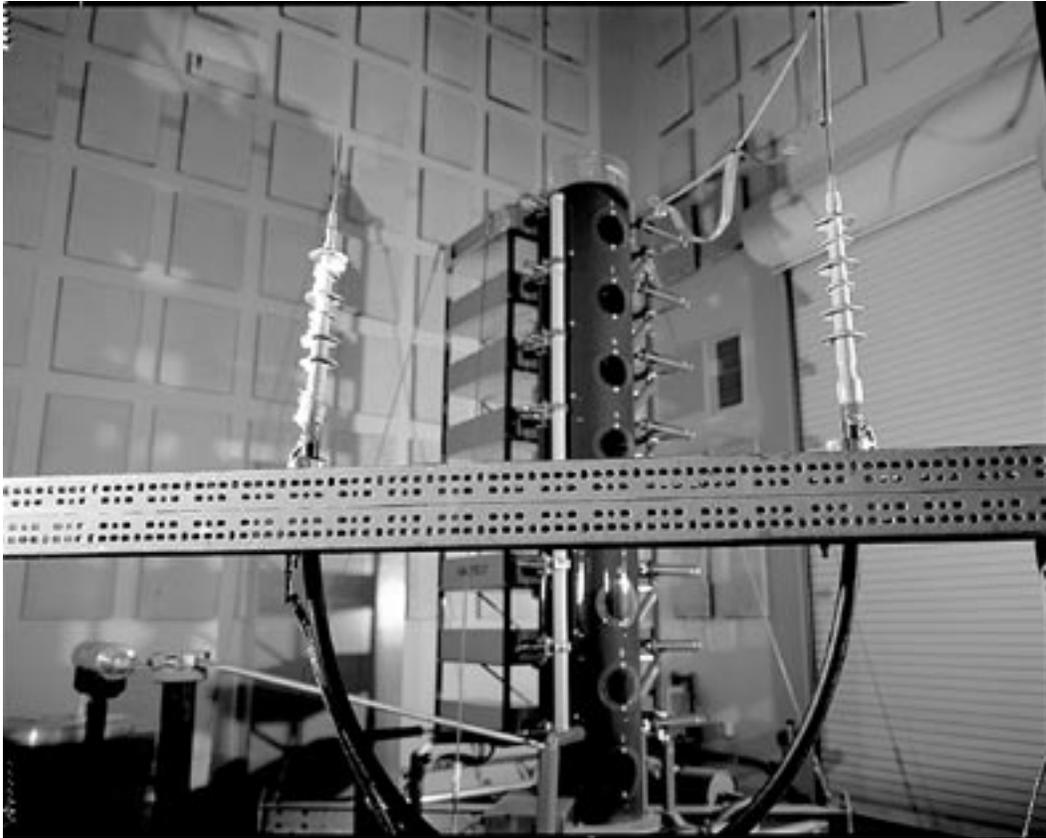


**3M** *Innovation*

**Y**ou're in a demanding industry. To be successful, you need a wide range of reliable products designed to effectively manage your daily processes. You need a supplier with a solid understanding of your industry and the technology that drives it. Quite simply, you need 3M. Our Electrical Products Division designs and manufactures a comprehensive line of products that can address your diverse applications. Widely recognized for our innovation, reliability and global corporate strength, 3M has the products and services you need and the name you trust.

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From our earliest endeavors with tapes, adhesives and abrasive minerals over a half-century ago, 3M has grown to worldwide recognition in vital technologies. 3M sales offices, laboratories and manufacturing plants in a hundred countries research and develop products that meet the world's needs. Investments in the hundreds of millions of dollars are made each year in the search for better answers that combine dependability with usability.

# THE TECHNOLOGY

**O**ur laboratory understanding of **TAPE TECHNOLOGY** forwards the effort to create useful, effective products across a wide range of electrical needs.



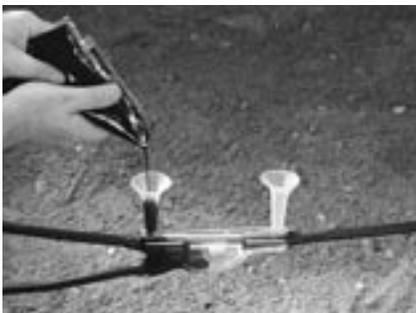
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Our experience with modern **RUBBER TECHNOLOGY** has developed a "cold shrink" family of products with the features electricians ask for.



3

Our chemical expertise with **RESIN TECHNOLOGY** has evolved into an ever-growing series of efficient, remarkably self-contained electrical products.



4

**O**ur involvement with **CONNECTING TECHNOLOGY** has generated a top performing line of connectors that are UL listed for the majority of known crimping tools with means greater convenience for the installer.



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# THE HUMAN FACTOR

**P**roducts are only as good as the people who create them. Teams of 3M chemists, engineers, designers and toxicologists, along with manufacturing, quality control, sales and distribution people are intent upon the established reputation for high quality, problem-solving products made for people.



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For this reason, each 3M product contains "human engineering." Products designed to be not only durable and cost effective, but to work smoothly as they're applied, to perform efficiently in installer's hands. Products that work for the people who need them. It's a vital combination of Technology...and the Human Factor.

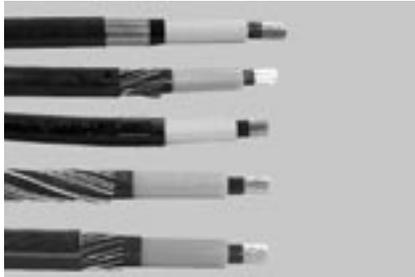
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# HIGH VOLTAGE POWER CABLE

## HIGH VOLTAGE CABLE TYPES

Of the nearly limitless variety of cables in use today, five of the most common are:

- Tape shielded
- Drain wire shielded
- BICC UniShield®
- Concentric Neutral (CN)
- Jacketed Concentric Neutral (JCN)



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Beyond cable shield types, two common configurations are used:

- Single conductor...consisting of one conductor per cable or three cables for a three-phase system.
- Three conductor...consisting of three cables sharing a common jacket.

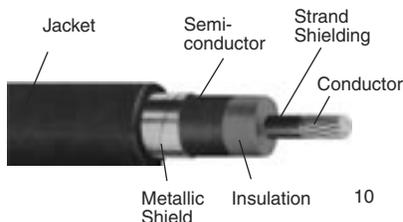


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Despite these visible differences, all power cables are essentially the same, consisting of:

- Conductor
- Strand shield
- Insulation
- Insulation shield system (semi-con & metallic)
- Jacket.

Each component is vital to an optimally performing power cable and must be understood in order to make a dependable splice or termination.



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## HIGH VOLTAGE CABLE COMPONENTS

### Conductor

The current carrying components. Made of copper or aluminum (less expensive but less efficient...requiring a larger conductor diameter to carry an equal electrical load when compared to copper conductor).

Conductor used with modern solid dielectric cables come in four basic configurations:

### Concentric Stranding

(Class B)

Not commonly used in modern shielded power cables due to the penetration of the extruded strand shielding between the conductor strands, making the strand shield difficult to remove during field cable preparation.

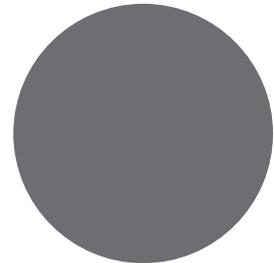
### Compact Stranding

Compacted to 90% of concentric conductor diameters. Although this conductor has full ampacity ratings, the general rule for sizing is to consider it one conductor size smaller than concentric or compressed. This reduced conductor size results in all of the cable's layers proportionally reduced in a diameter, a consideration when sizing for molded rubber devices.

### Solid Wire

This conductor is not commonly used in industrial shielded power cables.

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### Compressed Stranding

(common conductor configuration)

Compressed to 97% of concentric conductor diameters. This compression of the conductor strands blocks the penetration of an extruded strand shield, thereby making it easily removable in the field. For sizing lugs and connectors, sizes remain the same as with the concentric stranding.

### Strand Shielding

The semi-conductive layer between conductor and insulation which compensates for air voids that exist between conductor and insulation.

Air is a poor insulation, having a nominal dielectric strength of only 76 volts per mil, while most cable insulation have dielectric strengths over 700 volts/mil. Without strand shielding an electrical potential exists that will over-stress these air voids.

As air breaks down or ionizes, it goes into corona (partial discharges). This forms ozone which chemically deteriorates cable insulation. The semi-conductive strand shielding eliminates this potential by simply "shorting out" the air.

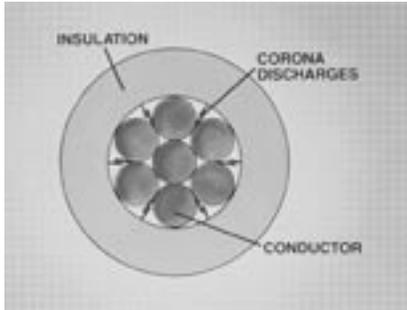
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# HIGH VOLTAGE POWER CABLE

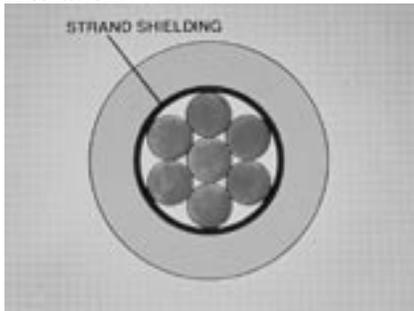
Modern cables are generally constructed with an extruded strand shield.

(Reference: AEIC NO. 5, D. Semiconducting Shielding.)



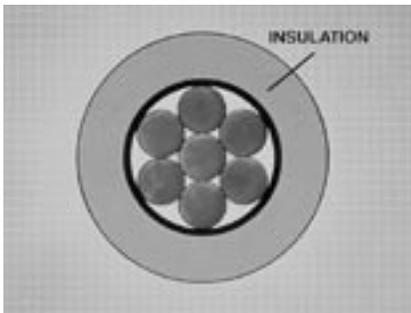
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## Insulation.



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A third la, different variations such as extruded solid dielectric, or laminar (oil paper or varnish cambric). Its function is to contain the voltage within the cable



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system. The most common solid dielectric insulations in industrial use today are:

- polyethylene
- cross-linked polyethylene (XLP)
- ethylene propylene rubber (EPR)

Each is preferred for different properties such as superior strength, flexibility, temperature resistance, etc. depending upon the cable characteristics required. The selection of the cable insulation level to be used in a particular installation shall be made on the basis of the applicable phase-to-phase voltage and the general system category as outlined below.

**a. 100 Percent Level** - Cables in this category may be applied where the system is provided with relay protection such that ground faults will be cleared as rapidly as possible, but in any case within one minute. While these cables are applicable to the great majority of the cable installations which are on grounded systems, they may be used also on other systems for which the application of cable is acceptable provided the above clearing requirements are met in completely deenergizing the faulted section.

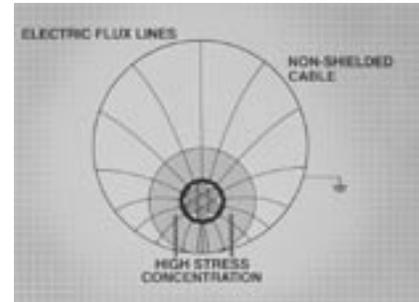
**b. 133 Percent Level** - This insulation level corresponds to that formerly designated for ungrounded systems. Cables in this category may be applied in situations where the clearing time requirements of the 100 percent level category cannot be met, and yet there is adequate assurance that the faulted section will be de-energized in a time not exceeding one hour. Also, they may be used when additional insulation strength over the 100 percent level category is desirable.

**c. 173 Percent Level** - Cables in this category should be applied on systems where the time required to de-energize a grounded section is indefinite. Their use is recommended also for resonant grounded systems. Consult the manufacturer for insulation thicknesses.

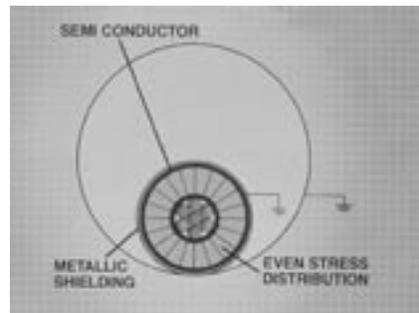
(Reference: AEIC No. 5 Reprinted with permission)

## Insulation Shield System

The outer shielding which is comprised of two conductive components: a semi-conductive layer (semi-con)



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under a metallic layer (see cable types for common shield varieties). The principal functions of the insulation shield system are to:

1. Confine the dielectric field within the cable
2. Obtain a symmetrical radial distribution of voltage stress within the dielectric
3. Protect the cable from induced potentials
4. Limit radio interference
5. Reduce the hazard of shock
6. Provide a ground path for leakage and fault currents.

The SHIELD MUST BE GROUNDED for the cable to perform these functions.

# HIGH VOLTAGE POWER CABLE



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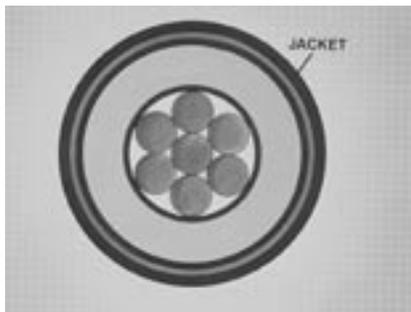
The semi-conductive component is available either as a tape or as an extruded layer. (Some cables have an additional layer painted on between the semi-con and the cable insulation.) Its function is similar to strand shielding: to eliminate the problem of air voids between the insulation and metallic component (in this case the metallic shielding). In effect, it “shorts out” the air that underlies metallic shield, preventing corona and its resultant ozone damage.

The metallic shield is the current carrying component that allows the insulation shield system to perform the functions mentioned earlier. This is the layer where various cables types differ most. Therefore, most cables are named after their metallic shield (e.g. tape shielded, drain wire shielded, UniShield®, etc.).

Shield type (cable identification) thus becomes important information to know when selecting devices for splicing and terminating.

## Jacket

The tough outer covering for mechanical protection as well as moisture barrier. Often the jacket serves as both an outer covering and the semi-conductive component of the insulation shield system, combining two cable jacket layers into one...the semi-conductive jacket. Typical materials used for cable jackets are PVC, neoprene, lead, etc. Frequently industrial three conductor cables have additional protection in the form of an armor layer.



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## HIGH VOLTAGE CABLE PREPARATION

It is necessary to begin with a good cable end. For this reason it is common practice to cut off a portion of cable after pulling to assure an undamaged end. A key to good cable preparation is the use of sharp, high quality tools.



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When the various layers are removed, cuts should extend only partially through the layer. For example, when removing cable insulation, the



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installer must be careful not to cut completely through and damage the conductor strands. Specialized tools are available to aid in the removal of the various cable layers.



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Another good technique for removing polyethylene cable insulation is to use a string as the cutting tool.



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When penciling is required (not normally necessary for molded rubber devices), a full, smooth taper is necessary to eliminate the possibility of air voids.

It is necessary to completely remove the semi-conductive layer(s) and the resulting residue. Two methods are commonly used to remove the residue: abrasives and solvent.

## Abrasives.

Research has proven a 120-grit to be optimum...fine enough for the high voltage interface and yet coarse enough to remove semi-con residue without “loading up” the abrasive cloth.



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The abrasive must have a non-conducting grit. DO NOT use emery cloth or any other abrasive that contains conductive particles since these could embed themselves into the cable insulation. When using an insulation diameter dependent device (e.g. molded rubber devices), care must be taken not to abrade the insulation below the minimum specified for the device.

## Solvents.

It is recommended that a non-flammable cable cleaning solvent be used. Any solvent that leaves a residue should be avoided. DO NOT use excessive amounts of solvent as this can saturate the semi-con layer and render them non-conductive. Know your solvent. Avoid toxic solvents which are hazardous to health.



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# SPLICING

Cable preparation materials are available which contain solvent saturated rags appropriately filled with the proper quantity of non-flammable, non-toxic cable cleaning solvent. These kits also contain a 120-grit non-conductive abrasive cloth.



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After the cable surfaces have been cleaned, the recommended practice is to reverse wrap (adhesive side out) a layer of vinyl tape to maintain the cleanliness of the cable.

## SPLICING

### Definition:

A splice may be considered as two or more conductors joined with a suitable connector...reinsulated, reshielded and re-jacketed with compatible materials... applied over a properly prepared surface.

Whenever possible, splicing is normally avoided. However splicing is often an economic necessity. There can be many reasons for building splices such as:

- The supplied length of cable is not sufficient to perform the intended job... only so much cable can be wound on a reel (reel ends)
- ... only so much cable can be pulled through so much conduit, around so many bends, etc.
- Cable failures
- Cables damaged after installation
- A tap into an existing cable (tee or wye splices)

In all the above cases, the option is to either splice the cable or replace the entire length. The economy of modern splicing products in many cases makes splicing an optimal choice.

Whatever the reason to splice, good practice dictates that splices have the same rating as the cable. In this way the splice does not derate the cable and become the weak link in the system.

## SPLICING STEPS

The previously quoted definition accurately develops five common steps in building a splice:

1. Prepare surface
2. Join conductors with connector(s)
3. Reinsulate
4. Reshield
5. Rejacket

It should be recognized that the greatest assurance against splice failure remains with the person who makes the splice. Adequate cable preparation, proper installation of all components and good workmanship require trained skills performed by people adept at them. Much has been done in the last few years to develop products and systems that make splicing easier. Yet the expertise, skills and care of the installer are still necessary to make a dependable splice.

### 1. Prepare the surface.

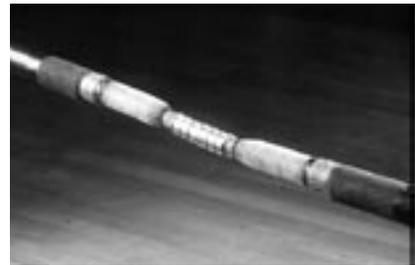
High quality products usually include detailed installation instructions. These instructions should be followed. A suggested technique is to check off steps as they are completed. Good instructions alone do not qualify a person as a "cable splicer." Certain manufacturers offer "hands-on" training programs designed to teach proper installation of their products. It is highly recommended that inexperienced splice and termination installers take advantage of such programs where available.



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### 2. Join conductors with connector

After the cables are completely prepared, the rebuilding process begins. If a cold shrink or premolded splice is being installed, the appropriate splice components must be slid onto the cable(s) before the connection is made. The first step is reconstructing the conductor with a suitable connector. A suitable connector for high voltage cable splices is a compression or crimp type.



Prepared for tape splice

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Prepared for pre-molded splice

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DO NOT USE mechanical type connectors (e.g. split-bolts). Connector selection is based on conductor material: copper or aluminum.

### Aluminum conductor

Connect with aluminum-bodied connector (marked CU/AL). These must come pre-loaded with contact aid (anti-oxide paste) to break down the insulating aluminum oxide coating on both the connector and conductor surfaces.

### Copper conductor

Connect with either copper or aluminum bodied connectors.

It is recommended that a UL listed connector be used that can be applied with any common crimping tool. This connector should be tested and approved for use at high voltage. In this way, the choice of the high voltage connector is at the discretion of the user, and is not limited by the tools available.



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### 3. Reinsulate.

Perhaps the most commonly recognized method for reinsulating is the traditional tape method. The most versatile approach, tape, is not dependent upon cable types and dimensions. Tape has a history of dependable service and is generally available. However, wrapping tape on a high voltage cable can be time consuming and error prone since the careful build-up of tape requires accurate half-lapping and constant tension in order to reduce build-in air voids. Technology has



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made available linerless splicing tapes. These tapes reduce both application time and error. Studies have shown time savings of 30% to 50% are possible since there is no need to stop during taping to tear off liner. This also allows the splicer to maintain a constant tape tension, thus reducing the possibility of taped-in voids. Tape splice kits which contain all the necessary tapes along with proper instructions are available. These versatile kits assure that the proper materials are available at the job, and make an ideal emergency splice kit.



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Another method for reinsulating utilizes molded rubber technology. These factory-made splices are designed to be human engineered for the convenience of the installer. In many cases these splices are also factory tested and designed to be installed without the use of special installation tools.

Most molded rubber splices use EPR as the reinsulation material. This EPR must be cured during the molding process. Either a peroxide cure or a sulfur cure can be used. Peroxide cures develop a rubber with maximum flexibility (for easy installation on a wide range of cable) and most importantly, provides an excellent long-term live memory for lasting, more reliable splices.

(Reference: IEEE paper Cat. 76 CH 119-7-PWR "Effect of Curing Agents on Long term Permanent Set of Molded Rubber Devices" by R.D. Erickson and P.N. Nelson, 3M Company)

### 4. Reshield.

The cable's two shielding systems (strand shield and insulation shield system) must be rebuilt when constructing a splice. The same two methods are used as outlined in the reinsulation process: tape and molded rubber.

For a tape splice, the cable strand shielding is replaced by a semiconductive tape. This tape is wrapped over the connector area to smooth the crimp indents and connector edges.



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The insulation shielding system is replaced by a combination of tapes. Semi-con is replaced with the same semi-conducting tape used to replace the strand shield.



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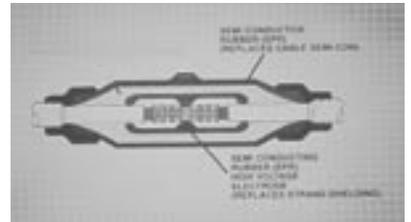
The cable's metallic shield is generally replaced with a flexible woven mesh of tin plated copper braid. This braid is for electrostatic shielding only, and not designed to carry shield currents. For conducting

shield currents, a jumper braid is installed to connect the cables metallic shields. This jumper must have an ampacity rating equal to that of the cables' shields.



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For a cold shrink or rubber molded splice, conductive rubber is used to replace the cable's strand shielding and the semi-conductive portion of the insulation shield system. Again, the metallic shield portion must be jumpered with a metallic component of equal ampacity.



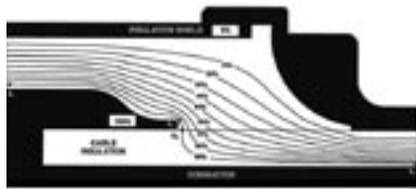
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A desirable design parameter of a molded rubber splice is that it be installable without special installation tools. To accomplish this, very short electrical interfaces are required. These interfaces are attained through p design shapes of the conductive rubber electrodes.



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# SPLICING



Laboratory field plotting techniques show that the optimum design can be obtained using a combination of



logarithmic and radial shapes.

## 5. Rejacket.

Rejacketing is accomplished in a tape splice by using a combination of the rubber splicing tape overwrapped with a vinyl tape.



In molded rubber splices, rejacketing is accomplished by proper design of the outer semi-conductive rubber, effectively resulting in a semi-conductive jacket.

When a molded rubber splice is used on internally shielded cable (such as tape shield, drain wire shield or UniShield® cables), a shield adapter is used to seal the opening that results between the splice and cable jacket.

As a general summary, for the versatility to handle practically any splicing emergency, or for those situations where only a few splices need to be made, or when little detail is known about the cable, the most effective splice is made with tape or a tape kit.

For those times when cable size, insulation diameter and shielding type are known and when numerous splices will be made, use molded rubber splices for dependability and simplicity as well as quick application.



# TERMINATIONS

(Reference: IEEE Std 48-1975. Quoted with permission as follows:)

“This standard supersedes IEEE Std 48-1962 Standard for Potheads. (Note: Current standard is IEEE Std. 48-1990) “The superseded document encompassed only the pothead, a cable termination designed primarily for cables having laminated insulation, and which sealed the end of a cable and provided insulation egress for the conductor or conductors.

“A considerable increase in the use of cables having extruded insulation has occurred since the issuance of IEEE Std 48-1962 and has encouraged the development of new types of cable terminations. As a consequence, there are available today many types of cable termination designed primarily for cables having extruded insulation which perform some, or all, of the functions of a pothead but which cannot be classified as such.

“This standard encompasses all (with one exception) terminations for alternating-current high-voltage cables having laminated or extruded insulation: conventional potheads, factory reassembled terminations, hand-wound tape and pennant stress cones, slip-on terminations and stress cones, resistance graded terminations, etc. The only exception is separable insulated connectors, a special type of high-voltage cable termination which is covered by another standard.

“In order to categorize the various types of terminations so that distinctions may be made, the terminations have been classified according to what they provide.

“A Class I High-Voltage Cable Termination (or more simply, a Class I Termination) provides: (1) some form of electric stress control for the cable insulation shield terminus, (2) complete external leakage insulation between the high-voltage conductor(s) and ground, and (3) a seal to prevent the entrance of the external environment into the cable and to maintain the pressure, if any, within the cable system. This classification encompasses the conventional potheads for which the original IEEE Std 48-1962 was written. With this new classification or designation the term pothead is henceforth dropped from usage in favor of Class 1 Termination.

“A Class 2 Termination is one that provides only (1) and (2): some form of electric stress control for the cable insulation shield terminus and complete external leakage insulation, but no seal against external elements. Terminations fall into this classification would be, for example, stress cones with rain shields or special outdoor insulation added to give complete leakage insulation, but no seal against external elements. Terminations falling into this classification would be, for example stress cones with rain shields or special outdoor insulation added to give complete leakage insulation, and the more recently introduced slip-on terminations for cables having extruded insulation when not providing a seal as in Class 1.

“A Class 3 Termination is one that provides only: (1) some form of electric stress control for the cable insulation shield terminus. This class of terminations would be for use primarily indoors. Typically, this would include hand-wrapped stress cones (tapes or pennants), and the slip-on stress cones.

“Some Class 1 and Class 2 Terminations have external leakage insulation made of polymeric material. It is recognized that there is some concern about the ability of such insulation to withstand weathering, ultraviolet radiation, contamination and leakage currents, and that a test capable of evaluating the various materials would be desirable. There are available today a number of test procedures for this purpose. However, none of them has been recognized and adopted by the industry as a standard. Consequently, this standard cannot and does not include such a test.”

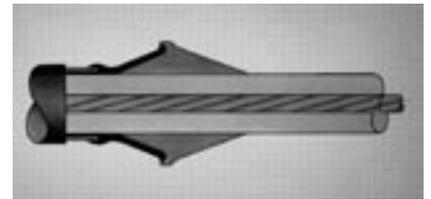
These IEEE Classes make no provision for “indoor” or “outdoor” environments. This is because contamination and moisture can be highly prevalent inside most industrial facilities (such as paper plants, steel mills, petro-chemical plants, etc.).

As a general recommendation, if there are airborne contaminants, or fail-safe power requirements are critical, use a Class 1 termination.

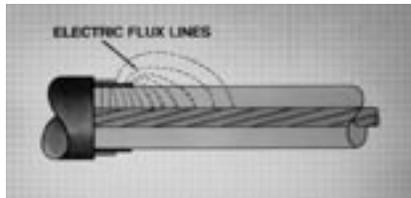
## STRESS CONTROL

In a continuous shielded cable the electric field is uniform along the cable axis and there is variation in the field only in a radial section. This is illustrated in Figures 44 and 45

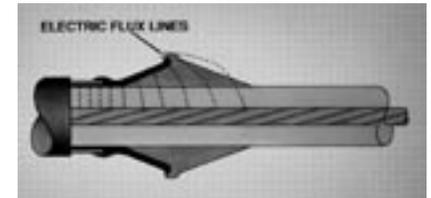
material to be applied in the termination. The particular length required is determined by the operating voltage and the properties of the insulating materials. This removal of a portion of the shield results in a discontinuity in the axial geometry of the cable, with the result being that the electrical field is no longer uniform axially along the cable, but exhibits variations in three dimensions.



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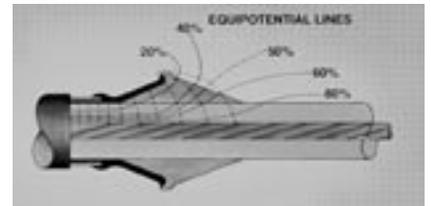
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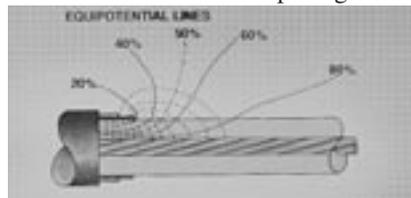
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which show the field distribution over such a radial section. The spacing of the electric flux lines and the corresponding equipotential lines is closer in the vicinity of the conductor than at the shield, indicating a higher electric stress on the insulation at the conductor. This stress increase, or concentration, is a direct result of the geometry of the conductor and shield in the cable section and is accommodated in practical cables by insulation thickness sufficient to keep the stress within acceptable values.

Figure 47 shows the electric field in the vicinity of the shield discontinuity. The electric flux lines originating along the conductor are seen to converge on the end of the shield, with the attendant close spacing of



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the equipotential lines signifying the presence of high electric stresses in this area. This stress concentration is of much greater magnitude than that occurring near the conductor in the continuous cable, and as a result steps must be taken to reduce the stresses occurring near the end of the shield if cable insulation failure is to be avoided.

## 2. Capacitive Stress Control

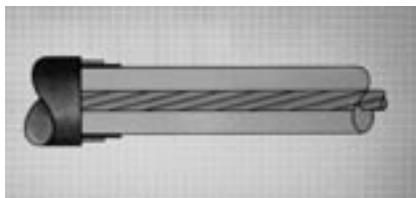
This method consists of a material possessing a high dielectric constant (K), generally in the range of K 30 and also a high dielectric strength.

DIELECTRIC CONSTANT = K:  
A MEASUREMENT OF THE ABILITY OF A MATERIAL TO STORE A CHARGE.

MATERIAL	K
AIR	1
CABLE INSULATION	3
130 C TAPE	3
HIGH K MATERIAL	30

This K is generally an order of magnitude higher than the cable insulation. Located at the end of the shield cut-back, the material capacitively changes the voltage distribution in the electrical field surrounding the shield terminus. Lines of electrical flux are regulated to equalize the electrical stresses in a controlled manner along the entire area where the shielding has been removed. (Figures 52 and 53)

In terminating a shielded cable, it is necessary to remove the shield to a point some distance from the exposed



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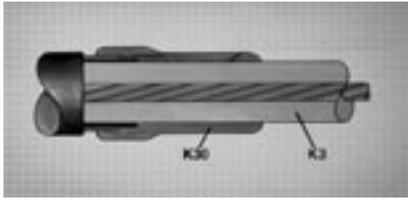
conductor as shown in Figure 46. This is to secure a sufficient length of insulation surface to prevent breakdown along the interface between the cable insulation and the insulating

All terminations must at least provide stress control. This stress control may be accomplished by two commonly used methods:

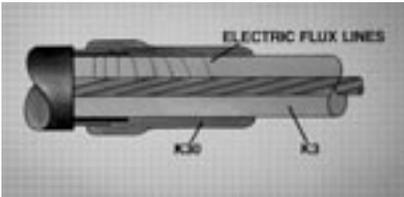
## 1. Geometric Stress Control

This method involves an extension of the shielding (figure 49) which expands the diameter at which the terminating discontinuity occurs and thereby reduces the stress at the discontinuity. It also reduces stresses by enlarging the radius of the shield end at the discontinuity. (Figures 50 and 51).

# TERMINATIONS

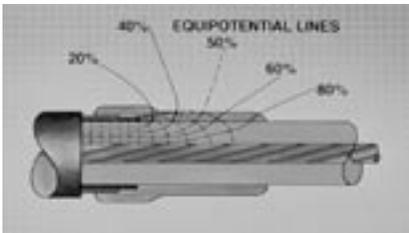


52



53

By changing the electrical field surrounding the termination, the stress concentration is reduced from several hundred volts per mil to values found in continuous cable - usually less than 50 volts/mil at rated cable voltage. (Reference: for a detailed technical explanation see "High Dielectric Constant Materials for Primary Voltage Cable Termination" by P.N. Nelson and H.C. Hervig, 3M Company.)



54

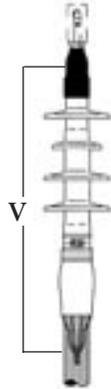
## EXTERNAL LEAKAGE INSULATION

This insulation must provide two functions: protection from flashover damage and protection from tracking damage.



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CLASS (kV)	BIL (kV-crest)
5.0	75
8.7	95
15	110
25	150
34.5	200
46	250
69	350



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Terminations can be subjected to flashovers such as lightning induced surges or switching surges. A good termination must be designed to survive these surges. Terminations are assigned a BIL (Basic Lightning Impulse Insulation Level) according to their insulation class (see IEEE Std 48.) As an example, a 15 kV class termination has a BIL rating of 110 kV-crest.

Terminations are also subjected to tracking. Tracking can be defined as the process that produces localized deterioration on the surface of the insulator, resulting in the loss of its insulating function by the formation of a conductive path on the surface.

A termination can be considered an insulator, having a voltage drop between the high voltage conductor and shield. As such, there develops a leakage current between these points. The magnitude of this leakage is inversely proportional to the resistance on the insulation surface. Fig. 56

Both contamination (dust, salt, airborne particles, etc.) and moisture (humidity, condensation, mist, etc.) will decrease this resistance. This results in surface discharges referred to as tracking. In an industrial environment it is difficult to prevent these conditions. Therefore a track resistant insulator must be used to prevent failure.

A high performance Class 1 termination is built with properly designed insulator skirts which are sized and shaped to form breaks in the moisture/contamination path, thus reducing the probability of tracking problems. Also, such skirt design can reduce the physical length of a termination by geometrically locating the creepage distance over the convolutions of the insulator, a factor when space is a consideration.

Good termination design dictates that the insulator be efficiently applied under normal field conditions. This means the product should be applied by hand with a minimum of steps, parts and pieces. Preferably, no special installation tools or heat should be necessary.

Because they are inorganic materials and do not form carbon (conductive) residues, both porcelain and silicone are considered the best in track resistance.

(Reference: IEEE paper Cat. 76-CH 119-7 PWR "Contamination Testing of Distribution Class Cable Terminations" by L.A. Johnson and W.C. Osborn, 3M Company and "Accelerated Environment Testing of Distribution Class Silicone Terminations" by H.C. Hervig, 3M Company.)

## SEAL TO THE EXTERNAL ENVIRONMENT

In order to qualify as a Class 1 Termination, the termination must provide a seal to the external environment. Both the conductor/lug area and the shielding cut-back area must be sealed. These seals keep moisture out of the cable to prevent degradation of the cable components. Several methods are used to make these seals such as: factory-made seals, tape seals (silicone tape must be used for a top seal), and compound seals. Fig. 57

For further information or copies of references contact

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All terminations are normally grounded. However, individual circumstances can exist where it is not desirable to ground both ends of the cable. The cable shield **MUST BE** grounded somewhere in the system. When using solid dielectric cables, it is recommended that solderless ground connections be used (eliminating the danger of over-heating cable insulation when soldering).

As a general summary, for highly contaminated and exposed environments or on extremely critical circuits, porcelain or silicone rubber terminations are preferred.

For potentially contaminated, moisture-prone areas...most likely the majority of cases...silicone rubber provides dependable Class 1 terminations.

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