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3M™ Cold Shrink Terminations:

Geometric vs. Dielectric Stress Control

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3M History of Cold Shrink

In 1968, 3M invented cold shrink with low voltage EPDM tubes. Since the initial development, 3M has continued to evolve the cold shrink technology, designing cable accessories such as medium voltage terminations with built-in mastic for top sealing, medium voltage terminations comprised mostly of cold shrink material, 69/72.5 kV terminations, splices and integrated splices.

While competitors have since entered the cold shrink market, 3M's 50-plus years in cold shrink product development has proved invaluable when designing new, in-demand products.

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Electrical Stress Control Discussion

3M uses high dielectric electric stress control (also called refractive stress control) in all 3M™ Cold Shrink Terminations, and while geometric electric stress control is also very common because it is easier to manufacture, there are some significant disadvantages to geometric stress control.

First, let's look at what electrical stress is and why it needs to be controlled. Electrical stress is defined as potential voltage difference across a distance and is typically reported in kV/mm (or v/mil). Larger voltage difference over a distance means higher electrical stress. Let's look at why we need stress control and how both types work.

The insulation shield on cable provides uniform electrical stress in the cable insulation. However, when the insulation shield is removed from the cable, the electrical stress will concentrate at the end of the insulation shield as shown in Figure 1. The equipotential lines are very close together at the end of the insulation shield, which means the electrical stress is very high. If this electrical stress isn't controlled by the cable accessory, the cable will fail.

The definition of a termination is to end, or terminate, the insulation shield. The electrical stress has to be controlled where the insulation shield is ended and there are two methods of controlling that electrical stress. In fact, all terminations must use one of these two methods.

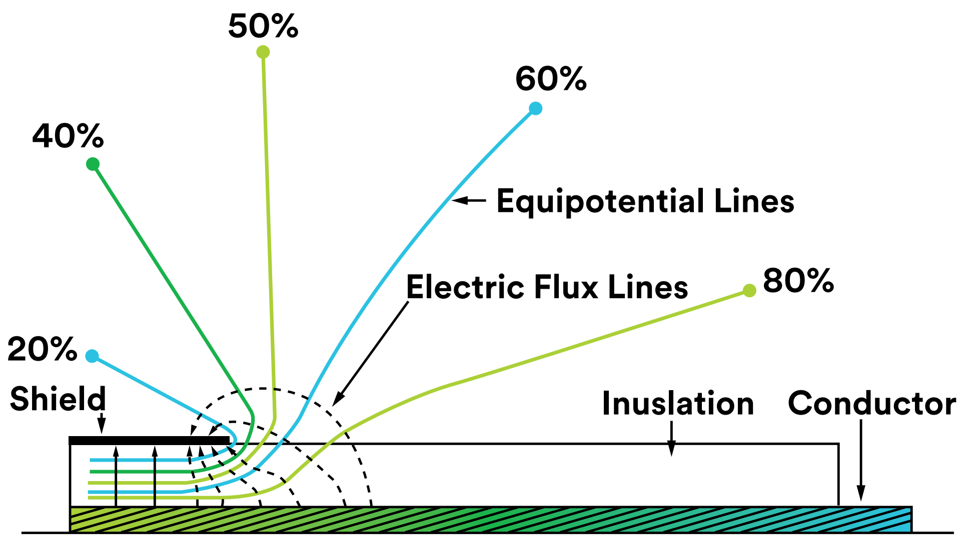


Figure 1: Cable with no electrical stress control

Geometric Stress Control

Geometric stress control uses extra insulation to overcome the high electrical stress. The insulation is gradually increased in a ramp and the insulation shield is extended to the top of the ramp. As seen in Figure 2, the equipotential lines at the end of the extended insulation shield are very close together, meaning the electrical stress on the surface of the termination will still be high. This higher electrical stress means that terminations using this type of stress control will have higher surface stress, which requires a longer termination to meet standards and can also cause more tracking in highly contaminated areas. The longer termination length means that geometric terminations have a long creepage distance, which may not translate to better performance, because of the high surface stress on geometric terminations.

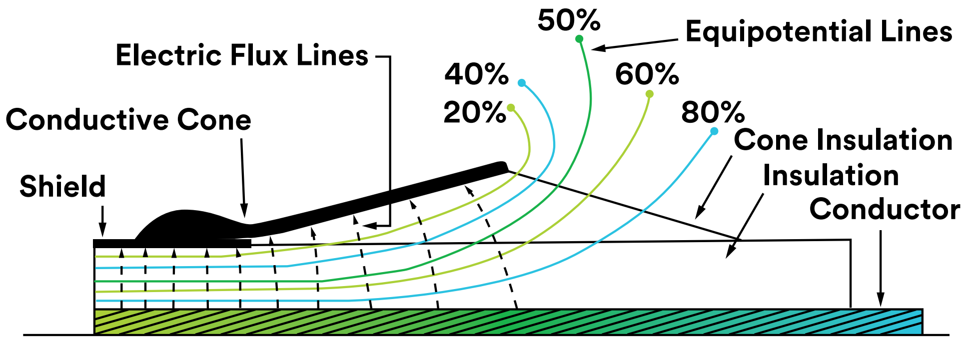


Figure 2: Cable with geometric electrical stress control

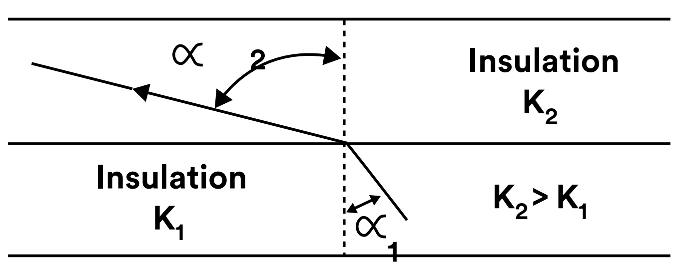
High Dielectric Stress Control

The other way to control the electrical stress is by using high dielectric or refractive stress control. This method uses a material that has a significantly higher dielectric constant— the electrical insulating ability of a material— than cable insulation. Typically, a higher dielectric constant means the material is not as good of an electrical insulator as materials with lower dielectric constants. Table 1 shows some typical dielectric constants of different insulating materials.

As seen in the table, stress control materials need to have a significantly higher dielectric constant than the cable insulation, because it causes the equipotential lines to bend or refract as shown in Figure 3.

Material	Typical Dielectric Constant
Air	1.0
XLPE	2.5 - 3.0
EPR	3.0 - 3.5
Silicone	3.5
Stress control tubes	14-25
Stress control mastic	25-30

Table 1: Typical dielectric constants of some materials



$$\frac{\tan \alpha 2}{\tan \alpha 1} = \frac{1}{K_2}$$

Figure 3: Refraction of equipotential lines

By refracting the equipotential lines, high dielectric stress control spreads out the equipotential lines, so that there is significantly less surface stress than on a geometric stress control termination. This is shown in Figure 4, which shows how the high dielectric stress control spreads out the stress lines. Notice that the equipotential lines at the end of the cable insulation shield are much farther apart than when using geometric stress control. This means that there is much less electrical stress on the surface of the termination, because the voltage difference is spread over a much longer distance.

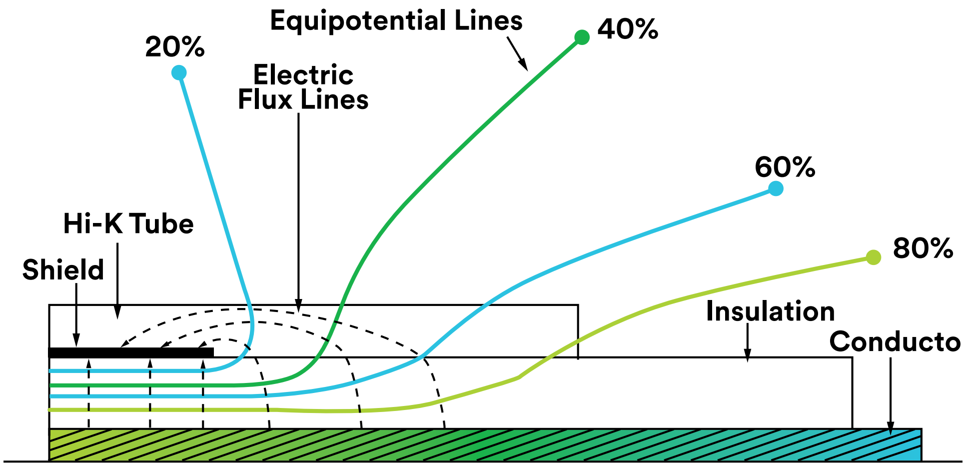


Figure 4: High dielectric stress control termination

Additional Differences Between the Electrical Stress Controls

Since using high dielectric stress control results in lower surface stress on the termination, terminations can be shorter and still test to a higher voltage level and perform better in the field than a longer geometric stress control termination. The high dielectric stress control terminations also perform better in contaminated areas because of this lower surface stress, which leads to less tracking. Both of these factors are very important for a long-lasting, high-performing termination.

Another difference is that high dielectric stress control terminations have more position tolerance than geometric stress control terminations. High dielectric terminations are designed with the high dielectric tube overlapping the insulation shield by 12 mm to 25 mm, which is a necessary component of its functionality and contributes to its position tolerance.

As the dielectric constant increases, typically the material also becomes more lossy (it experiences more dielectric losses). That just means there is slightly more microscopic amounts of current flowing through the high dielectric material than through the more insulating silicone rubber. This dielectric heating shows up as a slightly higher temperature at the semicon step of the cable, which is normal and typically does not affect the termination performance. Depending on the voltage of the system, this temperature increase can be between 2 and 5 degrees Celsius.

It is also important to note that it is more difficult to design and manufacture a high dielectric stress control material and termination than a geometric one, which is why most cold shrink and push-on terminations use geometric stress control, even though it is not the best stress control for medium voltage terminations. 3M developed high dielectric stress control material in the 1970s and has successfully and reliably used this type of termination for more than 45 years.

A 3M white paper, ‘Geometric vs Capacitive Stress Control: choosing cable termination accessories to help reduce electrical stress’[1] shows test data comparing the two types of terminations. At 15 kV, the geometric terminations passed all of the short-term IEEE-48 test requirements. However, at 25 kV geometric terminations were tested and all five failed before completing the sequence. On the other hand, four high dielectric terminations were tested and all four passed the test sequence. For all the test results, please consult the referenced white paper.

Reference:

1) Geometric vs Capacitive Stress Control: choosing cable termination accessories to help reduce electrical stress by George Fofeldea, https://multimedia.3m.com/mws/media/1622497O/geometric-vs-capacitive-stress-control-whitepaper-english.PDF

Summary

For systems up through 69 kV, high dielectric stress control terminations perform better than geometric stress control terminations. They offer better results because they spread out the equipotential lines, which creates a lower surface stress on the termination. This lower surface stress reduces the chances of tracking and allows a shorter termination to perform better than a longer geometric stress control termination. Some of these high dielectric terminations have been in service since their initial release in 1977, proving they have a long, reliable history.

References

1 Geometric vs Capacitive Stress Control: choosing cable termination accessories to help reduce electrical stress by George Fofeldea, https://multimedia.3m.com/mws/media/1622497O/geometric-vs-capacitive-stress-control-whitepaper-english.PDF