13. Silicone in Medium-to High-Voltage Electrical Applications

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The use of silicones in these applications is much related to cable end terminations or silicone rubber connections made at the end of underground high voltage cables insulated with polyethylene, as well as to silicone insulators for power lines.

Key benefits from silicones are their high electrical resistivity, resistance to environmental degradations and to electrical aging as well as their hydrophobicity, which results in lower assembly and maintenance costs [1-2].

Silicone Cable End Terminations

Modern materials allow pre-assembly and thus avoid problems associated with the use of molten casting material or mistakes made during manual assembly on the construction site. Today cable accessories are completely built at the supplier. Typically they consist of rubber terminations made of different insulating silicone rubbers.

Silicones allow for two types of design:

- Push-on technique where a PE ring acts as a space holder until placement, and using silicone rubbers with hardness from 35 to 50 Shore A
- Cold shrink technique using softer silicone rubbers with hardness from 25 to 35 Shore A

Insulation is made without chemical bonding between the termination and the cable, and it relies on the elastomeric characteristics of the silicone termination to exclude any entrapped air, particularly in areas of high electrical field and around the edges at the cable end. The high gas permeability of silicones allows any included air to diffuse out to leave an air-free joint.

Such silicone rubber cable end terminations are produced by rubber injection molding using a silicone high consistency rubber (HCR) or by liquid injection molding using a two-part liquid silicone rubber (LSR).

Silicones provide overall electrical insulation because of their high dielectric strength. In addition to their good resistance to high temperature, UV and ozone, they are hydrophobic and so do not promote surface insulation failures. But more important, specially formulated silicones have been developed to smooth the electrical fields within the connection end and to ensure long-term performance. This is achieved in composite cable terminations either using some electrically-conductive silicone rubbers or, in more modern and smaller accessories, shaped deflectors made from silicone rubbers with medium electrical permittivity (see Figure 1).

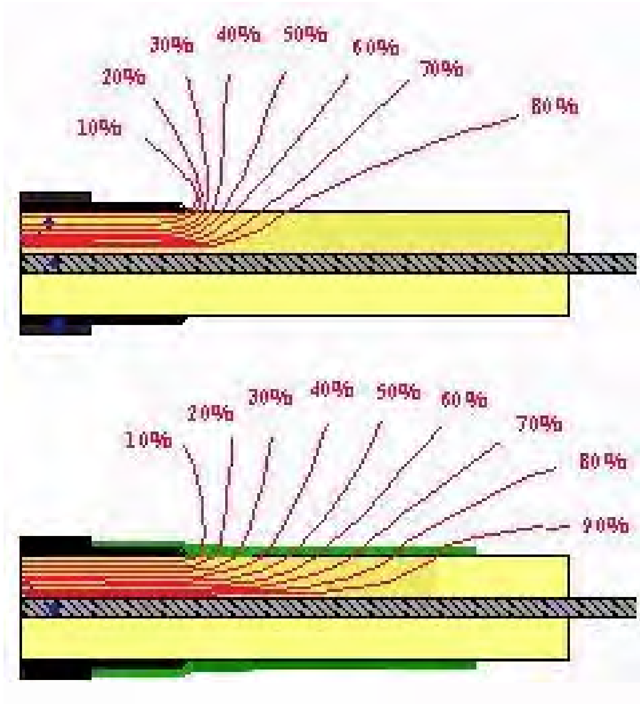

Figure 1. Field line density in a cable end termination at the cut of the screen without control (upper figure) or with a nonconductive/high permittivity field control silicone rubber (in green; lower figure).

Silicones are appreciated in cable end terminations because of their resistance to erosion caused by radiation. As silicones do not absorb UV-visible sunlight, they are not prone to chalking or cracking. Such phenomena are typical with organic-based materials and, associated with dirt pickup and humidity, can lead to a significant reduction of insulation properties.

Silicone resistance to so-called "tracking" is also higher than with organic-based insulation materials. Tracking is the formation of electrically-conductive surface paths under intensive electrical surface leaks and discharges. In organic materials, this leads to the formation of carbon-based decomposition products that unfortunately show high conductivity. With silicones, even if poorly designed or not properly assembled, decomposition leads to nonconductive silica, and silicones will meet the highest class of electrical erosion resistance.

Silicone Insulators

Another key property is hydrophobicity, particularly for electrical insulators, or devices installed between power lines and supporting structures. Water on an insulator made of a silicone elastomer remains as droplets and does not form a continuous film because of the low surface energy of the silicone elastomer surface [3-4-5]. This reduces surface currents on the insulator. Surface hydrophobicity is maintained even after surface discharges or deposition of airborne pollution because of the presence of low molecular weight, unreacted polydimethylsiloxane species in the composition of the silicone elastomers. These species can migrate to the external surface and maintain low surface energy or hydrophobicity [6]. Insulators made of silicone elastomer therefore need little cleaning or maintenance and perform over a long period of time (see Figure 2).

Figure 2. Comparison of an insulator after 23 years of use and exposure to pollution (left) vs. a retained sample kept at RT (right). Both still show excellent hydrophobicity as indicated by the high contact angle of the water droplets. (Picture courtesy of Lapp Insulators GmbH & Co.KG).

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This article has been published in the chapter "Silicones in Industrial Applications" in *Inorganic Polymers*, an advanced research book by Nova Science Publishers (www.novapublishers.com); edited by Roger De Jaeger (Lab. de Spechtrochimie Infrarouge et Raman, Univ. des Sciences and Tecn. de Lille, France) and Mario Gleria (Inst. di Scienze e Tecn. Molecolari, Univ. di Padoa, Italy). Reproduced here with the permission of the publisher.