White Paper on Suitability of Silicone for Outdoor Terminations

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Background

There are many technical papers written on the use of silicone in outdoor environments. The use of silicone in outdoor environments was started over 50 years ago and has become the material of choice for most outdoor polymeric insulators and terminations. It is used in both transmission and distribution applications and is used in both of these applications in Australia and New Zealand. Silicone has become the material of choice for many outdoor applications because of its inherent UV resistance, hydrophobicity and track resistance. The rest of this document shows technically why silicone materials perform well in outdoor applications.

UV Stability Comparison of Materials

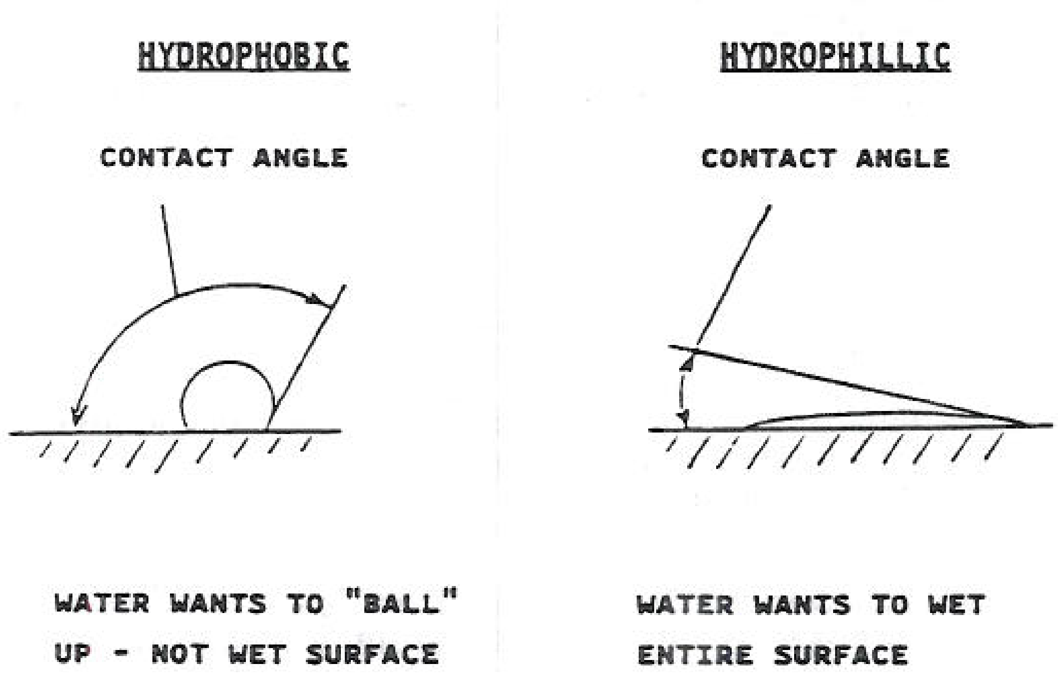
Ultraviolet light has a lot of energy that is destructive to many polymeric surfaces. If the UV energy is higher than the bond energy between atoms in the molecular structure of a polymer chain, the energy from the UV light can breakdown the molecular structure of the polymer. The backbone molecular structure of silicone materials is a silicone-oxygen bond, which has a very high bond strength. The backbone molecular structure of many other polymeric materials is a carbon-carbon bond. Some of the polymeric materials that have the carbon-carbon backbone are ethylene vinyl acetate (EVA, which is most heat shrink materials), polyethylene and ethylene propylene diene monomer (EPDM). The following chart shows the bond energy of these bonds compared to UV energy. (Ref. 1)

Bond	Bond Energy (Kj/m)
Si-O – (silicone)	445
C-C – (EPDM, polyethylene, EVA)	348
UV light energy	398

As seen from this chart, the UV energy from the sun is lower than the bond energy in the backbone bonds of the silicone material, so it is inherently UV resistant, which is one reason it is used so extensively for outdoor insulators and terminations for both medium and high voltage. Typically other polymeric materials that are used outdoors have UV absorbers or blockers or both added to their material formulations so they can be used in outdoor applications.

Hydrophobicity

Another important material property required for good outdoor performance as a medium or high voltage insulator or termination is the hydrophobic properties of the material. Hydrophobicity is measured by the contact angle of water when on the material. The larger the contact angle, the more hydrophobic is the material. The smaller the contact angle, the more hydrophilic is the material (see the figures below). The more hydrophobic the material, the better the material works as an electrical insulation for outdoor insulators or terminations. Think of a freshly waxed car that is in the rain (car wax is typically silicone based because its hydrophobic properties). The water beads up, but does not wet out the surface. In other words there is not a continuous wetted out surface.



Silicone is inherently hydrophobic, so that water beads up on its surface. This makes for a high resistance surface which reduces the amount of leakage current that will travel on the surface of the material. This reduction in leakage current means a longer product life and better electrical performance, as the material won't be degraded by excess leakage current. Porcelain is typically hydrophilic, so that its surface tends to wet out when exposed to rain. Due to this wetting out of the surface, which makes a low resistance surface due to the continuous water being a good conductor, porcelain insulators typically see much more leakage current than do polymeric silicone insulators. This issue plus the difference in weight are two of the primary reasons that polymeric silicone insulators are frequently used. Other polymeric materials such as EPDM and

EVA are inherently more hydrophilic than hydrophobic, but they have additives included in their formulations that make them hydrophobic. Depending on the formulation, these additives can be depleted over time and the materials will tend to become more hydrophilic.

When subjected to continuous contamination and moisture, some polymeric materials, including silicone, can lose this hydrophobic property. However, silicone materials have small molecules in the material called oligomers. These oligomers come to the surface to make the silicone hydrophobic again. These oligomers will even coat contamination that is on the surface of the silicone to make it hydrophobic. Studies have shown that if silicone does lose its hydrophobicity, it will recover that hydrophobicity in 24 hours or less once the material dries out. There are enough of these oligomers in the silicone material to keep it hydrophobic for the life of the product. Many silicone terminations have been in service for over 40 years and are still performing well.

Conclusion

Long service history and material properties that work exceptionally well for electrical insulators and terminations in outdoor environments help explain why silicone material is so widely used and accepted in these applications. Silicone materials have been used in outdoor applications very successfully since the 1960s. Based on this long successful history and the material properties that make silicone the polymeric material that is best suited for outdoor electrical use, it is not surprising that silicone medium and high voltage insulators and terminations are so widely accepted and installed. It is the material of choice in many countries, including the US and most Western European countries.

References:

1) "Test and Field Experience with Elastomeric Terminations" by Harold Hervig 3M Electrical Products Division
2) "Field and Laboratory Aging of Polymeric Distribution Cable Terminations: Part 1-Field Aging by Dr. R.S. Gorur Arizona State University and B.S. Bernstein EPRI

Bill Taylor – Graduated from the University of Texas at Austin with a BSEE degree in 1975. Worked as a plant electrical engineer for 13.5 years for two PetroChem companies. Went to work for 3M in February of 1989 as a product development engineer for medium and high voltage cable accessories. Is currently chairman of the IEEE Std 48, IEEE Standard for Test Procedures and Requirements for Alternating Current Cable Terminations Used on Shielded Cables Having Laminated Insulation Rated 2.5 kV through 765 kV or Extruded Insulation Rated 2.5 kV through 500 kV. Was also chairman of the IEEE/PES/ICC (Insulated Conductor Committee) from 2004-2005.