Arc Tracking and Silicone Self-Fusing Tape

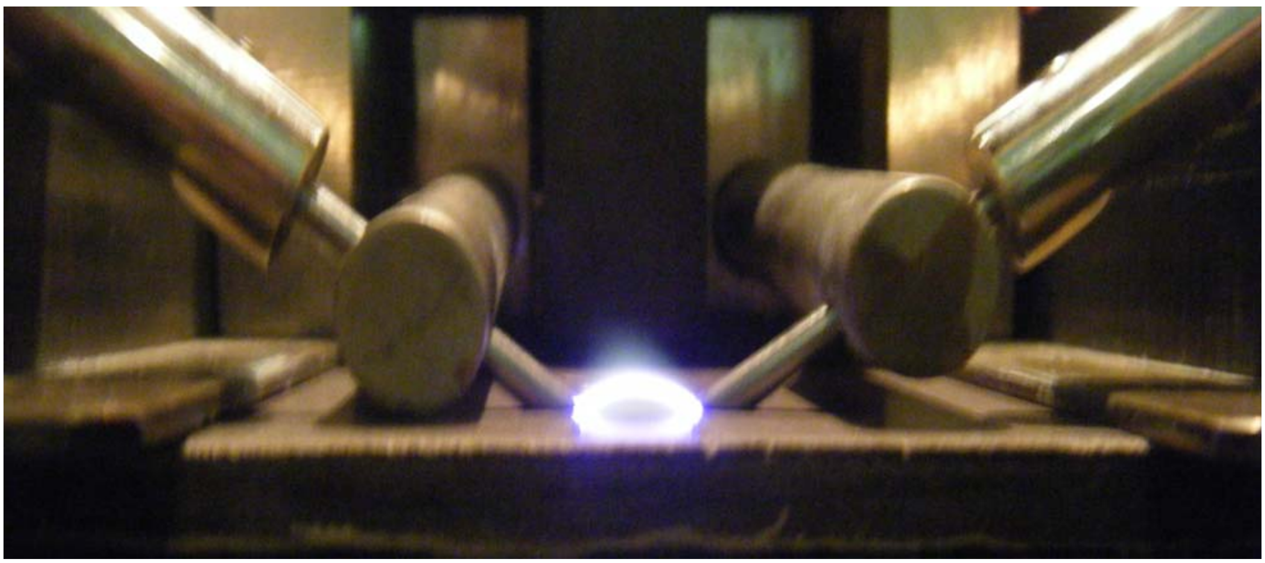
Geno Amalfitano
Arlon Silicone Technologies
1100 Governor Lea Road
Bear, DE 19701
United States
www.arlon-std.com

Abstract

Many electrical insulation applications are designed with dielectric breakdown strength (DBS), or the voltage potential required to break through an electrically insulating material, as a major factor. While this is a good test to determine how resistive a material is through its volume it does not provide information about surface resistivity of the insulation material. Arc tracking is a phenomenon where an electric current burns the top layer of an insulation material and allows the current to migrate across the insulation and ultimately cause damage. Arc tracking is defined as the number of seconds that a material resists the formation of a surface conducting path when subjected to an intermittent arc of high voltage and low current characteristics. The effect of arc tracking can cause electrical insulation failures and risks that may be missed by standard dielectric breakdown strength analysis. Arc tracking is also heavily influenced by the surrounding environment of the application. Because the outside layer of an electrical insulation can be exposed to the elements, different environments can affect the degree of arc tracking. This paper examines and compares the dry arc tracking resistance of silicone, self fusing and vinyl tape used in electrical insulation systems

Introduction

Arc tracking can simply be described as a high voltage, electric current that jumps from one point to another over the surface of a an insulation system. Electrical arcing occurs when a current jumps across an air gap and produces heat and visual light. An arc is formed by the electrical breakdown of a gas, which produces a continuous plasma discharge. This occurs when a current flows through a nonconductive media such as air and is called Arc Discharge [1]. The effect causes intense heat at the point of discharge and a column of light created from the partially ionized gas. The name arc tracking comes from the fact that the ionized gas temperature rises and the electric current remains connected to the current producing electrode ends, producing an arc shape [1]. Photograph I illustrates the arc tracking phenomenon.



Photograph I

Arc tracking resistance is a different insulation property than dielectric breakdown strength and volume resistivity. Dielectric breakdown strength is defined by McGraw-Hill Dictionary of Scientific and Technical Terms as "The maximum electrical potential gradient that a material can withstand without rupture; usually specified in volts per millimeter of thickness" [2]. Dielectric breakdown strength is measured as the voltage at which a current completely breaches an electrical insulation system and is measured in volts per unit of material thickness. The effect results in the formation of a narrow discrete channel, or a tree-like pattern of channels of catastrophic material failure. It is a massive dissipation of energy in a very confined volume [3]. The material literally has a hole blown through it by a high voltage, electric current. This is different from an arc tracking failure, where the electrical current jumps across the surface of an insulation material and starts to burn the surface, which may eventually lead to a dielectric breakdown failure or even an insulation fire.

Volume resistivity is a measure of leakage current resistance of an insulating material. CRC Press describes volume resistivity as “The ratio of the potential gradient parallel to the current in a material, to the current density. It is numerically equal-to the direct current resistance between opposite faces of a one centimeter cube of material, expressed in ohm-centimeters”[4]. A volume resistivity test places insulating material between two electrically conducting plates and determines if any current leaks through the insulation material. This electrical phenomenon is also very different from arc tracking because it occurs though the volume of an insulator and not across the surface of an insulator.

Arc tracking is of great importance because the origin of the arc is a hot point that can burn insulating materials and cause fires or create a conductive path. There are many commercial markets that have closely examined arc tracking for insulation design purposes, including the Avionics and Aerospace industries. Flame resistance is a concern in these industries and applications require highly electrically insulative materials that will not char or even ignite because of potential arc tracking phenomenon. There is also a major interest in arc tracking in home wiring applications. Older homes, which have Knob and Tube wiring systems, are susceptible to arc tracking and potential fires. These systems may need to be replaced or have a highly arc track resistant insulation material applied to them to reduce the risk of fire from electrical arc tracking [5]. Arc tracking resistant insulation is used more and more in wire wrapping applications because of the increased interest in electrical safety. Most industries that use electrical insulation are more closely examining arc tracking phenomenon and are trying to identify and use better arc track resistant material.

Silicone rubber is an obvious choice when attempting to identify an insulation material that will have high dielectric resistance. Silicone rubber is a synthetic polymer derived from sand or quartz and has an alternating silicon-oxygen backbone, which differs from the carbon-carbon backbone in natural or organic rubbers. The silicon-oxygen backbone of silicone provides many unique properties when compared to organic elastomers. Silicone rubber has a superior combination of insulating properties and flexibility in electrical insulation applications. Silicone elastomers are non-conductive and in many cases are better suited for flexible insulation applications than other insulating organic polymers due to longer bond length between the silicon-oxygen elements in the polymeric chain. For example, the polymeric make up of vinyl electrical tape consists of vinyl functional groups that branch from the main polymeric carbon chains. The vinyl groups provide decent elongation and good arc resistance, but both however are generally considered inferior properties when compared to a silicone elastomer. In the following study, Arlon MOX-Tape T1020-R004-12 and Arlon 920-10R12-P0, silicone, self-fusing tapes were compared to an industry leading vinyl electrical tape.

Arc Tracking Resistance Test

Two silicone, self fusing tapes and a vinyl electrical tape with pressure sensitive adhesive were compared in the arc tracking study. The study references a modified version of ASTM D495-99, Standard Test Method for High-Voltage, Low-Current, and Dry Arc Resistance of Solid Electrical Insulation. The test method determines resistance to high voltage, low current, arc tracking at the insulation system surface. The test method is designed to force formation of a conductive path on the insulation material surface due to the localized thermal and chemical decomposition and erosion of the polymer [6]. All of the electrically insulating tape candidates were cut into three inch long sections, which were stacked five high, to prepare a test specimen. Stacking the sections was necessary to build thickness so that the arc discharge was constrained to the specimen surface and would not discharge through the specimen volume. Twenty specimens of each candidate insulation were assembled in this fashion. The specimens were stacked carefully to make sure that there was no entrapped air between the layers. The test surface of each specimen was cleaned with isopropanol and thoroughly dried before testing. The dry arc tracking resistance of each specimen was determined using Beckman ART-1 Arc-Resistance test equipment. The two electrodes were removed and lightly sanded with P400 abrasive paper to remove any oxidation on the electrodes. Each electrode was then wiped clean using isopropanol and a chem wipe. The specimens were then individually placed on the test platform under both electrodes spaced 0.25" apart. A potential of ~12,500 volts at 10 milliamps was utilized to create the arc discharge. Initial surface discharges to the specimen occurred every 2 seconds for a 0.25 second duration for the first 60 seconds of the testing cycle. The discharge frequency was then increased to 1 discharge every second for a 0.25 second duration, between 60 and 120 seconds of the testing cycle. Finally, the discharge frequency was increased to one every half second for a duration of 0.25 seconds for the final 60 seconds of the testing cycle.

Arc Tracking Resistance Results

The Arlon MOX-Tape and Arlon silicone, self-fusing, insulation tapes exhibit vastly greater arc tracking resistance than the vinyl electrical tape. The Arlon MOX-Tape, T1020-R004-12, has the best arc tracking resistance with a mean time to arc tracking of 123.4 seconds. The Arlon tape, 920-10R12-P0, also performs very well with a mean time to arc tracking of

122.1 seconds. The vinyl electrical tape does not perform as well as either silicone tape; the mean time to arc tracking is only 11.5 seconds. This value is >90% lower than the arc tracking resistance of either silicone tape insulation in the study. The surface of the vinyl electrical insulation tape developed a char path very quickly during testing, which allowed the electrical discharge to easily migrate across the surface of the insulation. The silicone based insulation materials in contrast resisted arc tracking much longer and showed little initial char formation from the arc discharge. The silicone did not start build char until the 120 second test cycle mark or when the discharge frequency occurred every half second.

Chart I below shows an individual value plot comparing the arc tracking resistance of each test candidate. Chart I highlights the large difference in time to arc tracking between silicone and vinyl electrical insulation tape. The chart also shows the tight distribution of data, especially for silicone, self fusing tape. The time to arc tracking standard deviation of the Arlon MOX-Tape T1020-R004-12 is 0.5 seconds and the Arlon Tape 920-10R12-P0 standard deviation is 1.0 second, proving very consistent arc tracking resistance.

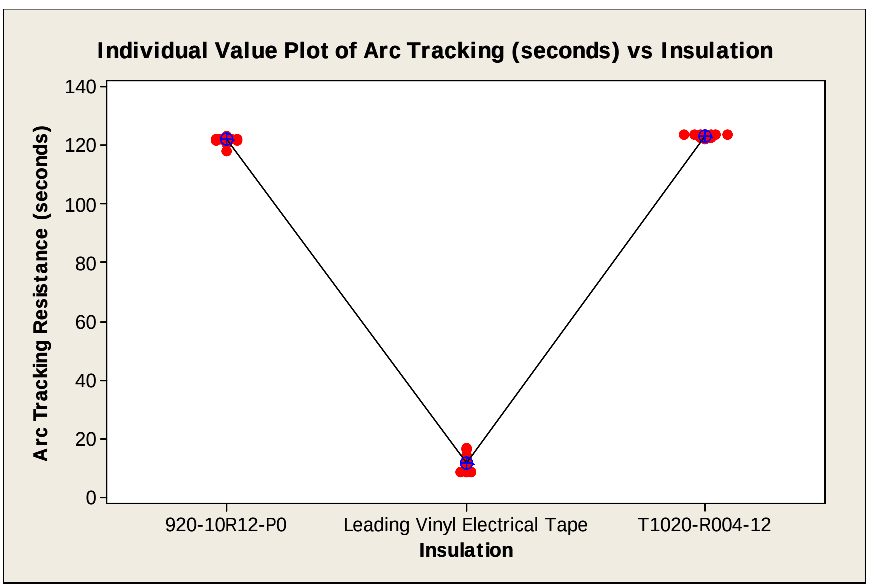
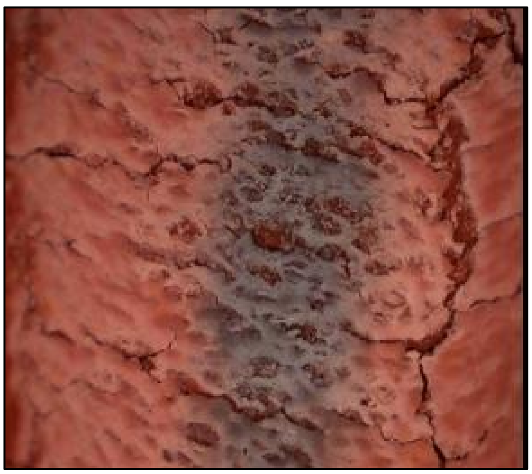
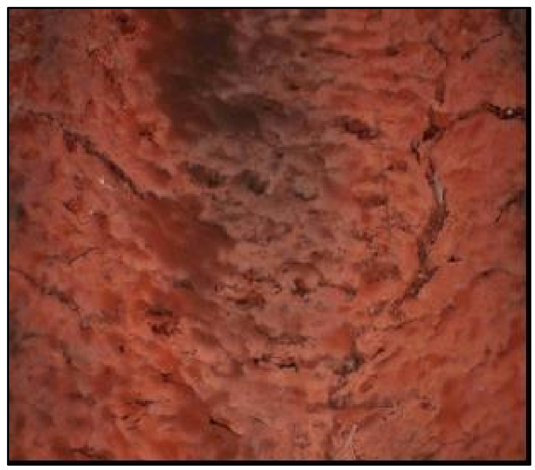


Chart I

The test materials were also examined under 5X magnification to take a closer look at the char path that the electrical discharges created. The difference is easily seen; the two silicone based insulation materials show a mild char on the tape surface. The micrograph of the vinyl electrical tape shows a distinct char channel across the surface of the insulation. The reason for this is that that when the vinyl electrical tape burns, carbon ash is produced, which creates a conductive path so that an electric discharge can quickly and easily track across the surface of the insulation. Silicone ash is mostly nonconductive, so the arc discharge must completely burn the surface of the insulation to facilitate any tracking.



T1020-R004-12



920-10R12-P0

Vinyl Electrical Tape

Conclusion

Silicone, self-fusing, Arlon MOX-Tape and Arlon Tape outperform a leading industrial, vinyl, electrical tape when it comes to high voltage arc tracking resistance. The dry arc tracking resistance of silicone tape is consistently greater than 120 seconds when tested according to ASTM D495. A leading vinyl electrical tape can only resist the same high voltage discharge for 11.5 seconds before yielding a conductive path across the insulation surface.

References

[1] Alexeff, Igor & Lonngren, Karl (2007). "Arc discharge" in *AccessScience* McGraw-Hill, http://www.accessscience.com.

[2] Sci-Tech Dictionary (2003). McGraw-Hill Dictionary of Scientific and Technical Terms.

[3] Robell, Kenneth (2005). Effect of Elastic Elongation on Dielectric Strength, *Study Based on Self-Fusing Silicone Tape*. Arlon Silicone Technologies.

[4] "Volume Resistivity Definition" (1989). CRC Press LLC. Retrieved from http://composite.about.com/library/glossary/v/bldef-v5988.htm.

[5] Lawrie, Robert J. (1997) In Adverse Environments, is Knob and Tube Wiring Susceptible to Arc Tracking [Electronic version]. Electrical Construction and Maintenance Vol. 96 issue 5 p12.

[6] ASTM Method D495-99 Standard Test Method, High-Voltage, Low-Current, Dry Arc Resistance of Solid Electrical Insulation. (2004). American National Standards Instituted.