Comments on RTV and HTV Materials for High Voltage Outdoor Insulation

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Abstract

The purpose of this short paper is to point out and comment on some aspects of silicone rubber materials used for outdoor insulators. The present note does not analyze in detail the properties of such insulating materials but it emphasizes factors affecting their performance.

Keywords

Silicone rubber, outdoor insulation, hydrophobicity, RTV silicone rubber, HTV silicone rubber, trihydrate alumina, arc resistance, low-molecular weight (LMW) polymer, corona discharges

Introduction

There is a vast body of technical literature regarding the RTV (Room Temperature Vulcanized) and HTV (High Temperature Vulcanized) polymer outdoor insulators [1] - [9]. In the last decades polymer insulators seem to replace traditional outdoor insulators made of porcelain and glass [10]. RTV and HTV silicone rubber seemed to be the preferred insulating material for outdoor high voltage applications [11]. Such materials are complex materials since they also include fillers in order to acquire a better arc resistance. Silicone rubber has a very important property, namely hydrophobicity.

Although the technology of polymer outdoor insulation proved to be reliable under various weather conditions, some questions w.r.t. to its particular characteristics need to be discussed. During the last decades, questions have been arisen. Pertinent questions as to the technology of both RTV and HTV rubber are:

1) Do fillers (such as Al_2O_3 $3H_2O$) influence negatively the mechanical properties of silicone rubber? Are the negative effects more pronounced for the RTV or for the HTV silicone rubber? Does a filler like Al_2O_3 $3H_2O$ benefit equally well HTV and RTV? If not, why is this so? Is there an optimum filler percentage which may give an optimum electrical performance for HTV? Is this optimum percentage different for RTV? If so, why?

2) Regarding hydrophobicity, is HTV more hydrophobic than RTV, or are they the same?

3) Is hydrophobicity due to low molecular weight degradation products or to unpolymerized monomer groups?

In this short paper, we will try to answer the above questions.

Comments and Discussion

Given that both the RTV and the HTV are complex materials, it can be said that fillers, such as Al_2O_3 $3H_2O$, generally improve the physical properties of the rubber in both its aforementioned types. There are, however, optimum levels of filler. Such an optimum level depends on factors such as base polymer, cure system, and possibly other formulation parameters. It must be emphasized that with proper formulating and processing, the fillers, such as trihydrate alumina (Al2O3 3H2O), can be incorporated into the rubber and can improve both the arc resistance and the physical properties. Having pointed the above, one cannot make a general statement, i.e. that Al_2O_3 $3H_2O$ benefits equally well HTV and RTV technologies. The benefit of the filler depends specifically on its type, amount and particle size as well as the quality of its dispersion and bonding within the matrix of the crosslinked polymer. Both formulating and processing issues are involved in achieving maximum benefit from the filler. There is an optimum level of filler for both HTV and RTV which is likely to be somewhat different. This again goes back to the specific chemical and processing technology employed. Utility

people assume quite often that silicone rubber is a generic material and is all the same regardless of the specific and processing systems used. Although it is true that some generalizations can be made about the silicone family of rubber, from a formulation viewpoint it becomes much more difficult. Moreover, one must define what it is that is "optimized" by the filler. The optimization of arc resistance will likely lead to high levels of filler. However, this may lead to more filler than is actually needed since one of the unique characteristics of silicone is its ability to suppress the leakage currents which lead to the arcing. Therefore, optimizing the arc resistance alone may limit other properties of the material such as leakage current suppression or processing / handling properties.

Hydrophobicity is a property of paramount importance. This can vary not only between RTV and HTV but also within each group. Hydrophobicity is due to the methyl side groups on the silicone polymer backbone. It is also to be pointed out that factors such as curing system, filler loading and surface conditions affect the hydrophobicity. The aforementioned factors affect the loss and recovery rate of hydrophobicity under various stress conditions. Generally speaking, the hydrophobicity of the silicone family of materials is quite good. Whether or not meaningful performance distinctions (or predictions) can be made by use of the contact angle measurements depends. Explaining further this point, one can say that the performance of the material in a polluted environment depends not only on the hydrophobicity but also on the ability of the surface to encapsulate and transfer hydrophobicity to the surface pollutants [12].

As to the question whether hydrophobicity is due to low molecular weight (LMW) degradation products or to unpolymerized molecular groups, it can be said that hydrophobicity is probably due to LMW polymer which can migrate through the bulk rubber and can be driven to the surface in order to achieve thermodynamic equilibrium with the air on the surface. The surface energy of the LMW polymer is close to that of air and is therefore driven out to the surface. As this layer undergoes degradation through exposure to corona discharges, arcing and related phenomena, the methyl side groups on the polymer chains are oxidized to form a material with higher surface energy. The untreated

LMW material within the bulk of the rubber then is driven to the surface through microcracks in the top surface layer of reacted material by the thermodynamic driving force and thus restores the hydrophobicity. This LMW polymer is present in the rubber from its initial vulcanization. Whether or not additional LMW material is generated by degradation mechanisms is a subject to be further explored.

Although the above are mainly comments about silicone rubber insulators, such comments are also relevant to silicone rubber coatings. The question of hydrophobicity becomes even more acute for silicone rubber coatings since such coatings are very thin and, consequently, their reservoir of LMW polymer is not as rich as in typical silicone rubber insulators [13], [14]. Moreover, the question of the duration of hydrophobicity and its recovery is crucial also in the case of insulators consisting of silicone rubber - EPDM blends [15], [16], and also for superhydrophobic insulators [17], [18].

Conclusion

Although silicone rubber seems to be a reasonable alternative to traditional materials, such as porcelain and glass, questions as to the details of the processes during its manufacturing still remain. Although silicone rubber is a generic name, silicone rubber insulators' performance depends on every single manufacturer' processing. Hydrophobicity is a very important property for silicone rubber, however, its recovery or depletion depends on the severity of weather conditions. This holds especially true for silicone rubber coatings.

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