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# Silicone insulators of power transmission lines with a variable inorganic load concentration: Electrical and physiochemical analyses

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ABSTRACT

Polymeric insulation is an increasing tendency in projects and maintenance of electrical networks for power distribution and transmission. Electrical power devices (e.g., insulators and surge arresters) developed by using polymeric insulation presents many advantages compared to the prior power components using ceramic insulation, such as: a better performance under high pollution environment; high hydrophobicity; high resistance to mechanical, electrical and chemical stresses. The practice with silicone insulators in polluted environments has shown that the ideal performance is directly related to insulator design and polymer formulation. One of the most common misunderstandings in the design of silicone compounds for insulators is the amount of inorganic load used in their formulation. This paper attempts to clarify how the variation of the inorganic load amount affects physicochemical characteristics of different silicone compounds. The physicochemical evaluation is performed from several measurements, such as: density, hardness, elongation, tensile strength. In addition, the evaluation of the physicochemical structure is carried out using infrared test and scanning electronic microscopy (SEM). The electrical analysis is performed from the electric tracking wheel and erosion test, in agreement with the recommendation of the International Electrotechnical Commission (IEC).



## 1. Introduction

In the past thirty years, glass and porcelain insulators have been substituted by a relatively new class of insulator composed of polymeric compounds [1]. This technology has been used in distribution and transmission systems. The first transmission line with composite insulators was installed in Germany in 1969 [2]. Currently, the polymer insulators represent more than 40% of the new insulation market in the United States [3].

In Brazil, the replacement of ceramic to polymer insulators began in 1987, because of the limited experience on the electrical performance of these polymeric compounds as function of the aging and physicochemical degradation caused by environmental agents [3,4]. However, currently, there is more than 50,000 km of transmission and distribution overhead lines, corresponding approximately to 400,000 new insulators [5].

Silicone, Terpolymer Ethylene and Propylene Diene (EPDM) are materials used in the manufacturing of great part of the polymeric insulators. However, the use of silicone in the insulator housing has increased in the last few years even more, mainly because of the great performance in the hydrophobicity recovery [2,3,6,7].

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The analysis of the insulation coordination for overhead transmission lines is not a trivial task. Specific issues related to the environment characteristics, weather and pollution should be taken into account. In regions with high pollution levels, silicone insulators are more appropriate (and also more expensive) than their similar-based EPDM. The silicone insulators are also more appropriate in areas with specific climatic conditions, e.g., sea coast locations and tropical weather conditions [3].

The adequate physicochemical formulation, based on polymer and other components, combined with an optimized physical structure of the insulator body can significantly improve the insulation levels of transmission and distribution networks. The variation in the polymeric housing formulation results in 20% up to 80% on the weight of the material. Some additives included in the polymeric housing of insulators reduce manufacturer costs, facilitate the processing of materials and also improve the performance of these insulators [1,3].

Some studies have been conducted to evaluate the aging and degradation process on polymeric insulators, in order to establish standards for aging/degradation tests in a reduced-time scale. The aging/degradation tests on polymeric devices are possible by means of an environment with temperature, moisture and pollution controlled, in order to induce an accelerated aging and degradation on the samples [3,8,9]. Based on the technical literature, the degradation caused by aging is responsible for approximately 65% of failures in polymeric insulators. This means that the remaining 35% are caused from mechanical and electrical stresses [3,4].

One of the most classical tests for assessing the performance of insulators on severe environmental conditions and polluted areas is expensive and long, i.e., approximately 5000 h [10]. However, a new test was proposed in 2004, recommended by the IEC 62217 [11], representing a test procedure less expensive and faster than the prior procedure with 5000 h. This test is known as roll of electrical routing or electric tracking wheel.

The roll of electrical routing is a relatively new test, which allows to compare the performance of different insulators keeping the same material or to evaluate different polymeric compounds keeping the same project.

This paper proposes a complete investigation of silicone compounds with different concentrations of inorganic loads using the roll of electrical routing. Physiochemical measurements were carried out to evaluate several electrical and mechanical variations among the silicone compounds. Therefore, results and conclusions presented from the test procedure proposed in this paper represent a great database and reference for further researches and manufacturing processes of polymeric insulators.

## 2. Silicone insulators

The silicone rubber compounds evaluated in the proposed study are five types, varying according to the inorganic load concentration:

1. (S1) – silicone rubber compound with HTV (High Temperature Vulcanizing) fumed Silica and Alumina Trihydrate (ATH) zero parts.
2. (S2) – S1 + 25 parties of fumed silica and ATH.
3. (S3) – S1 + 50 parties of fumed silica and ATH.
4. (S4) – S1 + 75 parties of fumed silica and ATH.
5. (S5) – S1 + 100 parties of fumed silica and ATH.

The compounds used in this research were manufactured by Bluestar Silicones Brasil Ltda.

## 3. Electric tracking wheel

The IEC 62217 describes two or four insulators characterized by the same compound with creepage distance between 500 mm and 800 mm, which are tested simultaneously in the stem routing. Before starting the test, insulators are cleaned with deionized water. In sequence, the samples are arranges in four positions, as illustrated in Fig. 1. The rotation process consists in each sample stays stopped around 40 s at each position. Each 90° rotation step takes approximately 8 s [11].

The first step of the cycle (Immersion Time, as described in Fig. 1), the sample is immersed in a saline solution. The following step (Following Time, in Fig. 1), the sample receives an excess of saline flow, ensuring that slight moisture on the surface induces discharges through the dry bands formed in the third step. The Energized Time or third step, the sample is energized with industrial-frequency voltage for 40 s. In the last step (Cooling Time, in Fig. 1), the sample is cooled after the overheating, resulted from the surface discharges in the Energized Time.

Through the test procedure, the saline solution was replaced during the weekly interruptions for inspection. These interruptions along the test time did not spend more

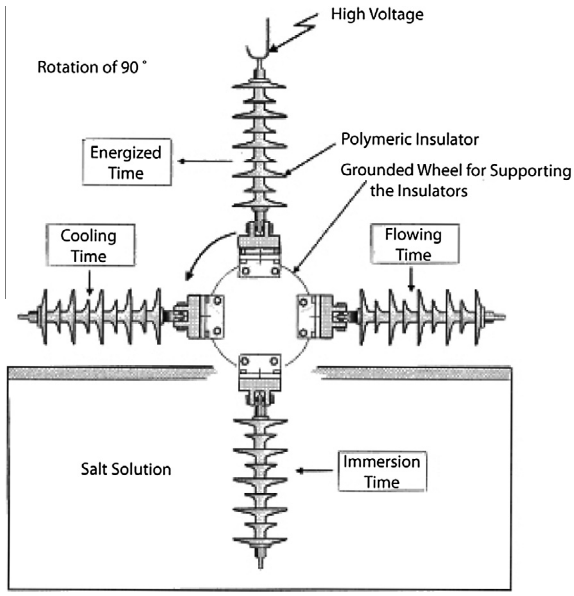


**Fig. 1.** Schematic illustration of the electric tracking wheel.