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Resistance of silicone high-voltage insulation to leakage current in modified inclined plane test

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Abstract: In this paper results of investigations of resistance to leakage currents of two different silicone rubbers subjected to a modified inclined plate test are presented. The modification of the experiment consisted in a change of the sample's inclination angle from 45° to 18º and in feeding a moistening solution to the upper surface of the sample. The main aim of the modification was to create laboratory test conditions as close to the ones observed in reality as possible.
The test results obtained for clean samples were compared with the ones obtained for polluted samples. The effects of leakage currents and of the associated internal partial discharges, which pose the most serious hazard to surge arresters, were examined.

1. Introduction

The inclined plane test is a standard method of investigating insulating materials, especially traditional ones such as resins and laminates, designed for use in high-voltage devices operated in high humidity conditions and in the presence of substances which increase electric conductivity [1].
When evaluating the hydrophobic proprieties of silicone rubbers by this method, the surface of the sample has to be artificially modified to prevent the moistening agent from flowing off it – the large inclination (45º) of the sample in the standard test results in the rapid flow of the moistening agent and due to the hydrophobicity of the surface of silicone rubbers makes the formation of a moistened path on the sample's surface and the passage of current between the electrodes impossible.
For technological reasons the inclination of the upper surface of surge arresters' non-ceramic housing sheds is small. Examinations of operating non-ceramic insulators and the housings of surge arresters reveal traces of erosion on the upper surfaces of their sheds (in the rod area) in places where pollution and water accumulate, which indicates the occurrence of surface discharges. Therefore to recreate such conditions in the inclined plane test, the upper surface of the tested silicone rubbers must be moistened and the inclination of the samples must be decreased.

In the course of operation, the surfaces of the non-ceramic housing of surge arresters lose (to different degrees) their hydrophobic proprieties. Different degrading factors act on different areas of the housing. For example, UV radiation affects mainly the unsheltered surfaces of the housing and precipitation falls on the upper surfaces of the sheds. As a result, surface wettability and voltage are unevenly distributed on the housing in the presence of moisture and pollution. This leads to changes in voltage distribution on the arrester's housing and along the column of arresters.

Pollution phenomena on the external surfaces of the housing belong to the major causes of failures of surge arresters. Capacitive couplings between the external pollution layer and the internal components are the vehicles through which pollution affects the arrester.

When the surface leakage currents are small in comparison with the capacitive current, the distribution of capacitive voltage is not significantly affected. This is the case in dry or slight pollution conditions. When the pollution is more severe, the magnitude of the external leakage currents exceeds that of the arrester's rated capacitive current. The result may be a transient voltage distribution on the housing surface that differs considerably from the normal capacitive distribution. Depending on the leakage current magnitude, the coupling to the ZnO varistor and the duration of the pollution event, heating of the varistor may result. If the surface leakage current magnitude is large enough, a possible large voltage unbalance may force the voltage across the arrester to reach the inflection point of the latter's voltage-current characteristic.

2. Test setup and object of investigations.

The object of the investigations were 3 and 5 mm thick samples of HTV silicone rubber and 0.4 mm thick samples of RTV coating, all in the shape of 120x50 mm rectangles. Clean samples and samples polluted with kaolin and salt at a weight ratio of 10:1 were investigated. In accordance with the results of measurements of SDD on naturally polluted non-ceramic insulators reported in the literature, the ESDD of the samples was 0.09 +/-0.02 mg/cm^2 [2, 3].
The test setup for investigating resistance to creeping currents (fig. 1), described in standard [1] and introduced in [4], was modified to feed an electrolyte solution at the sample's angle of inclination of 18º corresponding to the inclination of the upper surface of insulators sheds. According to standard [1], the sample should be fixed at an angle of 45º with its tested surface facing downwards. The solution was fed

onto fixed layers of absorbent-paper and percolated down to the tested surface.
A metering pump metered the wetting agent at a rate of 18 ml/hour. Ammonium chloride used as the wetting agent in the standard test was replaced with a saline solution whose conductivity was 1.5 mS/cm.
The electric stress was 0.8 kV/cm. During the test, the leakage current was recorded. A sample erosion of 0.2 mm or a recorded leakage current of 60 mA (a flashover could occur at a higher leakage current) was adopted as the end-of-test criterion [1]. If this current level was not reached within 6 hours of testing, the tested material was considered to have passed the test. Earlier investigations of the materials had shown that after 6 hours of the modified inclined plane test the criterion leakage current had not been reached and the differences between the two rubbers had been imperceptible. Therefore in the present investigations material erosion was adopted as the end-of-test criterion.

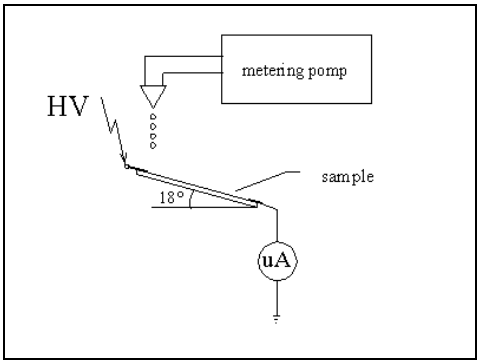
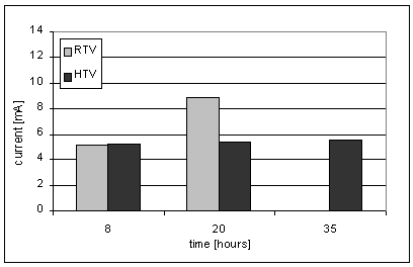


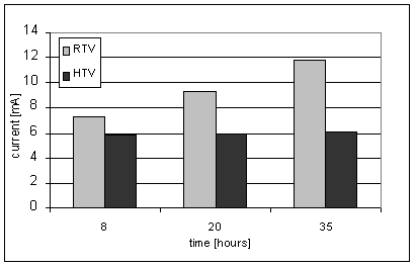
Fig. 1.Test setup.

3. Results of investigations.

An analysis of the recorded leakage current on the clean HTV and RTV samples shows that the modified inclined plane test does not require special preparation of the surface of the tested materials except for periodic moistening.
The shapes of the currents recorded for the RTV and HTV samples are different. In the former case, the recorded current has the form of separate current impulses with different amplitudes, decaying almost to zero. In the latter case, current impulse ignition occurs periodically and they impulses do not decay but show a growing tendency. The maximum value of a current impulse for the RTV samples was almost 25 mA higher than for the HTV samples. The differences in the shape of leakage current indicate the active suppression of the current by the RTV rubber in the presence of moisture.



(a)



(b)

Fig. 2. *Changes in average value of leakage current (higher than 1 mA) versus time of aging of*
- *polluted samples-(a) and clean samples -(b).*

Considering that the current flowed continuously on the HTV samples, the average current value was higher than in the case of RTV. Therefore the average value was calculated for current impulses which exceeded the level of 1mA (fig. 2).
At the beginning of the test the current value for the polluted RTV samples was lower than for the clean samples but after 20 hours of aging the values were almost the same.
The increase in leakage current was higher in the case of the polluted samples, causing deep erosion of the coating and exposing the plastic base. The testing of the polluted RTV samples was interrupted after 20-22 hours of aging. In the case of the HTV material, the increase in the average current value was small for both clean and polluted samples. This means that the presence of pollution did not significantly affect the process of aging of the HTV rubber.
The leakage current values after 6 hours of testing (the standard end-of-test criterion) did not permit the evaluation of the two materials.
In spite of the active suppression of current by RTV, erosion of this material proceeds faster than that of HTV. The presence of pollution caused nearly double acceleration in the erosion of the RTV coating.

4. Conclusions

1. Recent research has confirmed that the stability of the current-voltage characteristics largely depends

on the voltage distribution on the surface of the surge arrester's housing.

2. Owing to their hydrophobicity non-ceramic housings perform better under pollution conditions. There are many accelerated aging tests available for determining life but none of them gives a definitive diagnosis. One type of a polymer material may pass one type of test and then fail another. This makes it difficult for users to compose or choose materials.
3. The leakage currents and the changes in surface erosion determined through the modified inclined plate test indicate that the distribution of voltage on the arrester's non-ceramic housing may be variable.

5. References

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