Method for determining the resistance of polymer films and vulcanisates to destabilising factors

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The development of methods for the accelerated testing of polymeric electrical insulation materials for their resistance to electrical, radiation, and weather ageing, and also to corrosive media, makes it possible not only to predict the change in the service characteristics of articles of these materials but also to use them in estimating the effectiveness of the stabiliser introduced. The sensitivity of the test method is the determining factor in this case.

The proposed method of non-destructive inspection is based on the relationship of the irreversible structural changes with the molecular mobility and with the emergence in the material of ionisation processes when electric voltage is applied to it (SU 1013836, MKI G 01 N 27/62 (Byull. Izobret., No. 15, 1983)). The time of the start of sharp change in the dielectric permittivity of the material when ionisation processes of fixed-intensity partial discharges act upon it was selected as the structurally sensitive parameter in this case.

The test specimen is placed between the plates of an instrument capacitor with disc electrodes, connected successively with a calibration air capacitor to a controlled high-voltage alternating current source. Parallel to both capacitors are connected electrostatic voltage meters, the voltage ratio of which is used to judge the change in the capacitance of the instrument capacitor. The voltage on the capacitors is raised smoothly until ionisation processes emerge in the specimen. The instant of the emergence of ionisation processes in the test material and maintenance of constancy of their intensity are monitored from the level of radio frequency radiation of partial discharges.

The investigation was carried out on films of polyamide PK-4, polyvinyl chloride (PVC), polyimide PM-1, a vulcanisate based on SKS butadiene–styrene rubber, and a vulcanisate based on IRP-1267 organosilicon rubber, which are used as electrical insulation. The materials were subjected to electric discharges (electric ageing), holding in a 3% KOH solution (chemical ageing), and γ-radiation (radiation ageing), and were also exposed to hydrogen sulphide vapour (in hydrogen sulphide bathhouses of the “Goryachii Klyuch” health resort in the Krasnodar region).

As follows from the dependences given in Figure 1, under the action of ionisation processes, three time

![](image)

**Figure 1.** Influence of time of action of ionisation processes on relative change in capacitance with film PK-4 for control specimens (1, 5, 6) and for specimens aged under action of electric discharges for 3 h (2), 10 h (3), and 20 h (4). Ageing voltage 8 kV, voltage on electrodes in tests 2 kV (1–4), 2.5 kV (5), and 3 kV (6)
regions are clearly observed: I – a safe region, without any change in \( \Delta C/C_0 \); II – a region of sharp increase in \( \Delta C/C_0 \), connected with the start of intense radical chain reactions leading to degradation of the polymer; III – a prebreakdown region \( \Delta C = C - C_0 \), where \( C \) and \( C_0 \) are the capacitance during the test and at the instant of the emergence of ionisation processes in the specimen. With increase in the voltage on the capacitor electrodes, which corresponds to an increase in the intensity of the ionisation processes, the time of transition from region I into region II and from region II into region III decreases (curves 5 and 6). Thus, the ionisation stability of the test material can be estimated from the time of “safe” action of microdischarges, i.e. the time before sharp increase in the capacitance \( t_{inc} C \).

In a study of electric ageing it was shown that, for polyamide films exposed in the zone of action of discharges for 3 h, a sharp increase in capacitance (loss of ionisation resistance) begins, as for a non-aged film, within 1000 s. Constancy of \( t_{inc} C \) may indicate constancy of the degree of defectiveness and structural changes at the given exposure time.

More prolonged ageing (10 and 20 h) leads to a considerable reduction in \( t_{inc} C \), which is equivalent to an increase in intensity of the defect-forming action of the ionisation processes (see Figure 1, curves 3 and 4). In this case, the mechanical and electric strengths decrease only after 20 h ageing, which makes it possible to conclude that the examined method for determining the resistance of the polymer to electric ageing is more sensitive.

Tests conducted for other electrical insulation materials and other types of ageing also confirmed the given conclusion. Thus, for PVC films of 200 \( \mu \)m thickness, irreversible structural changes after \( \gamma \)-irradiation by the proposed method are recorded at a dose of only 0.1–0.15 MGy, whereas the tensile strength of the film \( \sigma \), begins to decrease after 1 MGy. Holding of polyimide film PM-1 of 20 \( \mu \)m thickness in a 3% KOH solution leads to a reduction in \( t_{inc} C \) after only 3 h exposure, whereas \( \sigma \), begins to change after 10 h similar holding.

The exposure of SKS rubber to hydrogen sulphide vapour for 6 months results in embrittlement, the appearance of microcracks, and loss of elasticity, whereas the start of structural changes, determined from \( t_{inc} C \) appears after exposure for only 2 months. For insulation IRP-1267, the change in the given parameter is recorded within 1 year.

Use of the examined method for determining the resistance of insulation materials based on polymers and vulcanisates has made it possible to achieve breakdown-free operation and to avoid the failure of electrical and automatic equipment of the “Goryachii Klyuch” health resort over a 5 year period by the timely replacement of underground and normal power cables operating under conditions of exposure to hydrogen sulphide vapour, alkali, and increased humidity.

Thus, using the given method, it is possible to predict the service life of polymeric materials under specific conditions, to select the type of insulation material on a sound basis, and also to select stabilising and antirad additives.

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