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Optical Recording of Bubble Dissolution of Diagnostic Gases in Electrical Insulating Liquids

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Abstract. The diffusion coefficients of the basic diagnostic gases were determined by optical recording of the bubble dissolving dynamics in degassed insulating liquid. It is necessary to understand the diffusion of diagnostic gases in insulating liquids for obtaining high-quality diagnostic conclusions obtained during the analysis of high voltage electrical equipment with paper-oil insulation using gas methods.

Introduction

There has been a trend of the aging of high-voltage electrical equipment nowadays in Russia [1]. Developing faults can cause not only economic, environmental, but also social problems. There is a method for detecting the faults of expensive high-voltage electrical equipment with paper-oil insulation analyzing the concentrations of diagnostic gases formed in an insulating liquid as a result of the fault development. Quality of the diagnostic decision made by the laboratory to a great extent depends on the diffusion of diagnostic gases within the insulating liquid at all stages of the analysis. Subsequently the diffusion coefficient is relevant and necessary data for obtaining high-quality diagnostic conclusions.

The trend based on the application of vegetable oils as biodegradable and fireproof insulating fluids for high-voltage electrical equipment is considered to be relevant in the power energy sector [2]. Thus, it is necessary to set up the diffusion coefficients of the basic diagnostic gases not only for common transformer oils, but also for more advanced insulating fluids.

Establishment of diffusion coefficients of the basic diagnostic gases in dielectric oil was studied recently [3]. However, we revealed discrepancies when comparing the results of the diffusion coefficients of the basic gases in rapeseed oil [4] obtained in the paper [3]. Obtained values of the diffusion coefficients of gases in rapeseed oil were much higher than those ones of transformer oil. On the other hand, great viscosity values of rapeseed oil were expected to lead to smaller values of diffusion coefficients. We consider that the detailed analysis and comparison of the conditions of experiments [3,4] revealed discrepancy. The fact that the degassing of oil in [3] was carried out using a membrane pump that generates depression, not vacuum that is why causing insufficient degassing. The presence of residual air can lead to its reverse diffusion from the oil into bubble, slowing thereby the solubility rate. Since the diffusion coefficient of the diagnostic gas is determined by the dynamics of the bubble dissolving, reducing the solubility rate causes an inadequate determination, namely, results in obtaining underestimated values, especially for poorly soluble gases, such as hydrogen. Backing forevacuum pump was used for rapeseed oil degassing in the paper [4] and in the present work.

Thus, the objective of this work is to determine the solubility of the basic diagnostic gases in the conditions of improved degassing and subsequently to find the diffusion coefficient in rape and transformer oils.

Experiments and Results

The methodology of the experiment is to record optically bubble solubility rates of a diagnostic gas within the degassed insulating liquid.

An experimental cell (Fig. 1) in the shape of a vertical cylinder (1), with the needle mounted into the wall (4) was developed for measurements to supply the flow of test gas. The bottom (6) and cover (2) of the cell are made of Plexiglas which enables to conduct optical recording eliminating the saturation of the oil by air. The mesh (5) which enables to keep the gas bubble within the fluid avoiding elastic deformation of the surface is installed in the upper part of the cell. The oil flows into the cell through the valve due to the depression made by a vacuum pump connected to the valve (3). The prepared cell was placed under the microscope, the eyepiece mounted with video camera.

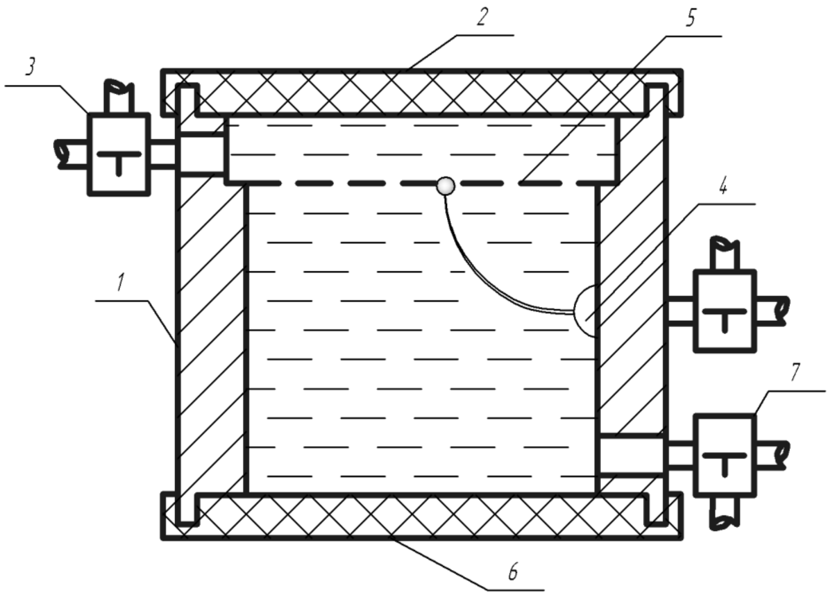
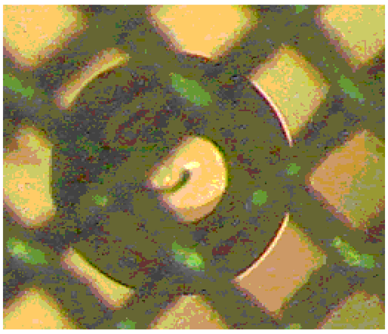
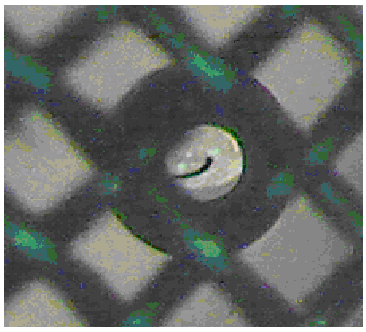


Figure 1. Test cell

Before carrying out the experiment the oil was degassed profoundly and gas-flow path was blown with test gas. Further, we produced a depression inside the cell using a vacuum pump connected to the cell valve (3). After that the test cell was filled with degassed oil through the valve (7). Next, we injected bubbles of the test gas through the flow path and carried out an optical recording using Elchrom sampling device as syringe dispenser. The record has been split into images with a given time interval (Fig. 2).



a – initial moment of recording



b – final moment of recording

Figure 2. The bubble of the test gas

We used graphic editor to take dimensions of gas bubbles on the received images, applying the method of constructing a circle through three given points. We scaled by comparing the dimensions of the reference sample with experimentally obtained dimensions of the bubble. Typical curves of hydrogen solubility in various insulating liquids are presented in Fig. 3.

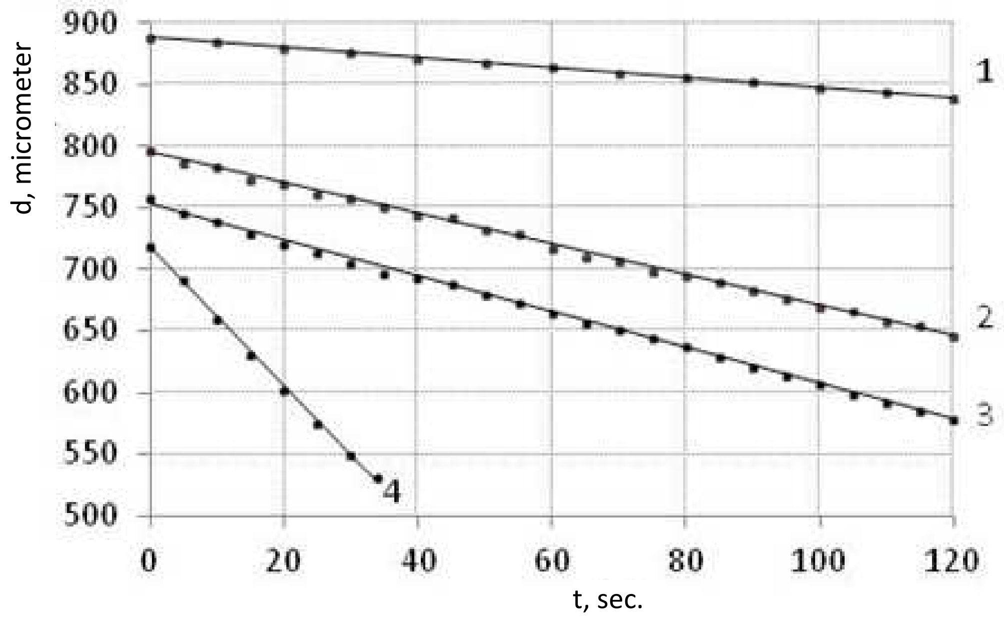


Figure 3. Typical curves of hydrogen solubility: 1- in castor oil; 2- in rapeseed oil; 3- in transformer oil; 4- in silicone fluid

Every diagnostic gas was tested 10-20 times. Values of diffusion coefficients have been obtained (Table 1).

Table 1. Diffusion coefficients

	Average value of diffusion coefficient [m^2/s]			
	Hydrogen	Methane	Ethane	Ethylene
Rapeseed oil	10^{-8}	$3\cdot10^{-9}$	$1.3\cdot10^{-9}$	$1.2\cdot10^{-9}$
Transformer oil	$1.4\cdot10^{-8}$	$2.3\cdot10^{-9}$	$1.1\cdot10^{-9}$	$1.2\cdot10^{-9}$

Conclusion

Carrying out this work we used the solubility coefficient of the basic diagnostic gases for transformer and rapeseed oils [5]. Currently, the solubility of the basic diagnostic gases in castor oil, silicone fluids and insulating Midel 7131 is being investigated to determine their diffusion ratio.

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