Journal of Engineering Physics and Thermophysics, Vol. 80, No. 3, 2007

DEGASSING OF A HYDROCARBON FLUID IN A HIGH-FREQUENCY ELECTROMAGNETIC FIELD

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UDC 532.546:537.87

The results of experimental investigations of degassing of hydrocarbon fluids in a high-frequency electromagnetic field and on electric heating are presented. Its relationship to a change in temperature and to the dielectric properties of fluids has been established. The effect of a virtually instantaneous evolution of gas from oil after the switching-in of a source of high-frequency electromagnetic energy has been revealed. It is shown that the dependence of the amount of the gas evolved from oil on power is nonlinear.

Introduction. Application of high-frequency electromagnetic radiation is a promising method for intensifying the production of high-viscosity oils [1–7]. Due to its deep penetration and the resulting volumetric heat generation, the electromagnetic radiation is capable of providing a much higher rate and higher performance than the traditional techniques of thermal effect by a heated vapor or a hot liquid. However, the decrease in the amount of the gas dissolved in oil in the process of a high-frequency electromagnetic effect considerably changes its physicochemical properties, which in turn influences the regime of operation of the electromagnetic energy source and, consequently, the efficiency of extraction of a high-viscosity oil. In view of this, the present work is devoted to experimental investigation of gas evolvement (degassing) in hydrocarbon media under the action of electromagnetic radiation. Some of the results of investigations of the degassing of media are presented in [8–10].

Physical Foundations and the Results of Investigations of the Degassing of Dielectric Media in a High-Frequency Electromagnetic Field. The physical foundation of the degassing of media in a high-frequency electromagnetic field is that a substance exposed to a harmonic electromagnetic field evolves heat, the intensity q of which is defined by the expression

$$q = \frac{\omega\varepsilon \,\mathrm{tg}\, \delta E^2}{2} .$$

The rise in temperature causes a change in the structure of the medium and a decrease in the value of surface tension at the liquid–gas interface. Precisely these phenomena and effects favor the degassing of liquid in a high-frequency electromagnetic field.

In order to carry out experimental investigations of the degassing of a hydrocarbon fluid in a high-frequency electromagnetic field an experimental setup was designed and assembled, the main parts of which are: a high-frequency energy source, a reaction chamber, and instrumentation. A VChD-3-6/81 generator (with a frequency of electromagnetic oscillations 81.36 MHz) served as a high-frequency energy source. The reaction chamber is a cylindrical tube of inner diameter 25 mm and length 500 mm [8]. The experimental procedure consisted of recording the changing temperature in the chamber and measuring the amount of the gas evolved from the oil. Tests were carried out at different powers. Temperature measurements were made by a U-like thermometer and a thermocouple. The amount of the gas evolved was measured by a gas flow micrometer.

As working fluids we investigated oils of the Kushkul', Shkapovskoe, and Krasnokholm oil deposits of the Republic of Bashkortostan, as well as of the Mamontovo oil deposit of the Tyumen' region and of the Mordovia-Karmal' bituminous deposit of the Republic of Tatarstan.

The data obtained were used to analyze the dynamics of the build-up gas factor Γ equal to the ratio of the gas volume evolved from oil to the volume of the oil itself in the reaction chamber, as well as the degassing rate

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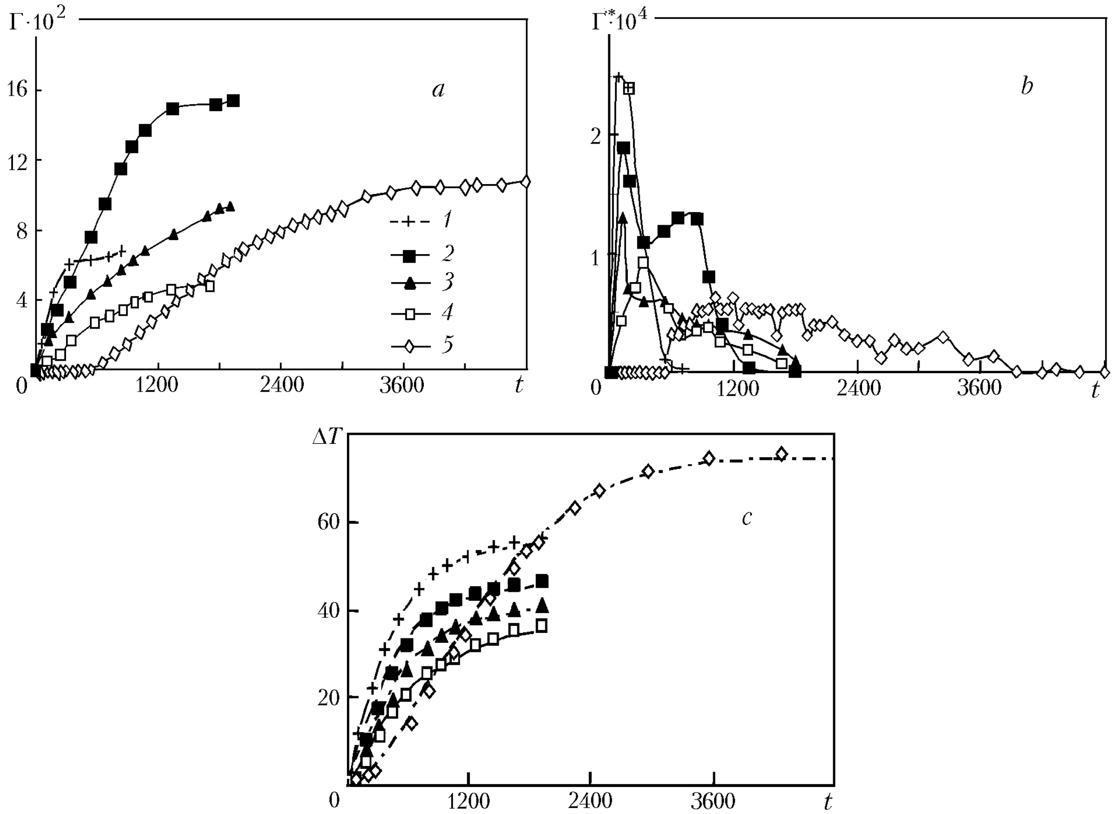


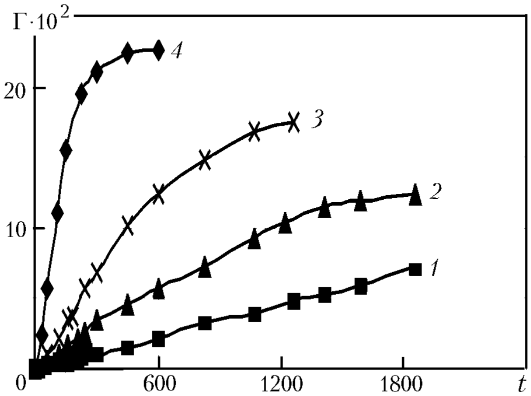
Fig. 1. Dependence of the build-up gas factor (a), degassing rate (b), and of the temperature (c) of oils on the time of exposure to: 1–4) high-frequency electromagnetic field [(1) bituminous oil of the Mordovia-Karmal' deposit; 2) oil of Kushkul' deposit; 3) oil of Mamontovo deposit; 4) oil of Krasnokholm deposit]; 5) electric heating.

Γ^* defined as the ratio of the gas volume evolved per unit time to the oil volume. Both values were considered in experiments to carry out a fuller comparison between the data of various experiments. In this case, the difference between the volumes of oil in the chamber in different tests did not lead to errors in the experimental results.

Figure 1a presents the dependence of a change in the build-up gas factor of various oils on the time of exposure to a high-frequency electromagnetic field of power 14 W. As follows from the figure, gas begins to evolve from the oil practically from the moment of the switching-in of a high-frequency energy source (in 30–60 sec). The process proceeds rather rapidly, becomes stabilized, and ceases. This is confirmed by the results presented in Fig. 1b, which presents the dependence of the rate of degassing of the oils investigated in a high-frequency electromagnetic field on time. Strong degassing occurs mainly in the first moments of the high-frequency electromagnetic action on the oil; thereafter the degassing rate decreases and drops to zero.

It is interesting to compare the characteristic features of degassing of oil from the Kushkul' deposit and of bituminous oil from the Mordovia-Karmal' deposit. The former has the highest build-up gas factor. However, its degassing rate is lower than for the latter oil. The values of the relative dielectric constant (2.65) and the loss tangent (0.038) of the bituminous oil at a frequency of 81.36 MHz are higher than for the oil of Kushkul' deposit (2.27 and 0.026, respectively). Due to this, the bituminous oil is heated faster and attains a higher temperature than the oil of Kushkul' deposit. This is confirmed by the data presented in Fig. 1c. Consequently, the degassing of media depends not only on the ability of bodies to be heated in a high-frequency electromagnetic field, but also on the initial gas factor.

As is seen from Fig. 1a, the time of the beginning of degassing on electric heating of oil from the Kushkul' deposit is much longer (about 8 min) than in a high-frequency electromagnetic field, although in both cases the temperature of the oil samples starts to rise from the beginning (Fig. 1c), with the powers of the electromagnetic fields



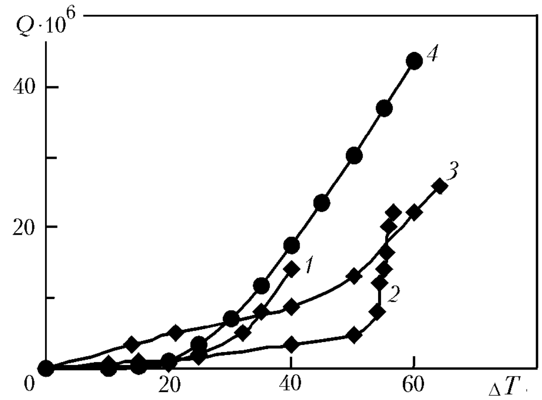


Fig. 2. Dependence of the build-up gas factor on the time of exposure for oil of Kushkul' deposit at different powers of a high-frequency electromagnetic field: 1) 7; 2) 8; 3) 14; 4) 42 W.

Fig. 3. Dependence of the amount of gas evolved from oil on temperature for different powers of the high-frequency electromagnetic field: 1) 8; 2) 14; 3) 42 W; 4) average theoretical approximation of curves 1–3.

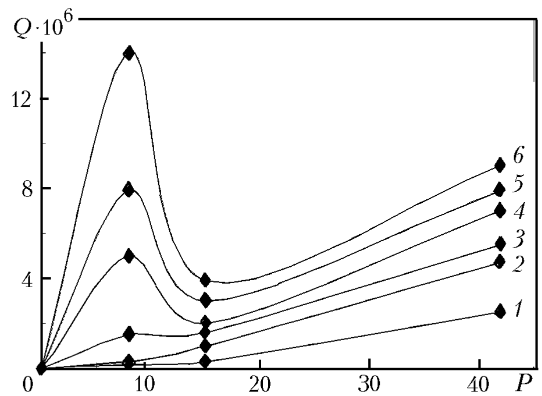


Fig. 4. Dependence of the amount of gas evolved from oil on power for different changes in the temperature of oil of the Kushkul' deposit by a high-frequency electromagnetic field: 1) 15; 2) 20; 3) 25; 4) 30; 5) 35; 6) 40 °C.

being the same. Comparing curves 2 and 5, we may also note that the time of complete degassing of the oil tested is about 2.6 times longer. According to the data of the curves presented in Fig. 1b it follows that the maximum degassing rates differ by approximately twice. These regularities are due first of all to the volumetric character of the high-frequency electromagnetic effect on media.

Figure 2 presents the dependence of the build-up gas factor on the time of exposure for oil of the Kushkul' deposit at different powers of the high-frequency electromagnetic field. It is seen that the higher the power of the high-frequency field, the more intense is the process of gas evolvement. It should be noted that the final experimental points correspond to the values at which gas ceases to evolve from the sample. A comparison of the curves shows that the build-up gas factor of oil depends nonlinearly on the power of a high-frequency electromagnetic field.

An analysis of the trends shown in Figs. 1 and 2 has made it possible to establish the dependence of the quantity of gas evolved from oil Q on temperature T (Fig. 3); curve 4 represents a certain average theoretical approximation of the experimental data presented by curves 1–3 and is described by the relation

$$Q = Q_0 \exp\left(-\frac{\gamma}{\Delta T}\right),$$

where $\gamma = 272.3^{o}C^{-1}$; $Q_0 = 110.1\ cm^3$.

Figure 4 presents the curves of the dependence of the gas evolved on power; they are of nonlinear character. It is seen from the graph that, first, the amount of the gas evolved depends on the power consumed and has a nonlinear character. Second, the evolution of the same amount of gas may occur at different powers; the most efficient power can be determined using this figure.

Conclusions. The investigations have shown that on switching-in of a high-power electromagnetic energy source a gas begins to evolve from the oil virtually instantly. This is due, first of all, to the volumetric character of the heating of media on exposure to high-frequency electromagnetic oscillations. Further gas evolution and its characteristic features are attributable to the disturbance of fluid structure, the degree of change of which is associated with the specific features of the increase in temperature of media and their dielectric properties. The dependence of the amount of gas evolved from the oil on the power is nonlinear.

Based on the results obtained, we may recommend the use of a high-frequency electromagnetic field for rapid degassing of hydrocarbon fluids.

NOTATION

E, complex amplitude of the vector of strength of a harmonic electric field, V/m; P, electromagnetic field power, W; Q, amount (or volume) of the gas evolved from oil, m^3; Q_0, volume of the reaction chamber, m^3; q, intensity of heat release in a dielectric interacting with a high-frequency electromagnetic field, W/m^3; T, temperature, ^{o}C; ΔT, change in temperature, ^{o}C; t, time, sec; γ, approximation parameter, $^{o}C^{-1}$; Γ, build-up gas factor of oil, m^3/m^3; Γ^*, degassing rate, $m^3/m^3 \cdot sec$; tan δ, loss tangent of a medium; ε, absolute permittivity of a medium, F/m; ω, cyclic frequency of a field, rad/sec.

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