Flow of Fluid Hydrocarbon Through Non-Metallic Pipes

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This work presents the results regarding the formation of charge clouds due to the oil movement through non-conductive plastic and glass pipes. We have analzsed the equations that depict the charge distribution, the measurement of electrical charges and their effects on plastic and glass pipes in the transport of oil products.

Keywords: plastic pipes, a non-destructive test, oil, diffusion, migration and load conversion.

The UHMWPE and HDPE pipes usage in the transport of liquid hydrocarbons in the manufacture of electrical insulator – based materials have the advantage of high resistance against electrochemical corrosion with a long lifetime. They do not require superficial protection, and they eliminate the hazard of electrostatic discharge.

The present research has as a main target – the replacement of metallic pipes with plastic tubing in the oil transport system from the marine platforms. The thermoplastic pipes are reliable to the bending action moments due to the marine currents, to the increasing pressure with depth at the place where they are mounted, to the fast variations in the pressure and temperature of the oil, which is transported through the pipe [1].

A non-metallic pipe must not be protected against corrosion, it doesn't need exterior covering, but other aspects have to be taken into consideration: pipe design, wall-material density, electric resistance, flexibility, thermal and electric conductivity, the mechanical resistance. For checking these requirements, a series of experimental trials must be performed [2].

This paper presents the approach on the charge clouds, which influence the flow regime due to the impurities existing in the transported oil.

The equations that control the electric charge distribution in the flowing of the low conductive fluids allow us to combine the experimental results with the theoretical data in order to assure a better understanding of the electrostatic charging phenomenon [3-5].

If we consider that any other dissociated ionic form existing in the flowing fluid is univalent, then the volume charging density of the electric charge can be written:

$$\rho_v = F(C_+ + C_-)\ [\text{mC/m}^3] \tag{1}$$

where:

F is the Faraday constant (96400 C/g equivalent);

C_+ and C_- are the ion concentrations (mval/m^3).

We presume that the positive and negative ion mobilities are equal, that means:

$$m = m_+ = m_- \tag{2}$$

then the fluid conductibility can be written:

$$\sigma = mF(C_+ + C_-) \tag{3}$$

for the fluids that do not transport electrical charges. Pure oil is electrically neutral and its conductivity isabout zero. Within the mass of oil there are impurities which become conductive by friction.

For the neutral fluids from the electric concentration point of view, the positive and negative ion concentrations are equal and the remaining conductibility can be written as:

$$\sigma_0 = 2mFC_0 \tag{4}$$

where $C = C_+ = C_-$

The electrical conduction follows the relationship:

$$\sigma = \sigma_0\left[\left(\frac{q}{2FC_0}\right)^2 + 1\right]^{\frac{1}{2}} \tag{5}$$

For:

$|\rho| << 2FC_0$, for $\sigma = \sigma_0$ for small charge densities (less $0.5\mu C/m^3$);

$|\rho| >> 2FC_0$, for $\sigma = m\rho_v$ for larger charge densities (0.5 - $50\mu C/m^3$)

The equation demonstrates the contribution of the impurity amounts to the superficial conduction of pipes. The partial differential equation for charge density in the fluid flowing may be written in general case [2]:

$$\frac{\delta\rho_v}{\delta t} + v\nabla\rho_v + \frac{\sigma_0}{\varepsilon}\rho_v - D\nabla^2\rho_v = 0 \tag{6}$$

where v=v(x, t) is the function of fluid flow rate; D is the diffusion coefficient.

The first term of the equation (6) represents the current density generated by the time variation of the number of charge carriers. The second term stands for the convection current density due to the displacement of the charges alongside with the oil fluid. The third term stands for the migration of the electric charges within the oil fluid. The last term represents the current density due to the charge diffusion within the oil fluid. This equation is usually applied for the accurate evaluation of electrical resistance of organic insulators. It reveals the correlation between charge density (ρy), the charge convection ($vD\rho_v$), at migration ($\sigma_0\rho_v/\varepsilon$) and the diffusion ($D\nabla^2\rho_v$) of electric charge.

Experimental part

The storage of electrical charge on the surface hydrocarbon liquid flowing through non-conducting pipes was experimentally measured with the device presented in figure 1 [5]. It was used a Faraday cylinder destined to the measurement of for the total charge stored in oil. The

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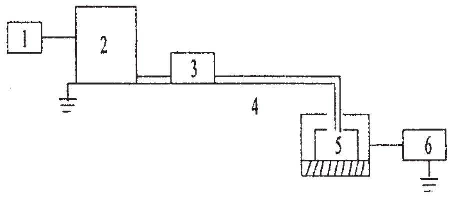
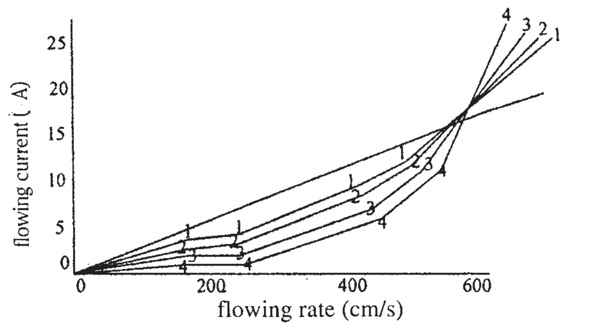
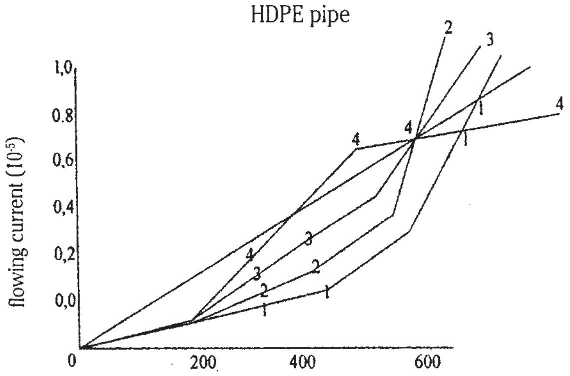


Fig. 1. The flowsheet of volume charge measurement chain.
1. pressure controller; 2. oil tank; 3. insulated metal valve on the tank exit; 4. glass/plastic piping with the 3 mm diameter and 10 m length; 5. Faraday cylinder; 6. electrometer



1 – flow rate $v_1 = v$; 3 – flow rate $v_3 = v^2$;
2 – flow rate $v_2 = v^{1.9}$; 4 – flow rate $v_4 = v^{2.4}$

Fig. 2. Flowing current on the inner surface vs flow rate of oil for HDPE pipe



flowing rate (cm/s)
1 – flow rate $v_1 = v$; 3 – flow rate $v_3 = v^2$;
2 – flow rate $v_2 = v^{1.9}$; 4 – flow rate $v_4 = v^{2.4}$

Fig. 3. Flowing current vs flowing rate oil for glass pipe

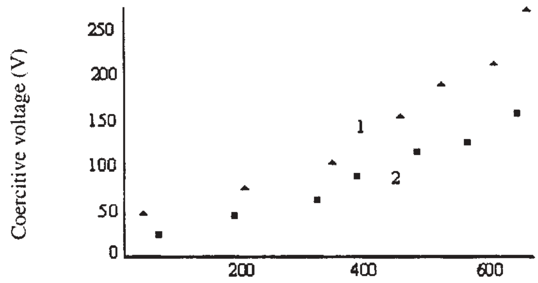
tank was tightly earthed. The oil flux was adjusted with a help of a regulator, the inlet and outlet were assured through a gauged metallic calibrated valve, electrically insolated at the exit of the tanker.

The oil was allowed to pass for 3 min and the total charge stored in the cylinder was recorded at intervals of 30 s. The total stored charge in the Faraday cylinder varies about linear on time at various flow rates. The normalised flow speed (v) was obtained by the measurement of the cylinder fluid quantity in relation to the pipe section area.

Result and discussions

The attempt in the neutralization of flowing electrical current and the elimination of the net storage of charges through electric assignment of the double layers is managed by the insertion of a 0.125 mm thick stainless steel line into the piping length and closed to the attached metallic valve.

At the pipe end, the last meter was covered with an aluminum foil, which formed an outer conductor of coaxial condenser. The central conductor was charged through



Flow rate (cm/sec)
1 - glass pipe; 2 - plastic pipe

Fig. 4. Storage voltage of the flowing current

the connection of a power feeder operated in d.c. aregime aluminum foil was kept at the earth potential.

The dependencies of flowing current on fluid flowing rate are given in figure 2 and figure 3 (v means the normal flow rate).

The variation in the tension applied on wire in order to produce negligible flowing current (not any movement on the most sensitive scale of the instrument would be noticed) for different flow rates is represented in figure 4.

The potential applied on the central conductor is positive in opposition with the earthed exterior conductor.

It is unlikely that the resulted neutralization of the flowing current is due to the negative charge injection from wire into fluid. If the exterior conductor is removed, there was not observed any effect until the 400 V are attended from the feeder. However, the main conductor voltage was increased over 70 V or 170 V, the flowing current changes its polarity.

These aspects show that the coaxial condenser disposal must reduce the diffusion depth into the double layer. If the applied tension increased and a double layer were formed, the applied voltage level would be big enough [6, 7].

Conclusions

The electric properties of the plastic materials are recommended for usage in the oil field activity. The usage of reinforced plastic and grounded materials from 10 in 10 meters of insolating material pipes lead to a larger safety in operation, a more reduced cost, an easier maintenance and assures the marine environment protection.

The present experimental results will be followed further investigations at 'PETROMAR' company under real conditions.

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