MEASUREMENT AND CALCULATION OF THE ELECTRIFYING CURRENT OF ELECTRIFIED OIL PRODUCTS USING THE SAMPLING METHOD

Stefan Stefanov[1], Ivan Prodanov[2]

[1] University of Mining and Geology "St. Ivan Rilski", 1700 Sofia,

[2] University of Mining and Geology "St. Ivan Rilski", 1700 Sofia, enemko@mail.bg

ABSTRACT. To assess the static electricity hazard in the case of the technological operations and at the fuel stations, it is necessary to know the strength of the electrification current. Hereby is presented the problem of measuring and calculating the electrifying current in the process of filling a reservoir with electrifying liquids. A labor stand and the the sampling method are used.

Keywords: static electricity, electrification

ИЗМЕРВАНЕ И ИЗЧИСЛЯВАНЕ НА ТОКА НА ЕЛЕКТРИЗАЦИЯ НА НАЕЛЕКТРИЗИРАНИ НЕФТОПРОДУКТИ ПО МЕТОДА НА ВЗЕМАНЕ НА ПРОБА

Стефан Стефанов[1], Иван Проданов[2]

[1] Минно-геоложки университет "Св. Иван Рилски", 1700 София,

[2] Минно-геоложки университет "Св. Иван Рилски", 1700 София, enemko@mail.bg

РЕЗЮМЕ. За оценка на опасността от статично електричество при технологичните операции и автозареждащите станции е необходимо да се знае силата на тока на електризация. В настоящата работа се разглежда проблемът за измерване и изчисляване на тока на електризация в процеса на запълване на резервоар с наелектризиращи се течности. Използван е лабораторен стенд и методът на вземане на проба.

Ключови думи: статично електричество, електризация

Introduction

In the process of filling reservoirs with flammable dielectric liquids, fires and blasts may occur as a result of static electricity discharge. Certain permissible minimum ranges of the electrifying current and of the specific density of the charge of liquid are known within which static electricity does not pose a threat. However, the control of the current and density of the product that is being transported within a reservoir along metal pipes is very difficult. Special measuring equipment in industry is not manufactured and the use of dynamic electrometers mounted directly on the pipelines with gauges placed in the liquid flow is currently still within the field of the laboratory practice only (Стефанов и др., 2013).

Exposition

1. Method of determining the strength of the electrifying current.

In order to assess static electricity risks during technological operations and at auto-charging stations, it is necessary to know the strength of the electrifying current

The strength of the electrifying current during the motion of the oil product along the pipeline can analytically be calculated according to the Koszman and Gavis equation (Koszman et al., 1962; Попов и др., 1977; Максимов и др., 1978):

$$I = \frac{\pi.\varepsilon_r.\varepsilon_0.R.T.\vartheta}{2.n.F}.N_u.\left(1-\frac{C_s}{C_o}\right).\left(1-e^{-\frac{l}{\vartheta.\tau}}\right). \quad (1),$$

where:

I is the electrification current in the pipeline;

$\varepsilon_r.\varepsilon_0$ is the permittivity of the oil product;

R is a universal gas constant;

T is the temperature of the oil product in the pipeline;

N_u is the Nusselt parameter;

n is the number of transferred ions;

C_o, C_s is the concentration of ions within the liquid volume and on the walls, respectively;

F is the Faraday constant;

$\tau = \frac{\varepsilon_r.\varepsilon_0}{\gamma}$ is the relaxation time.

When calculating the electrification current according to equation (1), it is difficult to determine some parameters that are part of the equation, such as the concentration of ions within the volume of the oil product and on the walls of the pipeline (C_o, C_s), the number of ions transferred, the diffusion coefficient, etc.

Measuring the electrification current in an operating pipeline is difficult due to the large volume that is pumped, the lack of the necessary equipment, and the complexity of the necessary measurement requirements to be observed. The suggested method makes it possible to calculate the electrification in the actual pipeline based on data from laboratory tests on the electrifiability of the pumped products.

To measure the electrification of oil products in laboratory conditions, a simple stand can be used whose diagram is illustrated in Fig. 1.

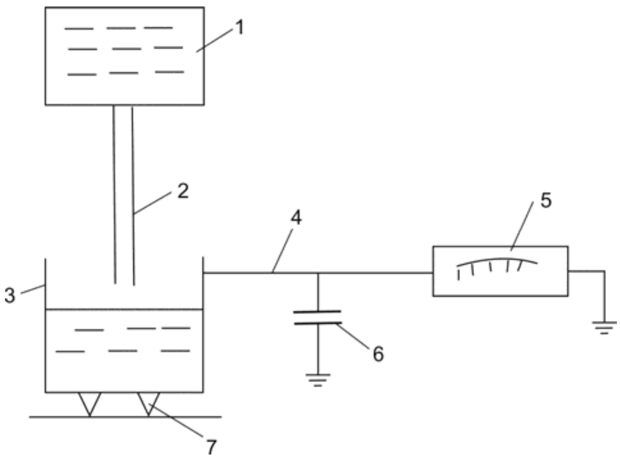

Fig.1. Diagram of a stand for measuring the electrification of oil products

The diagram comprises:
1 – upper tank;
2 – metal earthed pipe;
3 – lower tank isolated from the ground;
4 – shielding;
5 – electrostatic voltmeter;
6 – additional capacitor;
7 – insulators ($R > 10^3 \Omega$).

The tank capacity is 1 to 2 liters and the tanks are isolated one from another. An earthed pipe with a diameter of 5-10 mm and a length of 0.5-1m is attached to the bottom of the upper tank. The lower tank is isolated from the ground and an electrostatic voltmeter is connected via a shielded cable.

Electrification of the oil product is generated by means of pouring the oil product from the upper tank to the lower one. The data of the lower reservoir potential is measured and then the charge initiated by the electrification is calculated. Therefore, the capacity of the system reservoir-voltmeter needs to be known and constant.

The electric capacity of the tank is measured using a microfarad meter.

The amount of the charge accumulated in the lower tank is calculated after the following equation:

$$q = C.U \tag{2}$$

The average electrification current is determined by the ratio:

$$I_1 = \frac{q}{t}, \tag{3}$$

where t is the time of the pouring of the oil product from the upper tank into the lower, s .

The charge formation and accumulation in the pipe of the measuring equipment and of the pipeline that operates on the premises of the oil base are subject to the same law.

The analytical expression obtained from the data generated by the laboratory equipment for the assessment of the electrification current in the pipe is as follows:

$$I_1 = \frac{\pi.\varepsilon_r.\varepsilon_0.R.T_1.\vartheta_1}{2.n.F}.N_u.\left(1-\frac{C_{s_1}}{C_{o_1}}\right).\left(1-e^{-\frac{l_1}{\vartheta_1.\tau}}\right). \tag{4}$$

To calculate the strength of the electrification current in the pipeline of the oil bases or the fuel stations, a sample of the pumped product should be taken and tested by means of the stand under consideration. Besides, the concentration and the amount of ions transferred, the molecular diffusion coefficient, and all other parameters need to be the same in the calculation equations for the laboratory stand and for the operating pipeline

Dividing expression (1) by expression (4) and taking into consideration that $C_o = C_{0_1}$ and $C_s = C_{s_1}$, the following expression is obtained of the assessment of the electrification current in the operating pipeline with a length of l :

$$\frac{I}{I_1} = \frac{T.\vartheta.N_u}{T_1.\vartheta_1.N_{u_1}}.\frac{1-e^{-\frac{l}{\vartheta.\tau}}}{1-e^{-\frac{l_1}{\vartheta_1.\tau_1}}}. \tag{5}$$

For the long pipes with $e^{-\frac{l_1}{\vartheta_1.\tau}} \to 0$, expression (5) is as follows:

$$I = I_1.\frac{T.\vartheta.N_u}{T_1.\vartheta_1.N_{u_1}}.\frac{1}{1-e^{-\frac{l_1}{\vartheta_1.\tau_1}}}. \tag{6}$$

The Nusselt parameter can be expressed through the R_e and S_s parameters in the form of an involution dependency of the type of (Koszman, 1962):

$$N_u = C.R_e^m.S_c^n. \tag{7}$$

where:

$R_e = \dfrac{\vartheta.2.a}{V}$ is the Reynolds parameter;

D is the diffusion coefficient;

a is the pipe radius;

C is the concentration of charge carriers.

For the turbulent liquid mode, we assume that $m = 0.8$ [4]; then the ratio of the Nusselt parameters in expression (5) will be:

$$\frac{N_u}{N_{u_1}} = \left(\frac{\vartheta.a}{\vartheta_1.a_1}\right)^{0,8}, \qquad (8)$$

Taking into account equation (8), the ultimate expression for calculating the strength of electrification current in oil base pipelines is written as follows:

$$I = I_1.\frac{1-e^{-\frac{l}{\vartheta.\tau}}}{1-e^{-\frac{l_1}{\vartheta_1.\tau_1}}}.\left(\frac{\vartheta}{\vartheta_1}\right)^{1,8}.\left(\frac{a}{a_1}\right)^{0,8}. \qquad (9)$$

2. Example

When testing petrol ($\gamma = 10^{12},\ \Omega^{-1}.m^{-1};\ \varepsilon = 3$) by means of a test laboratory installation, the time for pouring the petrol out of the upper tank into the lower one is $t = 26\ s$, the capacity of the lower tank is $U = 650\ V$, and the capacity of the system lower tank - static voltmeter is $C = 20\ pF$.

The same petroleum product is transported along an operating pipeline with a length of $l = 1000\ m$ at the flow of $Q = 0.08\ m^3/s$.

The task is to calculate the strength of electrification current in the pipeline at:

$T = T_1$;

$l_1 = 500\ mm$;

$a = 100\ mm$;

$a_1 = 3\ mm$.

Taking into consideration (2) and (3), the average electrification current is:

$$I_1 = \frac{C.U}{t} = \frac{20.10^{-12}.650}{26} = 5.10^{-10}\ A;$$

the time for charge relaxation is:

$$\tau = \frac{\varepsilon_r.\varepsilon_0}{t} = \frac{3.8,85.10^{-12}.650}{10^{-12}} = 27\ s;$$

the speed in the operating pipeline is:

$$\vartheta = \frac{Q}{\pi.a^2} = \frac{0,08}{3,14.100^2.10^{-4}} = 2,5\ m/s;$$

the outflow rate in the laboratory system is:

$$\vartheta_1 = \frac{1,6.10^{-3}}{t.\pi.a_1^2} = 0,2\ m/s.$$

By substituting these data in expression (9), the strength of the electrification current in the operating pipeline is obtained:

$$I = 5.10^{-10}.\frac{1-e^{-\frac{1000}{2,5.27}}}{1-e^{-\frac{0,25}{22}}}.\left(\frac{2,5}{22}\right)^{1,8}.\left(\frac{0,1}{0,003}\right)^{0,8} =$$

$$= 9.8.10^{-7}\ A.$$

Conclusion

The methodology presented makes it possible to calculate the strength of the electrification current in a pipeline by using data measured in a laboratory stand and also without measuring and determining the diffusion coefficient, the viscosity of the liquid, the ion ratio, and other parameters.

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