MEASUREMENT AND CALCULATION OF THE DENSITY OF THE CHARGE OF ELECTRIFIED OIL PRODUCTS USING THE SAMPLING METHOD

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ABSTRACT. To assess the static electricity hazard in technological operations and fuel stations, it is necessary to know the specific density of the liquid charge. The method discussed in this work is the measuring and calculating of the static charge density of a sample of a petroleum product which is pumped along a turbulent flow pipeline based on the use of the known Faraday cylinder.

Keywords: static electricity, electrification, charge density

ИЗМЕРВАНЕ И ИЗЧИСЛЯВАНЕ НА ПЛЪТНОСТТА НА ЗАРЯДА НА НАЕЛЕКТРИЗИРАНИ НЕФТОПРОДУКТИ ПО МЕТОДА НА ВЗЕМАНЕ НА ПРОБА

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РЕЗЮМЕ. За оценка на опасността от статично електричество при технологичните операции и автозареждащите станции е необходимо да се знае специфичната плътност на заряда на течността. В доклада се разглежда метод за измерване и изчисляване на плътността на заряда от статично електричество на проба от нефтопродукт, изпомпван по тръбопровод от турболентен поток, на базата на използването на известния цилиндър на Фарадей.

Ключови думи: статично електричество, електризация, плътност на заряда

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. Measuring the charge density of electrified dielectric liquid using the sampling method

A method is considered for measuring and calculating the static electricity charge density of a sample from an oil product that is pumped along a turbulent flow pipeline. The method is based on the use of the famous Faraday cylinder.

In order to implement this method, a special cock is installed on the pipeline, in the immediate vicinity of the tank where the product is injected. This cock makes it possible to take samples in the course of the filling of the tank. The sample is directly inlet into the Faraday cylinder (Fig. 1) which, in this case, is transformed into two coaxially placed vessels isolated from each other.

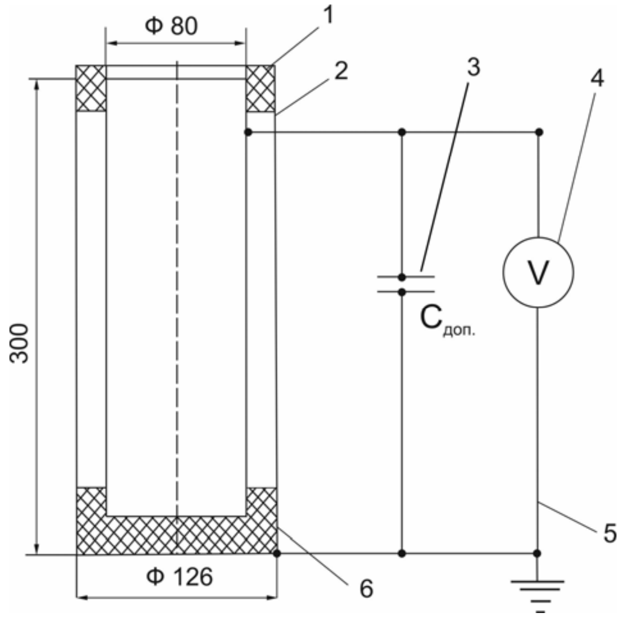

Fig. 1. Diagram of a stand for measuring the charge density of oil products

In Figure1:
1 is the inner cylinder;
2 is the outer cylinder;
3 is an extra volume;
4 is the voltmeter of the electrostatic system;
5 is the connecting wire;
6 is the insulation.

The outer vessel is earthed. The inner vessel is connected to the measuring device by means of a wire with sound insulation. The measuring device could be an ordinary voltmeter from the electrostatic system with a varied measurement range (30, 150, 300V) depending on the required sensitivity and precision of the method. However, any other electrometer with great input resistance could be used as well.

The cylinders are placed one into the other, thus forming the capacitor of the Faraday cylinder with a capacity of C_{ϕ}. If a sample of electrified liquid is poured into the inner cylinder, then voltage U will be registered after the capacity C_c of the whole system. The system capacity is a sum total of: the capacity of the Faraday cylinder, of the connecting wires, and of the measuring device. If the product charge is great, an additional capacitor $C_{\partial on}$ can be inserted. Thus:

$$C_c = C_{\phi} + C_n + C_v + C_{\partial on} \tag{1}$$

Taking into consideration the known capacity and the voltage measured after it, the charge of the selected liquid sample is determined:

$$Q = C_c.U \; . \tag{2}$$

Dividing the charge into the volume of the liquid sample, we obtain the specific density of the charge of the product that flows along the pipeline:

$$\rho = \frac{Q}{V}, \; C/m^3 \tag{3}$$

where $V, \; m^3$ is the volume of the selected sample.

The practical application of the suggested method of determining the specific density of the electrified liquid charge is possible under certain conditions: the flow of the oil product moving along the pipeline should be turbulent. In this case, it is assumed that the static electricity charge of the liquid is evenly distributed along the entire section. Consequently, the charge density of the selected liquid sample will correspond to the charge density of the flow in the pipeline. Besides, the time T for filling the Faraday cylinder with the sample has to be much shorter than the time constant of the capacity of the measuring system, i.e. the following condition needs to be met:

$$T << \tau = C.R \tag{4}$$

where R is the resistance of the insulation of the system comprising the Faraday cylinder, the connecting wires, and the measuring device.

Otherwise, in the course of the filling of the Faraday cylinder with the sample, the success of discharge of the system will be partial and the final result will be higher. If the time constant of the system is $10^2.T$, then for the time necessary to fill the vessel with the sample $T = 20 \;\; s$, the time constant of the system needs to be $3000 \;\; s$. Therefore, at the level of insulation $R = 10^2 \;\; \Omega$, which is practically feasible, the capacity of the system should be for instance:

$$C_c = \frac{\tau}{\rho} = \frac{3000}{10^{12}} = 3 \;\; pF \; . \tag{5}$$

The method sensitivity to the charge measured is directly related to the capacity of the system. The less the system capacity, the greater the sensitivity, i.e. the lower charge value can be registered. In turn, the lower capacity results in the decrease of τ. Consequently, in order to maintain the measurement error within constant levels, the system insulation needs to be raised.

2. Example

The isolation material between the cylinders - fluoroplastics;
Insulation of the connecting wires - fluoroplastics;
capacity of the Faraday cylinder - with the connecting wires: $50 \;\; pF$.

An additional capacity of $C_{\partial on} = 2300 \;\; pF$ is included parallel to the cylinder. Its purpose is to lower the voltage measured and to raise the time constant of the system discharge.

The insulation of the whole system (including the Faraday cylinder and the connecting wires of the static voltmeter) is no less than $10^2 \;\; \Omega$. Thus, the time constant of the system discharge is $\tau = 2380.10^{-12}.10^{12} = 2380 \;\; s$.

The volume of the cylinder is 1 liter, for example. The time taken for its filling is in the range of $20 \;\; s$. Therefore, the condition for $\tau = 10^2.T$ is fulfilled.

The sensitivity of the system at a deviation of the arrow of the voltmeter $C \;\; 50$ at the scale of $30 \;\; V$ will be as follows:

$$\rho_{\min} = 5.2330.10^{-12}.10^8 = 11{,}7 \;\; mC/m^3 \; .$$

Conclusion

It is necessary to take into account that the static electricity in a liquid with a density of $15 \; {}^{mC}\!/_{m^3}$ does not pose a risk of ignition of the filling air and vapor mixtures by electrical discharges. Therefore, the obtained sensitivity is sufficient for making a practical assessment of the risk of liquid electrification.

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