UDC 629.7.065(042.5)

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Aviation Fuel Supply Technological Equipment's Protection from Static Electricity

The physical aspects of the problem of the protection of technological equipment for the processes of aviation fuel supply from static electricity are considered. The causes of formation of a double electric layer during electrification of fuel and technological equipment are determined. The technical means of protection against static electricity are analyzed. The ways of reducing the electrification of fuel are outlined

Providing the reliability and trouble-free operation of technological equipment for the processes of aviation fuel supply remains one of the most important problems for today. At the same time, there are cases of explosions and fires during the fuel filling of tanks and fuel fillers by the static electric charges and spark discharges in steam-air cavities. In this case, the electrostatic charges that are introduced together with the fuel in the reservoir increase the electric field strength, which exceeds the critical value of 3 kV/mm and creates conditions for the spark breakdown of the gas space above the surface of the fuel, an explosion and a fire [1]. Therefore, the development of measures to prevent and eliminate dangerous manifestations of fuel static electricity is a very urgent problem.

According to modern notions, the appearance of surplus one-sign charges in the fluid flow (i.e. the electrification of flow) is caused by the existence of a double electric layer at the boundary of the phase distribution. The thin layer of one-sign ions (Helmholtz layer), which bonded with the surface of a solid body by the action of electrical and adsorption forces, has a thickness of $\delta_0 \approx 10^{-10}$ m. The second layer of other sign ions is the Gui's layer. The thickness of the double layer can reaches tens of millimeters. During the interpretation of electrification only as the process of capturing by the charges flow of the Gui's layer, it is impossible to explain the continuity of the charges formation. Indeed, after removing of Gui's layer by the flow of ions from the entire pipe the flow of charges should stop, that is in future the uncharged fuel must come from the pipeline. [2] Therefore, there are three reasons for the formation of a double electric layer:

- the predominant transfer of charge carriers from one body to another – diffusion;
- absorption processes at the boundary of distribution, when the charges of one of the phases predominantly precipitate on the surface of another phase;
- polarization of molecules of at least one of the phases, which leads to the polarization of molecules of another phase.

In the turbulent streams of hydrocarbon fuels the boundary of double-layer is blurred and undefined, so it is conventionally considered that its thickness reaches tens of millimeters. The current of electrization I (in amperes) during flowing in steel pipelines can be calculated by the formula:

$$I = 1,75 \cdot 10^{-13} \frac{\varepsilon T r^{7/8} v_0^{15/8}}{\nu^{5/8}} \left[1 - \exp\left(-\frac{L}{\tau v_0} \right) \right], \qquad (1)$$

where ε — dielectric permittivity; T — liquid temperature, K; r — radius of the pipeline, m; v_0 — average speed of fluid flow in the pipeline, m/s; ν — coefficient of kinematic viscosity, m^2/s; L – length of the pipeline, m; τ – time of the relaxation (scattering) of charge, s ($\tau = \varepsilon_0\ \varepsilon\ \rho_v$, where $\varepsilon_0 = 8,854 \cdot 10^{-12}$, F/m – absolute dielectric constant); ρ_v – specific volume electric resistance of the liquid, Ohm·m.

From (1) it can be seen that the current of electrization is proportional to the flow velocity in a power close to two and the radius of the pipeline in the first degree.

At a larger length of the pipeline the value of the current of electrization reaches the maximum:

$$I_{\max} = 1,75 \cdot 10^{-13} \frac{\varepsilon T r^{1/8} v_0^{15/8}}{\nu^{5/8}},$$

since the term of the last conjugate in the formula becomes small in relation to the unit, and the entire conjugate $\left[1 - \exp\left(-L/tv_0\right)\right] = 1$.

For a relatively small length of the pipeline, when its value is close to tv_0, the current of electrization is almost proportional to the length of the pipeline. The electrization currents are usually small and do not exceed 10^{-5} A.

The process of separation and accumulation in fuel of one-sign charges proceeds mainly in pipelines. In reservoir this process is slowed down with the exception of intense mixing of the flow and coagulation of pollution particles. If a fuel jet enters to the reservoir with sprinkling, there is significant electrization by the separation of the double electric layer at the fuel-air border. Significant electrification can occur during tank steaming, during cleaning walls with a stream of fluid that flows from the nozzle at a high speed. Electrification increases by the presence of finely divided water, pollutant particles, air bubbles.

Intense electrization is going on in filters and other technological equipment with a developed surface, during flow sprinkling. To protect against static electricity, it is necessary to limit the processes that lead to the appearance of the accumulation of pollutants. Methods and means of protection against static electricity include:

- grounding of technological equipment for the removal of charges of static electricity. The regulated resistance of grounding devices is ≤ 100 ohms. Such resistance should have an electric circle formed by pipelines with latches and tanks. During operation, it is necessary to monitor the reliability of the contacts that can be affected by corrosion, flowing dielectric fluid. Especially careful must be monitored the grounding of ‘floating roofs’, tanks, pontoons, float levelers, metal elements of valves, non-metallic pipelines. Tankers and fuel dispensers are in contact with the ground through wheels and tires with big electrical resistance. Such grounding cannot be reliable due to the fact that most of their path passes along the road with asphalt covering. That is why in the places of filling of the fuel dispensers and refueling of the aircraft, they must ground. For this purpose, special methods and means are provided. [2, 3];

- limiting flow velocity in pipelines. It is believed that in the presence of grounding, the safe speed for a liquid transportation that having a resistance $\rho_v \le 10^5$ Ohm·m is 10 m/s, and $\rho_v \le 109$ Ohm·m – 5 m/s. In this case, the value of specific volume electric resistance of jet engines fuel is $c_v = 1 \cdot 10^{11} \ldots 2{,}8 \cdot 10^{13}$ Ohm·m, of gasolines is $c_v = 10^{10} \ldots 10^{12}$ Ohm·m. In other equal terms, the electrization parameters, such as the volume density of charge ρ_F and the established charge Q_F, increase with increasing fuel pumping velocity through pipelines (Fig. 1). In order to provide fire safety from static electricity, a limit on the fuel transfer speed has been introduced. According to V.M. Gorelova and V.V. Malysheva the maximum possible rate of aircraft refueling is: for fuels TS-1 and RT – 700 l/min; T-1 – 500 l/min; T-8 – 1100 l/min.

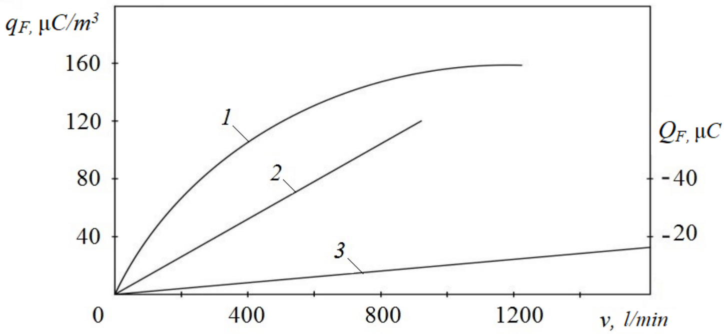

Fig.1 The dependencies $q_F = f(v)$ and $Q_F = f(v)$ in the aircraft tank:
1 – initial fuel without additive; *2* – fixed charge in the tank during pumped out of the original fuel; *3* – fuel with Sygbol additive (0,0002 %).

- prevention of fuel sprinkling during filling capacity: the tanks must be equipped with devices that ensure the filling below the fluid layer that is there. If there is no fuel in the reservoir after repair and the supply below the layer without sprinkling is impossible, it is necessary before the immersion of the nozzles in the liquid to sharply limit the flow velocity to ~ 0,7 m/s;

- increasing of the fuel purification degree from mechanical impurities and emulsion water. The main electrization occurs on filters, especially fine purification. The fuel electrization during filtering can increase in 200 times. Therefore, with the fuel purity requirements increasing, that is, with the filtration fineness increasing, the danger of fuel and air mixture ignition from the static electricity discharges is significantly increasing. The fuel electrization reducing can be achieved by cleaning it from pollution, resinous substances and water. So, the increasing of the fineness filtration to 5 microns reduces the degree of fuel electrification by 2 times, and the application for purifying silica gel or bleaching clay completely protects from the accumulation of static electricity during pumping.

There are using different technical means of protection against static electricity, such as: relaxation tanks, neutralizers, nitrogenation of air pillows over fuel, anti-electrification filters, but they only solve the problem locally. In the case of various designs of relaxation tanks using, they are installing near the tanks and consistently connected to the fuel supply pipelines. Typically, the relaxation tanks are pipelines with conical transitions with diameter that larger than the main pipe. Staying in a relaxation tank (fully filled), fuel gives to walls most of the charge. Calculation of relaxation tanks is reduced to the definition of their geometric sizes, in which the time of fuel staying is significantly exceed the time of relaxation of charge (1). Typically, the calculated average flow velocity in the relaxation tank is assumed to be 0,5 m/s. The efficiency of the relaxation tank can be increased by making it from the dielectric, for example fluoroplastic, and installing the needle electrodes in it in perpendicular liquid flow position [3].

There is only one way that guarantees the safe pumping of fuel through pipelines and the aircrafts refueling is the using antistatic additives [4]. Antistatic additives that are injected with a small dose can increase the value of safe fuel transport speed. According to Shell, the aviation fuels that containing 0,0005 and 0,0006 % of the additive ASA-3 can be pumped with speeds up to 150 and 300 m/s, respectively.

Conclusions

It is proved that the appearance of fuel electrization is caused by the existence of a double electric layer at the boundary of the phase distribution.

The current of electrization in a flow in steel pipelines is determined by the formula (1), from which it is evident that the current of electrification is proportional to the flow velocity in degree close to two and the radius of the pipeline in the first degree. The electrization currents are usually small and do not exceed 10^{-5} A.

The technical means of protection against static electricity have been determined. The methods of protection against static electricity are recommended.

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