Fire Extinguishing Efficiency of the Powders in Environments with Variable Oxygen Concentration

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Fire extinguishing practice with fire extinguishing agents is used to eliminate all groups, classes and types of fires. However, their most economically advantageous, wide and effective application is hindered by a number of unresolved problems. First of all, there is insufficient knowledge of the mechanism of their fire extinguishing effect in real fire conditions, when the oxygen concentration in the air in the combustion zone changes. In most cases of real fires in closed rooms, the oxygen concentration in the combustion zone decreases, for example, in basements to 10.6 - 19% (vol.), and in attics to 16 - 20% (vol.).

In case of fires and accidents at chemical industry enterprises and individual energy facilities, when devices and pipelines are damaged, as well as a result of spontaneous chemical reactions, the air in the fire zone may be enriched with oxygen. In modern practice, various types of oxygen-enriched technical devices are widely used (water tanks, pressurized chambers, medical pressure chambers, underwater objects).

Based on experimental studies, the patterns of increasing the fire extinguishing efficiency of powders in conditions of reduced oxygen concentration were determined, and the possibilities of their use for fire protection and fire extinguishing of devices and technologies with high oxygen concentration were substantiated.

Based on the statistical analysis of the results of the research conducted with computer software, it was established that there is a clearly expressed linear dependence of the fire-extinguishing efficiency (E) of powders on the change in oxygen concentration (nitrogen to oxygen ratio N_2/O_2 in the gas-air environment (Fig. 1):

$$E = K_o + K_1 \cdot \left(\frac{N_2}{O_2}\right) \qquad (1)$$

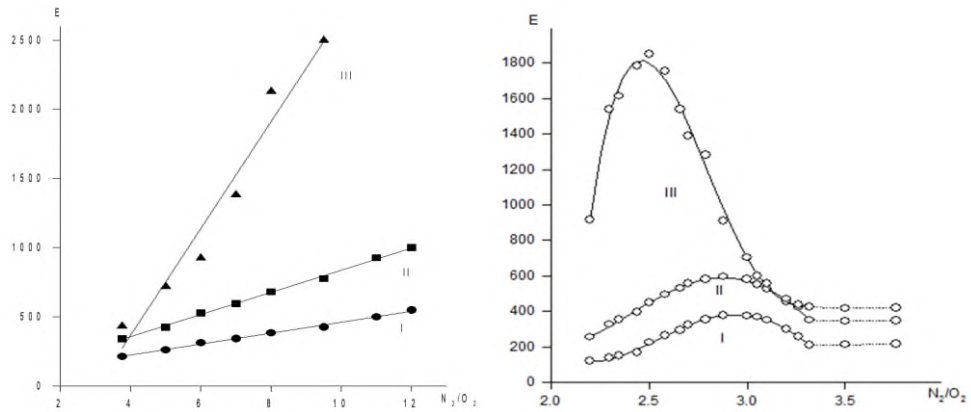

Fig. 1. – Dependence of fire extinguishing efficiency of powders on the volumetric ratio of nitrogen to oxygen in a combustible gas-air mixture: I – for $NaHCO_3$; II – for $(NH_4)_2HPO_4$; III – for KCl

An increase in the amount of nitrogen introduced into the combustible mixture leads to a volumetric decrease in the oxygen concentration and, as a result, to the enrichment of the combustible mixture with combustible gas. The graphs in Fig. 1 show a clear increase in the efficiency of all the studied powders with a decrease in the oxygen concentration in the combustible gas-air mixture. Thus, the fire extinguishing efficiency of the studied powders is located in the following series:

$$KCl > (NH_4)_2HPO_4 > NaHCO_3 \quad (2)$$

The study of the fire extinguishing properties of powders with increasing oxygen concentration in a combustible propane-butane mixture was carried out at a volume ratio of nitrogen to oxygen in a combustible propane-butane mixture in the range from 3.76 to 2.2. Further increase in the oxygen concentration in the gas-air mixture under these experimental conditions is practically impossible and dangerous due to the possibility of flame backlash.

Statistical analysis of the research results, conducted with computer software, indicates the presence of a polynomial dependence of the fire extinguishing efficiency (E) of powders on the change in the ratio of nitrogen to oxygen N_2/O_2 with a corresponding increase in the oxygen concentration in the gas-air environment:

$$E = a_0 + a_1 \cdot \left(\frac{N_2}{O_2}\right) + \cdots + a_n \cdot \left(\frac{N_2}{O_2}\right)^n \quad (3)$$

The conducted studies confirmed the assumption that the effectiveness of fire extinguishing powders increases with a decrease in the oxygen concentration in the gas-air environment. To achieve the maximum cost-effective efficiency of fire extinguishing powders in the practice of powder fire extinguishing, their joint or combined use with devices or means that reduce the oxygen content in a room with a gas-air environment is possible.

The experiments conducted show that the studied powders can be effectively used for fire extinguishing in environments enriched with oxygen, at its volumetric concentration of up to 30-35%, i.e. at a volumetric ratio of nitrogen to oxygen from 3.76 to 2.25. It should also be noted that potassium chloride-based powder is the most effective for extinguishing combustion in an oxygen-enriched environment, which is fully consistent with the conclusions of the authors [2], who studied potassium chloride-based aerosol-forming agents under similar conditions.

References

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