

PREVENTION OF EXPLOSIONS AND EXTINGUISHING OF IGNITIONS AT HYDROGEN POWER INSTALLATIONS

Chibisov A.L*., Smirnova T.M., Soina E.A., Fedotkin D.V., Kotsar' M.L.

Federal State Establishment 'All-Russian Research Institute for Fire Protection Rewarded by Badge of Honor' (FGU VNIPO EMERCOM of RUSSIA), mkr. VNIPO, Bld. 12, Balashikha, Moscow Region, 143903, Russia

⁽¹⁾Public Corporation "Leading Research Institute of Chemical Technology" (OAO "VNIHT"), Kashirskoye Shosse, Bld. 33, Moscow. 115409, Russia

*Факс: (495) 521-86-47

E-mail: chibisov@zebra.ru

Introduction

This article is devoted to the development of the design procedure for the determination of CO₂ mass which will allow to use CO₂ automatic fire-extinguishing systems in the industrial premises during the operation of the ventilation system. This procedure can be also used for the calculation of the certain parameters of the automatic gas fire-extinguishing systems at hydrogen power installations where combustible metals, gases including hydrogen, metal hydrides are handled and where cables and other fire load are available.

Results and discussion

In the article the mechanisms of the change of the gas phase parameters and its composition in the rooms with the operating ventilation system at the discharge of the fire-extinguishing gas – carbon dioxide (CO₂) is studied. There have been conducted both laboratory and full-scale tests.

A laboratory apparatus which constituted a metal chamber with a volume of 0,984m³ allowed to simulate the process of fire-extinguishing in the room with the operating ventilation and non-operating ventilation and to study the change of the gas – air medium parameters at the discharge of CO₂. The fire seat was modeled with the help of the heating element.

The air changes per hour K_p which is a ratio of the air volume removed by ventilation to the room volume per hour has been chosen as a basic criterion allowing to spread the results obtained under the laboratory conditions to the real rooms. The test results of the determination of the gas – air medium parameters and the influence of the temperature on them in the chamber with the heating element, without heating, at the operating ventilation and non-operating ventilation are presented in Figures 1-4.

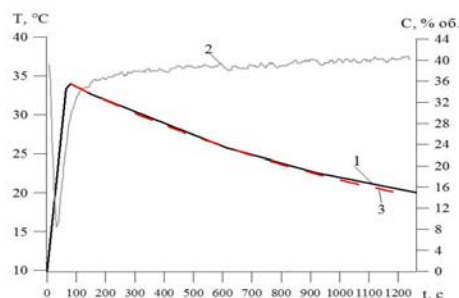


Fig. 1. The change of CO₂ concentration by volume and the gas temperature in the chamber at the discharge of gas and its 20- minute exposure (the temperature of the heating element surface was 250°C).

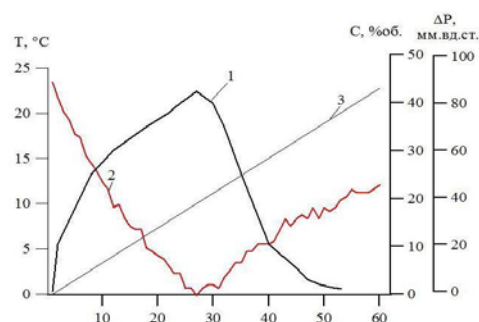


Fig. 2. The change of parameters of the gas-air medium in the chamber at the discharge of CO₂ (at the lack of ventilation with the heating element).

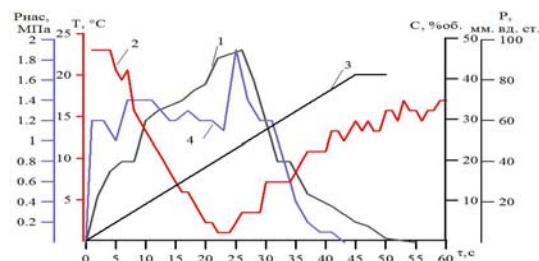


Fig. 3. The change of parameters of the gas-air medium in the chamber at the discharge of CO₂ (without the ventilation and the heating element).

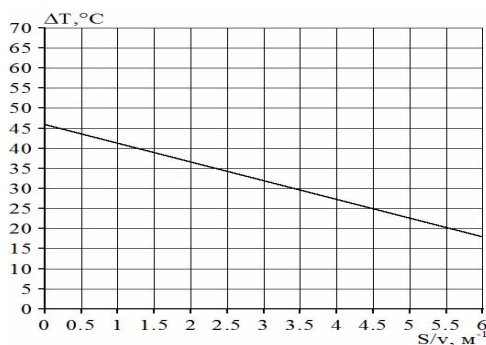


Fig.4. The dependence of the change of the average volume temperature on the specific area of the room surface.

The obtained results showed the following:

- the value of the effective extent of the chamber non-tightness depends on the underpressure created in the chamber;
- the main mass of CO₂ enters the chamber for the first 25 – 30 s. During this period the temperature of the gas – air mixture in the chamber decreases to 0°C and the pressure increases to 1000-1300 Pa;
- after the main mass of CO₂ enters the chamber the pressure decreases, the temperature increases to the reference value during the following 2-4 min. while CO₂ concentration achieves its maximal value;
- the decrease of CO₂ concentration in the chamber during the soaking period takes place according to the exponential law due to the dilution of the gas mixture by air in the chamber which is “sucked in” through the looseness because-of the underpressure created in the chamber;
- during the creation of the normative concentration for the discharge time (60 s) CO₂ concentration decreases by 1,5% vol. due to the dilution of the gas mixture by air at the air changes per hour $K_p = 2,79 \text{ h}^{-1}$. Only 40-50% of mass. CO₂ enters the chamber in the form of gas, the rest amount of gas enters the chamber in the solid phase which gasifies in 2-3 min.;
- the test with the heating element (Fig. 2) showed that the availability of the fire seat at the initial stage of fire development does not lead to the drastic increase of pressure at CO₂ discharge;
- the mechanisms of change of the main parameters of CO₂ discharge obtained under laboratory conditions are confirmed by the results of the full-scale tests in the rooms with the volume of 1804m³ and 40,5m³ when the enforced ventilation does not work. At non-operating

ventilation system the decrease of the average volume temperature value (ΔT) during CO₂ discharge depends on the heat exchange conditions, it is governed by the value of the specific area of the room surface (S/V) (Fig. 4). The larger the room volume the lower the average volume temperature at CO₂ discharge can be.

The necessity of the additional store of carbon dioxide mass ΔM for maintaining of the inerting concentration at the operating ventilation during the soaking period is determined by the following equations:

$$\text{if } \dots \frac{C_H \cdot e^{-\frac{K_p \cdot t}{60}}}{1 + K'_2} \geq C_\phi, \% \text{ vol.} \quad (1),$$

then ΔM=0

$$\text{if } \dots \frac{C_H \cdot e^{-\frac{K_p \cdot t}{60}}}{1 + K'_2} < C_\phi, \% \text{ vol.} \quad (2),$$

then ΔM is determined by the following equation:

$$\Delta M = \rho_1 \cdot V_p \cdot (1 + K'_2) \cdot \left[\ln \left(\frac{100}{100 - C_\phi \cdot (1 + K'_2) \cdot e^{-\frac{K_p t}{60}}} \right) - \ln \left(\frac{100}{100 - C_H} \right) \right] = \rho_1 \cdot V_p \cdot (1 + K'_2) \ln \left(\frac{(100 - C_H) \cdot e^{-\frac{K_p t}{60}}}{100 - C_\phi \cdot (1 + K'_2) \cdot e^{-\frac{K_p t}{60}}} \right) \quad (3)$$

where C_H – normative concentration, % vol.; C_ϕ – inerting concentration, % vol.; t – soaking time, min.; K_p – air changes per hour, hour⁻¹; K'_2 – coefficient taking into account the losses of the gas fire-extinguishing substance in case the ventilation system operates.

The value of K'_2 differs from that of K_2 which is calculated with the help of the procedure proposed in NPB 88-2001* [1]. K'_2 coefficient takes into account both the losses of the gas fire-extinguishing substance at the operating ventilation system, the location of the air inlets of ventilation and non-uniform distribution of CO₂ concentration in relation to the height of the room.

The analysis of the tests conducted and the bibliographic data showed that K'_2 coefficient which takes into account the losses of the gas fire-extinguishing substance can have the following values: 0,1 – at the location of the air inlets of ventilation system

in the upper part of the room; 0,2 – in the middle part; 0,3 – in the lower part.

Air changes per hour are determined by the following equation:

$$Kp = \delta \cdot \sqrt{\frac{2\Delta P}{\rho_e}} \cdot 3600, \dots \quad (4)$$

where δ – parameter of the room non-tightness, m^{-1} ; ρ_e – air density, $kg \cdot m^{-3}$; ΔP – the value of the underpressure in the room, Pa.

Conclusions

The test results obtained and the dependences proposed for their description

can serve a basis for the development of the design method for the determination of carbon dioxide in automatic gas fire-extinguishing systems for the rooms with the operating emergency ventilation system.

References

1. NPB 88-2001* Fire-Extinguishing And Alarm Systems. Design Norms And Rules.
2. El'terman V.M. Ventilation at Chemical Productions. M., Khimiya, 1980. – 288p.