Emergency ventilation industrial premises of chemical industry enterprises

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Abstract. The results of the study concentration field of chemical harmful substances in the entire volume of the room during the operation of emergency ventilation with a given air exchange are proposed. Explosion safety of production rooms is provided on condition of 10% of the lower limit of flame spread on gas-air mixes and observance of equality of concentrations of harmful substance in the working zone and in the leaving air. Emergency ventilation is proposed, which provides uniform removal of air from the entire volume of the room to exclude the formation of stagnant zones and ensure explosion safety in chemical emissions. Emergency ventilation with a natural flow of air through the holes with variable aerodynamic characteristics with a volume-oriented arrangement of supply and exhaust holes to ensure uniformity of the flow and removal of air from the entire volume of the production room.

1. Introduction
Description of the problem is that the accident rate in many industries of the Russian Federation and foreign countries remains at a high level, which leads to large-scale pollution of the environment and loss of life. Chemical, petrochemical and oil refining industries are still the most hazardous production facilities.

The analysis of cases of emergency situations with emission of harmful substances into the atmosphere indicates the need to develop technical and sanitary measures that bring the air quality of the working area of the room and on the border of the sanitary protection zone to the level of normative indicators.

Emergency release of harmful substance is sudden and short-term. The occurrence of an emergency release at a chemical plant is probabilistic in nature.

The existing circuit solutions of the emergency ventilation device consist in the removal of air from the zone of maximum concentrations of harmful substances, where explosive mixtures can be formed. Not tested scheme emergency ventilation with natural and mechanical partial flow of air. Their use would significantly reduce energy costs and the purchase of ventilation equipment.

2. Description of the terms decision
The solution to improve the efficiency of emergency ventilation of industrial premises of chemical production is the creation of additional systems of inflow and uniform removal of air from the entire volume of the room. The proposal is based on the fact that harmful substances when they leak from
the process equipment before the emergency ventilation is turned on are distributed in the room due to diffusion, operation of General mechanical ventilation, unorganized natural inflow and extraction with open Windows, transoms, doorways. At the same time, gas analyzers installed at a certain concentration value may not work.

The classification of emergency situations at the industrial facility is presented and the basic functions of emergency ventilation at emission of harmful substances of various degree of danger are described [1-7]:

1. An emergency situation in which the concentration of harmful substances in industrial premises is increased by no more than 1 order of permissible excess of the maximum permissible concentration (MPC), and short-term stay of people in such an atmosphere is permissible. Such an emergency situation can arise in case of violations of the technological regime, which are possible at chemical enterprises, lead to an increase in the release of harmful substances that significantly increase their concentration in production facilities. That is, $q_{hs} < 0.1q_{LCL}$, where $q_{hs}$ – concentration of harmful substances, mg/m$^3$, $q_{LCL}$ – lower concentration limit of flame propagation through gas-air mixtures, mg/m$^3$.

The task of emergency ventilation in this case is to prevent an increase in the concentration of harmful substances above the MPC in the working area and reduce the time of stay of people in the atmosphere with high concentrations.

Emergency ventilation performs a sanitary and hygienic function in the room that it vents.

2. An emergency situation in which without serious destruction of equipment and communications in the production room allocated significant amounts of chemicals. This can create concentrations that exceed the maximum permissible and working will have to use personal protective equipment. Therefore, the goal of the emergency ventilation is the rapid decline in concentrations after the accident up to the maximum allowed.

If the emitted harmful substance and at the same time explosive, that is $q_{LCL} > q_{hs} > 0.1q_{LCL}$, that emergency ventilation shall reduce the concentration to the limit, which is not a possible explosion or fire. At the same time, it is important that not only the average concentration, but also the concentration at all points of the volume at which sparking is possible or there are heated surfaces, would be below the limit level.

Emergency ventilation performs a sanitary and hygienic function and the function of preventing fire and explosion in the room ventilated by it.

3. An emergency situation in which there is a destruction of equipment or communications without the destruction of buildings, in most cases leads to the formation of explosive concentrations, that is $q_{hs} < q_{LCL}$. It is important to prevent the possibility of the consequences of accidents that may occur from an explosion or fire of substances in the air of the room.

The function of emergency ventilation in this case is to remove from the room air with high concentrations of explosive hazardous substances and release them into the upper atmosphere. This is necessary to avoid poisoning people, as well as accidents in neighboring buildings [8-14].

Emergency ventilation should prevent the consequences of the accident and in the room in which the accident has already occurred. To do this, emergency ventilation creates flows in the room, which carry air with fire and explosive concentrations of harmful substances away from possible flash points [15-18].

Accidents with the destruction of the building are not considered, as in this case the premises in which emergency ventilation can be used disappear.

The operating conditions of emergency ventilation are to exclude the formation of concentrations above 10 % of the lower limit of flame propagation through gas-air mixtures in the volume of the production room, $q_{LCL}$, mg/m$^3$:

1 condition. The concentration of harmful substances in an emergency release, $q_{hs}$, is the maximum value, $q_{max}$, and should be determined on the basis that:

$$q_{wa} < q_{hs} = \left( q_{max} < 0.1 \cdot q_{LCL} \right)$$ (1)
\[(0.1 \cdot q_{LCL} < q_{wa}) = (q_{max} < q_{wa})\]  \hspace{1cm} (2)

where \(q_{wa}\) – concentration of harmful substance equal to the maximum permissible value in the working area, mg/m³;

2 condition. The concentration of harmful substances in the past from industrial premises the down air, mg/m³, with the work of emergency ventilation should be equal: when \(q_{wa} < q_{LCL}\), \(q_d = 0.1q_{LCL}\); \(q_{wa} > q_{LCL}\), \(q_d = q_{wa}\).

3 condition. In order to ensure that the concentration of harmful substances in the volume of the production room does not exceed \(q_{wa}\), it is necessary that: \(q_{wa} \leq \frac{G_0}{L}\), where \(G_0\) – emergency consumption of harmful substances, kg/ h; \(L\) – air consumption, which must be provided in the production room in case of emergency release of harmful substances, m³/h.

4 condition. The air flow rate in the production room during the operation of emergency ventilation should be more than 0.2 m/s.

5 condition. To ensure uniform removal of air from the room, the area of the suction openings shall not exceed 50 % of the emergency ventilation duct.

3. Description of technology.

The scheme of emergency ventilation with the removal of harmful substances from the entire volume of the room is shown in figure 1.

Figure 1. Scheme of emergency ventilation with removal of harmful substances from the entire volume of the room: 1 – holes for natural air flow, equipped with flaps; 2 – process equipment; 3 – air intake openings; 4 – emergency ventilation ducts; 5 – device for air purification; 6 – ventilation unit; 7 – pipe emission of harmful substances into the atmosphere; 8 – air ducts mechanical supply General ventilation; \(H_r\) – height of the room, m; \(b_r\) – width of the room, m; \(l_r\) – length of the room, m.

The design of the leaf in the inlet is shown in figure 2.
Figure 2. Leaf design in inlet: $H_{leaf}$ – sash height, mm, $l_{leaf}$ – sash length, mm.

Figure 3 shows a nomogram that allows you to select the method of cleaning in case of emergency release of harmful substances with a given efficiency of 95% [18-22].

Figure 3. Nomogram determining the method of cleaning in the event of an emergency release of a harmful substance with a given efficiency of 95% in the interval $q_i/q_{wa}$ from 1 to 500: where $q_i$ – concentration of the harmful substance released, mg/m³; $K_{em}$ – multiplicity of air exchange during emergency ventilation, 1/h; $v$ – gas velocity, m/s; $H$ – height of the emission source, m; $M_{wa}$ – amount of harmful substances in emergency emissions, kg; $F_{csa}$ – cross-sectional area of the exchange tank of the treatment device, m²; $\mu_{wa}$ – molecular weight of harmful substance; $\mu_{air}$ – molecular weight of air; $MAC$ – maximum allowable concentration; $\infty$ – scope of the methods of purification with respect to $\mu_{wa}/\mu_{air} = 0.5...0.95$; $\infty\infty$ – scope of the methods of purification with respect to $\mu_{i}/\mu_{wa} = 1.01...5$; $\infty\infty\infty$ – field application of methods purification Halogens and sulfur-containing substances; $\infty\infty\infty\infty$ – working range of the method cleaning in excess of $q_i$ above $q_{wa}$ with a given efficiency, beyond its limits, the efficiency decreases.
4. The advantages of the proposed technology

The advantages are the creation of additional volume-oriented systems of natural or partially mechanical inflow and uniform mechanical removal of air from the entire volume of the room to exclude the formation of stable zones. New design elements of the emergency ventilation system for the organization of natural air flow in the form of flaps with variable aerodynamic characteristics are proposed. The boundary conditions for the use of emergency ventilation schemes with natural or partially mechanical air inflow, taking into account the influence of wind pressure and preventing the fall of the air temperature in the room below +5 °C, are presented.

Calculated dependences of determination of the areas of supply openings, areas of exhaust openings in compliance with the ratio of the areas of air receivers and air ducts of emergency ventilation is not more than 0,5, their spatial coordinates of the location depending on the number and location of technological equipment in the room, as well as the required aerodynamic characteristics of ventilation equipment depending on the number of harmful substances removed, the risk of their concentration above the normalized limit of flame propagation through gas-air mixtures, differentiation of purification methods taking into account the molar weights of the harmful substance and air are presented in [23].

5. Conclusion

The proposed emergency ventilation ensures uniform removal of air from the entire volume of the room to eliminate the formation of stagnant zones and ensure explosion safety in the emission of chemicals. At the same time, the natural step of air through the holes with variable aerodynamic characteristics with a volume-oriented arrangement of the supply and exhaust holes contributes to the uniformity of the inflow and removal of air from the entire volume of the production room. The presented solutions in combination with the definition of the most rational method of cleaning allow:

- reduce the amount of environmental risk associated with the possible massive impact on the environment of various chemicals;
- increase the energy saving of the system and reduce the cost of purchase, operation and maintenance of ventilation equipment.

References

[1] Polosin I 2007 Protection of atmosphere from emissions of industrial ventilation and boiler (Voronezh state University of architecture and civil engineering) p 192
[2] Polosin I 2001 Dynamics of processes of industrial ventilation (Abstract of the thesis of the doctor of technical sciences)
[3] Polosin I, Kuznetsov S, Portjannikov A and Derepasov A 2009 Realisation of mathematical model for an estimation of efficiency of schemes of the organisation of air exchange in shops Galvanocoverings Privolzhsky scientific magazine 2(10) 42–47
[4] Polosin I, Yaremenko S, Chernih R and Danilov T 2011 Prediction of the prevented ecological damage to the resources of the local bodies of water if the atmospheric protection Engineering systems and constructions 2 9–16
[5] Elterman V 1980 Ventilation of chemical manufactures (Moscow: Chemistry) p 288
[6] Kopytina Y, Kitaev D, Shechukina T and Apalkova E 2017 Diagnostics of environmental pollution and the integrated approach to the protection Ecology and industry of Russia 21(4) 59–63
[7] Sarmanaev S and Desjatkov B 2002 Modeling of a microclimate of inhabited and industrial buildings News of high schools. Building 1-2 70–78
[8] Zayats Yu and Belyaev V 2005 Numerical model of premises ventilation during emergency emissions of harmful substances Science and Progress in Transport 9 31–35
[9] Datsyuk T, Derjugin V, Vasilev V and Ivlev J 2003 Analysis of results of physical and mathematical modeling at the decision of problems of industrial ventilation News of high schools. Building 9 24–31
[10] Amelin A 1972 *Theoretical foundations of fogging by steam condensation* (Moscow: Chemistry) p 304

[11] Frank-Kamenetskii D 1967 *Diffusion and heat transfer in chemical kinetics* (Moscow: Nauka) pp 50–60

[12] Derepasov A 2017 Research air exchange production premises with holes in the overlappings *Housing and utilities infrastructure* **1-2** *(1)* 18–25

[13] Sushko E, Pereslavtseva I and Sheps R 2013 Use of angle filters to reduce dust concentration in aspiration air *Scientific herald of Voronezh State Architectural and Construction University. Series: Physicochemical problems and high technologies of building materials science* **6** 119–123

[14] Yaremenko S, Pereslavtseva I, Rudneva N and Malin V 2012 Energy spectra of the pulsation velocity in free turbulent ventilation flows *Engineering systems and facilities* **3**(8) 32–38

[15] Nakhod V and Fil E 2016 Providing Explosion-Fire Safety of Ventilation Systems *Potential of Modern Science* **4**(21) 89–93

[16] Elinsky I 1987 *Ventilation and heating electroplating facilities* (Moscow: Mashinostroenie) p 92

[17] Grimitlin A and Datsyuk T 2007 *Heating and ventilation of industrial premises* (St.-Petersburg: Northwest AVOK) p 399

[18] Skrypnik A 2002 *Cleaning of ventilation emissions from chemical harmful substances* (Voronezh state University of architecture and civil engineering)

[19] Skrypnik A and Zherlykina M 2004 Computational model determining the most probable values of the ventilation emission of chemical substances during an emergency *News of higher educational institutions. Construction* **5** 72–75

[20] Kolodyazhny S, Pereslavtseva I and Filatova O 2010 Dependence of the distribution of hazardous harmful substances in the premises ventilation rate *Engineering systems and constructions* **2** 192–196

[21] Chuikin S and Zherlykina M 2011 Ensuring environmental safety of the environment from food industry emissions *The Bulletin of MGSU* **7** 288–295

[22] Zherlykina M, Vorob’eva Y and Jaremenko S 2017 Technical Means and Methods of Environmental Protection in Case of Accident at Chemically Hazardous Industrial Facility *IOP Conference Series: Materials Science and Engineering (MSE)*

[23] Zherlykina M 2006 *Improving the efficiency of the emergency ventilation of industrial premises to ensure explosion in the release of chemicals* Dissertation on competition of a scientific degree of candidate of technical Sciences p 166