Movement of Liquid Mixture in the Injector of Sprinkler at Automatic Fire Extinguishing Systems

Ihar Kachanau, *Belarusian National Technical University*, Ihar Karpenchuk[1], Siarhei Pauliukou[2], [1-2]*Institute for Command-Engineers of the Ministry of Emergencies of Belarus*

Abstract. **The article discusses one of the ways to increase the effectiveness of fire-extinguishing foam at the automatic fire-extinguishing system, in particular, the main focus is on the change of the hydrodynamic parameter equipment (sprinkler, nozzle). Today the workflow data sprinklers explicitly has not been examined and not regulated current technical regulations. In this connection it is interesting to conduct studies of the fluid mechanics in these sprinklers and suggest the ways to improve characteristics such as foam multiplicity and dispersion. As a result of work theoretical studies of the mechanics of fluid motion in the fire sprinkler with pre-aeration of extinguishing agent carried out. The equations of motion of the gas-liquid mixture in the injector for aeration extinguishing agent were solved.**

Keywords: **automatic fire extinguishing systems, foam, diffuser, injector, gas saturation, dispersion**

I. INTRODUCTION

Automatic fire-extinguishing system is the most effective means of fire protection of buildings and structures [1-3]. Need for their application is the potential not only to detect a fire, but to eliminate it early. The use of foam in these devices allows you to: reduce the amount of water required for fire fighting the large areas and volumes, etc. Efficiency of foam firefighting are depends of the termination of access flammable vapors in the combustion zone and cooling the heated surface layer (the combustion of liquid).

Termination of access of flammable vapors is a major factor in fire-extinguishing foam and is associated with the formation of vapor barrier on the surface of some structure and stability. Cooling is mainly due to the cover of foam (from the foam separation process fluid). In this regard, it is assumed that the best foam would be one that has a significant resistance and plentiful water or low expansion foam (6 - 8) and fine-meshed, evenly distributes the bubbles in the layer of foam [4, 5].

The research [6, 7] conducted for the study of the basic characteristics of the foam affecting the extinguishing efficiency, leads to the conclusion that one of the important characteristics of the foam, which affects the rate of its destruction on the surface of the fuel, is the dispersion or the average size of the bubble in the foam. Thus, the dispersion gives an idea of the degree of fineness of bubbles and foam is determined by their size. Foam is consist of bubbles of different sizes. With the destruction of the foam dispersion is changing. Therefore, a change of dispersion vary hydrodynamic parameters of foam. Dispersity is inversely proportional to the size of the foam bubbles and largely determines its quality. The higher the dispersion, the better the foam is, the higher its resistance, the better the fire extinguishing efficiency can be achieved.

II. GENERAL REGULATIONS

Joint motion of the gas and the liquid may vary significantly. Extreme forms of joint motion is the movement of two continuous, simultaneous threads, interacting only one continuous interface or it is motion flow of foam in which the two phases form a complex and unstable structure. A specific feature of this environment is the fact that even in the case where both phases can be considered virtually incompressible, gas-liquid system behaves as a compressible fluid. For in-depth study of the motion of two-phase fluid in the vertical injector the equations averaged over one-dimensional motion of gas-liquid mixture in the cone will be recorded. The solution of these equations will allow us to determine the pressure loss in the injector, its geometric characteristics and hydrodynamical parameters. To solve this problem it is necessary written the conservation of momentum law and continuity equation for the elementary part of the diffuser injector. In deriving the equations of motion the methods used in [8, 9] were applied to derive the equations of motion of the gas-liquid mixture in a circular pipe.

The equations of motion for the two-phase flow in the diffuser

Scheme of a two-phase fluid in the diffuser injector is shown in Figure 1. Considered injector made as Venturi tube.

As shown in the figure, the cone is vertical. Denote the area of an arbitrary section of the diffuser through S.

It is known that the gas content of φ is given by [8, 9]:

$$\varphi\left(x_0,t_0\right)=\frac{1}{\Delta t}\int_{t_0}^{t_0+\Delta t}\varphi'\left(x_0,t_0\right)dt, \qquad (1)$$

where:

$\varphi'(x_0, t_0)$ − fraction of the area occupied by the gaseous state at time t;

$\Delta t >> 1/n_{sr.}$ ($n_{sr.}$ - average frequency of passage of individual formations gaseous fraction through the section), so we shall consider the two-phase flow in the diffuser as the motion of a compressible fluid.

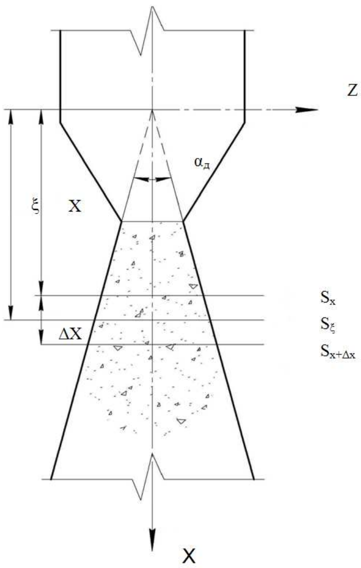

Fig. 1. Scheme of a two-phase fluid in the diffuser injector.

Define the forces acting on the elementary portion of the diffuser made between sections Sx and Sx + Δx, and their projection on the axis Ox.

Mass forces:

$$G = g \iiint_V \rho_{mt.} dV = g \int_x^{x+\Delta x} d\xi \int_{S_x} \rho_{mt.} dy dz, \quad (2)$$

where:
g - acceleration of gravity;
$\rho_{mt.}$ - density of the two-phase liquid ($\rho_{mt.} = \rho_{mt.}$ (x));
V - volume of the diffuser between the sections Sx and Sx + Δx;
ξ - coordinate intermediate section between sections Sx and Sx + Δx.

When the vertically placed injector mass forces will be:

$$G = g \int_x^{x+\Delta x} \rho_{mt.} S_\xi d\xi = g \int_x^{x+\Delta x} \pi \cdot tg^2 \frac{\alpha_d}{2} \xi^2 \rho_{mt.} d\xi, \quad (3)$$

where:
α_d – taper angle of diffuser.

Friction forces:

$$\vec{T} = \iint_{S_{w.}} \vec{\tau} dS = \int_x^{x+\Delta x} \tau \frac{d\xi}{\cos\frac{\alpha_d}{2}} \int_{l_\xi} \vec{e}_\tau dl, \quad (4)$$

where:
$S_{w.}$ – lateral surface of the truncated cone between sections S_x и $S_{x+\Delta x}$;
τ – shear stress at the wall of the diffuser;
l_ξ – length of circumference a circle of radius $r = \xi$ tg(α_d/2);
$\vec{e}_\tau$ – unit vector collinear with $\vec{\tau}$.

$$\int_{l_\xi} \vec{e}_\tau dl = -2 \cdot \pi \cdot \vec{e}_0 \cdot \cos\frac{\alpha_d}{2} \cdot \text{tg}\frac{\alpha_d}{2} \cdot \xi, \quad (5)$$

where:
$\vec{e}_0$ – unit vector collinear with *Ox*.

In the projection of the axis *Ox* friction force is:

$$T = -\int_x^{x+\Delta x} 2 \cdot \pi \cdot \text{tg}\frac{\alpha_d}{2} \cdot \xi \cdot \tau d\xi. \quad (6)$$

In determining the strength of the walls of the reaction we have:

$$\vec{N} = \iint_{S_{w.}} \vec{\sigma} dS, \quad (7)$$

where:
σ – normal stress on the wall of the diffuser.

In the projection on the *Ox* the same way as with the definition of the friction forces:

$$N = \int_x^{x+\Delta x} 2 \cdot \pi \cdot \text{tg}^2 \frac{\alpha_d}{2} \cdot \xi \cdot \sigma d\xi. \quad (8)$$

Determine the pressure forces acting on the cross-sectional area Sx and Sx + Δx, limiting portion Δx:

$$\begin{aligned} F &= p(x,t) \cdot S_x - p(x+\Delta x,t) \cdot S_{x+\Delta x} = \\ &= -S_{x+\Delta x} \cdot \left[p(x+\Delta x,t) - p(x,t) \right] \\ &\quad + p(x,t) \cdot \left(S_x - S_{x+\Delta x}\right), \end{aligned} \quad (9)$$

$$F = -\pi \cdot \text{tg}^2 \frac{\alpha_d}{2} \cdot$$

$$\left[(x+\Delta x)^2 \cdot \int_x^{x+\Delta x} \frac{\partial p}{\partial x} d\xi + p \cdot \left(2 \cdot x \cdot \Delta x + (\Delta x)^2\right) \right],$$

where:
p – pressure in the sections perpendicular to the axis Ox.

We make the assumption that there are no slippage phases, and phase velocities are equal. For the elementary part of the diffuser, made between sections Sx and Sx + Δx (Δx << 1, and replaced by Δx as dx), we write the conservation of momentum law. For this we use the formuls (3) - (9). Consider that for a continuous function:

$$\int_x^{x+\Delta x} f(\xi) d\xi = f(x) dx \quad (10)$$

(up to the members of the 2nd order). Neglecting terms of order of smallness than unity, we can write the change in momentum for the mass of the two-phase fluid from the section Sx and Sx + Δx, neglecting the mass exchange between the phases:

$$g\cdot\pi\cdot\mathrm{tg}^2\frac{\alpha_d}{2}\cdot x^2\cdot\rho_{mt}\cdot dx-2\cdot\pi\cdot\mathrm{tg}\frac{\alpha_d}{2}\cdot x\cdot\tau\cdot dx+ \\ +2\cdot\pi\cdot\mathrm{tg}^2\frac{\alpha_d}{2}\cdot x\cdot\sigma\cdot dx-\pi\cdot\mathrm{tg}^2\frac{\alpha_d}{2}\cdot\left(x^2\cdot\frac{\partial p}{\partial x}\cdot dx+2\cdot x\cdot p\cdot dx\right)= \\ =\left(m_{mt}+dm_{mt}\right)\cdot\left(v+dv\right)-m_{mt}\cdot v, \tag{11}$$

where

$m_{\text{mt.}}$ – mass flow rate of the two-phase fluid;

v - velocity of the two-phase fluid.

By Reley [10] due to the transience of the process flow through the surface of the bubbles is practically no weight.

To change use the following relations :

$$m_{\text{mt.}}=\pi\cdot\mathrm{tg}^2\frac{\alpha}{2}\cdot\left[-x^2\cdot\frac{\partial\left(\rho_{\text{mt.}}\right)}{\partial t}dt+\frac{\partial}{\partial x}\left(\rho_{\text{mt.}}\cdot v\cdot x^2\right)dx\right],$$

$$\frac{dv}{dx}=\frac{1}{v}\cdot\frac{\partial v}{\partial t}+\frac{\partial v}{\partial x} \tag{12}$$

$$dm_{\text{mt.}}=0\ \left(\text{the constancy of the total mass flow}\right),$$

Neglecting magnitudes 2 and third-order terms, equation (11) after the transformation we get:

$$g\cdot\rho_{\text{mt.}}+\frac{2\cdot\sigma}{x}-\frac{2\cdot\tau}{x\cdot\mathrm{tg}\frac{\alpha_d}{2}}--\frac{\partial p}{\partial x}-\frac{2\cdot p}{x}= \\ =\rho_{\text{mt.}}\cdot\left(\frac{\partial v}{\partial t}+v\frac{\partial v}{\partial x}\right)+v\left[-\frac{\partial\rho_{\text{mt.}}}{\partial t}+\frac{1}{x^2}\cdot\frac{\partial}{\partial x}\left(\rho_{\text{mt.}}\cdot x^2\cdot v\right)\right]. \tag{13}$$

To this equation add the continuity equation, which in this case takes the following form:

$$\pi\cdot\mathrm{tg}^2\frac{\alpha_d}{2}\cdot\left[x^2\cdot\frac{\partial\rho_{\text{mt.}}}{\partial t}+\frac{\partial}{\partial x}\ \left(x^2\cdot\rho_{\text{mt.}}\cdot v\right)\right]=0. \tag{14}$$

In the case of steady motion of (13) and (14) take the following form:

$$g\cdot\rho_{\text{mt.}}-\frac{2\cdot\tau}{x\cdot\mathrm{tg}\frac{\alpha_d}{2}}+\frac{2\cdot\sigma}{x}-\frac{dp}{dx}-\frac{2\cdot p}{x}= \\ \rho_{mt.}\cdot v\cdot\frac{dv}{dx}+v\cdot\frac{1}{x^2}\cdot\frac{d}{dx}\left(\rho_{\text{mt.}}\cdot x^2\cdot v\right); \tag{15}$$

$$\pi\cdot\mathrm{tg}^2\frac{\alpha_d}{2}\cdot\rho_{\text{mt.}}\cdot v\cdot x^2=\text{const}=m_{\text{mt.}}. \tag{16}$$

The result is a non-closed system of two equations with five unknowns (τ, σ, p, v, ρ_{mt}.), describing the motion of the gas-liquid mixture in the diffuser injector. Next, consider the case of a steady flow in the diffuser injector with small cone angles (α <15 °).

Since the diffuser is vertical and working pressure is much greater than the hydrostatic pressure in the diffuser section, we assume that the pressure from the same section of the diffuser [11]. As a result, the normal stress at the wall can be assumed equal to the pressure in the section. Then (15) takes the following form:

$$g\cdot\rho_{\text{mt.}}-\frac{2\cdot\tau}{x\cdot\mathrm{tg}\frac{\alpha_d}{2}}-\frac{dp}{dx}=\rho_{\text{mt.}}\cdot v\frac{dv}{dx}+v\cdot\frac{1}{x^2}\cdot\frac{d}{dx}\left(\rho_{\text{mt.}}\cdot x^2\cdot v\right), \tag{17}$$

or

$$g\cdot\rho_{\text{mt.}}-\frac{2\cdot\tau}{x\cdot\mathrm{tg}\frac{\alpha_d}{2}}-\frac{dp}{dx}=\rho_{\text{mt.}}\cdot v\frac{dv}{dx}+\frac{2\rho_{\text{mt.}}\cdot v^2}{x}. \tag{18}$$

The resulting equations of the time-averaged motion liquid mixture in the diffuser allow us to calculate the distribution of the mean pressure in the diffuser along its length, and to determine the pressure at the boundary at the end of the diffuser [12].

Equations of motion of two-phase fluid

We integrate (18):

$$g\cdot\rho_{mt.}\int_{x1}^{x2}dx-\frac{2\tau}{tg\frac{\alpha_d}{2}}\int_{x1}^{x2}\frac{dx}{x}-\int_{p1}^{p2}dp=\rho_{mt.}\int_{v1}^{v2}v\cdot dv. \tag{19}$$

After integration and transformation we obtain an expression that defines the pressure loss in the diffuser injector:

$$\Delta p=\left(\frac{2\cdot\tau}{tg\frac{\alpha_d}{2}}\right)\ln\frac{x_2}{x_1}-\frac{\rho_{mt.}}{2}\left(v_1^2-v_2^2\right)-g\cdot\rho_{mt.}\cdot l, \tag{20}$$

where:

l – the initial length of the diffuser sections before the cylindrical part.

Let’s analyze the equation (20). The last member of this equation is the change in pressure caused by the weight of the two-phase fluid in the volume of the diffuser on the current site of its length. Because the weight is much less than the two-phase fluid pressure forces, its value is negligible. The density of two-phase fluid $\rho_{\text{mt.}}$ is the density of the fluid flow in the initial section of the diffuser in the compressed section with a diameter d_0 and can be taken as the density of extinguishing agent without gas saturation, so $\rho_{\text{mt.}} = \rho$. Speed in the initial section v_1 can be taken as the flow rate without gas saturation in the narrow section at the output of the confuser and determine its through volume flow the working environment.

$$v_1 = v_0 = \frac{4Q}{\pi \cdot d_0^2}, \tag{21}$$

where:

Q – volume flow of extinguishing agent;

d_0 – sectional diameter of the compressed.

Relation x_2 / x_1 can be written as D / d_0, where D – the diameter of the outlet section of the diffuser.

In view of the assumptions, equation (20) becomes:

$$\Delta p = 2\frac{\tau}{tg\frac{\alpha_d}{2}}\ln\frac{D}{d_0} - \frac{\rho_{mt.}}{2}\left(v_0^2 - v^2\right). \tag{22}$$

Perform some transformation equation (22). Flow velocity from the equation (16) can be written as:

$$v = \frac{m_{\text{mt.}}}{\pi \text{tg}^2\frac{\alpha_d}{2}\cdot\rho_{\text{mt.}}\cdot x^2}, \tag{23}$$

Coordinate the design section X with the origin at the point of convergence of the cone can be written as:

$$x = l + \frac{d_0}{2\text{tg}\frac{\alpha_d}{2}}. \tag{24}$$

Since the mass of the liquid phase is much greater than that of air phase, we make the assumption that:

$$m_{\text{mt.}} \approx m \tag{25}$$

and

$$m_{\text{mt.}} \approx \rho \cdot Q \tag{26}$$

then (23) becomes:

$$v = \frac{\rho \cdot Q}{\pi \text{tg}^2\frac{\alpha_d}{2}\rho_{\text{mt.}}\left(l + \frac{d_0}{2\cdot tg\frac{\alpha_d}{2}}\right)^2}. \tag{27}$$

Having said this, the expression (21) the last term of (22) can be written as:

$$\frac{\rho_{mt.}}{2}\left(v_0^2 - v^2\right) = \frac{8\times Q^2\times\rho_{mt.}}{\pi^2}\left[\frac{1}{d_0^4} - \frac{\rho^2}{\rho_{mt.}^2\left(2\times l\times tg\frac{\alpha_d}{2} + d_0\right)^4}\right]. \tag{28}$$

After these assumptions, changes and substitutions have the following equation:

$$\Delta p = 2\frac{\tau}{tg\frac{\alpha_d}{2}}\ln\frac{D}{d_0} - \frac{8\rho_{mt.}\cdot Q^2}{\pi^2}\left[\frac{1}{d_0^4} - \frac{\rho^2}{\rho^2_{mt.}\left(2\cdot l\cdot tg\frac{\alpha_d}{2} + d_0\right)^4}\right]. \tag{29}$$

When driving two-phase flow in the diffuser injector density liquid mixture is not constant and is a function of pressure,

$$\rho_{mt.} = \rho_{mt.}\left(p\right). \tag{30}$$

The density of the gas-liquid two-phase flow as follows. At atmospheric pressure, the density of the foam can be written as:

$$\rho_{\text{mt.}} = \frac{\rho_{\text{air.}}\cdot\left(n-1\right)+\rho}{n}, \tag{31}$$

where:

$\rho_{\text{air.}}$ – density of air;

n – given the multiplicity of foam.

Due to the compressibility of air Foam in the diffuser will depend on the pressure. In general, the multiplicity can be written as:

$$n = \frac{V_{\text{air.}} + V}{V} = 1 + \frac{V_{\text{air.}}}{V}, \tag{32}$$

where:

$V_{\text{air.}}$ – the volume of air;

V – volume of foam solution.

The volume of air traffic at the two-phase flow in the diffuser can be represented as:

$$V_{air.} = \frac{V_{air.}^{atm}\times p_{atm}}{p_{abc}} = \frac{V_{air.}^{atm}\times p_{atm}}{\left(p + p_{atm}\right)}, \tag{33}$$

where:

$V_{air.}^{atm.}$ – the volume of air in the foam at atmospheric pressure;

p_{atm} – atmospheric pressure;

p_{abc} – absolute pressure;

p – pressure (gauge) in the design section of the diffuser.

Then the multiplicity of foam at a pressure in the design section will:

$$n_p = 1 + \frac{V_{air.} \times p_{at}}{V\left(p + p_{at}\right)}, \qquad (34)$$

or

$$n_p = 1 + \left(n - 1\right)\frac{p_{at}}{\left(p + p_{at}\right)}. \qquad (35)$$

In view of (35) the density of the two-phase flow in the design section will:

$$\rho_{mt.} = \rho_{air.}\left(1 - \frac{1}{1 + \left(n - 1\right)\dfrac{p_{at}}{\left(p + p_{at}\right)}}\right) + \frac{\rho\left(p + p_{at}\right)}{p + n \times p_{at}}. \qquad (36)$$

Since the density of the air (in the range of design pressures 0.05-1.0 MPa) is much smaller than that of the working fluid, the first term of (36) can be neglected, then the expression for the density of two-phase flow, depending on the pressure becomes:

$$\rho_{mt.} = \frac{\rho\left(p + p_{at}\right)}{p + n \times p_{at}}. \qquad (37)$$

Thus, in equation (29), which solves the problem of calculating the basic injector, determination of pressure losses during the motion of two-phase flow in the diffuser remains uncertain shear stress on the wall of the cone τ. The shear stress at the wall is defined as [11]:

$$\tau = \rho_{\text{mt.}} \cdot v_*, \qquad (38)$$

where:

v_* – friction velocity (or rate of shear stress on the wall) [11].

We use a semi-empirical Prandtl's theory of turbulent flow, which has the greatest fame. By this theory, the shear stress over the entire cross section of the flow is the same and is equal to the voltage at the wall (to be considered for a tube of circular cross-section). However, the non-uniform fluid flow (flow in the diffuser) shear stress at the wall of the diffuser and the cross section will be different from the stress in uniform motion. We make the assumption that because the resistance force is proportional to the square of diagrams of shear stresses on the channel walls at uniform and non-uniform motion, these areas are in accordance with Figure 2, and the shear stresses are proportional to the radius of the channel.

Then we can write the following equation:

$$2\pi \cdot \tau' \cdot \tau' = \pi\left(\tau \cdot \sin\frac{\alpha_d}{2} + \tau' + \tau'\right)\tau, \qquad (39)$$

where: τ' – shear stress in uniform motion.

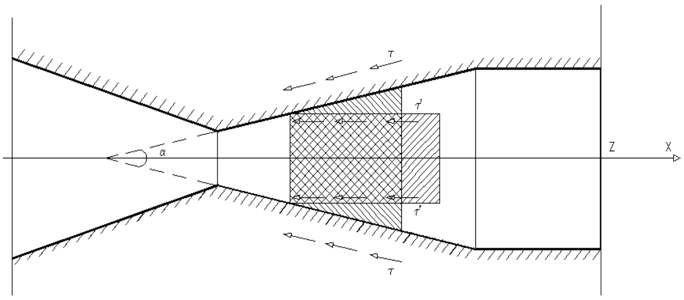

Fig. 2. Scheme of the transformation of shear stresses in nonuniform motion.

Solving the equation (39) with respect to τ, the shear stress at the wall of the diffuser can be written as:

$$\tau = \frac{\sqrt{1 + 2\sin\dfrac{\alpha_d}{2}} - 1}{\sin\dfrac{\alpha_d}{2}} \cdot \tau', \qquad (40)$$

or

$$\tau = k \cdot \tau', \qquad (41)$$

where:

k – coefficient taking into account non-uniform motion and depending on the cone angle diffuser:

$$k = \frac{\sqrt{1 + 2\sin\dfrac{\alpha_d}{2}} - 1}{\sin\dfrac{\alpha_d}{2}}. \qquad (42)$$

Formula (42) can be reduced by the method of least squares:

$$k = 0{,}996^{\alpha}, \qquad (43)$$

which is easy to calculate.

The shear stress at the wall in uniform motion can be written as [11]:

$$\tau' = \rho_{mt} v_*^2, \qquad (44)$$

To determine the dynamic speed we use derived from studies I. Nikuradze [11]:

$$v = v_*\left(5.75\lg\frac{a}{\Delta} + 8.5\right), \qquad (45)$$

whence

$$v_* = \frac{v}{\left(5.75\lg\dfrac{a}{\Delta} + 8.5\right)}, \qquad (46)$$

where:
Δ – equivalent roughness;
a – distance from the wall of the channel to the layer moves with an average speed v [11].

To determine the value and use "one seventh" the Karman's law [11]:

$$\frac{v}{v_{\max.}} = \left(\frac{a}{r}\right)^{1/7}, \qquad (47)$$

where:
$v_{\max.}$ – maximum velocity in the channel.
When turbulent $v / v_{\max.} = 0{,}75\text{-}0{,}9$ [11].

III. Extended Summary

As a result, we have the basic equations of motion of two-phase flow, characterized by uneven movement of the gas-liquid mixture in the diffuser injector, which allow us to calculate the distribution of the mean pressure in the diffuser length, and to determine the pressure loss in the diffuser, which gives the opportunity to design the output section of the hydraulic system with hydrodynamic resistance that offers an injector in a given mode. Solving the inverse problem and setting the pressure drop in the injector can determine the required flow of extinguishing agent (foaming agent) for automatic fire extinguishing systems.

References

[1] L. M. Meshman, *Design of water and foam automatic fire suppression systems.* Moskow. VNIIPO, 2002.

[2] V. V. Pivovarov, *Means fire automation. Range of applications. Type selection. Recommendations*. Moskow. VNIIPO, 2004.

[3] F. I. Sharovar, *Methods for early detection of a fire*. Moscow: Stroyizdat, 1988.

[4] Technical code of practice 45-2.02-190-2010 *Fire automatic systems of buildings.* Minsk: Stroitehnorm, 2011.

[5] STB 11.16.06-2011/GOST R 51043-2002 System of fire safety standards. Automatic water and foam fire fighting systems. *Sprinklers, spray nozzles and water mist nozzles.* General technical requirements. Test methods. Minsk: Gosstandart., 2011.

[6] I. F. Bezrodny, A .N. Giletich, V. A. Merkulov, V. P. Molchanov, and A. N. Shvyrkov, *Firefighting oil.* Moscow: VNIIPO, 1996, pp. 53 - 65.

[7] A. N. Baratov *Fire and explosion hazard of substances and materials, extinguishing agents*: Reference in 2 books. Moscow: Chemistry, 2007.

[8] S. S. Kutateladze and M. Styrikovich, *Hydrodynamics of gas-liquid systems.* Moscow: Energiya, 1976.

[9] I. V. Karpenchuk, I. Y. Ayshev, S. G. Petyhovskyi and V. V. Parmon, "The equations of motion of cavitation two-phase flow in the diffuser foam mixer PS-5" in *Emergency situations: prevention and elimination*, vol.7, no. 17, Minsk: The Research Institute of Fire Safety and Emergencies, 2005, pp. 154-160.

[10] O. M. Rayleigh, "On the pressure developed in the collapse of a spherical cavity" in *Philosophical Magazine*, vol.34, no. 200, UK: Taylor & Francis Group, 1917, pp. 94-98.

[11] E. Z. Rabinovich, *Hydraulics*. Moscow: Nedra, 1980.

[12] S. Y. Pauliukou, S. P. Eroma and V. V. Parmon, "Equations of motion of two-phase flow in the diffuser-injector aerator gas saturation in the extinguishing agent," in *VI International Scientific-practical conference*, 2012, pp. 224-226.

Ihar Kachanau. Doctor of (engineering) Sciences. Professor in the specialty "Mechanics". The scientific degree "Candidate of technics" awarded in 1982, the Doctor of engineering Sciences" – in 2003. Engaged in research activities since 1975. His main research interests lie in the following areas: the creation of a bimetallic tool methods of dynamic punching, separation pulp dredgers working, cleaning of steel products from corrosion high-pressure jets using bentonite slurry, a jet stream with pre-aeration screw and structuring.
He is currently the head of the department "Shipbuilding and Hydraulics" Belarusian National Technical University. He has initiated the establishment of the specialty of "Shipbuilding and technical operation of water transport" in the Republic of Belarus. He has been a scientific advisor of two science degrees, candidates, currently he supervises the work of four graduate students. He is the author of 197 scientific papers, including three monographs, 45 inventions. For examples: Kachanau I.V. Experimental stand for blasting metal surfaces / I.V. Kachanau, V.K. Nedbalsky, A.V. Filipchik // Agropanorama. – 2005. – №1. – P. 22-23; Kachanau I.V. Theoretical and experimental research by definition jet pressure of the working fluid on the flat surface of the treated / I.V. Kachanau, A.V. Filipchik // Science and technology. – 2012. – №1. – P. 79-85.
He is the Chairman of the Board of D 020,503 of the National Technical University. The head of the interim research team to implement the two-state research programs. E-mail: hidrokaf@bntu.by, phone: +375-17-292-76-77, +375-29-387-39-59

Ihar Karpenchuk. Candidate of (engineering) Sciences. Associate professor in the specialty "Mechanics". The scientific degree "Candidate of technics Sciences" awarded in 1987. Engaged in research activities in 1979. His main research interests lie in the following areas: study of the fluid mechanics and the optimization of the hydrodynamic parameters of the equipment, fire-fighting, forecasting emergencies in water bodies.
He is currently a professor of the department "Automatic Security Systems", the Institute for Command-Engineers of the Ministry of Emergencies of Belarus. He has worked out the thesis "Hydro methods to improve welfare, facilities and areas in emergency situations" to be awarded the degree of "Doctor of Science". He is the author of over 200 scientific papers, 30 patents and certificates. He was the scientific advisor of three science degree candidates. For examples: Karpenchuk I.V. Methodology and software for the calculation and visualization on a map on the flood zones in the breakout waterworks// Emergency Situations: Prevention and Elimination. – 2012. – P. 59-65; Karpenchuk I.V. A mathematical model of the motion-foaming solution, obeys a power law rheological// Vestnik KII. – 2011 – № 2(14). – P. 49 – 54.
He is a member of the Interdepartmental Commission on State Water Policy at the Council of Ministers. The head of the interim research team to implement the two tasks of the State scientific and technical program and the three tasks of the State program of research. E-mail: asb@kii.gov.by, phone: +375-29-356-46-12.

Siarhei Pauliukou. He is a postgraduate student of the Institute for Command-Engineers of the Ministry of Emergencies of Belarus. Currently he is working on his research dissertation to obtain the scientific degree "Candidate of (engineering) Sciences" for the paper "Improving the efficiency of fire-extinguishing foam systems by aeration of the working environment.
He is currently the head of the department "Automatic Security Systems" Institute for Command-Engineers of the Ministry of Emergencies of Belarus. He is the author of four papers. For example: S.Y. Pauliukou, S.P. Eroma and V.V. Parmon, "Equations of motion of two-phase flow in the diffuser-injector aerator gas saturation in the extinguishing agent," in *VI International Scientific-practical conference*, 2012, pp. 224-226.
He is a member of the scientific staff temporarily to implementation two tasks of the State scientific and technical program and the three tasks of the State program of research. E-mail: Pavlukov79@mail.ru, phone: +375-29-697-98-99.