INVESTIGATION OF THE CHARACTERISTICS OF THE INTERNAL FIREFIGHTING WATER PIPELINE ELEMENTS

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Abstract: An important task in the design of buildings for different purposes is ensuring the safety of people's livelihoods. To protect them from the negative factors of fire, various devices are used to localize and stop burning. One of the elements of the fire protection of the building is the internal firefighting water supply. For the supply of water to extinguish a fire, it is provided for the installation of firefighting hydrants sets with a diameter of 25 and 33 mm. To date, there is no clear procedure for selecting fire hydrant equipment of small diameter for different types of buildings. To formulate the requirements for them, the influence of various factors on the actual flow of water is investigated. According to the results of the experiment, empirical dependences of water consumption for semi-rigid hoses are obtained. Analysis of the simulation results shows that the actual flow of water from a fire hydrant largely depends on the pressure in the network and the diameter of the hose.
A comparison of actual water consumption with regulatory data is done. The inexpediency of the use of equipment, whose characteristics do not provide the necessary indicators, is shown. A 3-step procedure for selecting the characteristics of a fire hydrant is proposed, including determining the flow rate of water from a fire hydrant for semi-rigid hoses of different lengths, degree of deployment and arbitrary pressure values in the water supply network. The result is compared with the standard value. The proposed procedure allows to reasonably choose the equipment that can ensure the successful extinguishing of the fire. Its practical value is reducing the flow of water to extinguish a fire and reduce material losses.
Keywords: fire hydrant, pressure, water consumption, hose, sprayer, internal firefighting water supply.

1. Introduction

When designing buildings and structures, specialists have to solve tasks to ensure the safety of people's livelihoods [1]. The most important of these is the need to protect the building and people in it from the negative effects of a fire [2]. For this purpose, a variety of means, devices, facilities are used to identify, localize and stop burning [3, 4].

One of the elements of the fire protection of the building is the internal firefighting water supply (IFWS) [5]. To increase the effectiveness of fire extinguishing, installation of additional fire hydrants (FH) sets with diameters of 25 and 33 mm is provided in buildings regardless of their purpose. The equipment is intended for self-localization of fire by a tenant or employee before the arrival of fire departments. In this case, a significant reduction in the localization time of ignition, a decrease in material and human losses is assumed.

The FH advantages include simplicity of design, maintainability. It is connected to the internal water supply, which must provide the necessary pressure and water flow. The effectiveness of the FH use depends on how reasonably selected component parts. The issues of IFWS improving are investigated by the scientists from different countries. The conditions under which the water supply system is able to provide the necessary pressure and water flow for the needs of fire extinguishing are considered in [6]. Particular attention is paid to the adequacy of the calculation of the water supply system [7]. In [8], the requirements for fire-fighting equipment systems are analyzed, the conclusion is made that it is necessary to make adjustments to the regulatory documents taking into account the features of modern construction. Part of the work is devoted to the study of the arrangement of IFWS systems in high-rise buildings, the study of the FH characteristics and their influence on the performance of the system [9, 10]. At the same time, there are still unresolved issues regarding the selection of small diameter FH equipment for different types of buildings.

To ensure reliable fire protection and eliminate fire with minimal losses, it is necessary to clearly formulate the requirements for FH equipment, taking into account the IFWS specific features of a particular building. The aim of research is investigation of the FH characteristics, to develop a procedure for their selection under specific operating conditions. To achieve this aim it is necessary to solve the following tasks:

– investigate the influence of various factors on the actual amount of water that can be obtained from the IFWS to extinguish a fire;

– determine the sufficiency of the actual amount of water from the FH for extinguishing fires;

– suggest a procedure for selecting the FH characteristics depending on the operating conditions.

Solving these tasks will provide an opportunity to increase the fire protection of buildings and eliminate fire with minimal losses.

2. Methods

An experimental study of the actual flow rate of water from the FH for various combinations of its composition is carried out using statistical methods, mathematical modeling and methods of experimental design theory. In preparation for the experiment, a second-order polynomial dependence is used, the central, compositional, rotatable uniform plan, the standard plan-matrix. The information obtained using the plan-matrix of the full factorial experiment is not enough to determine the coefficients for the quadratic terms of the regression equation. To do this, use the star points. In a two-level experiment for four factors, the star-shaped arm is accepted.

In drawing up the experiment plan matrix, it is taken into account (**Table 1**): the amount of water that can actually be obtained from the FH depends on the pressure and flow of water in the water supply network, characteristics of FH equipment (the length and type of hose, the diameter of the atomizer nozzle).

Table 1
Levels of variation of factors

Variation interval and level of factors	Network pressure, MPa	Hose deployment, %	Diameter of nozzle, mm	Hose length, m
Zero level x_i=0	4	60	8	20
Variation interval	1	20	2	4
Lower level x_i=−1	1	20,4	4	10
Upper level x_i=+1	8	99,6	12	30
Star points: x_i=−1.41421	6,82	32	5,1	7
x_i=+1.41421	1,17	88	10,8	27
Code designation	X_1	X_2	X_3	X_4

According to the requirements of regulatory documents, FH is completed with a semi-rigid hose with a length of 10–30 m. The atomizer is equipped with a device for smooth variation of the diameter of the outlet opening in the range of 4–12 mm. These elements have different resistance. It affects the pressure loss, and, therefore, the actual water flow, which can be obtained from the water supply.

The purpose of the experiment is finding out how the characteristics of the water supply network and the FH equipment affect the water consumption, which can be obtained from the FH for extinguishing a fire.

3. Results

As a result of experimental studies, an empirical dependence of the water flow on the pressure in the water supply system, the length and degree of deployment of the hose, and the diameter of the nozzle of the atomizer was established. The check for the significance of the coefficients was performed by statistical estimates of the variance and comparison with the critical value of the Student criterion. Verification of the model adequacy is carried out by the Fisher criterion. Processing of the measurement results allowed to write the regression equation to determine the flow of water from the FH in the following form:

– for semi-rigid hoses with a diameter of 25 mm:

$$\begin{aligned} y_{25} &= 1{,}6216 + 0{,}5343x_1 + 0{,}0706x_2 + \\ &+0{,}61x_3 - 0{,}0335x_4 + 0{,}199x_1^2 - \\ &-0{,}0885x_2^2 - 0{,}1385x_3^2 - 0{,}0735x_4^2 + \\ &+0{,}1437x_1x_3 + 0{,}0187x_2x_3 - 0{,}0063x_3x_4; \end{aligned} \quad (1)$$

– for semi-rigid hoses with a diameter of 33 mm:

$$\begin{aligned} y_{33} &= 3{,}678 + 0{,}8233x_1 + 0{,}0716x_2 - \\ &-0{,}4526x_3 - 0{,}0716x_4 - 0{,}1862x_1^2 - 0{,}2737x_2^2 - \\ &-0{,}3862x_3^2 - 0{,}2988x_4^2 - 0{,}0156x_1x_2 + \\ &+0{,}0781x_1x_3 + 0{,}0031x_1x_4 + 0{,}0219x_2x_3 - \\ &-0{,}0156x_2x_4 + 0{,}0156x_3x_4, \end{aligned} \quad (2)$$

where y_{25} and y_{33} – the actual flow of water from the FH, l/s; X_1 – pressure in the water supply system, MPa; X_2 – degree of hose deployment,%; X_3 – nozzle diameter, mm; X_4 – hose length, m. The results of numerical solution of models (1) and (2) are shown in **Fig. 1.**

Analysis of the obtained data (**Fig. 1, *a***) shows that the actual flow rates of water from the FH are more dependent on the pressure in the network and vary over a wide range. Thus, at the minimum pressure, the flow rate is in the range of $0{,}13 \div 0{,}15$ l/s, at the maximum $1{,}04 \div 2{,}1$ l/s. This result is obtained under the most unfavorable conditions for the FH use: the minimum degree of hose deployment, the smallest diameter of the nozzle, the maximum hose length. Also, the calculation is carried out for the most favorable conditions for the FH use (**Fig. 1, *b***): the maximum degree of hose deployment, the largest nozzle diameter, the minimum hose length. It is obtained that at the minimum pressure the flow rate takes a value in the range of $0{,}33 \div 1{,}43$ l/s, at the maximum $0{,}79 \div 3{,}9$ l/s.

Regulatory documents established that water consumption for effective fire extinguishing should be greater than 0.5 l/s. Compliance with this condition will ensure the abstraction of the amount of heat that is released during a fire. Therefore, it can be concluded that the FH use with the characteristics of equipment that does not provide sufficient water consumption is inappropriate.

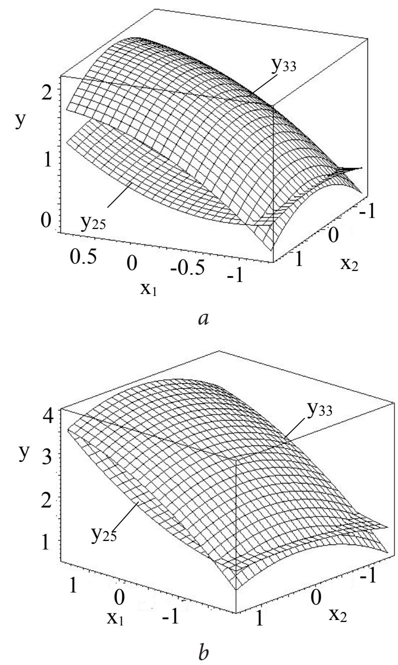

Fig. 1. The dependence of the actual water rate y on the network pressure X_1 at the degree of hose deployment X_2: *a* – diameter X_3 of the nozzle at the minimum level, hose length X_4 – at the maximum level; *b* – diameter X_3 of the nozzle at the maximum level, hose length X_4 – at the minimum level

Based on the research results, the procedure for selecting the FH characteristics is proposed. First, determine the necessary water flow for successfully extinguishing the fire, depending on the characteristics of the fire load (lower calorific value and reduced mass burnout rate). It takes into account the time of free development of fire and the time of extinguishing the fire. At the second stage, using the models (1), (2) determine the flow of water from the FH depending on the pressure in the water supply network, the FH characteristics (hoses (type, diameter, length, degree of deployment) and the sprayer diameter). At the third stage, the necessary and actual water consumption is compared. Based on the obtained result, they formulate a conclusion on the effective version of the FH equipment and give recommendations on the conditions of its use.

4. Discussion of results

It is experimentally determined that the flow rates of water from a FH equipped with a semi-rigid hose vary within $0{,}13 \div 3{,}9$ l/s. The pressure on the network to which the FH is connected has the greatest influence on the cost. To create optimal conditions for effective fire extinguishing, FH equipment (hose, nozzles) should provide the least resistance. They correspond to the maximum diameter of the hose and the nozzle of the sprayer, the minimum hose length. In this case, sufficient supply of water can be provided for different variants of room planning, regardless of the location of the IFWS pipeline and the FH located on it.

A procedure for selecting the FH characteristics is proposed. Its advantage is the ability to evaluate the various FH characteristics and their ability to provide the required flow rate under adverse conditions. In the future, it is planned to continue research by expanding the range of the investigated equipment. The practical value of the proposed method lies in the reasonable choice of equipment for extinguishing a fire at various facilities. This increases the fire protection of buildings, reduces water consumption for extinguishing a fire, and reduces material losses.

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