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STUDYING FIRE EXTINGUISHERS WITH THE COMBINED SUPPLY OF THE FOAM-WATER EXTINGUISHING AGENTS IN AN AEROSOL STATE

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SUMMARY: This research paper delves into the studies of the fire extinguishers with the combined supply of the foam-water extinguishing agents in an aerosol state used for the extinguishing simulated fires of "A" and "B" classes. The research was done using a mobile module with a 150-liter water tank and a pumping station equipped with a gasoline engine, and a finely atomized foam-water solution (water + foam concentrate) was used as a fire extinguishing agent, while the concentration of foam concentrate in the fire extinguishing agent was 3%, and that of water 97%. Experimental studies were conducted in three series, and each series of studies included three experiments. Thus, during the studies of the 1st series, the simulated fires of an "A" class were extinguished, and the 2nd and 3rd series of studies dealt with the extinguishing of simulated fires of a "B" class. The research data provided the values of the duration of supply of the fire extinguishing agents and their consumption. Using the method of least squares, the root means square values of the duration of supply of the fire extinguishing agent and the consumption of it when supplied by technical fire extinguishing means were obtained according to the research series and the number of the experiment. It has been established that the duration of supply of the fire extinguishing agents by technical fire extinguishing means depends on such factors as the type of fire extinguishing agent, the percentage and type of impurities in its composition, the tactical and technical characteristics of the fire extinguishing agent, the professional skills of the operator and methodical support.

Key words: *fire, fire-fighting, technical fire extinguishing means, simulated fires and the fire class*

INTRODUCTION

In today's conditions, ensuring fire safety is one of the factors that exerts certain influence on the quality and safety of life, production or business. Unfortunately, the occurrence of fires leads to the death of people, the destruction of material assets and has a direct negative impact on the environment. On the one hand, certain measures are taken to prevent the occurrence of fires, such as the treatment of building structures and materials with fire-retardant compositions *(Sadkovyi et al., 2021, Chernukha et al., 2020)*. In addition, the fire hazard indicators of solid combustible materials and substances during their combustion are studied *(Dubinin et al., 2022, 2023, Abramov et al., 2018)*. Research is done to predict the impact of dangerous fire factors on people *(Dubinin et al., 2020, 2022)*, environment *(Kustov et al., 2019, Vambol et al., 2017, Sadkovyi et al., 2020,*

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Pospelov et al., 2019, 2020) and water resources *(Rybalova et al., 2018, Vambol et al., 2017)*. On the other hand, research is done to localize and liquide fires *(Pospelov et al., 2021, Charter of actions...)* using fire extinguishing means and methods *(Handbook..., Korytchenko et al., 2018, Dubinin et al., 2018)*. Despite numerous fire prevention measures, fires can occur anywhere. It is extremely important to stop a fire at its earliest stage and, what is most important, in a safe manner with minimum grave consequences. However, it requires such equipment that uses a minimum amount of fire-extinguishing agent safe for people and the environment, and safe and easy-to-use even for an untrained person *(Grant et al., 2000)*. One of these fire extinguishing means is the equipment of the Danish "Fireexpress» Company, the official representative of which is the "Firesecurity LLC" Company in Ukraine *(Firesecurity LLC, Firexpress A/S)*. This equipment can be used in many areas ranging from private houses to vehicles to provide quick response to fires *(Firesecurity LLC, Firexpress A/S)*. Previous studies of similar fire extinguishing agents have shown their in-use effectiveness *(Korytchenko et al., 2018, 2019, 2020, 2021, 2023, Kasimov et al., 2018)*.

The "Firexpress" company *(Firesecurity LLC, Firexpress A/S)* has converted the standard water spraying system, which has traditionally been used for many years to extinguish fires, into a modern and highly efficient one. A high efficiency and mobility of the Fireexpress equipment is based on the method of fine spraying of a foam-water solution, which makes it possible to significantly reduce water consumption and, as a result, make fire extinguishing equipment lighter and more mobile *(Firesecurity LLC, Firexpress A/S)*. The use of finely sprayed water solution and environmentally safe foam concentrate significantly reduces the negative consequences of firefighting.

The developed equipment allows us to fight the fire in a short period of time, and at the same time to use water as efficiently as possible to reduce the demand for it and the consumption of it. After several years of research and numerous tests, the duel nozzle was invented and patented for the foam-water "Firexpress" solution sprayer *(Firesecurity LLC, Firexpress A/S)*.

The duel nozzle Fireexpress sprayer enables the use of the two different methods of extinguishing fires. One method consists in spraying a finely atomized foam-water solution into the center of the fire to absorb heat, and the second method consists in supplying a concentrated jet to extinguish the fires of fibrous materials or prevent the access of air to burning liquids by sealing. By adjusting the selector lever, the user can quickly switch between the fine spraying and concentrated jet modes *(Firesecurity LLC, Firexpress A/S)*.

The "Firexpress" equipment can be subdivided into two groups, depending on the way of water supply to the sprayer. For the first group of equipment, the water pressure is created by a membrane pump. For the second group, the water pressure is created by compressed air supplied from a cylinder *(Firesecurity LLC, Firexpress A/S)*. In order to increase the fire extinguishing effectiveness, foam concentrate is added to the extinguishing agent in the amount of 1 to 3%. Foam concentrate used for "Firexpress" equipment is a high-quality water film-forming foam concentrate Fomtec AFFF 3% manufactured by the Swedish company "Dafo Fomtec AB", which is suitable for extinguishing fires of various classes *(Firesecurity LLC, Firexpress A/S)*. The foam concentrate consists of fluorocarbon and hydrocarbon surfactants mixed with various solvents, preservatives and stabilizers. The Fomtec AFFF 3% foam concentrate was developed using the components specially selected to provide appropriate protective capacity and environmental friendliness. At the same time, it does not contain PFOS or PFOA synthetic chemicals that are widely used by various industries and are considered as compounds that pollute the environment and are dangerous for humans *(Firesecurity LLC, Firexpress A/S)*. Accordingly, the foam concentrate is safe for the environment. A number of experimental studies have been conducted on the effectiveness of the use of the technical means of extinguishing fires with finely sprayed water. For example, in *(Jenft et al., 2014)* research was done to study the extinguishing of fuel oil in an experimental container. According to the results of the study, the effectiveness of the use of fire-extinguishing agents in an aerosol state was established when extinguishing class "B" fires, both during the development of a fire at the initial stage, and during a developed fire with a maximum burning temperature.

In paper *(Santangelo et al., 2014)*, experimental study was carried out for the insight in the use of a system of application of fire-extinguishing agents in an aerosol state to restrain the development of a fire during the burning of wood. According to the results of the study, the effectiveness of the use of fire-extinguishing agents in an aerosol state was established when extinguishing class "A" fires, depending on the dispersion of water droplets and the intensity of the supply of fire-extinguishing agents in an aerosol state. And in *(Tanaka, Kato, 2023)*, experimental studies were carried out on the use of fire extinguishing agents in an aerosol state when extinguishing burning propane escaping from a container. According to the results of the study, the effectiveness of the use of fire extinguishing agents in an aerosol state was established when extinguishing class "C" fires, and the determining parameter in this case is the volume flow rate of fire extinguishing agents in an aerosol state. In paper *(Mahmud et al., 2016)*, the authors conducted experimental and numerical studies of spray systems for the use of fire-extinguishing agents in highly pressurized aerosol state for indoor fire extinguishing purporses. According to the research data, it was established that one of the main parameters important for the characteristics of the spraying of fire-extinguishing agents in an aerosol state is the distribution of the density of the flow of water droplets falling on the floor. Taking into account this fact, the studies of the characteristics of fire extinguishing agents in the aerosol state were carried out from the standpoint of the distribution of the density of the flow of water droplets created by one or several sprinklers. Accordingly, the effectiveness of the use of fire extinguishing agents in an aerosol state for extinguishing fires should be determined depending on the density of the flow of water droplets.

And in paper *(Wang et al., 2018)* an experimental study was carried out on fighting smoke during a fire using a water curtain of fire-extinguishing agents in an aerosol state. The obtained results indicate that the water curtain is effective in preventing the spread of smoke at an early stage fire. In addition, the authors investigated the effect of sprayers with different spray characteristics and proposed an optimal working pressure when using a system of fire extinguishing agents in an aerosol state. The use of technical means of extinguishing fires with the supply of fire-extinguishing agents in an aerosol state is a promising approach to extinguishing fires of various classes.

The purpose of this research is to carry out experimental investigations to determine the effectiveness of use of fire extinguishers with a combined supply of foam-water "Firexpress" fire extinguishing agents in an aerosol state (hereinafter referred to as technical fire extinguishing means) when extinguishing simulated fires of "A" and "B" classes.

MATERIALS AND METHODS

In this paper, the field of application of technical "Fireexpress" fire-extinguishing means used for the extinguishing simulated fires of "A" and "B" classes is determined on the basis of experimental studies. To carry out experimental studies, technical "Firexpress" fire-extinguishing means *(Firesecurity LLC, Firexpress A/S)*, special clothing and equipment, and simulated fire flames (stack of wooden blocks of pine in the shape of a cube, and rectangular and circle-shaped decos), a stopwatch, a measuring tape, water, flammable liquid (gasoline A-92) *(DSTU 7687:2015 Benzyny avtomobilni Yevro. Tekhnichni umovy)*, etc were used.

Empirical and theoretical research methods were used for the observation, comparison, measurement and analysis of the obtained research data.

The method of least squares was used for processing the duration of the supply of the fire extinguishing agent and the consumption of the extinguishing agent required for extinguishing simulated fires of "A" and "B" classes, depending on the research series and the number of the experiment. The method of selection and substantiation of scientific recommendations was used to define the field of application on the basis of the experimental studies that were carried out.

General research methods were used for the analysis of the duration of the supply of fire extinguishing agent and the consumption of fire extinguishing agent when extinguishing simulated fires, and the obtained calculation data are presented in

the form of Tables and diagrams. Methods of substantiation of scientific conclusions were used for the generalization and substantiation of the obtained data of experimental studies.

RESULTS AND DISCUSSION

The purpose of the research done is to carry out experimental studies of the fire extinguishers with the combined supply of foam-water extinguishing agents in an aerosol state.

Experimental studies of the use of the technical fire extinguishing means were carried out at the training ground by scientific and pedagogical staff of the Department for Fire Tactics and Emergency Rescue, Faculty of Operational Rescue Forces of the National University of Civil Protection of Ukraine, in cooperation with the employees of the"Firesecurity LLC" company *(Firesecurity LLC)*, the distributor of the equipment of the Danish "Firexpress" company *(Firexpress A/S)* within the framework of the research done to shed light on the topic of "Investigating fire extinguishing means with the combined supply of foam-water extinguishing agents in an aerosol state".

A mobile module with a 150-liter water tank and a pumping station equipped with a gasoline engine and a flow rate of 30 l/min was used during the research (Fig. 1); (*Firesecurity LLC, Firexpress A/S)*.

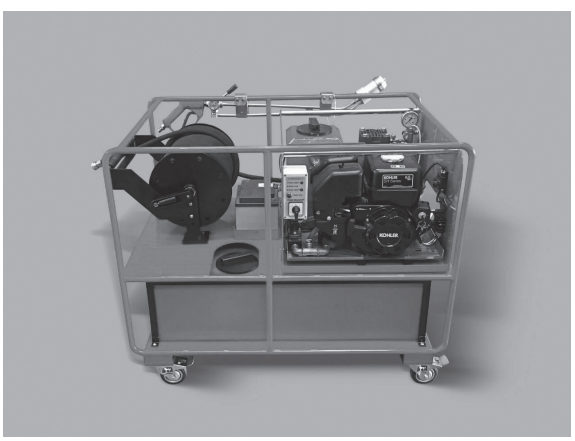

Figure 1. Mobile module with a 150-liter water tank and a pumping station with a gasoline engine

Slika 1. Mobilni modul sa spremnikom za vodu od 150 litara i crpnom stanicom s benzinskim motorom

A finely atomized foam-water solution (water + foam concentrate) was used as a fire extinguishing agent that was sprayed by using a duel nozzle of the "Firexpress" sprayer (Fig. 2); *(Firesecurity LLC, Firexpress A/S)*. In this case, the concentration of foam concentrate (foaming agent) Fomtec AFFF in the fire extinguishing agent was 3%, and the water content was 97%.

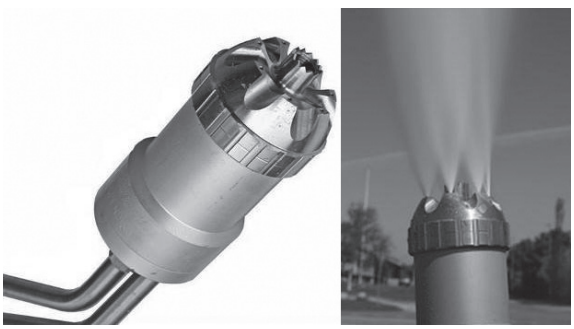

Figure 2. Duel nozzle of the "Firexpress" sprayer

Slika 2. Dualna mlaznica prskalice "Firexpress"

Experimental studies on the determination of the indicator of the fire-extinguishing potential of fire extinguishing agents with the combined supply of foam-water extinguishing agents in an aerosol state were carried out in accordance with *(DSTU 3675 Pozhezhna tehnika, DSTU 3734 Vognegasnyky peresuvni, 1998)*. The investigations were carried out on the open site of the training ground in the absence of precipitation and the wind speed not exceeding 2 m/s and at an ambient temperature of 20°C.

As an indicator of the fire-extinguishing potential or capacity, the duration of supply and consumption of extinguishing agent was determined for extinguishing simulated fires of "A" and "B" classes. Investigations were carried out in three series. Each series included three experiments (in each experiment one simulated fire was extinguished using one technical fire extinguishing device), the experiments were carried out in series one after another. Thus, during the studies of the 1st series, the simulated fire of an "A" class was extinguished for a stack of wooden blocks of pine in the shape of a cube (12 layers of 6 blocks of 40×40×500 mm, each). The bars forming the outer edges of the stack were fastened with nails. The stack was placed on a

rectangular steel structure that was installed horizontally on a deco filled with water and fuel (gasoline) of an appropriate volume *(DSTU 3675 Pozhezhna tehnika, DSTU 3734 Vognegasnyky peresuvni, 1998)*, followed by ignition using a torch (Fig. 3).

Figure 3. Setting fire to a pile of wooden blocks of pine in the form of a cube during the 1st series of research

Slika 3. Paljenje hrpe drvenih blokova borovine u obliku kocke tijekom 1. serije ispitivanja

After the fuel in the deco burns out, the deco is taken from under the stack and the fire is extinguished directly. When conducting experimental studies, an operator over 18 years old was involved, who had undergone training in labor protection and safety and had experience in extinguishing simulated fires with technical fire extinguishing equipment.It should be noted that the operator was in special clothes and had special outfit.

The 2nd and 3rd series of studies involved extinguishing simulated fires of a"B» class. When conducting the 2nd series of studies, a deco in the form of a circle with a diameter of 1100 mm and a height of 200 mm was used and during the III series of studies, a rectangular deco of 1500×1000×200 mm was used. The decos were installed in such a way as to ensure easy access to them from all sides, and then these were filled with water and fuel (gasoline) according to (DSTU 3675 Pozhezhna tehnika, DSTU 3734 Vognegasnyky peresuvni, 1998), followed by ignition using a torch (Fig. 4, 5).

Figure 4. Setting the deco on fire during the 2nd series of research

Slika 4. Paljenje ložišta tijekom 2. serije ispitivanja

Figure 5. Setting the deco on fire during the third series of research

Slika 5. Paljenje ložišta tijekom treće serije ispitivanja

During the 1st series of studies, technical fire extinguishing means were used only after the period of free burning of the stack, which lasted for 7 minutes (Fig. 6).

Figure 6. Stack burning for 7 minutes during the 1st series of studies

Slika 6. Spaljivanje hrpe 7 minuta tijekom 1. serije ispitivanja

Prior to extinguishing a simulated fire of an "A"class, the technical fire extinguishing device was activated, whereupon the operator directed a jet of extinguishing agent to the front surface of the simulated fire, from a distance of about 4 m equal to a maximum length of the jet of extinguishing agent. During the extinguishing process, this distance is decreased by gradually directing the jet of fire extinguishing agent to the front, top and side surfaces of the simulated fire, except for the back surface (Fig. 7, 8). In this case, the fire-extinguishing agent is supplied continuously, ensuring a maximum flow from the technical fire-extinguishing device.

Figure 7. Extinguishing a simulated fire of an "A" class and directing the jet to the front and side surfaces of the stack

Slika 7. Gašenje simuliranog požara klase "A" i usmjeravanje mlaza na prednje i bočne površine dimnjaka

Figure 8. Extinguishing a simulated fire of an "A" class and directing the jet to the upper surface of the stack

Slika 8. Gašenje simuliranog požara klase "A" i usmjeravanje mlaza na gornju površinu dimnjaka

The extinguishing of the simulated fire of an "A" class was stopped in the absence of flame or burning of stack bars. Further, on completion of the extinguishing process the simulated fire was monitored for 10 minutes to prevent the fire resumption in case of need. It should also be noted that during the studies the stack of wooden blocks of pine did not fall apart and kept its original shape in the form of a cube.

During the 2nd and 3rd series of studies technical fire extinguishing means were used only after the free burning of the fuel in the deco, during 1 minute (Fig. 9, 10). It should be noted that during the 2nd series of research the operator acted as an ordinary person wearing no special clothing and outfit, i.e. as the personnel of the facility capable of using technical fire extinguishing means under different conditions (Fig. 11, 12).

Figure 9. Fuel burning in a deco for 1 minute during the II series of studies

Slika 9. Gorivo gori u ložištu 1 minutu tijekom II. serije ispitivanja

Figure 10. Fuel burning in a deco for 1 minute during the III series of studies

Slika 10. Gorivo gori u ložištu 1 minutu tijekom III. serije ispitivanja

The simulated fire of a "B" class was extinguished by activating technical fire extinguishing means and after that the operator directed a fire extinguishing agent jet at the far end of the deco

with a gradual movement around the deco at a distance of about 4 m, which is equal to a maximum length of the jet of extinguishing agent. During the fire-fighting process this distance is decreased. Fig. 11 and Fig. 12 show the extinguishing process of a simulated fire of a "B" class during the II series of studies.

Figure 11. Extinguishing a simulated fire of a "B" class at the initial stage during the II series of studies

Slika 11. Gašenje simuliranog požara "B" klase u početnoj fazi tijekom II. serije ispitivanja

At the same time, the fire-extinguishing agent is supplied continuously, ensuring a maximum flow from technical fire-extinguishing means.

Figure 12. Extinguishing a simulated fire of a "B" class at the final stage during the II series of studies

Slika 12. Gašenje simuliranog požara "B" klase u završnoj fazi tijekom II. serije ispitivanja

Extinguishing a simulated fire of a "B" class during the III series of studies (Fig. 13 and Fig. 14).

Figure 13. Extinguishing a simulated fire of a "B" class at the initial stage during the III series of studies

Slika 13. Gašenje simuliranog požara "B" klase u početnoj fazi tijekom III. serije ispitivanja

Figure 14. Extinguishing a simulated fire of a "B" class at the final stage during the III series of studies

Slika 14. Gašenje simuliranog požara "B" klase u završnoj fazi tijekom III. serije ispitivanja

The extinguishing of the simulated fires of a "B" class was stopped in the absence of flame and the difference between the liquid levels (water + fuel), measured in the same place before and after the tests (the difference did not exceed 25 mm). Liquid levels were measured near the deco wall in order to reduce the possible error due to irreversible thermal deformations of the metal structure of the deco. The duration of supply of the fire extinguishing agent and its consumption were determined taking into account the above conditions.

Table 1 gives the results of experimental studies obtained when extinguishing simulated fires of "A" and "B" classes according to the three series of studies. The fire-extinguishing efficiency indicator values for fire-extinguishing technical means were processed using the method of least squares. The resulting root mean square value is also given in Table 1.

Thus, Table 1 gives the results of experimental studies carried out when extinguishing simulated fires of "A" and "B"classes, depending on the series of research. At the same time, the duration of the supply of the fire-extinguishing agent and the consumption of the extinguishing agent supplied by technical fire-extinguishing means are given as indicators of fire-extinguishing potential,in accordance with the research series and the experiment number. The obtained research data were processed by the method of least squares with the derivation of the root mean square value of the duration of supply of the fire extinguishing agent and its consumption. The obtained research data will be analyzed by plotting.

Fig. 15 shows a diagram for the dependence of the duration of supply of the fire extinguishing agent by a technical device on the consumption of fire extinguishing agent during the 1st series of studies when extinguishing a simulated fire of an "A" class taking into account three experiments.

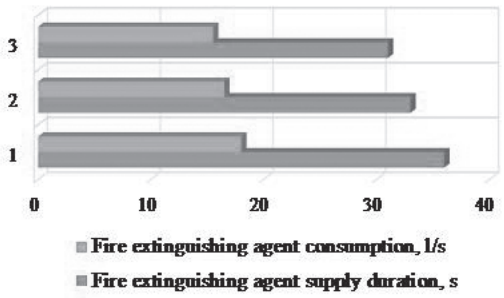

Figure 15. Dependence of the duration of supply of the fire extinguishing agent on the consumption during the 1st series of studies

Slika 15. Ovisnost trajanja opskrbe sredstva za gašenje požara o potrošnji tijekom 1. serije istraživanja

At the same time, the root mean square value of the duration of supply of the fire-extinguishing agent is $33.33\pm4.214_{0,9}$ s, and the consumption of the fire-extinguishing agent is $16.67\pm2.107_{0,9}$ l/s.

The dependence of the duration of supply of the fire extinguishing agent by a technical device on the consumption of the fire extinguishing agent

Table 1. Experimental investigation data obtained during the extinguishing of the simulated fires of "A" and "B" classes

Tablica 1. Podaci eksperimentalnog istraživanja dobiveni tijekom gašenja simuliranih požara klase "A" i "B"

Research series	Research No	Fire extinguishing agent supply duration, s		Fire extinguishing agent consumption, l/s	
I	1	36	$33.33\pm4.214_{0,9}$	18.0	$16.67\pm2.107_{0,9}$
	2	33		16.5	
	3	31		15.5	
II	1	15	$12.33\pm4.214_{0,9}$	7.5	$6.17\pm2.107_{0,9}$
	2	12		6.0	
	3	10		5.0	
III	1	22	$18.67\pm5.116_{0,9}$	11	$9.33\pm2.558_{0,9}$
	2	18		9	
	3	16		8	

during the II series of studies was plotted for extinguishing a simulated fire of a"B» class, taking into account three experiments (Fig. 16).

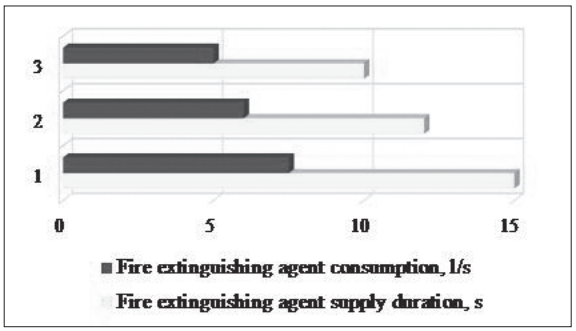

Figure 16. Dependence of the duration of supply of the fire extinguishing agent on the consumption during the 2nd series of studies

Slika 16. Ovisnost trajanja opskrbe sredstva za gašenje požara o potrošnji tijekom 2. serije ispitivanja

At the same time, the root mean square value of the duration of supply of the fire extinguishing agent is $12.33\pm4.214_{0,9}$ s, and that of the consumption of the fire extinguishing agent is $6.17\pm2.107_{0,9}$ l/s.

Fig. 17 shows a plotted dependence of the duration of supply of the fire extinguishing agent by technical means on the consumption of the fire extinguishing agent during the 3-d series of studies when extinguishing a simulated fire of a "B" class taking into account three experiments.

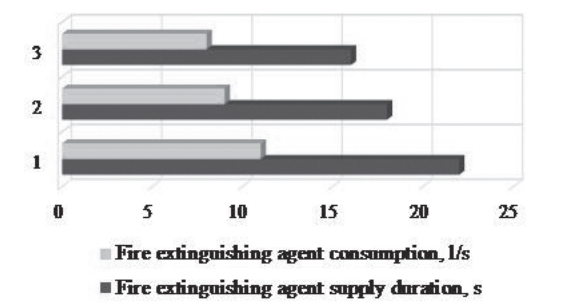

Figure 17. Dependence of the duration of supply of the fire extinguishing agent on the consumption during the 3d series of studies

Slika 17. Ovisnost trajanja opskrbe sredstva za gašenje požara o potrošnji tijekom 3d serije ispitivanja

At the same time, the root mean square value of the duration of supply of the fire-extinguishing agent is $18.67\pm5.116_{0,9}$ s, and that of the consumption of the fire-extinguishing agent is $9.33\pm2.558_{0,9}$ l/s.

The analysis of the obtained results shows that the use of technical means *(Firesecurity LLC, Firexpress A/S)* for extinguishing simulated fires of "A" and "B"classes is relatively different. First of all, the duration of extinguishing of the simulated fire of an "A" class is 1.5-2 times longer than that of extinguishing the simulated fires of a "B"class. When carrying out the experiments of the relevant research series, the specificity was established as for the shortening of the duration of supply of the fire extinguishing agent. It is explained by the adaptation to the use of the technical means *(Firesecurity LLC, Firexpress A/S)* and the improvement of the professional skills of the operator when extinguishing simulated fires. To compare the obtained results, regarding the use of the fire extinguishing means with the combined supply of foam-water extinguishing agents in an aerosol state, we will resort to the analysis of the relevant research papers. For example, in *(Chen et al., 2020)*, experimental studies were carried out on the use of the foam-water fire extinguishing agents in an aerosol state during extinguishing the fire of transformer oil that leaked out as a result of damage to the transformer. According to the results of the study, the duration of supply of the fire-extinguishing agent for the complete elimination of the fire was established and it was equal to 3.9 minutes at the foam supply intensity of 11.2 l/(min·m^2). At the same time, it was also established that an increase in the supplied volume of the fire extinguishing agent results in a decreased value of the duration of supply of the fire extinguishing agent.

In paper *(Xu et al., 2020)*, the authors conducted experimental studies using a fire extinguishing agent with a content of 6% AFFF foam and 94% water when extinguishing diesel fuel (1.1 kg) that was poured into a stainless steel oil tray of 0.5×0, 5×0.1 m. The fire extinguishing agent was supplied from an experimental setup. According to the results of the study, it was established when extinguishing a simulated fire of a "B"class that the duration of supply of the fire extinguishing agent

until the complete cessation of burning was 42 seconds.

And in paper *(Dong et al., 2019),* the authors studying the extinguishing of flammable liquids compared the fire-extinguishing efficiency of fire-extinguishing agents in an aerosol state with the addition of impurities in the form of potassium salt. According to the results of the study, it was established that the concentration of potassium salt was 5%, and the extinguishing time varied within 30.1 to 57.7 s. And in paper *(Ostapov et al., 2022),* experimental studies were carried out on extinguishing a simulated fire of an"A" class using an extinguishing setup with gel-forming compositions. Based on the results of the study, the dependence of the diameter of the drops of the fire extinguishing agent (gelling compositions) on the extinguishing time was established. So, accordingly, the larger the diameter of the drops, the shorter the fire-fighting time, and vice versa. The extinguishing time of the simulated fire of an "A" class varied during the studies in the range of 15.0 to 40.0 s.

Analyzing the above research within the framework of the conducted experimental studies, it should be noted that the duration of the supply of extinguishing agent for extinguishing a fire or the extinguishing time will depend primarily on the type of extinguishing agent and the percentage and type of impurities in its composition, as well as directly on technical fire extinguishing means and their tactical technical characteristics. In addition, it is necessary to take into account the professional training of the operator who supplies the extinguishing agent using technical fire extinguishing means. From the point of view of methodical support, it is necessary to substantiate and develop the methods of extinguishing simulated fires of different classes, taking into account modern approaches and regulatory legal acts. The conditions specified for the use of the technical fire extinguishing means intended for extinguishing fires are considered as determinant and should be considered as a whole when conducting experimental studies. As for the results of the research obtained for the use of the technical fire extinguishing means *(Firesecurity LLC, Firexpress A/S)* during the extinguishing of the simulated fires of "A" and "B" classes, it should be noted that these are rational and are in compliance with modern trends in the development of the fire extinguishing means and methods. And fire extinguishing means with a combined supply of foam-water extinguishing agents in an aerosol state *(Firesecurity LLC, Firexpress A/S)* are a promising avenue in the development of the latest fire extinguishing technologies.

CONCLUSIONS

This research deals with the experimental studies of the fire extinguishing means with the combined supply of foam-water extinguishing "Fireexpress" agents in an aerosol state carried out when extinguishing simulated fires of "A" and "B"classes.

A mobile module with a water tank of 150 liters and a pumping station equipped with a gasoline engine with a flow rate of 30 l/min was used as technical Fireexpress fire-extinguishing means. A finely atomized foam-water solution (water + foam concentrate) was used as a fire extinguishing agent, while the concentration of Fomtec AFFF foam concentrate (foaming agent) in the fire extinguishing agent was 3%, and the content of water was 97%. Fomtec AFFF 3% F is formulated using raw materials specially selected for their fire performance and their environmental profile. All raw materials are registered in European REACH-database. Fomtec AFFF 3% F is non-toxic, biodegradable and each individual component is fully tested and documented. Fomtec only use C6 Pure fluorosurfactants. AFFF products contains no PFOS or PFOA in accordance with US EPA Stewardship Programme 2010/15 and EU Directive 2017/1000. More details can be found in the Material Safety Datasheet (MSDS) *(Dafo Fomtec AB).*

When extinguishing simulated fires of "A" and "B" classes, experimental studies were conducted according to the three series of studies, and each series of studies included three experiments. Thus, during the research of the 1st series, the extinguishing of a simulated fire of an "A"class, namely a stack of wooden blocks of pine in the form of a cube was carried out. The 2nd and 3rd series of studies involved extinguishing the simulated fires

of a "B" class. When conducting the II series of studies, a deco in the form of a circle with a diameter of 1100 mm and a depth of 200 mm was used, and during the III series of studies, a rectangular deco of 1500×1000×200 mm was used.

According to the results of the experimental studies, the values of the duration of supply of the fire extinguishing agent (extinguishing time) and agent consumption values were obtained. Using the method of least squares, the root mean square value of the duration of supply of the fire extinguishing agent and that of the consumption of the extinguishing agent supplied by technical fire extinguishing means were obtained in accordance with the research series and the number of the experiment.

Thus, during the 1st series of studies, the root mean square value of the duration of supply of the fire extinguishing agent was $33.33\pm4.214_{0,9}$ s, and that of the consumption was $16.67\pm2.107_{0,9}$ l/s. In the 2nd series of studies, the root mean square value of the duration of supply of the fire extinguishing agent was $12.33\pm4.214_{0,9}$ s, and that of the consumption was $6.17\pm2.107_{0,9}$ l/s, and in the 3rd series of studies, the rms value of the duration of supply of the fire extinguishing agent was $18.67\pm5.116_{0,9}$ s, and that of consumption was $9.33\pm2.558_{0,9}$ l/s.

It has been established that the duration of supply of the extinguishing agent for extinguishing fires using technical fire extinguishing means depends on a number of factors. First of all, it depends on the type of fire-extinguishing agent, the percentage and type of impurities in its composition, directly on technical fire extinguishing means and their tactical and technical characteristics, as well as on the professional skills of the operator and methodical support.

The results of experimental studies obtained for fire extinguishing means with the combined supply of foam-water extinguishing agents in an aerosol state when extinguishing fires of "A" and "B" classes are a prerequisite for the further development of technical means used for extinguishing fires.

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ISPITIVANJE APARATA ZA GAŠENJE POŽARA KOMBINIRANOM UPORABOM PJENE I VODE U OBLIKU AEROSOLA

SAŽETAK: Istraživanje počiva na ispitivanjima aparata za gašenje požara pomoću aerosola sastavljenog od pjene i vode, i to na simuliranim požarima klase "A" i "B". Ispitivanje je provedeno korištenjem pokretnog modula sa spremnikom za vodu od 150 litara i crpne stanice opremljene benzinskim motorom te vrlo fino raspršenom otopinom pjene i vode (voda + koncentrat pjene) kao agensa za gašenje požara. Koncentracija pjene u agensu bila je 3 %, a vode 97 %. Pokusna ispitivanja provedena su u tri serije a svaka je serija uključivala tri pokusa. Ispitivanje prve serije gašenja provedeno je na simuliranom požaru "A" tipa, a ispitivanje druge i treće serije bilo je fokusirano na gašenje simuliranih požara "B" tipa. Rezultati ispitivanja dali su podatke o trajanju upotrijebljenog agensa i njegovoj potrošnji. Metodom najmanjih kvadrata dobivene su srednje vrijednosti trajanja agensa za gašenje i njegova potrošnja uporabom tehničkih pomagala za gašenje požara za svaki pojedini pokus iz serije. Utvrđeno je da trajanje količine protupožarnog agensa pomoću tehničkih naprava ovisi o vrsti protupožarnog agensa, postotku nečistoća u njegovom sastavu, taktičkim i tehničkim obilježjima protupožarnog agensa te vještini rukovatelja i metodičkoj podršci.

Ključne riječi: *požar, gašenje požara, tehnička sredstva za gašenje požara, simulirani požari i tip požara*

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