УДК 313.86

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ANALYSIS OF THE INFLUENCE OF THE TIME OF THE YEAR ON THE OPERATIONAL DEPLOYMENT OF FIRE TRUCK TANKS OF DIFFERENT CLASS

As an object of study, factors related to the season are considered that may impede the operational deployment of fire trucks of various classes. Since in accordance with the normative documents of the CSN of Ukraine one of the most important criteria for assessing the effectiveness of the personnel of fire and rescue units is the time of operational deployment, the aim of the work is to analyze the influence of the seasons on the time of operational deployment of fire tankers of various classes. However, in Ukraine, as in other leading countries of the world, the issues of increasing the effectiveness of operational deployments, taking into account meteorological conditions, have not been sufficiently considered. The conducted experimental studies under the influence of meteorological factors, in which third-year cadets of the National University of Civil Protection of Ukraine and firefighters of the regular fire and rescue units of the CSN of Ukraine took part, showed that the distribution of time for operational deployments on light, medium and heavy fire tankers that are in service in the fire and rescue units of the CSN of Ukraine, with a significance level of □ = 0.05 is normal. At the same time, the mathematical expectation of operational deployment time for the same types of options differs significantly not only depending on the class of fire tankers, the level of preparedness of personnel, but also on the time of year that was at the time of the chosen typical operational deployment options. It was determined that the factors considered to a greater extent influenced the results of the operational activities of cadets, and to a lesser extent, the activities of professional experienced rescuers. These features should be taken into account when adjusting recommendations for the operational deployment of light and heavy class fire tankers, as well as appropriate training for personnel.

Keywords: tank truck, operational deployment, operational calculation, time of rock, statistical analysis, time distribution

1. Introduction

According to [1], operational deployment of forces and means is the bringing of forces and means of fire and rescue units to the state of readiness to perform tasks during a fire or emergency, the process of interaction of operational numbers on fire trucks with each other and actions with the use of fire- technical equipment. This process, which is the key to successful and timely deployment of forces and resources, requires clear concerted action by personnel, complicated by the level of fire or emergency, as well as by the particularities of the season.

Therefore, the actual problem is to increase the efficiency of operational deployments, regardless of the season of fire trucks of different classes by the personnel of the fire and rescue units during the emergency rescue operations.

2. Analysis of recent publications and formulation of the problem

The problem of operational actions of units of the operational rescue service in the conditions of adverse meteorological factors is urgent all over the world. For example, in the United States, the Federal Emergency Response Agency FEMA not only coordinates the actions of all public services in localizing and eliminating various situations, but is also directly responsible for the preparation of fire and rescue units [2], in accordance with NFPA 1500-2002 [3, 4], both the local features (including the meteorological conditions of the region) and the firearms that are in their possession.

The requirements of NFPA 1001 [5], NFPA 1710 [6] and NFPA 1720 [7] specify that personnel involved in emergency operations must effectively arrange for the operational deployment of fire tankers, taking into account local and meteorological conditions, optimal use and rational use of fire-fighting machinery and equipment [8]. However, how these factors should be taken into account is not specified.

According to NFPA Standard 1001 [9], the professional qualifications of both professional units and fire crews consisting of volunteers must have the skills not only to carry out the error-free operational deployment of firefighting vehicles, but also to adapt them to the requirements of specific situation depending on the factors that may influence the actions of personnel during the operational deployment [9, 10]. Considering this background, NFPA 1410 [11] provides a method for measuring performance that relies on the time of operational deployment, firefighting and rescue procedures, taking into account the specificities of personnel and equipment involved. At the same time, in [12], where the technique of using fire-fighting equipment of a fire truck during the operational deployment is given, in this case, taking into account the time of year, the issues related to the characteristics of tanks of different classes are not considered.

The peculiarities of the actions of fire-fighting rescue units during the operational deployment of the compartments on fire trucks were considered in [13, 14], where it was determined that the most rational option would be the one when the entire composition of the operative calculation of the compartment ends at the same time, meaning that each number prompt calculation will spend the same amount of time to perform its operations. However, operational deployment features related to the class of fire-fighting equipment and the time of year or weather factors are not considered.

In [15] objective factors (time of year and time of day, precipitation, height of snow cover, wind, number and type of equipment involved, etc.) that influence the efficiency of operational activity by personnel of fire-fighting rescue units are considered. However, quantitative estimates are not given there, as has not been done in [16], where subjective factors (rational sequence of performing operational deployment, professional qualities of rescuers, human capabilities, etc.) are considered.

Such estimates were obtained in [17], but there were no statistical estimates of the timing of operational deployment of fire trucks of different class by personnel of different levels of preparedness at different seasons. Although in [18], where the features of operative deployment of fire tankers under reduced ambient temperature conditions are considered, it is noted that the actions of personnel in this case are complicated by the stiffness of the rescuers' movements and the increased probability of equipment failure in the case of a significant increase in the previous operational time.

Considering this, in Germany, for example, the technical equipment of emergency rescue units, and accordingly the types of fire trucks, is determined by the specific capabilities of each community or city and the meteorological features of each region [19]. The basic standard there, as for other EU countries, is the standard EN 1846 [20], which, among other things, divides fire trucks into three mass classes, taking into account the various factors and local conditions that may affect the operational response of the fire crew. However, issues related to the seasons or meteorological factors have not been considered there.

That means, in Ukraine, as well as in other leading countries of the world, the question of increasing the efficiency of operational deployments of fire trucks of different class with regard to the season is not considered enough.

All this testifies to the need for a comparative analysis of the execution time of typical operational deployments on fire trucks of different classes, taking into account the time of year.

3. The purpose and objectives of the study

The purpose is to analyze the impact (meteorological factors) of the seasons on the operational deployment of fire tankers of different class.

Objectives of the study:

– organization of experimental studies;

– statistical analysis of results of experimental research of operational deployments;

– to develop proposals for the use of the results obtained.

4. Analysis of the impact of the seasons on the operational deployment of fire tankers of different class

In order to solve this problem, experimental studies were first conducted, involving subjects from the cadets (C) of the National University of Civil Defense of Ukraine and fire (F) operative-rescue units of the State Emergency Service of Ukraine in Kharkiv region. They performed the operational deployments of "Passing the barrel GPS-600 through a working line on three sleeves with a diameter of 51 mm from the tank truck" (OP1) and " Passing one barrel" A "and one barrel" B "with the laying of a trunk line on five sleeves with a diameter of 77 mm and two working lines with the installation of a tank truck on a fire hydrant "(OP2) from the tankers AC -40 (131) model 137A (AC сер), MAZ ATS-4-60 (5309) -505m (AC важк) and APPD-2" Valdai " AC -1,3-4 / 400 (5301) (AC легк) both in summer and winter.

To check the difference in the time of operational deployment, depending on both the class of cars and the level of readiness of personnel, as well as the season, it is necessary to obtain statistical estimates of the experimental results (mathematical expectations and standard deviations) for the selected variants of operational deployment under different starting conditions, to check the correspondence of statistics normal distribution, and after that check how much the difference is significant by Student's criteria.

Thus, the proposed methodology of experimental research allows both to obtain quantitative estimates of the time of operational deployment, which will simultaneously characterize the class of fire truck, the level of preparedness of personnel and the time of year, and to check how significantly each of the selected factors influences the time of execution of typical variants of operational deployment fire trucks.

5. Statistical analysis of results of experimental research of operational deployments

The results obtained, since samples with volume $n = 20 < 30$ were used in each case, were verified for normality of distribution by the Shapiro-Wilkie criterion [21].

For this purpose, for example, in relation to the OP1 of light-hearted АЦ, in the winter, students initially calculated the average time of operative deployment

$$\bar{t}_{ÎÐ1}(ÀÖ_{ëåãê}) = \frac{\sum_{i}^{n} t_{ÎÐ1_i}(ÀÖ_{ëåãê})}{n}, \quad (1)$$

where $t_{\text{ÎÐ } 1_i}(\text{ÀÖ}_{\text{ëåâê}})$ – time of operational deployment of APPD-2 "Valdai" i; combat calculation, consisting of cadets of the 3rd year, c;

standard deviation

$$\sigma_{\text{ÎÐ } 1}(\text{ÀÖ}_{\text{ëåâê}}) = \sqrt{\frac{1}{n} \cdot \sum_{i=1}^{n} \left(t_{\text{ÎÐ } 1_i}(\text{ÀÖ}_{\text{ëåâê}}) - \bar{t}_{\text{ÎÐ } 1}(\text{ÀÖ}_{\text{ëåâê}})\right)^2}, \qquad (2)$$

and

$$n \cdot m_2 = \sum_{i=1}^{n} \left(t_{\text{ÎÐ } 1_i}(\text{ÀÖ}_{\text{ëåâê}}) - \bar{t}_{\text{ÎÐ } 1}(\text{ÀÖ}_{\text{ëåâê}})\right)^2, \qquad (3)$$

where m_2 – the selective central moment of the second order.

Because the estimates t_i are the result of independent observation processing, they were arranged in a non-descending order and marked with symbols $t_1, t_2, ..., t_{n=20}$.

This made it possible to calculate the intermediate sum S by the formula:

$$S = \sum_{i}^{k} a_{n-i+1} \cdot (t_{(n-i+1)} - t_i) = 6{,}69, \qquad (4)$$

where k – index, which ranges from 1 to $n/2 = 12$; a_{n-i+1} – coefficient that has special values for sample volume n (its values, which are given in table 2, taken from table 10 [21]).

Tab. 1 [21] for significance level α=0,05 and n=20 gives value $W_{\text{òàáë}} = 0{,}905$.

Tab. 1. Results of passing of the GPS-600 barrel by cadets through a working line on three sleeves with a diameter of 51 mm from the tanker APPD-2 "Valdai"

n	1	2	3	4	5	6	7	8	9	10
t_i, c	35,4	35,6	35	39,3	34,7	34,2	37,8	35,8	36	37,3
$(t_i - \bar{t}_i)^2$	0,026	0,130	0,058	16,484	0,292	1,082	6,554	0,314	0,578	4,244
n	11	12	13	14	15	16	17	18	19	20
t_i, c	33,4	32,7	36,3	34,4	34,6	35,1	35	35,1	32,8	34,3
$(t_i - \bar{t}_i)^2$	3,386	6,452	1,124	0,706	0,410	0,020	0,058	0,020	5,954	0,884
$\bar{t}$, c	39,74									
σ, c	1,96									
$n \cdot m_2$	48,77									

Tab. 2 summarizes the ordered series of operational deployment time values obtained.

Tab. 2. An ordered series of retrieved deployment time values

k	$t_{(20-k+1)}$, c	t_k, c	$t_{(20-k+1)} - t_k$, c	a_{n-k+1}	$a_{n-k+1} \cdot (t_{(20-k+1)} - t_k)$
1	39,3	32,7	6,60	0,4493	2,96538
2	37,8	32,8	5,00	0,3098	1,549
3	37,3	33,4	3,90	0,2554	0,99606
4	36,3	34,2	2,10	0,2145	0,45045
5	36	34,3	1,70	0,1807	0,30719
6	35,8	34,4	1,40	0,1512	0,21168
7	35,6	34,6	1,00	0,1245	0,1245
8	35,4	34,7	0,70	0,0997	0,06979
9	35,1	35	0,10	0,0764	0,00764
10	35,1	35	0,10	0,0539	0,00539
S					6,687
S^2					44,717

Whereas

$$W = \frac{S^2}{n \cdot m^2} = \frac{44,717}{48,77} = 0,916 \geq W_{òàáë} = 0,905, \qquad (5)$$

the distribution according to [21] is considered normal.

Calculations similar to (1)–(5) were also performed to analyze the time of operational deployments based on other selected results. They showed that in terms of significance α=0,05 they can be considered normal.

The results obtained are summarized in Tab. 3 and Tab. 4, as well as in Picture 1, which shows the distribution of the time of operational deployment "Passing the barrel GPS-600 through a working line on three sleeves with a diameter of 51 mm from the tanker" light (APPD- 2 Valdai) and heavy (MAZ АЦ-40 (5309)) classes, taking into account the time of year.

Tab. 3. Results of operational deployment of cadets and firefighters "Passing the barrel GPS-600 through a working line on three sleeves with a diameter of 51 mm from the tanker" light "and" heavy" class, taking into account the time of year (OP1)

$OP1_{АЦ\ лег.\ клас}$							
Summer				Winter			
C		F		C		F	
$\bar{t}_{ë}$,ñ	$\sigma_{ë}$	$\bar{t}_{ë}$,ñ	$\sigma_{ë}$	$\bar{t}_{ë}$,ñ	$\sigma_{ë}$	$\bar{t}_{ë}$,ñ	$\sigma_{ë}$
35,24	1,6	32,22	1,15	39,74	1,96	36,56	1,26
$OP1_{АЦ\ тяж\ клас}$							
$\bar{t}_{Ò}$,ñ	$\sigma_{Ò}$	$\bar{t}_{Ò}$,ñ	$\sigma_{Ò}$	$\bar{t}_{Ò}$,ñ	$\sigma_{Ò}$	$\bar{t}_{Ò}$,ñ	$\sigma_{Ò}$
52,56	1,29	48,27	1,21	57,19	1,45	49,12	1,34

The presence of estimates of mathematical expectations and standard deviations for the obtained samples (Tab. 1, 2) of the operational deployment time allowed us to check how significantly the mean values obtained by independent study samples using the Student's t-test [22].

In this case, for example, for situations when comparing the time of OP1 from light and heavy tanker trucks to cadets and firemen with regard to meteorological factors were considered, the hypothesis was considered

$$H_0:\ \bar{t}_{ë}(ï) = \bar{t}_{ë}(ê) \tag{6}$$

and its alternative

$$H_1:\ \bar{t}_{ë}(ï) \neq \bar{t}_{ë}(ê), \tag{7}$$

which proves the difference between the averages.

In order to select a specific method for calculating the t-test [23], the hypothesis about the equality of variances was first tested. As a criterion for testing the null hypothesis

$$H_0:\ \sigma_{ë}(ï) = \sigma_{ë}(ê), \tag{8}$$

the F-criterion was selected

$$F = \sigma_1^2 / \sigma_2^2, \tag{9}$$

where σ_1^2 – the larger of the variance estimates in the two samples.

Tab. 4. Results of operative deployments of cadets and firefighters "Passing of one barrel" A "and one barrel" B "with laying of a main line on five sleeves with a diameter of 77 mm and two working lines with installation on fire hydrant "light" and "heavy" tanker trucks based on the time of year (OP2)

$OP2_{АЦ\ ляж.\ клас}$							
Summer				Winter			
C		F		C		F	
$\bar{t}_{ë}$,ñ	$\sigma_{ë}$	$\bar{t}_{ë}$,ñ	$\sigma_{ë}$	$\bar{t}_{ë}$,ñ	$\sigma_{ë}$	$\bar{t}_{ë}$,ñ	$\sigma_{ë}$
53,27	1,92	49,46	2,68	66,72	2,13	53,56	2,06
$OP2_{АЦ\ тяж.\ клас}$							
$\bar{t}_{Ò}$,ñ	$\sigma_{Ò}$	$\bar{t}_{Ò}$,ñ	$\sigma_{Ò}$	$\bar{t}_{Ò}$,ñ	$\sigma_{Ò}$	$\bar{t}_{Ò}$,ñ	$\sigma_{Ò}$
74,51	2,00	70,32	2,31	87,45	2,51	79,84	1,69

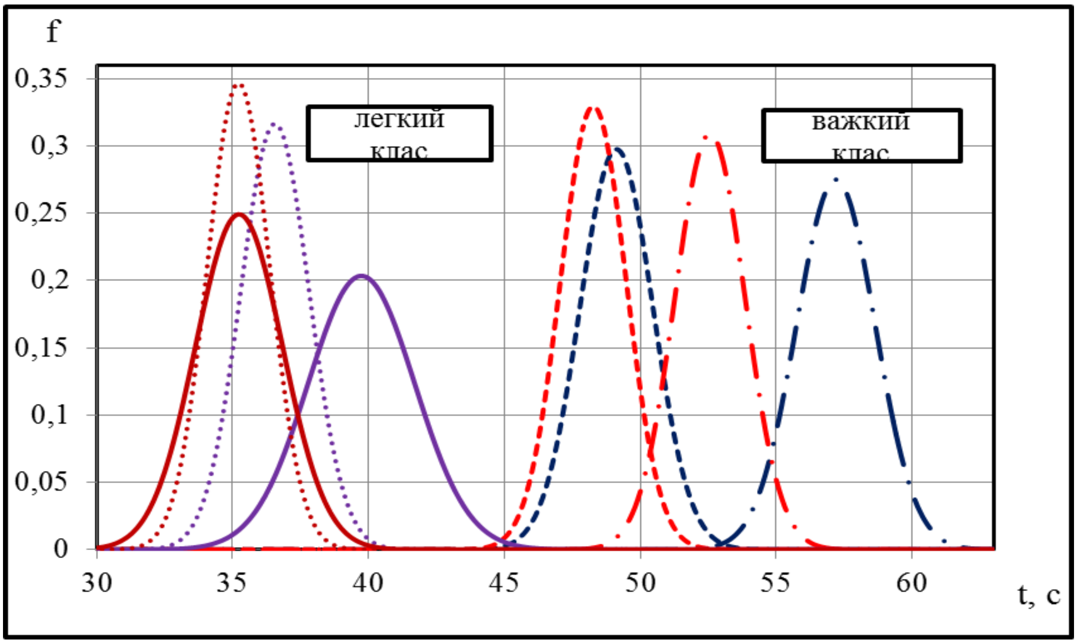

Fig. 1. Distribution of time of operational deployment of light and heavy tanker trucks depending on the time of year (blue color - winter, red - summer) and the level of preparedness of firefighters (solid line - cadets, dotted - firefighters of regular units)

The critical value is $F_{кр}$, which at the level of significance $\alpha = 0,05$ and the number of degrees of freedom

$$\upsilon_{\text{ё}}(\text{ï}) = n_{\text{ё}}(\text{ï}) - 1 = 19,\ \upsilon_{\text{ё}}(\text{ê}) = n_{\text{ё}}(\text{ê}) - 1 = 19, \tag{10}$$

where $n_{\text{ё}}(\text{ï}) = n_{\text{ё}}(\text{ê}) = 20$ the number of operational calculations, which performed the operational deployment of OP1 and OP2 as a result of which the statistical characteristics of the obtained distributions were estimated, is equal to [22]

$$F_{\text{êð}} = F_{\text{òàáë}} = 2{,}15. \tag{11}$$

The results of comparison (4) with (6) are shown in table 5

Tab. 5. Results of statistical verification of the ratio of sample dispersions of operational deployment from tanker trucks of light and heavy class, taking into account the season

Fкр							
F	C	F	C	F	C	F	C
OP_1л	OP_1л	OP_1т	OP_1т	OP_2л	OP_2л	OP_2т	OP_2т
1,20	1,50	1,22	1,28	0.59	1,23	0,53	1,57

It can be seen that in the considered cases the null hypothesis is validly recognized and the variance is allowed when performing the operational deployment of both cadets and firefighters of regular fire and rescue units. Which means

$$\sigma^2_{\text{âî}}(\text{ÎÐ}_1 n) = \sigma^2_{\text{ï³ñëÿ}}(\text{ÎÐ}_1 \text{ê}); \tag{13}$$

$$\sigma^2_{\text{âî}}(\text{ÎÐ}_2 n) = \sigma^2_{\text{ï³ñëÿ}}(\text{ÎÐ}_2 \text{ê}) \tag{14}$$

Based on this, the standard error of the difference S x, given that the sample size is small (<30), and the number of degrees of freedom υ when calculating the t-test is calculated [23] as follows

$$S_{(\text{Ë}-\text{Ò})}(\text{ÎÐ}_{1,2}) = \sqrt{\frac{(n_{\text{ё}}(n)-1)\cdot\sigma^2_{\text{ё}}(n/\text{ê}) + (n_{\text{ё}}(\text{ê})-1)\cdot\sigma^2_{\text{ё}}(\text{ï}/\text{ê})}{n_{\text{ё}}(\text{ï}) + n_{\text{ё}}(\text{ê}) - 2}\cdot\left(\frac{1}{n_{\text{ё}}(n)} + \frac{1}{n_{\text{ё}}(\text{ê})}\right)} = \tag{15}$$

$$n_{\text{ё}}(n) + n_{\text{ё}}(\text{ê}) - 2 = 38 \tag{16}$$

Summary results of the calculation of standard error estimates deploy time given in Tab. 6.

As a result for

$$t_{\text{íàáë}} = \frac{\left|\bar{t}_{\text{çèìË}}(\text{ï}) - \bar{t}_{\text{ë³òË}}(\text{ï})\right|}{S(\text{ÎÐ}\,1_{1\text{ë³ò}}\,\text{ï})} \tag{17}$$

obtained (Tab. 7) indicators of the t-test for statistical estimates of the time of operational deployment.

Tab. 6. Results of calculation of standard error of estimation of time of operative deployment from tankers of light and heavy class taking into account time of year

S(л-т)							
П	К	П	К	П	К	П	К
OP_{1}л	OP_{1}л	OP_{1}т	OP_{1}т	OP_{2}л	OP_{2}л	OP_{2}т	OP_{2}т
0,381	0,567	0,403	0,433	0,810	0,642	0,640	0,717

Tab. 7. Calculation results of t-test for estimation of time of operative deployment from tanker trucks of light and heavy classes taking into account the time of year.

$t_{наб}$							
F	C	F	C	F	C	F	C
OP_{1}л	OP_{1}л	OP_{1}т	OP_{1}т	OP_{2}л	OP_{2}л	OP_{2}т	OP_{2}т
11,39	7,93	2,11	10,69	5,06	14,78	14,88	18,04

Analysis of the results in table 7 shows that in all cases

$$t_{íàáë} => t_{òàáë}(\alpha = 0,05) = 2,04 \qquad (18)$$

That means, the results of the statistical analysis of the experimental results showed that at the significance level α=0,05 the results obtained during the operational deployment at different times of the year from light and heavy class tankers differ significantly.

6. Discussion of the results of an experimental test of how the time of year (meteorological factors) influence the timing of rapid deployment of fire trucks of different class

The analysis of the results shows that the mathematical expectation of the time of operational deployment for the same variants is significantly with the level of significance = 0.05 differs not only depending on the class of fire truck, but also on the level of preparedness of the personnel and the influence of adverse meteorological factors, which actions of rapid deployment of firefighting equipment. It was determined that these factors influenced the results of cadets ($t_{íàáë\ min}(\hat{E}) = 10,69$), to a lesser extent, the results of professional firefighters ($t_{íàáë\ min}(\ddot{I}\ ) = 2,11$).$\alpha$

Strength of the obtained results is obtaining reliable indicators, which are given in table. 3 and Table. 4, which can be the basis for determining specific proposals for the improvement of emergency vehicles of fire trucks, the choice of specific options for operational deployment, as well as the preparation of personnel using standards determined on the basis of the experimental results of the time of operational deployment of fire trucks. This will enhance the operational capabilities of fire and rescue units in the autumn and winter, especially at the stage of initial preparation for the implementation of various options for the operational deployment of fire trucks of different classes.

At the same time, it should be noted that the application of the chosen approach in practical activity is accompanied by the complexity of conducting experimental research, the results of which are the basis for scientifically-based decisions to increase the effectiveness of personnel in the autumn and winter, because to carry out this process highly skilled, skilled have knowledge and skills both in practice of operational activity of fire-rescue units, and in organization of experimental d investigations in such a way that statistically significant results are obtained that will form the basis of the relevant proposals.

7.Conclusions

1. The proposed methodology of experimental research allows both to obtain quantitative estimates of the time of operational deployment (mathematical expectations and standard deviations), which will simultaneously characterize the class of fire truck, the level of readiness of staff and the time of year, and to check on the criterion of students selected factors affect the timing of typical deployments of tanker trucks.

2. The results of the statistical analysis of the experimental results showed that at the significance level = 0.05, the results obtained during the operational deployment of mid-range tanker trucks at different times of the year from the light and heavy class tankers, differ significantly, which confirms the need for increased attention to training various variants of operational deployment in the autumn and winter, as well as the possibility of using the obtained statisticsα2. The results of the statistical analysis of the experimental results showed that at the significance level (mathematical expectations and standard deviations) to substantiate the relevant standards for assessing the quality of preparedness of personnel of fire and rescue units for the operational deployment of fire trucks in different seasons.

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АНАЛІЗ ВПЛИВУ ПОРИ РОКУ НА ОПЕРАТИВНІ РОЗГОРТАННЯ ПОЖЕЖНИХ АВТОЦИСТЕРН РІЗНОГО КЛАСУ

В якості об’єкта дослідження розглядаються чинники, пов’язані з порою року, які можуть ускладнювати оперативне розгортання пожежних автоцистерн різного класу. Оскільки у відповідності до нормативних документів ДСНС України одним з найважливіших критеріїв оцінки ефективності діяльності особового складу пожежно-рятувальних підрозділів є час оперативного розгортання, метою роботи є аналіз впливу пори року на час оперативного розгортання пожежних автоцистерн різного класу. Проте в Україні, як і в інших провідних країнах світу, питання підвищення ефективності оперативних розгортань з урахуванням метеорологічних умов розглянуті недостатньо. Проведені експериментальні дослідження за умов впливу метеорологічних чинників, в яких брали участь курсанти третього курсу Національного університету цивільного захисту України та пожежні штатних пожежно-рятувальних підрозділів ДСНС України, показали, що розподіл часу проведення оперативних розгортань на пожежних автоцистернах легкого, середнього та важкого класів, що стоять на озброєнні в пожежно-рятувальних підрозділах ДСНС України, з рівнем значимості α=0,05 є нормальним. При цьому математичне очікування часу оперативного розгортання для однотипних варіантів суттєво відрізняється не тільки в залежності від класу пожежних автоцистерн, рівня підготовленості особового складу, але й від пори року, яка була на момент проведення визначених варіантів оперативного розгортання. Визначено, що в більшій мірі розглянуті чинники вплинули на результати оперативної діяльності курсантів, в меншій мірі – на діяльність професійних досвідчених рятувальників. Сильною стороною отриманих результатів є визначення достовірних показників, які можуть бути основою конкретних пропозицій щодо вдосконалення аварійно-технічного обладнання пожежних автоцистерн, вибору конкретних варіантів оперативного розгортання, а також підготовки особового складу із застосуванням нормативів, визначених на основі експериментальних результатів часу оперативного розгортання.

Ключові слова: автоцистерна, оперативне розгортання, оперативний розрахунок, пора року, статистичний аналіз, розподіл часу

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Надійшла до редколегії: 28.09.2019
Прийнята до друку: 08.10.2019