The object of the study is the selective dispersion of dangerous parameters of the gas environment during material fires. The practical importance of research consists in using the difference of sample dispersions of dangerous parameters of the gas environment on the intervals of absence and presence of ignition of materials for detection of ignition. The theoretical substantiation of the method of detecting fires in premises based on sample dispersions of current measurements of an arbitrary dangerous parameter of the gas environment, corresponding to the general populations of reliable absence and presence of fire, has been carried out. The method, at a given level of significance, determines the unbiased uniformly most powerful fire detection rule. This makes it possible to determine how much differences in sample variances are significant with a given level of significance and are caused by ignition or are random factors. Laboratory experiments were conducted to verify the proposed method. It was established that the influence of ignition on the value of the difference in the sample dispersion at the corresponding intervals of monitoring the carbon monoxide concentration, smoke density, and temperature of the gaseous environment of the laboratory chamber is different and depends on the type of ignition material. At the same time, the minimum difference of the sample dispersions is characteristic for observing the smoke density for all the studied materials. However, early detection of ignition of alcohol, paper, wood, and textiles when observing the smoke density is carried out when the threshold is exceeded by 9.01, 5.31, 2.13 and 2.55 times, respectively. It is shown that the method of early detection of fires, which is based on the detection of significant differences in sample dispersions of data from the relevant general populations

Keywords: early detection of fire, ignition materials, selective dispersion, hazardous parameters, gas environment

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METHOD FOR EARLY IGNITION DETECTION BASED ON THE SAMPLING DISPERSION OF DANGEROUS PARAMETER

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1. Introduction

Safety refers to basic human needs and is a deficit need. This means that until a person feels safe, s/he cannot properly take care of the needs of a higher order (social and spiritual). Guaranteeing safety involves ensuring a standardized level of absence of threats to the vital interests of a person: his/her life, health, and well-being [1]. Human development has led to the predominance of man-made threats over natural threats. At the same time, threats of the first type became complex, affecting not only the person directly but also disrupting the process of his/her life activity [2]. In peacetime, the main sources of such threats should primarily be considered objects (O) of critical infrastructure [3]. Energy threats are the most dangerous, as they represent not only man-made and ecological danger but also lead to interruptions in the supply of heat and electricity to the population and production facilities [4]. No less dangerous are enterprises of the oil and gas industry, accidents at which have large-scale and long-term consequences [5]. However, the widespread introduction of various digital technologies into control and security systems has led to the emergence of a new dangerous factor from the information technology side [6]. It should be noted that the greatest danger from the point of view of the intensity of dangerous events is represented by fires (P) as a result of burning (Z). P leads to poisoning, injuries, and death of people [7]. At the same time, there is damage to the O themselves, as well as to the elements of their construction [8]. The use of fire extinguishers and means of extinguishing P lead to a negative impact on the environment, causing pollution of reservoirs [9], soil, and also atmospheric air [10]. On a global scale, such an impact leads to acid precipitation, the greenhouse effect, and oncological diseases [11]. The predominant part of P is accounted for by residential, public, and industrial buildings. At the same time, more than half of P is accounted for by residential buildings. However, the greatest material damage is inflicted by P production O (45 %). The maximum number of deaths occurs in residential buildings (80 %) [12]. The indicated negative statistics of P in the world require a significant reduction in their number. The priority directions for reducing the number of P are considered to be the implementation of preventive measures [13], the prediction of P and the use of methods for early detection of sunburn. However, forecasting and preventive measures are aimed at reducing the number of P in the long term [14]. At the same time, early detection of sunburns (ROZ) makes it possible to quickly apply modern systems and means of their suppression with the aim of preventing the occurrence of P. Therefore, early OZ is considered as one of the urgent solutions to the problem of reducing the number and prevention of P in the premises of P.

2. Literature review and problem statement

The results of [15] show that ROZ is the most effective way to reduce the number of P, however, the ROZ maintenance technologies are absent in this work. Any P is a complex process and is characterized by stages of origin, development, and decay [16]. The features of each of the indicated stages of P in the premises are associated with the complex mechanisms of heat release of the source of ignition and the characteristics of absorption and reflection of the heat flow by the enclosing structures [17, 18]. Under these conditions, automation of fire safety systems of premises becomes a priority [19]. The increase in the complexity of the configuration of modern premises and the variety of types of fire loads requires an increase in the sensitivity and accuracy of fire alarm systems [20]. Existing fire alarm and automation systems based on sensors (D) of smoke, heat, and gas have limited fire protection capabilities [21]. The detection of P (VP) in such systems is based on the output signal exceeding the corresponding D set threshold [22]. At the same time, the VP time for various materials and premises can be from tens of minutes to an hour or more. During this time, P usually goes through stages from Z to growth and even full development [16]. In addition, under real conditions, interfering disturbances cause false VPs [23]. However, works [16–23] do not propose methods of ROZ based on second-order sampling moments (VM) for the output signals of traditional DVs. In [24], the dynamics of the bispectrum amplitude of the output signals of traditional DVs are studied. D are not considered. In addition, estimating the amplitudes of the bispectrum of the output signals is a difficult procedure to implement. The use of self-adjusting Ds with adaptive threshold setting for ROZ with guaranteed reliability is studied in [25]. However, the threshold is adapted to the current power of the output signal of the corresponding OP. At the same time, the time of ROZ significantly depends on the initial threshold, which is usually unknown under real conditions.

The ROZ method based on the use of non-traditional D visual observation is considered in [26]. However, ROZ is limited to the detection of smoke and fire. The method is based on color image analysis algorithms and machine learning. However, the complexity of the occurrence of real P under conditions of poor visibility and the presence of foci shaded by objects significantly reduce the effectiveness of such methods [27]. In addition, the use of visual D affects the productivity of employees [28]. Under the conditions of poor visibility and low contrast of the image, it is suggested to use infrared D for ROS [16]. However, the use of D images of different wave ranges entails the use of complex methods of processing output signals, which ultimately leads to a high cost of ROZ. In addition to this, false VP is characteristically based on D images [29]. To improve the quality of OZ under difficult conditions, it is proposed to use a neural network in [30]. The method of deep learning of a neural network for RZ is considered in [31]. However, despite potential possibilities, the method [30, 31] requires a priori a large number of training scenarios for various types of P, conditions of C, illumination, estimates of flame parameters and smoke density. In [32], the results of an experimental study of combustion characteristics for three types of wood under the influence of a heat source of different levels are reported. The presence of two characteristic peaks of the rate of heat release of burning wood and the intensity of smoke has been established. One of the smoked occurs before the wood, and the other after its charring. However, the dynamics of dispersion of temperature and smoke density of HS during wood burning is not considered. In [33], the particularities of the influence of wood burning on the dynamics of the HS temperature are studied. Analogous studies for organic glass and cypress are carried out in [34]. However, in [33, 34], there are no studies of the peculiarities of the dynamics of the dispersion of the main OP HS before and after Z of materials. In [35], the possibilities of the ROZ method based on the group processing of signals from a set of identical Ds and the use of a neural network are explored. The method of group processing of output signals of a set of different types of D is studied in [36]. However, the methods [35, 36] are considered to be quite complex in implementation and require the specification of a special library of the reference dynamics of output signals D for different OPs at Z. ROZ methods based on the comparison of the dispersion of the OP GS at adjacent observation intervals with the use of traditional Ds are not offered and are not investigated. Work [37] reports the method of ensuring the reliability of OZ based on the use of traditional D. The basis of the method is a selective cumulative distribution function for the current recurrence of the vector consisting of OP GS. However, the procedure for determining the recurrence of the vector of the composite OP GS turns out to be essentially parametric, sensitive to the specific dynamics of the composite OP GS with three materials. Under real conditions, information about the current dynamics of OP is usually unknown and may change over time. In [38], an adaptive method for determining the recurrence of a vector consisting of OP GS is proposed. The method [38] is based on the adaptation of the recurrence region to the current dynamics of OP. However, following [38], adaptation of the recurrence region will only make it possible to reduce the number of unknown parameters compared to [25]. At the same time, the method [38] turns out to be quite difficult to implement. In [39], the method of ROZ is proposed, which is based on the use of traditional D OPs and the frequency-time representation of fluctuations of OP GS. However, this method is quite difficult to implement. Simpler methods based, for example, on the sample variance (VD) of the OP are not considered. In [40], the ROS method, based on the assessment of the correlation of current state OPs, is considered. Despite the fact that this method ensures operability in case of irregularity of signals from D, it turns out to be quite difficult to implement and requires significant computing power. In [41], a method for early detection of dangerous state-of-the-art atmospheric air based on a sample window function of uncertainty for the current state vector is proposed. Despite the merits of the method, related to the ability to determine the radial speed of movement of atmospheric pollutants relative to the location of the control post, it remains quite difficult to implement. This limits its use for indoor air pollution control. In work [42], a method for detecting hazardous atmospheric regions based on the use of a window structure function of the current recurrence of the impurity concentration is proposed. In general, this method makes it possible to reveal the dynamics of the level and scale of local heterogeneity of HS impurities. However, this method is difficult to implement. For this reason, its use for indoor air pollution control is limited. At the same time, simpler methods of ROZ based on a comparison, for example, of the dispersion of signals from D OP at adjacent intervals of observation of OP, are not considered. The study of the features of the average bicoherence dynamics of OP GS with Z materials is carried out in [43]. It has been established that features averaged in the range from 0 to 2 Hz of bicoherence of OP HS can be used as a sign of ROZ. However, in [43], the methods of RZ based on the use of average bicoherence are not considered, and the use of this method is associated with mathematical difficulties and is quite complex. In [44], the peculiarities of the use of the empirical cumulative recurrence distribution function of incremental signals at the output of the DOP GS for ROZ are studied. It is noted that the cumulative function can be used as a sign of the appearance of Z in the room. However, the method of ROS based on the cumulative function is not considered in [44]. The application of the current measure of recurrence of incremental OP GS for forecasting P is considered in [45]. It is shown that the current measure of the recurrence of increased OP HS is an effective sign of Z. The accuracy of the forecast P in this case is from 4 % to 13 %. It is noted the prospect of using this feature for RZ. However, the use of the specified feature for RZ is limited by significant computational complexity. At the same time, methods of simplifying the calculation of this characteristic are not considered.

Thus, modern fire protection systems do not provide early fire protection caused by materials in the premises. For early VP, it is proposed to use instead of traditional D OP GS D images in various wave ranges. This requires the use of complex image processing technologies, which have certain limitations and disadvantages. At the same time, the use of traditional DOP GS and modern methods of statistical data processing makes it possible to solve various problems of RZ. However, known methods of processing signals from traditional DOP GS are quite difficult to implement. In addition, for these methods, it is difficult to determine the probabilities of correct and false OZ. That is why there is a need for simpler methods of ROZ based on VM for current signals of traditional DOP GS premises. In this regard, the development of simpler methods of ROZ, based on VM of current measurements, performed by traditional DOP GS, should be considered as an unsolved part of the considered problem of preventing object Ps.

3. The aim and objectives of the study

The purpose of our work is to devise a method for early detection of indoor fires based on the use of different sampling variances for current measurements of an arbitrary hazardous parameter of the gas environment at fixed observation intervals. The detection of such differences in the intervals of the absence and presence of ignition can be considered as a statistical conclusion about the early detection of ignition in the premises for their operational suppression and prevention of object fires.

To achieve the goal of the work, the following tasks are set:

– to perform a theoretical justification of the method of early detection of ignition in the premises on the basis of sample dispersions of the current values of an arbitrary dangerous parameter of the gas environment, observed at fixed time intervals;

– to conduct experiments to verify the proposed method at intervals of reliable absence and presence of ignition of test materials.

4. The study materials and methods

4. 1. The object and hypothesis of the study

The object of this study is OP GS in the case of ignition of materials.

The hypothesis assumed that the sample variances of the current measurements of DOP GS, observed at adjacent fixed intervals, are different, and this difference allows the implementation of RZ in the premises. The accepted assumption was to obtain samples of a large size. The simplification concerned the study of OP GS in LC, which was a kind of leaky room.

4. 2. The study materials

The research materials included the output signals of DOP GS in the laboratory chamber and samples (B) from these signals of a fixed size, corresponding to two general populations, determined by the absence and presence of test materials (TM) in the laboratory chamber (LC). TM was alcohol (burning rate 33000 kg/m^{2}s, lower heat of combustion 13400 kJ/kg), paper (burning rate 8000 kg/m^{2}s, lower heat of combustion 27200 kJ/kg), wood (burning rate 14000 kg/m^{2}s, lower heat of combustion 13800 kJ/kg) and textiles (staple fiber) (burning rate 6.7 kg m^{-2} s^{-1} 10^3, lower heat of combustion 13800 kJ/kg). The CO concentration, smoke density, and temperature of HS were measured in LC [46]. Temperature measurements were made by D TPT-4 (Ukraine) [48], smoke density by D IPD-3.2 (Ukraine) [48], and CO concentrations by D Discovery (Switzerland) [49]. It was assumed that the peculiarities of the influence of Z TM on the temperature, smoke density, and CO concentration of HS in LC are similar to those of the same TM in real rooms [50].

4. 3. The study methods

The main research method was the sampling method. The sample values of the output signals D, corresponding to the two general sets of OP GS, were independent. It was assumed that the first general set of OP measurements corresponded to the reliable absence of Z TM in LC. This aggregate served as a training aggregate. The second general set of OP GS measurements adjacent to the first one corresponded to the verifiable presence or absence of Z TM in LC. To measure the OP of HS [51], corresponding to the indicated adjacent general populations, D were used, which were located in the upper region of LC, which is characteristic of the maximum heterogeneity of HS during the ignition of materials [52]. The time-continuous signals from the D specified OPs of the GS were subjected to time discretization with an interval of 0.1 seconds. Discrete signals D for each investigated OP GS were stored in a PC for their subsequent analysis. In the course of the analysis, adjacent V of a fixed size of 100 measurements were extracted from the discrete signals of the DOP GS. This dimension B ensured their representativeness to the corresponding general populations, as well as the approximation of the distribution for the VD to the Gaussian distribution. On the basis of the comparison of the calculated VDs and their standard errors with a given level of significance, ROZ was carried out. At the same time, ROZ was performed first for alcohol, and then for paper, wood, and textiles. After each of the indicated TMs, natural ventilation of the LV was carried out for 5–7 minutes. Natural ventilation of the LV was intended to restore the initial state of the HC after each TM. The method of calculating the VD and their standard errors was carried out in accordance with the methodology given in [53].

5. Devising a method for early detection of ignition

5. 1. Theoretical justification of the ignition detection method

Early ignition of materials in unpressurized rooms affects the parameters of HS. The main OPs for humans are usually temperature, CO concentration, smoke density, as well as derivatives of these parameters. The specified parameters can be used for ROP and prevention of P [54]. Let's consider an arbitrary OP GS. Let B be produced by this parameter of fixed size m. In this case, the statistical properties of a given B $x1$, $x2$, ..., xm, where m=1, 2,..., m will be completely described by its sample distribution function $F(x)$ [53]. However, due to the complexity of use, its simpler characteristics in the form of corresponding VMs are often considered instead of $F(x)$ [55]. The first primary and second central VMs are most used in applications. In this case, the first moment characterizes the position (mathematical expectation) of data B, and the second – the dispersion (variance or standard deviation) of data B. Therefore, the ROZ problem can be stated in the form of checking the specified VMs for two general populations of values of an arbitrary OP GS, corresponding to the reliable absence and the presence of Z. In this case, the general population corresponding to the absence of Z is the training population, and the population corresponding to the presence of Z is the test population. Let the Bs extracted from the training and testing populations be described by the corresponding sample distribution functions $F1(x)$ и $F2(x)$. Then in the absence of 3 $F1(x)\approx F2(x)$, and in the case of 3 $F1(x)\neq F2(x)$. Similar relationships will be valid for the corresponding VMs of the specified sample distributions. Let us choose to check $F1(x)$ and $F2(x)$ their second-order central moments (CS). Let there be B of size $m1$ values of an arbitrary OP $x11$, $x12$,..., $x1m$, where m=1, 2,..., $m1$ from the training population for this parameter. Then B size $n2$ values of the same OP $x21$, $x22$,..., $x2n$ are produced, where 1, 2,..., $n2$ from the population being checked. Then the ROZ method can be based on the results of testing sample central moments of the specified B from the corresponding general populations. In this case, the training B must precede the B from the tested population. This means that $x11$, $x12$,..., $x1m$ must precede in time B $x21$, $x22$,..., $x2n$. In this case, the temporal localization of ROZ or its absence is determined accurate to the position of the interval B $x21$, $x22$,..., $x2n$ on the time axis. To increase the efficiency of OZ in this case, it is advisable to reduce the size of B and consider them on the time axis as adjacent B. However, the implementation of this approach is associated with well-known mathematical difficulties [54]. To overcome this, it is proposed to use large B, the sizes $m1$ and $n2$ of which are at least 100 OP values. Following [56], for most VMs we can assume that they asymptotically approach a Gaussian distribution. In this case, the degree of approximation increases with increasing size B. Let us denote by $S1$ and $S2$ the sample central moments of the second order, determined by B $x11$, $x12$,..., $x1m$ and $x21$, $x22$,..., $x2n$, respectively:

$$S1=\sum_{i=1}^{m1}\left(x1i-X1\right)^2/m1, \quad (1)$$

$$S2=\sum_{i=1}^{n2}\left(x2i-X2\right)^2/n2, \quad (2)$$

where $X1=\sum_{i=1}^{m1}x1i/m1$ and $X2=\sum_{i=1}^{n2}x2i/n2$ define the corresponding sample initial moments of the first order. Let $S2$ be different from $S1$. In other words: what should be the difference $S1$–$S2$ in order to consider it significant and assert that the true moments of the general populations under consideration are really different and are not caused by random reasons, but by Z. Following [56], the difference $S1$–$S2$ can be investigated using the results of the theory of standard errors. For large B, following [56], we assume that (1) and (2) are determined by asymptotic Gaussian distributions:

$$S1,\sqrt{\left(\mu1_4-S1^2\right)/m1} \text{ and } S2,\sqrt{\left(\mu2_4-S2^2\right)/n2},$$

in which:

$$\mu1_4=\sum_{i=1}^{m1}\left(x1i-X1\right)^4/m1 \text{ and } \mu2_4=\sum_{i=1}^{n2}\left(x2i-X2\right)^4/n2$$

define the corresponding sample central moments of the fourth order, and the quantities:

$$\sqrt{\left(\mu1_4-S1^2\right)/m1} \text{ and } \sqrt{\left(\mu2_4-S2^2\right)/n2}$$

characterize the standard errors of determination of $S1$ and $S2$ for B $x11$, $x12$,..., $x1m$ and $x21$, $x22$,..., $x2n$. Taking this into account, the difference $S1–S2$ will be characterized by an asymptotic Gaussian distribution, defined as:

$$S1-S2,\sqrt{\left(\mu1_4-S1^2\right)/m1+\left(\mu2_4-S2^2\right)/n2}.$$

This means that the normalized difference:

$$\xi=\left(S1-S2\right)/\sqrt{\left(\mu1_4-S1^2\right)/m1+\left(\mu2_4-S2^2\right)/n2}$$

will have an asymptotic Gaussian distribution (0, 1). In this case, the probability of the value ξ falling into an arbitrary interval will be determined using the Laplace function table [56]. Thus, the ROZ method based on testing the difference $S1–S2$ can be formulated as a problem of testing the corresponding null hypothesis. Let the null hypothesis (H_0) be that $S1–S2=0$. In this case, the competing hypothesis (H_1) means that $S1–S2\neq0$. To test these hypotheses, it is necessary to determine the two-sided critical region, based on the requirement that the probability of the normalized difference ξ falling into this region, if the null hypothesis is true, is equal to the accepted significance level α (probability of a false CV). In this case, the greatest power of such a rule is achieved in the case when the "left" and "right" critical points are chosen so that the probability of the normalized difference falling into each of the two intervals of the critical region is equal to α/2. Considering that the normalized difference ξ in the case of the null hypothesis has a Gaussian distribution (0, 1), symmetric about zero, the critical points will be symmetric about zero. This means that the probability of the normalized difference ξ falling into the interval from 0 to ∞ is 0.5. This implies a method for determining the boundary of the two-sided critical region for the normalized difference ξ based on the argument of the Laplace function, which corresponds to a function value equal to (1–α)/2. Taking this into account, the ROZ method will be determined by the inequality:

$$\left|S1-S2\right|>\Delta_k\sqrt{\left(\mu1_4-S1^2\right)/m1+\left(\mu2_4-S2^2\right)/n2}, \quad (3)$$

where Δ_k is the argument of the Laplace function, which corresponds to a function value equal to (1–α)/2. In this case, the area of acceptance of the null hypothesis (absence of Z) taking into account inequality (3) will be determined as:

$$\left|S1-S2\right|<\Delta_k\sqrt{\left(\mu1_4-S1^2\right)/m1+\left(\mu2_4-S2^2\right)/n2}. \quad (4)$$

Taking into account relations (3) and (4), the proposed ROZ method with a given significance level α (probability of false discovery), defined by (3), will provide the greatest power (probability of correct OD). The fulfillment of the inverse inequality (4) indicates the absence of 3 and the validity of the null hypothesis. Moreover, from inequalities (3) and (4) it follows that to increase the ability of the method to detect small values of the difference $|S1–S2|$ the value of the right side of inequality (3) should be reduced. For a given level α, this can be accomplished by increasing the size of the corresponding B. If the size of B $m1=n2=p$, then the ROZ method will be determined by rule (3) of the form:

$$\left|S1-S2\right|>\Delta_k\sqrt{\left(\mu1_4-S1^2+\mu2_4-S2^2\right)/p}. \quad (5)$$

In expression (5), the value of the size B p should ensure an asymptotic approximation of the distribution $S1–S2$ to the Gaussian distribution. For large sizes p B (about 100), the proposed method is valid even when the values of an arbitrary OP of GS differ from the Gaussian distribution. This is explained by the fact that the VMs $S1$ and $S2$ are determined by the sum of a large number of terms, each of which has only a relatively small variance. Following [57], it can be shown that method (5) at a given significance level provides a uniformly unbiased most powerful OP rule. This means that rule (5) provides the maximum probability of OP for a given significance level. At the same time, in [58] it is noted that even in cases where the size B turns out to be smaller or when the sampling distribution does not tend to Gaussian, it is often possible to obtain a solution to the problems posed using standard errors.

5. 2. Experimental verification of ignition detection method

The verification of the proposed VD-based ROZ method for measuring the considered OP GS was carried out by conducting a laboratory experiment at 3 alcohol, paper, wood, and textiles in LC. The results of the experimental verification of the ROZ method (5) with a significance level of α=0.05 for measurements of CO concentration, smoke density, and HS temperature in LC at 3 HM are given in Tables 1–3, respectively.

Table 1

Results of verification of method (5) for carbon monoxide concentration

No. of entry	Param/material	Alcohol	Paper	Wood	Textile
1	$\|S1–S2\|$	6.391	1.575	0.541	0.012
2	$\Delta_k\|S1–S2\|$	1.157	0.315	0.1	0.00263
3	Solution (5)/Excess	+/5.52	+/5.00	+/5.41	+/4.56

Table 2

Test results of method (5) for smoke density

No. of entry	Param/material	Alcohol	Paper	Wood	Textile
1	$\|S1–S2\|$	0.046	0.045	0.00128	0.012
2	$\Delta_k\|S1–S2\|$	0.0051	0.00848	0.0006	0.0047
3	Solution (5)/Excess	+/9.01	+/5.31	+/2.13	+/2.55

Table 3

Test results of method (5) for temperature

No. of entry	Param/material	Alcohol	Paper	Wood	Textile
1	$\|S1–S2\|$	9.174	2.241	0.2	0.62
2	$\Delta_k\|S1–S2\|$	1.328	0.688	0.041	0.171
3	Solution (5)/Excess	+/6.91	+/3.26	+/4.88	+/3.63

In Tables 1–3, rows are highlighted in orange in which the plus sign in the numerator indicates the decision on OP based on (5), and the denominator indicates the numerical value of the module exceeding the VD difference of the corresponding threshold.

6. Discussion of results of testing the early detection method

From the results (Tables 1–3), it follows that the proposed method with a significance level of α=0.05 allows the OD of the studied TMs based on a comparison of the VD measurement data of the studied OPs measured by traditional D in LC. At the same time, from the Table 1 it follows that the ROS of alcohol, paper, wood, and textiles based on measuring the concentration of carbon monoxide GS in LC occur when the threshold is exceeded by 5.52, 5.00, 5.41, and 4.56 times, respectively. Following Table 2, ROS TM based on smoke density measurements occur when the threshold is exceeded by 9.01, 5.31, 2.13, and 2.55 times, respectively. Based on temperature measurements (Table 3) – 6.91, 3.26, 4.88, and 3.63 times, respectively. From the analysis of data in Tables 1–3 it follows that the proposed method (5) makes it possible to carry out ROZ with a given level of significance based on data from the D OP GS in LC for all studied TMs. In this case, the influence of 3 on the difference in HP for CO concentration, smoke density, and temperature of GL LK turns out to be different and depends on the GL material. For example, the maximum difference in VP for CO concentration and GL temperature occurs for alcohol (6.391 and 9.174) and paper (1.575 and 2.241), respectively. The minimum difference in VD is characteristic of smoke density for almost all HMs. However, despite this, the ROZ of alcohol, paper, wood, and textiles based on the use of smoke density measurements is carried out when a threshold is exceeded by 9.01, 5.31, 2.13, and 2.55 times, respectively. This means that the smoke density can be considered from the point of view of ROZ in accordance with (5) similar to the CO concentration and HS temperature. It should be noted that the proposed ROZ method is based on identifying the significance of differences in VD in data from the general populations under consideration. Thus, the proposed method, taking into account a given level of significance, makes it possible to carry out RP of materials based on the VD of OP GS, measured by traditional D. At the same time, it can be assumed that the use of the proposed method in modern technologies of early VP due to the RP function will sure change the growing global trend of emergencies due to P [59]. This will reduce the number of deaths, damage to equipment, as well as their structural elements [60]. It will reduce the negative impact on the environment [61], as well as reduce the amount of damage from P [62]. The results of the study generally do not contradict the known data [63]. The peculiarity of the method is the comparison of VD for output signals of traditional large-sized Ds belonging to two adjacent general populations of OP GS. The limitations of this study include the selection of a finite set of types of TM and OP GS in LC. At the same time, the disadvantage of the study is the impossibility of the method of point-time localization of ROZ in real time for observing the OP of GE.

Further development of the research should be aimed at overcoming these limitations and the noted drawback, as well as conducting large-scale fire tests in real premises.

7. Conclusions

1. A theoretical substantiation of the method for early detection of ignition in premises was carried out based on a comparison of sample dispersions of the current values of an arbitrary dangerous parameter of the gaseous environment, observed at two fixed time intervals. In this case, the sampling time intervals correspond to two adjacent general populations. The first is characterized by a reliable absence of ignition and is called the training set, and the second is characterized by the unknown presence of ignition and is called the tested set. The method, at a given significance level, provides a uniformly unbiased, most powerful fire detection rule. This allows us to establish to what extent the identified differences in the sample variances of the means are reliable with a given level of significance and are caused by the combustion of materials, and not by random factors.

2. Laboratory experiments were carried out to test the proposed method for early detection of fires based on a comparison of sample dispersions of dangerous parameters of the gas environment at intervals of reliable absence and presence of fires of test materials. It is shown that for a significance level of 0.05 the method allows for early detection of fires in alcohol, paper, wood, and textiles. It has been established that the effect of ignition on the magnitude of the difference in the sample dispersion at the corresponding observation intervals of CO concentration, smoke density, and temperature of the gaseous medium of the laboratory chamber is different and depends on the type of ignition material. When observing the density of smoke, the detection of ignition of alcohol, paper, wood, and textiles is carried out when the threshold is exceeded by 9.01, 5.31, 2.13, and 2.55 times, respectively.

Conflicts of interest

The authors declare that they have no conflicts of interest in relation to the current study, including financial, personal, authorship, or any other, that could affect the study and the results reported in this paper.

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Data availability

The data will be provided upon reasonable request.

Use of artificial intelligence

The authors confirm that they did not use artificial intelligence technologies when creating the current work.

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