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IMPROVEMENT OF EXPLOSION HAZARD MONITORING SYSTEMS FOR TECHNOGENIC FACILITIES

Abstract. The purpose of this work *is to find solutions aimed at improving the explosion hazard monitoring systems of man-made facilities in the presence of a multicomponent fuel-air mixture by means of an integrated explosion hazard assessment and improving the accuracy of control equipment.*

Materials and methods. *Analytical methods for studying the process of oxidation of combustible gases and vapors on catalysts based on the classical provisions of electrical engineering, thermodynamics and catalysis, experimental studies of serial single-chamber thermocatalytic sensors of pellet type with a platinum-palladium catalyst when they operate in a multicomponent fuel-air mixture, evaluation and generalization of the results of theoretical and experimental studies were used in this work.*

Results. *The peculiarities of the oxidation process of combustible gases and vapors in thermocatalytic sensors with a non-selective platinum-palladium catalyst under changing the temperature regime of the working thermocouple were established. It has been shown that thermocatalytic sensors with a non-selective platinum-palladium catalyst under a certain temperature regime of operation allow for an unambiguous assessment of the explosiveness of such components as methane, butane, and heptane, which allows for an integrated assessment of the explosiveness of a multicomponent fuel-air mixture. For the studied sensors, this is ensured by selecting a preheating temperature of* 350^0C *for the working thermocouple in the air.*

Scientific novelty. *The conditions under which thermocatalytic sensors with a non-selective platinum-palladium catalyst allow for an integrated unambiguous assessment of the explosive hazard of the environment, including in the presence of a multicomponent fuel-air mixture, have been established.*

Practical significance. *It consists in establishing the conditions under which it is possible to unambiguously assess the explosive properties of fuel-air mixtures, including multicomponent ones, using a single thermocatalytic sensor, which reduces the cost of explosion monitoring systems and increases the reliability of explosion control under conditions where various explosive gases and vapors of volatile combustibles can simultaneously accumulate in the air.*

Keywords: *hazard, combustible gases, fuel, monitoring systems, sensors, integrated explosion hazard assessment.*

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Introduction

Technogenic objects that use or store explosive gases and volatile combustibles pose a danger to humans and the environment. In addition, explosions of gas-air and fuel-air mixtures lead to significant material losses, destruction of buildings, structures, machinery, process equipment, equipment, etc. [1]. Reducing the risk caused by explosions of such mixtures is achieved both by preventing the possibility of such hazardous events and by developing measures aimed at reducing the severity of their consequences.

One of the main measures aimed at reducing the likelihood of explosions is automatic continuous monitoring of the content of explosive gases or vapors in places of their possible release into the air, which allows timely decisions to be made to prevent the formation of explosive mixtures and to eliminate possible sources of ignition of such mixtures [2].

With the development of information technology, systems for monitoring the safety of man-made facilities are becoming increasingly common. In this case, explosion hazard monitoring is a continuous observation of the content of explosive gases or vapors in places of their possible release into the air in order to assess the hazard, predict risks and take measures to minimize or eliminate them. Today, almost all modern monitoring systems are based on computers and information systems. In this case, monitoring systems are transformed into computer-based monitoring systems [3].

The issue of explosive hazards at man-made facilities is becoming increasingly acute nowadays, when artillery and rocket attacks on enterprises and settlements, the use of aircraft, and the fall of debris from downed air targets pose a high threat of damage to the integrity of tanks and transportation routes containing explosive gases and volatile flammable liquids. Therefore, given the significant increase in the risk of explosions and fires at man-made facilities, research aimed at preventing them is of particular importance.

Analysis of recent research and publications

The development of methods and means for monitoring the content of explosive gases and vapors of volatile combustibles is the subject of research by many scientists [4], [5]. Among the control means currently used for these purposes, the most common are those based on thermocatalytic, semiconductor and optical methods.

Coal mine explosion hazard monitoring systems mainly use thermocatalytic sensors [4]. They are characterized by a simple design, low cost, and are able to ensure stable operation of the control equipment in difficult underground operating conditions characterized by high humidity, significant air dust, the presence of uncontrolled gas components, and the possibility of significant methane overloads in case of emergency gas gassing of mine workings [5].

Semiconductor (metal oxide) sensors are also simple in design and relatively inexpensive. Their advantage is high sensitivity and long service life. However, these sensors are quite sensitive to overloads [6] and are not stable enough in time, especially when monitoring high concentrations of vapors or gases, which imposes certain restrictions on their use in monitoring systems for the explosive hazard of objects [6]. They are widely used in ventilation and air purification systems and in portable gas analyzers [7]. Semiconductor methane sensors and propane sensors are used in explosion monitoring systems.

Sensors based on the optical absorption method are the fastest, but are quite vulnerable to changes in temperature, pressure, humidity, and various gas impurities. A significant factor limiting the use of these sensors is air dustiness, smoke, and smog in the place of their installation. Known solutions aimed at reducing the impact of these factors on the operation of optical sensors [8], [9] significantly complicate both the sensors and the control means, and increase their cost. Therefore, the use of such sensors in explosion hazard monitoring systems is justified only when it is impossible to meet the necessary requirements for the response time of protective equipment when using thermocatalytic or semiconductor sensors.

Other well-known methods for monitoring explosive gases and vapors of volatile combustibles include flame ionization, photo-ionization, and chromatographic methods [10], [11]. Control devices based on these methods are quite sensitive and allow monitoring the content of maximum permissible concentrations of gases and vapors. However, such devices are quite complex and expensive, which actually excludes the possibility of their use in explosion hazard monitoring systems. Their application in monitoring systems is most often limited to environmental monitoring.

The analysis and practice of using sensors for monitoring the content of explosive gases and vapors of volatile combustibles [12] indicate that thermocatalytic and semiconductor sensors should be preferred in the development and implementation of explosion hazard monitoring systems for man-made facilities.

Currently, in Ukraine, VARTA 1 gas detectors of various modifications are used for automatic continuous monitoring of pre-explosive concentrations of combustible gases and volatile combustible vapors (except in coal mines) [12], which consist of a control unit and separate measuring devices in the amount of up to 24 (VARTA 1-03.24). Measuring devices consist of two parts: a housing with a processor board and a head with a thermocatalytic or semiconductor sensor. The method of supplying the air mixture to the sensor is diffusion. The required number of measuring devices and their combination by type is determined by the customer depending on the required number of control points and the number of explosive components. Separate measuring devices are used in the gas alarm to control the explosion hazard for monitoring the methane content DM-24, propane content DP-24 and combustible gas content DGG-24. The latter is adjusted using calibration mixtures for a specific type of combustible gases or vapors of volatile combustibles, and when monitoring the content of gasoline vapors – by hexane. The DM-24 and DP-24 measuring devices use semiconductor sensors, while the DGG-24 uses thermocatalytic sensors.

When different combustible gases and vapors of volatile combustibles, such as methane, butane, propane, gasoline vapors, diesel fuel, can enter the air at the same time, the use of this gas detector requires the installation of several measuring devices configured or responding to certain types of explosive substances. This significantly complicates the control system and increases both its initial cost and maintenance costs. In addition, the overall error of measuring the concentration of a particular component, or the alarm for this component, is significantly affected by the presence of other combustible vapors or gases, which causes its significant value. For example, at the value of the first alarm threshold in the presence of methane of 0.5% by volume, the permissible basic absolute error of the alarm for the main component is ±0.25% by volume, for other combustible components ±0.45% by volume, and due to the influence of temperature and humidity limits ±0.35% by volume. Obviously, with such values of methane measurement error, the alarm can be triggered both in the absence of methane in the air and only after exceeding the second alarm threshold. The same situation is possible for the other measured components.

In view of the above, research on monitoring the explosive hazard of man-made facilities, especially in terms of improving methods and means of controlling the content of explosive gases and vapors of volatile combustibles, is a very urgent task.

The aim of the work is to find solutions that allow improving the system of monitoring the explosiveness of man-made objects by integrating the explosiveness of a multicomponent fuel-air mixture and increasing the reliability of its control equipment.

Research methods

Analytical methods of studying the oxidation of combustible gases and vapors on catalysts based on the classical provisions of electrical engineering, thermodynamics and catalysis, experimental studies of serial single-chamber thermocatalytic sensors of pellet type with a platinum-palladium catalyst when they operate in a multicomponent fuel-air mixture, evaluation and generalization of the results of theoretical and experimental studies were used in this work.

Presentation of the main material

The explosive properties of a fuel-air mixture, provided that various combustible gases and vapors of volatile combustibles may be present in the air at the same time, do not depend on the content of one single component, but are determined by their combination and the properties of each component. Provided that each component of the mixture does not affect the oxidation reaction of other components, the condition under which the mixture becomes explosive can be represented by the following expression

$$\frac{C_1}{C_{LEL1}}+\frac{C_2}{C_{LEL2}}+.....+\frac{C_n}{C_{LELn}}\geq 1, \tag{1}$$

where C_1, C_2, C_n – is the concentration of components in the mixture, in kg/m^3 or % volume; $C_{LEL1}, C_{LEL2}, C_{LELn}$ – is the lower ignition limit (LEL) of the mixture for each individual component, respectively, in kg/m^3 or % volume.

In this case, when setting the first alarm threshold at 10% of the LEL of a multicomponent fuel-air mixture, the alarm condition can be represented as follows

$$\frac{C_1}{C_{LEL1}}+\frac{C_2}{C_{LEL2}}+.....+\frac{C_n}{C_{LELn}}\geq 0{,}1. \tag{2}$$

In the presence of measuring devices that monitor the content of each individual combustible component, provided that different combustible gases and vapors of volatile combustibles (e.g. methane, butane and gasoline vapors) can simultaneously enter the air, the fact of reaching the first alarm threshold can be determined by calculating the total current value of the ratio of the concentration of components in the mixture to their LEL. If the VARTA 1-03.24 gas detector is used in the monitoring system to control the explosive properties of a multicomponent fuel-air mixture, additional processing of information on the content of individual components or appropriate modification of the software of this gas detector is required in the monitoring system.

It should be noted that determining the alarm threshold by calculation based on the current value of the content of individual components is far from an optimal solution. The reason for this is the presence of significant errors in measuring the concentration of each individual component, primarily those caused by the presence of other combustible vapors or gases and characterized by unidirectional action. As a rule, when a measuring device is adjusted to a specific combustible component, the presence of other combustible components leads to an overestimation of the readings of the measuring devices (error with a + sign). Obviously, this increases the likelihood of false alarm activation. In addition, with this approach to determining the threshold, it is necessary to have separate measuring devices to determine the concentration of each component, which greatly complicates and increases both the initial cost of the system and the cost of its maintenance.

Another solution is to use sensors that directly provide an integrated assessment of the explosiveness of a multicomponent mixture. Among all the control methods considered, the only method that can be used to create such sensors is thermocatalytic, since regardless of the type of combustible component, it is oxidized on a catalytically active thermocouple, which is accompanied by heat generation, an increase in its temperature and resistance.

Today, the most widely used thermocatalytic sensors consist of two sensitive thermoelements – a working (active) and a comparative one. The thermoelements have the same geometric dimensions and electrical parameters. They are placed in a reaction chamber made of porous ceramics or metal-ceramic an internal diameter of 5-6 mm [4]. The analyzed mixture enters the reaction chamber mainly due to its diffusion caused by the presence of a gas concentration gradient. The sensing elements of modern sensors look like a miniature ball made of aluminum γ-oxide, inside which there is a platinum wire spiral that simultaneously serves as a heating element and a resistance thermometer. The surface of the catalytically active element is coated with a platinum-palladium catalyst. The working and compensation elements are most often included in one arm of a bridge measuring circuit [4]. Heat from the elements is mainly removed by thermal conduction, convective heat transfer and radiation.

At low concentrations of combustible gases or vapours and an excess of oxygen in the controlled gas mixture, it can be assumed that each combustible component diffuses independently to the surface of the fuel element at a rate determined by its diffusion coefficient. The thermal effect of each fuel component is also independent, and the total heat release on the fuel element from the oxidation reaction of combustible components P_Σ is equal to the sum of the thermal effects of all components

$$P_\Sigma = \sum_{i=1}^{n} Q_i C_{rki} \gamma_{ei} \ , \tag{3}$$

where Q_i – is the lower calorific value of the *i*-th fuel component, J/kg; C_{rki} – is the concentration of the *i*-th component in the reaction chamber, kg/m^3; γ_{ei} – is an effective diffusion conductivity of the fuel element relative to the *i*-th component, m^3/s.

In general, the effective diffusion conductivity of the element is determined by its geometric parameters, the oxidation efficiency of the fuel component on the element surface, and the parameters of mass transfer to its surface [4].

$$\gamma_e = 10^{-2} k_e \beta_e F_e, \tag{4}$$

where k_e – is an oxidation efficiency of the fuel component; β_e – is the mass transfer coefficient, m/s; F_e – is the element surface area, m^2.

The oxidation reaction of combustible gases and vapors on a platinum-palladium catalyst can occur in the kinetic and diffusion domains [4].

The rate of the oxidation reaction in the kinetic region depends on the type and temperature of the catalyst, as well as the concentration of the reacting components. When controlling pre-explosive gas or vapor concentrations in the range up to 0.2 LEL, when the oxygen concentration in the mixture is significantly higher than the concentration of combustible components, it can be assumed that the oxidation reaction rate in the kinetic region is determined by the content of combustible components. In the case of methane oxidation over a platinum-palladium catalyst, this region is characteristic at a temperature of the thermocouple up to 360 ^{0}C. Oxidation is accompanied by simultaneous adsorption of oxygen and combustible components by the catalyst surface. At higher catalyst temperatures, the chemical reaction rate increases to the point where a zero methane concentration and some oxygen deficiency are formed on the active surface of the thermocouple. The reaction rate and, consequently, the amount of heat generated in this case is determined by the rate of methane diffusion to the surface of the thermoelement. For a platinum-palladium catalyst, the diffusion region occurs at temperatures above 360 ^{0}C during methane oxidation [4]. For other hydrocarbons (propane, butane, hexane, etc.) and volatile fuel components, due to their lower self-ignition temperatures, the diffusion region occurs at much lower temperatures.

The mass transfer coefficient depends on the diffusion properties of the fuel component and can be generally represented as [4].

$$\beta_i = D_i / \delta_D, \tag{5}$$

where D_i – is the molecular diffusion coefficient of the *i*-th fuel component in air, m^2/s; δ_D – is the thickness of the diffusion boundary layer, m.

The analysis of the above expressions shows that at a constant gas and element temperature, the power released on the working element due to the oxidation of the *i*-th fuel component is determined by the properties of the catalyst, the design of the element and is proportional to the product of its concentration in the chamber, the lower heating value of the component and its diffusion coefficient. In the ideal case, when the oxidation reaction of all components occurs in the diffusion region, the oxidation efficiency of fuel components included in expression (4) is $k_e = 1$ and expression (1) can be represented as

$$P_{\Sigma} = K_s \sum_{i=1}^{n} Q_i C_{rki} D_i, \qquad (6)$$

where K_s – is the coefficient that takes into account the design features of the sensor and the properties of the catalyst, m.

In fact, when using serial thermocatalytic sensors with a platinum-palladium catalyst, it is impossible and impractical to realize the temperature regime of thermoelements at which the oxidation reaction of all components occurs in the diffusion region. The reason for this is that at temperatures above 360 ^{0}C, as a prerequisite for the methane oxidation reaction to occur in the diffusion region, higher methane homologues and many other fuel components characterized by a significantly lower self-ignition temperature are oxidized not only on the catalytically active element but also on the comparison element. In addition, when a thermocatalytic sensor operates in a mode that ensures the oxidation of all components of the mixture in the diffusion region, it is impossible to ensure the unambiguousness of the alarm, for example, at a content of 0.1 LEL of each individual component. This is due to the fact that the sensitivity of the sensor to the components of the mixture is not proportional to their NMW. Table 1 shows information about the properties of combustible gases and gasoline components, as well as the relative sensitivity (for hexane) of the thermocatalytic sensor when it operates in the diffusion region and the value of the first alarm threshold for different components when the sensor is tuned for hexane.

Table 1. Characteristics of combustible gases and components of gasoline vapors and the relative sensitivity of the thermocatalytic sensor to them (for hexane)

The name of a gas or fuel component	Diffusion coefficient, $D \cdot 10^6$ m^2/s	Specific heat of combustion, MJ/kg	Molecular weight, a.o.m.	LEL		Relative sensitivity		1st threshold, %vol.		k_e
				%vol.	kg/m^3	per unit of mass	by %vol.	calcu-lation	neces-sary	
Methane	19,6	55,7	16	5,0	0,036	3,3	0,59	0,20	0,50	0,4
Ethane	11,6	52,1	30	3,2	0,043	1,9	0,63	0,19	0,32	0,58
Propane	9,4	46,0	44	2,2	0,045	1,3	0,65	0,17	0,22	0,71
Butane	8,2	45,7	58	1,8	0,046	1,15	0,81	0,15	0,18	0,83
Pentane	7,29	45,4	72	1,4	0,047	1,02	0,86	0,14	0,14	1
Hexane	7,21	45,1	86	1,2	0,048	1,00	1,0	0,12	0,12	1
Heptane	6,65	44,9	100	1,0	0,049	0,92	1,07	0,11	0,10	1,02
Octane	6,10	44,8	114	0,96	0,051	0,84	1,23	0,097	0,096	1,05
Decane	5,60	44,6	142	0,78	0,052	0,77	1,27	0,095	0,078	1,20
Benzene	8,95	40,6	78	1,4	0,050	1,12	0,99	0,12	0,14	0,85
Ethanol	11,9	29,0	46	3,1	0,064	1,06	0,54	0,22	0,31	0,71
Hydrogen	66	287	2	4	0,004	58,2	1,3	0,92	0,4	2,27

These data show that in this mode of operation, when the sensor is set to 0.1 NMW for a particular component, for example, hexane, in the presence of methane, the first threshold alarm will be triggered not when it reaches 0.5% vol. but when it reaches 0.2% vol. which is 0.04 NMW. Accordingly, for propane – 0.06 LEL, butane – 0.08 LEL. Thus, when all combustible components are oxidized in the diffusion region, it is impossible to ensure the unambiguousness of the alarm when using a single sensor, both for individual components and for a multi-component fuel-air mixture.

Consider the possibility of unambiguously assessing the explosive properties of a multicomponent mixture for the case when methane, butane and hexane can simultaneously accumulate in the air, according to which it is customary to set up an alarm in the presence of gasoline vapor, by changing the temperature regime of the thermocatalytic sensor. When selecting the temperature of preheating of the thermoelements at which there will be no oxidation of combustible components on the comparison element, the oxidation reaction of some components characterized by a high auto-ignition temperature will occur in the kinetic region. For these components, the oxidation efficiency coefficient can be significantly less than unity. In this case, expression (6) must be supplemented with the oxidation efficiency coefficient and it takes the following form

$$P_{\Sigma} = K_S \sum_{i=1}^{n} k_{ei} Q_i C_{rki} D_i, \tag{7}$$

From the obtained expression (7), it can be seen that in this case, the heat generation at the working thermocouple depends on its content, the efficiency of its oxidation, and the product of the lower heating value of the component and its diffusion coefficient.

Based on expression (7) and the data of Table 1, the theoretical value k_e was calculated at which the same value of the 1st threshold of alarm operation for combustible components is ensured at the level of 0.1 LEL (Table 1). Based on the above data for a three-component mixture (methane, butane, and hexane), the sensitivity of the detector to methane and butane should be reduced (relative to the sensitivity when the reaction occurs in the diffusion region), respectively, by 2.5 and 1.2 times.

To evaluate the possibility of performing an integrated assessment of the explosive properties of a multicomponent mixture by changing the temperature regime of the thermocatalytic sensor for the case when methane, butane, and hexane can simultaneously accumulate in the air, we observed the change in the output signal of serial thermocatalytic sensors used in the AT-3-1 and AT-3-3 mine methane analyzers when their temperature regime changes. For the study, 10 sensors with a non-selective platinum-palladium catalyst were used. The sensors were connected to the measuring bridge and installed in a small-sized chamber, which was first filled with clean air (to set the bridge zero), and then with certified gas mixtures with pre-explosive concentrations of components. The measuring bridge was powered by a stable current source, the value of which consistently varied from 170 to 230 mA, with a gradation of 5 mA. After each increase in current, with a time delay of 10 s (sufficient for the end of transients), the output voltage of the measuring bridge was read. For all sensors (with a slight variation in absolute values), the dependence of the output voltage of the sensors on the current through the thermoelements for different combustible components was identical. A characteristic view of the dependence of the output voltage of the sensors on the value of the current through the thermoelements when pre-explosive concentrations of combustibles are supplied to the chamber is shown in Fig. 1.

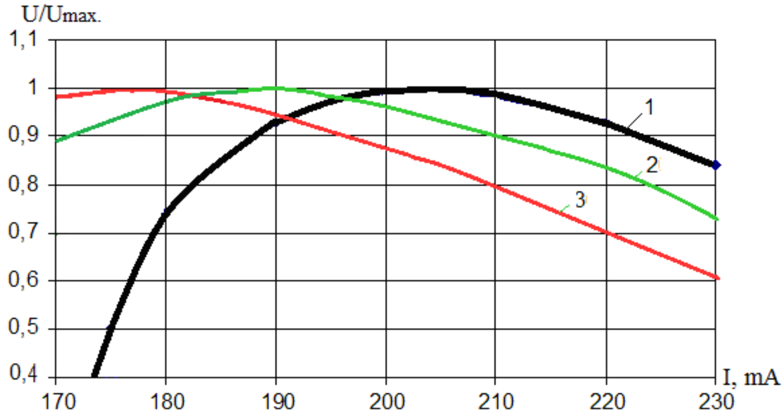

Fig. 1. Dependence of the relative value of the output voltage of the sensors on the current through the thermoelements when pre-explosive concentrations of combustibles are supplied to the chamber: 1 – methane; 2 – butane; 3 – hexane

The relative value of the output voltage of the sensors at different values of the current through the thermoelements U/U^{max}. in this case is actually the coefficient of oxidation efficiency of the fuel component. The analysis of the obtained dependencies shows that at a current through the thermoelements of 175 mA, the value of the oxidation efficiency coefficient of fuel components is: for methane – 0.42, butane – 0.92, and hexane – 1.0. These values are close to the calculated values of the coefficient given in Table 1, which ensure the unambiguity of the 1st threshold of alarm operation for combustible components at the level of 0.1 LEL.

The relationship between the temperature of a platinum resistor and its resistance R_e is determined by the known expression

$$R_e = R_{0e}\left(1+\beta t_e\right), \tag{8}$$

where: R_{0e} – is the resistance of the thermoelement at 0 ^{0}C, Ohm; β – is the temperature coefficient of resistance of platinum, 1/^{0}C; t_e – is the temperature of the element, ^{0}C.

At a current through the thermocouple of 175 mA, the temperature of the working thermocouple in the air, calculated on the basis of expression (8), was about 350 ^{0}C. Thus, under this temperature regime of operation of the studied thermocatalytic sensors with a platinum-palladium catalyst, an unambiguous alarm is practically ensured when the established explosive hazard indicators, for example, 0.1 LEL, are reached, both in the presence of a single component and when they are simultaneously released into the air. It is characteristic that the maximum relative value of the output voltage of the sensors from the current through the thermoelements when pre-explosive concentrations of combustibles are supplied to the chamber is uniquely related to their self-ignition temperature. The lower this temperature is, and therefore the lower the activation energy of the oxidation reaction of the combustible component on the catalyst, the lower the value of the heating of the thermocouple, the higher the maximum is. Taking this into account, by selecting the temperature regime of the sensor, almost all combustible components listed in Table 1 provide unambiguous alarm operation when using a single thermocatalytic sensor. The only exception is hydrogen, due to its ability to create explosive mixtures at a content (by weight) an order of magnitude lower than that of other components.

It should be noted that the temperature operating conditions of the sensor, which ensure unambiguous protection operation, are defined for a specific type of thermocatalytic sensor. For other types of sensors, it may be slightly different. This is due to the fact that the flow of gas or fuel vapors to the working thermocouple of the sensor depends not only on its effective diffusion conductivity in relation to the combustible component, but also on the diffusion conductivity of the filter element. In the studied sensors, at a preheating temperature of the sensor element of about 400^0C, the effective diffusion conductivity of the sensor element for methane is approximately equal to the diffusion conductivity of the filter element. With other conductivity ratios, the dependence of the relative value of the output voltage of the sensors on the current through the thermoelements may shift slightly. Therefore, when developing gas analyzers for an integrated assessment of the explosiveness of a multicomponent fuel-air mixture, additional research is needed. In practice, when using modern microcontrollers, the selection of the sensor's operating mode can be carried out automatically when it is set up for two test mixtures, such as methane-air and hexane-air.

In addition, it should be noted that if the specified temperature operating mode of the sensor is selected, the oxidation of such components as methane and ethane will occur in the kinetic region, and propane and butane in the transition region. In this case, a change in the temperature mode of operation of the thermoelements, which may be due to instability of the power supply parameters or changes in the temperature and composition of the air, can lead to significant measurement errors. Therefore, to realize such a mode of operation of the sensor, it is necessary to maintain either a constant temperature of the environment where the sensor is installed or to change the power supply parameters of the sensor depending on the temperature of the environment. All this requires further research in this area.

Conclusion

The research has shown that thermocatalytic sensors with a non-selective platinum-palladium catalyst under a certain temperature regime allow for an integrated assessment of the explosive hazard of a multicomponent fuel-air mixture. For the studied sensors, this is ensured by choosing a preheating temperature of the working thermocouple in air of 350 ^{0}C. Under such conditions, the reaction of catalytic oxidation of such combustible components of the mixture as methane and ethane, propane and butane occurs in the kinetic and transient region, so a change in the temperature regime of the thermocouple can lead to significant measurement errors. Therefore, further research in this area is to substantiate solutions to minimize the errors in determining the NMR under the condition of an integrated assessment of the explosiveness of a multicomponent fuel-air mixture by a thermocatalytic sensor.

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ВДОСКОНАЛЕННЯ СИСТЕМ МОНІТОРИНГУ ВИБУХОНЕБЕЗПЕЧНОСТІ ТЕХНОГЕННИХ ОБ'ЄКТІВ

Анотація. Метою роботи є пошук рішень, спрямованих на вдосконалення систем моніторингу вибухонебезпечності техногенних об'єктів за наявності багатокомпонентної паливоповітряної суміші шляхом інтегральної оцінки вибухонебезпечності та підвищення точності засобів контролю.

Методи дослідження. В роботі застосовані аналітичні методи досліджень процесу окиснення горючих газів та парів на каталізаторах, що базуються на класичних положеннях електротехніки, термодинаміки та каталізу, експериментальні дослідження серійних однокамерних термокаталітичних датчиків пелістерного типу з платино-паладієвим каталізатором при їх роботі в багатокомпонентній паливоповітряній суміші, оцінка та узагальнення результатів теоретичних та експериментальних досліджень.

Результати. Встановлені особливості протікання процесу окиснення горючих газів та парів в термокаталітичних датчиках з неселективним платино-паладієвим каталізатором при зміні температурного режиму роботи робочого термоелементу. Показано, що термокаталітичні датчики з неселективним платино-паладієвим каталізатором за певного температурного режиму роботи дозволяють здійснювати однозначну оцінку вибухонебезпечності за такими компонентами, як метан, бутан та гептан, що дозволяє здійснювати інтегральну оцінку вибухонебезпечності багатокомпонентної паливоповітряної суміші. Для досліджених датчиків це забезпечується при виборі температури попереднього розігріву температури робочого термоелемента в повітрі 350 ^{0}С.

Наукова новизна. Встановлені умови, за яких термокаталітичні датчики з неселективним платино-паладієвим каталізатором дозволяють здійснювати інтегральну однозначну оцінку вибухонебезпечності середовища, у тому числі за наявності багатокомпонентної паливоповітряної суміші.

Практична значимість. Полягає у встановленні умов, за яких можливе здійснення однозначної оцінки вибухових властивостей паливоповітряних сумішей, у тому числі багатокомпонентних, при використанні одного термокаталітичного датчика, що дозволяє зменшити витрати на системи моніторингу вибухонебезпечності та підвищити надійність контролю вибухонебезпечності за умов, коли в повітрі можуть одночасно накопичуватись різні вибухонебезпечні гази та пари летких горючих речовин.

Ключові слова: небезпека, горючі гази, паливо, системи моніторингу, датчики, інтегральна оцінка вибухонебезпечності.

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