Scientific article
UDK 004.942

DEVELOPMENT OF A SOFTWARE PRODUCT FOR ACCOUNTING FOR THE HETEROGENEITY OF THE DISTRIBUTION OF IGNITION SOURCES OF A FUEL-AIR MIXTURE CLOUD

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Abstract. A methodical apparatus for calculating the zones of damage during an explosion of a fuel-air mixture is considered, and a method for calculating the conditional probability of ignition of a cloud of a fuel-air mixture is proposed, taking into account the placement of ignition sources. Based on the methodology, a software product was developed that allows you to analyze objects with different locations of ignition sources and, based on the methodology, take into account the mode of operation of these sources.

Keywords: explosion, fuel-air mixture, dangerous goods, road transport, ignition sources

For citation: Usatenko I.G., Byzov A.P. Development of a software product for accounting for the heterogeneity of the distribution of ignition sources of a fuel-air mixture cloud // Supervisory activities and forensic examination in the security system. 2023. № 2. P. 104–113.

Introduction

Currently, the leading industry in Russia is the oil industry. It includes the extraction, processing, transportation of oil and oil products.

Because of the growth of the economy, the volume of oil production increases, therefore, the amount of transported hazardous substances increases.

Now in Russia, in the Federal Service for Ecological, Technological and nuclear supervision, more than 2 000 sites for the transportation of hazardous substances are registered. Therefore, with the growth of their number, the question arises of ensuring the industrial safety of these objects. According to the data of the Federal State Information System «IAS-DTP», in the period from 2014 to 2017, the Russian Emergencies Ministry was called for 86 accidents involving motor vehicles carrying dangerous goods.

Studying the data of the Main Directorate of the Ministry of Internal Affairs of Russia on the territory of the Rostov Region. From 2015 to 2017, 10 accidents were recorded involving road transport carrying dangerous goods, of which 12 people were injured in six accidents, one of them was folded. According to the All-Russian Center for Monitoring and Forecasting Emergency Situations of the Ministry of Emergency Situations of Russia for the period from 1991 to 2017, more than 7 000 major accidents occurred on roads involving vehicles carrying dangerous goods (fig. 1).

Because of these accidents, 17 940 people died and 50 440 people were injured [1–2].

According to the Rostekhnadzor annual activity report for 2020, more than 2 000 sites for the transportation of hazardous substances that are part of hazardous production facilities are registered in Russia. The number of sites for the transportation of hazardous substances that are part of other hazardous production facilities amounted to 1907.

The length of non-public tracks is about 19 000 km, including railway lines – 11 395 km.

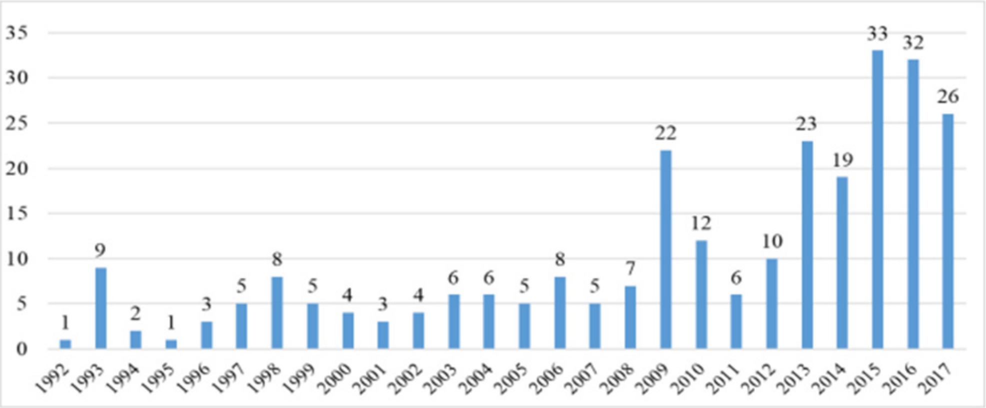


Fig. 1. **Data from the All-Russian monitoring center**

The number of special vehicles for the transport of dangerous goods is 29 199, of which 5 835 are road, 23 364 are rail, and the need for the transport of hazardous substances by road is increasing [3].

A fatal accident that occurred in 2020 was registered with an organization operating facilities of hazard class III. August 29, 2020 in the organization LLC «Khimprom» in the washing and steaming department of the railway shop, while performing gas-hazardous work to clean the containers-cisterns inside, a washer-steamer of tanks died.

There is an acute issue of improving the safety situation for the transportation of hazardous substances by road, while taking into account the parameters of the curvature and inclination of the road, the presence of settlements and bridges, meteorological conditions – all this increases the efficiency and safety of the transportation of hazardous substances and materials [4].

The article [5] presents a methodology for choosing a model for the transportation of dangerous goods by road. The model generates routes that are optimal in terms of risk minimization and losses.

The authors of [6] developed an algorithm for checking roads when transporting hazardous materials based on a genetic algorithm and a Levenberg neural network – Mar-Quardt (GA-LM-NN) by analyzing data from 15 attributes of each section of the road network.

At present, Russia has adopted an approach to assessing individual risk based on the construction of potential risk fields and determining the parameters of the distribution of people in the territory. The final field of potential territorial risk consists of a superposition of potential risk fields from different hazard sources for different scenarios [7].

As a rule, when constructing potential risk fields for accidents with the formation of fuel-air mixtures (FA), their static nature is assumed and the place of release is taken as the center of the cloud [8–11], or a deterministic estimate of the fields of damaging parameters is carried out based on the assumption of the transfer of the center of the cloud 300 m in case of instantaneous depressurization of the tank and 150 m in case of a long outflow, which corresponds to 70 % of all accidents.

Theoretical foundations and calculation methods

Subject of study: a method for assessing the probability field of damage in the event of an explosion of fuel assemblies, taking into account the heterogeneity of the distribution of sources of ignition of the cloud of fuel assemblies for areas of transportation of hazardous substances.

The purpose of the work: based on the study of the methodological apparatus for assessing the probability field of damage in the explosion of fuel assemblies, legal documents and literary sources in this area, to improve the methodology for assessing the probability field of damage in the event of an explosion of fuel assemblies, taking into account the heterogeneity of the distribution of sources of ignition of the cloud of fuel assemblies for areas of transportation of hazardous substances.

To date, various methods are used to assess the consequences of explosions of FA clouds. The foundations of existing approaches are:

1) equation B.E. Gelfand – for explosions of combustible substances;

2) equation A.N. Birbraer – for accidents where both deflagration and detonation of a substance are possible;

3) a technique that takes into account the energy characteristics of gas-vapor-air mixtures;

4) methodology for assessing the consequences of accidental explosions of fuel assemblies.

The basis of the B.E. Gelfand is also taking into account the TNT equivalent of an explosion of fuel assemblies of combustible substances. These dependencies are used in GOST R 12.3.047–2012 «Fire safety of technological processes» (Appendix E):

$$\begin{cases} \Delta P\text{ф} = P_0 \cdot \left(0{,}8 \cdot \frac{\text{М}_{\text{пр}}^{0{,}33}}{\text{Г}} + 3 \cdot \frac{\text{М}_{\text{пр}}^{0{,}66}}{\text{Г}^2} + 5 \cdot \frac{\text{М}_{\text{пр}}}{\text{Г}^3}\right) \\ \text{М}_{\text{пр}} = \frac{Q_{\text{сг}}}{Q_0} \cdot Z \cdot \text{М}_{\text{гпвс}} \end{cases}.$$

The method makes it possible to carry out a quantitative assessment of the parameters of the explosive shock wave that occurs during the combustion of a cloud of fuel assemblies in open space.

The methodology proposed in the order of Rostekhnadzor dated December 15, 2020, № 533 «On the approval of the FNiP in the field of industrial safety» General rules for explosion safety for fire and explosion hazardous chemical, petrochemical and oil refining industries», approved by Decree of the Government of the Russian Federation dated July 30, 2004, № 401«On the Federal Service for Ecological, Technological and Nuclear Supervision».

The method proposed in this document makes it possible to estimate the levels of consequences of an explosion in TNT equivalent, based on the mass of the vapor-gas-air mixture released into the environment as a result of the accident, and the properties of substances: the specific heat of combustion of the vapor-gas mixture, its specific explosion energy, expressed in TNT equivalent. Criteria of types (kinds) of damage (destruction) are defined.

The mass of gas-vapor substances involved in the explosion is determined by the formula:

$$m` = z \cdot m,$$

where z – fraction of the reduced mass of gas-vapor substances involved in the explosion.

The TNT equivalent of an explosion of a vapor-gas medium WT (kg), determined by the conditions for the adequacy of the nature and degree of destruction during explosions of vapor-gas clouds, as well as solid and liquid chemically unstable compounds, is calculated by the formulas:

For steam-gas media, the formula is correct:

$$W_T = \frac{0{,}4 \cdot q`}{0{,}9 \cdot q_T} \cdot z \cdot m,$$

where 0,4 is the share of the energy of the explosion of the gas-vapor environment, spent directly on the formation of a shock wave; 0,9 – fraction of the energy of the explosion of trinitrotoluene spent directly on the formation of a shock wave; $q`$– specific heat of combustion of the gas-vapor medium, kJ/kg; qT is the specific explosion energy of TNT, kJ/kg.

In this case, we can assume that the boundaries of the destruction zone are determined by the radii R, the center of which is the corresponding technological block or the most probable place of depressurization of the technological system. The boundaries of each zone are characterized by the values of excess pressures along the shock wave front ΔP and the dimensionless coefficient K.

The radius of the destruction zone (m) is determined by the formula:

$$R = K \cdot \frac{\sqrt[3]{W_T}}{\left(1+\left(\frac{3180}{W_T}\right)^2\right)^{\frac{1}{6}}},$$

where K is a dimensionless coefficient characterizing the impact of an explosion on an object.

If a vapor mass of more than 5 000 kg is involved in an accident, the radius of the destruction zone can be determined by the formula:

$$R = K \cdot \sqrt[3]{W_T}.$$

The dependence used in this technique was obtained based on Hopkins' law, created because of large-scale studies of the actual destruction of buildings and structures during bombings during World War II.

Excessive pressure at the front of the air shock wave ΔPΦ, (kPa), is calculated according to the formula:

$$\Delta P_\Phi = \begin{cases} \Delta P = 1700 \; at \; \varphi \leq 0{,}24 \\ \frac{23{,}1075}{\varphi^3} \; at \; 0{,}24 < \varphi < 0{,}455 \\ \frac{700}{3 \cdot \left(\sqrt{1+29.8 \cdot \varphi^3}-1\right)} \; at \; 0{,}455 < \varphi \leq 2 \\ \frac{22}{\varphi \cdot \sqrt{\log(\varphi,10)+0.158}} \; at \; \varphi \geq 2 \end{cases} \cdot$$

Despite a rough estimate that does not take into account the properties of the substance, it was noted that when using the methodology based on the Hopkins law, the calculation results would give results with a high degree of accuracy, but with the participation of a substance weighing no more than 100 tons.

It is generally accepted that in the event of an accident, detonation and deflagration of the FA cloud are possible, it is necessary to accept the most negative scenario for the development of the accident.

The cloud volume is given by the equation:

$$V = \frac{2240 \cdot k \cdot G}{\mu \cdot C_{\text{НКПД}}},$$

where G is the mass of the released substance, kg; k – coefficient depending on its type and method of storage (for gases stored at normal atmospheric pressure, k=1; for gases liquefied under pressure, k=0,5; when spreading, flammable liquids (flammable liquids) k=0,2–0,07); μ is the molecular weight of the substance; CNKPD – lower volume concentration limit of detonation, %; in the absence of data, you can take CLEC equal to the lower flammable limit CLEL.

The radius of a hemispherical cloud is given by the equation:

$$r_0 = 0{,}78 \cdot \sqrt[3]{V}.$$

Due to the supersonic propagation of the detonation wave, the HPVS cloud does not have time to expand by the end of the detonation and practically retains its original volume.

The specific volumetric calorific value of HPVA qV, kJ/m^3 is determined by the formula:

$$q_V = q_{V,\text{стх}} \cdot \frac{C_{\text{НКПД}}}{C_{\text{стх}}},$$

where $q_{V,\text{стх}}$, $C_{\text{стх}}$, $\rho_{\text{стх}}$ – respectively, the specific volume energy, concentration and density of the stoichiometric mixture.

The adiabatic index of a stoichiometric mixture is determined by the formula:

$$\gamma = \frac{1{,}3}{1{,}85 \cdot 10^{-5} \cdot (q_m - 1200) + 1} \; .$$

Excess pressure in the detonation wave front within the cloud can be determined by the formula:

$$\Delta P_{\text{дет}} = 2{,}586 \cdot (\gamma - 1) \cdot q_m - P_a,$$

where P_a – Atmosphere pressure.

As a result of the detonation wave reaching the edge of the cloud boundary, an air shock wave propagates in the air surrounding the cloud. Its parameters depend from the reduced distance $\overline{R}$, м/кДж$^{1/3}$, are determined by the formula:

$$\overline{R} = \frac{R}{\sqrt[3]{2 \cdot E_{\text{ув}}}} \; ,$$

where R – distance value from the center of the cloud ($R > r_0$); $E_{\text{ув}}$ is the value of the explosion energy converted into an air shock wave, kJ, determined by the formula

$$E_{\text{ув}} = 2 \cdot q_V \cdot \delta \cdot V,$$

where δ – is the fraction of the total explosion energy converted into an air shock wave according to the formula:

$$\delta = 1 - \left(\frac{2 \cdot P_a}{\Delta P_{\text{дет}}}\right)^{\frac{\gamma - 1}{\gamma}} .$$

Excessive pressure at the front of the air shock wave ΔP_{Φ},, (Pa), is calculated by the formula:

$$\Delta P_{\Phi} = \begin{cases} \Delta P_{\text{дет}} \text{ при } \overline{R} \le 0{,}05 \\ \frac{1{,}227 \cdot 10^{-3}}{\overline{R}^{4{,}68}} + 490 \text{ при } 0{,}05 < \overline{R} < 0{,}068 \\ \frac{4{,}156 \cdot 10^{3}}{\overline{R}^{1{,}7}} \text{ при } 0{,}068 < \overline{R} \le \; 0{,}31 \\ \frac{4960}{\overline{R}} + \frac{974}{\overline{R}^{2}} + \frac{146}{\overline{R}^{3}} \text{ при } 0{,}31 \le \overline{R} \end{cases} .$$

Methodology for assessing the consequences of accidental explosions of fuel assemblies. Safety Guide «Methodology for assessing the consequences of accidental explosions of the fuel-air mixture», approved by order of Rostekhnadzor dated March 31, 2016, № 137.

The technique makes it possible to take into account the energy characteristics of gas-vapor-air mixtures when calculating, linking the consequences of an explosion of a gas-vapor cloud with a specific potentially hazardous substance, to make an approximate assessment of various parameters of an air shock wave and to determine the probable degree of injury to people and damage to buildings during accidents with explosions of fuel assemblies.

The technique is recommended for use:

– when determining the scale of the consequences of accidental explosions of fuel assemblies;

– in the development and examination of safety declarations for hazardous production facilities.

The main structural elements of the calculation algorithm are:

– determination of the mass of combustible matter contained in the cloud;

– determination of the effective energy reserve of fuel assemblies;

– determination of the expected mode of explosive transformation of fuel assemblies;

– calculation of the maximum overpressure and momentum of the compression phase of air shock waves for various modes;

– determination of additional characteristics of the explosive load;

– assessment of the damaging effects of an explosion of fuel assemblies.

To calculate the parameters of an air shock wave at a given distance R from the center of the cloud during the detonation of the fuel assembly cloud, the corresponding dimensionless distance is preliminarily calculated by the formula:

$$R_x = \frac{R}{\left(\frac{E}{P_0}\right)^{\frac{1}{3}}},$$

where P_0 – Atmosphere pressure, Pa.

Excessive pressure at the front of the air shock wave ΔPF, (Pa), is calculated by the formula:

$$\Delta P_Ф = \begin{cases} 1800 \; at \; R < 0{,}2 \\ 100 \cdot P_x \cdot P_{01} \; at \; R \geq 0{,}2 \end{cases},$$

where P_{01} – Atmospheric pressure, atm.

In the case of a deflagration explosive transformation of a fuel assembly cloud, the velocity of the visible flame front V_r, which is determined by the formula:

$$V_г = k \cdot M_г^{\frac{1}{6}},$$

where k – a constant equal to 43 and the degree of expansion of the combustion products σ.

For gas mixtures, it is accepted $\sigma = 7$.

Dimensionless pressure Px1 is determined by the formula:

$$P_{x1} = \left(\frac{V_г}{C_0}\right)^2 \cdot \left(\frac{\sigma - 1}{\sigma}\right) \cdot \left(\frac{0{,}83}{R_x} - \frac{0{,}14}{R_x{}^2}\right),$$

where C_0 – speed of sound in air equal to 340 m/s.

Excessive pressure at the front of the air shock wave ΔPF, (Pa), is calculated by the formula:

$$\Delta P_Ф = \begin{cases} P_a \cdot \left(\frac{V_г}{C_0}\right)^2 \cdot \left(\frac{\sigma - 1}{\sigma}\right) \cdot \left(\frac{0{,}83}{R_{кр}} - \frac{0{,}14}{R_{кр}{}^2}\right) \text{ при } R < R_{кр} = 0{,}34 \\ P_a \cdot P_{x1} \cdot P_0 \text{ при } R \geq R_{кр} \end{cases},$$

where P_a – Atmosphere pressure, kPa.

Based on the analysis of methods for assessing the affected areas in the event of explosions of fuel assemblies, it can be concluded that the methodology for assessing the consequences of accidental explosions of fuel assemblies, approved by order of Rostekhnadzor dated March 31, 2016, № 137 for calculating the impact of damaging factors, takes into account more factors than others considered methods.

In order for a cloud explosion to occur, not only a cloud of fuel assemblies is necessary, but also an ignition source. In the Russian legislation, there is the only method that allows you to determine the probability of cloud ignition, taking into account the distribution of ignition sources, approved by Rostekhnadzor dated September 17, 2015, № 366.

The conditional probability of ignition of emergency emissions of explosive substances, in the presence of periodically operating sources of ignition, is calculated by the formula:

$$P_И = 1 - Q(\tau),$$

where Q(τ) – the probability of not igniting the cloud from sources Иk, the natural logarithm which is calculated as:

$$LnQ(\tau) = \sum_{i=1}^{I} \sum_{j=1}^{J} F_{ih} \cdot \mu_j \cdot \left[\left(1 - a_j \cdot p_j\right) \cdot e^{-\lambda_j p_j d_h} - 1 \right] \quad ,$$

where: *i* – number of the elementary area in the computational domain; *j* = 1, *J* – ignition source number on the elementary pad; F_{ih} – area of the *i*-th elementary site, ha; μ_j – distribution density of ignition sources, pieces/ha; *aj* – fraction of the activity time of the *j*-th ignition source.

Research results and discussion

Based on the presented methods, a software product was developed that allows you to analyze objects with different locations of ignition sources and take into account the operating mode of these sources based on the methodology. The result of the work is a file in which the given map is divided into elementary areas, in which the conditional probability of ignition of a cloud of fuel assemblies is calculated, taking into account the heterogeneity of the distribution of ignition sources. For clarity, we will depict two different maps in different modes of operation of the equipment.

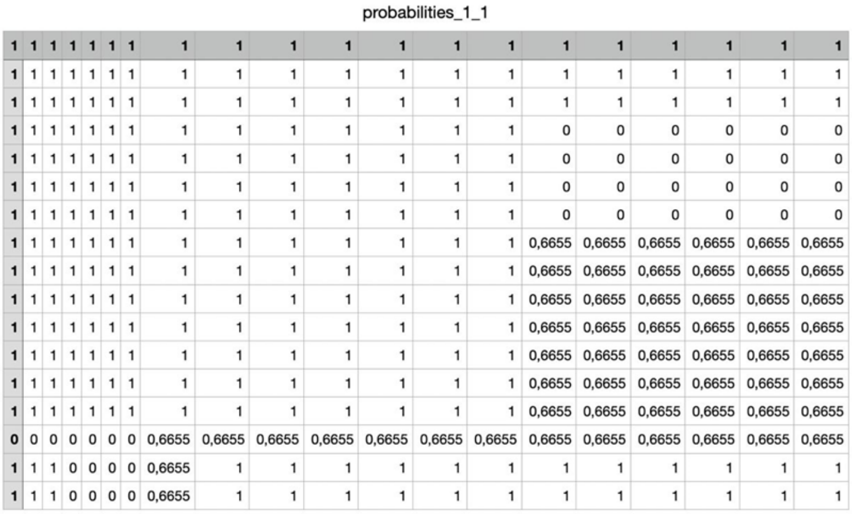
The indicated sources of ignition and their coordinates (map 1) are shown in Fig. 2.

map_1

1	Объект автостоянки	1	1	5	5
3	Бойлерная 1	4	4	10	3
4	Огонь	15	15	3	6

Fig. 2. **Coordinates of objects on the map 1**

Case 1 is shown in fig. 3. Parking – smoking. Open flame – continuous action inside and outside the building. Boiler room.



probabilities_1_1

1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
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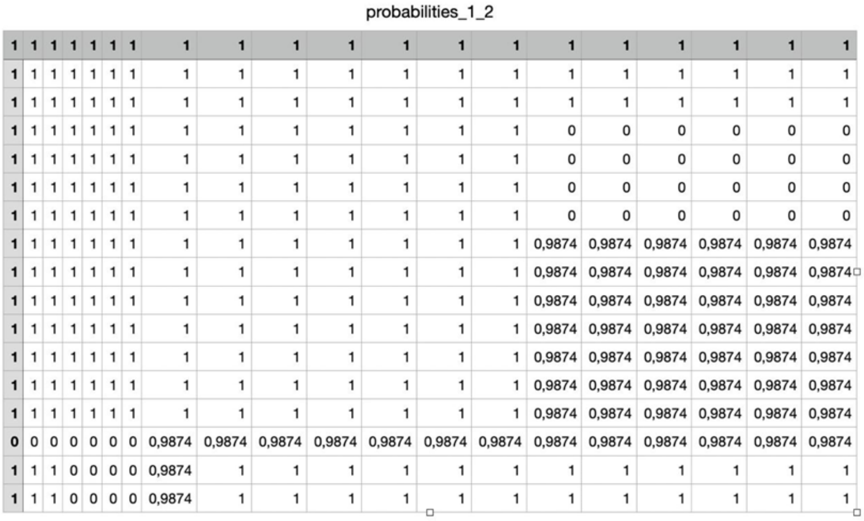
1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	0,6655	0,6655	0,6655	0,6655	0,6655	0,6655
1	1	1	1	1	1	1	1	1	1	1	1	1	1	0,6655	0,6655	0,6655	0,6655	0,6655	0,6655
1	1	1	1	1	1	1	1	1	1	1	1	1	1	0,6655	0,6655	0,6655	0,6655	0,6655	0,6655
1	1	1	1	1	1	1	1	1	1	1	1	1	1	0,6655	0,6655	0,6655	0,6655	0,6655	0,6655
1	1	1	1	1	1	1	1	1	1	1	1	1	1	0,6655	0,6655	0,6655	0,6655	0,6655	0,6655
1	1	1	1	1	1	1	1	1	1	1	1	1	1	0,6655	0,6655	0,6655	0,6655	0,6655	0,6655
1	1	1	1	1	1	1	1	1	1	1	1	1	1	0,6655	0,6655	0,6655	0,6655	0,6655	0,6655
0	0	0	0	0	0	0	0,6655	0,6655	0,6655	0,6655	0,6655	0,6655	0,6655	0,6655	0,6655	0,6655	0,6655	0,6655	0,6655
1	1	1	0	0	0	0	0,6655	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	0	0	0	0	0,6655	1	1	1	1	1	1	1	1	1	1	1	1

Fig. 3. **Distribution of conditional probabilities of ignition of a cloud of fuel assemblies, taking into account the mode of operation of sources for 1 case**

Case 2 is shown in fig. 4. Parking – peak hours. Open flame – intermittent action inside and outside the building. Boiler room.



probabilities_1_2

1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
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1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	0	0	0
1	1	1	1	1	1	1	1	1	1	1	1	1	1	0,9874	0,9874	0,9874	0,9874	0,9874	0,9874
1	1	1	1	1	1	1	1	1	1	1	1	1	1	0,9874	0,9874	0,9874	0,9874	0,9874	0,9874
1	1	1	1	1	1	1	1	1	1	1	1	1	1	0,9874	0,9874	0,9874	0,9874	0,9874	0,9874
1	1	1	1	1	1	1	1	1	1	1	1	1	1	0,9874	0,9874	0,9874	0,9874	0,9874	0,9874
1	1	1	1	1	1	1	1	1	1	1	1	1	1	0,9874	0,9874	0,9874	0,9874	0,9874	0,9874
1	1	1	1	1	1	1	1	1	1	1	1	1	1	0,9874	0,9874	0,9874	0,9874	0,9874	0,9874
1	1	1	1	1	1	1	1	1	1	1	1	1	1	0,9874	0,9874	0,9874	0,9874	0,9874	0,9874
0	0	0	0	0	0	0	0,9874	0,9874	0,9874	0,9874	0,9874	0,9874	0,9874	0,9874	0,9874	0,9874	0,9874	0,9874	0,9874
1	1	1	0	0	0	0	0,9874	1	1	1	1	1	1	1	1	1	1	1	1
1	1	1	0	0	0	0	0,9874	1	1	1	1	1	1	1	1	1	1	1	1

Fig. 4. **Distribution of conditional probabilities of ignition of a cloud of fuel assemblies, taking into account the mode of operation of sources for the 2nd case**

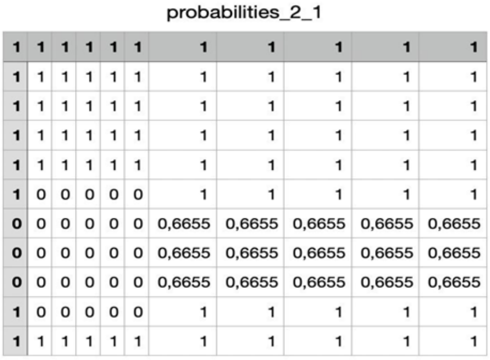
The specified sources of ignition and their coordinates on (map 2) are presented in fig. 5.

map_2

2	Основная дорога	1	5	10	3
4	Открытое пламя 1	2	6	10	4
6	Производственные зоны	6	8	3	4
3	Бойлерная	7	2	1	3
4	Открытое пламя 2	6	4	3	3
1	Автостоянка	1	1	4	4

Fig. 5. **Coordinates of objects on the map 2**

Case 1 is shown in fig. 6. Road – rush hours. Flame 1 – continuous action inside and outside the building. Production areas – medium equipment. Boiler room. Flame 2 – continuous action inside and outside the building. Parking – smoking



probabilities_2_1

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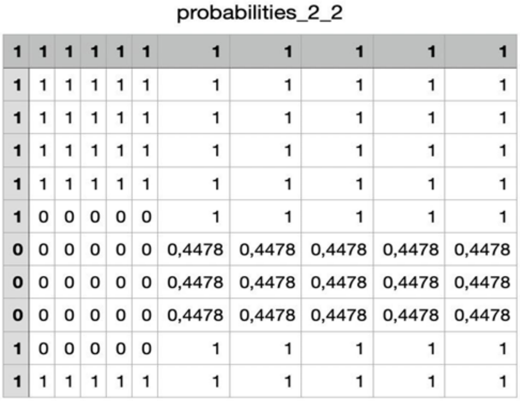
1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1
1	0	0	0	0	0	1	1	1	1	1
0	0	0	0	0	0	0,6655	0,6655	0,6655	0,6655	0,6655
0	0	0	0	0	0	0,6655	0,6655	0,6655	0,6655	0,6655
0	0	0	0	0	0	0,6655	0,6655	0,6655	0,6655	0,6655
1	0	0	0	0	0	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1

Fig. 6. **Distribution of conditional probabilities of ignition of a cloud of fuel assemblies, taking into account the mode of operation of sources for 1 case**

Case 2 is shown in fig. 7. The road is a different watch. Flame 1 – continuous action inside and outside the building. Production areas – Medium equipment. Boiler room. Flame 2 – a rare effect inside and outside the building. Parking – different hours.



probabilities_2_2

1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1
1	0	0	0	0	0	1	1	1	1	1
0	0	0	0	0	0	0,4478	0,4478	0,4478	0,4478	0,4478
0	0	0	0	0	0	0,4478	0,4478	0,4478	0,4478	0,4478
0	0	0	0	0	0	0,4478	0,4478	0,4478	0,4478	0,4478
1	0	0	0	0	0	1	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1

Fig. 7. **Distribution of conditional probabilities of ignition of a cloud of fuel assemblies, taking into account the mode of operation of sources for case 2**

Conclusion

In the Russian legislation, there is a methodology for assessing the risk of accidents on process pipelines associated with the movement of explosive liquids, approved by Rostekhnadzor, but which does not receive due attention, because it is difficult to understand, but there is a possibility to simplify and adapt it by using software modules for performing automated calculations.

So, to date, two software modules have already been written that make it possible to build maps of the potential risk distribution fields for accidents associated with the formation of fuel assemblies and put labels on them with the probability of a negative event occurring, which makes it possible to assess the probability field of damage during an explosion of fuel assemblies, taking into account heterogeneity distribution of sources of ignition of the cloud of fuel assemblies for areas of transportation of hazardous substances. After the implementation of a software module that allows compiling the results obtained from other modules and plotting these fields on maps of real objects, the use of this technique will become more accessible to a larger number of people involved in industrial safety due to its automation. It will be enough for a specialist to upload a file with a terrain plan, specify the necessary parameters and get numerical and graphical results. With this improvement, the methodology will become available to a wider circle of people, which will lead to a positive impact on industrial safety during the transportation of flammable liquids.

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Information about the article: the editors received the article: 02.04.2023;
accepted for publication: 10.04.2023

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