Research Article

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Basic calculation methods of investigation of circumstances and mechanism of man-made explosions

The article purpose is to analyze the danger of man-made explosions and provide calculation methods for determining the mechanism of the occurrence of an explosion during forensic examinations of the study of the circumstances and mechanism of man-made explosions.

The relevance of the article is caused by the fact that present-day production and everyday life cannot dispense with the usage of combustible and explosive substances. The particular attention to be paid to emergency prevention related to explosives, as well as the research to determine the mechanism of man-made explosions. The research on the mechanism of man-made explosions will make it possible to determine the technical cause of their occurrence, to analyze for what reason and for whose fault the event occurred, and also what measures should be taken to minimize the likelihood of such situations occurence.

It is noted that in order to obtain reliable conclusions about the mechanism of man-made explosions, it is necessary to use scientifically based methods and methodologies allowing us to assess the extent of destruction. The degree of destruction of surrounding building structures and harm to people depends on overpressure caused as the result of a significant expansion of the explosion products and their spread to all directions from the center of explosion. The most frequent causes of explosions in the explosive object are: destruction and damage to production tanks, equipment and pipelines; deviation from production regulations (excess pressure and temperature of equipment operating mode), low-quality control of equipment and work while conducting require work, and untimely or poor-quality maintenance of technological equipment.

The authors declares no conflict of interest of relavance to this topic.

The main calculation methods for the research of the man-made explosions in open areas, indoors, and limited space are given, which will allow to systematize the research process and analyze the flow of explosions in specific situations, and to establish a mechanism for their occurrence when conducting forensic examinations of the circumstances and mechanism of man-made explosions.

Keywords: *explosive, gas-vapor mixture, concentration limits for flame propagation, emergency situation, overpressure, man-made explosion.*

Formulation of Research Problem. Emergency situations (hereinafter referred to as *ES*) of a man-made nature related to man-made explosions are highly dangerous. An explosion combines a set of dangerous factors that can result in injury and death of people, as well as significant material losses and environmental pollution.

Since modern production and everyday life are impossible without the use of flammable substances and explosives, particular attention should be drawn to prevention of the occurrence of emergencies associated with explosions, as well as research on determining the mechanism of the occurrence of man-made explosions to further minimize their occurrence. Therefore, this topic is relevant and necessitates detailed consideration.

Analysis of Essential Researches and Publications. Forecasting the effects of man-made explosions occurring while deflagration of explosive-fire-hazardous mixtures at facilities of economic activity has been studied in detail by L. P. Piliuhin [1]. The scientist described destruction of buildings and structures due to the influence of excess pressure. Dynamics of scenarios of fire and explosions is provided in a research paper by N. N. Brushlynskyi and A. Ia. Korolchenko [2]. Consequences of fires and man-made explosions depending on conditions of a dangerous scenario are outlined by S. I. Taubkin [3]. His son, I. S. Taubkin, developed foundations for performing forensic examinations of circumstances and mechanism of man-made explosions [4].

The mechanism of man-made explosions occurrence as well as the algorithm for conducting a research have been outlined by O. V. Tarakhno, V. M. Syrykh and R. V. Tarakhno in the following research papers: *Pressing*

[1] Пилюгин Л. П. Прогнозирование последствий внутренних аварийных взрывов. Москва, 2010. 380 p.

[2] Брушлинский Н. Н., Корольченко А. Я. Моделирование пожаров и взрывов. Москва, 2000. 482 p.

[3] Таубкин С. И. Пожар и взрыв, особенности их экспертизы. Москва, 1999. 600 p.

[4] Таубкин И. С. Судебная экспертиза техногенных взрывов. Организационные, методические и правовые основы. Москва, 2009. 592 p.

issues of a research on explosions of gas-air mixtures during fire investigation [1] *and Expert research on the version of gas-air mixture explosion indoors* [2].

The **Article Purpose** analysis of the danger of man-made explosions and provision of calculation research methods to determine the mechanism of their occurrence during forensic examinations of the circumstances and mechanism of man-made explosions.

Main Content Presentation. Research on man-made explosions in an open area aims to determine conditions for formation of explosive concentrations of combustible substances, possibilities for ignition and consequences of the development of explosive events. The potential danger is enterprises using large volumes of combustible gases and flammable liquids (gas stations, warehouses of liquefied gases and petroleum products, gas pipelines and oil pipelines). First of all, this is due to the threat of releasing significant volumes of combustible substances into the atmosphere to further explode.

Accordingly, simulation of emergencies associated with emergency leakage of gas or flammable liquids from technological equipment and formation of explosive areas is a pressing issue.

To obtain valid conclusions on the possibility of occurrence of fire and explosions, scientifically substantiated techniques should be implemented. In existing scientific and regulatory-procedural guidelines on forecasting consequences of emergency release of combustible substances into the environment, a sequence of calculation of such parameters as excess pressure, radius and time of "life" of the object engulfed in flames, etc. are provided. An important issue of research on man-made explosions in open area is to determine the possibility of destruction of buildings, constructions and death of people from the effects of explosion. The degree of destruction of surrounding building structures and damage to people depends on excess pressure which develops as a result of sharp thermal expansion of combustion products and spreads in all directions from the center of explosion. Excess pressure is determined as follows:

$$\Delta P = P_o \left(0,8 \frac{m_{тнт}^{0,33}}{r} + 3 \frac{m_{тнт}^{0,66}}{r^2} + 5 \frac{m_{тнт}}{r^3} \right), \text{ кПа,} \quad (1)$$

where: P_o — atmospheric pressure, kPa;

$m_{тнт}$ — TNT equivalent, kg;

r — distance from the geometric median of steam-gas mixture, m [3].

Determination of the explosion power is determined by the formula:

[1] Таран О. В., Сирих В. М., Тарахно Р. В. Проблемні питання дослідження вибухів газоповітряних сумішей при проведенні пожежно-технічних експертиз. *Проблемы пожарной безопасности* : сб. науч. тр. Харьков, 2009. Вып. 25. P. 175—180.

[2] Ibid. Експертне дослідження версії виникнення вибуху газоповітряної суміші у приміщенні. Ibidem. Харьков, 2010. Вып. 27. P. 198—205.

[3] Таубкин С. И. Op. cit.

$$m_{ТНТ} = \frac{Q_Г m_{ГВ}}{4520}, \text{ кг}, \quad (2)$$

where: $Q_г$ — combustion heat of combustible substance, kJ/kg;

$m_{гв}$ — mass of explosive combustible substance, kg;

4520 — explosion heat of trinitrotoluene, kJ/kg.

However, unlike an explosion of condensed explosives, combustion of a gas-vapor mixture (hereinafter referred to as *GVM*) in the explosion regime occurs only on the outer part of the cloud and at a different speed in which concentration of combustible substance is in the range from lower to upper flammability limit.

Therefore, while evaluating parameters of the explosion of the gas-vapor cloud in open area, it is considered that the explosive (kinetic) combustion involves from 2 % to 10 % (max) of a combustible substance [1].

What is more, explosion of condensed explosives occurs in the detonation mode, at the same time transition of deflagration combustion of GVM in detonation is possible only for a small range of combustible gases: for example, hydrogen, acetylene. Given the above, the maximum possible efficiency of the GVM explosion due to deflagration is not more than 30%. Some part of energy converts into heated combustion products. After, the TNT equivalent of the explosion is determined as follows:

$$m_{тнт} = \frac{0{,}3zQ_г m_{гв}}{0{,}9 \cdot 4520}, \text{ кг}, \quad (3)$$

where: 0,3 i 0,9 accordingly some part of energy spent on formation of explosion of gas-vapor cloud and trinitrotoluene;

$m_{гв}$ —mass of combustible substance that entered the environment as a result of an emergency and formed GVM, kg;

z —coefficient of involvement of energy of steam and gases in explosion.

The area with calculated center of explosion and limits determined by the $r_{пор}$ blast radius is considered to be the area where destruction and injury to people takes place. And the probable destructive effect while explosion can be calculated from the generalized data by the approximation formula:

$$r_{пор} = \frac{k_i \sqrt[3]{m_{вз}}}{\left[1 + \left(\frac{3180}{m_{вз}}\right)^2\right]^{\frac{1}{6}}}, \text{ м}, \quad (4)$$

where: k_i —dimensionless coefficient of the impact level of explosion which is determined depending on the excess pressure;

$m_{вз}$ —mass of combustible substance involved in an explosion and equal to $m_{гв} \cdot z$, kg.

[1] Таран О. В., Сирих В. М., Тарахно Р. В. Проблемні питання дослідження вибухів … .

It is known, an emergency with the risk of explosion and subsequent fire at an industrial building or premises may occur as a result of accidental depressurization of an outdoor installation. The probability of explosion in the event of a combustible gas leakage into the room is created when the gas concentration reaches the lower flammability limit. Thus, to establish the possibility of combustion, it is necessary to compare the actual average concentration of combustible gas with the lower flammability limit of this gas.

The average actual concentration of gas formed in the room due to emergency leakage can be calculated by the formula:

$$\varphi'_{сер} = \frac{m_г}{V_{прим}(1-\eta)} = \frac{m_г}{V_{вільн}}, \text{ кгм}^{-3} \quad \text{or} \quad \varphi_{сер} = \frac{100 m_г}{\rho_г V_{вільн}}, \%, \qquad (5)$$

where: $\varphi'_{сер}$, $\varphi_{сер}$ —accordingly mass and volume average actual concentration of gas in a free volume of a room;

$m_г$ — mass of gas entered the room while emergency, kg;

$V_{прим}$ — total room volume, m^3;

η — some part of room volume occupied by equipment or furniture;

$V_{вільн}$ — free volume of a room, m^3.

To identify the average concentration of combustible gas, it is needed to know the mass of gas that entered into the room while the emergency leakage, with a certain mass flow rate of $g_г^{надх}$ for a certain time of the emergency situation.

As it is known[1], the mass flow rate at which gas flows through the opening and enters the room can be calculated by the formulas:

• if the leakage mode is subcritical ($\frac{P_{сис}}{P_{атм}} < 2$) —

$$g_г^{надх} = K_{отв} S_{отв} P_{сис} \sqrt{\frac{1}{R_{пит} T} \cdot \frac{2k}{k-1} \left[\left(\frac{P_{атм}}{P_{сис}} \right)^{\frac{2}{k}} - \left(\frac{P_{атм}}{P_{сис}} \right)^{\frac{k+1}{k}} \right]}, \text{ кг·с}^{-1}; \qquad (6)$$

• if the leakage mode is critical ($\frac{P_{сис}}{P_{атм}} > 2$) —

$$g_г^{надх} = K_{отв} S_{отв} P_{сис} \sqrt{\frac{1}{R_{пит} T} \cdot \frac{2k}{k+1} \left(\frac{2}{k+1} \right)^{\frac{2}{k-1}}}, \text{ кг·с}^{-1}, \qquad (7)$$

where: $K_{отв}$ — gas flow rate through an opening (usually $K_{отв} = 0{,}64$)

k —adiabatic index of combustible gas;

$P_{сис}$ — the pressure in the gas supply system which is greater than the pressure of the environment where leakage occurs, Pa;

$P_{атм}$ —pressure in the environment in which gas leaks, Pa;

[1] Рябова І. Б., Сайчук І. В., Шаршанов А. Я. Термодинаміка і теплопередача у пожежній справі : навч. посіб. Харків, 2002. 356 р.

$S_{отв}$ —the area of opening through which gas leaks, m^2;

T — gas temperature, K;

$R_{пит}$ — relative gas constant, $J \cdot kg^{-1} \cdot K^{-1}$.

Therefore, the time for which the average actual concentration of gas formed in a room as a result of accidental leakage and lack of gas exchange with the environment and will reach the value of the lower flammability limit can be estimated by the formula:

$$\tau_{нкмпп} = \frac{m_г}{g_г^{надх}} = \frac{V_{вільн}\varphi'_н}{g_г^{надх}}, \text{ c}, \quad (8)$$

where: $\varphi'_н$ —mass lower concentration limit of combustible gas flammability, kg m^{-3}. The equation of the material balance of combustible gas entered into the environment can be expressed by the differential equation:

$$\frac{dm_г}{d\tau} = V_{вільн}\frac{d\varphi'_г}{d\tau} = g_г^{надх} - g_{гс}^{вит}\frac{\varphi'_г}{\rho_{гс}}, \quad (9)$$

where: $\varphi'_г$ —the average mass concentration of gas in the room at the τ time, kg m^{-3};

$g_{гс}^{вит}$ — mass flow rate at which the mixture of air and combustible gas leaks out of the room through openings (calculated depending on the gas exchange scheme), kg s^{-1};

$\rho_{гс}$ — density of the gas-air mixture under such conditions, kg m^{-3}.

The mass flow rate at which the gas mixture leaks through openings of a room can be calculated by the formula:

• if openings are at the same level —

$$g_{гс}^{вит} = \frac{2}{3}K_{отв}S_{отв}\sqrt{\frac{2gh_{отв}\rho_{пов}\rho_{пг}(\rho_{пов} - \rho_{пг})}{(\rho_{пов}^{0,33} + \rho_{пг}^{0,33})^3}}, \text{ кг} \cdot \text{с}^{-1}, \quad (10)$$

• if openings are at different levels —

$$g_{гс}^{вит} = K_{отв}S_{прип}S_{вит}\sqrt{\frac{2gHg_{пов}\rho_{пг}(\rho_{пов} - \rho_{пг})}{\rho_{пов}S_{прип}^2 + \rho_{пг}S_{вит}^2}}, \text{ кг} \cdot \text{с}^{-1}, \quad (11)$$

where: $K_{отв}$ — gas flow rate through an opening, which takes into account the loss of kinetic energy of the gas flow during its passage through openings as a result of friction, vorticity, etc. and depends on the shape of opening and wall thickness (for window and door openings are taken equal as 0.6 ÷ 0.65);

$S_{прип}$ —the area of opening working to an air inflow;

$S_{вит}$ — the area of exhaust opening;

g — acceleration of gravity,

H — distance between centers of fresh air outlet and exhaust opening;

$\rho_{пов}$ —density of air outdoors;

$\rho_{пг}$ —density of gas environment in premises.

Solving the equation of material balance enables to determine the gas mass that accumulates in a premises during a certain time of the development of emergency, taking into account gas exchange with the environment:

$$m_г = \frac{g_г^{надх} \rho_{гс} V_{вільн}}{g_{гс}^{вит}} \left(1 - e^{-\frac{g_{гс}^{вит} \tau}{\rho_{гс} V_{вільн}}} \right), \text{ кг.} \quad (12)$$

Solving the equation within $\tau = 0$, $\varphi_г = 0$ та $\tau = \tau_{нкмпп}$, $\varphi_г = \varphi_н$ helps to calculate the time in which the average concentration of combustible gas in a free volume of a room will reach the value of the lower flammability limit, given partial leakage of combustible gas through openings of a room in the course of its emergency entry:

$$\tau_{нкмпп} = \frac{V_{вільн} \rho_{гс}}{g_{гс}^{вит}} \ln \frac{g_г^{надх}}{g_г^{надх} - \frac{g_{гс}^{вит} \varphi'_н}{\rho_{гс}}}, \text{ с.} \quad (13)$$

Over a certain time of flammable gas leakage, the lower flammability limit can be reached only in some part of a room. The so-called zone of explosive gas contamination is created. The radius of the zone of explosive gas contamination is estimated as follows:

$$R_{заг} = 1{,}1314 L \sqrt{\ln\left(\frac{1{,}38 \varphi_о}{\varphi_н} \right)}, \text{ м,} \quad (14)$$

where: L — the length of premises, m;

$\varphi_н$ —volumetric lower combustible gas flammability limit, %;

$\varphi_о$ — pre-exponential factor which is determined by empirical formulas:

• in the immovable environment —

$$\varphi_о = 3{,}77 \cdot 10^3 \frac{m_г}{\rho_г V_{вільн}}, \text{ %;} \quad (15)$$

• in movable environment (vпов> 0,1 м·с$^{-1}$) —

$$\varphi_о = 300 \frac{m_г}{\rho_г V_{вільн} v_{пов}}, \text{ %,} \quad (16)$$

where: $v_{пов}$ — the speed of air in a room, m·c^{-1}.

The time it takes for an explosive mixture to reach a potential ignition source (e.g. electric switch, open flame installations, etc.) can be estimated by the formulas (in the absence of airflows):

• in the immovable environment —

$$\tau = 1{,}92 \cdot 10^{-4} \frac{\rho_г V_{вільн} \varphi_н}{g_г^{надх}} e^{\left(\frac{R}{1{,}1314 L} \right)^2}, \text{ с,} \quad (17)$$

• in the movable environment —

$$\tau = 2{,}4 \cdot 10^{-3} \frac{\rho_г V_{вільн} v_{пов} \varphi_н}{g_г^{надх}} e^{\left(\frac{R}{1{,}1314L}\right)^2}, c, \qquad (18)$$

where: R — distance from the source of gas leakage to the probable ignition source, m.

Investigation of accidents at work due to explosions in pressure equipment (to establish the probable cause of their occurrence) is one of the main tasks assigned to the study of man-made explosions (this conditioned by occurrence possibility of such a physical phenomenon as gas-dynamic discontinuity). Due to release of energy that accumulates while gases compression, the vessel is torn into individual fragments. As it is known, during the arbitrary decay of a gas-dynamic discontinuity, three situations are possible which are outlined in detail below.

The first situation. The gas-dynamic discontinuity splits into two waves that spread in different directions from the initial discontinuity and to a contact discontinuity. This situation can occur during collision of two masses of gas moving towards each other at a significant speed, if the following condition is fulfilled [1]:

$$u_1 - u_2 > (P_2 - P_1)\sqrt{\frac{2/\rho_1}{P_1(\gamma_1 - 1) + P_2(\gamma_1 + 1)}}, \qquad (19)$$

where: P_1, P_2 —pressure of gas environments (pressure of the first P_1 pressure environment is lower that the pressure of the second P_2 gas environment);

u_1, u_2 —speed of gas movement in the first and second environment;

ρ_1 —density of gas in the first environment;

γ_1 —adiabatic index of the first gas environment;

In practice, such events may occur at industrial machinery and equipment as a result of violations of conditions of technological processes. Thus, one of the stages in establishing the cause of explosion under the mentioned circumstances is the research on technological automation.

The second situation is when the gap splits into two separate rarefaction waves moving in opposite directions and into a contact discontinuity. Thus, in practice, the above-mentioned situation is realized while destruction of the vessel shell with subsequent collision of gases. It should be stressed that this is the most typical scenario for the development of an emergency explosion of pressure vessels with both combustible and non-combustible substances which is implemented in the following conditions [2]:

$$\frac{2c_{s2}}{\gamma_2 - 1}\left(1 - \frac{P_1}{P_2}\right)^{\frac{\gamma_2 - 1}{2\gamma_2}} < u_1 - u_2 < (P_2 - P_1)\sqrt{\frac{2/\rho_1}{P_1(\gamma_1 - 1) + P_2(\gamma_1 + 1)}}, \qquad (20)$$

[1] Таубкин С. И. Op. cit.

[2] Таубкин С. И. Op. cit.

where: γ_2 — the adiabatic index of the second gas environment;
c_{s2} —speed of sound propagation in gas environment.

Thus, the destruction of vessels, being under the pressure, which contain liquefied gas or low-boiling liquid, is also accompanied by the appearance of an outside air wave and entering of the rarefaction wave into a vessel. This phenomenon provokes boiling of the liquid phase in a vessel and intense vaporization. During the described process, i.e. release of energy of the phase transition and the energy accumulated due to compression of the substance, the walls of the vessel shell are destroyed with possible spread of fragments over long distances.

The third situation is when the gas-dynamic discontinuity splits into two separate waves of rarefaction (their spread occurs in opposite directions). As a result, dispersion of gases takes place. At a fairly high speed of dispersion, the pressure in rarefaction waves drops to 0, and at the place of arbitrary discontinuity the area without gas appears which is being expanded: a vacuum. Thus, the explosion of the vessel with compressed gases and low-boiling liquids in the focal area of fire is called *BLEVE* (*Boiling Liquid Expanding Vapor Explosion,* that is explosion of vapors expanding while liquid boiling).

Studying the version of the occurrence of a physical or combined explosion conditioned by *BLEVE*, the potential possibility of such a phenomenon for a particular substance that was in the vessel is usually established. For this purpose, calculate the proportion of substance that immediately evaporates at a defined temperature according to the formula:

$$\xi_T = \frac{H_T - H_{T_{кип}}}{\Delta H_{вип}} = \frac{c_p\left(T - T_{кип}\right)}{\Delta H_{вип}} \qquad (21)$$

where: ξ_T —the proportion of liquid that immediately evaporates at T temperature;
H_T —relative enthalpy of liquid at T temperature;
$H_{Tкип}$ —relative enthalpy of liquid at $T_{кип}$ temperature according to atmospheric pressure;
$\Delta H_{вип}$ — relative heat of evaporation at the boiling point according to atmospheric pressure;
c_p —relative heat capacity of the liquid phase;
$T_{кип}$ —temperature of liquid boiling according to atmospheric pressure;
T — temperature of the liquid phase (in the availability in the vessel of the relief device, the T value is estimated by the formula:

$$T = \frac{B}{A - \lg P_к} - C_A + 273 \text{, K,} \qquad (22)$$

where: $P_к$ — discharge pressure of the relief device;
A, B, C_A —Antoine constants (determined according to the reference literature).

If ξ< 0,35, then *BLEVE* does not occur. At ξ> 0,35 probability of the occurrence of this phenomenon is significant.

The explosive power of a vessel with superheated flammable and combustible liquids or liquefied hydrocarbon gases is determined by the TNT equivalent, and the degree of destruction of the facility structure is due to ΔR excess pressure and *i* momentum of an explosion, which can be estimated by the formulas:

$$\Delta Ð = P_o\left(0{,}8\frac{m_{пр}^{0{,}33}}{r} + 3\frac{m_{пр}^{0{,}66}}{r^2} + 5\frac{m_{пр}}{r^3}\right), \text{ кПа,} \quad (23)$$

$$i = 123\frac{m_{пр}^{0.66}}{r}, \quad (24)$$

where: P_o —atmospheric pressure, kPa;

r — distance from the center of vessel, m;

$m_{пр}$ — provided mass or the TNT equivalent of the explosion (mass of trinitrotoluene provoking a similar degree of destruction), kg;

$Q_{ТНТ} = 4{,}52 \cdot 10^6$ J·kg^{-1} — explosion heat of trinitrotoluene;

E_{eff} —the effective energy of the explosion during the expansion of vessel environment which is calculated by the formula:

$$E_{eff} = V\frac{P_p - P_o}{\gamma - 1}, \quad (25)$$

where: γ —the adiabatic index of the expanding gas atmosphere;

V —the volume of the tank being demolished;

P_p — the pressure at which the tank demolishes[1].

To sum up, the above calculations enable to analyze how explosions occur in particular situations, and to determine the mechanism of their occurrence while forensic examination of the circumstances and mechanism of man-made explosions.

Conclusions. The scientific paper presents main methods of studying man-made explosions in the open area, indoors and in limited amounts. It should be emphasized that in forensic expert practice of research on man-made explosions, experts often encounter ambiguous situations related to the mechanism of occurrence and development of such explosions. A full and multidisciplinary analysis of probable circumstances of the development of an emergency with application of calculation methods is provided allowing to resolve this issue and to perform corresponding researches in short terms.

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Р. Н. Гусейнов, Ю. В. Панчук

Основні розрахункові методи дослідження обставин і механізму техногенних вибухів

Проаналізовано небезпеку техногенних вибухів, комплекс небезпечних чинників яких може спричинити тяжкі наслідки.

Метою статті є проведення аналізу небезпеки техногенних вибухів і наведення розрахункових методів дослідження для визначення механізму їх виникнення.

У статті викладено основні розрахункові методи дослідження техногенних вибухів на відкритій місцевості, у приміщеннях і в обмеженому об'ємі, що дасть змогу систематизувати процес дослідження та проаналізувати, як відбуваються вибухи в конкретних ситуаціях, і визначити механізм їх виникнення під час виконання судових експертиз дослідження обставин і механізму техногенних вибухів.

Ключові слова: *вибухова речовина, газопароповітряна суміш, концентраційні межі поширення полум'я, надзвичайна ситуація, надлишковий тиск, техногенний вибух.*

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Основные расчётные методы исследования обстоятельств и механизма техногенных взрывов

Цель данной статьи — проанализировать опасность техногенных взрывов и привести расчётные методы исследования для установления механизма их возникновения при проведении судебных экспертиз исследования обстоятельств и механизма техногенных взрывов.

Актуальность данной работы обусловлена тем, что современное производство и быт не могут обходиться без использования горючих и взрывоопасных веществ. При этом особое внимание следует уделять предупреждению чрезвычайных ситуаций, связанных со взрывами, а также проведению исследований по определению механизма возникновения тех-

ногенных взрывов. Исследования механизма возникновения техногенных взрывов позволят установить техническую причину их возникновения, проанализировать, по какой причине и по чьей вине наступило данное событие, а также какие меры следует предпринимать для минимизации вероятности возникновения подобных ситуаций.

Отмечено, что для получения достоверных выводов о механизме возникновения техногенных взрывов необходимо использовать научно обоснованные методы и методики, позволяющие оценить масштабы разрушения. Степень разрушения окружающих строительных конструкций и поражения людей зависит от избыточного давления, создаваемого в результате значительного расширения продуктов взрыва и распространения во все стороны от эпицентра. На взрывоопасных объектах причинами взрывов чаще всего являются: разрушение и повреждение производственных резервуаров, оборудования и трубопроводов; отклонение от технологического регламента (превышение давления и температурного режима работы оборудования), некачественный контроль за оборудованием и работой при проведении необходимых работ, а также несвоевременное или некачественное технологическое обслуживание оборудования.

Приведены основные расчётные методы исследования техногенных взрывов на открытой местности, в помещениях и ограниченном объёме, что позволит систематизировать процесс исследования и проанализировать протекание взрывов в конкретных ситуациях, а также установить механизм их возникновения при проведении судебных экспертиз исследования обстоятельств и механизма техногенных взрывов.

Ключевые слова: *взрывчатое вещество, газопаровоздушная смесь, концентрационные пределы распространения пламени, чрезвычайная ситуация, избыточное давление, техногенный взрыв.*

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