DOI:https: //doi.org/10.32353/khrife.1.2019.022
UDC343.148.6

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COMPARISON OF POTENTIALALLY DANGEROUS FACTORS WHILE USING OF RARE MOTOR FUEL GAS

A detailed analysis of the potentially dangerous factors in the use of diesel, gasoline, methane and propane-butane fuels was carried out in cars. A detailed analysis of potentially dangerous factors when using diesel, gasoline, methane and propane-butane fuels in automobiles has been carried out. 6 options of fuel usage are considered: a tank with g asoline and a system supplying it to the carburetor and further to the engine cylinders, a tank with diesel fuel and the system feeding it to the engine cylinders, gas cylinder installation when installing cylinders with methane on the roof of the car, gas cylinder installation when mounting cylinders with methane in the luggage compartment of the car, gas installation when installing cylinders with propane-butane mixture on the roof of the car, gas installation when installing cylinders with propane-butane mixture in the cargo compartment of the car. Meanwhile, the potential danger while the vehicle is in motion is analyzed, as well as while it is in the open parking lot and in the garage. As the initial data, the common operation period was taken – in summer with the temperature of 30°C and possible fuel leakage with the probability of formation of an explosive mixture. Nonane is taken as a model when considering gasoline, and Pentadecane is used for diesel fuel.

It was noted that the gasoline self-ignition temperature ranges from 255°C to 435°0C, the lower concentration limit of petrol explosiveness can be considered as 0.76% vol., while under selected conditions indoors, gasoline vapor can reach the concentration of up to 0.8 vol. %. The relative vapor density of diesel fuel betting the same conditions is 8.52 kg/m3. With the explosion, the pressure in the closed volume will reach 5.2 atm.

It was noted that the gasoline self-ignition temperature ranges from 210°C to 370°0C, the lower concentration limit of petrol explosiveness can be considered as in 0.5 % vol., while under selected conditions indoors, gasoline vapor can reach the concentration of up to 0.13 vol. %. With the explosion, the pressure in the closed volume will reach 5.0 atm.

The self-ignition temperature of methane is 537°C, the lower concentration limit of explosiveness of this gas is 5.28% (vol). The vapor density of methane at the temperature of 300°C (303K) is 0.64 kg/m3, which is significantly less than the density of air. The explosion pressure in the closed volume will reach 7.7 atm.

The propane-butane mixture used in summer contains about 40% of propane and 60% of butane. Spontaneous ignition temperature of propane is 4700C, butane is 4050C. The calculated lower explosion limit of this mixture is 1.5% (vol), and the vapor density of mixture at the temperature of 300°C is 2.1 kg/m3, which is almost twice the density of air under the same conditions. The calculated explosion pressure in the closed volume will reach 8.3 atm.

It was concluded that when using certified equipment which is professionally installed, methane, which cannot accumulate in the lower part of the room or any compartment, is much safer than propane-butane and, especially, than gasoline or diesel fuel, as vapor densities of both are more than air density.

Keywords: automobile fuel, gasoline, diesel fuel, methane, propane, butane, explosion, relative density, explosion limits, self-ignition temperature, explosion temperature of explosion, pressure of explosion.

Formulation of Research Problem. Constant health of oil and its refining products, including all types of liquid motor fuels, provokes the use of cheaper fuels, including combustible gases: natural gas (methane) and propane and butane extracted extracted from petroleum. One of the main issues is the potential danger of using such fuel. As a matter of fact, both gasoline and diesel fuel and methane and propane mixtures are flammable substances. Both fires and explosions, unfortunately, occur when using any of them. There are many examples of fires in recent years with the burning and explosion of fuel and while driving a car[1] and during parking[2] at gas stations[1] and in garages[2]. In this case, both liquid and

[1] V Dnepre vo vremja dvizhenija zagorelsja avtomobil' s. dvumja det'mi [in Dnipro, a car with two children caught fire while driving]. URL: https://ru.tsn.ua/.../v-dnepre-vo-vremya-dvizheniya-zagorelsya-avtomobil-s-dvumya-detmi–1195215.html (data zvernennia 10.04.2017) [in Russian].

[2] Na avtotrasse pod Zhitomirom sgorel avtomobil' s. GBO [A car with HBO burned down on the highway near Zhytomyr]. ViDEO URL: http://zhzh.info/news/2018–11–01–37693 (data zvernennia 10.04.2017) [in Russian].

gaseous fuel burns and explodes. In this paper, a comparison of the potential hazards of operating vehicles with liquid fuel and vehicles with gas balloons.

Analysis of recent research and publications. Given that more and more users are switching from liquid fuel to gaseous, the problem of choosing fuel is widely discussed. Economic [3] and environmental[4] aspects of this problem, as well as the complexity of installing and maintaining gas-balloon systems are discussed.Much attention is paid to comparing the advantages and disadvantages of using methane and propane-butane mixtures.

In detail, with statistics on Russia, the fire safety of gas cylinders and the causes in each case of the explosion are analyzed in[5].

Research Purpose. This paper discusses 6 options for using a car engine fuel. Tank with gasoline and the system of supplying it to the carburetor and further into the engine cylinders, the tank with diesel fuel and the system of supplying it into the cylinders of the engine, gas-balloon installation when installing cylinders with methane on the roof of the car, gas-balloon installation when installing balloons with methane in the luggage compartment, gas-cylinder installation at installation of cylinders with a mixture of propane and butane on the roof of the car, gas-cylinder installation at installation of cylinders with a mixture of propane and butane in the luggage compartment of the car. This analyzes the potential danger during the movement of the car, as well as when stored in an open parking lot and in a closed garage.

In each case, the extended operating period – summer with ambient air temperature of 30^0C and possible fuel leakage and the likelihood of

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[1] U Vinnytsi 4 osoby zghorily v avtomobili zazhyvo [in Vinnitsa, 4 people were burned alive in a car]. URL: https://znaj.ua/content/u-vinnyci-chotyryosoby-orily-v-avtomobili-zazhyvo (data zvernennia 10.04.2017) [in Ukrainian].

[2] Na Dnepre v rezul'tate pozhara v garazhe sgorel muzhchina [On the Dnieper a man was burned in a garage fire]. URL: https://24tv.ua/ru/na_dnepre_v_rezultate_pozhara _v_garazhe _sgorel_muzhchina _n981223 (data zvernennia 10.04.2017) [in Russian].

[3] Gaz VS benzin. Vygodno li v Ukraine ustanavlivat' GBO na avtomobil [Gas vs gasoline. is it profitable in Ukraine to install HBO on a car]. URL: https://www.segodnya.ua/./gaz-vs-benzin-vygodno-li-v-ukraine-ustanavlivat -gbo-na-avtomobil–668480.html (data zvernennia 10.04.2017) [in Russian].

[4] Jeksperty rasskazali, stoit li menjat' benzinovyj dvigatel [Experts have said whether it is worth changing a gasoline engine]. URL: https://ru.tsn.ua/.../eksperty-rasskazali-stoit-li-menyat-benzinovyy-dvigatel- avto-na-gazovyy–416222.html (data zvernennia 10.04.2017) [in Russian].

[2] *Vasjukov G. V., Korol'chenko A. Ja., Rubcov V. V.* Pozharnaja bezopasnost' gazoballonnyh avtomobilej [Fire safety of gas vehicles.]. Avtomobil'naja promyshlennost', 2006 g., № 2 [in Russian].

formation of an explosive mixture were taken as baseline data. During 2018, 4,346 fires occurred in vehicles in Ukraine (4,212 fires in 2017; 3, 2%), which is 5, 5% of the total number of fires in Ukraine.

As a result of these fires, 22 people were killed (18 in 2017; 22.2%), which is 1,1% of the total number of deaths in Ukraine. No deaths were reported (in 2017 – 1 child). The mentioned fires injured 55 people (in 2017 – 80 people; –31, 3%), including 3 children (in 2017 – 1 child).

Fires destroyed and damaged 3,924 vehicles. Material losses from the fires amounted to 972 million 446 thousand UAH, which is 11, 7% of the total losses. Among the vehicles most often burned:

– passenger cars (3 209 against 3 158 fires; 1, 6% or 73, 8% of the total number of vehicle fires);

– trucks (462 against 448 fires; 3, 1% or 10, 6%);

– buses (285 vs. 248 fires; 14.9% or 6.6%).

The causes of fires in some vehicles are given in Table. 1.

Table 1

Causes of fire in some vehicles

Causes of Fires	Passenger Cars		Trucks Buses		Buses	
	2018	2017	2018	2017	2018	2017
Arson	734	802	43	47	47	48
PPB when conducting el.-, gas welding works	41	30	7	2	7	4
Careless behavior with fire while smoking	47	31	23	13	5	0
Careless behavior with fire	64	127	22	28	9	7
The disadvantage of production technology	41	15	10	0	2	0
Overheating (destruction moving parts) due to friction	22	10	30	16	3	1
Depressurization of fuel (gas) system	234	39	27	4	8	0
Malfunction of electrical systems	1861	1872	244	273	193	169
Other reasons	165	232	56	65	11	19
Total fires:	3209	3158	462	448	285	248

The most common fires in some vehicles are listed in Table. 2.

Table 2

Occurrence of fires in some vehicles

Fire place Passenger cars Trucks Buses	Passenger Cars		Trucks Buses		Buses	
	2018	2017	2018	2017	2018	2017
Driver's cab, interior	510	577	117	99	53	53
Engine compartment	2011	357	197	38	179	12
Body	467	494	90	106	35	33
Other	221	1730	58	205	18	150
Total fires:	3209	3158	462	448	285	248

The most common option is when the fuel tank is located behind the vehicle – in or under the luggage compartment. The most common option is when the fuel tank is located behind the vehicle in or under the luggage compartment. Installing the fuel tank near the engine, which reduces the length of the fuel line and increases the overall reliability of the fuel supply increases the fire hazard and overload of the front or rear axle wheels, respectively, at the front or rear engine layout. Therefore, in cars with a front engine location, the fuel tank is located behind. For low-capacity vehicles, the fuel tank is located on the side, bottom or rear. In vehicles with a rear engine location, the fuel tank is in the front. In *safe* cars the fuel tanks are located within the base of the car: For a front-wheel drive car with an engine location in the front, the most rational is the location of the fuel tank in the rear seat. In this case, the likelihood of fuel burning in the side and frontal impacts is reduced.

At the same time, this probability increases somewhat when struck from behind.The most important internal sources of fire in a car include heated surfaces in violation of the tightness of the fuel system or lubrication system.

In the working car there are two zones of maximum temperatures:

– engine compartment;

– zone of the exhaust path from the manifold to the muffler exhaust pipe.

In the internal combustion engine, the exhaust gas temperature along the exhaust path is 800–830 ^{0}C, and the surface temperature is 710–770^{0}C. Of course, this is a very high temperature, it is higher than the auto-ignition temperature of most fuel and lubricants used in vehicles.

In a car, fuel can only accumulate in the engine niches and in some engine compartments. Because the engine compartments are not sealed, there is intense air exchange with the environment. In this case, the vapor concentration in the fuel evaporation zone is limited by the upper limit, depending on the air velocity in the zone.

At an air speed equal to 0,15–0, 18 m/s the concentration of vapors may not exceed 0, 01 mg/l. At a speed equal to 0, 25–0, 3 m/s – 0, 001 mg/l.

Taking in account that air velocities in the engine compartments of cars exceed the above values by an order of magnitude (1, 5 – 5 m / s), the concentration of the vapor or fuel accumulated cannot reach dangerous values and the ignition is excluded[1].

Nevertheless, the fuel tank leakage or the spill from the spare canister in the luggage compartment, given that the vapor density of gasoline or diesel is much higher than the density of the air, leads to the rapid appearance of the mixture with a dangerous concentration.

Gasoline. The most likely gasoline leakage points are leakage from a spare canister in the trunk, garage or other storage location; leakage from the tank (due to damage to the tank or due to the tightly closed lid); leaks in the fuel system or under the bonnet (due to leaks or malfunctions of the fuel pump or fuel line). The characteristic odor of gasoline and the clearly visible spots of this substance, in most cases, cause immediate troubleshooting. And what if the malfunction went unnoticed?

The lower concentration limit of the most hazardous A-66 flame spread is determined to be 76 % (vol)[2], corresponding to this value for nonane C_9H_{20}[3]. Тиск насиченої пари нонану при 30^0C складає 6 мм рт. ст. Отже[4], при даній температурі в закритому приміщенні пари бензину можуть знаходитися з концентрацією 6×100/760 = 0, 8 об. %.

Molecular weight of nonane is 182 atomic mass units. The density of nonane vapor at a temperature of 30^0C (303K) is 182 × 273 / (22, 4 × 303) = 7, 32 kg/m^3. Air density under the same conditions – 1, 14 kg / m^3. At this ratio, gasoline vapors will generally mix with the air in the lower trunk, garage or underbody. Getting into such a mixture of open flames is likely to cause an explosion. The direct ignition of the ignition source to the surface of the fire fluid is most likely.

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[1] Rassledovanie pozharov [Fire investigation]: uchebnik / pod red. G. N. Kirillova, M. A. Galisheva, S. A. Kondrat'eva. Sankt-Peterburg : Sankt-Peterburgskij universitet Gosudarstvennoj protivopozharnoj sluzhby MChS Rossii, 2007. S. 134–136 [in Russian].

[2] Pozharo-vzryvoopasnost' veshhestv i materialov i sredstva ih tushenija [Fire and explosion hazard of substances and materials and means of extinguishing them]. Spravochnik / pod red. A. N. Baratova i A. Ja. Korol'chenko. Kniga pervaja. Moskva : Himija, 1990. S. 163 [in Russian].

[3] Pozharo-vzryvoopasnost' veshhestv i materialov i sredstva ih tushenija [Fire and explosion hazard of substances and materials and means of extinguishing them]. Spravochnik / pod red. A. N. Baratova i A. Ja. Korol'chenko. Kniga vtoraja. Moskva : Himija, 1990. S. 54 [in Russian].

[4] *Yelahin H. i., Shkarabura M. H., Kryshtal M. A., Tyshchenko O. M.* Osnovy teorii rozvytku ta prypynennia horinnia [Fundamentals of the theory of development and termination of combustion]. Chastyna 1. Cherkasy, 2004. S. 145 [in Ukrainian].

In this case, the heat from the ignition source will cause an increase in the surface temperature of the liquid layer, evaporation of additional portions of combustible vapors, increase the concentration of these vapors above the surface to the lower concentration limit of the flame propagation, ignition of these additional portions of vapor with more heat, increasing the amount of vapor. and, as a consequence, the spread of flames across the entire surface or explosion. Thus, at this temperature, the leakage of gasoline in the trunk of the car or in a closed garage will quickly lead to the formation of explosive concentrations. In a tightly closed luggage compartment, an explosive concentration due to leakage from the spare canister can be generated even when the vehicle is moving.

In the engine room at this temperature while moving the vapor in a concentration greater than 8 vol. %, unlikely, as this space is ventilated and the evaporating vapors are immediately mixed with excess air. But, when the car is standing still and the engine is idling, malfunctions of the fuel system or gas pump can cause the formation of vapors that will not be eliminated by the radiator bleeding system.The self-ignition temperature of gasoline ranges from 255°C (for the most dangerous A-66) to 435°C (for aviation 91/115).

This means that at such a temperature the ignition is possible even without an open fire, for example, when gasoline enters the hot surface of a muffler. Since during the explosion the combustion products do not work at first and all the oxidation reaction energy goes into thermal, the explosion temperature will be 15–20^{0}C higher, i.e. about 1500K, that in this case is not significant.

With the complete conversion of the mixture of nonane with air into the products of combustion (explosion) one mole of nonane when reacted with 14 moles of oxygen and 64 moles of nitrogen[1]

$$C_9 H_{20} + 14(O_2 + 3{,}76N_2) = 9CO_2 + 10H_2O_2 + 52{,}64N_2 (1)$$

forms 64 moles of combustion products. That is, the volume of the mixture under hypothetical normal conditions would increase by 1, 06 times.

Given the increase in temperature from 303K to 1500K, it can be predicted that the pressure of the explosion in a closed volume will be equal (760 × 1, 06 × 1500) / 303 = 3980 mm Hg. ie, about 5, 2 atm.

Diesel.

As with gasoline, the most likely leakage points are leakage from a spare canister in the boot, garage or other storage location; leakage from the tank (due to the formation of holes in it or due to the tightly closed lid); leaks in the fuel system or under the hood (due to leakage or malfunction of the fuel pump). Like gasoline, diesel fuel has a noticeable odor and forms well-visible spots, causing immediate troubleshooting.

[1] Ibidem. P. 33.

The probability of not seeing the fault is very small in this case, but it still exists. The lightest fraction of the most volatile diesel fuel grade «A» (according to GOST 305-82) begins to boil at a temperature of 150^0C, which corresponds again to nonane, the saturated vapor pressure of which at 3030^0C is 6 mmHg. Nevertheless, the fractional composition of this hydrocarbon in diesel is very small. The clear majority are fractions having a boiling point of 255–322^0C. So, the model can be taken pentadecan with a boiling point of 270^0C. The lower concentration limit of the flame spread of the most dangerous diesel fuels of grades «Л» and «С» according to GOST 305-82 is determined as 5 % (vol.)[1].

The saturated vapor pressure of pentadecane at 300°C is less than 1 mmHg. Art. Therefore, at this temperature indoors, the vapor of diesel fuel can be at a concentration of not more than 1 × 100/760 = 0, 13 vol. %.

This means that even getting into the open fire will not cause an explosion or fire. Of course, this does not mean that you can light a fire or smoke in such a room. Nevertheless, accidentally getting into an open fire room is not likely to cause an explosion. Ignition is only possible here by directly raising the ignition source to the liquid surface. Molecular weight of nonane is 212 atomic mass units. The density of nonane vapor at a temperature of 30^0C (303K) is 212×273/(22, 4×303)=8, 52 kg / m^3. Air density under the same conditions – 1, 14 kg / m^3. Therefore, diesel vapors, like gasoline vapors, will mix with the air in the lower trunk, garage or underbody. But, unlike gasoline vapor, the dangerous concentration at 30°C will not work. The temperature of self-ignition of diesel fuels is even lower than the temperature of self-ignition of gasoline, and ranges from 210°C (for fuel grade «Л» according to GOST 305-82 to 370°C (for aviation 91/115).

This means that at such a ignition temperature possible even without open flames, for example, when the fuel gets on the hot surface of the muffler. When directly raising the source of ignition to the surface of the liquid or the ingress of liquid on the hot surface of the combustion is quite likely. The temperature of the surface layer of the liquid will increase at a temperature of 60-700C. At a temperature of 60-70°C, the evaporation of additional portions of combustible vapors will cause the concentration of these vapors above the surface to increase to 0.5% (about), i.e. to the lower concentration limit of the flame spread. Flashing these extra portions of steam will cause an extra amount of heat, an extra amount of vapor and, as a result, the spread of flames across the surface or an explosion.

The temperature of the explosion will be 15–20^0C higher, ie about 1400K, which in this case is also not significant. При повному перетворенні суміші пентадекану з повітрям у продукти згорання

[1] Pozharo-vzryvoopasnost' veshhestv i materialov i sredstva ih tushenija [Fire and explosion hazard of substances and materials and means of extinguishing them]. Kniga vtoraja. S. 266 [in Russian].

(вибуху) один моль пентадекану при реакції з 23 молями оксигену і 86, 48 молями нітрогену[1]. $C_{15}H_{32} + 23(O_2 + 3{,}76N_2) = 15CO_2 + 16H_2O + 86{,}48N_2$(2)

forms 117, 48 mole of combustion products. That is, the volume of the mixture under hypothetical normal conditions would increase by 1, 07 times. Given the increase in temperature from 303K to 1400K, it can be predicted that the burst pressure in a closed volume will be equal to

(760 × 1, 07 × 1400) / 303 = 3760 mmHg. ie, about 5, 0 atm.

Methane.

Methane, used as an automobile fuel, is usually contained in cylinders of high strength at a pressure of 200-250 atm. As with methane, cylinders can be placed either in the luggage compartment or on the outside of the vehicle.

Possible causes of methane leakage are malfunction of gas equipment and leaks in the pipeline system. To enable the detection of methane leaks, it is gifted with the addition of small amounts of substances with a very specific odor (ethyl mercaptan, etc.). The odor of odorant, which is usually perceived as a smell of methane, is not very difficult to notice. However, the potential risk of leakage cannot be underestimated.

The lower concentration limit of flame spread for methane is 5,28% (vol)[2]. At 30^{0}C this substance is in a gaseous state. Molecular weight of nonane is 16 atomic mass units. The density of nonane vapor at a temperature of 30^{0}C (303K) is 16×273/ (22, 4×303) =0, 52 kg/m^3. This means that in a closed room, the achievement of dangerous concentration is virtually eliminated. Therefore, with the location of the cylinders on the outer surface, the explosion is excluded even if the gas equipment malfunctions.

But the possibility of creating an explosive mixture in a very tightly closed luggage compartment or in the garage exists. The self-ignition temperature of methane is 537^{0}C which is much higher than the corresponding figure for gasoline or diesel. Data on the combustion temperature of methane in the air range from 1900^{0}C to 160^{0}C, an average of 2030^{0}C (2303K), the explosion temperature will be approximately 2320K.

When the mixture of methane with air is completely converted into the products of combustion (explosion), one mole of methane is reacted with 2 moles of oxygen and 52 moles of nitrogen.

$CH_4 + 2(O_2 + 3{,}76N_2) = CO_2 + 2H_2O + 7{,}52N_2$(3) forms 10, 52 молі продуктів згорання. Thus, the volume of the mixture would not change at all under hypothetical normal conditions. Taking in account the

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[1] Ibidem. S. 33.

[2] Pozharo-vzryvoopasnost' veshhestv i materialov i sredstva ih tushenija [Fire and explosion hazard of substances and materials and means of extinguishing them]. Kniga vtoraja. S 466 [in Russian].

temperature increase from 303K to 2320K, it can be predicted that the burst pressure in a closed volume will be equal to (760 × 2320) / 303 = 5820 mmHg that is, about 7 atm.

This is more than the explosion pressure for gasoline or diesel.

Propane-butane.

Mixture of propane and butane used in automobiles contains about 40% C_3H_8 propane and 60% C_4H_{10} butane in the summer. This mixture is in liquid form in cylinders under pressure up to 16 atmospheres. As with methane, cylinders can be placed either in the luggage compartment or on the outside of the vehicle. The same and probable causes of a gas leak are gas equipment malfunctions and leaks in the pipeline system.

To ensure leakage detection, this mixture is also gifted with the addition of odorless substances.The lower concentration limit of the spread of flame for propane is 2, 3% (vol)[1],, for butane – 1, 2% (vol). For the mixture under consideration by the well-known formula[2]: КМПП = 100 / (40/2, 3 + 60/1, 2) = 1, 5% (vol). At 30^0C this mixture is in a gaseous state. The molecular weight of propane is 44 atomic mass units. The density of its vapor at a temperature of 30^0C (303K) is 44 × 273 / (22, 4 × 303) = 1, 77 kg / m^3 For Bhutan, the corresponding figures are 58 atomic units of mass and 58 × 273 / (22, 4 × 303) = 2, 33 kg / m^3. The vapor density of the mixture at this temperature is 1, 77 × 0, 4 + 2, 33 × 0, 6 = 2, 1 kg/m^3, which is almost twice the density of air under the same conditions (1, 14 kg / m^3). Therefore, propane-butane vapors will be miscible with the air preferably in the lower part of even an open space, including the lower part of the luggage compartment of the vehicle. Concentration of combustible gases in this mixture quickly reaches a mark of 5% (vol.).The temperature of propane self-ignition is 470^0C[3], butane – 405^0C. This is higher than the corresponding figure for gasoline or diesel, but lower than for methane.According to the standard procedure, for example, the theoretical temperature of the explosion of propane and butane is almost the same and is 2130^0C (2400K).

When the mixture of propane with air is completely converted to combustion products (explosion), one mole of propane is reacted with 5 moles of oxygen and 18, 8 moles of nitrogen.$C_3H_8 + 5(O_2 + 3{,}76N_2) = 3CO_2 + 4H_2O + 18{,}8N_2$(4)

[1] Pozharo-vzryvoopasnost' veshhestv i materialov i sredstva ih tushenija [Fire and explosion hazard of substances and materials and means of extinguishing them]. Kniga vtoraja. S. 143 [in Russian].

[2] *Yelahin H. I., Shkarabura M. H., Kryshtal M. A., Tyshchenko O. M.* S. 130 [in Ukrainian].

[3] Pozharo-vzryvoopasnost' veshhestv i materialov i sredstva ih tushenija [Fire and explosion hazard of substances and materials and means of extinguishing them]. Kniga vtoraja. S. 143 [in Russian].

forms 25, 8 moles of combustion products. That is, the volume of propane-air mixture under hypothetical normal conditions would in general increase by 25, 8/24, 8 = 1, 04 times.

Given the increase in temperature from 303K to 2400K, it can be predicted that the burst pressure in a closed volume will be equal to

(760 × 2400, 1 × 04) / 303 = 6260 mmHg. ie, about 8, 3 atm.

Accordingly, one mole of butane is reacted with 5 moles of oxygen and 24 moles of nitrogen

$$C_4H_{10} + 6.5(O_2 + 3.76N_2) = 4CO_2 + 5H_2O + 24.4N_2 (5)$$

forms 33, 5 moles of combustion products. That is, the volume of the mixture under the hypothetical normal conditions would increase by 33, 5/31, 9 = 1, 05 times. Given the increase in temperature from 303K to 2400K, it can be predicted that the burst pressure in a closed volume will be equal to

(760×2400×1, 05)/303 = 6320 mmHg. ie, about 8, 3 atm.

Conclusions. As the above calculations suggest, the least potential risk of fire and explosion when using modern automotive fuels is to acknowledge the danger of using methane.The explosion pressure of this substance is slightly higher than the explosion pressure of liquid fuels, but methane is not able to accumulate not only in open spaces, but even in closed spaces, if the smallest slits are available. In addition, methane has the highest self-ignition temperature of all types considered. Gas cylinders, which are usually mounted in the trunk or on the roof of the car, are the most durable of all fuel storage tanks and can withstand considerable damage, even in severe accidents.

Available statistics state that no fires and explosions due to methane equipment have been recorded at all during the average year.

Instead, propane-butane plant equipment caused about 10% of fires and explosions, with the remaining 90% occurring in rare fuels.Provided that certified equipment is used and professionally installed, methane cylinders and their «strapping« are much safer than LPG cylinders and, more so, than liquid fuel tanks and canisters.

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ПОРІВНЯННЯ ПОТЕНЦІЙНО НЕБЕЗПЕЧНИХ ФАКТОРІВ ПРИ ВИКОРИСТАННІ РІДКОГО ТА ГАЗОПОДІБНОГО АВТОМОБІЛЬНОГО ПАЛЬНОГО

Проведено аналіз потенційно небезпечних факторів при використанні в автомобілях дизельного, бензинового, метанового та пропан-бутанового пального. Доведено, що метан при використанні сертифікованого обладнання і професійному його монтажі значно безпечніше, ніж пропан-бутан і, тим більше, ніж бензин або дизельне пальне.

Ключові слова: автомобільне пальне, бензин, дизельне пальне, метан, пропан, бутан, вибух, питома густина, концентраційні межі поширення полум'я, температура самоспалахування, температура вибуху, тиск вибуху.

Received by the Editorial Board: 12.06.2019