Specifics of Occurrence and Research on Fires in Modern Vehicles

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This article purpose is to set out an algorithm for determining mechanism of fire occurrence, taking into account the tangible and materialized sources of information submitted for examination. For achieving this goal, the author uses both general scientific and specialized methods of scientific cognition, including systematic approach, comparative legal method, deduction and induction, as well as methods of interpretation, structural analysis and observation. The author analyzes existing fire hazards in various types of motor vehicles and provides relevant statistical data. Characteristic causes of fires for motor vehicles are investigated and their conditional differentiation is performed. Possible scenarios for the course of such fires are presented and the probable places of occurrence of fires are indicated. specifics of intentional and unintentional fires are ana-

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lyzed in detail. The main distinguishing signs of these groups of fires are given. The main causes of unintentional fires in motor vehicles are interaction of combustible substances in case of depressurization of fuel system with the potential thermal impulse of the exhaust gas exhaust system, as well as thermal manifestations of electrical energy, in particular, short circuits in electrical equipment of the vehicle. Vehicle manufacturers and/or their owners are proposed to equip vehicles with an automatic fire extinguishing system and fire extinguishers of appropriate type that provide for extinguishing precisely in order to minimize material losses and the impact of fire hazards on people and environment.

Keywords: *car; ignition source; combustion intensifier; fire hazard; cause of fire; vehicles.*

Research Problem Formulation

Vehicles are a source of increased danger. The materials from which vehicles are made are mostly combustible and capable of spreading flames. In addition, each vehicle contains explosive and fire hazardous substances, such as fuel permanently stored in a tank or cylinder as a design feature. Fires in vehicles occur under certain conditions – in the event of an interaction between a combustible substance and an ignition source that occurs as an unregulated process. A fire is a destructive event that combines a set of hazards that can cause injury and death, as well as significant material damage and environmental pollution. Even current advanced developments do not exclude possibility of fires. Since modern humanity cannot do without vehicles, special attention must be paid to preventing fires, and this requires investigating the causes of fires and minimizing their consequences. Thereby this topic is relevant and requires careful consideration.

Analysis of Essential Researches and Publications

In our opinion, the issues of fires in motor vehicles and determining the causes of their occurrence using specialized knowledge have not been given enough attention in the scientific works of Ukrainian researchers. For example, the fire hazard of vehicles was studied by A. Havryliuk [1], O. Bazhynov [2], and M. Kravtsov (who noted fire hazard of electric vehicles and hybrids) [3]. Vehicle systems and assemblies

1 Гаврилюк А. Ф. Пожежна небезпека колісних транспортних засобів : монографія. Львів, 2018. 80 с. URL: http://surl.li/xddyyp (date accessed: 01.01.2025).

2 Бажинов О. В., Кравцов М. М. Небезпека транспортних засобів : монографія. Харків, 2022. 160 с. URL: http://surl.li/arqlkp (date accessed: 01.01.2025).

3 Кравцов М. Н. Пожарная опасность электро, гибридов и автомобилей. *Автомобіль і електроніка. Сучасні технології.* 2017. № 12. С. 117–122. URL: http://nbuv.gov.ua/UJRN/veit_2017_12_23 (date accessed: 01.01.2025).

were analyzed by V. Hudym et al.[4] in terms of fire hazard. Fire protection of wheeled vehicles was considered by A. Havryliuk[5]. Research on external signs of the presence of flammable and combustible liquids found at the scene of the fire is devoted to the work of O. Matiiuk, I. Riabinin, R. Huseinov and I. Shebalkov[6]. At the level of textbook, the fires were studied by S. Vovk[7] et al. Thus, insufficient attention has not been paid to the study of the causes of fires in motor vehicles.

Article Purpose

Propose an algorithm for determining mechanism of fire in modern vehicles, taking into account the tangible and materialized sources of information provided for examination.

Research Methods

For conducting research, both general scientific and specialized methods of scientific knowledge were used including a systematic approach, comparative legal method, deduction and induction, as well as methods of interpretation, structural analysis and observation.

Main Content Presentation

In modern conditions, transport is one of the most important sectors of the economy designed to meet the needs of population and production and significantly influence economic development and is an integral part of everyday life. Modern vehicles are a number of technical devices that are the latest achievements of technical thought and production. One of the most important and at the same time difficult tasks in the design of cars is their protection against fires. Given the definitions contained in regulatory legal acts, the concept of *vehicles* can be considered in a broad and narrow sense. In a narrow sense, this concept is used when mentioning road transport. In a broad sense, it includes railway, water, road, aviation, and also urban electric transport[8].

Law of Ukraine *On Motor Vehicle Transport* defines a motor vehicle as *"a wheeled vehicle (bus, truck, car, trailer, semi-trailer) used for the transportation of passengers, cargo or special work functions"*[9].

4 Гудим В. І., Гаврилюк А. Ф. Аналіз систем та агрегатів автотранспортних засобів за рівнем пожежної небезпеки. *Пожежна безпека.* 2013. № 23. С. 58–63. URL: http://nbuv.gov.ua/UJRN/Pb_2013_23_10 (date accessed: 01.01.2025).

5 Гаврилюк А. Ф. Протипожежний захист колісних транспортних засобів та шляхи його підвищення. *Там само.* 2017. № 31. С. 11–16. URL: https://sci.ldubgd.edu.ua/jspui/handle/123456789/4671 (date accessed: 01.01.2025).

6 Матіюк О. О., Рябінін І. М., Гусейнов Р. Н., Шебалков І. Л. Дослідження зовнішніх (візуальних) ознак наявності легкозаймистих і горючих рідин, виявлених на місці пожежі. *Теорія та практика судової експертизи і криміналістики.* 2020. Вип. 21. С. 373–387. DOI: 10.32353/khrife.1.2020_26 (date accessed: 01.01.2025).

7 Вовк С., Харчук А., Сухай А., Шелюх Ю. Дослідження пожеж : навч. посіб. Львів, 2022. 528 с. URL: https://books.ldubgd.edu.ua/index.php/ed/catalog/view/196/147/637-1 (date accessed: 01.01.2025).

8 Баркова С. П. Щодо поняття «транспортні засоби». *Форум права.* 2013. № 2. С. 13–18. URL: http://nbuv.gov.ua/UJRN/FP_index.htm_2013_2_4 (date accessed: 30.09.2024).

9 Про автомобільний транспорт : Закон України від 05.04.2001 р. № 2344-III (зі змін. та допов.). URL: https://zakon.rada.gov.ua/laws/show/2344-14#Text (date accessed: 30.09.2024).

The need for transportation of goods and passengers by road in our country is growing from year to year due to the expansion of domestic and international trade and economic relations. The volume of road transportation is increasing every year and the number of traffic collisions and transport fires is growing accordingly. In current environment, important element of sustainable socio-economic development of the State is ensuring the required level of fire safety and minimizing losses from fires.

Fire is a thermal transformation of substances and materials, accompanied by the release of heat, light and combustion products.

According to ДСТУ 2272:2006, *"**fire** is an unregulated process of destruction or damage to property by fire that causes factors dangerous to living beings and the environment"* [10].

Fires on motor vehicles are not only dangerous (for both individuals and legal entities), but cause economic damage. Thus, understanding the causes of road fires is the first step towards road safety. By taking appropriate measures, vehicle owners can significantly reduce the risk of fires and protect themselves and the rest of the road users and if the vehicle is stationary, understand what malfunctions should be paid attention to. Fire in transport is dangerous because it begins most often in latent mode, and they learn about it when the smell of burning and smoke is already noticeable: spread of fire here is much faster than in buildings (2-3 minutes).

The population often buys used cars whose malfunctions cause them to operate in emergency mode, which in turn increases the number of traffic collisions and fires.

In accordance with clause 7 of the Procedure for accounting for fires and their consequences [11] (hereinafter referred to as the *Procedure*), *the document certifying the fact of a fire* is a fire report in appropriate form of this Procedure, which is drawn up at the place of fire by an authorized official of the State Emergency Service (no later than 24 hours from the moment of liquidation of the fire or submission of a written statement about the fire; in two copies having equal legal force). The act shall indicate the information data obtained from the inspection of the fire site and the survey of the owner (user) of the fire object or its representative, as well as persons who witness the destructive event.

By its Resolution dated 10.12.2019 in case № 559/1094/17, the Supreme Court concluded that the proof of force majeure (fire) is a duly executed fire report, not a certificate of such fact. Therefore, in case of compensation for damage by insurance organizations, the vehicle owner should pay attention to the following [12].

In 2023, there were 3,613 vehicle fires in Ukraine (3,389 fires in 2022; +6.6%), which is 5.3% of the total number of fires in Ukraine. These fires resulted in 41 deaths (in 2022 – 22 people; +86.36%)

10 ДСТУ 2272:2006 Пожежна безпека. Терміни та визначення основних понять [Чинний від 01.07.2007]. Київ, 2007. 32 с. URL: https://antifire.ua/dbn/19-DSTU_2272_2006.pdf (date accessed: 01.01.2025).

11 Порядок обліку пожеж та їх наслідків : затв. постан. КМУ від 26.12.2003 р. № 2030 (зі змін. та допов.). URL: https://zakon.rada.gov.ua/laws/show/2030-2003-%D0%BF#Text (date accessed: 07.01.2025).

12 Постанова Верховн. Суду від 10.12.2019 р. Справа № 559/1094/17. Адмін. провадж. № К/9901/35037/18. URL: https://iplex360.com.ua/sud.php?doc=86274775 (date accessed: 07.01.2025).

that is equal to 2.8% of the total number of deaths in Ukraine. These fires injured 127 people (68 people in 2022; +86.76%). Fires destroyed 2,970 pieces of equipment [13].

Analysis of statistical data indicates a trend towards an increase in the number of vehicle fires. Although these incidents are rare compared to the total number of vehicles, their consequences can be devastating. Therefore, research focused on identifying the causes of vehicle fires remains important for understanding the risks associated with. In addition, such research is crucial for exploring ways to potentially reduce the likelihood of fires and minimize their consequences.

The causes of fires caused by ignition sources can be divided into external and internal ones. These include: failure to comply with fire safety regulations, technical malfunctions, improper operation, structural faults and intentional arson.

It is worth noting that fires with a free development time of more than 5 s account for 39% of the total number of vehicle fires (22% of deaths), and 55% of fires with a free development time of more than 10 min caused 71% of deaths, which indicates the rapid development of vehicle fires and their dangerous impact. Vehicle fires occur and spread rapidly due to design and technological features, the presence of flammable and combustible liquids (fuel, lubricants, cooling and brake fluids) and components (artificial leather, plastics, foam rubber, synthetic substances, fabrics, etc.), poor and/or incomplete control over the technical condition, improper operating conditions, and long manufacturing time. Fire cause is a circumstance, action, or process that directly causes a fire. One of the most common causes of vehicle fires (according to statistics) is fire-hazardous modes of operation of the onboard electrical system (35%). As vehicle on-board systems diversify year after year to increase comfort and meet the needs of the driver, the electrical networks in these vehicles are also expanding and evolving, which consequently increases the risk of fire through electrical system.

At the same time, when electrical equipment fails and its emergency mode of operation causes a fire, the insulating material plays a major role in igniting and/or maintaining combustion. Most often, this material is combustible with medium flammability. More than 24% of vehicle fires are caused by the melting of hoses and pipes containing flammable substances under the influence of exhaust gases from a damaged exhaust manifold and subsequent interaction with the combustible system, fuel and other operational flammable liquids getting onto heated surfaces of the engine or turbocharger, leaks in fuel and hydraulic system valves; 11% are caused by arson; in approximately 32% of cases, the cause of the fire is not known.

The most dangerous for passengers are fires that occur during vehicle operation. If a fire breaks out in the engine compartment, combustion products can enter the vehicle and cause poisoning before the vehicle stops and passengers get out. If the brake system components are damaged by flames, they can malfunction, leading to traffic collision. It should be noted that 68% of fires occur in the engine compartment, and 13% in the passenger compartment or cab. Fires that occur during traffic collision are particularly dangerous because of the severe consequences (burns or death

13 Аналітична довідка про пожежі та їх наслідки в Україні за 12 місяців 2023 року. Київ, 2024. 39 с. URL: https://idundcz.dsns.gov.ua/upload/2/0/1/8/2/6/2/analitychna-dovidka-pro-pojeji-122023.pdf (date accessed: 30.09.2024).

of passengers). Injuries and blockage of people inside the vehicle, as well as deformation of the body as a result of accidents, complicate the process of extinguishing the fire and prompt evacuation of victims. In addition, damaged vehicle systems and components contribute to the rapid spread of flames. The main causes of vehicle fires in garages and parking lots are careless handling of fire, non-compliance with fire safety requirements when starting the engine, defects in the fuel system and sparks from electrical equipment.

In cars, components and systems are structurally combined, and their emergency modes can cause a fire. Modern vehicles have more powerful and technologically sophisticated branched electrical networks and power systems. Developed fuel lines, heating of engine components and systems can lead to extremely high thermal radiation, and at a certain critical value, a fire can occur there.

Fire hazard of vehicle compartments depends on the availability of flammable substances and potential sources of ignition [14]. Oxidizer is known to be present at all times that generally satisfies the concept of combustion.

Since oxidizers are present in almost every compartment and assembly of a vehicle, the fire hazard depends on what substances they contain and on the likelihood of an ignition source of sufficient power in that compartment or assembly, i.e., on manufacturability of the vehicle under research.

All other things being equal, compartments containing flammable liquids and combustible gases have a higher fire hazard than compartments containing only solid combustible materials [15].

Flammable or explosive substances have properties contributing to initiation and development of a fire or explosion.

Fire hazard is a cumulative property of materials and substances that characterize their ability to ignite and spread combustion.

All materials and substances are characterized by a flammability index in terms of fire.

Flammability is ability of materials and substances to ignite under the influence of an ignition source and continue to burn after it is removed.

The fire hazard of various combustibles depends on their aggregate state, physical and chemical properties and specific storage and use conditions.

According to the degree of fire hazard, substances and materials from which vehicles are made and that make up their components can be divided into the following groups:

1) flammable ones are substances (materials, mixtures) capable of igniting from a short-term action of an ignition source with low spark energy;
2) combustibles ones are substances capable of self-combustion after removal of ignition source;
3) highly combustible ones are substances that can burn only under the influence of an ignition source (for example, in case of fire) but are not capable of independent combustion;
4) non-combustible ones are substances that are not capable of burning.

14 ДСТУ 8828:2019 Пожежна безпека. Загальні положення [Чинний від 01.01.2020]. Київ, 2020. 87 с. URL: https://zakon.isu.net.ua/sites/default/files/normdocs/dstu_8828_2019.pdf (date accessed: 01.01.2025).

15 Бажинов О. В., Кравцов М. М. Небезпека транспортних засобів : монографія. Харків, 2022. 160 с. URL: http://surl.li/arqlkp (date accessed: 01.01.2025).

This division is conditional and depends on many circumstances.

Thus, fire hazard factors of motor vehicle compartments can generally be considered to be:

- use of combustible substances and materials;
- formation of fire hazardous environment in the compartment, inside systems and devices;
- appearance of an ignition source in a fire hazardous environment;
- emergence of conditions favorable for development of combustion and the spread of fire.

Fire load means the components and assemblies that make up a motor vehicle, all substances and materials of construction, as well as materials (substances) used in its systems that are capable of burning. The fire load is characterized by the mass, type and composition of combustible materials, as well as the amount of heat released during its combustion per unit surface area. The distribution of the fire load has a significant impact on the characteristics of fire development. The fire hazard of these materials is characterized by their ability to ignite, form flammable concentrations, explode and burn (from an ignition source, in case of interaction with other substances and oxidizers) [16].

Almost the entire combustible load is contained inside the vehicle (liquefied gas, fuels and lubricants, operating fluids, interior trim, seats, electrical insulation, polymeric containers for liquids) and in hybrid vehicles and electric vehicles, traction battery.

Combustible materials are component of wheels, decorative parts (made of polymers) and paint and varnish coating which quality depends on the state-of-the-art technology used.

The fire load containing various combinations of combustible materials of different nature is calculated according to the following formula, where its numerical value Q is expressed in megajoules:

$$G = \sum_{i=1}^{n} G_i Q_i,$$

where: n is number of combustible and flammable components in the machine;

Q_i is lower calorific value of the i-th material (MJ/kg);

G_i is the weight of the i-th material (kg).

For example, a modern truck on average contains 120—450 kg of rubber products, 120—200 kg of diesel fuel, 50—70 kg of motor and transmission oil, 4—6 kg of polyurethane foam, 1.8—2.9 kg of polyethylene, 2.6—3.8 kg of PVC, 2.5—3.4 kg of cardboard, and 9-10 kg of artificial leather. The calorific value of diesel fuel is 43.59 MJ/kg, engine and transmission oil: 41—42 MJ/kg, rubber products: 32—34 MJ/kg, polyurethane foam: 24.3 MJ/kg, polyethylene: 47.14 MJ/kg, PVC: 14.31 MJ/kg, cardboard: 13—14 MJ/kg, artificial leather: 17—18 MJ/kg. Thus, the fire load of a truck is in the range of 10,300—14,500 MJ. Modern vehicles have higher heat release rates during combustion compared to previously produced vehicles which is due to increased use of polymers.

In electrical systems, the fire load includes the insulation of conductive conductors of electrical wires, housings and radio components of electronic assemblies. Poly-

16 Пожежна безпека автомобіля / Навч.-метод. центр цивільн. захисту та безпеки життєдіяльн. Закарпат. обл. : офіц. сайт. 18.11.2021. URL: https://nmc.dsns.gov.ua/zk/news/ostanni-novini/494 (date accessed: 07.01.2025).

ethylene, polyvinyl chloride plastic and rubber are used for insulation. Electronic boards are usually made of paper-laminated plastic or fiberglass. Plastic masses, compounds, impregnated paper, paint and varnish coating and other similar materials are used in the construction of housings and some radio components.

In a fuel system, the combustible medium includes flexible fuel lines and the fuel itself, that can be diesel, gas, or gasoline.

Due to the fact that fuel system is isolated from the external environment, the occurrence of a fire hazardous environment in the engine compartment is possible only in the event of a leak. The analysis of the causes of fires in motor vehicles shows that the places of depressurization, mechanism of this process and its causes may vary and usually depend on the design characteristics of the vehicle, quality of manufacturing and installation of parts, operating conditions and the level of maintenance.

Fuel combustion occurs in the vapor or gas phase (e.g., diesel or gasoline/gas) and is characterized by concentration and temperature limits for flame spread. Fire hazardous concentrations can form in engine niches and vehicle compartments, mainly in the engine compartment.

In addition to fuel, other combustible liquids are used, including engine and transmission oils, coolants, brake fluids, etc.

The main combustible load in a vehicle cab is made up of interior parts, including the dashboard, seats, ceiling, floor, door, and other upholstery, and electrical wiring insulation. Most of these parts are made of combustible polymers.

In the engine compartment, the combustible load is made up of finishing materials, containers with a supply of operating fluids, engine oil, coolant. In or under the trunk, fuel tank, liquefied gas cylinder [17].

Determining the source of ignition and the cause of a vehicle fire is a complex task that requires a thorough understanding of the composition and characteristics of both the structural materials used to make the vehicle and the fuels and lubricants required for its operation. While determining the cause of a fire, it is necessary to take into account the ignition, flash and melting points of all materials used in the automotive industry. Fires in vehicles have significant differences from those in residential buildings. Flames in a car spread very quickly: usually within the first 15 minutes, a car suffers significant damage or complete destruction.

The main sources of ignition that cause car fires include thermal impulses of an electrical nature, in particular sparks (due to a short circuit or other emergency conditions in the internal electrical network); frictional sparks (caused by an accident, technical malfunction); friction of surfaces (braking system, clutch), surfaces of the exhaust system, heated above the ignition temperature of flammable vapors and flammable liquids and materials; open fire (due to repair work, arson, explosion, etc.).

Causes of fires at motor vehicles:

- during operation, malfunctions in the fuel and electrical systems. Less commonly, fire is caused by the ingress of combustible mixtures caused by depressurization of the fuel or hydraulic systems onto elements of the exhaust gas exhaust system or by an explosion of a gas cylinder;
- during repair work, careless handling of fire, non-compliance with

17 Гаврилюк А. Ф. Зазнач. твір. URL: http://surl.li/xddyyp (date accessed: 01.01.2025).

fire safety rules in technological procedures, as well as during welding. The situation is further complicated by the lack of knowledge of the vehicle design features by the persons performing the repair;

- in parking lots or garages, careless handling of fire, non-compliance with fire safety rules when starting the engine, as well as improper operation of heat-generating equipment or electrical devices;
- fires caused by deliberate arson constitute a separate category. In such cases, the open fire source is usually created through the use of flammable or combustible liquids. The characteristic signs of arson include finding a car in a parking lot with the engine turned off and electrical equipment disconnected, as well as the location of the fire inside the cab, in the engine compartment or outside the vehicle as a result of traffic collision or ammunition explosion.

They can be categorized into two main groups: intentional and unintentional.

Intentional fires are mostly related to insurance fraud, revenge, or other criminal intentions (deliberate introduction of an open fire source or use of special devices). Most often, such incidents occur at night (approximately between 02:30 and 04:00), when the number of potential witnesses is minimal and the first signs of fire are not immediately detected. This contributes to uncontrolled spread of flames leading to larger fires with more serious consequences.

If a car fire is extinguished as quickly as possible, there is a significant chance of determining the cause of the fire, as well as identifying residues of combustible or flammable substances or other materials used as ignition agents. This is especially true when fires occur in urban areas, where fires are usually detected and extinguished at an early stage, which helps preserve the evidence needed to determine the cause of the incident. Such fires are most often caused by third-party ignition sources. Vehicle arsons are also often committed to hide other crimes. Signs of arson: fire damage to the upper and lower parts of the radiator and heater pipes, as well as the fan drive belt, which usually indicates the use of combustion initiators. Additional evidence of intentional arson is the burning of the front rubber engine mounts. Based on our own expert practice, we have systematized the signs of arson with the use of accelerators and cases caused by technical malfunctions (*q.v. Table*).

Differential signs of arson with the use of combustible liquids / combustible materials or as a result of a technical malfunction associated with the leakage of combustible liquids / combustible materials

Sign	Arson with the use of combustible liquids	Technical malfunction (leakage of combustible liquids/ combustible materials)
Fire center outside the vehicle	+	–
Fire center outside the area of “regular” potential ignition sources	+	–
Fire center inside the cab	+	–

Table completion

Stratification of spills of the arson type	+	–
Stratification of spills of the not arson type	–	+
Localization of center signs in places of possible depressurization of gas distribution systems	–	+
Availability of remnants of ignition devices	+	–
Morphological characters of mechanical glass fracture	+	–
Morphological characters of arbitrary disconnection of pipelines with liquid and gas	–	+
Fire while driving or immediately after stopping (hot exhaust)	–	+
Discrepancy between the identification features of the detected fluid and the "standard" vehicle fluids	+	–

Expert practice indicates that use of combustible liquids and combustible materials at a fire scene leaves characteristic visual signs. This is due to the peculiarities of the combustion of such substances, which is homogeneous, diffuse and occurs in turbulent conditions. The vapor that is released from the surface of the combustible liquids and materials mixes with the surrounding gas environment through convective and molecular diffusion mechanisms, forming a vapor-air mixture known as a combustible system. The flame temperature in this case reaches 1200—1350 °C. These combustion specifics cause specific signs of thermal damage at the fire site.

The external signs of the use of combustible liquids and materials during fires at motor vehicles include characteristic traces in the form of burnt spots that resemble puddles of spilled liquid. Such spots can be found on plastic surfaces or on paint and varnish coating of metal elements. They usually have a blob-like shape with a clear boundary between the charred area and the unburned part of the material. Most often, these traces remain in places where the temperature during the fire did not affect the surface for long.

Rapidly evaporating combustible liquids and materials (gasoline, sulfuric ether, hexane, acetone, etc.) most often do not leave stains on surfaces without paint and varnish coatings (while combustion of combustible liquids and materials vaporing, surface temperature does not reach a level that causes noticeable thermal damage). In the case of heavier liquids (such as kerosene or diesel fuel), stains are bound to form. In addition, similar traces can remain after combustion of oils, bitumen, or molten polymers. Foamed polymers usually burn very intensely and sometimes do not leave any charred residues at all. However, most often the presence of such residues indicates that a polymer or other material, and not combustible liquids or combustible materials, burned in this place. For example, after the combustion of polyurethane foam, only a puddle of liquid products of its depolymerization remains. It is worth noting that thermoplastic polymers can melt and flow and their burnout areas usually have a blob-like shape, similar to that which occurs during ignition of combustible liquids and materials.

While analyzing thermal signs at a fire scene that indicate the use of flammable and combustible substances as combustion intensifiers, the following should be taken into account:

- characteristics of materials in the fire zone are evidence that ignition of substances and materials of the fire load may require the prolonged use of a powerful ignition source or flammable and combustible liquids. It can be evidence of the actual use of such liquids. This group of indicators includes the situation when the scale of the consequences of a fire is disproportionate to the small amount of fire load or low rate of heat transfer during combustion;
- place of origin, peculiarities of initial stage of the fire and the rapid dynamics of its development may indicate the use of flammable and combustible substances. This is the case when there are no powerful sources of ignition in the fire center and the rapid development of the fire would not have been possible without artificial initiation using such substances. Sudden flame spread that is not justified by other factors may also mean the use of combustion intensifiers. Especially when the fire is accompanied by "plops" (characteristic loud sounds similar to a weak explosion) and is intense from the very beginning, this is an obvious sign of the use of combustible liquids or combustible materials. At the same time, it should be remembered that availability of these substances at the fire site cannot be explained by technological conditions or fuel leakage;
- lack of focal signs in the traces of thermal effects on the fire object is observed when there are no clearly defined places of combustion. This situation most often occurs when a fire develops rapidly, which is typical for the use of combustible liquids and combustible materials as combustion enhancers. In particular, spillage of such substances over a large area often interferes with the formation of focal features. However, while analyzing this sign, it is important to remember that other factors can cause rapid fire development (intensive gas exchange caused by the constant flow of oxygen into the combustion zone; availability of powerful ignition source and the flammable properties of materials). In addition, smoothing or complete disappearance of focal signs is often observed in the case of a large-scale burning that is stopped without involvement of State Emergency Service units to extinguish the fire;
- availability of a characteristic odor felt at the scene of the fire by witnesses or employees of the State Emergency Service while extinguishing procedure.

When combustible liquids and materials are used to set fire to a vehicle, the liquid spreads over the entire area of the spill, resulting in a significant burning zone. Characteristic sign of use of combustible liquids and materials is surface burning on the vehicle body that is large and shaped accordingly. In the event of a rapid fire extinguishment, when paint and varnish coating does not have time to burn completely, characteristic traces of liquid spreading in the form of areas of coating burnout can remain on the front fenders. In the event of a spill of combustible liquids and materials on the hood of a vehicle, specific areas of local or uneven burnout of paint and varnish coating appear. The borders of such areas usually have a wavy shape. Spill marks can look like one large area or several smaller ones separated by fragments of unburned coating. The bulk of the spilled liquid drains through drainage channels, in particular onto the ground behind the front wheels of the vehicle. In these areas, characteristic thermal damage to the body is often observed. The most severe damage is usually localized in the area of the drainage channel, where more liquid has entered. By analyzing location and shape of the spots left by the liquid on the body surface, you can roughly determine the location of the initial spill. It is important to take into account the nature and intensity of burning in the areas of drainage holes, in the areas adjacent to, as well as where liquid may have accumulated. These features will help to clarify the circumstances and mechanism of motor vehicle arson.

Majority of unintentional fires occur in the engine compartment of motor vehicles (this applies to cars, trucks and other equipment).

Analysis of the causes of fires at the motor vehicles indicates their rapidity. This is due to the use of significant amount of flammable materials both during production and in the process of operation of vehicles. These include motor fuel (gasoline, diesel, liquefied gas), lubricants (various types of oils), rubber and technical materials (seals, tires, mats, etc.), as well as facing, upholstery and insulating materials (for example, organic glass, polystyrene, polyurethane foam, polyethylene, vinyl leather, paper-laminated plastic, etc.). A significant part of these materials is characterized by a high combustion temperature and rapid flame spread.

Taking into account the design features of cars, it is possible to predict the source of ignition, that is, determine the probable cause of ignition of engine oil, materials of construction and decoration.

The most common cause of fuel ignition is its overheating by heat coming from outside. Overheating can occur if fuel gets on engine parts, the heater, wires heated by overload currents or short-circuit currents. Fuel ignition and ignition of the vapor-air mixture from an open flame are possible if the rules for using the preheater are not followed, during welding work near the fuel tank or fuel lines.

Ignition of the vapor-gas mixture can occur due to a spark of static electricity during fuel transfer or refueling, especially from a fuel tank. Depressurization of the fuel system due to traffic collision can also lead to ignition of the fuel from sparks of mechanical origin that occur as a result of an impact. It is possible for the vapor-gas fuel mixture to ignite from an open source of fire, even a low-calorie one, for example, a match flame or an unextinguished cigarette.

For ignition of flammable structural and finishing materials used in the automotive industry, fairly high temperatures and thermal energy are required.

Sources of ignition can be electrical conductors that overheat due to overload or short-circuit currents, the thermal effect of an electric arc during short circuits, hot exhaust gases in the event of a leak in the exhaust system in the area of flammable materials, overheated heater elements or a source of open fire. The fuel system and electrical equipment of the motor vehicles are the main sources of increased fire danger. The highest temperature regime in the engine compartment is observed in the exhaust tract, from the collector to the exhaust pipe of the muffler. In an internal combustion engine, the temperature of the exhaust gases along the exhaust tract reaches 800–830 °C, while the temperature of the outer surfaces of the exhaust tract is slightly lower and is 710–770 °C. An additional factor that increases the risk of fire is the high saturation of motor vehicles with flammable materials. In addition, the absence of structural barriers between important parts of the car, for example, between the engine compartment and the interior or between it and the luggage compartment, contributes to the rapid spread of combustion. While analyzing the cause of the fire, it is worth considering that the ignition process can be significantly accelerated due to the instantaneous spread of the flame through a layer of spilled fuel. This can happen if the fuel system is damaged, that allows the fuel to quickly cover large areas of the car surface.

Many fires in cars and trucks are caused by antifreeze leaking onto hot engine surfaces, which is especially true for older cars. The scenario for such a fire is usually as follows: the driver notices an increase in engine temperature or steam coming out of the engine compartment. After the car stops, the engine starts to catch fire. The main cause of the fire is the composition and properties of antifreeze (a coolant – a mixture of ethylene glycol and water in a ratio of 50/50). Ethylene glycol has an autoignition temperature of 380 °C, and the ignition temperature of its vapors in air is 112 °C. The range of vapor concentrations at which flame propagation is possible is from 3.2 to 15.3%. It is known that the elements of a running engine (manifold in gasoline models or the turbocharger in diesel models) can heat up to temperatures significantly higher than the autoignition point of ethylene glycol. In the event of an antifreeze leak onto such surfaces, the water component evaporates, leaving pure ethylene glycol. This substance quickly heats up to its flash point (116 °C), creating conditions for ignition. The flash can occur due to a spark from the engine electrical components in a volume of space saturated with ethylene glycol vapor. If there is no spark, ignition is still possible if ethylene glycol comes into direct contact with a hot manifold or turbocharger. Such incidents most often occur while the engine is running.

Fires caused by fuel ignition most often occur due to various malfunctions in fuel equipment connections. The autoignition temperature of gasoline varies from 255 to 370 °C, while the temperature of an electric spark exceeds 2000 °C, which ensures instant ignition of gasoline vapors. When determining the causes of fires, it is important to pay attention to the detection of leaky areas in metal pipelines of the fuel system. While using highways made of polymer materials, it is more difficult to determine the location of the leak (due to the complete combustion of these elements). It should be noted separately that fuel getting on the hot parts of the engine or turbocharger can cause ignition. In the event of a fuel leak under the car and its ignition, serious damage to the rear of the car is characteristic, in particular, the rear tires burst into flames, as well as availability of traces of burning on the ground. Another reason for emergency mode of the fuel system is a violation of the rules for operating the vehicle, for example, using low-quality gasoline, deviations from technological standards and maintenance schedules, mechanical damage or unreliable connections. Fuel system malfunctions can be determined by indirect signs that precede the fire and are detected during an interview with the owner of the vehicle or witnesses to the incident (interruptions in engine operation: difficulty starting, unstable idling, reduced power, as well as sounds like “plops”). Other indicators include increased fuel consumption, the smell of gasoline in or near the car interior, and traces of fuel leaks indicating leak in the system.

Fires occur by a similar mechanism when engine oil leaks and gets on the hot surface of the manifold. The oil ignites spontaneously at a temperature of 450 °C.

Determining the causes of fires caused by the conversion of electrical energy into heat is a difficult task, due to the large number of conductors grouped in harnesses. In such cases, the wires can fuse together or become brittle due to the significant impact of high temperatures. Conductors and elements of power electrical equipment that are not protected by fuses, in particular the generator, the power wires to it, the starter traction relay and the fuse block of the on-board power supply system, pose a particular fire hazard. A short circuit in the on-board network of motor vehicle often occurs due to damage to the insulation that leads to its friction against sharp parts of the structure due to vibration of the wires while the car is moving. One of the signs of a short circuit is a discharged battery: its absence on the car excludes possibility of ignition due to a short circuit. However, such a situation does not always indicate that the fire was caused by a short circuit. While inspecting car wiring, it is worth remembering that during short circuit, conductors melt, forming voluminous lumps of metal. At the same time, wires that have burned out from the effects of the flame have a characteristic sharpening. While determining the location of the short circuit to determine the causes of the fire, it is important to remember that the weak flame that occurs during such an event must be near a combustible material to ensure further spread of the fire. The external condition of the wires (including their insulation) can be used to roughly determine the maximum heating temperature during a fire, which will help to understand the mechanism of its development in more detail (*Fig. 1*).

Fig. 1. Appearance of copper stranded conductors with traces of thermal exposure at different temperatures

Recently, the most relevant causes of fire are explosions of ammunition as a result of hostilities of the Russian Federation. During the explosion, potential energy is converted into kinetic and thermal energy, which is transformed, in particular, into an open flame. In addition, the amount of heat released during such explosions ranges from 1 to 6 MJ, and the temperature of detonation combustion is several thousand degrees Celsius, which in turn significantly exceeds the minimum energy for igniting the available combustible materials in motor vehicle. During explosion of ammunition, thermal pulses of various ignition sources arise, which are capable of igniting the combustible material of the motor vehicle in the area of impact of ammunition or near it within the limits of the influence of dangerous explosion factors. Such groups of ignition sources, in particular, include heat received from a hotter or incandescent body, and an unusual ignition source (open flame).

In an electric vehicle (hybrid vehicle), a significant fire hazard is posed by a traction battery[18] equipped with lithium-ion cells, which have a certain susceptibility to risks: explosiveness, sensitivity to overdischarging and overcharging. Full discharge is extremely dangerous, as it can irreversibly damage the battery. Attempting to charge a fully discharged battery can cause an explosion. In addition, such batteries are very sensitive to mechanical damage, overheating and improper use of chargers. Overcharging that is actually overloading the battery with current, significantly increases the risks: decrease in capacity, damage to the battery or even its loss. Although when a full charge is reached, the generated reverse current usually compensates for the charging flow, inexpensive chargers can demonstrate a different picture. In practice, use of cheap Chinese or domestic chargers often leads to rapid battery wear. In addition, they can get very hot, which causes chemical reactions with the release of hydrogen, which can provoke an explosion. As for motor vehicle with a hybrid or electric power plant, the batteries are located closer to the bottom to increase the maneuverability of the car. However, in the event of a collision with large objects or sharp debris getting under the wheels, the battery can suffer significant damage, which often leads to an instant fire of the motor vehicle. Lithium batteries are occasionally prone to explosive spontaneous combustion. The burning intensity of these batteries can cause serious consequences. Characteristics of lithium (Li): flammable silver-white soft metal; atomic mass 6.94; density 534 kg/m^3; melting point 179 °C; boiling point 1372 °C; specific heat of combustion 43,221 kJ/kg; thermal conductivity coefficient 71.2 W/(m×K); ignites when heated in air; combustion temperature ≈1300 °C; autoignition temperature in air 180–200 °C; vigorously decomposes water; ignites in chlorine, bromine and iodine vapors; burns in carbon dioxide; reaction with nitrogen begins at room temperature, and in case of overheated reaction with nitrogen proceeds with ignition; melts and ignites in concentrated nitric acid; store in sealed containers with a neutral medium (argon), prevent contact with air and water; in the molten state causes destruction of welds, reacts intensively, with splashing, with building and thermal insulation materials (fiberglass, asbestos, concrete, etc.); extinguishing agents: special powders.

18 Lee E.-P. Analysis of Car Fire Cases Related to a Lithium Battery and Cause Investigation Technique. *Fire Science and Engineering*. 2019. Vol. 33. No. 2. Pp. 98–106. DOI: 10.7731/KIFSE.2019.33.2.098 (date accessed: 01.01.2025).

Dynamics of motor vehicles fire depends on its location, for example, the engine or luggage compartment, interior, fuel system, etc. According to available data, in the event of a fire in the engine compartment of a parked car, the flame penetrates the interior in 8–10 minutes. The interior is completely engulfed in fire in another 1–2 minutes. Then the fire engulfs the entire vehicle, breaking the tightness of the fuel system, which leads to the ignition of the leaking fuel. In the event of a fire in the interior with open windows, when the flame source is located in the back seat, the glass collapses within approximately 6 minutes. The complete combustion of the interior, together with the engine and luggage compartments, is completed in 30 minutes; 45 minutes later, only flameless smoldering of elements (seats, tires, and trim materials) is observed. Particularly dangerous is spontaneous combustion of a lithium battery that is practically impossible to extinguish by conventional methods. During thermal acceleration of a faulty or damaged battery, not only stored electrical energy is released: special chemical reactions produce additional energy for self-heating, oxygen and flammable gases. Due to this, the battery can burn without access to air making methods of isolation from oxygen ineffective. In addition, metallic lithium reacts actively with water, forming flammable hydrogen gas. Therefore, water for extinguishing is effective only if the mass of the lithium electrode is insignificant. In general, extinguishing lithium batteries is effective only to a certain extent. The main goal remains to reduce the temperature of the battery and prevent the spread of fire. Specifics of such a fire can completely destroy the motor vehicle in a few minutes. Extinguishing a lithium battery is effective with special fire extinguishers (*Fig. 2*) or argon.

Fig. 2. Special fire extinguishers for Li-Ion batteries

According to scientific data [19], occurrence of combustion requires the interaction of three material objects: an ignition source, a combustible medium (substance) and an oxidant. Under normal combustion conditions, the oxidant is oxygen in the air in a concentration characteristic of air. The answer to the question of the cause of the fire lies in determining the nature of the interaction of these three objects. For maintaining the combustion

19 Степаненко С. Г., Білкун Д. Г., Яник Я. М., Тимощук Ю. Т. Дослідження пожеж [Fire Research] : довідк.-метод. посіб. Київ, 1999. 224 с.

process, certain conditions should be met: the presence of a combustible substance with the appropriate characteristics (humidity, temperature), a sufficient amount of oxidant (oxygen or other chemicals that promote oxidation), as well as an ignition source with sufficient energy potential (a spark, flame or an object heated to a high temperature). In clarifying the causes of a fire, the primary goal is to determine its initial source.

ДСТУ 2272:2006 states: *"The primary source of fire is the place where the fire originated"* [20]. The primary source of fire is determined based on an analysis of the state of structural elements, assemblies, objects and materials after exposure to flame, taking into account the degree of their thermal damage. At the same time, the physical laws of the course of thermal processes in the combustion zone and possible paths of fire spread in specific conditions are taken into account. As a result of the action of high temperatures, the substances and materials from which the motor vehicle or technical component is made that have fallen into the fire zone undergo various changes. These changes are manifested in changes in the physical and mechanical properties of materials, deformations, partial destruction or complete burnout. The detected traces of thermal impact are stored on material information carriers: they are transferred for expert analysis; they remain directly at the case object that requires detailed study.

The source of fire is determined after inspecting research object[21]. Before conducting the inspection, it is necessary to find out whether the motor vehicle was in motion, parked, in the repair and maintenance area or garage at the time of the fire. The answers to these questions will allow us to further put forward versions of the possible cause of the fire. During the inspection, two zones are distinguished: the territory adjacent to the fire site and the burning zone. It is necessary to carefully inspect the area, pay attention to suspicious objects (canisters, bottles that could contain flammable and combustible liquids, other means of ignition), traces that could be left by persons involved in the fire and take measures to preserve, record and remove such traces (*Fig. 3 and 4*).


Fig. 3, 4. Image of burn marks and a glove with fragments of car glass

20 ДСТУ 2272:2006. URL: https://antifire.ua/dbn/19-DSTU_2272_2006.pdf (date accessed: 01.01.2025).

21 Пракшин Ю. К., Зернов С. И. Методика осмотра места пожара. Киев, 1988. 168 с.

From expert practice, it is known that three main methods of arson are most often used. The *first method* involves breaking one of the windows with a heavy object and throwing a previously prepared container (approximately 0.5-5 liters in volume) filled with an accelerant inside, along with an ignition source (for example, a bunch of matches, a hunting match, or a lit cloth). In this case, the object used to break the glazing may remain inside the motor vehicle. The *second method* involves pouring a liquid: combustion intensifier on the external surfaces of the car, in particular the glass, body, and wheels. The most common target is the windshield, hood, and front wheels. Sometimes pieces of fabric soaked in combustion intensifier are used to cause a fire, which are placed under the wheels. The third method involves opening the fuel tank neck, inserting a cloth soaked in combustion intensifier. The rest of the fabric is left outside and set on fire. Such fires are characterized by the appearance of local zones of thermal damage. In particular, local burning of car tires and the hood paint and varnish coating can be observed (*Fig. 5 and 6*).

If flammable liquids are brought into the cabin, they settle either on the seat cushions or on the floor and rubber mats, where their remains can be found after a fire. External arson of motor vehicle is usually carried out by pouring a combustion accelerator onto the windshield. We have considered specifics of spread of the liquid and the visual signs of its availability earlier.

Fig. 5, 6. Display of local traces of surface liquid burnout

During inspection of burning area, probable source of the fire and the paths of fire spread are determined [22].

At this stage, traces of thermal impact are recorded on the external surfaces of the vehicle. Particular attention is paid to damage to the paint and varnish coating, glazing elements, bumpers, headlights, lights, wheels, etc. Next, they proceed to inspect the interior, in particular the wiring harnesses in the dashboard area. Wires with traces of melting are removed in compliance with all procedural standards. The exact location of the element

22 Кріса І. Я., Михайлов Ю. М., Бєлан С. В., Штангей Г. В., Єременко В. П. Методи визначення осередку пожежі : навч. посіб. / за заг. ред. П. Ф. Борисова. Харків, 2005. 215 с.

removal must be indicated on the packaging and an explanatory diagram should be attached to the inspection report. During the inspection of the luggage compartment, the degree of thermal impact on the objects located there is determined. During the inspection of the engine compartment, damage to components and assemblies in the under-hood space is recorded. Particular attention should be paid to such elements as carburetors, injectors, fuel pumps and fuel lines, exhaust gas exhaust system, electrical equipment and wiring harnesses. If necessary, these components are removed for further examination. In addition, it is necessary to record the presence of the battery and the "mass" switch (if available), as well as determine whether the electrical equipment of the motor vehicle was energized at the time of the thermal impact.

One of the key ways to determine the source of a fire is to analyze indirect signs of malfunctions in the motor vehicle fuel system (during witness interviews): malfunctions in the injection system, as well as defects in its other structural elements, including: reduced efficiency of the fuel pump (inability to create operating pressure); clogged fuel filter; blocked or deformed fuel drain line; system leak; mechanical damage.

During a fire, it is extremely important to consider the direction of the wind, as strong winds can significantly affect nature of the damage: if the wind is blowing from the rear of the vehicle, the front usually suffers more significant damage from the fire; if the wind is directed from the front, the main damage can be observed in the vehicle rear.

During inspection of freight vehicles, thermal damage to trailers (semi-trailers) and cargo is described. The inspection involves specifying the characteristics of the damage (quantity, type, method of placement and degree of thermal exposure). As with any other object, the first step in determining the cause of a fire is to determine its source, the place where it originated. In the motor vehicle, this process begins with identifying the area of the most severe thermal damage in the three main compartments: engine, passenger compartment (driver's cab) or trunk (platform or trailer). Although this is not always possible, in most cases, comparing the degree of damage in these areas helps to identify the place that suffered the most damage.

If the fire source is located in the passenger compartment of the vehicle, its interior suffers significant damage: the interior burns out almost completely, roof can deform, and the engine compartment and trunk are partially or completely burned and covered with soot. At the same time, these areas are usually preserved in better condition compared to the interior. If the fire was extinguished at an early stage, it is quite easy to determine its source, focusing on the degree of damage to the finishing materials. For example, the source of the fire in a truck that was parked was determined by the *center cone* formed by combustion products on the windshield and the burning of the dashboard: the cone downward-facing tip (*Fig. 7*) indicated that the fire had started in the dashboard and the degree of damage to the panel itself made it possible to more specifically identify the place where the fire had originally started next to the ashtray (*Fig. 8*).

During the dismantling of the dashboard, another sign was recorded, indicating the location of the fire center near the ashtray: traces of a change in the structure of the orange-colored metal were found on the metal frame (base for the panel),

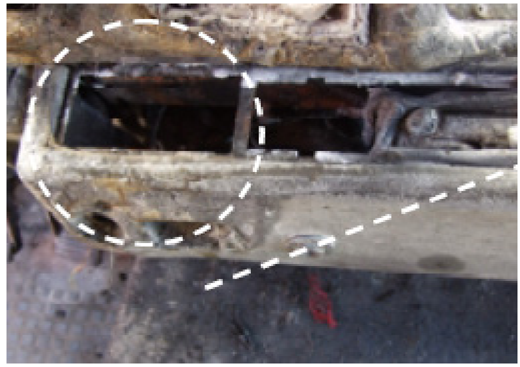

Fig. 7, 8. Center cone

while other parts of it were covered with traces of soot (therefore, it was in this area that the metal was exposed to the highest temperature). Thermal changes on metal elements can be caused by individual or combined actions of certain factors and processes. These changes manifest themselves as deformations, melting, transformations of the surface relief, structural changes of various nature and the formation of an oxide film of various shades on the metal surface. The intensity of such changes directly depends on the strength of the heating and duration of its effect. Some of them are irreversible, so they should be recorded during the inspection of the motor vehicle (in inspection report, by taking photographs):

- deformation of metal parts and elements of the motor vehicle is due to the thermal effect on them and, as a result, a change in the physicochemical and physical and mechanical properties; formation of oxides on the metal surface, at a temperature of 200–300 °C, an oxide film layer is formed on the steel surface, which causes the appearance of so-called colors of variability on the metal. It is necessary to distinguish between the colors of variability that form on the surface of steel after heating and cooling, and the color shades that occur when steel is exposed to high temperatures;
- melting and fusion of metal occur under the influence of temperatures exceeding the melting point of this material. In the event of a fire in the engine compartment, significant localized damage, burnout of rubber elements, gaskets and melting of silumin parts are usually observed. In motor vehicle with a front engine location, the front wheels usually burn out, while the rear ones suffer less damage. The flame can spread to the interior, causing it to burn out completely, while the trunk, especially in peripheral areas, is less affected. If the fire source is located in the trunk (platform or semi-trailer), it usually burns out, while the interior and engine compartment are only covered in soot. More noticeable damage, such as from melting, rarely occurs in these areas. At the same time, the mentioned signs are not always preserved: combustible materials of motor vehicle, especially in the case of prolonged

burning without extinguishing, can burn out completely. Therefore, it remains important to separate the three main areas of damage. Additional information about the location of the ignition can be obtained by inspecting the vehicle electrical wiring.

If, during inspection after the fire, damage to the electrical wiring by an electric arc is found in the area of the headlights or steering wheel, then it can be stated that the fire did not start in the engine compartment or the instrument panel. The proof here is built by the method of the opposite. If we assume the opposite, for example, the fire started in the engine compartment, then burning of the wires in the engine compartment should have led to the car being de-energized before the combustion goes beyond the engine compartment. Thus, when the flame front reaches the headlights or steering column, the wires there will clearly not be under voltage. If arcing is detected there, then the combustion began there earlier. Therefore, as with all other objects, in burned-out motor vehicles, the primary focus should be sought in the area of combustion that is furthest from the power source.

Let us give an example. During the inspection of a truck that caught fire while driving, a zone of maximum thermal damage was discovered (on the right in the lower part of the body, between the cab and the trailer). However, the exact location of the fire was not immediately determined. The electrical wiring in this zone had no visible defects or melting, and there were also no signs of emergency operation of other systems. Only an inspection of the space under the trailer clarified the situation. After dismantling the wooden floor covering of the trailer, not far from the zone of maximum damage, a burnt positive wire of the battery was found, which passed under the trailer. One end of this wire was tightly fused to the metal bracket of the gearbox, while the other remained connected to the generator in the engine compartment. A detailed examination of the section of the wire between the battery and the soldering point with the bracket revealed four zones of melting of the conductive cores. This area was removed for further investigation. The meltdown was analyzed using a metallographic method to determine the nature of the short circuit: primary or secondary. Research results of indicated that the meltdown furthest from the current source (at the point of contact with bracket) occurred due to a primary short circuit. This made possible to accurately determine the initial ignition location and determine the cause of the fire in the motor vehicle.

If arcing is detected during the inspection of a fire-damaged motor vehicle, it is advisable to find out which electrical circuit the wire with the arcing belongs to. Then the area with the arcing should be removed and sent for examination to determine the primary (secondary) nature of the short circuit. In the incident scene inspection report, it is necessary to record where this conductor was removed from. The rules for removing automobile wires are the same as for conventional electrical wiring.

There are known cases of fires in heavy-duty trucks, where the source of ignition was the thermal energy released during the friction of the tire on the floor covering of the semi-trailer platform. Thus, during a fire that broke out in the semi-trailer of a cargo truck while it was moving, center of the fire was found on the floor covering of the cargo platform (in the rear part) in the area ofthe left rear wheel of the last axle (*Fig. 9 and 10*).

Fig. 9, 10. Photo of fire center

In this area, a burn was found in the platform coating. The degree of carbonization of this coating on the wheel side was greater than on the cargo side. The platform floor coating on the wheel side had abrasions, located directly above the wheel tires and corresponding to their size. The above signs, as well as the absence of any elements of the fuel system and electrical system of the motor vehicle in the fire zone, gave reason to say that during the movement of the motor vehicle, the process of friction of the wheel tires on the floor coating of the cargo platform of the semi-trailer took place, which led to the fire. In the process of investigation, it was found that the semi-trailer was loaded with 81% of the permissible cargo mass. During the inspection of a semi-trailer identical to the burned one, the distances between the wheel tire and the floor covering were measured in normal operation (the semi-trailer is empty, the air suspension cushions are inflated) the distance was approximately 85 mm, and with the cushion deflated, approximately 25 mm. These and other data allowed us to conclude: during the movement of the motor vehicle, air suspension cushion of the left rear wheel of the last axle of the semi-trailer failed (deflated), as a result of which the wheel tires rubbed against the floor covering of the semi-trailer cargo platform, which led to their increased heating and subsequent ignition.

The main purpose of research on fires in motor vehicle is to identify the mechanism of their occurrence, as well as to identify this event as a key factor that led to the ignition. Analyzing the causes of motor vehicle fires is a difficult task due to the destruction or significant damage to the traces of combustion on the object. This is due to the compactness of the units and assemblies, the speed of fire development, as well as strong thermal and flame effects. As a result of the analysis, an information model is created that reflects the mechanism of fire occurrence and development. For determining the cause of the ignition, version analysis is used that is based on tracking mechanism of combustion from a potential ignition source. Taking into account the location of the primary fire source and the characteristics of the combustible load, expert assumptions are formed regarding the possible ignition source. If the proposed version does not correspond to the coordinates of the primary fire source or the power of the source is insufficient to ignite the material, it is rejected. The approved version serves as the basis for collecting, systematizing and analyzing information. It is a probabilistic logical construct: preliminary hypothesis that requires further clarification, verification and reasoned confirmation.

Verification of the proposed versions involves two points: refutation of versions that contradict the facts of objective reality and substantiation of the version that remains after eliminating the rest.

Conclusions

The main causes of fires on motor vehicles are considered. Most of the causes of such fires are classified. Intentional and unintentional fires are considered in detail. The main distinguishing signs of these groups of fires are given. The main causes of unintentional fires on motor vehicles are recognized as the interaction of a combustible substance in the event of depressurization of the fuel system with a potential thermal pulse of the exhaust gas system, as well as thermal manifestations of electrical energy, in particular, a short circuit of the motor vehicle electrical equipment. During a visual inspection of specific traces on motor vehicle, the expert is able to properly justify the use of a combustion intensifier in a fire. For fire protection, it is recommended to introduce a fire extinguishing system in the under-engine compartment (the most potentially dangerous place) as an additional option when assembling motor vehicle at the factory or in specialized services. In addition, electric vehicles and hybrid vehicles should be equipped with fire extinguishers of the appropriate type, designed to extinguish lithium, with corresponding changes to the standards for equipping vehicles with fire extinguishers.

Особливості виникнення та дослідження пожеж у сучасних транспортних засобах

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Метою статті є викладення алгоритму визначення механізму виникнення пожежі з урахуванням наданих на експертизу матеріальних і матеріалізованих джерел інформації. Для досягнення поставленої мети застосовано як загальнонаукові, так і спеціалізовані методи наукового пізнання, поміж яких системний підхід, порівняльно-правовий метод, дедукція й індукція, а також методи тлумачення, структурного аналізу та спостереження. Розглянуто наявну пожежну небезпеку в різних видах автотранспортних засобів і наведено відповідні статистичні відомості. Досліджено характерні причини пожеж для автотранспортних засобів та виконано їх умовну диференціацію. Наведено можливі сценарії перебігу таких пожеж, зазначено ймовірні місця виникнення загорянь. Докладно проаналізовано особливості навмисних і ненавмисних пожеж. Наведено основні відмінні ознаки цих груп пожеж. Основними причинами ненавмисних пожеж на автомобільному транспорті визнано взаємодію горючої речовини в разі розгерметизації паливної системи з потенційним тепловим імпульсом системи випуску відпрацьованих газів, а також теплові вияви електричної енергії, зокрема коротке замикання електричної апаратури автомобіля. Виробникам транспортних засобів і/або їхнім власникам запропоновано обладнувати транспортні засоби автоматичною системою пожежогасіння і вогнегасниками відповідного типу, що передбачають гасіння саме із метою мінімізувати матеріальні втрати та вплив небезпечних чинників пожежі на людей і довкілля.

***Ключові слова:** автомобіль; джерело запалювання; інтенсифікатор горіння; пожежна*

небезпека; причина пожежі; транспортні засоби.

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Declaration of Competing Interest

The authors declare no conflict of interest.

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