Features of forensic research on wheeled vehicles with LPG equipment

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The article considers the issue of LPG equipment installed and operated on modern vehicles, as well as its varieties, peculiarities of structure and configuration.

This article purpose is to get acquainted with the types of LPG equipment of modern cars and determine research peculiarities while forensic expert inspection of such vehicles.

The order of forensic expert actions while technical inspection of investigated wheeled vehicle is given, authors insist on the need to take into account the availability of LPG equipment while determining the market value of vehicle determining the cost of repair and material damage caused to the vehicle owner.

The advantages and disadvantages faced by car owners with installed LPG equipment are considered. Considerable attention was paid to the classification of gas cylinder equipment, discrepancies were noted while installation of gas LPG equipment on carburetor and injection engines.

Keywords: *forensic expert, LPG equipment, components of LPG equipment, air-gas mixture, environmental requirements, forensic expert inspection of wheeled vehicle.*

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Research Problem Formulation

While forensic inspection review of modern vehicles, forensic expert is faced with latest developments in automotive industry (in particular, LPG equipment installed on vehicles). Currently, there is a lot of LPG equipment (that differ in their design by generation, brands and models) installed on wheeled vehicles, so forensic expert needs to determine the type, variety, configuration, fastening points and determination of lifetime of the devices requiring additional forensic research.

Analysis of Essential Researches and Publications

Analysis of available LPG equipment installed on wheeled vehicles is periodically carried out[1]. The need to take into account the cost of installing LPG equipment on the car or its individual components, as well as the peculiarities of the structure and repair actions belong to the tasks of an forensic automobile expert.

Article Purpose

This article purpose is to get acquainted with the types of LPG equipment of modern cars and determine research peculiarities while forensic expert inspection of such vehicles.

Main Content Presentation

In modern conditions, a significant increase in the oil cost and fuel prices in the world and Ukraine, more and more car owners are transferring the engines of their vehicles to natural gas.

The first and greatest advantage of transferring road transport to the use of gas is to reduce fuel costs. In addition, there are other advantages of using this type of fuel in car [2]:

- high octane rating of gas practically eliminates detonation extending engine life cycle (savings on replacing motor oil and sparking plugs);
- motor oil life cycle increases by 15-20 %;
- engine inter-repair work increases;
- car can consume both types of fuel (gasoline or gas), for the which driver needs only to switch the toggle (switch);
- distance that can be traveled at one gas station increases;
- in the gas there are no catalysts for the destruction of metals and harmful impurities (lead and sulfur), it does not form soot on pistons, valves and sparking plugs (it extends life cycle);
- gas-air mixture is homogeneous while its combustion, the load on the piston group and the crankshaft are significantly reduced, so the engine works softer;
- due to combustion peculiarities of the consumption of grease decreases;
- in conditions of reasonable and correct operation, the LPG equipment inter-repair period is not less than 5 years;
- number of harmful emissions decreases [2].

1 Золотницкий В. А. Автомобильные газовые топливные системы. Москва, 2007. 128 с. Афонин С. Н. Газовое оборудование автомобилей. Легковые, грузовые. Устройство, установка, обслуживание. Практическое руководство. Ростов-на-Дону, 2001. 53 с.

2 Лиханов В. А., Деветьяров Р. Р. Применение и эксплуатация газобаллонного оборудования. Киров, 2006. 184 с.

Installing LPG equipment on the car has its drawbacks, the main of which is the equipment cost itself. At the same time:

- engine power decreases (propane-butane by 5%, methane up to 15%);
- fuel consumption increases by 10-20% (gas only);
- Dynamics deteriorates using the first and second generation of LPG equipment;
- LPG equipment above the second generation is not used on carburetor engines;
- improper installation and adjustment of LPG equipment lead to accelerated wear of the engine;
- strictly observe operating and maintenance modes;
- condensate from a gas reducer should be drained at least once per 10-12 thousand km of run;
- limiting (maximum) loads on the engine should be excluded;
- at present, there are fewer gas stations on the roads of Ukraine than gasoline gas stations;
- gas cylinders occupy the useful space of the trunk;
- increases the total weight of the car with LPG equipment.

Modern automotive equipment works on a mixture of liquefied petroleum gases (propane - butane: Liquified Petroleum Gas (LPG))or compressed natural gas (methane: Compressed Natural Gas, CNG) Therefore, forensic expert, in addition to thorough knowledge of the structure of automotive equipment and methods of its repair, should clearly distinguish between the types of LPG equipment installed on the wheeled vehicle and know its structure for further consideration in his expert work.

Propane is a gas produced while oil refining. Cylindrical or toroidal cans are used for propane. At present, there are cylindrical cans with an outer diameter of 200, 240, 270, 300, 315, 360, 400 and 450 mm and a volume of 10 to 230 liters. The most popular sizes installed on cars are 40, 50, 60, 90 liters. Cylindrical cans are mostly installed in luggage compartment (cars with a flat trunk floor), less often, under the floor of the luggage compartment (cars brands: *ZAZ-1102 Tavria, ZAZ-1103 Slavuta, VAZ-2121 Niva* and some other off-road vehicles). Toroidal cylinders correspond to the shape and size of spare tire that allows you install them instead of such a wheel. The most popular volumes are 40 and 42 liters (600 × 200 mm). There are internal, external and vertical toroidal cylinders. The weight of one propane can (depending on the volume) is 20-30 kg.

Methane is a natural gas, it is cheaper and more explosive than propane. Vehicle engine power drop in case of its use can be 10-15%. Methane is stored in cylinders withstanding a pressure of 200—250 atm. (can weight depending on the volume : 80—110 kg). At the same time, the cost of a set of methane equipment is twice to three times higher than that of propane one. Methane LPG equipment is more often installed on commercial cars and trucks that can carry massive cans (*GAZelle, GAZ, ZiL, URAL,* etc.), very rarely, on passenger cars.

Components and LPG equipment:

- gas cylinder
- pipelines
- gas charging valve and petrol valve
- gas dispenser and mixer;
- reducer-evaporator;
- electronic control unit;
- switch of fuel type.

Most often, forensic expert has to explore cars on which LPG equipment (propane — butane) is installed.

Forensic expert should distinguish between the generation of installed LPG equipment(propane — butane). They differ mostly in gas supply elements, control

systems and the possibility of installation on certain engines. The fuel systems of the gasoline engine have undergone three stages of modification. Over time, designers have improved the process of supplying fuel to the combustion chamber of the cylinders. Carburetor systems have been used for many years, but with the development of engine production, insufficient fuel supply to the carburetor has been revealed, which makes it impossible to achieve the desired power parameters. Engineers have developed an injector timing mechanism to increase engine power while saving fuel through electronic fuel control. At this stage, electronic control units were added. This has become the most primitive system of gas equipment using methane or propane. During installation, the cylinders are usually located in the luggage compartment, the fuel line is connected to the shut-off device, the gas passes through the line and enters the evaporation chamber connected to the cooling system. The heated gas mixture is fed to the gear dosing device. Initially, reducer and the evaporator chamber were considered separate units, but over time they were combined into one unit.

Gas is the most real alternative to gasoline and diesel fuel. Each kilometer traveled on gas costs on average a third cheaper than on gasoline, so it is clear that the basis of the transition to gas is the financial component. Previously, it was possible to experience large-scale savings: LPG equipment for primitive carburetor engines were cheap and propane-butane cost half as much for gasoline. Currently, the situation is different: in order to purchase gas equipment with a modern engine, you need a completely different level of components and qualifications of the master who will install it. In addition, along with the new safety requirements for cylinders, the installation of LPG equipment has led to a significant increase in the price of kits.

Recently, the use of liquefied gas as automotive fuel has become popular because it is cheaper than gasoline. However, there are also other advantages, for example, it is environmentally friendly than other types of fuel, its exhaust contains fewer harmful substances (in particular, CO_2 almost twice), gas has a higher octane number (103-105), which makes it almost impossible to detonate the engine. The wear of the cylinder-piston group of internal combustion engine decreases on the gas:

- while starting cold engine, a film of gasoline is not formed that washes away lubrication;
- the gas burns more slowly, as a result, pressure in the cylinders does not increase so quickly and the shock loads on the engine parts due to better mixture of gas and air are less than gasoline;
- gas mixture is more evenly distributed by cylinders, that improves engine idling, it works softer and quieter;
- after starting a cold engine on gas, it is possible to go almost immediately, no long-term heating is required (as on gasoline);
- gas does not thin the motor oil, so it can be changed less often than using gasoline;
- almost no soot will form, gas compared to gasoline is much cleaner, so dirt does not get into the carburetor.

The disadvantages of gas include less heat of combustion, so the engine power per gas is less by about 5 %, so sometimes it is advised to install another ignition. However, this is a controversial issue, firstly, it is advisable to work only on cars

running on high-octane gasoline (more than 95) so that you do not have to put ignition later whenever you need to go on gasoline. Secondly, there is an opinion that at high speeds while working on gas, on the contrary, ignition should be somewhat later than for gasoline.

Many of LPG equipment shortcomings are controversial. For example, while installation holes for mounting the cylinder are drilled in the body, a gas line is attached under the bottom and a reducer is installed under the hood. In a few years, mounting sites can become centers of corrosion, so you need to worry about the corrosion treatment of all mounting holes. If you insert the so-called "tablet" instead of a cylindrical can, it will take the place of a spare wheel that has nowhere to go (or not to carry it at all, or to carry it in the trunk). Opponents of gas installation say there is a high probability of a cylinder exploding that is usually an exaggeration. The facts of the cylinder explosion on the territory of the eastern regions of Ukraine in recent years have not been recorded. Gas cylinder is stronger than the gasoline tank, in addition, there are protective valves and mechanisms that are triggered in the event of a gas leak.

There are certain reservations about installing LPG equipment on turbine engines. The gas has a higher combustion temperature, so the exhaust temperature increases the thermal load on the turbine impeller and affects the resource of the exhaust valves. Catalysts have temperature restrictions that are available in most gasoline engines. In the catalyst should burn everything that is not burned in the cylinder. In high temperature conditions, catalyst begins to melt (especially during high engine speeds) and blocks the exhaust. During low and medium speeds LPG equipment does not damage the motor.

There is an opinion that the gas dries the engine, it should not be installed on expensive cars. This is true, but such a process occurs only at high speeds (more than 4000 rpm). To minimize the consequences, install a gasoline injection. Under the influence of the load, the engine heats up, and gasoline contains oils that are absent in the gas. Therefore, after installing LPG equipment over time, the smell of gas can appear, even if the connections are completely sealed. This is because rubber hoses (pipelines) are impregnated with fumes. In the case of the use of high-quality hoses (pipelines), such a problem will not be.

There is also an opinion that LPG equipment for cars is beneficial only to those who have large engines. Therefore, we calculated the feasibility of installing LPG equipment (for example, on the car Skoda Fabia 2002 model year), that travels an average of 1000 km per month. Suppose that in a city 100 km it needs 8 liters of gasoline and gas consumption of 15-20 % more than gasoline (10 liters of gas per 100 km). If 1 liter of A-95 gasoline costs UAH 62, and gas - UAH 40, then to ride on gasoline for a month, you need to spend about UAH 5,000 (for gasoline) and UAH 4,000 (for gas), i.e. monthly savings of UAH 1,000. If you install a new Italian LPG equipment of the fourth generation that costs about 12,000-13,000 UAH, it will pay off in a year. If you drive more, then faster. LPG equipment maintenance (air filter replacement, computer diagnostics) is best performed after every 10,000 km of mileage where it is installed (these services cost up to UAH 500), even at such costs the savings are obvious. It should be noted that in the case of low mileage, the installation of LPG equipment is advantageous. If the equipment works properly, the cost of its maintenance will be moderate, and fuel savings will cover them.

Another advantage is a double range: if the gas runs out, you can go on gasoline (this is convenient during long-distance travel and is relevant in queues at gas stations or fuel shortages).

For classifying the types of gas cylinder equipment in Ukraine, the *generation* term is used (the larger it has a number, the more complex and perfect it is). At the same time, there is some confusion in the qualifications of generations (more precisely in its numbering). The difference lies primarily in the method of controlling the supply of gas into cylinders and the corresponding design nuances, so in order to avoid confusion, LPG equipment can be divided into carburetor and injection engines.

For carburetor engines, the systems of the first and second generation today are understood as LPG equipment with vacuum-mechanical regulation of gas supply. The dosing diaphragm in the evaporator gearbox as the initial information takes into account the liquefaction in the intake manifold, depending on the load on the engine and the position of the throttle. Such equipment was created primarily for carburetor engines, although some modifications of the 2nd generation LPG equipment are put on budget injector cars. These systems are simple, unpretentious, reliable and affordable, although they have a disadvantage, namely: higher gas consumption compared to modern systems.

Currently, it is difficult to find a set of vacuum-controlled LPG equipment in high-quality design, since it is considered obsolete.

The first attempt of designers to involve electronics for injection engines to control two-fuel power supply systems were control systems for oxygen sensor combustion of fuel and regulation of fuel supply by a stepper motor. Such systems are often called the third generation, they were intended for injection engines (mono-injection), although with some modifications they were mounted on carburetor engines. The gas in the engine of this generation changes from the liquid phase to the gaseous phase in the gearbox, but the control of the fuel metering is no longer responsible for the vacuum, but electronic unit, that takes into account data from the lambda probe, engine sensors and throttle position. Actually the gas is measured by a mechanical step batcher, to the cylinders it is fed by the mixer established on a throttle valve. Quite complex and expensive, but insufficiently economical equipment of this type has not taken root, giving way to the next, fourth generation.

Currently, the most common are gas injection systems that completely inherited the principle of gasoline supply in cars with a classic distribution of injection. Electromagnetic gas injectors (individual for each cylinder) are inserted into the intake manifold, which are controlled by an electronic unit intercepting the signals coming to the gasoline injectors from the standard electronic engine control unit. The gas reducer, pipelines, shut-off valves and cylinder are almost indistinguishable from the units of previous generations. Such gas injection today can be considered the most rational in terms of combining price, design and gas consumption. Properly set up 4th generation LPG equipment systems (this type is the most common in Ukraine) consume only 10-15% more gas than gasoline. The main disadvantages of

these systems are the high price (two to three times higher than LPG equipment with vacuum control) and the need for equipment to fine-tune the system on the car. In addition, it is necessary to choose components of only reputable brands and install LPG equipment in specialized workshops.

There are also more modern systems: the fifth generation, using gas injection, but with one significant difference: liquefied gas is not converted into a gaseous state, the car consumes it in the same form in which it is stored in a cylinder (liquid). The pump, located in the cylinder, injects liquid gas in the main and further to the injectors, which inject it into the intake manifold opposite each cylinder. Alternatively, on engines with direct fuel injection, it is possible to inject gas through the petrol injectors directly into the cylinder. But such a system additionally uses an expensive module for switching the supply to the injectors of gasoline or liquefied gas. As in the petrol mode of operation, injection of liquid propane-butane is controlled by electronics. And to regulate the proper combustion of liquid gas using software created specifically for a particular engine model. As a result, such a system responds more quickly to changes in load and, thanks to accurate dosing, consumes more fuel (gas at the gasoline level). LPG equipment kit with injection is more demanding on gas quality and level of service.

First generation of LPG equipment

Reducers for the first generation of LPG equipment can be of two types: vacuum and electronic. A significant disadvantage of gas systems of this generation is the so-called “long way” of gas to the combustion chamber, as a result of which depressurization often occurred and as a result a strong smell of gas in the interior of the vehicle. Such systems were cheap, manufacturers saw that the systems were in demand and began to improve them. The simplest injector (without lambda probe) LPG equipment, that has a vacuum control and a mechanical gas dispenser, can be installed on carburetor engines. The fundamental difference between an electronic reducer and a vacuum reducer is the principle of operation of the shut-off element of the discharge chamber (in a vacuum reducer this work is performed by a special vacuum membrane, which is supplied with a vacuum from the intake manifold). This obsolete type of gas equipment is very rare nowadays.

The first generation systems meet the outdated environmental requirements of Euro 1, so it was banned in Ukraine back in 2006 (although sometimes continue to be installed until now). The second-generation gas installation can be installed on vehicles that have driven for more than 25 years. The third generation of LPG equipment hardly anyone installs, such an installation can be found only on machines driven from Europe.

Second generation of LPG equipment

The next generation differs slightly from the first one, the gearbox is upgraded (in particular, the shut-off valve has become electromagnetic, and not vacuum, as before). Now the driver does not need to leave the car to switch to another type of fuel, because there is a special button in the cabin to switch the type of fuel, that is, it is more convenient to operate the HBO. In addition, a cold start has been implemented: a small

amount of gas is released before the system is let in, which further ensures easy start of the cold engine. It has become possible to use the gas system on injector-type engines of the first generation of spray injection or mono-spraying. This generation of HBO is installed on a vehicle with lambda probe and catalytic converter injector engines as well as a catalytic converter.

Third generation of LPG equipment

Third generation of LPG equipment includes electronic adjustment of the gas supply to the combustion chamber. The system reads data from the oxygen sensor and adjusts the amount of gas received by the engine using a stepper motor. The temperature sensor located on the gearbox monitors the minimum temperature. When the reducer is heated above the minimum temperature, the controller switches on the gas supply. This generation of LPG equipment meets Euro 2 standards by reading data from the oxygen sensor and electronically adjusting the fuel supply. LPG equipment is supplied with its own correction system, but the reaction rate to adjust the working mixture is limited by the speed of the step dispenser. The mode of operation simulating of nozzles and the lambda probe is used for uninterrupted operation of the standard control system.

In this system, the gas is supplied individually by the dozer (gas injector) to each cylinder of the engine. The electronic unit controls the gas injector. The gas is supplied to the intake manifold through mechanical nozzles automatically opened by the overpressure that occurs in the supply line. Instead of the dosing gas register (as in the LPG equipment-1 and LPG equipment-2 systems), a gas motor and a special electronic control unit are installed to regulate the quality of the air-gas mixture composition. This innovation made it possible to almost eliminate the possibility of sudden loud noises completely. Disadvantages of this generation of LPG equipment: slow system response to changes in the engine operating mode of the vehicle.

The third generation systems meet the of Euro 2 requirements .

Fourth generation of LPG equipment

Fourth LPG equipment generation, the fuel supply has changed dramatically, gas injectors have appeared that inject gas into the cylinders. The gearbox does not inject fuel into the manifold, which allows it to maintain a constant gas pressure (excess pressure is removed by gas injectors). Each individual nozzle has its own cylinder. The injectors have their own loops directed from the controller, which gives the command to inject fuel to each injector, so it happens in a certain period of time. In the methane versions of the 4th generation of LPG equipment, not only the reducer but also the cylinders have been changed (thick-walled ones are used due to the high methane pressure). The gas supply for each cylinder is separate, which allows you to significantly increase the speed of response to the adjustment of the gas-air mixture and optimize engine performance. This is the best known technical solution for the moment.

Fourth generation of LPG equipment is the most common, it is the most economical and reduces the power of the car the least (up to 10%), although it requires the gearbox to be well warmed and the gas to be warm. It is installed on any injector vehicles, as well as vehicles

with new on-board diagnostic systems (EOBD, OBD II).

An important feature and advantage of LPG equipment-4: the function of automatic transition from gas to gasoline and vice versa (if the gas cylinder has become empty). This type of gas injection removes the problem of sudden loud noises and requires less attention to the air filter and spark plugs of the working mixture, gas consumption is as close as possible to gasoline consumption.

The basis of safety is availability of a multi-valve on the gas cylinder.

The expert should pay attention to the electronic control unit of the gas cylinder equipment. They differ in a set of adjustable parameters and can have an automatic adjustment or auto-calibration function that allows to set the optimal operating modes. Modern electronic complexes (for example, *King, Lovato, OMVL, Zavoli,* etc.) have maximum automation during adjustment of equipment and practically do not require the professional participation.

The Fourth generation systems meet the of Euro 2 requirements .

Fifth generation of LPG equipment

In all precursors, the gas was supplied to the combustion chamber in the gaseous state, in the 5th generation of LPG equipment in liquid state, in addition, the fuel pump in the cylinder pressurizes the system. Advantages of this generation of LPG equipment: the lack of a gearbox, there is no need to preheat the car with gasoline, nothing more interferes with the cooling system, gas costs have significantly decreased, the number of pipelines in fuel lines has been reduced to a minimum, the capacity of riding on gas has significantly increased. However, it has become impossible to refuel methane, because this gas comes in liquid form (a temperature below 160 °C is necessary for methane to liquefy).

The fifth generation of LPG equipment is compatible with EOBD, OBD II and OBD III on-board diagnostic systems, it uses the computing power of the vehicle and can be used in any engine with fuel injection. A gas pump is installed in the HBO cylinder together with the multi-valve that starts operating after opening the vehicle door (this creates a gas pressure of approximately 15—16 atm in the mains during the engine start). Instead, there is no gas reducer and no additional gas filter. The gas enters each cylinder separately through electrospray nozzles located in the intake manifold as close as possible to the cylinders. An important difference is the ingress of gas into the cylinders in the liquid state, which reduces the loss of engine power and gas consumption and allows the engine to run on gas under subzero ambient temperatures.

It should be noted that these systems are very complex and sensitive to the quality (purity) of gas. The cost of LPG equipment-5 is about 30% more expensive than LPG equipment-4. The fifth generation systems meet the requirements of Euro 3 and Euro 4.

Sixth generation of LPG equipment

This is a generation of gas cylinder equipment designed for direct fuel-stressing engines that is not yet widespread. In the 6th generation systems, there is no distinction between gas and gasoline injectors, the gas supply is cut into the regular gasoline supply system (the difference is only in two different tanks: gasoline and gas). The equipment has been eased to the maximum.

The gas supply system is similar to the previous generation, the main difference of the direct injection from the distributed is the placement of the nozzles (in the first case, directly in the head of the engine block, in the second, on the ramp in front of the intake manifold).

LPG equipment-6 is installed on gasoline engines such as TSI, FSI, TFSI, because this system does not require additional cutting of gas nozzles to the intake manifold of the engine (gas enters through gasoline nozzles). In the trunk there is a gas cylinder with a built-in pump that maintains a pressure of about 16 atm in the main (pipeline). There are two main lines — the main line and the return line, with which the residual gas is returned to the cylinder. A controller controlled by electronics is cut into the gasoline fuel supply system, it cuts off the gas/gasoline supply. Therefore, this allows LPG equipment-6 to minimally interfere with the original vehicle electronics and fuel injection system.

The sixth generation systems meet the of Euro 2 requirements.

Seventh generation of LPG equipment

For a long time, LPG equipment of the 4th generation with gasoline spraying was installed on engines with direct fuel injection. This was due to the fact that gasoline nozzles are close to the combustion chamber and require cooling, which is provided by the gasoline mixture. If the nozzles are not cooled, they will quickly fail, requiring expensive repairs. *Vialle* professionals have developed a new system for direct-injection vehicles which is that fuel is supplied by a standard gasoline injector, but there is no gas at all.

The basis of the 7th generation Direct Blue LPG equipment system is the FSU fuel mixing module, which providing smooth switch between gasoline and liquefied gas. The size of such a module is about the size of a medium battery, its purpose is to create a pressure similar to gasoline and deliver fuel to the injectors.

While system installation, the foreman does not interfere with the engine control system ensuring reliable operation in any mode and maintaining the strength at the same level as on gasoline. The 7th generation LPG equipment makes possible to operate the car only on gas without using gasoline at all, even the engine can be started on gas at any time of the year.

The LPG equipment kit is selected for a specific vehicle model, the software is rigidly linked to the engine code. This generation of HBO unit is quite advantageous because it retains the power of the vehicle, has a simple system design (because there is no reducer-evaporator and gas nozzles), and it is quickly mounted (because there is no reducer, this does not require intervention in the cooling system).

Having analyzed the automobile market of Ukraine, it can be concluded that a large majority of modern vehicles with LPG equipment are represented by fourth-generation equipment. Therefore, while technical inspection of the test wheeled vehicle, the expert commodity expert, in addition to the vehicle itself, must make a photo fixation and recording in the inspection report of the type of LPG equipment, date of its installation (indicated in the certificate of registration of the vehicle in the section of special marks), operability and main components of the kit.

As an example, we will give the components of the most massive *Stag 200 GoFast* kit:

- gas cylinder with a multi-valve (type, content, with or without a quantity indicator, method of placement and fastening);
- filling valve (placement);
- gas main (pipeline type);
- *Stag-4 GoFast* electronic control unit;
- gas reducer (its brand and fasteners);
- nozzles with vents (number, type and location);
- gas vapor phase filter (metal housing);
- choke in the manifold;
- switch of fuel type with indication of gas cylinder filling level.

After checking the completeness and integrity of the LPG equipment, if possible, start the engine of vehicle and check its operation on gasoline and gas.

To date, the most commonly encountered LPG equipment brands are STAG Autogas, PRINS VSI, BRC, Vialle LPI, ZENIT, KME, TOMASETTO.

While drawing up the forensic expert conclusion, it is necessary to adjust the cost of the vehicle in accordance with the information given in the "Bulletin of the commodity expert" taking into account the period of its operation. When calculating the cost of repairing the damaged vehicle, forensic expert should take into account the volume and cost of dismantling/installation and adjustment of the LPG equipment and the cost of its individual damaged components.

Conclusions

The article analyzes modern types of LPG equipment and presents the features of the expert's actions during the study of vehicles with such equipment.

These data will help experts to understand the types of LPG equipment of modern wheeled vehicles and to understand the peculiarities of the sequence of work during the expert inspection of such vehicles.

Особливості дослідження експертом колісних транспортних засобів із газобалонним обладнанням

Сергій Науменко, Володимир Бражник, Іон Санду

Розглянуто питання газобалонного обладнання, яке встановлюють та експлуатують на сучасних транспортних засобах, а також його різновидів, особливостей будови та комплектації.

Метою статті є ознайомлення з різновидами газобалонного обладнання сучасних автомобілів і визначення особливостей дослідження під час експертного огляду таких транспортних засобів.

Наведено порядок дій експерта під час проведення технічного огляду досліджуваного колісного транспортного засобу. Зауважено про необхідність ураховувати наявності газобалонного обладнання під час визначення ринкової вартості транспортного засобу, відновлювального ремонту та матеріального збитку, завданого власникові автомобіля.

Розглянуто переваги й недоліки, із якими стикаються власники автомобілів зі встановленим газобалонним обладнанням. Докладно розглянуто класифікацію газобалонного обладнання, зазначено розбіжності під час установлення газобалонного обладнання на карбюраторні й інжекторні двигуни.

Ключові слова: *судовий експерт; газобалонне обладнання; складові газобалонного обладнання; газоповітряна суміш; екологічні вимоги; експертний огляд колісного транспортного засобу.*

Особенности исследования экспертом колёсных транспортных средств с газобаллонным оборудованием

Сергей Науменко, Владимир Бражник, Ион Санду

Рассмотрены вопросы газобаллонного оборудования, которое устанавливают и эксплуатируют на современных транспортных средствах, а также его разновидностей, особенностей строения и комплектации.

Целью статьи является ознакомление с разновидностями газобаллонного оборудования современных автомобилей и определение особенностей исследования при экспертном осмотре таких транспортных средств.

Приведён порядок действий эксперта при проведении технического осмотра исследуемого колёсного транспортного средства.

Обращено внимание на необходимость учитывать наличие газобаллонного оборудования при определении рыночной стоимости транспортного средства, восстановительного ремонта и материального ущерба, причинённого владельцу автомобиля.

Рассмотрены преимущества и недостатки, с которыми сталкиваются собственники автомобилей с установленным газобаллонным оборудованием. Подробно рассмотрена классификация газобаллонного оборудования, отмечены различия при установке газобаллонного оборудования на карбюраторные и инжекторные двигатели.

Ключевые слова: *судебный эксперт; газобаллонное оборудование; составные газобаллонного оборудования; газовоздушная смесь; экологические требования; экспертный осмотр колёсного транспортного средства.*

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Declaration of Competing Interest
The authors declare that they have no conflict of interest.

References

Afonin, S. N. (2001). *Gazovoe oborudovanie avtomobilei. Legkovye, gruzovye. Ustroistvo, ustanovka, obsluzhivanie. Prakticheskoe rukovodstvo* [Gas equipment for cars. Cars, trucks. Arrangement, installation, maintenance. How-to]. Rostov-na-Donu [in Russian].

Likhanov, V. A., Devetiarov, R. R. (2006). *Primenenie i ehkspluatatsiia*

gazoballonnogo oborudovaniia [LPG equipment application and operation]. Kirov [in Russian].

Zolotnitskii, V. A. (2007). *Avtomobilnye gazovye toplivnye sistemy* [Car gas fuel systems]. Moskva [in Russian].

Naumenko, S., Bragnik, V., Sandu, I. (2022). Features of forensic research on wheeled vehicles with LPG equipment. *Theory and Practice of Forensic Science and Criminalistics.* Issue 1 (26). P. 95—107. DOI: 10.32353/khrife.1.2022.06.