

## Gas Installations Requirements for Cars and Automobile Repair Shops Offering LPG Services

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**Summary.** This paper presents classification and characteristics of gas installations (LPG). It enumerates applicable requirements related to the functioning of automobile repair shops that deal with LPG installations. It also describes testing aimed at vehicle adaptation to the gas supply system as well as technical examinations of systems already in operation. Besides, it outlines repair shop equipment, which is essential for offering such services in workshops and for facilitating their works.

**Key words:** LPG gas installations, automobile repair shops, supply systems.

nostics and repair of systems of different manufacturers. Among many types of gas installations there is great interest in sequential gas injection systems which enable precise estimation of the fuel dose due to the signals coming from petrol controller and thus lead to lower fuel consumption. The least popular are air pre-mixing systems installed mainly in carburettor engines of older vehicles. Another advantage of sequential injection systems is lower emission of toxins in comparison with the air pre-mixing ones [6].

### INTRODUCTION

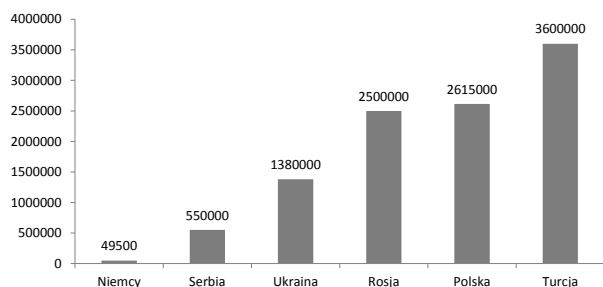
High popularity of LPG propulsion systems installed in motor vehicles in recent years in Poland results mainly from economic reasons, that is constantly changing prices of petrol. An increasing demand for LPG is noticed year by year as a result of considerable differences between gas and petrol prices. In particular, the cheaper gas fuel attracts people who travel a lot since it has an influence on the operation costs. LPG installation cost is not very high, taking into consideration that it is likely to pay back within even less than a year of vehicle exploitation. Additional advantage of gas installations is the fact that their constructors have been working towards obtaining the lowest fuel consumption and reaching the engine parameters as similar as possible to those of petrol engines [12].

Strong demand for gas systems results in the emergence of specialist automobile repair shops that deal with offering such installations. This kind of shops have appropriate equipment and qualified staff capable of selecting proper gas system fitting a particular vehicle so that the lowest fuel consumption and compliance with environmental standards are ensured [1, 15]. Apart from LPG installations, automobile repair shops offer the diag-

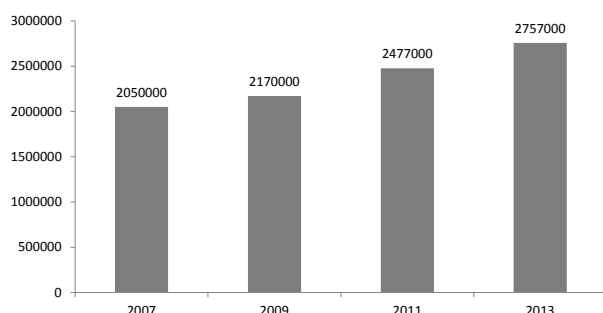
### CLASSIFICATION AND CHARACTERISTICS OF CAR GAS INSTALLATIONS

Fuelling vehicles with gas has been known since the beginning of motorization [16]. In 1860, a Frenchman Jean Lenoir modified a steam engine to run on coal gas and patented it for stationary use. Lenoir's engine raised the interest of a young merchant from Cologne, Nikolaus Otto who had been working on the improvement of combustion engines for many years. In 1910, LPG was first discovered by an American, Walter Snelling. In 1910 this convenient and relatively safe fuel was applied to mobile gas stoves, whereas Ford T was the first vehicle fuelled by LPG. LPG is a popular alternative fuel for combustion engines also in Poland (Fig. 1, Fig. 2). Its popularity is primarily caused by the cheap price compared to petrol or diesel oil. Fig. 3 presents the components of a typical gas installation.

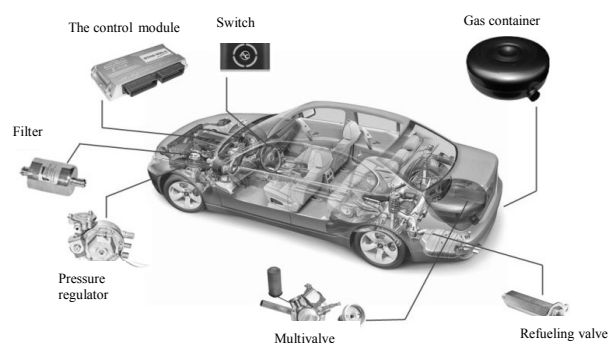
Current gas installations differ from each other considerably. An important factor in the selection of a proper installation is the supply system: whether it is a carburettor, single-point injection, multi-point injection or direct injection. Classification of LPG installations is presented in Table 1.



**Fig. 1.** Number of cars fuelled with LPG in selected countries in 2013 [20]



**Fig. 2.** Number of cars fuelled with LPG in Poland in 2013 [20]



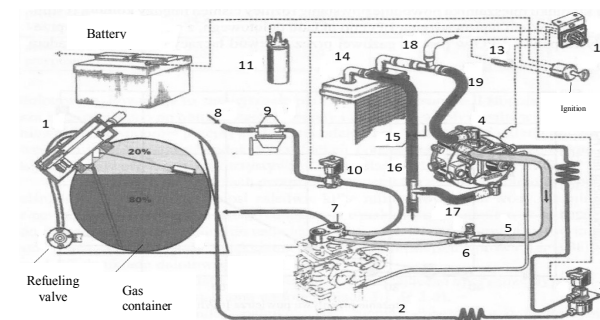
**Fig. 3.** Components of a typical gas installation [20]

**Table 1.** Classification of gas installations [8]

Systems	Characteristics
1 <sup>st</sup> generation	intended to be installed in vehicles which do not have lambda probe, that is vehicles with carburetor engines or injection engines not controlled by lambda probe
2 <sup>nd</sup> generation	cooperating with lambda probe whose signal is used for a proper control of air-fuel mixture
3 <sup>rd</sup> generation	adapted to vehicles with lambda probe; compared to the previous generations a significant difference is lack of mixer
4 <sup>th</sup> generation	adapted to OBD engines, installed in vehicles with multi-point fuel injection system controlled electronically; in such systems signals from petrol injectors are used to control the dose of the injected gas
5 <sup>th</sup> generation	in contrast to all the preceding generations, gas injection is in the liquid phase, not gaseous; therefore there is no need to use the pressure regulator/vaporizer

The first generation LPG system is used in vehicles with carburettor; it has no catalytic converter or lambda probe (Fig. 4). It is the simplest installation which does not re-

quire any electronic controllers. Because of their lack this solution is cheap, but also the least precise and economical. LPG in the liquid phase flows from the container through the multivalve into the pressure regulator/vaporizer where it is transformed into the gaseous phase and becomes ready for mixing with the air. Then, the gas enters the mixer by manually operated fixed-value gas flow adjuster. The air-gas mixture produced in this way in the mixer flows to the intake manifold and through the intake valves reaches the cylinder.

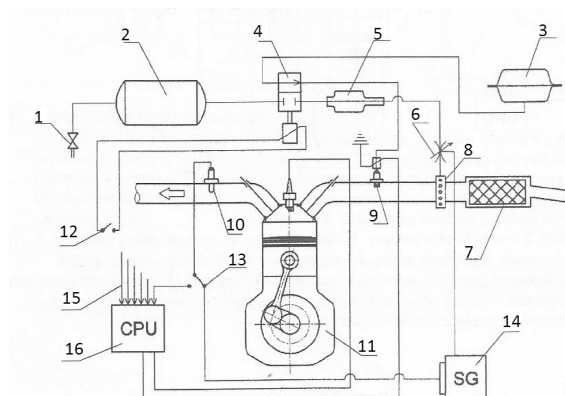


**Fig. 4.** 1<sup>st</sup> generation LPG system diagram: 1 – multivalve, 2 – LPG line, 3 – LPG electrovalve, 4 – pressure regulator, 5 – LPG line between pressure regulator and mixer, 6 – control valve, 7 – mixer, 8 – petrol line, 9 – petrol pump, 10 – petrol electrovalve, 11 – ignition coil, 12 – LPG/petrol switch, 13 – fuse, 14 – heater, 15 – heater valve, 16 – line through which the coolant enters the heater 17 – line through which the coolant enters the pressure regulator 18 – line between the heater and the engine, 19 – line through which the coolant returns from the pressure regulator [8]

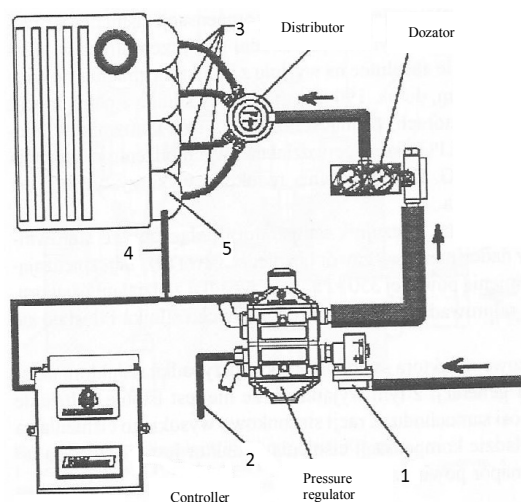
The second generation gas system is applied to vehicles equipped with single-point and multi-point petrol injector with catalytic converter and lambda probe (Fig. 5). Once it reached the gaseous phase, LPG goes through the gas flow adjuster into the mixer where it is mixed with the air. An important component of the control system in this type of installation is an actuator: it enables the control of the amount of the gas sucked by the engine through the mixer. On the other hand, the electronic system controls the amount of supplied gas, which provides the air-gas mixture in suitable proportions. The air-gas mixture produced in this way flows to the intake manifold and through the intake valves reaches the engine cylinders. This type of gas installation is operated directly from the interior of the driver's cabin.

The third generation gas system is used for vehicles with multi-point fuel injection (Fig. 6). Gas is injected directly into the intake manifold, which is possible due to the stepper motor. This type of installation requires no mixer. One of the characteristics of the system is its high operation speed. All cylinders are controlled simultaneously.

The fourth generation gas system is applied to vehicles equipped with multi-point petrol injector with catalytic converter and lambda probe as well as an on-board diagnostic system (EOBD or OBDII). It is a more economical and safer type of installation but also more expensive compared to the previous ones (Fig. 7). Liquefied gas is supplied to the pressure regulator through an integrated gas electrovalve. After reducing gas pressure to approximately 2 bar and transforming into the gaseous phase, LPG flows to the filter modul.



**Fig. 5.** 2<sup>nd</sup> generation LPG system diagram: 1 – filler valve, 2 – gas container, 3 – petrol container, 4 – electrovalve, 5 – pressure regulator, 6 – gas flow adjuster, 7 – air filter, 8 – mixer, 9 – petrol injector, 10 – lambda probe, 11 – engine, 12 – fuel switch, 13 – lambda probe switch, 14 – gas controller, 15 – sensor signals, 16 – petrol controller [10]

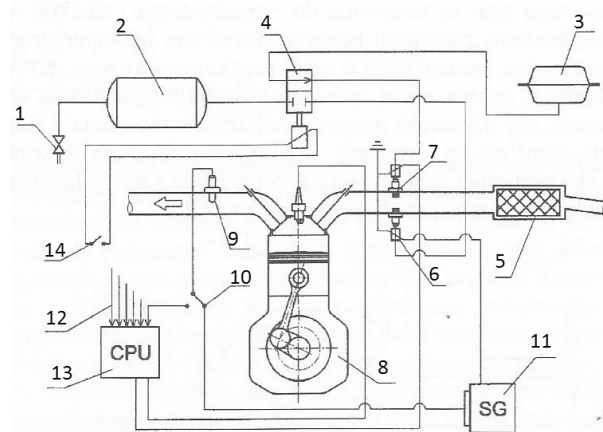


**Fig. 6.** 3<sup>rd</sup> generation LPG system diagram: 1 – electrovalve, 2 – return line that routes LPG back from the pressure regulator at the moment of opening the safety valve, 3 – lines through which LPG enters the intake manifold 4 – compensation line, 5 – intake manifold [8]

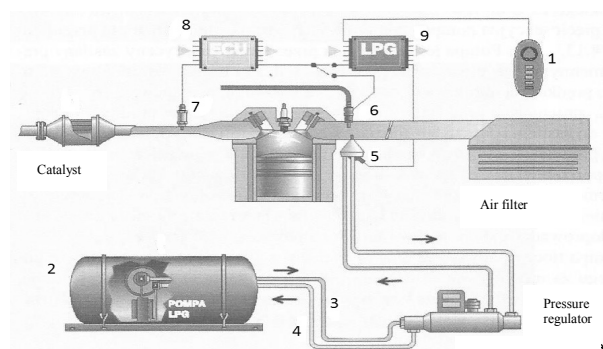
This module is responsible for thorough cleaning of gas from dirt particles. After leaving the control module, the gas flows to the injector rail with injectors mounted on the input of the intake manifold of each cylinder. Engine computer regulates the dose of LPG and calculates the injector opening time as well as its duration separately for each cylinder. Gas flows from the injectors towards the intake valves and then the fuel-air mixture enters the cylinders where it is burned. The parameters of the LPG-driven engine are similar to those of the petrol-fuelled engine.

The fifth generation gas system is related to sequential gas injection in the liquid phase (Fig. 8). In contrast to the previous generations, this type of installation is characterized by the injection of gas in the vapor phase. This leads to lower fuel consumption as well as the improvement of dynamic vehicle performance. One of the advantages of this system is reducing the emission of toxic components in exhaust gases. Gas accumulated in the container is transported

to the pressure regulator. A stop valve installed along with the pressure regulator blocks the LPG flow when the engine is fuelled with petrol. Fuel flows to the injectors, where it is injected near the intake valves. In front of the valves fuel mixes with the incoming air and flows to the cylinders. LPG injectors are controlled using information sent from the petrol injectors.



**Fig. 7.** 4<sup>th</sup> generation LPG system diagram: 1 – filler valve, 2 – gas container, 3 – petrol container, 4 – electrovalve, 5 – air filter, 6 – gas injector, 7 – petrol injector, 8 – engine, 9 – lambda probe, 10 – lambda probe switch, 11 – gas controller, 12 – sensor signals, 13 – petrol controller, 14 – fuel switch [10]



**Fig. 8.** 5<sup>th</sup> generation LPG system diagram: 1 – petrol/LPG switch, 2 – pump with LPG container, 3 – LPG feed line, 4 – LPG return line, 5 – gas injector, 6 – petrol injector, 7 – lambda probe, 8 – engine controller, 9 – gas installation controller [8]

## LPG INSTALLATION REQUIREMENTS FOR VEHICLES

LPG installations in cars shall only be made by automobile repair shops that have been granted a type-approval certificate for offering services consisting in adapting vehicles for gas fuelling. Applicable requirements in this regard shall also be observed by businesses cooperating with such garages [18, 19]. Type-approval certificates are issued by the Minister for Transport and their list is published, amongst others, by the Motor Transport Institute. LPG installation shall be carried out taking into account the provisions defined in the Annex No. 9 to the Regulation of the Minister for Infrastructure of 31 December 2002 on

technical conditions applicable to vehicles as well as the scope of the necessary equipment (Journal of Laws of 2003 No. 32, item 262). Provisions set out in the Annex No. 9 are meant to ensure the appropriate level of safety of gas powered vehicles during their exploitation and they require as follows [14, 17]:

- the components of the gas system shall be appropriately distributed in the vehicle and shall not hinder the functioning and use of other pre-assembled units of the supply system, and they shall be adequately protected against corrosion and physical damage (if the gas container is installed in a load compartment),
- vehicles equipped with the installation shall meet producer requirements as regards the maximum permissible vehicle laden mass, centre of gravity and permissible axle loads,
- the installation shall not decrease vehicle ground clearance and its components shall not be attached less than 20 cm from the road surface; closer distance is permissible if below there is another part of vehicle located within 15 cm from the road surface and it protects gas installation components (regulations applicable to vehicles with gas container installed under the car, which is nowadays very unusual),
- the system installed shall not hinder performing the periodic technical vehicle tests,
- the opening of the exhaust pipe shall not be pointed towards the components of LPG installation,
- the driver's cabin shall be equipped with a fuel switch and switching shall be possible without turning off the engine,
- the installation components located in the driver's cabin through which the gas flows shall be adequately exposed,
- no current shall pass through gas containing components of the installation,
- no component of the system shall project beyond the outline of the vehicle, with the exception of the filling units if they do not project more than 10 mm,
- rubber connectors can only be splitted with tools,
- electrical system shall contain at least one fuse and shall be protected against overloads,
- gas flow into the intake system shall be stopped within no more than 2 seconds when the engine is not running and after switching to a different fuel,
- the correctly installed container shall be protected against the effects of collision,
- the container shall be separated from the vehicle parts adjacent to it and from container mounting components by the elastic spacer that does not absorb moisture,
- container position shall enable reading of legalization details, identification markings and container fill level,
- containers shall not be installed in passenger compartments or in the engine compartment and no rigid components with sharp edges shall be located close to them,
- LPG container position shall enable gas flow in the liquid phase,
- if there is no heat shield, the distance between the container and the components of the exhaust system shall be at least 0,1m,
- the filling unit shall be located in an accessible place to ensure that the container can be filled from outside of vehicle,
- metal components that form part of the gas installation shall not contain seams and for LPG they shall be made of copper or steel,
- lines shall be made in locations where access is possible for inspection; they should not rub against other vehicle parts and their mounting shall prevent vibration (no lines shall be installed where a vehicle is lifted up),
- soldered, welded or bite-type compression lines shall not be used,
- metal lines subjected to movements shall be mounted in such way so that they form loops; the radius of curvature shall be adjusted to the line diameter,
- wall thickness of the rigid fuel lines shall be at least 0,8 mm and its outer diameter shall not exceed 12 mm assuming that they are applied to liquefied gas,
- acceleration or deceleration of vehicle shall not influence the pressure regulator performance and the distance between regulator and the exhaust system shall be at least 0,1 m (in case of the absence of the heat shield),
- containers shall be covered by the complete gas-tight housing or be equipped with the gas-tight housing that covers only the valves,
- complete housing shall have at least two ventilation valves whereas covering housing at least one valve (vents shall have a minimum clear opening of 4,5 cm<sup>2</sup> and their openings shall not be pointed towards the exhaust system, for liquefied gas they shall be pointed downwards),
- any connecting lines used for ventilation as well as housing over the valves shall be gas-tight at a positive pressure of 0,01 MPa.

#### REQUIREMENTS RELATED TO LPG-FUELLED VEHICLE TESTS

Technical inspection for the gas powered vehicles consists in: verification of gas container documentation, testing gas system for the proper selection of the components and installation, general assessment of the installation condition, control of the proper operation of the components as well as leakage checking (Table 2). Prior to the subsequent tests the validity of the gas container certificate issued by Transport Technical Supervision shall be checked [3].

#### EQUIPMENT REQUIREMENTS FOR AUTOMOBILE REPAIR SHOPS OFFERING LPG INSTALLATIONS

To ensure the highest level of service, automobile repair shops offering LPG installations must be equipped with appropriate specialist devices i.e. exhaust gas analyzer, gas leakage detector, OBD scanner and diagnostic tester [18]. The characteristics of the above-mentioned devices were presented in Table 3. Some of important devices that

**Table 2.** Gas installation tests [5, 11]

Gas installation tests	Activities
Proper selection of installation components	Checking: – installation completion, its connecting system and position in the vehicle, – required type-approval markings on the installation components, – gas container and safety valve selection,
Correctness of installation	Checking whether: – there is at least one fuse protecting the electric system against overloads, – the stop valve is closed when engine is not running, – copper lines are protected by plastic or rubber cover, – the container is separated from the vehicle parts adjacent to it and from container mounting components by the elastic spacer that does not absorb moisture, – non-return valves were used for joining containers,
	In installations with lambda probe and catalytic converter the inspection consists in checking: – whether the container has no visible modifications or damage and if the mounting components are sufficiently stable, – whether flexible fuel lines have no damage, cracks or show no signs of wear, – whether metal lines are correctly formed and whether the rigid lines mounting ensures their protection from tension and vibrations, – ventilation ducts and low pressure in terms of existence of properly tightened bands at their ends, – whether the filling valve position ensures accessible filling up from the outside of the vehicle and whether the valve is secured against rotation, – whether no other devices that are not required for the proper functioning of the engine were connected to the installation, – whether gas is correctly routed back from the safety valves,
Leakage checking	Checking: – the seats of filling valves and safety valves, gas electrovalve and lines where they connect with other installation components, – the container and valve housings.

**Table 3.** Characteristics of the selected devices in LPG-installation workshops [7, 13]

Device	Technical characteristics
Exhaust gas analyser	– enables to measure engine speed, AFR, excess-air ratio and engine oil temperature
Gas leakage detector	– enables to discover all types of leakage in the gas supply system – enables to detect leakage location and its level
OBD scanner	– enables to determine engine defects, thus allows the assessment of the engine condition and its components
Diagnostic testers	– enable to detect the reasons for vehicle malfunctioning in a short period of time – enable to read information from the controller and error memory, programming, indicating actual values, activation of executive components as well as make the controller perform specific functions, – enable to find information about localization of damaged vehicle components, current parameters (e.g. the angle of the throttle opening) or mechanical and electronic connections, – they can also function as OBD scanners

should be part of the equipment of every repair shop include a lift column, which enables access to the vehicle as well as the so called hand tools i.e. all kinds of wrenches, riveters, pliers, and screwdrivers. In order to ensure work facilitation these devices should be located in suitable racks, cabinets, on the work bench or tool wagons that apart from storing different kinds of accessories are mobile. Another important part of garage equipment includes individual exhaust extractors, which discharge exhaust gases from a vehicle situated on the inspection bay through the lines connected to the exhaust pipe. Flue gases are discharged outside the building via piping system connected to the exhaust extractor. During repair works the leakage of various environmentally-unfriendly petroleum derivatives is possible. Before this waste goes to the sewage system with the rain water, it should be separated with a special separator of petroleum derivative substances, which is equipped with coalescing filter cartridge.

The equipment of automobile repair shops offering LPG-installations should also include dedicated computer programs as they facilitate and improve the work conditions.

## CONCLUSIONS

Automobile repair shops specializing in LPG installations must meet many requirements in order to provide vehicle users with safety when offering such services [2, 4]. Before the actual installation they carry out different types of assessment intended to determine whether or not gas supply system is possible for a particular vehicle. If so, they can move to the next step, which consists in the adaptation of the LPG-system to the specific type of vehicle. For proper installation, the gas system components shall comply with the applicable legal requirements, suitable equipment shall be used and works shall be carried

out by appropriately skilled personnel. Every repair shop that installs gas systems in vehicles should have a suitable location, client-oriented working hours, parking places as well as ventilating, heating, electrical and sewerage systems and water connections. Moreover, there are requirements for vehicles already equipped with gas installation, meaning they must be subjected to annual technical inspection, which includes flue gas analysis, leakage checking, control of the proper functioning of installation parts, verification of container documentation and checking the proper selection of installed components.

The issues presented in this paper indicate the required responsibility with regard to adaptation of vehicles to LPG systems. This is primarily a matter of safety of the users during vehicle exploitation, which is the overall objective of that kind of services.

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## WYMAGANIA ODNOŚNIE MONTAŻU INSTALACJI LPG W SAMOCHODACH ORAZ ZAPLECZA WARSZTATOWEGO PROWADZĄCEGO TEGO RODZAJU USŁUGI

**Streszczenie.** W artykule przedstawiono klasyfikację i charakterystykę instalacji gazowych LPG. Wymieniono obowiązujące wymagania dotyczące funkcjonowania warsztatów montujących instalacje gazowe LPG. Opisano badania mające na celu przystosowanie danego pojazdu do montażu gazowego układu zasilania oraz badania techniczne zamontowanych już układów. Charakterystyce poddano także wyposażenie niezbędne do realizowania usług oferowanych w warsztacie oraz usprawniających jego pracę.

**Słowa kluczowe:** instalacje gazowe LPG, warsztaty samochodowe, układy zasilania.