

Liquid Propane Gas (LPG)

Autogas is the common name for liquefied petroleum gas (LPG) when it is used as a fuel in internal combustion engines in vehicles as well as in stationary applications such as generators. It is a mixture of propane and butane.

Autogas is widely used as a "green" fuel, as its use reduces CO₂ exhaust emissions by around 15% compared to petrol. One litre of petrol produces 2.3 kg of CO₂ when burnt, whereas the equivalent amount of autogas (1.33 litre due to lower density of autogas) produces only $1.5 \times 1.33 = 2$ kg of CO₂ when burnt. CO emissions are 30% lower, compared to petrol and NO_x by 50%. It has an octane rating (MON/RON) that is between 90 and 110 and an energy content (higher heating value—HHV) that is between 25.5 megajoules per litre (for pure propane) and 28.7 megajoules per litre (for pure butane) depending upon the actual fuel composition. (Toyota, 2015)

Autogas is the third most popular automotive fuel in the world, with approximately 16 million of 600 million passenger cars powered using the fuel, representing less than 3% of the total market share. Approximately half of all autogas-fueled passenger vehicles are in the five largest markets (in descending order): Turkey, South Korea, Poland, Italy, and Australia.

System Types



Vialle LPI liquid injection on a 2003 Lexus IS 300 2JZ-GE.

The different autogas systems generally use the same type of filler, tanks, lines and fittings but use different components in the engine bay. Liquid injection systems use special tanks with circulation pumps and return lines similar to petrol fuel injection systems.

There are three basic types of autogas system. The oldest of these is the conventional *converter-and-mixer* system, which has existed since the 1940s and is still widely used today. The other two types are known as *injection* systems, but there are significant differences between the two.

A converter-mixer system uses a converter to change liquid fuel from the tank into vapour, then feeds that vapour to the mixer where it is mixed with the intake air. This is also known as a venturi system or "single point" system.

Vapour phase injection systems also use a converter, but unlike the mixer system, the gas exits the converter at a regulated pressure. The gas is then injected into the air intake manifold via a series of electrically controlled injectors. The injector opening times are controlled by the autogas control unit.

This unit works in much the same way as a petrol fuel injection control unit. This allows much more accurate metering of fuel to the engine than is possible with mixers, improving economy and/or power while reducing emissions.

Liquid phase injection systems do not use a converter, but instead deliver the liquid fuel into a fuel rail in much the same manner as a petrol injection system. These systems are still very much in their infancy. Because the fuel vapourises in the intake, the air around it is cooled significantly. This increases the density of the intake air and can potentially lead to substantial increases in engine power output, to the extent that such systems are usually *de-tuned* to avoid damaging other parts of the engine. Liquid phase injection has the potential to achieve much better economy and power plus lower emission levels than are possible using mixers or vapour phase injectors.

System Components



Fuel filler in E-Gas Ford Falcon



Filler with mounting and cover removed

The fuel is transferred into a vehicle tank as liquid by connecting the bowser at the filling station to the filler fitting on the vehicle. The type of filler used varies from country to country, and in some cases different types are used within the same country.

Adaptors that allow a vehicle fitted with a particular system to refuel at a station equipped with another system are available. The fill valve contains a check valve so that the liquid in the line between the filler and the tank(s) does not escape when the bowser nozzle is disconnected.

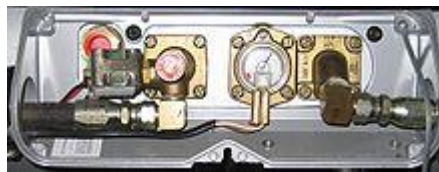
In installations where more than one tank is fitted, T-fittings may be used to connect the tanks to one filler so that the tanks are filled simultaneously. In some applications, more than one filler may be fitted, such as on opposite sides of the vehicle. These may be connected to separate tanks, or may be connected to the same tanks using T-fittings in the same manner as for connecting multiple tanks to one filler.

Fillers are typically made of brass to avoid the possibility of sparks when attaching or removing the bowser that might occur if steel fittings were used.

Tank



Autogas tank in boot of Volvo sedan



Tank valves. From left, relief valve (with red cap), service valve, gauge and fill valve



Autogas tank inside spare wheel recess

Vehicles are often fitted with only one tank, but multiple tanks are used in some applications. In passenger car applications, the tank is typically either a cylindrical tank, made from steel, mounted in the boot of the vehicle or a toroidal tank (also steel) or set of permanently interconnected cylinders placed in the spare wheel well. In commercial vehicle applications, the tanks are generally cylindrical tanks mounted either in the cargo space or on the chassis underneath the body. Increasingly, the tank is an aluminum Conformable Tank, which is lighter, has more capacity and cannot rust.

The emergency pressure relief valve in the tank is called a hydrostatic pressure relief valve. It is designed to open if the pressure in the tank is dangerously high, thus releasing some vapour to the atmosphere to reduce the pressure in the tank. The release of a small quantity of vapour reduces the pressure in the tank, which causes some of the liquid in the tank to vapourise to re-establish equilibrium between liquid and vapour. The *latent heat of vapourisation* causes the tank to cool, which reduces pressure even further.

The gauge sender is usually a magnetically coupled arrangement, with a float arm inside the tank rotating a magnet, which rotates an external gauge. The external gauge is usually readable directly, and most also incorporate an electronic sender to operate a fuel gauge on the dashboard.

Vapouriser

The vapouriser (also known as a converter or reducer) is a device designed to change the fuel from a pressurised liquid to a vapour at around atmospheric pressure for delivery to the mixer or vapour phase injectors. Because of the refrigerant characteristic of the fuel, heat must be put into the fuel by the vapouriser. This is usually achieved by having engine coolant circulated through a heat exchanger that transfers heat from that coolant to the LPG.

There are two distinctly different basic types of vapouriser for use with mixer type systems. The *European* style of vapouriser is a more complex device that incorporates an idle circuit and is designed to be used with a simple fixed venturi mixer. The *American* style of vapouriser is a simpler design which is intended to be used with a variable venturi mixer that incorporates an idle circuit.

Vapour Phase Injectors

Most vapour phase injection systems mount the solenoids in a manifold block or *injector rail*, then run hoses to the nozzles, which are screwed into holes drilled and tapped into the runners of the intake manifold. There is usually one nozzle for each cylinder. Some vapour injection systems resemble petrol injection, having separate injectors that fit into the manifold or head in the same manner as petrol injectors, and are fed fuel through a *fuel rail*.



Vapour phase injectors

Liquid Phase Injectors

Liquid phase injectors are mounted onto the engine in a manner similar to petrol injectors, being mounted directly at the inlet manifold and fed liquid fuel from a fuel rail.

Electrical and Electronic Control

There are four distinct electrical systems that may be used in autogas systems - fuel gauge sender, fuel shut-off, closed loop feedback mixture control and injection control.

In some installations, the fuel gauge sender fitted to the autogas tank is matched to the original fuel gauge in the vehicle. In others, an additional gauge is added to display the level of fuel in the autogas tank separately from the existing petrol gauge.

In most modern installations, an electronic device called a tachometric relay or safety switch is used to operate electrical shut-off solenoids. These work by sensing that the engine is running by detecting ignition pulses. Some systems use an engine oil pressure sensor instead. In all installations, there is a filterlock (consisting of a filter assembly and a vacuum or electric solenoid operated shut-off valve) located at the input to the converter. In European vapouriser, there is also a solenoid in the vapouriser to shut off the idle circuit. These valves are usually both connected to the output of the tachometric relay or oil pressure switch. Where solenoids are fitted to the outputs of fuel tanks, these are also connected to the output of the tachometric relay or oil pressure switch. In installations with multiple

tanks, a switch or changeover relay may be fitted to allow the driver to select which tank to use fuel from. On bi-fuel, the switch used to change between fuels is used to turn off the tachometric relay.

Closed loop feedback systems use an electronic controller that operates in much the same way as in a petrol fuel injection systems, using an oxygen sensor to effectively measure the air/fuel mixture by measuring the oxygen content of the exhaust and control valve on the converter or in the vapour line to adjust the mixture. Mixer type systems that do not have a closed loop feedback fitted are sometimes referred to as *open loop* systems.

Injection systems use a computerised control system which is very similar to that used in petrol injection systems. In virtually all systems, the injection control system integrates the tachometric relay and closed loop feedback functions.

LPG injection for diesel vehicles

LPG may be used for a supplemental fuel for diesels of all sizes. Diesel contains 128,700 BTU per US gallon, where propane contains 91,690 BTU per US gallon. If LPG is 30-40% less expensive, there may very well be a saving. Any actual savings are dependent on the relative cost of diesel versus LPG. In Australia, where diesel costs substantially more than LPG, savings of 10 to 20% are claimed.

The above systems add small quantities of LPG with the primary aim of improving economy, but much larger quantities of LPG can be injected in order to increase power. Even at full output a diesel engine runs about 50% lean of stoichiometric to avoid black smoke production, so there is a substantial amount of oxygen in the intake charge which is not consumed in the combustion process. This oxygen is therefore available for the combustion of a substantial addition of LPG resulting in a large increase in power output.