Vialle LPi Technical Manual

Introduction - Liquid Propane Injection (LPi)

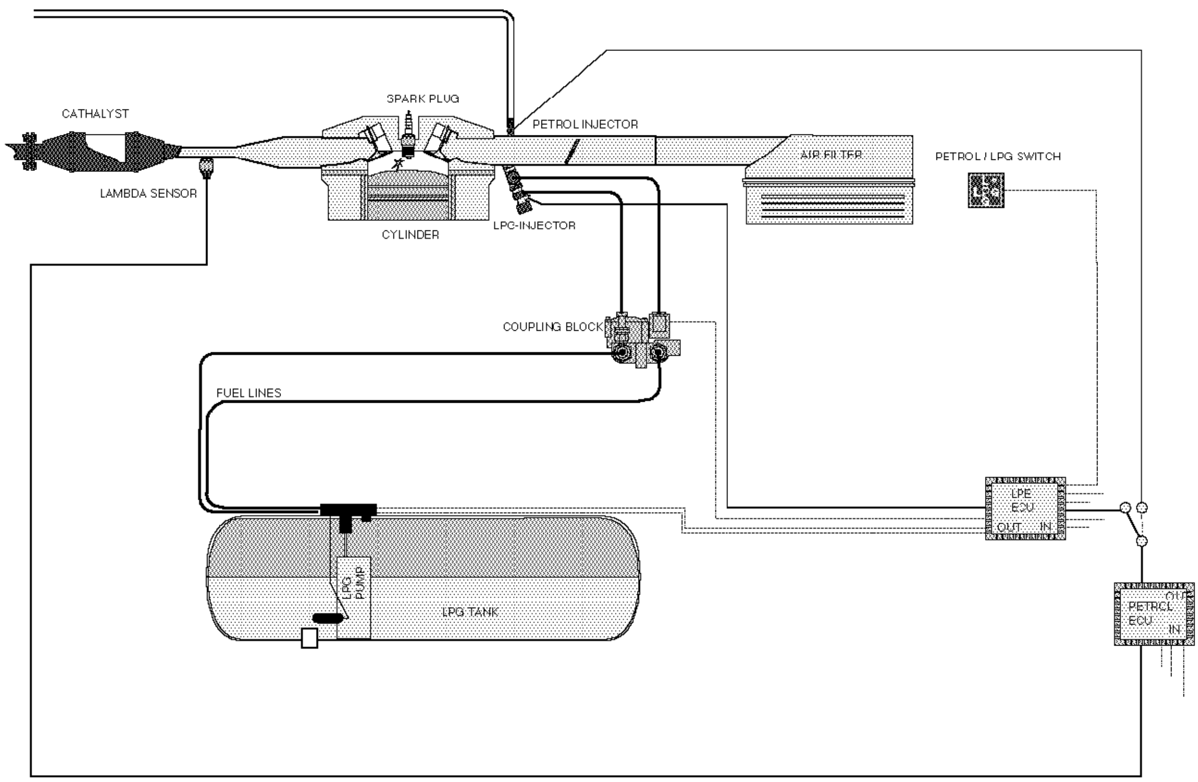
Liquid Propane Injection means injecting LPG in liquid form.
The LPi system is a completely new approach of metering an LPG/air mixture into a combustion engine.

Until now an evaporator/venturi system, possibly in combination with an electronic fine adjustment, determined the mixture metering.

This advanced system achieves a more accurate mixture control than can be achieved with a pressure-controlled system. The objective is to make the LPG-system approach the petrol injection system in so far as is possible. It is therefore a logical choice to inject the LPG in liquid form at the inlet valve.

A lot of development work has been done in order to introduce this entirely new system. Almost all components are new and differ completely from the parts that made up earlier generations of LPG systems. The evaporator and the gas/air mixer have been replaced by the coupling block and injectors, the tank is fitted with a pump to circulate the liquid LPG and the copper pipe has been replaced by two synthetic ones.

The system is shown in the picture below.



Liquid or vapour injection?

Vapour injection is a logical successor to the evaporator venturi systems.
Metering vapour at the inlet valves reduces the volume of explosive mixture in the inlet system. However, the required quantity of vapour makes time-controlled metering unrealistic.
Liquid does offer that possibility as the quantities to inject are low. The time-controlled injection makes it possible to influence the mixture control on each cylinder.

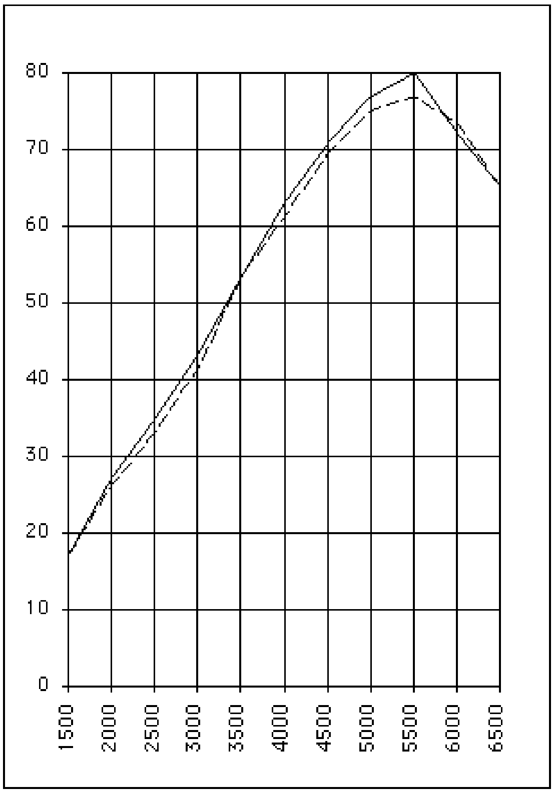
Vapour metering requires specific control electronics that hinders self-learning of the engine management system.
Liquid injection is controlled from the existing engine management system that fully retains and uses its autodidactic properties.

There is no loss of power as there is no air displacement effect which, in case of a vapour system, causes a filling loss of 7%. Vapoured LPG takes the place of air, less air means less power.

Advantages of LPi

- LPG can be metered highly accurately.

- The system is insensitive to ambient influences such as air resistance resulting from the forward speed and contamination of the air filter.
- Optimum use of the available car electronics, the fuel computer determines the mixture control, also for LPG. This prevents disturbance of the original engine management system.
- The volume of explosive mixture in the inlet system is minimal as a result of time-controlled injection. This prevents consequential damage in case of a backfire.
- No loss of power as the inlet system is free of throttles such as venturis.



Injection

There is a number of options for the method of injecting fuel into the inlet channel.

The method used, differs per car make and model. Considerations that play a part are cost price, technical feasibility, driveability and environmental regulations.

The various methods include:
- simultaneous or parallel injection
- semi-sequential injection
- fully sequential injection.

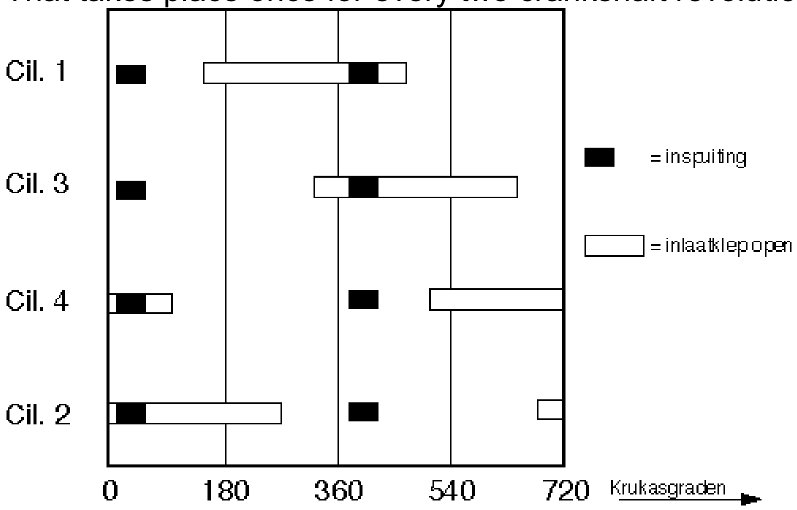
Simultaneous or parallel injection

With this method all injectors simultaneously inject the fuel at each complete revolution of the crankshaft.

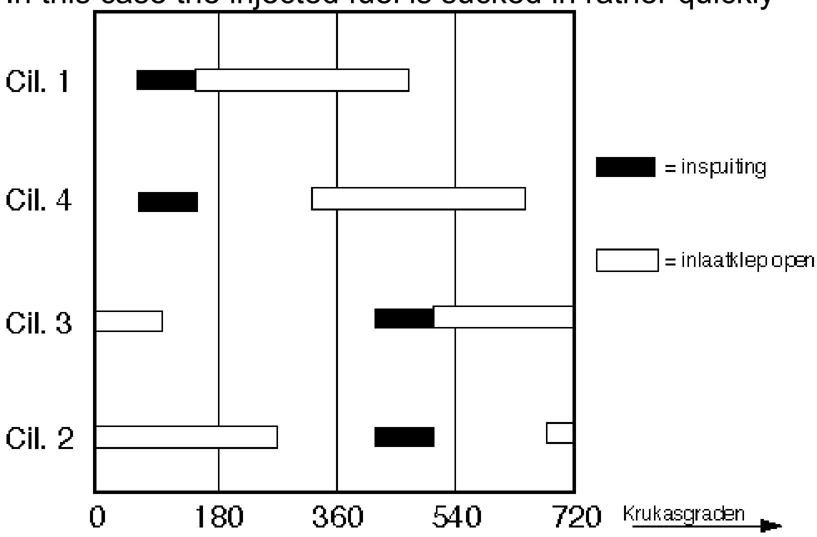
At one revolution the fuel is directly sucked in, at the next revolution the fuel is as it were laid ready for the inlet valves that are not yet open.

Semi-sequential injection

With semi-sequential injection the fuel is injected per injector group.
That takes place once for every two crankshaft revolutions.



In this case the injected fuel is sucked in rather quickly



Fully sequential injection

With this method the injection moment is determined per injector. As a rule the injection must be completed before the inlet valve opens. Sometimes the injection only begins on the opening of the inlet valve.

The major advantage of the fully sequential method is that the injection quantity can be determined separately for each cylinder.

The introduction of the 'on board diagnosis' (OBD-2) has made fully sequential injection necessary.

This is the only way to enable shutting off fuel per cylinder (e.g. in the case of a faulty spark plug, catalyst protection and traction control).

Insert full sequential pic

The options of the LPi system

The LPi system follows the injection strategy of the petrol injection computer. This means the fuel metering of LPG is exactly the same as for petrol.

All options such as fuel shut off at decelerating, rpm-limit, height de-rating, full load enrichment and l =1 control are also performed for LPG.

LPG Characteristics

At room temperature and atmospheric pressure LPG is gaseous. The gas can be liquefied by lowering the temperature or by increasing the pressure. For storage in car fuel gas tanks only the pressure has to be increased.

The pressure increase is the result of evaporation of liquid gas in a confined space. By evaporation the volume becomes on average 250 times greater, dependent on the composition of the LPG.

Evaporation and condensation occur in a continuous process that only stops when the tank is completely empty. The pressure of the vapour (vapour pressure) that hangs above the gas depends on the temperature and the composition. This is indicated by the vapour distribution curve.

The vapour distribution curve

The prevailing pressure at a certain temperature above gas of a certain composition can be read fairly accurately in the vapour distribution curve.

Vapour distribution curve

The curve also shows why the composition of the gas varies with the seasons.
At a temperature of -10°C butane will not come out of a tank, because the vapour pressure is too low.
The fuel gas composition observed in the Netherlands is in summer 70% butane and in winter 70% propane.

When LPG is heated in the line, e.g. in the engine compartment, the liquid may convert to vapour.
To ensure that the LPG is always in liquid form, the pressure is increased by 5 bar.

This pressure increase is realised by means of a booster pump in combination with a pressure regulator.
The pressure increase gives sufficient certainty that the LPG is in liquid form at the injectors.

The fuel supply system - Introduction

Vapour is compressible so it cannot be injected accurately. Injecting the LPG in liquid form requires a certain system pressure. This system pressure is realised by the diaphragm pump in the tank. This pump pumps the gas via the coupling block to the LPG injectors.

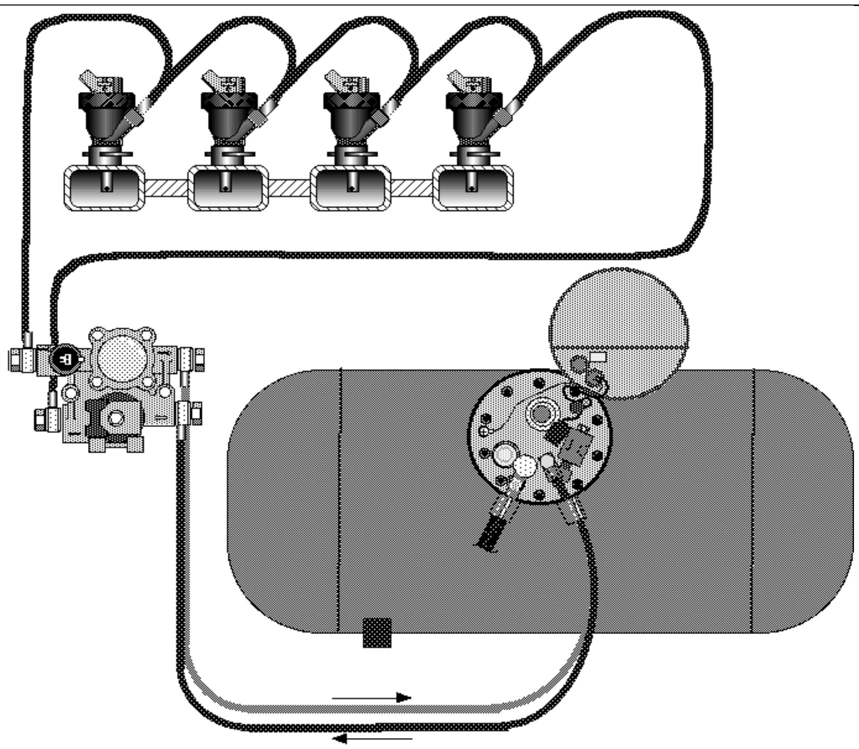
The pressure regulator keeps the system pressure at 5 bar above the tank pressure. Heat from the surrounding components may cause vapour bubbles in the lines.

Circulating the liquid gas under pressure prevents heating and therefore any possible vapour in the line.

The components normally are interconnected by synthetic lines. However for certain export markets there is a possibility that it is prohibited to mount synthetic lines underneath cars. In this case we still use copper pipe.

The synthetic lines have a bursting pressure of 345 bar. The drawing below represents the circulation circuit.

Pic of fuel supply circuit



The LPG tank with PTC pump

The new generation LPi tanks are fitted with a Multivalve in which the LPG pump is integrated. PTC stands for Pump Tank Combination. This pump circulates the liquid LPG.
In the new Multivalve, the tank fittings, which were previously mounted separately on the tank, are now all integrated on one fittings plate.

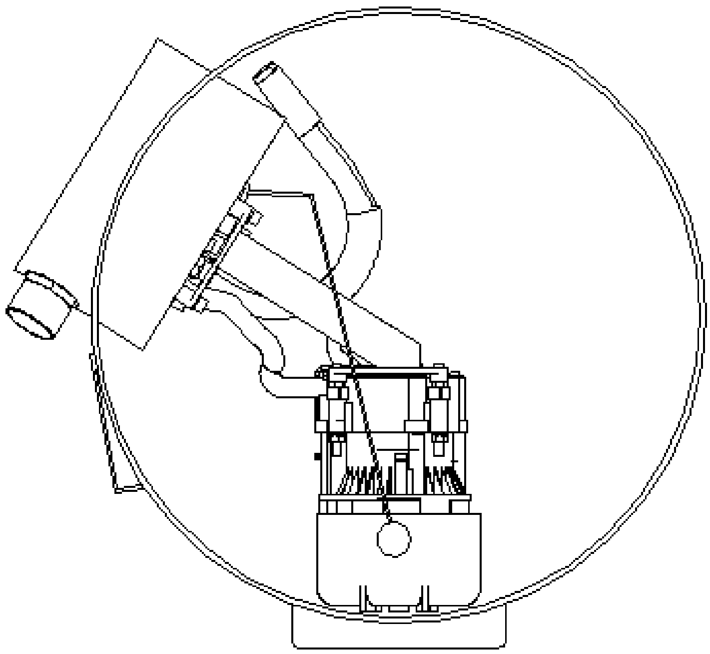
The riser pipe, used in conventional LPG tanks, is no longer present in LPi tanks. The PTC tank does contain a curved steel lead-through pipe. This pipe ensures that the 2 hoses from the pump unit are correctly positioned in the vapour section of the tank, which is filled to a maximum of 80%.

A buffer sleeve is located on the underside of the Multivalve around the pump unit. This ensures that liquid LPG and no vapour is drawn in for as long as possible. There are magnets in the tank which catch any metal particles.

The fittings plate

The PTC tank no longer has a removable casing containing the individual fittings. The fittings sheet is now mounted within the body of the tank. This sheet is gas-tight sealed by a cover with a rubber ring. The pump electronics are integrated in this cover.

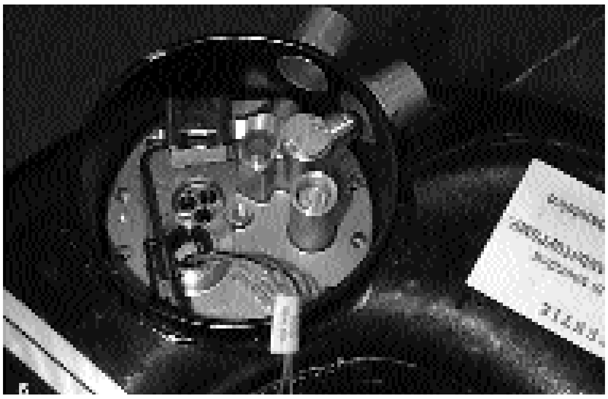
The fittings casing contains 2 feed-through openings: one for the filling hose (diameter Ø30 mm) and one for ventilation and the wiring lead-through (diameter Ø32 mm). This opening is larger in order to comply with the legal feed-through surface requirement of 500 mm2.



The Multivalve

The fittings plate of the Multivalve contains the following fittings:

1. The service valve
2. The pressure relief valve
3. The LPG level sensor
4. The 80% filling hose connection
5. The LPG return connection on the return valve
6. The electrical lead-through for the pump power supply



The fittings cover

The function of the fittings cover in a PTC tank is twofold:

- To achieve a gastight seal of the fittings casing.

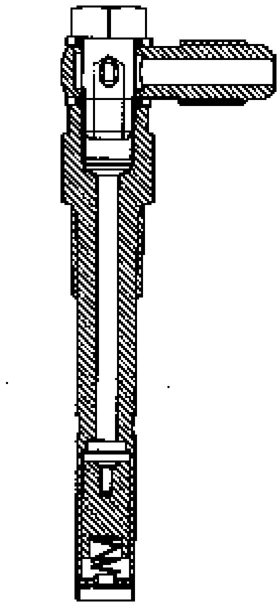
- This cover also contains the electronics which transform the supplied direct current into the alternating current required by the pump motor.

The capacitor that protects the pump electronics is now, otherwise than before, cast in the electronics.

The return valve

The return valve, which is integrated in the Multivalve, ensures that no LPG will escape from the tank in the case of a return line break.
The valve also muffles the gurgling sound made by the back flowing LPG.

The LPG that flows from the coupling block pushes away the plunger against the spring pressure. A minor overpressure of 0.1 bar suffices. This is why we can assume that the return line pressure is equal to the pressure in the tank.

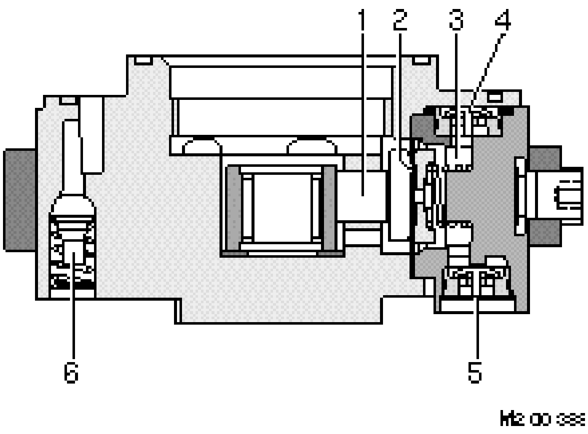


The fuel pump

The liquid LPG is pumped round by a star-shaped diaphragm pump. The pump has 5 pump chambers which are each fitted with a suction valve and a delivery valve.

When the resistance in the circulation circuit becomes too high, an overpressure safety is activated and the LPG is pumped through a pressure relief valve (± 8 bar above the tank pressure). The plungers are operated by a rotating eccentric. The pump is screwed on the drive motor.

1.	Plunger	4.	Delivery valve
2.	Diaphragm	5.	Suction valve



The pump unit

A new pump motor has been developed for the PTC tank with Multivalve. The pump unit is now considerably smaller than that of the first generation. This is mainly because the construction of the motor is smaller and the large buffer container has been replaced with a rubber buffer sleeve. In the present situation, we are also able to equip ring tanks of less height.

The pump motor

The pump motor is a brushless AC motor. This is powered via the three-pole connector that is mounted on the electrical feed-through on the underside of the Multivalve. The direct current is transformed to alternating current by the electronics in the fittings cover. The rotor in the motor has permanent magnets. As advantage it can obtain a large torque from a small device. The motor can rotate at 5 different speeds, achieved by controlling the electric fields with varying frequencies. This is again regulated by the LPE which is responsible for controlling the pump drive.

The advantages of this pump motor in comparison with the preceding motors are:

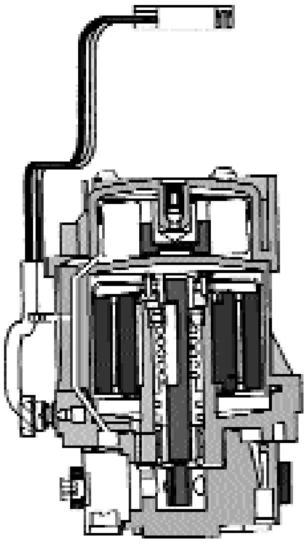
- The low current consumption (1-3A), depending on the RPM. The start-up current too is roughly half that of the preceding model.

- The noise produced by the motor is less

- The complete unit is smaller

Lubrication of the pump motor

Because LPG does not posses any lubricating properties, both bearings are lubricated by a small oil supply at the bottom of the bearing housing. The oil is carried up to the top bearing by an oil lift screw and then flows back into the lower bearing housing.



The pressure relief valve and the pump ventilation

Two longer hoses are attached to the pump:
- A flexible synthetic hose for the pressure relief valve.
- A rubber hose for the ventilation of the pump motor.

When the pressure relief valve blows off, it is only in vapour.
The pump motor may not be filled with liquid LPG. This is because the oil in the pump motor could evaporate when the tank blows off or when driving the tank empty.

Because of this, the 2 hoses are carefully fed through the steel pipe when mounting the pump unit. This steel pipe is curved upwards in the tank. This ensures that the tail ends of these hoses are always situated in the gas, because the tank is filled to a maximum of 80%. For this reason also, it is important that we never fill the tank to more than 80%.

The complete construction of the PTC unit

The route taken by the LPG through the unit is as follows:
At the bottom of the pump, the liquid LPG is sucked into the buffer sleeve, and cannot escape due to the non-return membrane in this sleeve.
After the LPG has been pressurised by the membrane pump, it passes through the LPG filter. This LPG filter will last for the whole of the car's life, and requires no maintenance. After this filter, the liquid LPG leaves the pump housing under pressure via the LPG hose, which is secured by hose clamps.
Ultimately, the pressurised LPG reaches the coupling block by means of the service valve. The return LPG makes its way back to the tank via the return valve.

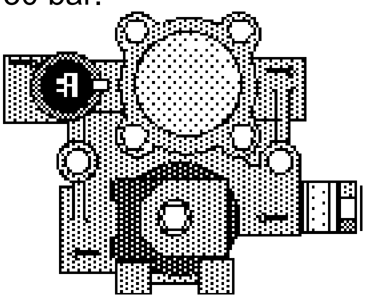
The coupling block

The coupling block forms the connection between the tank and the injectors. The block is mounted under the hood. The position in which it is mounted is irrelevant.

The coupling block includes a solenoid valve that opens and closes simultaneously with the output valve on the tank.
The coupling block also includes the pressure regulator and the pressure transmitter.

The liquid LPG flows through the valve to the injectors. Then the unused LPG returns via the pressure transmitter and the pressure regulator to the tank.

The pressure in the coupling block is 5 bar higher than the tank pressure and it varies from 7 to 30 bar.



1. Feed from the tank
2. Valve coil
3. Output to injectors
4. Feed from the injectors
5. Pressure transmitter

Connecting the coupling block

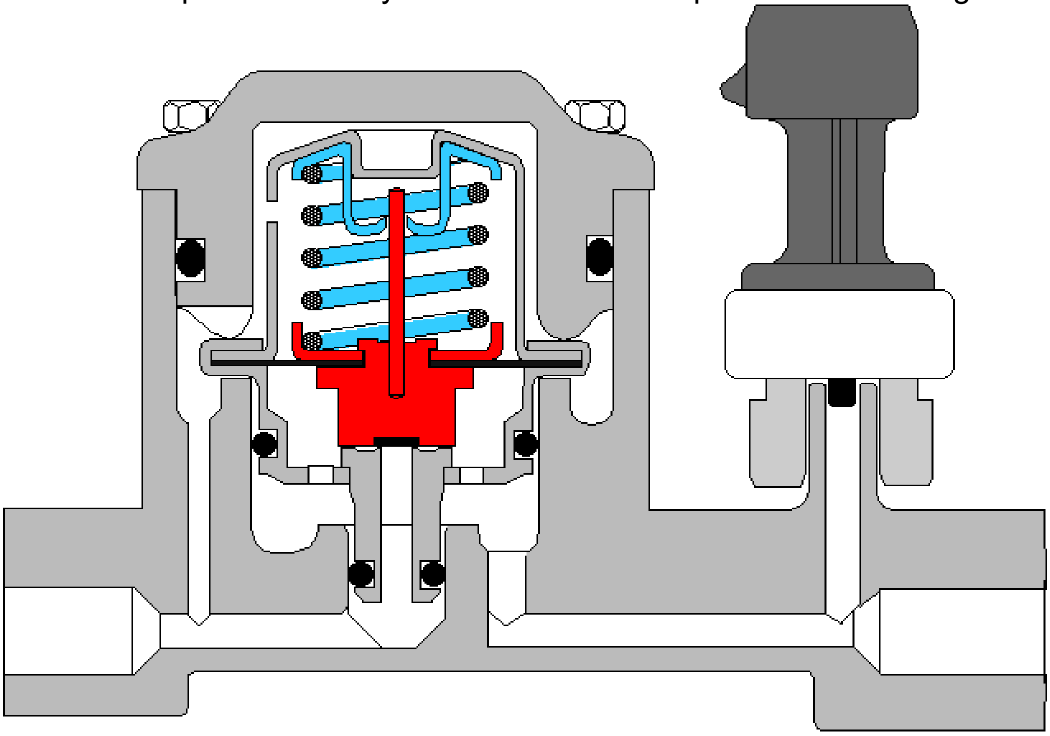
The coupling block has four connections for the flexible high-pressure lines.

They are connected using a banjo and banjo bolt

It is very important not to interchange the connections because of the LPG flow. The pressure regulator only allows one direction of flow. The direction of flow is indicated on the house.

The coupling block must not be disassembled.

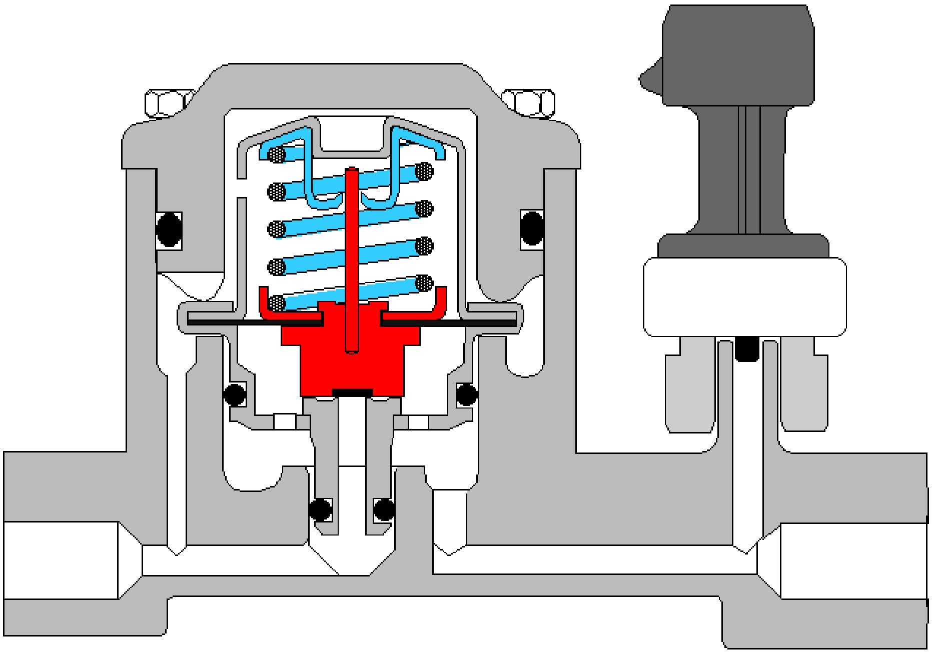
When a component is faulty the block must be replaced as one integral unit.



The pressure regulator

The pressure regulator keeps the pressure at 5 bar above the tank pressure. The tank pressure varies with the temperature and the composition of the LPG. Refer also to the vapour distribution curve.

The pump in the tank increases the pressure in the line. The spring-loaded diaphragm valve releases the return to the tank only when an overpressure of 5 bar has been reached. There is tank pressure above the diaphragm. The valve opens when the system pressure is equal to the tank pressure + spring pressure (5 bar).



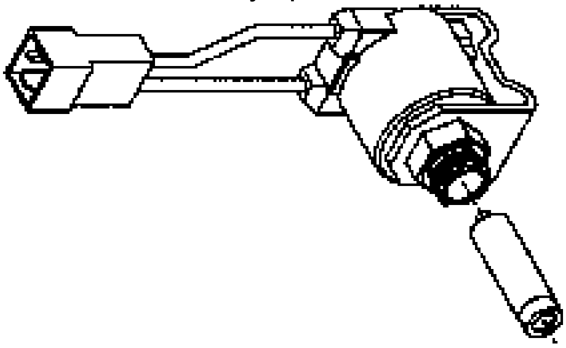
1. System pressure from the injectors
2. Tank pressure

The solenoid valve

The valve that is mounted in the coupling block does not differ from the valves used in the evaporation system.

The valve is a mandatory component that shuts off the LPG supply in case of a line failure downstream from the valve.

The valve is always powered with 12 Volt when LPG has been selected as fuel.



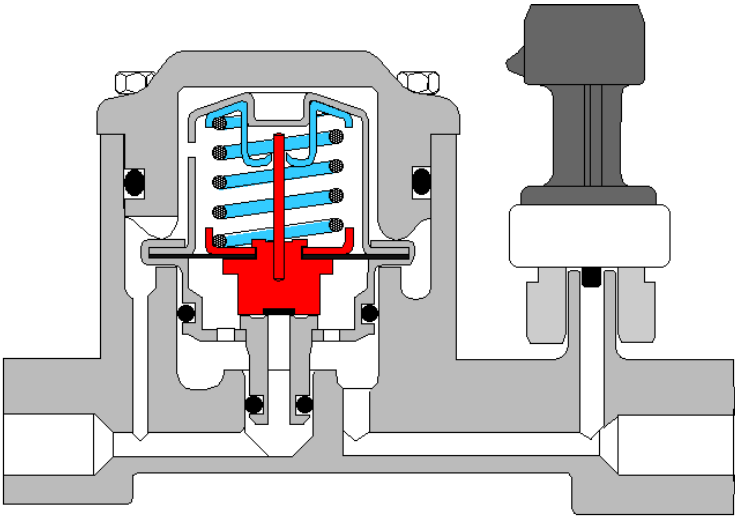
1. Valve coil
2. Plunger

The pressure transmitter

The pressure transmitter measures the absolute pressure of the LPG that has passed the injectors. The transmitter has a measuring range from 0 to 30 bar and it converts the pressure into a voltage between 0 and 5 Volt.

The transmitter has three connections: power supply, signal wire and mass. The 5 Volt power supply is controlled from the LPE.

The output voltage is measured as a differential. This is to say that the differential voltage is measured relative to the mass connection. The transmitter voltage is an



The injectors

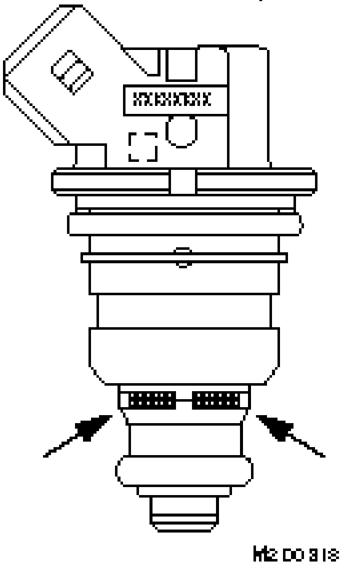
Bottom-feed injectors are used to inject the liquid LPG.

The advantage of this type of injector is that unlike top-feed injectors the heat of the injector coil does not cause the LPG to rise in temperature. In addition there remains hardly any LPG in the injector that cannot be circulated.

The injector coil has a resistance of 1.8ž.

A filter is placed before the gas input to prevent coarse assembly dirt from entering.

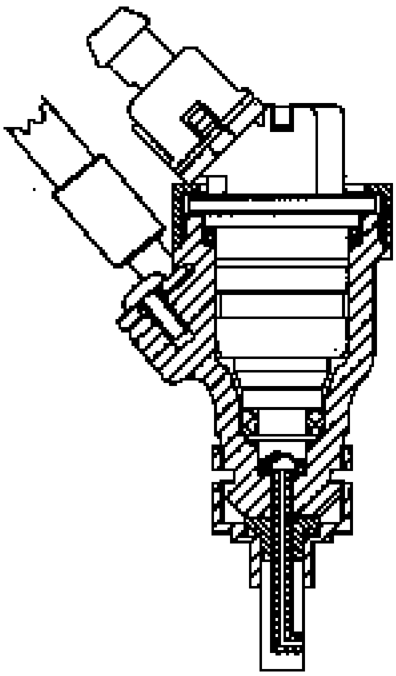
Several different types of injectors exist. Each injector has its own colour and code and therefore, its own production.



The injector holder

The injectors are always placed in a universal injector holder. Sealing is provided by O-rings. The injector is kept in place by a screwed ring. The injector holders are made of synthetic material to prevent heating through the manifold. The LPG is fed through synthetic lines, kept in place by a clamping plate.

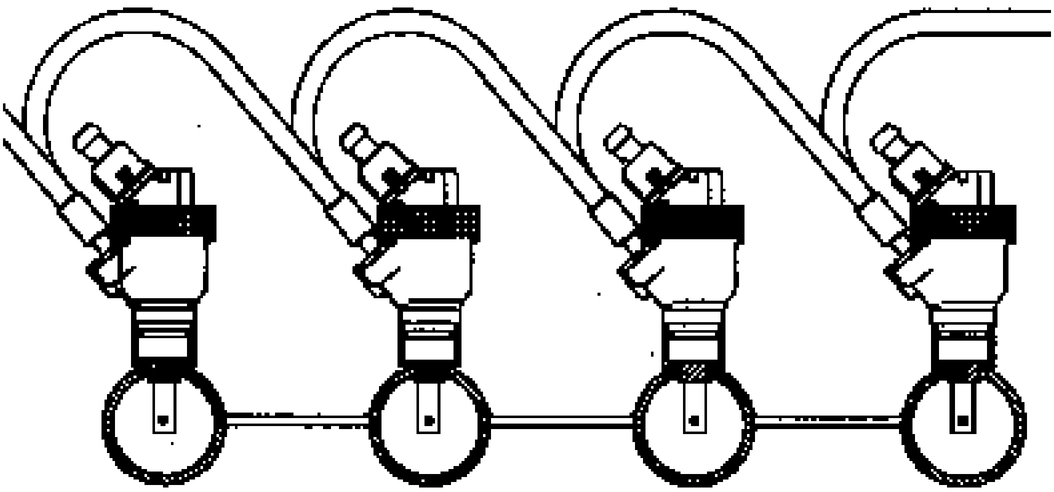
Dependent on the location on the manifold the gas is guided through discharge pipes. These discharge pipes can be constructed in various ways.



1. Connector
2. Injector
3. Screwed ring
4. O-ring
5. LPG feed
6. Injector holder
7. O-ring
8. Adaptor for manifold mounting
9. Discharge pipe

Placing the injectors on the engine

There are various possibilities for placing the injector holders on the engine. The choice depends on the
available space and the shape of the inlet manifold.

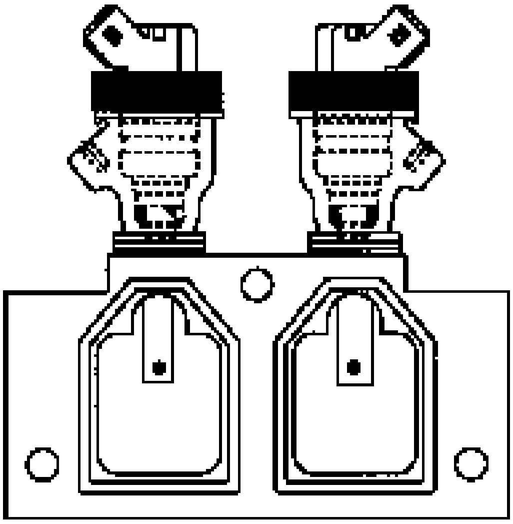


The loose adapters

In most cars, the available space is limited. In this case we make use of loose adapters.. First we drill holes in the manifold with the aid of a special template. After the manifold has been drilled , the special aluminium adapters are mounted using a blind rivet gun.

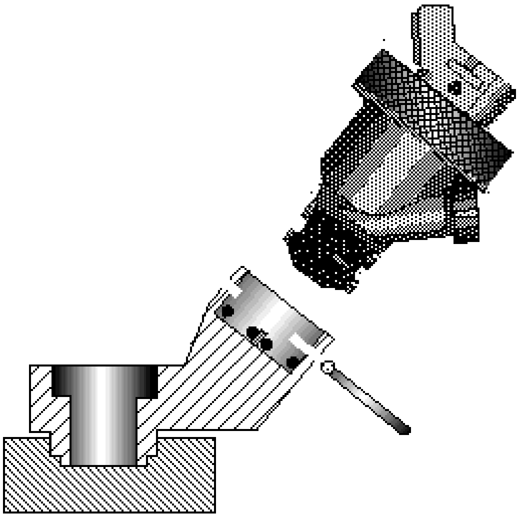
The intermediate sheet

In some cars it is possible to shift the intake manifold by 2.5cm. In these cars, the intermediate plate is an option. The injectors are mounted in the intermediate sheet, after which the plate is mounted between the engine and the intake manifold.



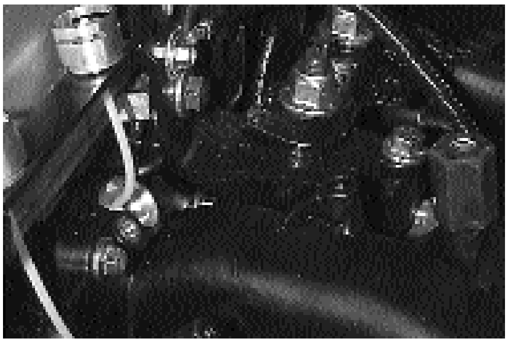
The intermediate adapter

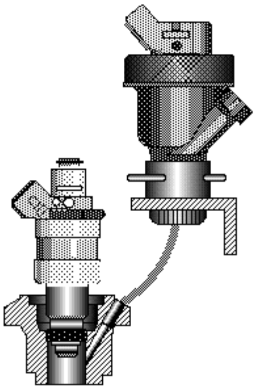
When there is sufficient space available, we can make use of an intermediate adapter. In this event, an adapter is mounted at the location of the petrol injector. This injector is then replaced in the adapter, as well as the LPG injector. In principle, with this method there is no need to adapt the manifold. The injector discharge pipe is integrated in the adapter.



Placing the LPG injector, removed from its holder

Another possibility is to mount an adapter with a discharge passage located under the petrol injector. The LPG injector is then placed at a distance from this adapter. The connection between the adapter and injector is made by a flexible line. This has arisen as a solution to the problem of insufficient space for the placement of the LPG injector.



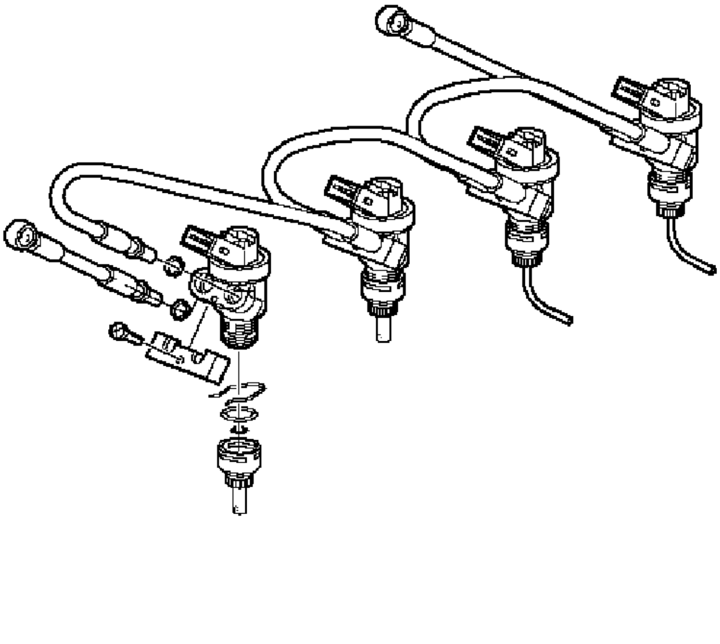


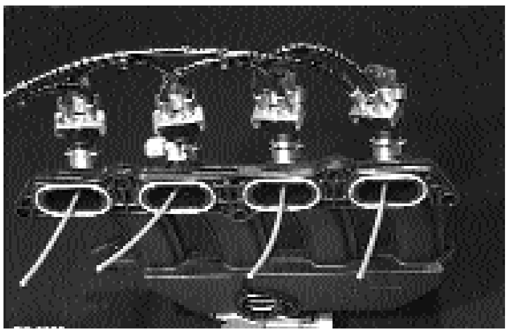
Injector discharge angle

The aim is to achieve injection at, or as close as possible to, the inlet valve(s). Because the LPG injector can sometimes only be placed further from the inlet valve, there is the risk that the LPG will be injected against the manifold wall. This leads to a danger of freezing when the liquid LPG evaporates, which again influences driveability. To avoid this problem, a possible solution is a holder with a discharge hose (see fig. 29).

Because LPG extracts heat from the surroundings directly at the discharge of the liquid LPG, freezing phenomena can also occur here (freezing after condensation of the water vapour). This risk is greater in cars with synthetic manifolds because in this case, the manifold does not heat up as much and therefore gives off less heat to the surroundings of the injected LPG.

In order to prevent the problem of freezing at the outlet of the discharge pipe, we can employ a discharge pipe with an interior that is non heat-conducting. The effect of this is that practically no heat can be extracted from the discharge outlet and therefore, the liquid LPG only evaporates when close to the heat source.





The Electrical System - Introduction

Starting point for the LPi system is making optimal use of the available electronics of the engine management system.

In fact the petrol control unit determines how much LPG is injected. The petrol control unit will keep determining the petrol injector time, also when LPG is used as fuel. This injector on-time is converted into an on-time for the LPG injector.

The petrol control unit has already made a large number of calculations to obtain an optimal mixture. The air quantity is measured, the temperature of that air, the engine temperature, the load, etc. Therefore the LPE does not have to do that any more.

The calculated LPG injection time is then corrected with a number of parameters, including the LPG pressure, battery voltage.

The LPE not only controls the injector power module, but also the valves, the fuel pump, the fuel quantity meter and the switch. In some cases the LPE manipulates the engine temperature data. Besides the LPE is provided with a diagnoses outlet.

Lpe input output schematic

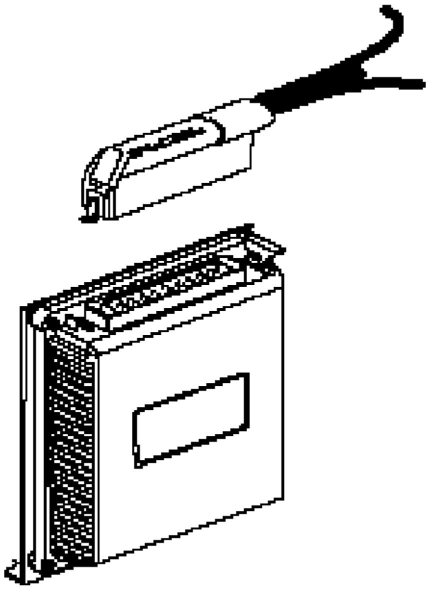
The LPE unit

The LPE unit is the electronic control unit of the system. This unit consists of the following components:

- A motherboard on which the universal electronic systems are placed.
- A module board with the more specific electronics, e.g. for a deviating l-probe.

The LPE is always provided with the basic software, which is complemented with the brand/model-specific engine data.

The unit has a splash proof 35-pin connector which allows mounting under the hood. In some cases a separate power module is used for control of the injectors. This power module is mounted in a similar housing.



The injector characteristic

The main task of the LPE is to calculate the LPG injection time and to control the injectors or the power module (when there is an external power module)

The injector control is earth-switching. The negative side of the injector is connected to the earth.

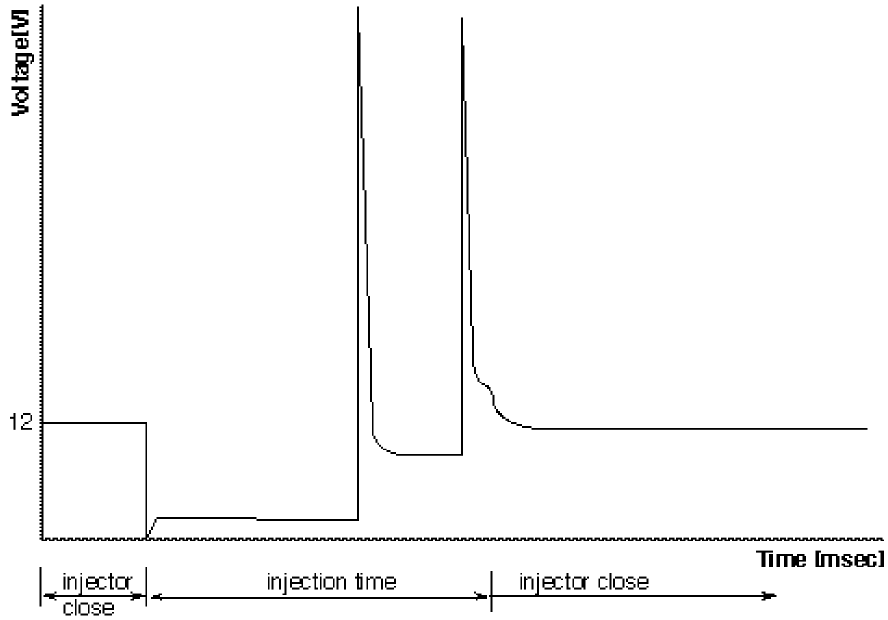
Opening the injector against the high system pressure (bottom-feed injector) requires a considerable current. Because we have a constant supply voltage, a high opening current can be achieved by using a low-impedance injector.

Injector impedance formula

This current is sufficiently high to open the injector against the system pressure and the spring tension. After these forces have been overcome, however, a hold current of +/- 1.5A is all that is required to keep the injector open. If we did not reduce the current after the injector is open, the coil would overheat and burn through. To produce this lower hold current, we employ the following 2 methods:

- Control strategy up to and including LPE 4

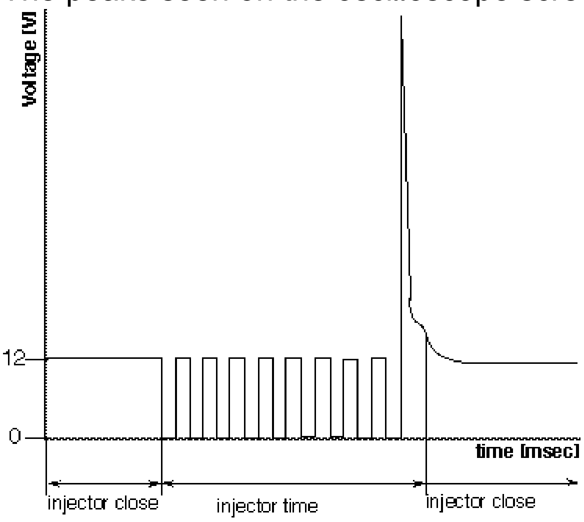
When the injector has been opened with a current of +/- 7A, a series resistor will be connected to reduce the hold current to the required +/- 1.5 A. The hold current remains at this value until the injector is closed.(fig.32)



- Control strategy beyond LPE 5

. From LPE 5 and higher, the principle of switching the current off and then on after the injector has opened is used. This enables the regulation of the current. The advantage of this method is that less heat dissipation occurs at the driver.(fig.34).

The peaks seen on the oscilloscope screen are caused by the induction of the injector coil.



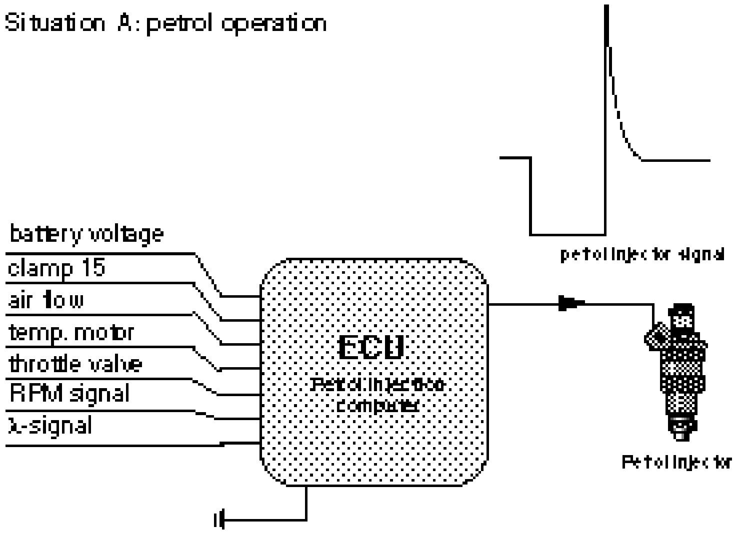
Injector signal processing

The petrol control unit determines the on-time of the petrol injectors after calculating a large number of variables. This injector signal is an ideal basis for the calculation of the LPG injector on-time.

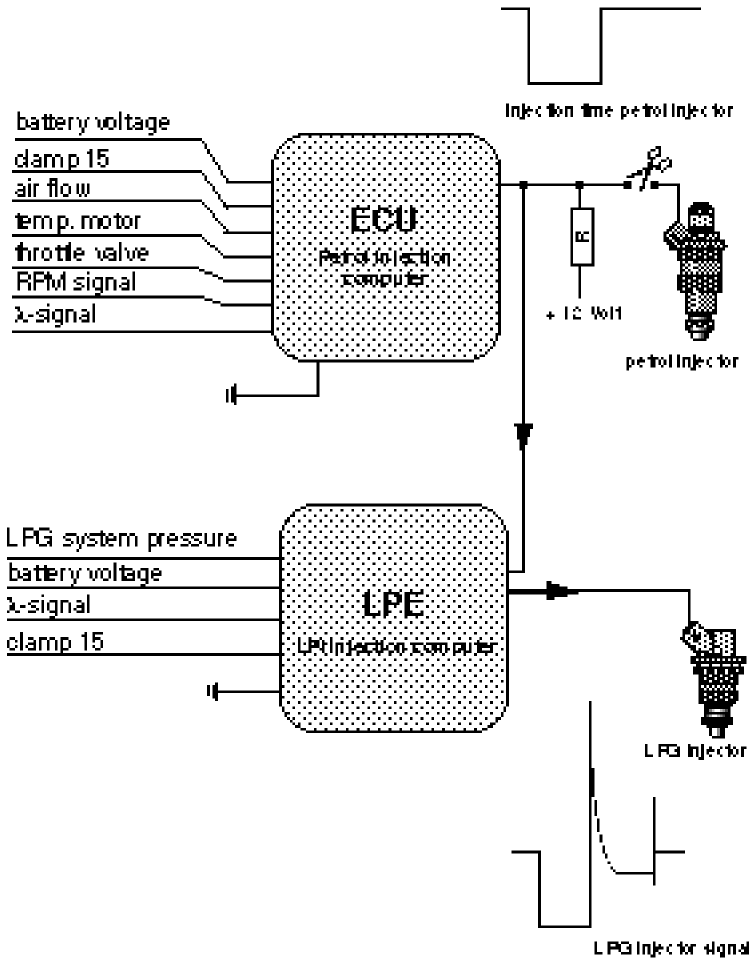
The injector signal is tapped from the interrupted control wire on the petrol computer side. Because during LPG operation a resistance is connected to it instead of an injector (coil), there is no induction peak.

The incoming signal is converted by the LPE into an injector on-time for the LPG injectors.

Situation A: petrol operation



Situation B: LPG operation



Beyond the LPE4 there is a possibility to connect a wire with the engine temperature sensor (coolant). This option is being used to manipulate the temperature during the warm up phase. In this case the petrol ECU calculates a shorter petrol injection time. This way we are given the opportunity to switch to LPG faster after a cold start.

The engine-running safety

The LPi system does not apply a specific engine-running safety as such. That would require taking up the RPM signal of the BDP transmitter or the ignition as a sign that the engine is running.

The petrol system is already provided with an engine-running safety, and this is also used for the LPi system.
This original safety is used on either the injector supply or the petrol pump supply.

By using the power supply in question for the LPE as well as for the drivers, the engine-running safety is also active for the LPi system.

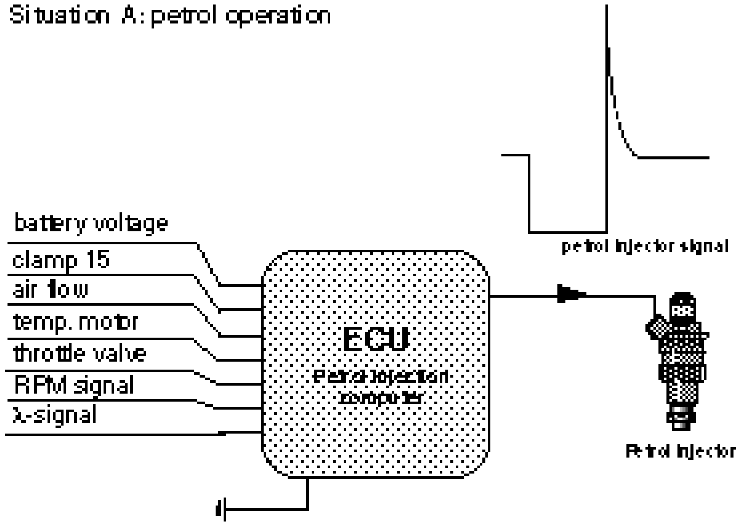
Injector signal processing LPE 5

Injector signal processing with a serial simulation resistance.

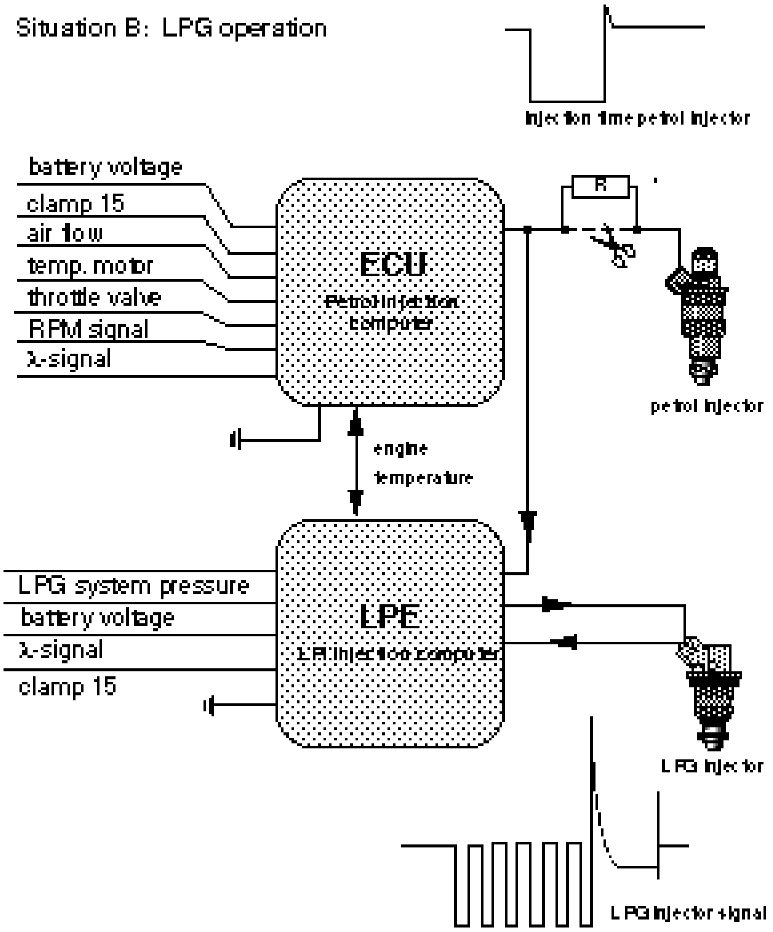
The injector signal is tapped from interrupted control wire on the same principle like we used before.
Normally we'll use serial placed simulation resistance's in combination with the LPE 5. This new principle is used to avoid injector faults on the moment that the relays are switching. The petrol injection system is charged on the normal way like when it's running on petrol.

The incoming signal is converted in the LPE 5 into a LPG-injector signal with the strategy like we can see on page 21.

Situation A: petrol operation



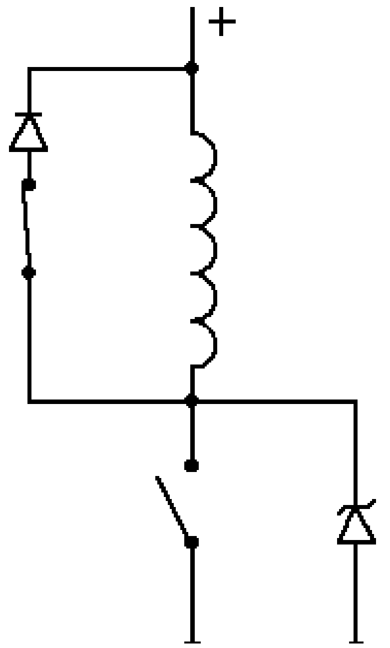
Situation B: LPG operation



In the next figure we see a feed-back wire from the LPG-injector supply to the LPE pin 14. The LPE 5 has an integrated power-module which is sending out a hold current by switching the current on and off. At every switch-off, a peak voltage is generated. The energy from these peaks may be an interference source for the other electric circuits in the LPE. To avoid these problems an idling circuit is placed over the LPG-injector coil. With this circuit we:

- Extinguish the peak;
- Recycle the peak energy.

Recycling the peak energy is shown in fig. 37. When the LPG-injector signal is being switched off, S1 is opened. The current will no longer flow from battery to the LPE. But it will flow, after it has passed the LPG-injector, through the idling circuit (S2 is closed when S1 is opened) and back to the battery.



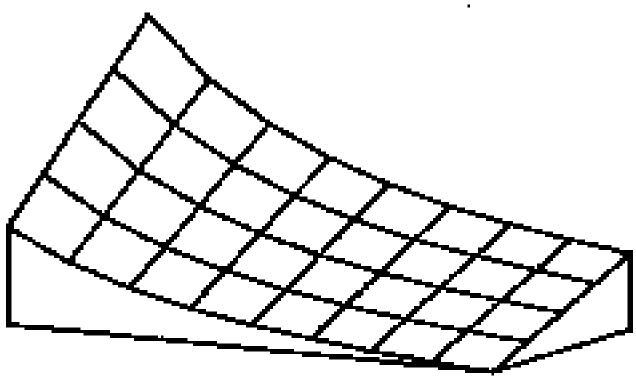
Because the voltage of the peak is higher than the voltage of the battery, the LPG-injector will remain open. Even as the LPE does not activate the injector anymore. Before the LPG-injector closes mechanically the LPE has closed S1 so

The injector off-set

The opening and shutting of the injector is a mechanical reaction to an electric signal. The injection needle has a certain mass inertia through which a reaction time is necessary to lift and close the needle.

On opening as well as shutting, the needle lags on the electric control. This lagging can be divided into response lag and close lag, which together determine the difference between activation time and injection time.

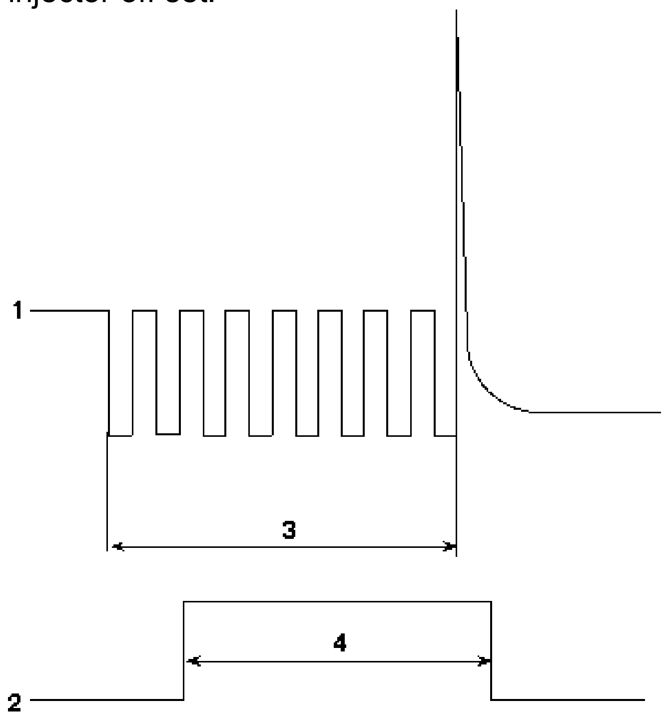
The difference between electrical activation time and mechanical injection time is called injector off set.
For the exact dose of fuel, the off set needs to be known.



The response lag depends on both the battery voltage and the fuel pressure. In figure 39 the off set depending on the battery voltage and pressure is shown.

The close lag only depends on the spring pressure behind the injector needle and therefore it doesn't change. On calculating the injection time, the LPE takes variable signals, such as battery voltage and LPG pressure into account.

When the battery voltage is lower, the response lag is higher, and so the injector production is lower. This means the electrical activating time must be extended to get the same output. Furthermore, a higher LPG pressure, for example, leads to a higher LPG output and therefore, the activating time may be shorter. But the higher pressure increases the response time which leads to lower output, which in turn leads to a longer activating time. Figure 39 shows the injector off set.



1	Electrical pulse (LPE 5)
2	Injector response
3	Pulse time
4	Mechanical injection

The fuel selector switch

The fuel selector switch is a touch control that has already been used for quite some time in the AMS LPG system. The fuel selection is indicated by a two-colour LED; red is petrol, green means LPG.

Ams style fuel selector switch schematic

After starting on petrol the LED blinks green-off, while waiting for the switching moment. The same happens when switching from petrol to LPG while driving. In this stage the engine always runs on petrol.

The LED is connected between the green and brown wire of the switch. The touch control contact is made by connecting the white and the yellow wire.

The switch with tank read-out

Beyond LPE 4 the wiring loom makes it possible to make use of the switch with tank read-out. The advantages of this new switch with tank read-out are:

- One less breaker needs to be installed: the breaker in the wire of the petrol level gauge.
- The petrol level can be read, even when the car is in LPG operation.
- The problem of reading from the original gauge no longer exists, even when a heavily damped petrol gauge is fitted.

The injector shut-off unit

The petrol injectors are shut off when driving on LPG.
The shut-off unit consists of two relays that are earth-controlled in the LPE. The other side of the coil receives a constant 12 Volt supply.

When the injectors are shut off, a compensating resistance or replacement coil is connected to the petrol computer. This compensating signal is necessary to prevent a disruption of, or an error diagnosis in the petrol system. In later generations of breaker relays, the compensating resistors are positioned such that when in LPG operation, they are fed by the original injector power supply. This is to prevent certain problems when switching over (see technical specifications). In case of a four cylinder engine, a 4-group relay is employed. For 6 cylinder engines, a 6-group relay is employed

Petrol start and switching time from petrol to LPG

All LPi cars start on petrol. After starting, the engine will run on petrol for some time prior to switching to LPG.

Starting point of the LPi system is the conversion of the petrol injection time to an LPG injection time. The result is that injection takes place according to all values calculated by the original petrol computer, modified for the LPG fuel.

This strategy applies to all operating conditions, including the cold start. When the petrol computer during idling applies mixture enrichment, this enrichment mainly depends on the temperature.

The main arguments for enrichment are the increased friction resistance and fuel deposition on the cold cylinder wall and the valves. The latter argument does not apply for LPG, because the low boiling point ensures effective evaporation, even at low temperatures. Therefore, the injected LPG quantity is too high, which may cause the engine to stall. Consequently, the switching moment has been made depend on three factors:

- The LPE surroundings temperature
- The engine temperature
- The signal from the l sensor

The LPE surroundings temperature

Beyond software version 205908 the outside air temperature (at the LPE) is measured. This is done with a NTC resistance inside the LPE.

This extra parameter provides, in combination with the engine temperature and the I signal, a better determination of the engine temperature,
The engine temperature

Cold engine:

If the engine has been stopped for more than 3 hours, the switching moment only depends on the outside temperature (LPE) and the delivered signal of the I sensor. The switching time for a cold engine is longer than for a warm engine.

Example outside temperature	-20 >	time	240	seconds
	0 >	time	120	seconds
	20 >	time	60	seconds
	40 >	time	10	seconds

Warm engine:

If the engine has been stopped for less than half an hour, the engine has fixed switching time. This time is programmed for each application (±5 seconds, not affected by the I-sensor signal)

Partially warmed up engine:

If the engine is partially warmed up, the switching time is variable between 5 seconds and the cold engine switching time and is influenced by:

- Outside- and/or engine temperature
- Temperature of the I-sensor
- Runtime of the engine in the last drive cycle
- Elapsed time since the engine is stopped
- Loan during last drive cycle (e.g. idle in stead of 120 km/h)

The I-sensor signal

The I-sensor signal provides information on the mixture control under static conditions. When the signal is changing, it can be assumed that mixture control takes place in closed-loop. This means that no mixture enrichment takes place under static conditions. Under those circumstances it is possible to switch to LPG.

When the I-sensor signal is of influence (cold start and partial warmed engine), the LPE checks if the I-sensor is regulating. When the LPE has detected 5 cycles, it satisfies the requirement concerning the item I-sensor temperature. When all requirements are met, the LPE switches to LPG. When no I-sensor signal is detected the LPE will switch after 3 to 5 minutes.

Fuel pump motor control

The power for the pump motor is supplied from the battery as direct current and is delivered to the fittings cover containing the pump electronics via a 5-pole relay. The direct current is transformed to alternating current in the fittings cover, and is then supplied to the pump motor via a 3-pole lead-through in the fittings casing. The anti-interference capacitor is integrated in the pump electronics. Five rpm's are available: 500, 1000, 1500, 2000 and 2800 rpm.

The LPE sends a variable duty cycle to the pump electronics, dependent on the motor load (injector activating time). The pump electronics then convert this into an electric field with a different frequency (dependent on the motor load). This causes the pump rpm to be higher or lower. The power supply is protected by a 15A fuse. The mass, which is only present due to the pump electronics, runs from the fittings sheet via the wiring loom to the mass intersection LPE - engine block mass in the engine compartment.

Pump motor control strategy

The pump motor only rotates when LPG is the selected fuel. Therefore, the motor is activated even when the engine is still running on petrol after the car has been started up and LPG operation is selected. When the ignition is switched on, the pump rotates for +/- 1 second at a higher rpm (than is programmed in the LPE) of 2000 rpm. This occurs in reaction to the detection of the engine-running signal (petrol pump control) on ignition.
The possibility of controlling at 5 different rpm's will not always be used. This depends on the LPG output. The rpm is determined in the LPE by comparing the injector activating time and the engine rpm (duty cycle). The acceleration is therefore load-dependent. If the control wire is loose, the electronics sends the pump to its default value: in most cases 2000 rpm.

Control of the LPG shut-off valves

The LPG shut-off valves of the tank and the coupling block are controlled simultaneously.

When LPG has been selected as fuel the LPG will power the shut-off valves, even when the engine is still running on petrol.

The shut-off valves no longer carry a voltage when the engine safety is activated (no ignition signal).