VOL. 11, NO. 14, JULY 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

CONVERSION OF A GASOLINE ENGINE INTO AN LPG-FUELLED ENGINE

Norrizal Mustaffa [1], Mohd Mustaqim Tukiman[1], Mas Fawzi [2] and Shahrul Azmir Osman [2]
[1]Faculty of Engineering Technology, [a]Automotive Research Group, Center for Energy and Industrial Environment Studies, Malaysia
[2]Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia, Parit Raja, Batu Pahat, Johor, Malaysia
E-Mail: norrizal@uthm.edu.my

ABSTRACT

This paper presents the conversion methodology of a spark ignition (SI) engine to operate on liquefied petroleum gas (LPG) as an alternative fuel. Minor modifications were carried out to enable the conversion and the system was controlled by a dedicated LPG electronic control unit (ECU) through input signal from the original engine ECU. Existing system remains unchanged and the selection mode of the fuel was easily switched by a selection button.

Keywords: liquefied petroleum gas, spark ignition engine.

INTRODUCTION

In recent years, skyrocketing liquid fuel price and stringent emissions regulation have increased more interest in alternative fuels for the automotive industry. Liquified petroleum gas (LPG) is one of the gaseous alternative fuel suited for SI engine that is receiving attention nowadays.

LPG is a mixture gas that composes mainly of propane (C_3H_8) and butane (C_4H_{10}). The advantages of LPG include higher octane number compared to traditional fuels, low carbon to hydrogen ratio, does not contain aromatic hydrocarbons, lower cost for development of LPG infrastructure, abundantly available, good knocking resistance, better fuel consumption, better cold start performance, prolong engine life and lower toxic emissions production (Masi, 2012), (Sulaiman *et al*., 2013), (Gumus, 2011).

In view of Malaysian automotive industry, LPG as an alternative fuel is parallel to the National Automotive Policy (NAP 2014) with the objective to develop Malaysia as the regional automotive hub in energy efficient vehicle (EEV). NAP 2014 vision is to transform the competitiveness of the Malaysia automotive industry to face the global challenges (Malaysia Automotive Institute, 2014). This is also in line with the current Malaysian National Green Technology Policy target to reduce 40% of CO_2 equivalent emission by year 2020 (KeTTHA, 2009).

The use of LPG in SI engine conducted by Myung (Myung *et al*., 2012) using 2359 cc SI 4 inline engine showed reduction in fuel consumption, carbon dioxide (CO_2), carbon monoxide (CO) and hydrocarbon (HC) but slight increase in nitrogen oxide (NO_x). However, a study carried out by Mustafa and Briggs, (Mustaffa and Briggs, 2009) showed a reduction of NO_x while using LPG and the other results are in agreement with Myung *et al*., (2012).

The conversion of SI engine into LPG system depends on the fuel delivery system either using carburettor or injection systems. Different types of fuel supply require different LPG system and the conversion methodology subjected to space constraint and availability. In this project, the LPG conversion kit was designed to allow the installation on the test vehicle without any major modification. After installation, the vehicle is able to switch between two fuel system operation either petrol of LPG fuel.

ENGINE CONVERSION METHOD

Spark ignition (SI) engine

In this project, 1600 cc naturally aspirated spark ignition engine of a Proton Gen-2 was used. The detailed specifications of the test engine are as per shown in Table-1.

Table-1. Proton Gen 2 engine specifications.

Engine model	S4PH – 1.6
Number of cylinders	4
Orientation	East-West
Valve train	DOHC 16V
Combustion chamber	Pentroof type
Bore x stroke	76.0mm x 88.0mm
Compression ratio	10.0 : 1
Fuel injection	Indirect injection
Lubrication system	Pressure feed, full-flow filtration
Cooling system	Water-cooled
Maximum torque	148Nm (4000rpm)
Maximum power	110hp (6000rpm)

LPG conversion kit component

All the components used in this conversion were very crucial and must comply all the safety specifications. The fuel tank used in this project is a toroidal tank from Tugra Makina with maximum capacity of 34 liter and maximum pressure of 33 bar. The tank met the requirement of MS 642:1982.

The fuel line must meet standard of MS ISO 8789:2005 with the 25 bar maximum pressure and able to operate in the temperature range of -40°C up to 100°C.

VOL. 11, NO. 14, JULY 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

The LPG injectors are controlled by electric current through solenoid and are used to inject LPG into the intake manifold. The size of injector depends on the engine capacity and each cylinder has a dedicated injector. The solenoid valve is a shut off valve that enables the LPG flow to the injector. This component is also controlled by electric current and will be activated when the LPG system is in operation.

The LPG fuel pump is a diaphragm pump that circulates the LPG in the fuel line system. The pump must be able to give a maximum pressure of 6 bar. A pressure sensor manufactured by Keller is used to measure the injection pressure and it regulates automatically the pressure in LPG fuel line with the pressure given by the fuel pump.

This LPG system is operated by a custom ECU that integrates with the petrol ECU. This ECU receives signals from lambda sensor, pressure sensor, temperature sensor, ignition coil and petrol injectors, then calculates the right injection quantity and timing of the LPG.

Installation of the LPG kit

The installation of LPG kit was conducted with a proper and careful engineering work that follows the MS 775:2005. The installation diagram is shown in Figure-1.

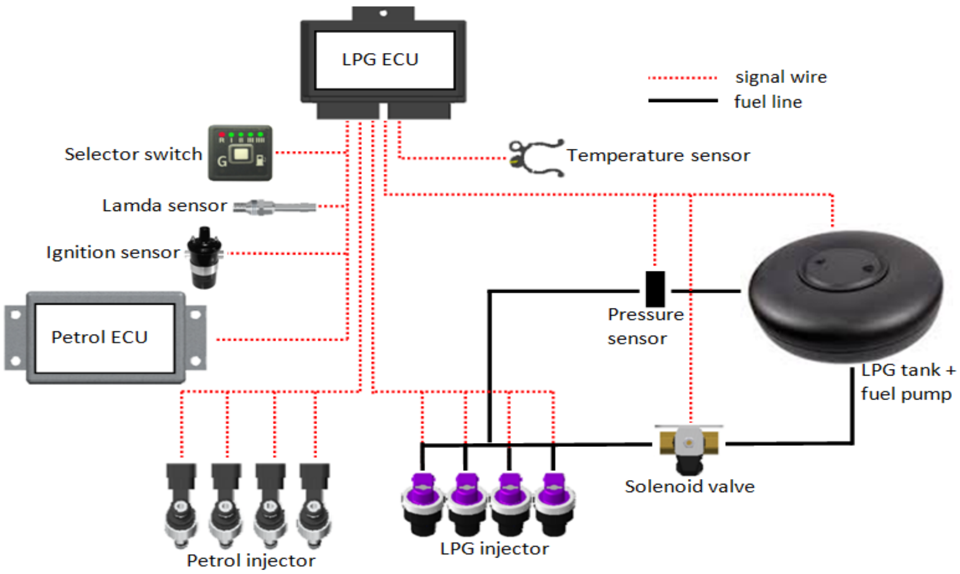

Figure-1. Installation diagram of LPG conversion kit.

A toroidal tank type dedicated for LPG fuel tank is also known as doughnut tank. The dimension of the tank selected for this vehicle was 550 mm diameter, 200 mm height and it is within the spare tire space of the test vehicle as shown in Figure-2. The modifications required for installation is minimal. Rubber mat was placed between the spare tire and tank surface to avoid chassis damage and to reduce vibration. To complete the fuel tank installation, a ventilation hose was installed at the center of the fuel tank. A 48 mm hole was drilled at the bottom center of the spare tire for ventilation purpose and as a passage for the LPG fuel supply and return lines. In case of any leakage at the fuel tank area, LPG will flow out through this ventilation hose. Since the LPG is heavier than air, it will accumulate at the bottom (Krishnan, Kulkarni, & Mohite, 2005), (Raslavičius *et al*., 2014), (Saraf *et al*., 2008).

Figure-2. Toroidal tank.

A multivalve as shown in Figure-3 was installed inside the fuel tank comprising a fuel pump, a pressure sensor, a level indicator and a solenoid. The fuel pump used was a submerged and dual stage turbine pump type. Its maximum flow rate is over 120 liter per hour. During its operation, LPG will be pumped in its liquid form and the fuel pump will be cooled using the liquid LPG itself.

The pressure sensor acts as a safety feature which automatically cuts off the LPG supply and allows the engine to run in petrol mode. The pressure sensor measures the injection pressure of the LPG whereby it was the combination of the tank pressure and pump pressure. The level sensor installed inside the tank used floating arm sensor type to indicate the level of LPG inside the fuel tank.

The fuel line is a pathway to transport liquid LPG in the system. The fuel line was made of a special thermoplastic compound and acts as an insulator to prevent the heating of the fuel during operation and changes in environmental temperature. It was installed and secured from the fuel tank to the injectors for both supply and return lines. A safe distance from exhaust pipe was duly considered. Figure-4 shows the fuel lines installed under the test vehicle.

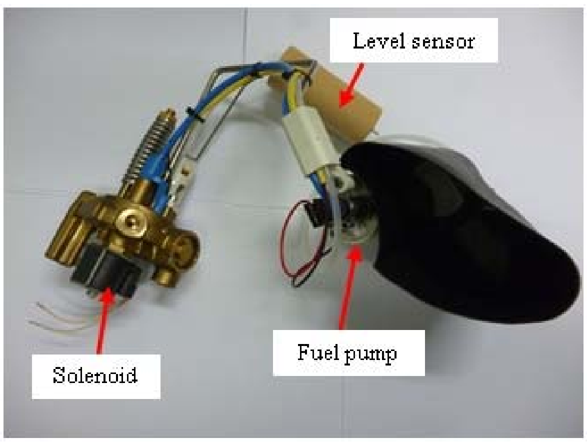

Figure-3. Multivalve.

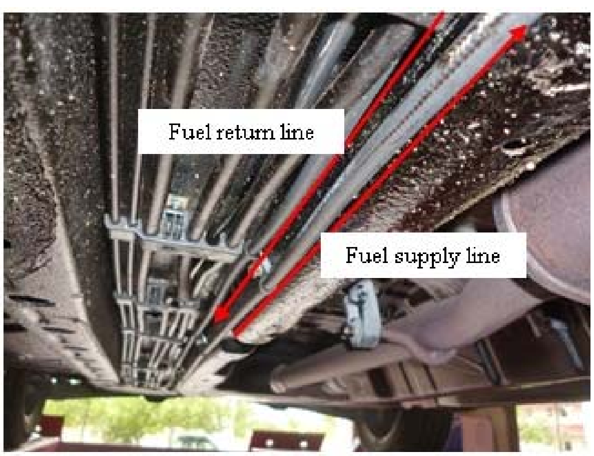

Figure-4. Installed fuel lines under the test vehicle.

In this system, two solenoids were installed at two different locations, first after the fuel pump and the second before the injectors. The first fuel pump solenoid was fixed at the multivalve as per Figure-3. The second solenoid was placed in the front boot as shown in Figure-5 and was operated from the command from ECU. Fuel out from this solenoid was connected to the injectors.

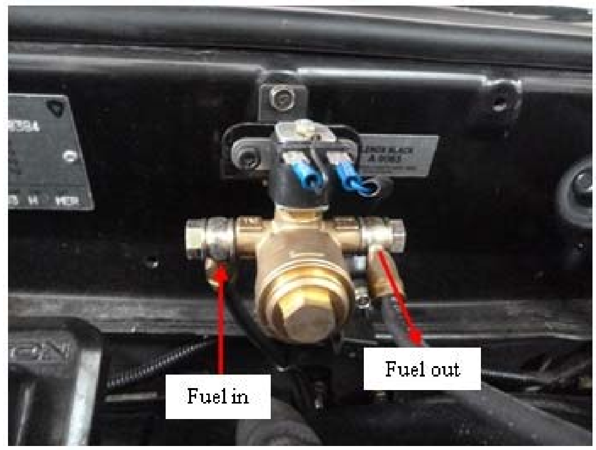

Figure-5. Solenoid valve.

The injector module consists of injector assembly and nozzle set as shown in Figure-6. The injector module was installed in the intake manifold in close proximity of the intake valve. In this installation, M10x1 thread was drilled at the intake manifold in order to locate the nozzle set. A steel bracket was used as a holder for all the injector assemblies. Each engine cylinder of the test vehicle has its own injector module and each injector module has a fuel in and a fuel out port where LPG in its liquid form will circulate within the fuel lines. Figure-7 shows a photo of the installed injector module in the test vehicle.

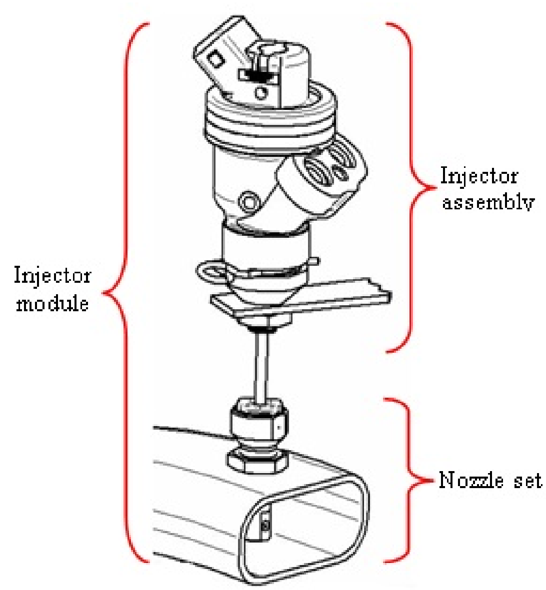

Figure-6. Injector module.

VOL. 11, NO. 14, JULY 2016 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

Figure-7. Installed injector module.

In order to maintain near stoichiometric condition during combustion of LPG, lambda signal and the engine speed signal were collected from the original lambda sensor and ignition coil of the petrol engine. Thus, there is no additional sensor installed for that purpose.

In this conversion, the LPG ECU was connected with the original engine ECU. LPG ECU receives injection signal from petrol ECU and manipulate the signal for the LPG injector module. The injection duration was adjusted based on the lambda sensor signal.

LPG wiring is an additional wiring kit and there is no modification performed on the petrol wiring. Complete wiring diagram of the LPG kit installation is shown in Figure-8.

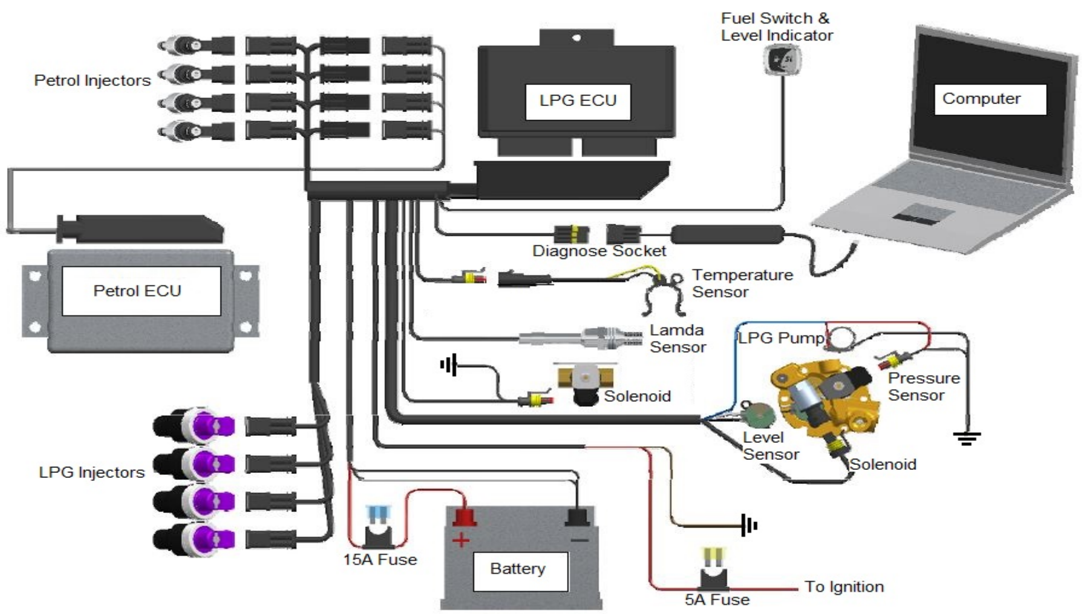

Figure-8. LPG wiring diagram.

LPG kit tuning

Activation of the system is required before the LPG mode is selected. The activation was done by connecting the LPG ECU to the dedicated software installed in a computer. Once the system was activated, the green lamp indicator on the selector switch as per Figure-9 turns on and the petrol indicator, orange lamp turns off.

The calibration and tuning process of the LPG system was also employed the same software. The LPG system was tuned by mapping the LPG ECU according to the petrol ECU and the signals from related sensors. All the sensors were thoroughly checked before performing the tuning.

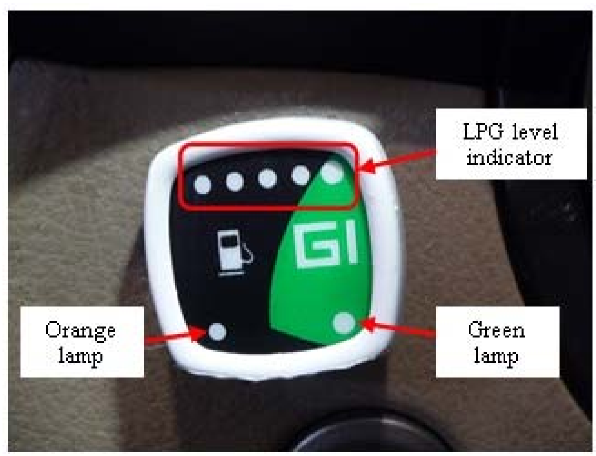

Figure-9. LPG selector switch.

LPG kit inspection

During the tuning process, all the LPG components installed were inspected, especially for any leakage. The most important inspection is at the joints and fittings of the fuel line. The inspection was performed visually and tested using Refco leak detector spray and gas leak detector.

COMISSIONING AND TESTING

This project is a work in progress. Next, converted engine will be tested for performance using a chassis dynamometer and the emissions produced will be measured. The data collected will be analyzed and compared with the petrol fuel results.

All experiments are expected to be conducted in the near future at the Internal Combustion Laboratory, Faculty of Mechanical and Manufacturing Engineering, Universiti Tun Hussein Onn Malaysia.

CONCLUSIONS

The installation of LPG conversion kit on the SI engine was successfully performed according to the MS 775:2005. This conversion required very minimal modification and upon completion, an inspection on leak tests is needed to carry out to make sure the installed kit is safe to use.

ACKNOWLEDGEMENTS

The authors would like to thank the Universiti Tun Hussein Onn Malaysia for supporting this research under the Short Term Grant VOT. U383.

REFERENCES

[1] Gumus, M. (2011). Effects of volumetric efficiency on the performance and emissions characteristics of a dual fueled (gasoline and LPG) spark ignition engine. Fuel Processing Technology, 92(10), 1862–1867.

[2] KeTTHA. (2009). The National Green Technology Policy.

[3] Krishnan, S., Kulkarni, D. S., & Mohite, J. P. (2005). Gasoline to Gas - Revolution. SAE Paper, 2005-26-033.

[4] Malaysia Automotive Institute. (2014). Malaysia Automotive Technology Roadmap Highlight.

[5] Masi, M. (2012). Experimental analysis on a spark ignition petrol engine fuelled with LPG (liquefied petroleum gas). Energy, 41(1), 252–260.

[6] Mustafa, K. F., & Gitano-Briggs, H. W. (2009). Liquefied Petroleum Gas (LPG) as an Alternative Fuel in Spark Ignition Engine : Performance and Emission Characteristics, Proceedings of ICEE 2009 3rd International Conference on Energy and Environment, 189–194.

[7] Myung, C.-L. *et al*.,. (2012). Comparative study of regulated and unregulated toxic emissions characteristics from a spark ignition direct injection light-duty vehicle fueled with gasoline and liquid phase LPG (liquefied petroleum gas). Energy, 44(1), pp.189–196.

[8] Raslavičius, L., Keršys, A., Mockus, S., Keršienė, N., & Starevičius, M. (2014). Liquefied petroleum gas (LPG) as a medium-term option in the transition to sustainable fuels and transport. Renewable and Sustainable Energy Reviews, 32, 513–525.

[9] Saraf, R. R., Thipse, S. S., & Saxena, P. K. (2008). Emission Analysis and Lambda Characterization of LPG Automotive Engines. SAE Paper, 2008-01-2753.

[10] Sulaiman, M. Y., Ayob, M. R., & Meran, I. (2013). Performance of Single Cylinder Spark Ignition Engine Fueled by LPG. Procedia Engineering, 53, 579–585.