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RESEARCH ARTICLE

An Investigation of Effect of Fuel Temperature on Engine Performance and NO Emissions in a Spark Ignition Engine Running on LPG

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HIGHLIGHTS

> Reducing the LPG temperature will cause a considerable decrease in NOx emissions.
> The engine output power is reduced by almost 1.85% with the increase in LPG gas temperature.

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ABSTRACT

LPG is the second most commonly used fuel in the world in spark-ignition engines after gasoline. It has a wider operating range than gasoline and less harmful exhaust emissions are produced. However, when LPG is used as fuel instead of gasoline, the engine output power reduces approximately 5-10%. This is because, LPG occupies 15-20% a larger volume (compared to gasoline) in intake manifold. Since this lowers the energy density of the fuel-air mixture, power output of the engine reduces in parallel to the reduction in the amount of energy drawn into the cylinder at each cycle. Another parameter that reduces energy density hence the volumetric efficiency is the increase of the charge temperature of fuel-air mixture. Increase in the temperature of mixture causes decrease in the energy density in intake manifold and thus causes reduction in engine performance. In this study, an experimental system has been established to investigate the effect of LPG fuel temperature on engine performance and exhaust emissions. Experiments carried out in high speed under high load shown that, with increase in the LPG fuel temperature at regulator outlet; engine output power reduced by nearly 1.85% while NO emission increased by 7%.

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1. Introduction

LPG is liquefied under pressure, and is stored in steel tanks under pressures ranging from 1.03 to 1.24 MPa. LPG is widely used in heating, cooking and as fuel. LPG is obtained from natural gas and by separation of light components of crude oil during refinery [1, 2]. LPG is an environmentally friendly fuel for spark ignition engines, potentially advantageous in terms of emissions compared to gasoline. Studies have shown that there are some advantages of LPG over gasoline. Among these are; (i) less exhaust emissions, (ii) reduced engine maintenance costs, (iii) faster adaptation to cold working conditions, (iv) offering lower operating costs. On the other hand, 5-10% reduction in engine power output occurs due to its 15-20% larger volume than gasoline [2, 3].

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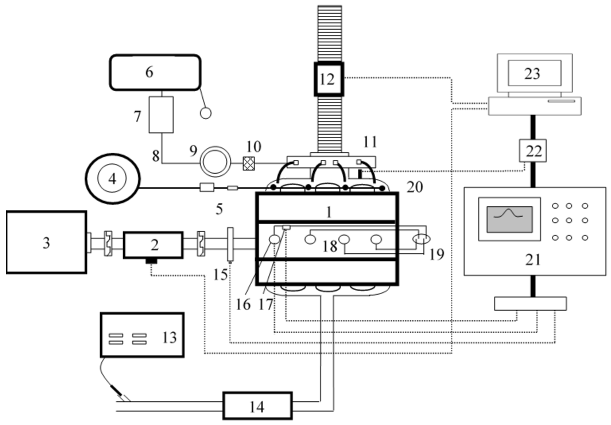
Many studies have been made over SI engines running on LPG. Some of these studies are as follows; in an SI engine equipped with sequential and multi-point gas injection system, at different LPG usage levels (25%, 50%, 75% and 100%), volumetric efficiency decreased significantly at 25% LPG usage level, and has been shown to reduce proportionally for 50%, 75% and 100% [4]. In a small-sized spark ignition engine running on LPG, engine power output is around 95% of that of gasoline [5]. When the performance of an evaporator assembled in LPG injection system in a spark ignition engine is analyzed; the performance has been observed to decrease by 4% with LPG compared to the same figure for pure gasoline [6]. Absorption air temperature decreases in case the thermal energy needed for the evaporation of LPG is obtained from the intake air, thereby engine output power increases approximately by 6% thanks to the increase in volumetric efficiency [7]. In a turbocharged SI engine running on natural gas and working under poor conditions, when intake manifold temperature is increased in parallel to that of air/fuel mixture; power capacity, shaft efficiency and NOx emissions remain at a constant level [8]. When quasi-dimensional cycle model has been used for the cycle estimation of SI engine, improvements in exhaust emissions has shown, but no significant improvement in engine performance could be saved [9]. In an SI engine with third generation LPG injection system conversion applied, experiments conducted in the permanent and non- permanent state conditions have shown that LPG temperature is a significant parameter effective on engine performance [10]. In LPG injection systems, LPG is sprayed into the intake manifold in gas phase. In these systems, fuel arrives to the pressure regulator after exiting the tank. The regulator enables fuel change phase from liquid to gas. The latent heat of vaporization needed to avoid descendance to extremely low temperatures is obtained from the engine coolant. After start-up, coolant temperature increases and its heat energy is transferred to LPG through regulator. However, when the coolant temperature exceeds a certain level an excess increase occurs in LPG temperature. Increased LPG temperature provides an increase in the temperature of the mixture entering the engine and thus the engine volumetric efficiency decreases. Another reason for the low power output of spark-ignition engines using LPG is this [11].

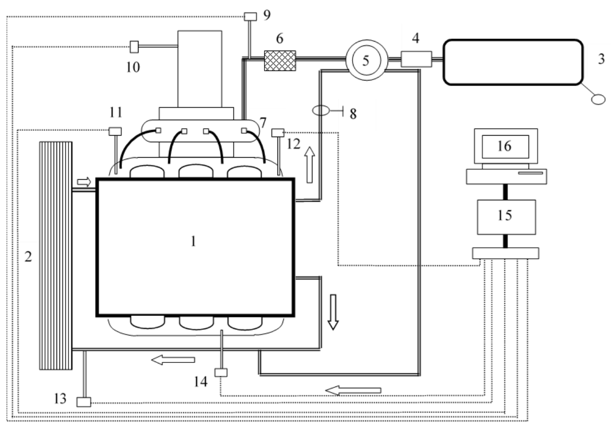
2. Material and Method

In this study, test rig was set up to investigate the effects LPG fuel temperature on engine performance and exhaust emissions. LPG temperature was changed by controlling the flow rate of engine coolant at the entrance of regulator by means of a valve. In our experiments, a 4-stroke, water-cooled, fuel injection, spark ignition engine, Ford MVH418, as mounted on the hydraulic brake (dynamometer) bench is used. A 3rd generation sequential injection LPG system was assembled to this engine. In Table 1 are the specifications of the engine used, Figure 1 is a schematic view of the test set-up with related equipments and Figure 2 is the connection diagram for the LPG ijection system.



1- Engine
2- Torque and speed sensor
3- Hydraulic dynamometer
4- Gasoline tank
5- Gasoline fuel line
6- LPG tank
7- Digital balance
8- LPG fuel line
9- LPG pressure regulator
10- LPG filter
11- LPG injectors
12- Air flow meter
13- Exhaust gas analyzer
14- Muffler
15- Crank angle encoder
16- Piezoelectric pressure transducer
17- Ignition timing clamp
18- Spark plugs
19- Distributor
20- Intake manifold air pressure sensor
21- Amplifier and oscilloscope
22- Data acquisition card
23- Computer

Figure 1. A schematic view of the test set-up



1- Engine
2- Coolant heat exchanger
3- LPG Tank
4- The fuel flow measurement device
5- Regulator
6- LPG Filter
7- LPG injectors
8- Regulator-valve engine coolant line
9- Regulators op- collector LPG at the entrance temperature ($T_{LPG-Regulator}$)
10- Intake manifold on the air inlet temperature (T_{air})
11- Manifold fuel-air mixture at the outlet temperature ($T_{Charge-manifold}$)
12- Valve fuel-air mixture at the entrance temperature ($T_{Charge-valve}$)
13- Cooling water temperature ($T_{Cooling\ Water}$)
14- The exhaust gas temperature ($T_{exhaust}$)
15- The data acquisition card
16- Computer

Figure 2 Detailed schematics for LPG flow line and engine coolant circuit

Table 1 Engine details

Engine type	Ford MVH418 4-stroke, water cooled, fuel injection, spark Ignited
Number of cylinders	4
Compression ratio	10:1
Diameter (mm)	80.6
Strok (mm)	88
Capacity (mm ^{3})	1796 x 10^3
maximum power	6250 rev / min . 93 kW
maximumtorque	4500 rev / min . At 157 Nm

Temperature of LPG at regulator outlet, charge temperatures of LPG-air mixtures at the point where it is sprayed into intake manifold and at the entrance to suction valve were measured using K-type thermo-couples. Measurments of the amount of air consumed by the engine in the experiments were carried out with Sierra 628S-BW2-EN2-V1 DDR-type device. Data measured with these devices were acquired through PCIe-6363 data acquisition card manufactured by National Instrument.

One way to learn about the engine performance is the analysis of engine exhaust gases. For this purpose a Bosch BEA 270 exhaust emission device was employed to determine emission figures. This device serves figures of CO, CO_2 and O_2 as percentages and those of HC and NO as ppm. Furthermore, the excess air coefficient can be obtained through this device.

In the experiments; an AVL GH13Z-31 pressure sensor, for monitoring the pressure-volume change in the engine, and an AVL 365C Encoder Set, for positioning in-cylinder pressure measurements in accordance with crankshaft angle and cylinder volume parameters, were employed. A Kistler 4503 torque sensor was also employed. a 25-ton tank was used for engine block coolant and hydraulic brake system.

3. Results and Discussion

In steady state experiments; variation of engine performance and exhaust emissions in different LPG temperatures was investigated. The valve we installed on the line through which the coolant flows to the regulator, piece number 8 in Figure 2, was used for changing the LPG temperature. The flow rate of coolant through regulator decreases as the valve throttled, thus the LPG temperature at regulator outlet decreases. In the opposite case, the temperature of LPG increases. At different engine speeds and loads, the flow rates of both coolant and LPG through regulator varies.

In order to observe the responses of the engine at different operating conditions, experiments were carried out with the steady state conditions given in Table 2, in different LPG temperatures. To ensure that only variable during the tests is the temperature of LPG; the engine is allowed to run at stable running conditions during which engine coolant temperature, ambient temperature and lambda figures did not vary in time before acquiring experimental data.

Table 2 Steady state test conditions

Experiment name	Speed (r/min)	Engine Torque (Nm)	Test conditions
Group 1 tests	2550	33	Low speed, low-load
Group 2 tests	2520	72	Low-speed, high load
Group 3 tests	4050	50	High-speed, low-load
Group 4 tests	3860	80	High speed, high load

According to the test results; When to valve installed on the line to regulator switched to fully open position from its throttled position; measurements for the temperature of LPG at regulator outlet, temperatures of fuel-air mixture at manifold output and at entrace of valve were made using K-type thermo-couples at points 9, 11, and 12 shown in Figure 2 respectively. The variation of these values with time are shown in Figure 3, Figure 4 and Figure 5.

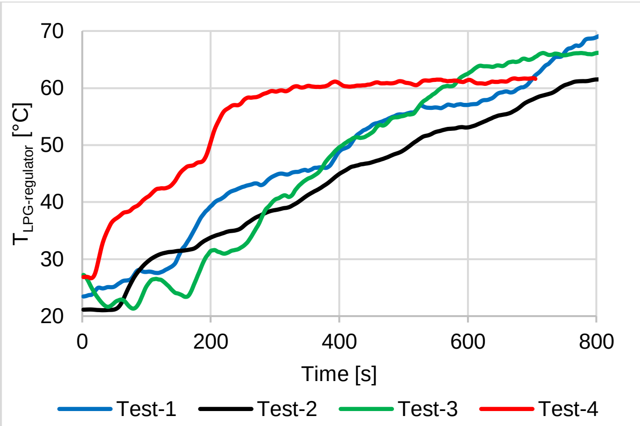


Figure 3. LPG temperature at regulator outlet ($T_{LPG-regulator}$)

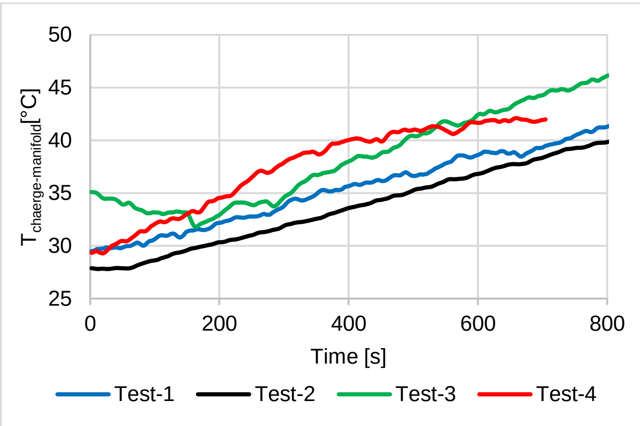


Figure 4. Temperature of fuel-air mixture at manifold output ($T_{charge-manifold}$)

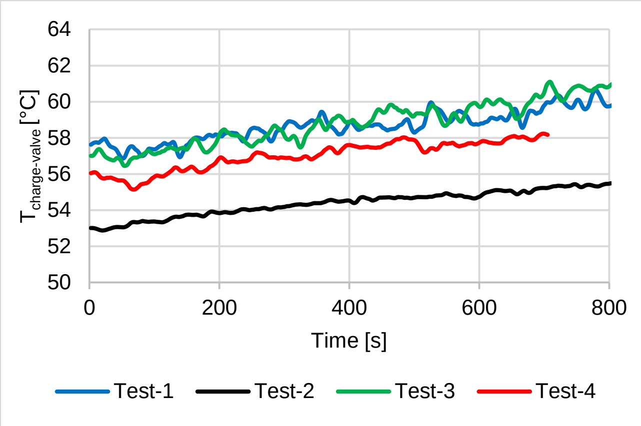


Figure 5. Temperature of fuel-air mixture at entrance of valve ($T_{charge-valve}$)

The amount of energy transferred to LPG needed for phase change is increased as the flow rate of engine coolant passing through the regulator increased, therefore the temperatures at points 9, 11 and 12 were increased respectively.

The variation of effective power with increasing LPG temperature at regulator output are shown in Figure 6, Figure 7, Figure 8, and Figure 9.

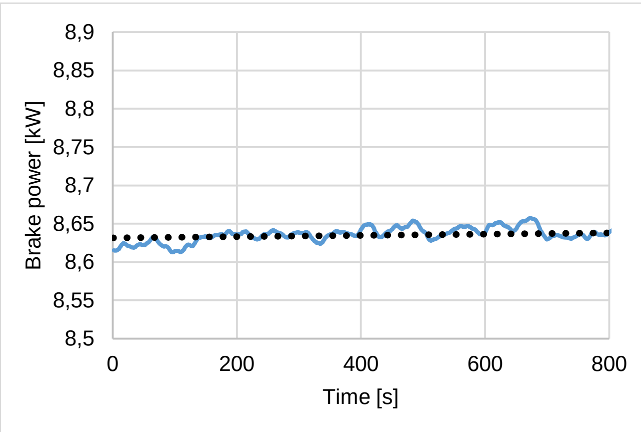


Figure 6. The variation of effective power with time for Test-1

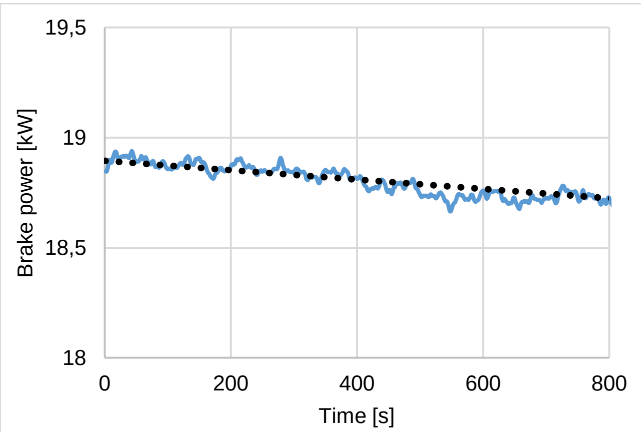


Figure 7. The variation of effective power with time for Test-2

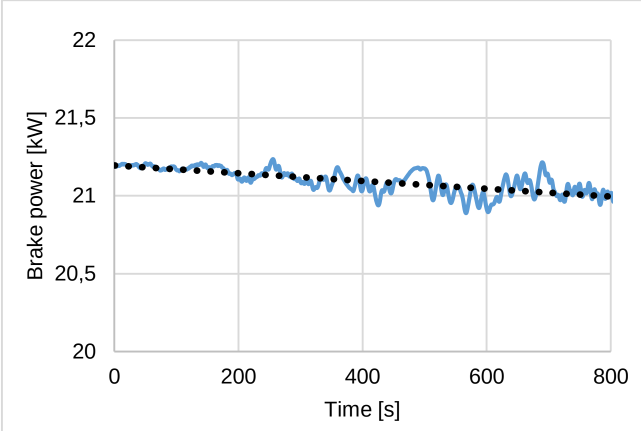


Figure 8. The variation of effective power with time for Test-3

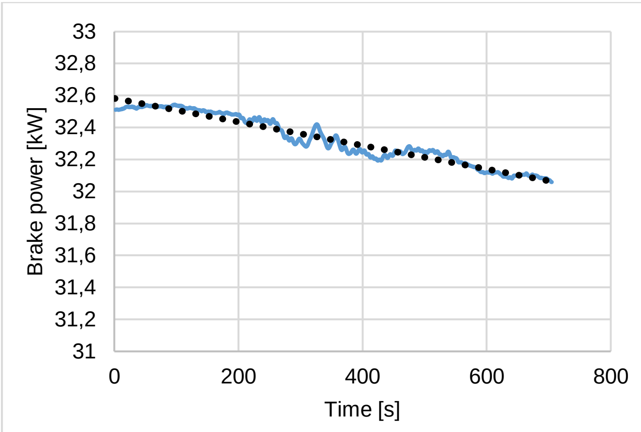


Figure 9. The variation of effective power with time for Test-4

In Figure 6, during the first group experiments, Although the temperature of LPG is increased, the temperature of air-fuel mixture was not affected much since LPG flow rate was at very low levels, and therefore no significant change in effective power could be observed. When Figure 7 is analyzed, increasing LPG temperature at regulator outlet led to a decrease especially in the effective power, which is this most important parameter analyzed in the scope of this study, and throughout the experiment; engine effective power has reduced by approximately 1.0% as the LPG temperature increased from about 20 °C to 65 °C. In Figure 8, engine effective power has reduced again by approximately 1.0% as the LPG temperature increased from about 20 °C to 68 °C. In Figure 9 around 1.85% reduction in engine effective power is observed as the LPG temperature increased from about 25 °C to 62 °C. Thus maximum power loss is shown to have occurred during high speed and high load experiments [12].

In Figure 10 and Figure 11, variation of NO emissions with time is shown for experiments 1, 2, 3 and 4. LPG temperature at regulator outlet also increased continuously increased during these experiments.

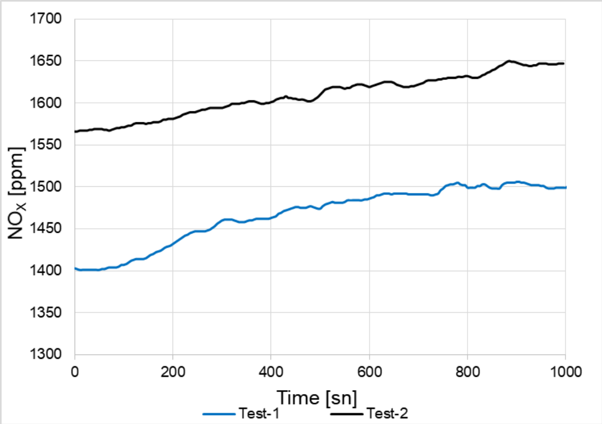


Figure 10. Variation of NOX emission with time for Test-1 and Test-2

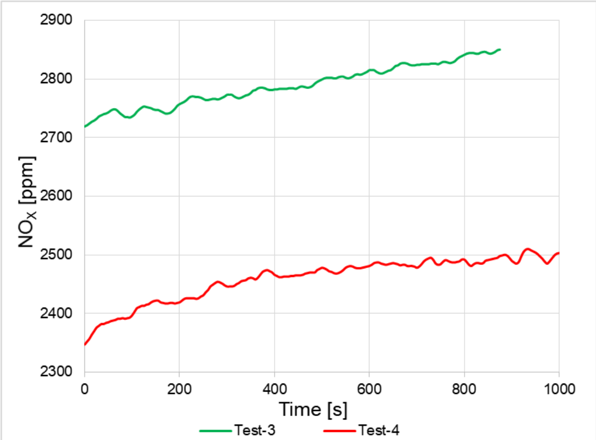


Figure 11. Variation of NOX emission with time for Test-3 and Test-4

In Figure 10 and Figure 11, it was observed that; in first group experiments, NO emissions increased by about 8% while LPG temperature at regulator outlet increased from 20 °C to 75 °C; in second group experiments, NO emissions increased by about 6% while LPG temperature at regulator outlet increased from 20 °C to 65 °C; in third group experiments, NO emissions increased by about 6% while LPG temperature at regulator outlet increased from 20 °C to 68 °C; and in fourth group experiments, NO emissions increased by about 7% while LPG temperature at regulator outlet increased from 25 °C to 62 °C [12]. Growth rate in NO emissions signify a great value for NO emissions emitted from all SI engines on which an LPG conversion is applied.

4. Conclusion

a. In low speed low load experiments, effective power remained almost unchanged while LPG temperature at regulator outlet increased from 20 °C to 75 °C; In low speed high load experiments, effective power has reduced by about 1.0% while LPG temperature at regulator outlet increased from 20 °C to 65 °C; In high-speed low load experiments, effective power has reduced by about 1.0% while LPG temperature at regulator outlet increased from 20 °C to 68 °C; and In high-speed high load experiments, effective power has reduced by about 1.85% while LPG temperature at regulator outlet increased from 25 °C to 62 °C.

b. NO emission, which is a direct function of combustion temperature, is observed to increase with increased LPG temperature at regulator outlet. This increase is found to be at levels of 8%, 6%, 6% and 7% in low speed low load experiments (first group), low speed high load experiments (second group), high speed low load experiments (third group) and high speed high load experiments (fourth group) respectively.

c. The excessive increase of LPG temperature at regulator outlet led reduction in engine effective power and a significant increase in NO emissions.

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References

[1] Lutz BR, Stanglmaier RH, Matthews RD, Cohen J, Wicker. R., editors. *The effects of fuel composition, system design, and operating conditions on in-system vaporization and hot start of a liquid-phase LPG injection system* (1998).

[2] Baljit D, David C, editors. *Tailpipe emissions comparison between propane and natural gas forklifts* (2000).

[3] Choi GH, Kim JH, Homeyer C. Effects of Different LPG Fuel Systems on Performances of Variable Compression Ratio Single Cylinder Engine. In: *ASME 2002 Internal Combustion Engine Division Fall Technical Conference* (2002). p. 369–375.

[4] Gümüş M. Effects of volumetric efficiency on the performance and emissions characteristics of adual fueled (gasoline and LPG) spark ignition engine. *Fuel Processing Technology* (2011) **92**:1862–1867.

[5] Li L, Wang Z, Deng B, Han Y, Wang H. Combustion and Emissions Characteristics of a Small Spark-Ignited LPG Engine. In: *Spring Fuels & Lubricants Meeting & Exhibition*: SAE International400 Commonwealth Drive, Warrendale, PA, United States (2002).

[6] Masi M. Experimental analysis on a spark ignition petrol engine fuelled with LPG (liquefied petroleum gas). *Energy* (2011) **4**:252–260. doi:10.1016/j.energy.2011.05.029.

[7] Jermy MC, Harrison M, Vuorenkoski AK, Mohamad TI, Kaparis E., Macartney M. Overcoming power loss in LPG/LPG conversions of vehicle engines. *International Journal of Heavy Vehicle Design* (2006):1–22.

[8] Klimstra J, Westing JE. Performance of Natural-Gas-Fueled Engines with Variable Intake-Manifold Temperatures. In: *SAE Technical Paper Series*: SAE International400 Commonwealth Drive, Warrendale, PA, United States (1992).

[9] Bayraktar H, Durgun O. Investigating the effects of LPG on spark ignition engine combustion and performance. *Energy Conversion and Management* (2005) **46**:2317–2333. doi:10.1016/j.enconman.2004.09.012.

[10] Masi M, Gobbato P. Measure of the volumetric efficiency and evaporator device performance for a liquefied petroleum gas spark ignition engine. *Energy Conversion and Management* (2012) **60**:18–27. doi:10.1016/j.enconman.2011.11.030.

[11] Ceviz MA, Kaleli A, Güner E. Controlling LPG temperature for SI engine applications. *Applied Thermal Engineering* (2015) **82**:298–305. doi:10.1016/j.applthermaleng.2015.02.059.

[12] Öner İV. *The effects to engine performance and cyclic variabilitys of fuel temperature in lpg using engines*. PhD Thesis. Erzurum (2014).