

# THE ANALYSIS OF THE INFLUENCE OF SEQUENTIAL SYSTEMS FOR GAS ON MOTOR VEHICLES

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**Abstract:** The paper presents the results of developmental researches related to determining the influence of application of various systems for LPG on vehicle properties. On model Florida Zastava the following sequential systems were installed: Sequent 24 BRC, Omegas LR, e-G@S, Fast Lovato and Alisei N Zavoli. The results of comparative investigations obtained on dynamometric rolls indicate the advantages of particular systems.

**Keywords:** VEHICLE, LPG, SEQUENTIAL SYSTEMS.

## 1. Introduction

Fossil fuels (around 99%) are still dominant as drive fuels for automobile engines, in spite of many attempts to introduce other alternative fuels (LPG, CNG, alcohol, hydrogen and others). In this paper, some experience in applying liquid petroleum gas and compressed natural gas on vehicles, as alternative fuels for dual drive, will be considered.

All vehicles which use liquid fuels can be adjusted to application of gas, in bi-fuel systems. Which of the systems for LPG/CNG will be applied depends on the purpose of vehicle and type of main fuel. Long-term decision is that bi-fuel systems are applied on petrol engines. The main property of these systems is that engine is activated only by petrol or gas, according to attuned device, driver's desire or available fuel. The paper has analysed systems with gas injection applied on vehicles with plastic intake manifold. System for gas injection consists of the following important elements: electronic control unit (ECU), switch indicator, gas filter, gas pressure regulator, injector rail, gas temperature and pressure sensor.

To the existing electronic control unit of the system for petrol injection one more electronic unit is added, which makes the connection with the existing petrol system. System for gas injection is the system of new generation of dual systems (petrol-LPG/CNG). System for gas makes possible injecting of gas into each intake manifold separately. According to defined procedure, the engine starts functioning with fuel at start, and after certain period of time or achievement of given temperature the control unit switches the engine functioning to gas. The principle applied by electronic control unit for gas is calculating of injection time applied on gas injector. Control of engine is given to petrol electronic control unit, while electronic control unit for gas turns that information into suitable control form for gas. New gas systems can use different types of injectors in dependence on application conditions. Electronic control unit for gas calculates the time of gas injection by using specific information, such as pressure in injector, gas temperature, cooling liquid temperature, number of engine revolutions as well as input data of petrol electronic control unit.

With the aim of investigating the influence of system for LPG injection on engine with plastic intake manifold TU5JP, installing of system Sequent 24 of company BRC, Italy, was performed [4]. In Department for Cars Development Zastava, comparative investigations of speed properties were performed. For applied system for gas Sequent 24 of company BRC, the procedure for programming the system functioning with the following properties was defined:

- Auto-calibration does not exist; instead, adjustment is defined according to system producer's recommendations.

- Programming involves 8 steps. Transfer to the subsequent phase is not possible without successfully completed previous phase.
- The influence of programmes is considerably limited regarding system Sequent 24, by which the producer is protected against errors in programming.

Based on obtained results, it can be concluded that the application of LPG-a led to degradation of speed properties. The obtained results were expected, which is the consequence of applying gas as fuel, quality of applied system for gas and adequate programming of system for gas, i.e. quality of gas system software. The analysis must also take into account the influence of applied programming adjusted to engine brake on which the comparative investigations were performed and which had to be modified in relation to the recommended one and had to be adjusted to test conditions.

For investigation of the influence of programming of sequential systems for gas injection without auto-calibration, the system Sequent 24 of company BRC/4/ was used, which does not provide the auto-calibration option; instead, adjustment of the system is realised according to the procedure defined by the producer. The initial adjustment includes adjustments at:

- idle stroke
- idle stroke with extra load (light, air-conditioning etc)
- at 3000o/min, with load.

The initial adjustments are realized at a standstill, after installing the system in the vehicle, i.e. after installing the system on engine in given case, with the adjustment results presented in /3/. The following interventions on the investigated system are possible in the case of system programming optimization:

- at idle stroke
- with load.

The system for gas Sequent 24 of company BRC does not allow other options in the adjustment process. That fact can be facilitating for a less demanding installer, but quite limiting in developmental system optimization. The results of realized investigations showed that there are not many possibilities in the optimization process of such a system. Consequently, the price of such a system is considerably higher than the price of other producers' sequential systems for LPG.

In systems with auto-calibration, the initial adjustments are realized at a standstill, too, after installing the system for gas in vehicle. In general, the adjustment of system configuration is realized when the engine is not running. After that, the auto-calibration procedure is started, where adjustment is performed according to the demands of the system producer. After the completion of auto-calibration procedure, each system will define its system map. The map is constructed on the basis of two pieces of

data: engine rpm and petrol injection timing. In case that you are not satisfied with auto-calibration, possible modifications can be realized by optimization of map value on gas, i.e. map coefficients loaded during automatic calibration process, both at minimum and beyond idle stroke range.

## 2. The application of sequential systems for LPG

When selecting the sequential system for LPG, the following must be taken care of:

- that the system for gas is homologated according to valid regulations
- that the gas tank with strengthening must also be homologated according to valid regulations; in addition to that, gas tank must satisfy the time condition for safe installing.

At the market, there is a wide range of sequential systems for gas injection, produced by both the leading system producers and the unsuccessfully licensed and new producers. The worst version is when the installer composes the system himself, without any examinations and tests. That is especially bad when performed by a bad installer with the false aim of making it less expensive. Based on previous experience in the application of vacuum gas systems and on market offers, the following systems for gas injection were selected for developmental investigations:

- Sequent 24 BRC
- OMEGAS Landi Renzo
- e-G@S
- Fast Lovato
- Alisei N Zavili.

All the systems were installed into the engine compartment; tank with support was installed into luggage compartment, while the commutator for the selection of fuel type was installed on the dashboard. The proposed solutions for installing the gas system should provide:

- additional installing of optional drive units on the vehicle (A/C, servo controller etc.)
- standardized installing for all the versions of one vehicle model
- standardization of parts which are to be installed.



Fig. 1 Sequent 24 BRC

The systems were installed on vehicle Florida In 1.6L Zastava, with engine for petrol injection, according to Euro III. The selected sequential systems for LPG represent the new generation of systems. The principle used by ECU for gas is the calculation of time of injection applied on gas injectors. Control of engine running is mainly performed by petrol ECU, while ECU for gas converts it into a suitable control form for gas. New gas systems can use various types of injectors in dependence on application conditions. ECU for gas calculates the time of gas injection using specific information, such as pressure in injectors, gas temperature, cooling

liquid temperature, revolutions per minute and input data of petrol ECU.

Fig.1 shows the installing of the system for gas injection Sequent 24 BRC. The installing of the system was adjusted to the strengthening of car body in the engine compartment. For this system, there are no limitations regarding installing of ECU for gas, which is located on right inner mudguard. The injectors are installed on the upper side which makes them easily accessible if needed. Vaporizer is connected to the car battery support.



Fig. 2 OMEGAS Landi Renzo

Fig.2 shows the installing of device OMEGAS Landi Renzo. This vehicle did not undergo the strengthening of car body in engine compartment. System configuration is similar to the previous solution. ECU for gas is installed next to the petrol one. The injectors are installed on the upper side. Vaporizer is connected to the car battery support. The final aim is standardization of the linking point of gas system elements, within limits of the observed vehicle model.



Fig. 3 Installing of switch indicator



Fig. 4 Cylindrical LPG tanks



In both previous systems, as in all following ones, the selector of fuel type is located on the dashboard, and is visible by the driver during the drive, Fig.3. Gas tank can be cylindrical, Fig.4, or toroidal, Fig. 5.



Fig. 5 Toroidal LPG tanks



Fig. 6 Sequential systems for LPG e-G@S

In system e-G@S, ECU for gas is located differently, next to the car battery. Other gas system points are roughly similar to previous solutions.



Fig. 7 Sequential systems for LPG Fast Lovato

Solutions for system Fast, Fig.7, are similar except linking point of ECU for gas on partition wall. Fig.8 shows the solution for installing the system Alisei N Zavoli, on vehicle Florida, with Toyota engine, which is different from the standard one. The

installing of system for gas is adjusted to the engine, which is why the vaporizer is dislocated in comparison with other solutions.

For all the systems, programming and adjusting are performed by the computer. The systems are programmed by auto-calibration, except of Sequent 24, which has a defined programming procedure. Programming of this system is more demanding, whereat the influence of some drive units on the vehicle is taken into consideration.



Fig. 8 Sequential systems for LPG Alisei N Zavoli

Basic regulation is performed without load, at a standstill:

- at idle stroke
- at 3000o/min.

The recommendation is to carry out the necessary corrections in driving after each basic adjustment.

### 3. Analysis of the influence of applying various systems for gas

With the aim of determining the effects of application of various systems, the following investigations are realized:

- on engine brake
- on rolls
- on the road.

Comparative researches include the following investigations:

- properties of engine/vehicle which uses petrol/LPG
- properties of engine/vehicle with various systems for LPG.



Fig. 9 Investigations of vehicles on rolls

The paper includes the investigation of vehicles on dynamometer rolls, Fig.9, with the aim of determining the effects of application of various systems for LPG. The investigations included the following activities:

- vehicle adjustment
- comparative recording of properties of vehicle which uses petrol and LPG (curve of power on wheels)
- comparative recording of vehicle properties with various systems for LPG.

The selected methodology for measuring power on vehicle wheel provides fast and accurate comparative measuring with the aim of observing the influence of various changes on force-speed properties of the vehicle. The procedure makes it possible to use the measured values in order to calculate the external speed property of the engine. Owing to the applied adjustment of measuring to standard conditions, good comparability of the results is provided, because varying of important factors is eliminated.

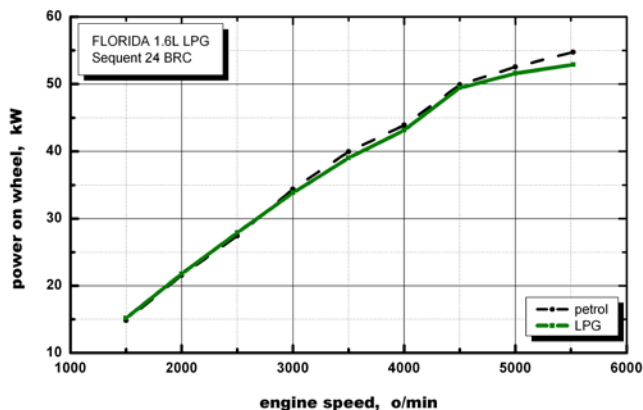


Fig. 10 Zastava Florida 1.6L LPG- Sequential 24 BRC

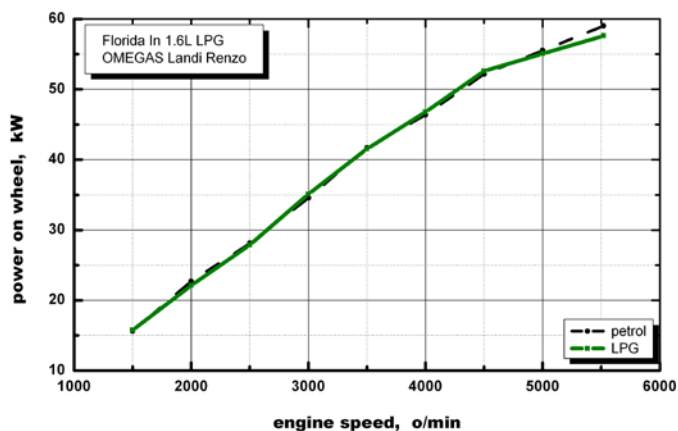


Fig. 11 Zastava Florida 1.6L LPG-OMEGAS Landi Renzo

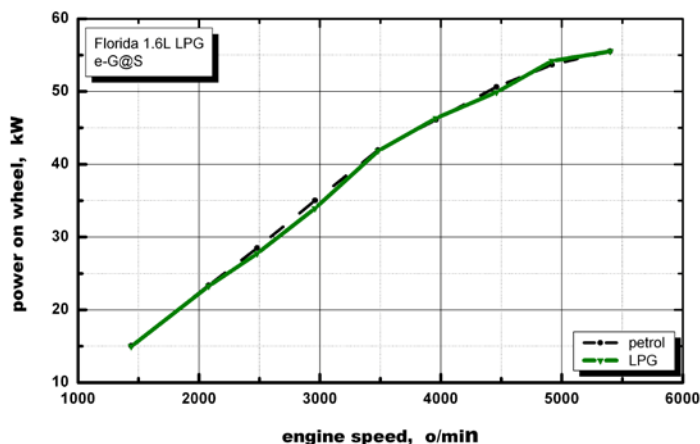


Fig. 12 Zastava Florida 1.6L LPG-e-G@S

Fig.10, 11, 12 and 13 show the effects of application of various systems on vehicle Florida, with multipoint system for petrol, which satisfies Euro III. Different systems are programmed in different ways and they provide different results. At smaller r.p.m. mainly all systems for gas function well. At higher r.p.m. the differences are obvious, especially in programming without correction. Persistent correction of adjustments can lead to the desired congruence of behaviours when using petrol and LPG, but that should not be the only aim.

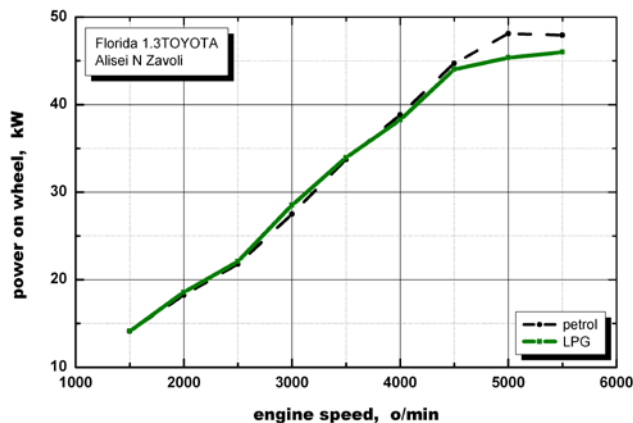


Fig. 13 Zastava Florida 1.3 Toyota LPG- Alisei N Zavoli

#### 4. Conclusion

Development and introduction of new solutions in car industry is a necessity, especially bearing in mind ever stricter market demands and valid regulations. In addition to that, it is necessary to improve the methods for estimation of performed interventions constantly. The presented results indicate the influence of installed sequential systems for LPG on vehicle properties, which is necessary in vehicle development process.

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