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Methods of improving the performance indicators of vehicles with gas cylinders with a universal fuel supply system

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Abstract

This article presents ways to improve the operation performance and environmental safety of natural gas vehicles with a universal fuel supply system. In this, two passenger vehicles with a universal supply system were studied, and the traction-speed characteristic of the vehicles was determined by the acceleration indicator during the pilot test. Fuel economy characteristics were determined by calculating the distance traveled by the amount of gas fuel in the gas cylinder tank. Also, by adjusting the gas-gasoline modes in the engine to the conditions of operation, the methods of reducing gasoline consumption and thus increasing the environmental safety of the vehicle are mentioned.

Keywords: Vehicle, compressed natural gas (CNG), universal fuel supply system, operation performance, computer program, multiplier map, environmental safety, fuel consumption.

Introduction

The operation efficiency of vehicle is the improvement provision of its general transport processes from the point of view of economy, ecology and safety. This, in turn, is related to the technical quality and usefulness of the vehicle.

The quality of the vehicle is determined by the presence of features that provide clearly defined operation requirements depending on its function. Its usefulness is low overall cost and fuel efficiency[1]. In addition to operation requirements for vehicles, environmental safety requirements are also very important. The reason for this is the worsening of the global environmental situation and the high level of negative impact of vehicle transport.

The main part of the current vehicle fleet is equipped with internal combustion engines, which mainly use gasoline and diesel fuels extracted from petroleum as engine fuels. The amount of toxic and harmful gases released into the environment as a result of the movement of vehicles running on these fuels has the largest share among all other types of vehicles and makes up 74.5 percent of the total[2]. The increase in the negative impact on the environment caused by the use of traditional petroleum fuels in the operation of vehicles creates the need to use environmentally friendly fuel resources as an alternative to them.

Today, the use of compressed natural gas (CNG) as an alternative fuel for motor transport is becoming increasingly popular. CNG fuel has many advantages over gasoline. For example, compared with the environmentally friendly E10, CNG can reduce CO_2 emissions by about 20% and improve thermal efficiency by about 13%, which is mainly due to the higher H/C value of natural gas[3]. Also, S. F. Fosilov researchers have identified and studied the reduction of exhaust gases when converting gasoline vehicles to CNG vehicles as shown in Table-1[4]. The use of this type of fuel is effective in improving the operation characteristics of vehicles and ensuring environmental safety.

Foreign results show that burning CNG will lead to 54%–83% reduction in black carbon (BC) emissions per kilometer, depending on actual driving conditions[5]. These comparisons show that CNG is a cleaner fuel than gasoline for motor vehicles in terms of BC emissions and provide a viable option for reducing BC emissions cause by transportation.

In a study by Zongyan Lv et al., it can be seen that CNG vehicles are more environmentally efficient than Liquefied Petroleum Gas (LPG) vehicles 6, which can also be seen in Figure-1[6].

In addition, when gas fields are explored in Central Asia, it ranks second only to Western Siberia in terms of natural gas reserves and the level of its extraction. Potential gas reserves are 16.5 trillion cubic meter, explored reserves - 3.1 trillion cubic meter. More than 93% of these reserves correspond to the share of Uzbekistan (40%) and Turkmenistan[4].

About 7...8 million tons of oil (including gas condensate), 64-66 billion cubic meter of natural gas and 5.5 million tons of coal are extracted annually in Uzbekistan, that is, natural gas makes up about 65% of the total production fuel and energy balance and globally natural gas accounts for approximately 22-24 percent of the fuel and energy balance[7].

It is very convenient as an alternative to gasoline used in vehicles. When converting gasoline and diesel engines to gas fuel, the vehicle is re-equipped and additional equipment and a gas tank are installed in the engine supply system. Vehicles that have been retrofitted to run on gas are collectively known as gas cylinder vehicle (GCA).

Table-1: Emissions of toxic substances and their reduction when switching vehicles to gas fuel.

Name of toxic substances	The amount of harmful substances when the vehicle runs on gasoline fuel, tons/year	The amount of harmful substances during the operation of the vehicle in CNG, tons/year	Reduction in the amount of pollutants compared to a gasoline vehicle, tons/year
CO	1,704	0,587	1,117 (65%)
CH	0,284	0,207	0,077 (27%)
NO_2	0,113	0,138	0,025 (22%)
SO_2	0,005	-	-
$C_{20}H_{12}$	0,54 x 10^{-6}	-	-
Total :	2,106	0,932	1,174 (56%)

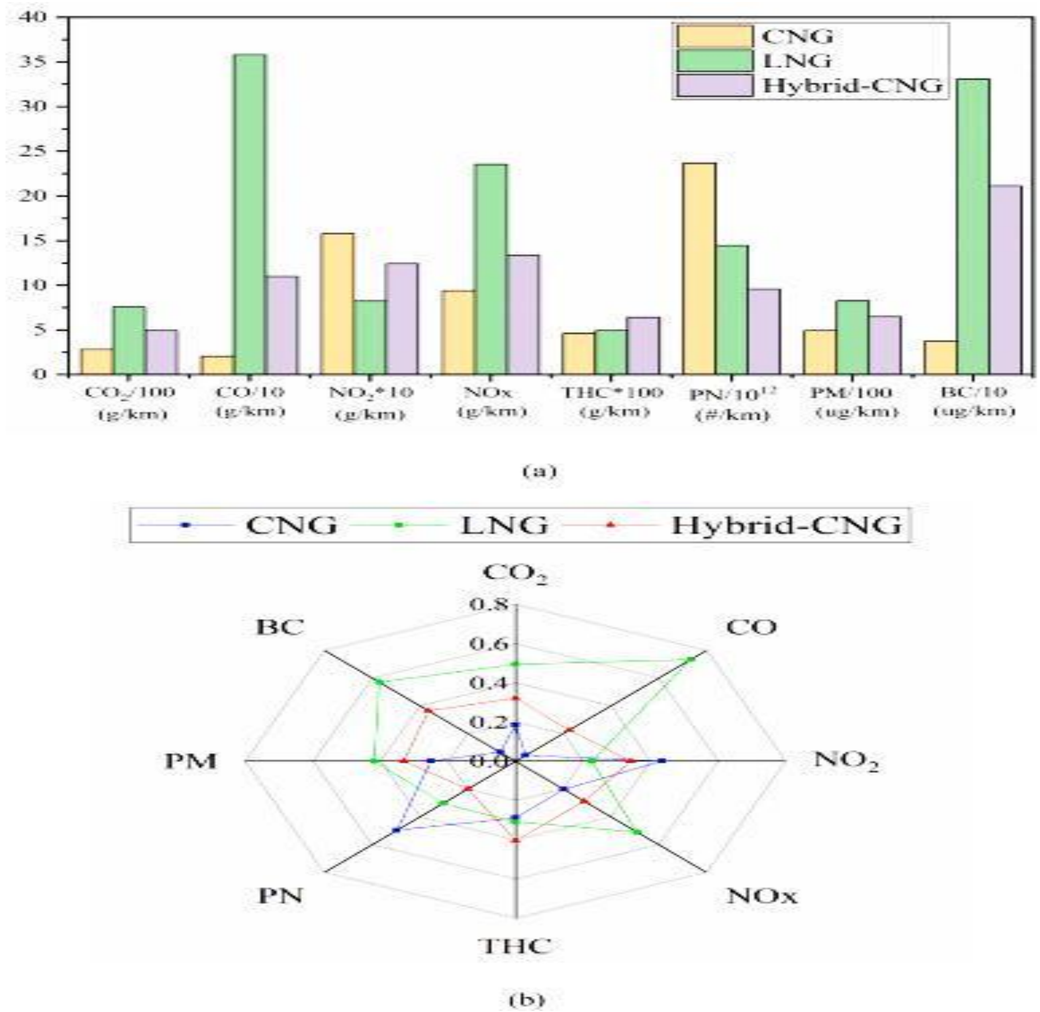


Figure-1: (a) EFs of the three buses, (b) Radar chart of pollutant emission factor normalization (each point in the figure represents the standardized values of each pollutant emission factor for each vehicle).

Vehicles running on CNG fuel will be re-equipped with gas cylinder equipment (GCE) and certain changes and additional equipment will be installed in the fuel supply system.

Today, there are three different ways to re-equip (convert) vehicles to gas fuel[8]: i. bi-fuel - has a universal fuel supply system and two equivalent fuel supply systems for spark, including gas and gasoline; ii. dual-fuel (gas-diesel) - has a fuel supply system, where when the engine is running on CNG, part of the diesel fuel is used as an enrichment dose for burning the gas-air mixture in the internal combustion engine; iii. gas (dedicated) - engines that can be converted to work only on natural gas are considered, and the gas-air mixture is ignited in the cylinders by a spark plug.

Today, re-equipment with bi-fuel i.e. universal fuel supply system for CNG cars is becoming popular. There are currently four generations of CNG vehicles equipped with a universal CNG fuel system, among which the 4th generation GBU is the most efficient and economical type. The main components of the 4th generation CNG vehicles are shown in Figure-2[13].

Electronic control units (ECU) in the gas supply system are very important in improving the operation characteristics of the GCA, their use serves to further improve the fuel efficiency and traction-speed characteristics of the GCA. In improving the operating characteristics of the GCA with an electronic control system, the optimal selection of the gas-petrol mode switching indicators and the adjustment of the multiplier maps of the computer programs in accordance with the structural indicators of the vehicle and the operating conditions give an effective result in improving the operating indicators of the GCA.

Materials and methods

The following are among the researchers of our republic and foreign researchers on the research of ecological and operation indicators of vehicles running on compressed and liquefied natural gas: P.V. Bushuev[12], B.I. Bazarov, A.S. Gavaev, V.I. Erokhov, A.A. Koryakin, A.I. Morev, Yu.V. Panov, N.G. Pevnev, A.L. Penkin, V.I. Rudskikh, G.I. Samol, D.N. Snejko, R.M. Temirbaev, A.B. Trofimov, O. Arslan, Ch. Lai, Mk. Ch. Lim, M. .Masi, L.J. Sitnik and others have conducted many scientific researches and studies.

In his scientific work, P.V. Bushuev conducted research on the method of regulating the fuel efficiency of city buses equipped with gas-powered electronic control systems by optimizing their operation. B. I. Bazarov scientific research on the traction-speed characteristics of gas cylinder vehicles, ensuring fuel economy and environmental safety, as well as the main solutions for the use of fuel in special mining and agricultural vehicles, existing problems took. In his research, A.S. Gavayevvehicleried out research on determining the rules of low-temperature working conditions, the toxicity of vehicle exhaust gas, its influence on fuel consumption, and on the basis of this, increasing the performance of gas cylinder vehicles.

In general, today there is very little research to analyze and improve the towing speed characteristics, fuel economy and environmental performance of CNG-powered passenger vehicles with dual-fuel universal fuel supply systems, also narrowly studied in the sources. At the same time, scientific research on optimization of basic programs of new generation electronic control units of gas cylinder vehicles has been vehicleried out very little.

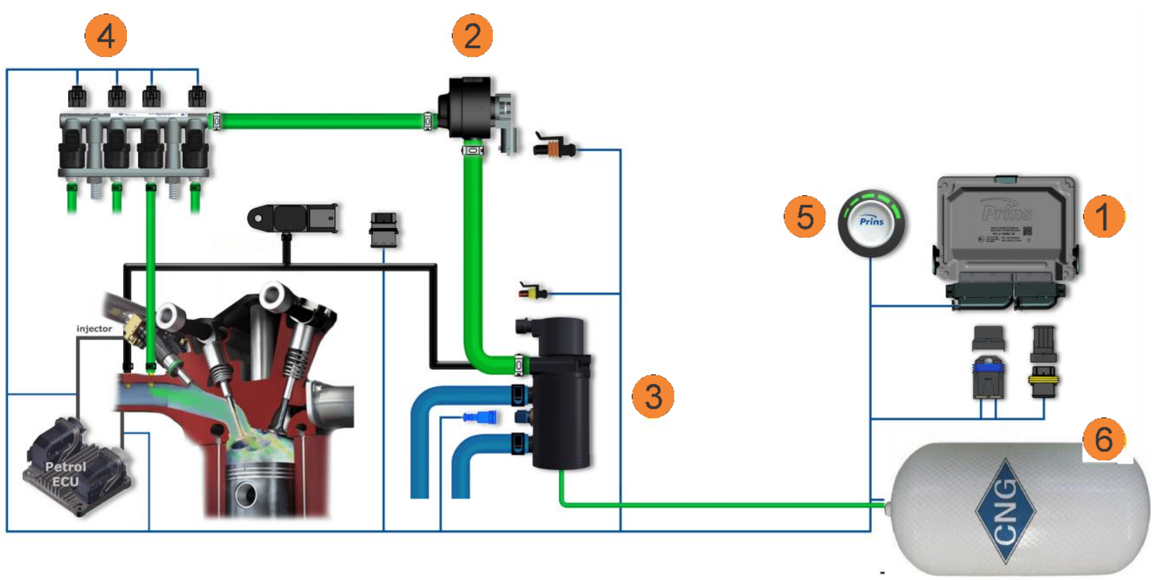


Figure-2: 4th generation GCE of CNG vehicles 1-CNG fuel electronic control unit; 2- gas valve; 3-gas reducer; 4-gas injector; 5-gas-petrol mode change button; 6- gas cylinder container.

Computer programs of "gas-gasoline" modes of separately installed electronic control units for gasoline and gas fuels to increase the operation efficiency and environmental safety of the 4th generation GCE installed on gas cylinder vehicles with a universal fuel supply system the above goals can be achieved by optimizing the basic indicators in accordance with the operating conditions.

With the cooperation of experts of Tashkent University of Transport and Jizzakh Polytechnic Institute, an experimental test was vehicleried out on two passenger vehicles to improve the performance indicators of passenger vehicles with gas cylinders with a universal fuel supply system. These vehicles are equipped with 2022 Chevrolet Cobalt LTZ A/T automatic transmission with 1.5 liter engine and 2018 Chevrolet Nexia-3 LTZ A/T with manual transmission. Gas cylinders with a capacity of 80 liters were installed, both vehicles were re-equipped with Stag-200 fourth-generation GCE with a universal fuel supply system, and we can see its installation scheme in Figure-3[9].

Results and discussion

During the experimental test, gas ECUs of vehicles were connected to the computer through a special connector cable. With the help of the ACG as Synchro program installed on our computer, we bring the gas-gasoline modes to the optimal temperature shown in Figure-4, where the changes are adapted to operational and climatic conditions. The air temperature is set in the "Hot start" line of the "Gas controller settings" section of the ACG as Synchro program in the summer season, and the gas will always start when the temperature in the gas reducer is within the specified degree.

In this case, there will be an opportunity to save the fuel consumption of the vehicle and, in parallel, to ensure environmental safety. Cold start has a substantial contribution to the total PN emissions with gasoline, while motorway driving is also characterized by, not only local, peaks. Natural gas application limits particle emissions during these phases[10]. CNG-Hot-Start tests had the lowest OFP value about 54.2 mg/km while Gasoline-Cold-Start tests had the highest OFP value about 259.4mg/km. VOCs had a decisive position in OFP production and accounted for over 90% of total OFP, CNG-fueled vehicles could sharply reduce VOCs, in turn, to reduce OFP. After a rough estimate, CNG-fueled vehicles can reduce OFP economically and efficiently after large-scale use[11]. The environmental efficiency of GCA compared to gasoline vehicles is high, but the engine power is reduced to almost 19-20 percent. In order to increase the traction-speed characteristics of vehicles during operation, changes were made to the multiplier maps of the ACG as Synchro program on the computer, as shown in Figures-4 and Figures-5. It was tested on city roads, and the fuel consumption was determined by filling the gas cylinder three times under a pressure of 20mPa.

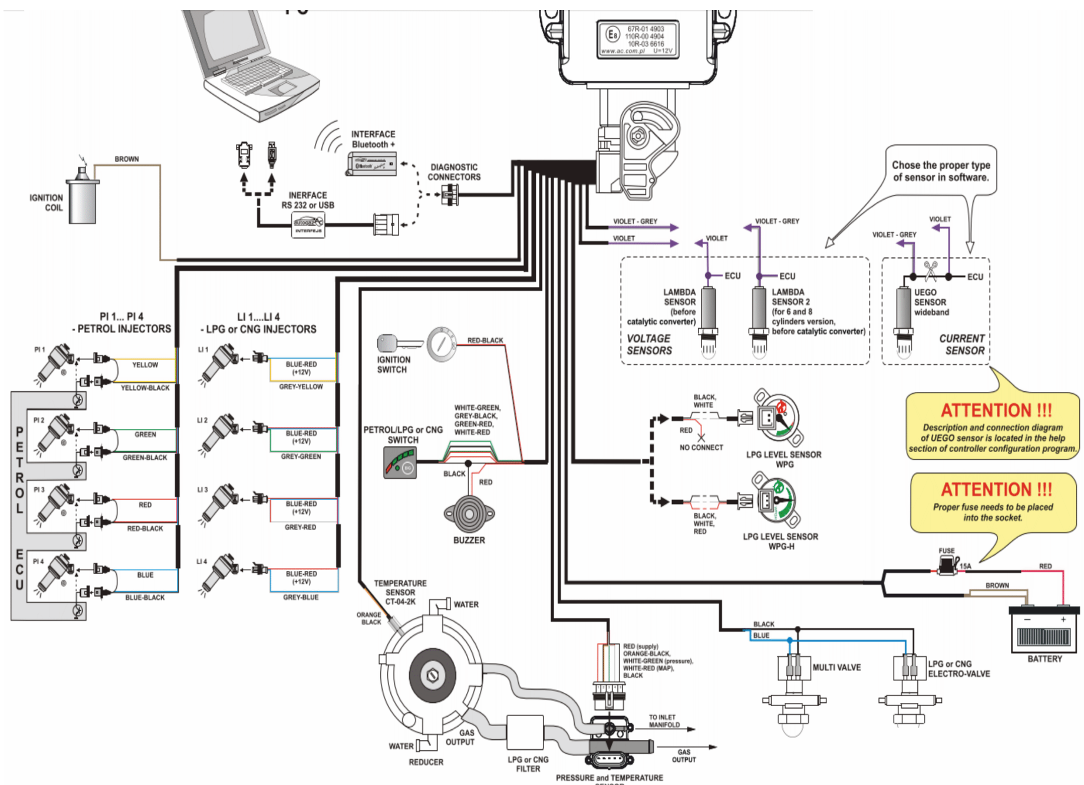


Figure-3: Stag-200 automotive installation wiring diagram.

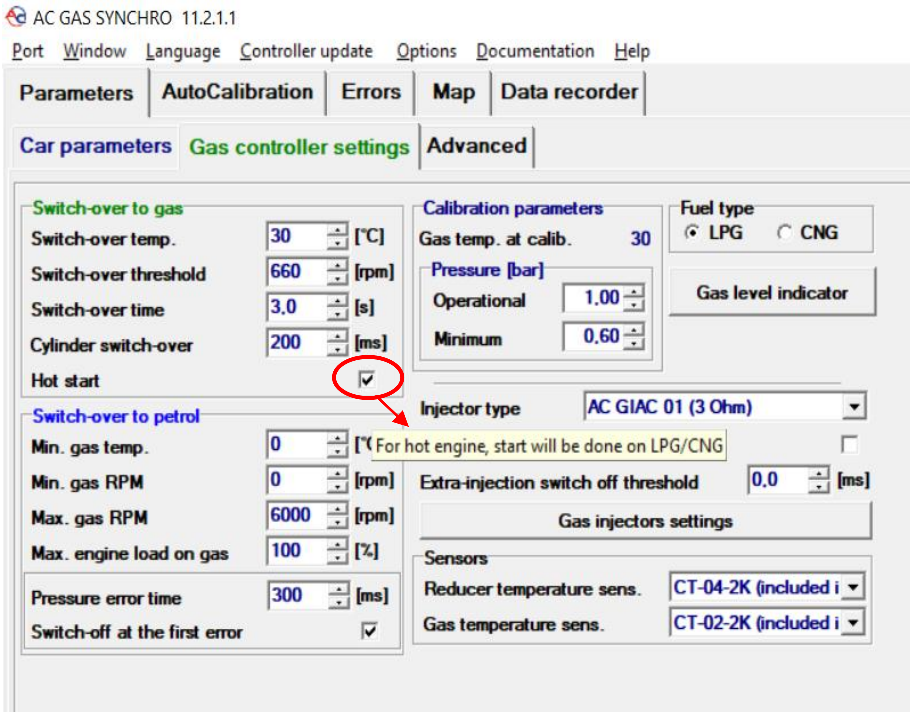
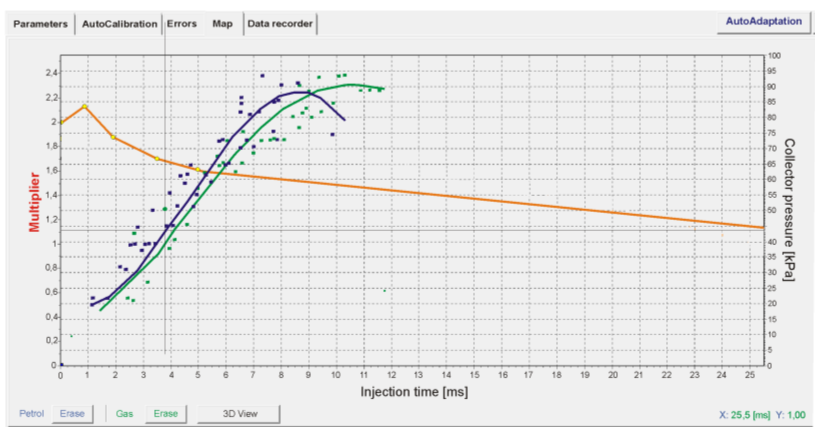
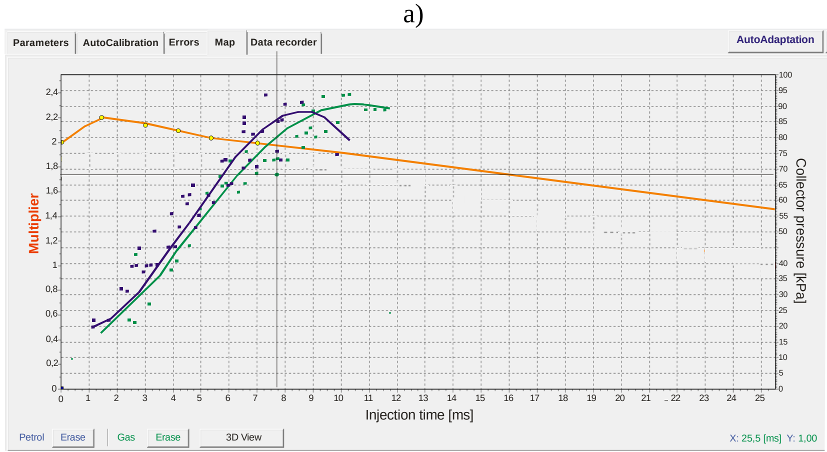


Figure-4: ACG as Synchro software settings of Generation 4 GCE.



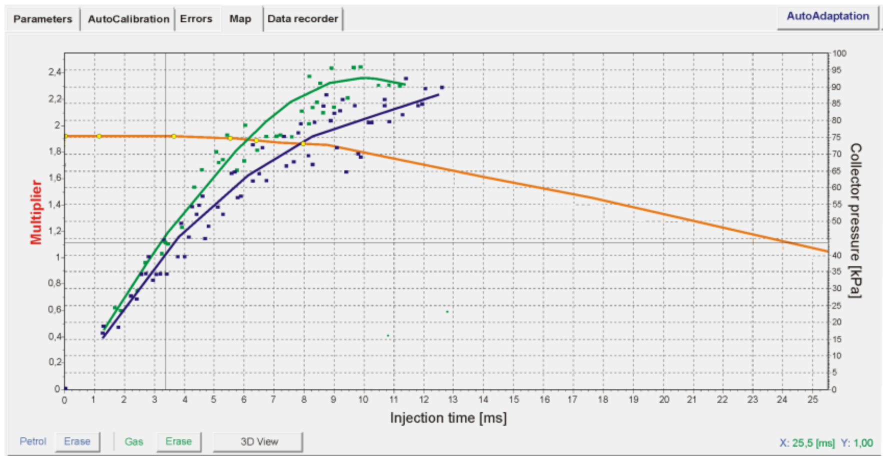
a)



b)

Figure-5: Condition on Chevrolet Cobalt LTZ A/T Multiplier Map a) previous situation; b) changed state.

According to the results of the experimental test, the acceleration time of Chevrolet Cobalt LTZ A/T and Chevrolet Nexia-3 LTZ A/T vehicles after changing the multiplier map and in the previous condition, i.e. 100km/h on gasoline and CNG fuels the time to reach the clock speed was analyzed (Table-2). Also, according to the results of three tests conducted on inner city roads, it was found that these vehicles consume 19.4 cubic meter of gas fuel and cover the following distances (Table-3).



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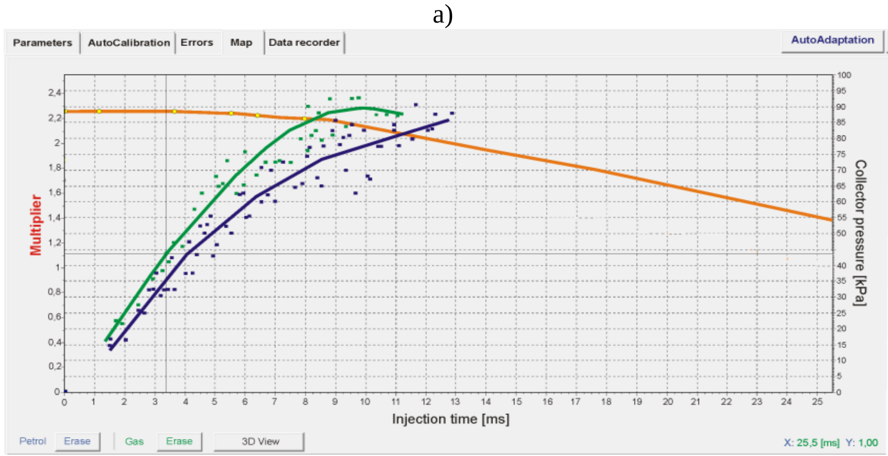

b)

Figure-6: Chevrolet Nexia-3 LTZ A/T status on the multiplier map a) previous situation; b) changed state.

Table-2: Time taken to reach 100 km/h before and after the GCA multiplier map was changed in the computer program.

Type of Vehicle	The time taken for the vehicle to reach a speed of 100 km/h			
	On gas (CNG)		On gasoline	
	Before the change	After the change	Before the change	After the change
Chevrolet Cobalt	14,3	13,1	12,2	11,9
Chevrolet Neksiya	15	13,4	12,9	12,7

Table-3: Analysis of vehicle fuel consumption.

Type of Vehicle	The total distance traveled under pressure with a gas consumption of 19.4 cubic meter, km			
	Experiment 1	Experiment 2	Experiment 3	Middle
Chevrolet Cobalt	257	230	250	245,6
Chevrolet Neksiya	210	236	237	227,6

In the process of determining vehicle traction speed characteristics and fuel consumption, it is effective to change the basic settings of the gas-petrol modes in the computer programs installed for GCE in accordance with the operating conditions and to optimize the indicators of CNG fuel transfer to the engine with pressure. At the same time, we can see the possibility of improving the performance of the vehicle by adjusting the multiplier map in the program in a suitable position for the engine operation in the experimental test results.

Conclusion

In short, the following factors should be taken into account in order to improve the operation performance and environmental safety of gas cylinder vehicles with a universal supply system: i. it is possible to reduce gasoline consumption and thereby increase environmental safety by changing the basic indicators of gas-gasoline modes of gas cylinder vehicles with a universal supply system, taking into account climatic conditions; ii. to change the operating indicators of gas cylinder vehicles with a universal supply system, in particular, the indicators of the multiplier map in the computer program installed in the gas ECUs to improve the vehicle traction speed, fuel economy characteristics, in accordance with the engine parameters and accordingly will need to be adjusted.

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