# The concept of improving the performance indicators of gas-cylinder vehicles

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**Abstract.** This article presents the analysis of operational and environmental indicators of gas cylinder vehicles, their prospects and optimal installation of gas cylinder equipment. In order to improve the operational performance of gas cylinder gas-cylinder vehicles and ensure their environmental safety, the method of choosing gas cylinder equipment according to the technical specifications of the vehicle and setting the appropriate program settings in the optimal state is shown.

## 1. Introduction

Today, there are more than 1.45 billion vehicles in the world [6], and most of them use petroleum-based gasoline and diesel fuels. Vehicles powered by this fuel have been in operation for almost a century, but the use of conventional fuels has created global environmental problems, while limited oil reserves have led to a deficit of fuel products for these vehicles. In order to prevent these problems, it is necessary to use alternative fuels and popularize them.

Alternative fuels used in modern vehicles include methanol and benzomethanol mixture; hydrogen; liquefied petroleum, propane-butane mixtures (PBM), compressed natural gas (CNG) or liquefied petroleum gas (LPG), gas generator, biogas, gas condensate fuels, include aqueous fuel emulsions and others [1,2]. The use of CNG as an vehicle fuel was discovered in Italy in the early 1930s [4], Since the 1970s, it has become popular around the world, and this was caused by the shortage of petroleum products that began at that time. After that, CNG began to appear as a comprehensively promising alternative as a vehicle fuel. The sharp rise in oil prices in the late 1970s and early 1980s led to a further increase in the number of CNG vehicles and their improvements.

The number of natural gas vehicles in the world is more than 29,793 million as of 2019-2020, and the number of gas filling compressor stations for vehicles is 33,383 [8, 12]. Asia is the leader in the distribution of the amount of natural gas vehicles by region (Table 1).

**Table 1.** Distribution of CNG vehicles and compressed natural gas (CNG) refueling stations by region [8]

| Regions | CNG vehicle | CNG filling stations |
|---|---|---|
| Asia | 20 473 673 | 20 275 |
| Yevropa | 2 062 621 | 5194 |
| North America | 224 500 | 1856 |
| South America | 5 484 676 | 5848 |
| Africa | 295 349 | 210 |

## 2. Literary analysis

CNG is obtained directly from gas fields and accompanying gases released during the processing of oil products. CNG is mainly composed of methane (82...98%), and additionally contains ethane (up to 6%), propane (1.5%) and

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butane (up to 1%). CNG is delivered through branched gas pipelines to gas-collecting compressor stations, and from there it is distributed as fuel to vehicles. Methane is a colorless and odorless gas, slightly soluble in water, lighter than air (specific density 0.55 compared to air) and belongs to the class of saturated hydrovehiclebons. Methane molecules are composed only of vehiclebon and hydrogen, therefore, when ignited, it does not emit toxic gas. The high amount of hydrogen in CNG ensures more complete combustion of fuel in the engine cylinders compared to liquefied petroleum gas or gasoline.

The main characteristics of CNG and gasoline fuels are presented in Table 2 [1,2]. Comparing these characteristics to each other, the use of CNG as a fuel in an internal combustion engine gives 12 different efficiency indicators during operation.

**Table 2.** The main characteristics of CNG and gasoline fuels

| **Indicators** | **CNG** | ***Gasoline*** |
|---|---|---|
| 1 | 2 | 3 |
| Molecular mass | 16,03 | 114,2 |
| Elemental Composition, *%*:<br>*H*<br>C | <br>25,03<br>74,57 | <br>15,0<br>85,0 |
| H/C ratio | 4,0 | 2,25 |
| Gas constant:<br>*kgsm/kg·K*<br>*kkal/kg·⁰C* | <br>52,81<br>0,124 | <br>7,6<br>- |
| Density of the vapor state under standard conditions:<br>*kg/m³*<br>when the fuel is liquid *kg/l* | <br>0,670<br>0,415 | <br>-<br>0,626 |
| Evaporation Temperature, *kkal/kg* | 122,6 | 65 |
| Relative density | 0,554 | 3,18 |
| Oxygen required from air for the complete combustion of fuel will be:<br>$m^3/m^3$ fuel<br>$m^3/kg$ fuel | <br>9,52<br>14.2 | <br>-<br>12,35 |
| The heat of combustion of a stoichiometric mixture under standard conditions; $kkal/m^3$ | 770 | 850 |
| Boiling point, $^0C$ | -161,6 | 99,2 |
| Boiling Temperature, $^0C$ | 590…690 | 480-520 |
| The ignition temperature of a stoichiometric mixture, $^0C$ | 2020 | 2100 |
| Coefficient of molecular change when a stochnometric mixture burns | 1,0 | 1,058 |
| Octane rating | 100…120 | 100 |
| The maximum value of the normal speed of flame propagation, *m/s* | 3,4…3.7 | 4,0-4,2 |
| The coefficient of excess air at the same speed | 0,95 | 0,89 |
| The value of this coefficient at the lower concentration limit | 2,0 | 1,76 |
| Value at the limit of high concentration | 0,65 | 0,3 |
| Flammability limits in air, $g/m^3$ % | 5...15; 16,66...102,6 | 1,5/6,0 |
| The minimum energy of ignition, 10-3 J oil heat | 0,23 | 0,28 |
| Wobbe Index (or Wobbe Number): high value<br>lower value | 12300<br>11300 | -<br>- |

The conversion of vehicles from gasoline to gas makes it possible to reduce the harmful emissions five times, on average, and the effect of noise by half [3]. According to research conducted by Kenedy Aliila Grayson and others [4], 280 barrels of gasoline are saved annually for one light vehicle, and $46,500 is saved through the use of CNG in vehicles. According to many research, the amount of harmful gases and noise emitted by vehicles running on CNG is significantly reduced compared to gasoline vehicles. The service life of the engine lubrication system is extended and the oil viscosity is maintained optimally for a long time due to the use of this fuel.

CNG fuel cheaper than gasoline or diesel[2] (As an example of fuel prices in the Republic of Uzbekistan, CNG fuel for vehicles is 3.18 times cheaper than gasoline fuel and almost 4.54 times cheaper than diesel fuel) [9]. It has inherently lower air pollution emissions. It has lower greenhouse gas emissions. Its use extends petroleum supplies, and there are large quantities of the fuel available in the world [13]. The CNG has an advantage of higher brake thermal efficiency on an average of 1.1% and 1.6% than that of gasoline [11].

The price of STG ranges from 1900 to 2850 soums per $m^3$ (1 $m^3$ = 1.1 liters), with an average of 2500 soums.

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## 3. Result and Discussion

When using CNG fuel in vehicles, they are retrofitted with gas cylinder equipments (GCE). As a GCE installed for modern vehicles, mainly pressure regulator petrol solenoid valve with manual override switch (It stops petrol flow when operating on CNG), on-off valve and refueling connector, control module/change-over switch (It is an electronic control component with fuel selection switch), CNG level indicator (LED Indicator), gas air mixer, CNG cylinder with valve, vapor bag & bracket, petrol hose, low- pressure gas hose, ignition advance processor, high pressure gas tube, wire harness, non-return valve (NRV) in petrol return line, pressure gauge consists of parts.

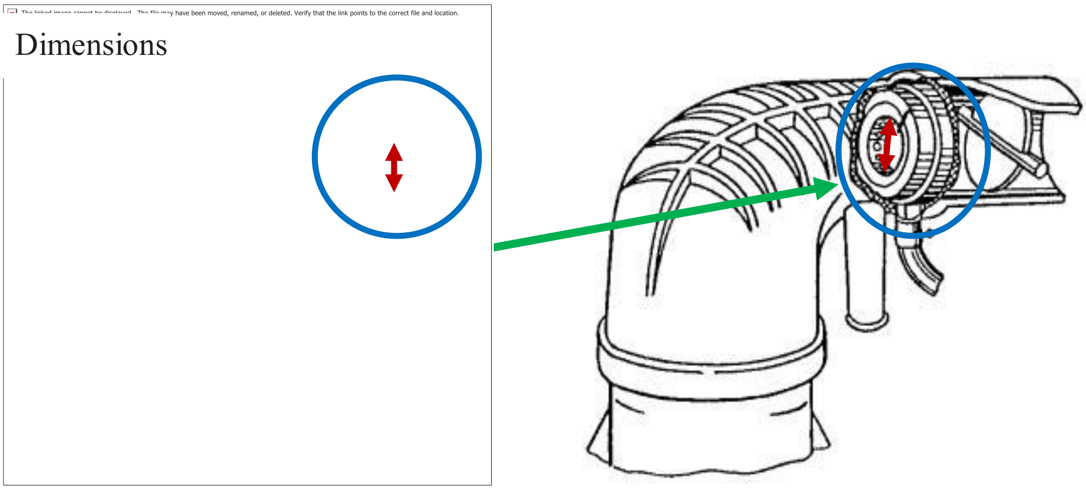


**Fig. 1.** Gas air mixing device in the 3rd generation GCE of CNG vehicles

Today, re-equipment of vehicles running on CNG fuel with 4th generation GCE is becoming popular (Fig. 2). This generation GCE can be converted to almost all modern internal combustion engines, is very simple in design, and also very efficient. Unlike the 1st-2nd-3rd generation GCE of CNG vehicles, the 4th generation GCE is equipped with gas injectors that deliver CNG fuel to each cylinder. this is, in turn, leads to increased engine power and significant fuel savings.

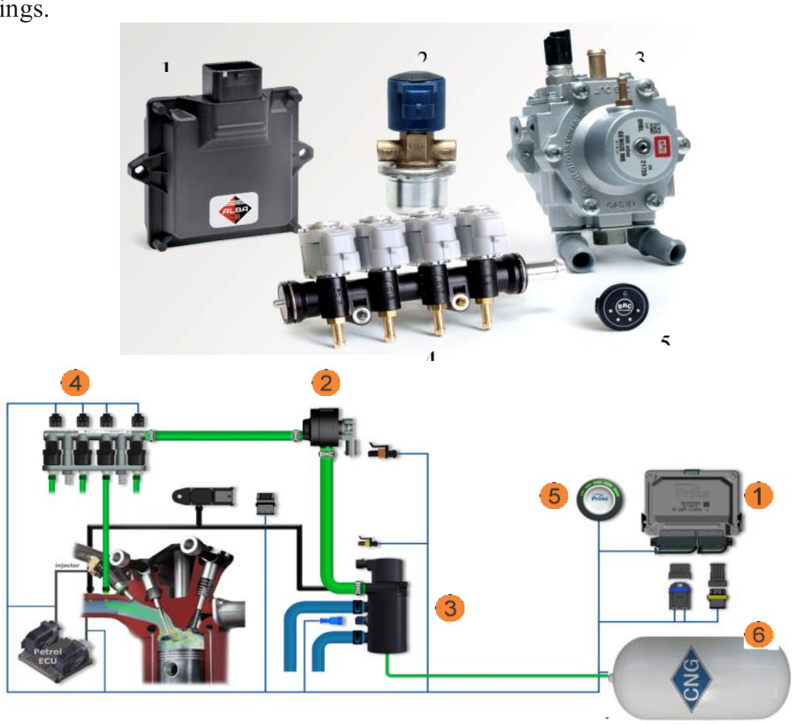


**Fig. 2.** 4th generation GCE of CNG vehicles: 1- ECU (Electronic Control Unit); 2- Filter; 3- Injectors; 4-Evaporator (eVP-500); 5- Switch; 6- CNG-tank

In the 3rd generation GCE of CNG vehicles, the gas air mixing device (Fig. 1) mixes fuel with air and introduces it into the cylinder through the inlet manifolds. In this case, the amount of air flow passing through the gas air mixer cannot reach the required level in the engine load mode. The reason for this is the small diameter of the gas mixer hole (Fig. 1), when the gas pedal is pressed, the necessary amount of air cannot enter through the holes for complete combustion of fuel. As a result, a rich fuel mixture is formed in the cylinder and energy efficiency decreases.
In the 4th generation CNG vehicles, the above deficiency is eliminated and separate gas injectors are installed in each intel manifolds for gas transfer (Fig. 2 (4)), and an electronic control unit (ECB) of CNG (Fig. 2 (1)) that optimally manages the process is installed. After equipping vehicles with 4th generation GCE, the gas ECU is programmed on the computer in the appropriate program (Fig. 3). Today's popular Stage, Digironic, Europegas, Prins, Autogas system, BRS, Autogaz AC and others can be mentioned among these programs.
Through the above programs, the "gas-gasoline" fuel exchange mode in the engine supply system can be changed in relation to the specific temperature of the fuel or the number of crankshaft revolutions. We can change this process by installing a program by connecting a computer to the gas ECU (Fig. 3-4).
During the operation of vehicles equipped with 4th generation GCE, it is possible to reduce gasoline consumption by reducing the time of transition from gasoline mode to gas, and this, in turn, provides an opportunity to save fuel costs and improve the environmental safety of vehicles.
In order to effectively control the "gas-gasoline" modes of vehicles equipped with a universal fuel supply system running on CNG, the optimal program is selected for the gas mode control ECU, and the main indicators of the control of the "gas-gasoline" mode are changed. These indicators are the engine temperature and the frequency of crankshaft revolutions. The ECU uses gasoline fuel to reach the optimal temperature in the cooling system during the initial start-up of the vehicle engine in gasoline mode, and this temperature is 30° C for gas mode operation, which is determined by the computer, depending on the temperature after reaching, it automatically switches to gas mode, i.e. starts using CNG fuel.We can control this task in the "Switch-over temp" function of the program (Fig. 4).

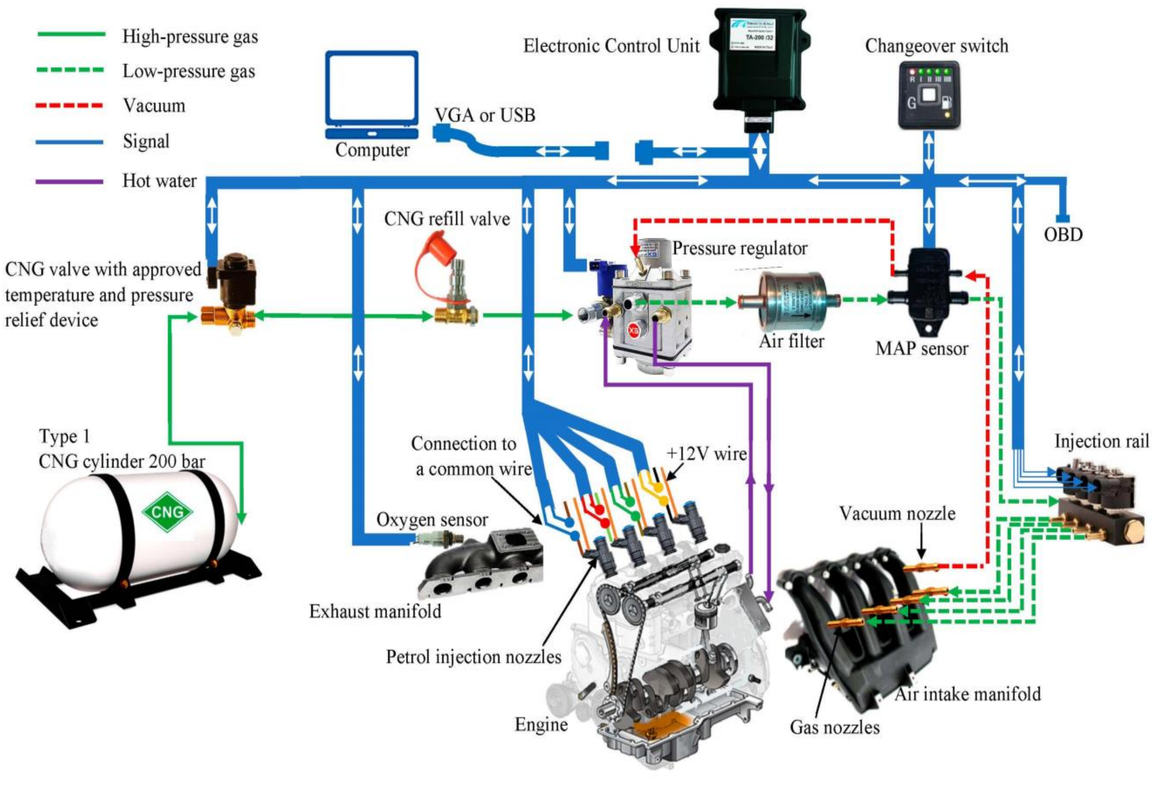


**Fig. 3.** The arrangement of CNG components in petrol-fueled vehicles [14]

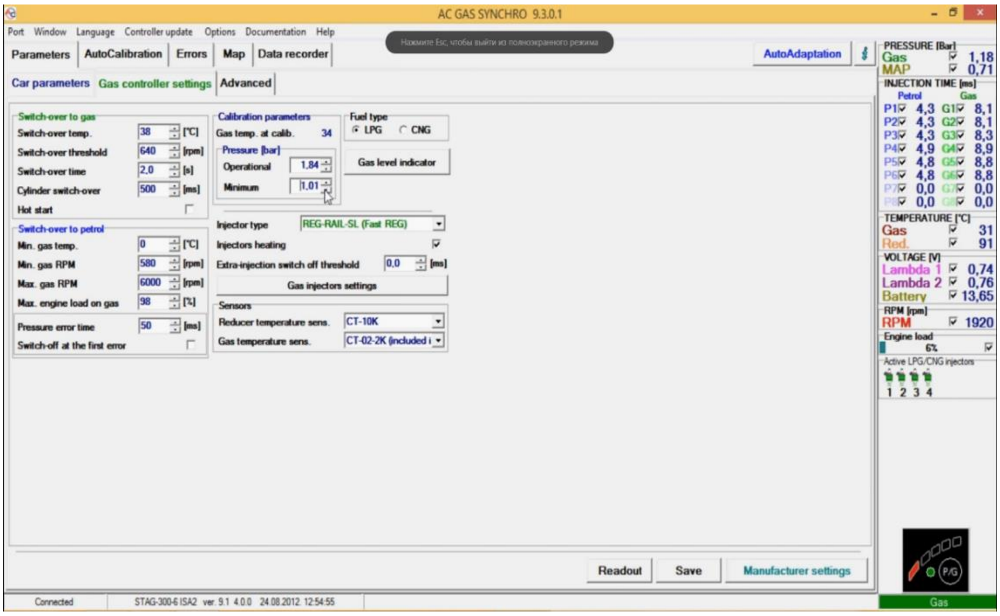


**Fig. 4.** "Gas controller settings" section of the AC GAS SYNCHRO 9.3.01 program that changes the gas - gasoline mode

Based on the above, the experts of the Department of "Transport Energy Devices" of the Tashkent State Transport University will vehicularly out an analytical experiment-test practice on improving the operational indicators and environmental safety of CNG vehicles equipped with the 4th generation GCE.

A Chevrolet Cobalt vehicle with an engine working volume of 1485 cm3 produced in 2021 was selected as the experimental test object. This vehicle, produced by the factory, is intended for gasoline fuel, and it is stated by the manufacturer that it consumes 8.4-10 liters of gasoline fuel in the city to cover a distance of 100 km [10]. This vehicle was retrofitted with 4th generation GCEs in June 2022 and has AC GAS SYNCHRO 9.3.01 firmware installed. It is specified that the gas mode starts at 38°C and the frequency of crankshaft revolutions is up to 6000 min-1 times per minute.

When the vehicle engine is started, it switches from gasoline to gas for 5-7 minutes, and in the engine load mode, it switches from gas to gasoline when the constant tachometer reading reaches 6000 min-1. As a result, gasoline consumption increases (Figure 5).

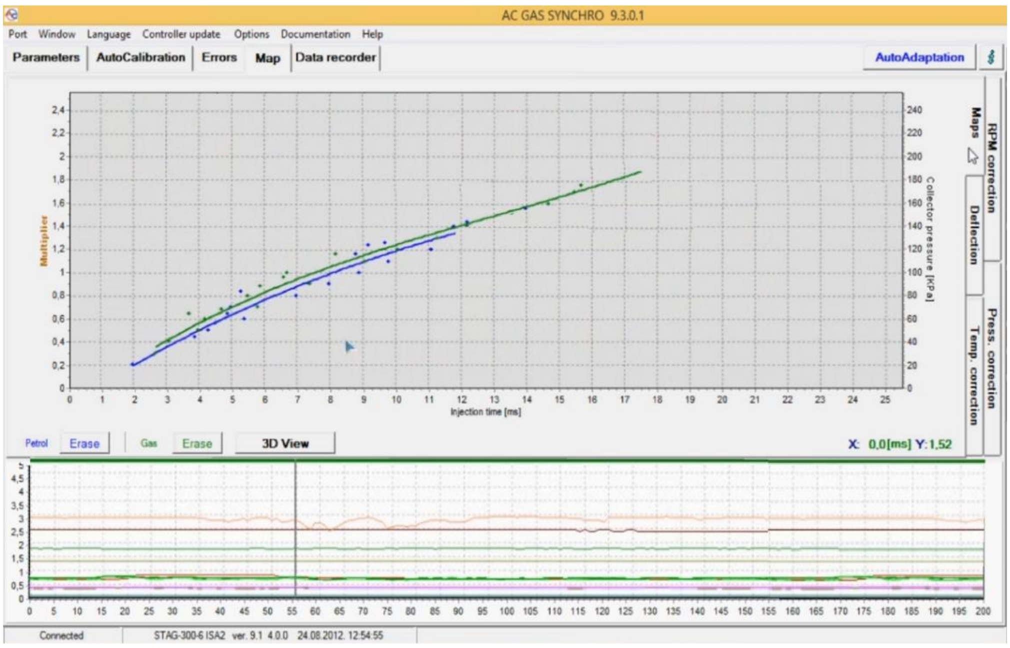


**Fig. 5.** The increase in gas consumption was observed in the gas-gasoline mode change graph

The optimal selection of the gas-gasoline mode changing indicators of the above-mentioned gas ECU has a great impact on the improvement of the operational indicators of gas cylinder vehicles and the efficiency of environmental safety indicators.
In this case, from the "Gas controller settings" section of the AC GAS SYNCHRO 9.3.01 program installed in the Chevrolet Cobalt GCE state, we change the "Switch-over time" indicator to 540 $min^{-1}$. This, in turn, leads to a change in the gas-gasoline mode switching cycle in the engine, i.e. the engine starts to work on gas fuel when the crankshaft reaches the set speed of 540 $min^{-1}$.
It is very important to choose GCE in accordance with the technical specifications of the car and to set the appropriate program settings in an optimal state in order to improve the performance indicators of gas cylinder cars and ensure their environmental safety.

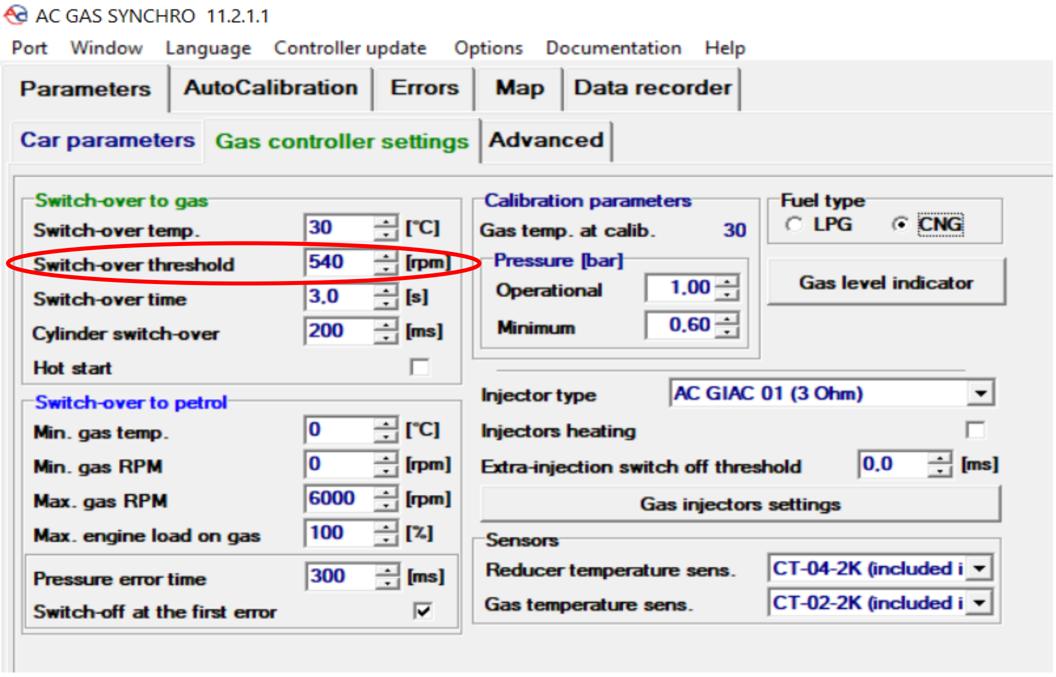


**Fig. 6.** Change of "Switch-over time" section of AC GAS SYNCHRO 9.3.01

## 4. Conclusion

In conclusion, the effective use of modern technologies used in the automobile industry and the operation of cars, which is rapidly developing today, will give high results in the further development of these areas. Making rational changes to the basic program of cars with electronically controlled universal (gas-petrol) supply system, taking into account the operating conditions, leads to improvement of their energetic and environmental indicators.

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