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# ANALYSIS OF THE CHARACTERISTICS OF NATURAL GAS AS FUEL FOR VEHICLES AND AGRICULTURAL TRACTORS

**Al-Maidi A. A.H.[1,3]*, Chernetsov D.A.[2], Rodionov Y.V.[3], Vdovina E.S.[4], Nikitin D.V.[3] and Mikheev N. V.[5]**

[1*,3] Plant Protection Dept.Coll. of Agriculture, University of Misan. Misan, Iraq.
[2]College of Engineering and Technology of, Land Transport. M.S. Solntseva, Russia.
[3]Department of Technical Mechanics and Machine Parts, Tambov State Technical University, Tambov, Russia.
[4]Department of Economics, Tambov State Technical University, Tambov, Russia.
[5]Michurinsky State Agrarian University, Russia.

## Abstract

The article explains the use of compressed natural gas Compressed Natural Gas (CNG) as engine fuel on modern diesel engines for internal combustion on both motor transport and agricultural machinery. The main characteristics of the elements in the natural gas are analyzed, which affect the combustion process and the parameters of the engine output. The results of the tests are given from foreign researchers, an analysis is made based on the conclusion about the quality of the gas supplied used As fuel for cars and agricultural tractors.

***Key words:*** fuel gas engine, diesel engine, diesel engine for gas, compressed natural gas, blast resistance, pressure ratio.

## Introduction

The fleet of vehicles in the Russian Federation operates on CNG is about 100 thousand cars, while the agricultural sector and tractor in the agricultural sector have a weak tendency to switch to diesel engine. This is mainly due to the weak network of gas stations, and the point is that the fleet of machinery and tractors with diesel gas engines has the worst performance in terms of fuel consumption compared to similar diesel engines in the workload.

The selection of suitable machines should be accompanied by a selection of the best cutters suitable for the withdrawal of these machines at the speed that suits them and the appropriate work. This will lead to increased productivity and reduce the cost of agricultural production, which is the main objective of most agricultural researchers with regard to fuel prices. Agricultural operations in the time available. Also, the problem of transport impact on the environment is one of the most important. In many cities, mobile sources of emissions in the atmosphere (road transport, road construction, agricultural machinery, etc.) are the main causes of environmental pollution.

The environmental category of vehicles of operational age is more than 10 years, as a general rule, with Euro 0: these cars have 5-10 times greater emissions of pollutants than those with a logical environmental category of Euro 3 and higher (Denisov, 2012).

Taking into account that economic utilitarian issues, as well as the logical environmental shift to alternative fuels are of paramount importance, achieving high fuel efficiency in the consumption of gas engines is a vital condition for successful expansion in the use of gas fuels. Determining the fuel price of a gas engine is lower than the price of diesel fuel, and contributes to the early transition to this type of fuel. Do not forget that Russia is the world's largest gas power with the largest reserves of natural gas.

Determining the optimal rules governing the process

***Author for correspondence :** E-mail : aa9090184@gmail.com

by designing and adjusting the engine parameters during the transmission of the diesel engine to the gas and diesel cycle in order to achieve the best fuel economy in agricultural operations, crop service and environment-friendly is one of the main problems today in the development of tractors.

## Quality gas supplied

There are currently around 80 models of cars and tractors, which are used as fuel for engines (HEMT) com preparing for natural gas (Gnedova *et al.*, 2015).

The standards for gas-powered devices, including tractors powered by compressed natural gas (CNG), originally for gas, have been modified on the gas transmission network (GTS). Therefore, in addition to the thermal value requirements for natural gas provided to consumers via CTA, normalization parameters determine the performance of gas and gas transmission equipment (because the potential content of acid gases, oxygen may cause corrosion, severe humidity - determine the capacities of gas hydrates) Determines thermal energy and adequate ejaculation resistance).

Gas fuel requirements (primarily to thermal value) in gas engines, ECE defines regulation 49 (UNECE, 2008). The use of reference fuel is regulated in a pilot study for "engine approval (engine family)" for the level of emissions of polluting gaseous substances, particulates and smoke.

According to these rules, the primary engine must be able to adapt to any fuel composition (*i.e.*, represented in the gas market) or only fuel-grade, during the CNG tests of CNG.

KPG (high calorie gas with tolerance corresponding to thermal value), which is introduced in the European market, is simulated with reference fuel during tests (Table 1).

**Table 1 :** Fuel Reference Characteristics.

| **Index** | **Reference fuel** | | |
|---|---|---|---|
| | **GR** | **G23** | **G25** |
| Component composition: | | | |
| Methane,% mol. | 84-89 | 92,5 | 86 |
| Ethane,% mol. | 13 | - | - |
| Nitrogen,% mol. | - | 7,5 | 14 |
| Inert gases,% mol. | 1 | 1 | 1 |
| Content of sulfur (no more), mg / m$^3$ | 10 | 10 | 10 |
| Lower calorific value, MJ / kg | 49,5 | 43,9 | 39,0 |
| The Wobbe lower number, MJ / m$^3$ | 50,2 | 43,4 | 39,2 |
| Lower heat of combustion, MJ/m$^3$ | 3,47 | 3,41 | 3,38 |
| Detonation resistance, MCH | 75,6 | 102 | 104,2 |

**Table 2:** Explosion resistance and pressure ratio of gas components.

| **Index** | **Gas** | | | |
|---|---|---|---|---|
| | **Methane** | **Ethane** | **Propane** | **Butane** |
| Critical compression ratio | 15 | 14 | 12 | 8 |
| Detonation resistance, MCH | 100 | 11 | 34 | 11 |

Thus, the quality limits of gas fuel are determined by the thermal value of the fuel male and the low explosion resistance of reference fuel 75 MF (Gnedova *et al.*, 2015).

One of the main factors determining the effective use of gas as fuel for cars and tractors is the explosion resistance, which is characterized by the number of methane (compared to the number of octane of gasoline, OCH). MCH shows the amount of $CH_4$ present in a mixture of methane and hydrogen, which begins to explode with the same pressure ratio as the gas being tested (Kirillov, 2008).

There is no procedure (globally recognized) that regulates the conditions and regulations for the determination of MCHs. MCH can vary from different calculation methods, from 5 to 8 units. (Gnedova *et al.*, 2011). When using gas from different sources, its thermal value (HTV) can also vary significantly. For example, when HTS for H-gas changes from 33.23 (G23 reference fuel) to 39.55 MJ/m$^3$ (GR), with a 16% increase, the explosion resistance drops from 100 to 72 Mh. Reduce the gas explosion resistance of the gas engine, first, reduce the pressure ratio of the engine that can operate without explosion (Table 2), fuel efficiency (Caterpillar Gas Engines, 2007). Second, it decreases the engine's rotation and power, where it can operate without detonation.

A study of the kinetic properties of alternative gaseous fuels was conducted in (Malenshek and Olsen 2009). According to the outcomes, the explosive resistance of the gaseous fuels was determined, with the components of their constituents ranged to a fairly wide range, and the serious pressure (ε) at which the detonation occurred (Table 3). The theoretical efficiency of the engine is determined by calculation, which can be attained using fuels with different detonation resistance.

The emission resistance of methane gas engine fuel is typically 70-90 mA, which links to a range of critical pressure ratios of 12 to 14. This can result in a change in engine efficiency of 0.62-0.65, or 4.6% (Gnedova *et al.*, 2015).

The impact of pressure on performance was confirmed by studies conducted on a multi-cylinder gas engine (Damrongkijkosol ). In particular, the effect of ε on engine performance parameters, economy and toxic

**Table 3:** Characteristics of gas samples.

| Name of gas | Component composition | | | | | MCH | Critical compression ratio |
|---|---|---|---|---|---|---|---|
| | $CH_4$,% | $H_2$,% | $N_2$, % | CO,% | $CO_2$,% | | |
| Synthesisgas (from PG) | 39,7 | 46,7 | 0,8 | 0,9 | 11,9 | 62,4 | 10,49 |
| Coal gas | 0 | 24,8 | 16,3 | 58 | 1 | 30,0 | 8,42 |
| Synthesis gas (tree) | 10 | 40 | 3 | 24 | 23 | 61,5 | 11,39 |
| Synthesis gas (tree) | 1 | 31 | 35 | 18 | 15 | 70,2 | 10,33 |
| Sewagegas | 60 | 0 | 2 | 0 | 38 | 139,1 | 17,6 |
| Landfill Gas | 60 | 0 | 0 | 0 | 40 | 139,6 | 17,6 |
| Synthesis gas (from PG) | 1,2 | 30,8 | 49 | 15,6 | 3,4 | 66,3 | 10,91 |
| Coal gas | 7 | 44 | 0 | 43 | 6 | 23,9 | 7,96 |

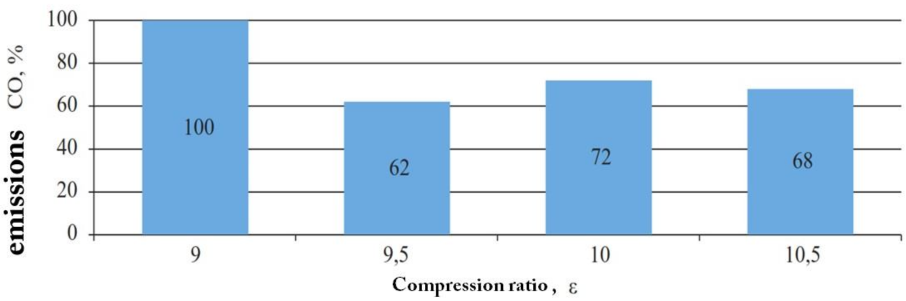


**Fig. 1:** Effect of pressure ratio on carbon monoxide emissions

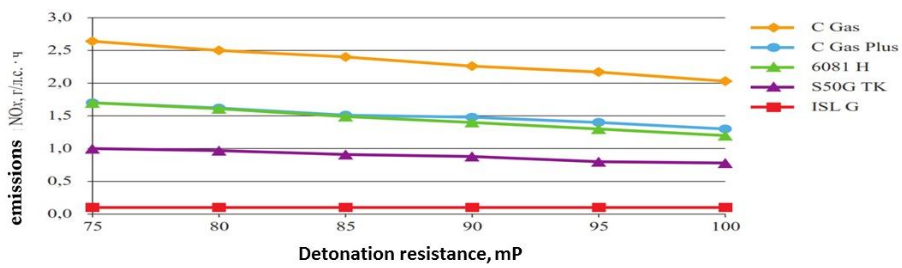


**Fig. 2:** Specific emissions of nitrogen oxides during engine operation on gas fuel with different detonation resistance.

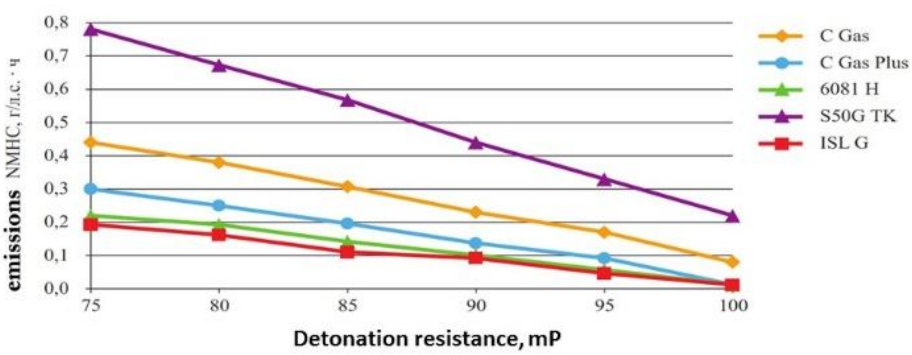


**Fig. 3:** Specific emissions of non-methane hydrocarbons when the engine is driven by gas fuel with different detonation resistance.

component emissions, on the ChaiyotDamrongkijkosol 2-liter engine, was investigated and converted to work on gas. Experiments were performed on four different values ε (9; 9.5; 10 and 10.5). When the ε value increased from 9 to 10.5, engine rotation increased by 5%. The fuel consumption of the gas engine is reduced with an increase in the pressure ratio of 5.5% and has a minimum at ε = 9.5.

As the pressure increases, the combustion process increases, resulting in a reduction in carbon monoxide emissions with approximately 38% engine exhaust gases, which ranges their minimum values at ε = 9.5 (Fig. 1).

The impact of Compressed Natural Gas CNG emission resistance on the poisonousness of exhaust gases for gas engines was studied by M. Feston (Feist and Deere 2009). The study was performed in five gas engines models: The Cummins ISL G (2007), Cummins C Gas Plus (2006), John Deere 6081H (2005), Detroit Diesel Series S50G TK (1999) and Cummins C Gas (1998) (Figs. 2 and 3) (Germany Country Report, 2012). Data indicate that emissions of toxic components with exhaust gases with an increase in MF are reduced to almost all types of engines.

Gas engine manufacturers concentrate initially on the quality of natural gas provided by the GTS to their areas of operation. Currently, the engine management system is based on microprocessor technology and has some adaptive capabilities. Usually equipped with a detonator, which, due to increased ignition timing, regulating control can be run on GMT timing with low detonation resistance.

Exhaust gas neutralization systems are equipped with an oxygen sensor (lambdasonde), which allows ideal maintenance of the catalyst when the quality of the CNG changes. The quality of Compressed Natural Gas CNG is consolidated in the international gas engine market according to the following criteria (Gnedova *et al.*, 2015; Gnedova *et al.*, 2015):

- ISO 15403 «Natural gas for use

as a compressed fuel for vehicles»

- ГОСТ 27577-2000 Compressed natural fuel gas for internal combustion engines. TU (standard of the Russian Federation);

  Transformed Thermometer (TUV) (RF Standard).

- J1616 1994 «Surface vehicle recommended practice – recommended practice for compressed natural gas vehicle fuel»

(The American standard developed by the SAE (Association of Motor Engineers);

- SAE J1616 (American Standard);
- CARB (specification CNG, USA, Calyalonia);
- DIN 51624 "Car Fuel and Natural Gas - Requirements and Testing Procedures" (German Standard);
- Legge 14 novembre 1995 481. "Disposizionigenerali in tema di qualita del gas natural" (the standard standard setting rules for network natural gas used for production of CNG)

Organization of the Polish Ministry of Economy on quality requirements for Compressed Natural Gas (CNG) (Polish Standard);

- GB 18047-2000 "CNG as fuel for vehicles" (Chinese Standard);
- Automobile fuel. - Biogas as fuel for high-speed otto engines »

(The standard of compressed methane used as fuel for vehicles (types A and B), developed by the Swedish Institute of Standardization, which was adopted on 15 September 1999 and is internationally recognized in European countries);

- PCD 3 (2370) C "Compressed Natural Gas (CNG) for automotive purposes" Specification "(India standard);
- PNS 2029: 2003 "Natural Gas Used as Compressed Fuel for Vehicles - Specification" (Philippine Standard);
- 10K/34/DDJM/1993 (Decree of the Director-General of Oil and Gas, dated 1 February 1993) (Indonesia Standard).

Standardization criteria for compressed natural gas used in vehicles, which are reflected in national standards, are summarized in International Standards Organization ISO 15403.

Part 1 of ISO 15403-1 defines the performance requirements of natural gas to ensure a safe and reliable operation of gas filling equipment and gas-powered equipment. The second part of ISO 15403-2 defines the requirements for quantitative parameter values, and normalizes the quality of natural gas as fuel for vehicles.

An important necessity for the operational safety of gas fuel is the requirement of low water content, in the presence of which in mixture with the acidic components (H) may corrode the gas cylinder (which in combination with cyclic changes in pressure (gasoline - consumption) Damage and destruction). Moreover, the condensation of water in liquid or solid state or the formation of gas hydrates can cause clogging in the fuel system. Thus, the dew point of the aquatic phase must be in the gas outlet for the gas or Compressed Natural Gas (CNG) mobile gas without the lowest working temperature that will be the fuel stations and vehicles (Broomhall *et al.*, 2011).

The maximum water content of the gas in which the gas should be drained at the Compressed Natural Gas Compressed Natural Gas CNG (at the maximum pressure of the cylinder) is determined taking into account regional climatic conditions.

Heavy hydrocarbons in natural gas can condense in the gaseous state, at pressure and temperatures that characterize the use of Compressed Natural Gas CNG, which can disrupt the compressor and form a two-phase mixture. This will result in a gas injection violation to inject the engine and will have a negative impact on its operation. All rubber components are also exposed to unfavorable effects of heavy hydrocarbon condensates. ISO 15403 determines the formation of the liquid phase C (at the maximum pressure of Compressed Natural Gas CNG and the surrounding ambient temperature) not exceeding 1% (Stoffen, 2009).

Vehicles containing gray can corrode the metal parts of the equipment. The reduction of total sulfur content reduces the toxicity of exhaust gases and avoids acid poisoning in the exhaust gas neutralization catalyst.

The gas engines CAT and Cummins limit sulfur content in Compressed Natural Gas Compressed Natural Gas Compressed Natural Gas Compressed Natural Gas Compressed Natural Gas CNG at 10 ppm (10 mg / kg), which meets Euro-5 requirements for sulfur content in automotive fuel (Chiu, 2005).

Methanol can cause corrosive discs with natural gas and damage to fuel system components. In accordance with ISO 15403, methanol may not be added to natural gas at gas filling stations. Natural gas should not contain glycol or methanol. Fuel must not contain solids.

The potential content of oil in natural gas should not have a negative impact on the reliability of the vehicle. It is recommended to use filters on the fuel supply line of the tractor. It is important that dust particles do not enter compressed gas cylinders. It should be noted that for this purpose, the United States Standard for Compressed Natural Gas CNG SAE J1616 recommends the installation of filters with permissible values for mechanical impurity particles:

- On the refueling connector - 40 microns;
- Injection and regulator system - 5 microns.
- Injections - 1 micron.

The size of the allowable particle impurities, established by ISO 15403-2 (according to the occupied area of the gas supply system), from 400 (at the entrance) to 1 µm (in front of the injection).

In standards GOST 27577-2000, DIN 51624 and SS 155438, the minimum allowable level of KPG explosion resistance is determined by the number of octane and methane (calculated by component composition).

In GB 18047-2000 and ISO 15403, this parameter is not unified, but calculation methods are provided for OCH and MF calculations. In some standards, gas density is normalized.

The second set of indicators mostly regulates the content of inert gas, methane, propane and butane in KPG.

The inert gas content ($CO_2$, N) in KPG is normalized in 11 out of 12 criteria considered. Normally, the carbon content does not exceed 3%, and the maximum price (5%) is set by the standard 10K/34/DDJM/1993. It should be noted that this standard aims to use domestic Compressed Natural Gas CNG gas which contains a large amount of Inert ingredients have a relatively small amount of methane, and to ensure the desired thermal value, a large amount of hydrocarbons is left higher in it.

The combustible components of Compressed Natural Gas CNG are normalized in 6 out of 12 revised standards.

The content of methane in Compressed Natural Gas CNG is, as a general rule, 85-99% (the minimum allowable content of SN is the development of DIN standards 51624 (80%) and 10 K/34/DDJM/1993 (62%) (Josten, 2009).

In particular, in Indonesia, natural gas contains a small amount of methane. In Germany the filling stations with L-methane gas content are close to 80%. For other countries, natural gas that has large amounts of inserts, methane content of 85 (Philippines) and 88% (CA).

The possible content of ethane in CPG is limited to standard PCD 3 (2370) C (8%) and CARB specification (6%). The highest level of propane in the CPG group is the standards of promissory notes 2029: 2003 (12%), 10K / 34 / DDJM / 1993 (8%), DIN 51624 (6%. The maximum level of butane for the development of promissory notes CPG 2029: 2003 (4%) and 10 K/34/DDJM/1993 (4%).

Climate conditions allow these states to have high levels of propane and butane in KPD without loss in the liquid phase. The content of butane in Compressed Natural Gas CNG standards in other countries is limited to 1.8-4%.

The content of pentane in DIN 51624 and 10 K/34 / DDJM/1993 is limited to 1 and 4%, respectively. The ratio of hexane and hydrocarbons is limited to 0.2-0.5%. The allowed content is regulated at 0.1%.

## Conclusion

Based on the analysis, it can be clearly concluded that the best environmental and technical-economic performance of engines as a whole is achieved in Greenwich with high explosion resistance.

Fuel parameters for gas engines must be within the limits set by CNG's compressed natural gas standards. Thus, when observing higher thermal energy values, the engine temperature can be observed while energy is low at low values.

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