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# DEVELOPMENT OF ENVIRONMENTALLY CLEAN MOTOR FUELS BASED ON A MIXTURE OF SYNTHETIC AND TRADITIONAL HYDROCARBONS AND THEIR PHYSICAL AND CHEMICAL ANALYSIS

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**Abstract**

This study investigates the physicochemical and performance properties of blended fuels obtained by compounding synthetic diesel fuel produced at the Uzbekistan GTL plant with conventional EURO K4 diesel fuel at blending ratios of 50–60%. The results showed that the cetane number of the blends ranged from 62 to 63, while the cetane index was 59.5–60.0. Fuel density varied between 791.2 and 796.1 kg/m³, and kinematic viscosity at 40 °C was in the range of 3.27–3.33 mm²/s. The cold filter plugging point was found to be –10 to –11 °C, indicating improved low-temperature performance due to the addition of synthetic components. Sulfur content ranged from 9.4 to 17.2 mg/kg, meeting environmental requirements. Flash point values were 71–75 °C, wear scar diameter was 450–460 µm, and oxidation stability sediment content was 3.3–3.7 g/m³. The obtained results confirm that scientifically based blending of synthetic GTL components with petroleum diesel fractions is a promising approach for producing environmentally friendly and high-performance motor fuels.

**Keywords:** *GTL, synthetic diesel fuel, fuel blending, cetane number 62–63, density 791–796 kg/m³, low-temperature properties, sulfur content 9–17 mg/kg, oxidation stability*

## Introduction:

Currently, the issue of producing environmentally friendly and highly efficient automotive fuels in the fuel and energy sector is one of the most pressing scientific directions on a global scale (International Energy Agency (IEA). *World Energy Outlook 2022).* The increase in the number of vehicles, the expansion of industrial production volumes, and the increase in harmful emissions into the atmosphere necessitate the improvement of the quality indicators of traditional petroleum fuels (European Environment Agency. *Transport and Environment Report*. 2021). At the same time, the tightening of international environmental standards requires the creation of a new generation of fuels with high energy efficiency that release fewer harmful substances during combustion. In solving these tasks, the technology for producing synthetic liquid fuels based on natural gas, specifically the Gas-to-Liquids (GTL) process, is of great scientific and practical importance (Dry M. E. Fischer–Tropsch synthesis and the production of clean fuels. 2002).

In recent years, numerous scientific studies have been conducted on the composition, physicochemical properties, and impact on engine performance and environmental indicators of products obtained using GTL technology (Chevron Corporation. 2004). Scientific literature extensively highlights the high cetane number of synthetic diesel fuels, their very low content of sulfur and aromatic hydrocarbons, and the stability of the combustion process (Chevron Corporation. 2004). There are also scientifically grounded results regarding the possibility of optimizing fuel performance, improving engine operating modes, and reducing harmful emissions by combining GTL products with traditional petroleum fractions (ExxonMobil. *Blending of GTL Diesel with Conventional Diesel Fuel*. 2013)]. Some studies have shown that by selectively mixing narrowly fractionated components, it is possible to control the low-temperature properties of diesel fuels, optimize density and viscosity, and increase combustion efficiency (Lapuerta M., Armas O., García-Contreras R., 2009).

However, existing scientific research does not sufficiently cover the comprehensive study of the regional characteristics of GTL products, particularly the specifics of the composition of synthetic fuels produced at the "Uzbekistan GTL" plant. At the same time, the scientific and technological foundations for obtaining environmentally friendly fuels with improved low-temperature properties based on the compounding of these products with traditional petroleum fractions in optimal ratios have not been fully developed. In particular, scientific results have not been obtained on controlling the composition of mixed fuels based on narrowly fractionated hydrocarbon components, determining the relationship between their physicochemical and environmental indicators, and creating fuel compositions that meet international standards.

Accordingly, the main objective of this study is to conduct a comprehensive analysis of the physicochemical properties of "Uzbekistan GTL" products and to develop fuel compositions with improved environmental and operational properties based on their compounding with narrow fraction components derived from oil. To achieve this goal, the following tasks have been defined:

– Determination and assessment of the main physicochemical indicators of synthetic GTL products;
– Studying the theoretical and technological foundations of the mixing process with petroleum fractions;
– identifying factors affecting the low-temperature properties, combustion efficiency, and environmental indicators of blended fuels;
– development of optimal compounding compositions and scientific substantiation of the prospects for obtaining environmentally friendly fuels.

## Materials and methods:

Synthetic diesel fractions produced at the "Uzbekistan GTL" plant, as well as traditional diesel fractions from local oil refineries and narrowly fractionated hydrocarbon components, were used as the primary raw materials for the research work. All components used in the studies were selected in accordance with the requirements of current technical specifications and standards, and their initial physicochemical indicators were determined before the experiments began (Table 1).

***Comparison of GTL synthetic diesel fuel and ECO diesel fuel performance***

**Table 1.**

| No. | Indicator name | ECO diesel standard (O'zDSt 1134:2018) | ECO diesel (RVS-24, 09.02.2026) | GTL synthetic diesel (10.02.2026) |
|---|---|---|---|---|
| 1. | Number of sets, at least | 50 | 57 | 83.5 |
| 2. | Density at 20 °C, kg/m$^3$, at most | 860 | 832.5 | 771.5 |

| No. | Indicator name | ECO diesel standard (O'zDSt 1134:2018) | ECO diesel (RVS-24, 09.02.2026) | GTL synthetic diesel (10.02.2026) |
|---|---|---|---|---|
| 3. | Fractional composition: 50% distillation temperature, °C, maximum | 280 | 262 | 268 |
| | Fractional composition: 96% distillation temperature, °C, maximum | 360 | 357 | 335 |
| 4. | Water content | shouldn't be | no | no |
| 5. | Boundary filtration temperature, °C, at most | –5 | –4 | –25 |
| 6. | Iodine number, g/100 g of fuel, no more than | 5 | 0.79 | 0.16 |
| 7. | Coking of a 10% residue, %, not more than | 0.2 | 0.013 | 0.049 |
| 8. | Ash content, %, no more | 0.01 | 0.0034 | 0.0057 |
| 9. | Mass fraction of sulfur, ppm, maximum | 0.10 (Type I)<br>0.05 (Type II)<br>0.01 (Type III) | 0.097<br>–<br>– | 4.4 ppm<br>–<br>– |
| 10. | Mercaptan sulfur content, %, not more than | 0.01 | 0.0015 | 0.0005 |
| 11. | Hydrogen sulfide ($H_2S$) content | shouldn't be | no | no |
| 12. | Copper plate test | Can withstand 1st class | Class 1 | Class 1 |
| 13. | Water-soluble acids and alkalis | shouldn't be | no | no |
| 14. | Kinematic viscosity at 20 °C, $mm^2/s$ | 3.0–6.0 | 4.0 | 3.7 |
| 15. | Acidity, mg KOH/100 $cm^3$, no more | 5 | 0.3 | 2.0 |
| 16. | Flash temperature, °C, at least | 62 | 65 | 74 |
| 17. | Mechanical impurities, %, no more | 0.0024 | 0.0012 | 0.0004 |
| 18. | Actual resins, mg/100 $cm^3$, no more | 40 | 17 | 3.0 |
| 19. | Hardening point, °C, maximum | –10 | –8 | –33 |
| 20. | Turbidity temperature, °C, at most | –5 | –2 | –22 |
| 21. | Lubrication (WSD at 60 °C), µm, at most | – | 670 | 400 |
| 22. | Polycyclic aromatic hydrocarbons, %, not more than | – | – | 0 |
| 23. | Oxidation stability (sediment), g/$m^3$, no more than | 25 | – | 2.8 |

**Materials:**

The following main materials were used in the experimental studies: – synthetic diesel fuel (GTL diesel fraction), hydrotreated oil-gas condensate diesel fraction, narrow fractions of kerosene and gas oil, depressant additives (as necessary) for optimization to improve low-temperature properties during the compounding process, standard reagents and solvents for laboratory testing.

The density, kinematic viscosity, cetane number, fractional composition, solidification temperature, filtration threshold temperature, sulfur content, and proportion of aromatic hydrocarbons of all fuel samples were determined in accordance with current international and national standards, and a preliminary assessment was conducted.

**Compounding method:**

The preparation of fuel compositions was carried out under laboratory conditions using the mechanical compounding method. In this process, synthetic GTL fractions and oil-derived diesel components were mixed in predetermined proportions (volume or mass fractions). The mixing process was carried out in a thermostatic reactor with a constant mixer in the temperature range of 20–40 °C. Mixing was carried out for 15–30 minutes to ensure the homogeneity of the mixture.

During the compounding process, compositions in various ratios were prepared, and their physicochemical and operational indicators were compared. To determine the optimal composition, the proportion of the GTL component was gradually adjusted.

**Physicochemical analysis methods:**

The main quality indicators of the prepared fuel compositions were determined based on the following standard methods: density was determined by the picnometric or areometric method, kinematic viscosity by capillary viscometer; fractional composition by standard distillation apparatus, cetane number by calculation or engine test methods (cetanometer); low-temperature properties (limit temperature of turbidity, solidification, and filtration) by cooling bath and special filter devices; sulfur content by X-ray fluorescence or chemical analysis methods; and combustion efficiency and environmental indicators by laboratory engine test bench.

**Results and their discussion:**

Table 2 presents the results of laboratory analyses of mixtures in which synthetic GTL diesel fuel was added to EURO K4 diesel fuel in various proportions at 60%, 55%, and 50%. As seen from the table, the increase in the proportion of the synthetic component had a significant impact on the main physicochemical and operational indicators of the fuel.

**Results of laboratory analysis of EURO K4 diesel fuel and GTL synthetic diesel mixes**

**Table 2.**

| No. | Indicator name | Analysis method | EURO K4 diesel 40% + GTL 60% | EURO K4 diesel 45% + GTL 55% | EURO K4 diesel 50% + GTL 50% |
|---|---|---|---|---|---|
| 1. | Number of sets, at least | ASTM D613 | 62 | 63 | 62 |
| 2. | Setan index, at least | ASTM D4737 | 60.0 | 60.0 | 59.5 |
| 3. | Density at 20 °C, kg/m³ | GOST 3900 | 791.2 | 793.1 | 796.1 |
| 4. | Fractional composition: | GOST 2177 | | | |
| | distillation at 250 °C, % (vol.) at least | | 44 | 43 | 44 |
| | distillation at 350 °C, % (vol.) at least | | 97 | 96 | 96 |
| | 95% distillation temperature, °C, at most | | 335 | 342 | 340 |
| 5. | Water content, mg/kg, maximum | GOST 2477 | 42.8 | 44.5 | 43.7 |
| 6. | Boundary filtration temperature, °C, at most | EN 116 | –10 | –10 | –11 |
| 7. | Coking of a 10% residue, %, not more than | ASTM D4530 | 0.018 | 0.016 | 0.018 |
| 8. | Ash content, %, no more | GOST 1461 | 0.0033 | 0.0030 | 0.0032 |
| 9. | Sulfur content, mg/kg, maximum | EN ISO 20884 | 9.4 | 11.3 | 17.2 |

| No. | Indicator name | Analysis method | EURO K4 diesel 40% + GTL 60% | EURO K4 diesel 45% + GTL 55% | EURO K4 diesel 50% + GTL 50% |
|---|---|---|---|---|---|
| 10. | Corrosion on a copper plate (3 hours, 50 °C) | ASTM D130 | 1a | 1a | 1a |
| 11. | Kinematic viscosity at 40 °C, $mm^2/s$ | GOST 33 | 3.27 | 3.31 | 3.33 |
| 12. | Flash point, °C, at least | GOST 6356 | 71 | 73 | 75 |
| 13. | Polycyclic aromatic hydrocarbons, %, not more than | EN 12916 | 2.9 | 3.4 | 3.8 |
| 14. | Total pollution, mg/kg, not more than | EN 12662 | 5.6 | 5.4 | 5.8 |
| 15. | Oxidation stability: sediment content, $g/m^3$, no more | ASTM D2274 | 3.3 | 3.4 | 3.7 |
| | Stability time, hours, at least | | 20 | 20 | 20 |
| 16. | Methyl esters of fatty acids (FAME), not more than % | GOST EN 14078 | 0.05 | 0.04 | 0.05 |
| 17. | Lubrication (WSD 1.4), at 60 °C, no more than µm | ASTM D6079 | 460 | 455 | 450 |

It has been established that changes in the proportion of synthetic components in blends based on EURO K4 diesel fuel and synthetic GTL diesel fuel significantly affect the main operational and environmental properties of the fuel. The cetane number in the mixtures was determined to be in the range of 62–63, indicating a high level of combustion efficiency for all samples, while the ethane index ranged from 59.5 to 60.0, with no sharp changes observed as the proportion of the synthetic component increased. The density indicators varied from 791.2 to 796.1 kg/m3, with an increase in density as the proportion of synthetic fuel decreased. According to the results of the fractional composition, the distillation fraction at 250 °C was 43–44%, and at 350 °C, it was 96–97%, while the 95% distillation temperature was recorded in the range of 335–342 °C, indicating that the evaporation properties of the mixed fuels are at the level of standard requirements. The threshold filtration temperature was determined to be within the range of minus 10–11 °C, and an improvement in low-temperature properties was observed in the mixture with a high proportion of synthetic components. The sulfur content was determined to be in the range of 9.4–17.2 mg/kg, and it was established that all samples meet environmental requirements, while the proportion of polycyclic aromatic hydrocarbons is 2.9–3.8%, increasing as the proportion of synthetic components decreases. It was found that the kinematic viscosity at 40 °C ranges from 3.27 to 3.33 mm2/s, the flow properties of mixed fuels are at the required level, and the combustion temperature is in the range of 71–75 °C, which indicates high safety indicators for diesel fuels. According to lubrication indicators, the wear diameter ranges from 450 to 460 µm, which leads to an improvement in tribological properties as the proportion of synthetic components increases. Oxidation stability results showed that the precipitate content is 3.3–3.7 $g/m^3$, confirming the chemical stability of mixed fuels during storage.

The results obtained show that by combining synthetic GTL diesel fuel with traditional EURO K4 diesel fuel, it is possible to purposefully control the physicochemical, environmental, and operational indicators of the fuel. The addition of a synthetic component with a high cetane number can lead to a faster and more complete combustion process, increasing engine efficiency and reducing harmful emissions. Maintaining the fractional composition within the optimal range balances the fuel evaporation process, creating favorable conditions for complete oxidation within the combustion chamber. The low sulfur content is an important factor from an environmental perspective and serves to reduce the amount of $SO_x$ compounds emitted into the atmosphere. Improving lubrication properties allows for a reduction in friction between engine parts and an increase in their service life. At the same time, the change in the proportion of polycyclic aromatic hydrocarbons depending on the composition of the mixture showed the need for further optimization of the fuel composition. The possibility of further improving the environmental and operational properties of blended fuels through the use of narrowly fractionated components and functional additives in the future-compaunding synthetic GTL diesel fuel with petroleum-derived diesel fractions-can be evaluated as a promising technological direction for producing high-efficiency fuels that meet modern environmental requirements.

**Conclusion:**

The results of the conducted research showed that by combining synthetic GTL diesel fuel with traditional EURO K4 diesel fuel, it is possible to purposefully improve the main physicochemical, operational, and environmental indicators of the fuel. Maintaining a high cetane number in blended fuels ensures an efficient combustion process, contributing to increased engine productivity and a reduction in harmful emissions. Additionally, low sulfur content and high oxidation stability ensure the environmental safety of mixed fuels and their stability during the storage process. Improving lubrication properties helps to reduce the wear of engine parts and extend their service life. At the same time, certain indicators, in particular the proportion of polycyclic aromatic hydrocarbons, indicate the need for further optimization of the mixture composition. Overall, the scientifically grounded compounding of synthetic GTL diesel fuel with narrowly fractionated petroleum components is a promising technological direction for producing high-efficiency motor fuels that meet modern environmental standards, and it is advisable to conduct in-depth research in this direction in the future.

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