Experimental studies of gasoline petroleum fractions

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Abstract. The results of experimental studies of gasoline and petroleum fractions are discussed in the article, as well as their main physical and chemical properties, density and pressure of saturated vapors, liquid phase, two-phase region, critical region, and boundary curves. The article is recommended for agricultural specialists, researchers, teachers, graduate students, undergraduates, and students of agricultural universities in the field of "Agricultural Engineering".

1. Introduction
The issues of ensuring the reliability, cost-effectiveness and environmental safety of mobile equipment are relevant for many economy sectors where such equipment is used. Therefore, solving these issues by choosing the fuel of optimal quality is of constant interest for agricultural production. Road transport is widely used in agricultural production, it operates in rather difficult conditions. The transport is moving when moving out from the crop fields in difficult road conditions and usually without having a hard surface. At present, 6275 gasoline-powered cars are operating in the Krasnodar Territory, so increasing their operational performance, such as service life, fuel efficiency and environmental safety, is highly relevant.

2. Main physical and chemical properties of the fractions
The following gasoline fractions from three different fields were selected as objects of study: 110-120°C, 105-140°C, IBP-180°C, 180-240°C of the Mangyshlak oil; IBP-180°C of Troitsko-Anastasevskaya oil and IBP-180°C of a mixture of West Siberian oil.

Detailed characteristics of these oils are presented in the scientific literature [1, 2, 3]. A characteristic feature of the Mangyshlak oil is its high paraffin content, as a result of which it has a high setting point, low sulfur content and a large number of resinous substances.

The oils of Western Siberia significantly vary in quality depending on the timed deposits. These are mainly high sulfur oils.

Troitsko-Anastasevskaya oil of the pool IV is a heavy low-paraffin, low-sulfur oil, contains few gasoline fractions. Naphthenic hydrocarbons prevail in fractions of this oil boiling off at temperatures above 120°C; in oil fractions, more than half of the composition is a mixture of aromatic and naphthenic hydrocarbons.

The IBP-180°C fraction of West Siberian oil was obtained from an industrial unit, the remaining fractions were obtained by distillation in an industrial thermophysical laboratory on a specially manufactured apparatus with a distillation column equipped with an adiabatic shell.
The main physicochemical properties and distillation of the studied fractions according to GOST 2177-66 are given in table 1.

Relative density \( \rho^2 \) was determined according to Russian State Standard GOST 3900-85 with a constant volume pycnometer, refractive index \( n^D_0 \) was defined using IRF-22 type refractometer, modular mass \( M \) was determined by cryoscopic method in benzene. \( T_{I.B.} \) and \( T_{E.B.} \) were determined using the Engler apparatus according to Russian State Standard GOST 2177-66, group hydrocarbon composition was defined by the method of fluorescence-indicator analysis.

The table shows that all the considered fractions are similar in their hydrocarbon composition. Apparently, this is common for the gasoline fractions of many oils. In the fractions of the Troitsko-Anastasevskaya oil, which are boiling under 180°C, the naphthene content is 2.5-3 times higher than that of the similar fractions in the Mangyshlak and West Siberian oils.

Table 1. The main physical and chemical properties and distillation of fractions according to Russian State Standard GOST 2177-66.

| Property                          | Fraction boiling limit, °C |
|----------------------------------|----------------------------|
|                                  | 110-120 Mangyshlak | 105-140 Mangyshlak | HK-180 Mangyshlak | 180-240 Mangyshlak | IBP-180 Tr.-An. | IPB-180 West Siberian |
| Refractive index, \( n^D_0 \)    | 1.4105         | 1.4172         | 1.4170         | 1.4395         | 1.4135         | 1.4135 |
| Density, \( \rho^2 \)            | 0.7322         | 0.7454         | 0.7444         | 0.7897         | 0.7552         | 0.7385 |
| Molecular mass, m                | 108            | 119.5          | 118            | 160            | 120            | 110     |
| Volumetric average boiling point | 119.9          | 124.9          | 130.9          | 204.7          | 121.6          | 120     |
| The content of paraffins and naphthenes, % | 91.2          | 88.2           | 87.2           | 90.1           | 96.5           | 90.6    |
| Aromatic hydrocarbon content, %  | 8.8            | 11.8           | 12.8           | 9.9            | 3.5            | 9.4     |

| Boiling, % volumetric | Temperature, °C |
|-----------------------|-----------------|
| 0                    | 185             |
| 10                   | 197             |
| 20                   | 199.5           |
| 30                   | 201             |
| 40                   | 202             |
| 50                   | 203.5           |
| 60                   | 205             |
| 70                   | 207             |
| 80                   | 210             |
| 90                   | 214.8           |
| 100                  | 223             |

The content of paraffins and naphthenes, %

| Boiling, % volumetric | Temperature, °C |
|-----------------------|-----------------|
| 0                    | 65              |
| 10                   | 81              |
| 20                   | 103             |
| 30                   | 112             |
| 40                   | 119             |
| 50                   | 125             |
| 60                   | 131             |
| 70                   | 135             |
| 80                   | 140             |
| 90                   | 148             |
| 100                  | 157             |
3. Density and SVP

Various thermodynamic surface sections of fr. IBP-180°C of Mangyshlak oil are given in this section for illustration purposes. The dependency graphs of the remaining fractions are similar and therefore are not given.

3.1. Liquid phase

The P-V-T dependence of the oil fractions is represented in Figure 2. It can be seen that isotherms at low temperatures are in the form of slightly inclined curves. With temperature increasing, the value of the derivative increases. In order to coordinate the experimental data and eliminate possible measurement errors, the isotherms and isobars were jointly plotted on the graphs. The monotonicity of the thermodynamic surface of the state confirmed the reliability of the obtained experimental data [4, 5, 6].

3.2. Two-phase field

The isotherms of fractions in P-V coordinates are presented in Figure 3.

As can be seen from the figure, all isotherms have the form of weakly inclined lines in the two-phase field, the slope of which increases with increasing temperature and pressure. The largest value isotherms have near the left boundary curve. Apparently, this is due to the fact that the volatile components of the fraction, which have the highest value of saturated vapor pressure, are first boiled.
Away in the two-phase field. In the center of the two-phase field and near the right boundary curve at low temperatures, isotherms are close in shape to isobars.

**Figure 2.** P-V-T dependence of the IBP-180°C fraction of Mangyshlak oil.

Where: Isotherms (equal temperature lines): 1 - t=130°C; 2 – t=180°C; 3 – t=230°C; 4 – t=280°C; 5 – t=300°C; 6 – t=305°C; 7 – t=310°C. Isobar (equal pressure lines): 8 – P=3 MPa; 9 – P=5 MPa.

In the P-V coordinates, all the studied fractions, regardless of their width, have approximately the same binodal shape, i.e. the boiling range for different fractions on the same isotherms did not differ significantly. The values of specific volumes and pressures on the saturation lines for various fractions at a temperature of t=180°C are presented in Table 2.

**Table 2.** Specific volumes and pressure on the saturation lines of oil fractions.

| Name                  | G', cm³/g | G'', cm³/g | P', MPa | P'', MPa |
|-----------------------|-----------|------------|---------|----------|
| 110-120°C Mangyshlak oil | 1.711     | 44.5       | 4.39    | 4.10     |
| 105-140°C Mangyshlak oil | 1.671     | 43.5       | 4.18    | 3.90     |
| HK-180°C Mangyshlak oil | 1.672     | 37.0       | 5.12    | 4.70     |
| HK-180°C Tr.-An. oil  | 1.643     | 38.1       | 5.78    | 5.04     |
| HK-180°C West-Siberian oil | 1.705     | 38.0       | 6.43    | 5.80     |
The clear correlation between the distance between saturation lines and the fraction width was observed in the P-T coordinates. The wider the fraction, the greater the distance. This is clearly seen from table 2.

The pressure drop across the saturation lines for the widest fraction (IBP-180°C of West Siberian oil) at the 180°C isotherm is 2.5 times greater than for the narrowest fraction. These differences increase even more with increasing temperature [7,8].

3.3. Boundary curves

Boundary NK-180°C curves of Mangyshlak oil represented in Figure 3 and Figure 4 in P-V and P-T coordinates were obtained as a result of graphic processing of large-scale graphs, the resolution of which corresponded to the accuracy of obtaining experimental data.

![Figure 3. IBP-180°C fractions isotherms of Mangyshlak oil.](image-url)
The sharp bends on the isotherms disappeared in the immediate vicinity of the critical point. Therefore, the graphs were plotted in logarithmic and double logarithmic coordinates, but the error in distinguishing points of the boundary curves increased.

**Figure 4.** Boundary curves of IBP-180°C fractions, where: 1 - Upper Boundary Curve, 2 - Lower boundary curve.

**Figure 5.** Left boundary curve of the IBP-180°C fraction of Mangyshlak oil, where: Isotherms (equal temperature lines): 1 - \( t=130 \)°; 2 – \( t=180 \)°; 3 – \( t=230 \)°; 4 – \( t=280 \)°.
The singled-out fragment of the left boundary curve is presented in Figure 5 on an enlarged scale. The right border curve was singled out similarly. Such graphs were plotted for all fractions. In addition to the sharp bend, the points on the boundary curves were determined by min functions in PV-P coordinates.

The density single-out error on the left boundary curve is approximately 2 times larger than the measurement error and increases up to 3-4 times. For the right boundary curve, this error is 3-5 times higher than the measurement error.

It was noted that the left boundary curve has an S-shape, but less pronounced than the right one. For all fractions, the inflection region of the left boundary curve (except for the 180-240 °C fractions of the Mangyshlak oil) lies in approximately the same temperature 180-200 °C range. This characteristic bend is clearly visible in Figure 5.

3.4. Critical region

In order to reduce the error in constructing the boundary curves in the critical region using the obtained results, large-scale \( \rho - t \) graphs were plotted for all fractions. With the help of them, an attempt was made to determine the critical temperature and critical density. Figure 6 is presented as an illustration, from which it is seen that the allocation of critical parameters is associated with uncertainty due to the variation of \( \rho \) values on the saturation line near the critical point. The relative maximum error in determining critical temperatures for the studied fractions was ± 0.04± 0.05%. The values of critical densities were determined using the same graphs. For this, the rule of rectilinear diameter was used. The relative maximum determination error was ± 0.5± 1% for all fractions. Critical pressure values were determined using graphs in P-V coordinates. The parameters were determined for all samples considered, except for the 180-240°C fraction of Mangyshlak oil.

The critical parameters obtained such way were subsequently used in a preliminary generalization of the experimental data.
4. Conclusions
According to the aforementioned, the following conclusions can be drawn:
1. In order to obtain high-quality fuel for gasoline engines used in agriculture, IBP-180 fractions of Mangyshlak and Troitsko-Anastasevskaia oils are required.
2. The distillation of the fractions must be carried out under normal conditions in accordance with the refractive index, density, molecular weight, volume average boiling point, the content of paraffins and naphthenes, and the content of aromatic hydrocarbons.
3. Gasoline engines are much cheaper than diesel engines in terms of operation and repair, which saves money on repair and maintenance work.
4. Due to the fact that the use of diesel fuel is more expensive than gasoline, it is more profitable for agricultural enterprises to use gasoline-powered cars as a technological transport, which will reduce production costs and increase their competitiveness [9, 10].

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