GENERALIZATION OF EXPERIMENTAL DATA ON THE THERMAL
CONDUCTIVITY OF PETROLEUM FRACTIONS

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In papers [1-3] experimental data were given on the thermal conductivity \( \lambda \) of narrow (10 and 25\(^\circ\)) and broad fractions of the high-paraffin Mangyshlak petroleum of the Uzen' deposit.

In order to generalize the results obtained we make use of the theory of corresponding states. It is well known that among the real substances, groups exist for which the law of corresponding states is satisfied with sufficient accuracy. It will be shown that an investigation of the fractions of Mangyshlak petroleum establishes a group of approximately similar substances as they are related as to composition and their thermophysical properties vary in the same way [3]. In this case, according to the law of corresponding states, for a range of variation of parameters within which the pressure influence on thermal conductivity can be neglected, the following relation will hold true:

\[
\lambda = \lambda_0 \varphi (\tau),
\]

here \( \lambda_0 \) is a constant specific for each substance and \( \varphi (\tau) \) is a universal (general) function for approximately similar substances; when experimental data on the thermal conductivity of petroleum fractions are to be generalized, the problem is to determine this function: \( \tau = T / T_X \) is the reduced temperature and \( T_X \) is the characteristic temperature.

An analysis of our experimental results [1-3] showed that for a generalization of the experimental data on \( \lambda \) of fractions of the Mangyshlak petroleum their mean boiling point can be used with sufficient accuracy as the characteristic temperature.

Figure 1 illustrates the experimental data on the thermal conductivity of 37 narrow and 6 broad fractions of Mangyshlak petroleum in a temperature range from 20 to 200\(^\circ\)C using the coordinates \( \lambda^* = \lambda_T / \lambda_0 \), \( \tau = T / T_{\text{boll}} \).

The values of \( \lambda_T = 0.7 \) are the \( \lambda \) values at the reduced temperature \( \tau = 0.7 \) obtained from the condition of narrowing the interval of extrapolation of experimental data (the thermal conductivity data considered in the paper refer to petroleum fractions with greatly differing boiling points, from 50\(^\circ\)C to 500-550\(^\circ\)C). Based on our experimental material in the temperature range from 20 to 200\(^\circ\)C it proved necessary to choose \( \tau \) in such a way that, in order to obtain \( \lambda_T \) in the

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**Fig. 1.** Generalized dependence of thermal conductivity of petroleum fractions. a) Fraction of Mangyshlak petroleum; b) fraction of Ozeksuat petroleum; c) normal paraffin hydrocarbons.

**Fig. 2.** Dependence of \( \lambda_T = 0.8 \) on the mean boiling point: 1) normal paraffin hydrocarbons; 2) fraction of Ozeksuat petroleum; 3) fraction of Mangyshlak petroleum.

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Fig. 3. Generalized dependence of thermal conductivities of petroleum fractions in the coordinates $\lambda_T / \lambda_T = 0.31$, $\beta T$: a) fraction of Mangyshlak petroleum; b) fraction of Ozeksuat petroleum; c) normal paraffin hydrocarbons.

An analysis of the data given in Fig. 1 shows that the greatest deviation of the experimental points on the thermal conductivity of the Mangyshlak petroleum fractions from the generalizing dependence

$$\lambda^* = 1,550 - 0.913 \tau + 0.1 \tau^2,$$

obtained by the method of least squares does not exceed 2.5% the rms deviation is 1%. It is thus justified to assume the fractions of the Mangyshlak petroleum to be approximately similar.

We also plotted in a reduced-coordinate system the results of thermal conductivity investigations of narrow fractions of high-paraffin Ozeksuat petroleum [4, 5] and paraffin hydrocarbons of normal structure [6, 7] being the main constituents of these fractions of both types of petroleum. Here the maximum deviation of the experimental $\lambda$ values from the generalizing relation (2) does not exceed 3%.

It was not possible to process the results of investigating $\lambda$ of petroleum fractions by other authors as no data on their mean boiling points were available.

The method suggested thus permits a sufficiently accurate (up to 3%) extrapolation of thermal conductivity from one experimental point in the temperature range of 20-200°C.

In connection with the above-said it is interesting to compare the thermal conductivities of limiting hydrocarbons of normal structure and the fractions of the above petroleum types at a certain reduced temperature (Fig. 2).

As shown by the authors of [6-8], with normal paraffins between $n = 5$ and $n = 9$ ($n$ being the number of carbon atoms in the molecule) the thermal conductivity can be observed to decrease rapidly as $n$ increases. For all hydrocarbons with $n \geq 10$ at the corresponding reduced temperatures a constant value was obtained for the coefficient of thermal conductivity: $\lambda_T = 0.8 = 0.120 \text{ W/m} \cdot \text{deg}$.

An analysis of the data presented in Fig. 2 shows that for the fractions of the Mangyshlak and Ozeksuat petroleum types, the thermal conductivity coefficient varies in the same way, that is, $\lambda_T = 0.8$ decreases as the mean boiling point of the fraction increases (up to $\sim 130^\circ$C for the Mangyshlak petroleum and $\sim 120^\circ$C for the Ozeksuat petroleum) and then remains constant in the entire temperature range in which $\lambda_T = 0.1070 \text{ W/m} \cdot \text{deg}$ and for the Ozeksuat petroleum $\lambda_T = 0.1125 \text{ W/m} \cdot \text{deg}$. A certain drop of $\lambda_T$ of the fractions compared with the thermal conductivity of normal paraffins can obviously be explained by the presence of aromatic and naphthene hydrocarbons in the fractions, as well as limiting hydrocarbons of isomeric structure, which, as is well known, have a lower thermal conductivity than the hydrocarbons of normal structure.

Besides the considered method of generalizing the experimental data on $\lambda$ of petroleum fractions, the temperature dependence of the density $\beta$ can also be used to obtain the characteristic temperature. The processing of experimental $\lambda$ data of 37 narrow and 6 broad fractions of Mangyshlak petroleum in the coordinates $\lambda_T / \lambda_T = 0.31$, $\tau = \beta T$ is shown in Fig. 3. The same coordinate system was used to process the experimental data on $\lambda$ of narrow fractions of the Ozeksuat petroleum and of normal paraffin hydrocarbons [9]. As was to be expected, the generalized dependence is described by an equation obtained by the author [9]:

$$\lambda^* = 1,728 - 2,348 \tau'.

This method is most expedient to apply in order to process experimental data on the thermal conductivities of broad fractions and final petroleum products whose boiling point is difficult to determine. This problem, however, requires further investigation.

The investigations carried out showed that the law of corresponding states can be applied successfully when experimental results on the thermal conductivity of petroleum products are to be generalized; here the data on their chemical composition can be taken as a criterion of approximate similarity.