Thermal conductivity of R-32/R-125 (40/60 wt. %) mixture in the vapor phase

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Abstract. The gaseous thermal conductivity of binary mixture of R-32/R-125 (40/60) was measured with a coaxial cylinders method in the temperature range of 305–426 K and the pressure range of 0.1–1.8 MPa. The thermal conductivity as a function of pressure and temperature was considered. The correlations for thermal conductivity on dew line and in ideal gas state are presented.

1. Introduction
The well-known R-32 and R-125 refrigerants are used both in pure form and in the form of components of binary mixtures. Mixtures based on these components have gained popularity due to the fact that they meet the basic requirements for the working substances of refrigeration and heat pump technology. They are low toxic, non-explosive, and show high efficiency. The ozone-depleting potential of R-32/R-125 mixtures is zero. These mixtures are used as substitutes for the forbidden freons R-12 and R-22.

Measuring thermal conductivity in the mixtures of refrigerants is important both for direct use and for the preparation of generalizing equations for various engineering calculations. This work investigates a mixture of refrigerants with 40.3 mass % R-32 (difluoroethane) and 59.7 mass % R-125 (pentafluoroethane). The thermal conductivity values for this mixture in the vapor phase are obtained experimentally. Also, calculations of thermal conductivity in the state of ideal gas and on the dew line are performed depending on the temperature.

2. Experiments
The mixture of R-32/R-125 (40/60) was prepared in the laboratory by the weight technique. Samples of R-32 refrigerants from Russia with a purity of 99.9% and R-125 from China with a purity of 99.5% were taken. These components were used without further purification. The limit composition error was 0.05 wt. %.

Thermal conductivity was measured with a stationary coaxial cylinders method. The apparatus and procedure were described in detail in [1–3]. The coaxial measuring cell consisted of an inner cylinder and an outer cylinder, thus providing an annular gap of 0.366 ± 0.005 mm. The outer cylinder was 140 mm in length, and the length of the inner one was 101.3 mm. Copper–constantan thermocouples were used to measure the temperature of the cylinders and the temperature difference between them. Corrections were entered to take into account the influence of free ends on value of thermal conductivity [1]. Installation was calibrated against 99.998 vol. % pure argon. The measured values
are consistent with published data and this confirms that the apparatus function within the total experimental error.

Before starting the experiment the system was vacuumed up to a pressure of 1.5–2.0 Pa. To preserve the composition of the mixture under study, the measuring cell was filled up with a liquid phase [3]. The error of the experimental data on the thermal conductivity was equal to 1.5–2.5%, while that on the temperature was 0.05 K and that on the pressure was within 4 kPa.

3. Results
The measured values of the thermal conductivity of the binary mixture of R-32/R-125 (40/60) were obtained in the temperature range from 305 to 426 K and by pressures from 0.1 to 1.8 MPa. Seventy four experimental points were obtained along 9 quasi-isotherms. These data are shown in table 1.

Table 1. Experimental thermal conductivity of R-32/R-125 mixture.

| T (K)  | p (MPa) | \( \lambda \) (mW(mK)) | T (K)  | p (MPa) | \( \lambda \) (mW(mK)) | T (K)  | p (MPa) | \( \lambda \) (mW(mK)) |
|--------|---------|------------------------|--------|---------|------------------------|--------|---------|------------------------|
| 305.67 | 0.176   | 13.92                  | 335.32 | 1.833   | 18.49                  | 381.35 | 1.790   | 21.40                  |
| 305.68 | 0.407   | 14.17                  | 351.28 | 0.132   | 17.58                  | 396.19 | 0.129   | 21.31                  |
| 305.69 | 0.547   | 14.34                  | 351.31 | 0.440   | 17.84                  | 396.30 | 0.341   | 21.42                  |
| 305.98 | 0.614   | 14.72                  | 351.51 | 0.725   | 18.13                  | 396.19 | 0.605   | 21.62                  |
| 305.66 | 0.849   | 14.81                  | 351.53 | 0.903   | 18.30                  | 396.38 | 0.849   | 21.82                  |
| 305.68 | 0.944   | 14.95                  | 351.57 | 1.121   | 18.47                  | 396.31 | 1.099   | 22.06                  |
| 323.56 | 0.155   | 15.38                  | 351.48 | 1.303   | 18.80                  | 396.11 | 1.469   | 22.34                  |
| 323.46 | 0.298   | 15.42                  | 351.44 | 1.522   | 18.83                  | 396.39 | 1.620   | 22.47                  |
| 323.34 | 0.603   | 15.85                  | 351.35 | 1.498   | 18.97                  | 396.33 | 1.754   | 22.60                  |
| 322.98 | 0.917   | 16.06                  | 351.36 | 1.794   | 19.39                  | 411.31 | 0.128   | 22.69                  |
| 322.99 | 0.917   | 16.06                  | 368.80 | 0.126   | 18.87                  | 411.35 | 0.445   | 22.93                  |
| 323.02 | 0.929   | 16.07                  | 368.79 | 0.303   | 19.04                  | 411.49 | 0.666   | 23.09                  |
| 323.02 | 1.024   | 16.22                  | 368.81 | 0.527   | 19.23                  | 411.51 | 0.977   | 23.30                  |
| 323.72 | 1.117   | 16.60                  | 368.54 | 0.792   | 19.44                  | 411.23 | 1.236   | 23.49                  |
| 323.75 | 1.421   | 17.13                  | 368.57 | 1.093   | 19.71                  | 411.24 | 1.691   | 23.84                  |
| 323.73 | 1.738   | 17.83                  | 368.33 | 1.348   | 19.97                  | 426.87 | 0.124   | 23.87                  |
| 335.71 | 0.160   | 16.41                  | 368.29 | 1.604   | 20.27                  | 426.79 | 0.344   | 24.07                  |
| 335.77 | 0.284   | 16.40                  | 368.29 | 1.776   | 20.47                  | 426.77 | 0.349   | 24.06                  |
| 335.66 | 0.444   | 16.51                  | 381.55 | 0.123   | 19.94                  | 426.63 | 0.587   | 24.22                  |
| 335.71 | 0.689   | 16.81                  | 381.59 | 0.441   | 20.25                  | 426.55 | 0.852   | 24.46                  |
| 335.59 | 1.006   | 17.20                  | 381.52 | 0.691   | 20.40                  | 426.74 | 0.980   | 24.48                  |
| 335.59 | 1.183   | 17.43                  | 381.53 | 0.921   | 20.61                  | 426.67 | 1.165   | 26.64                  |
| 335.62 | 1.436   | 17.77                  | 381.55 | 1.101   | 20.72                  | 426.82 | 1.364   | 24.72                  |
| 335.55 | 1.478   | 17.82                  | 381.38 | 1.289   | 20.93                  | 426.75 | 1.652   | 24.95                  |
| 335.57 | 1.806   | 18.38                  | 381.35 | 1.538   | 21.14                  |

The initial data were approximated by the following dependence [2, 3]:

\[
\lambda(T, p) = a_0 + a_{10} \frac{T}{100} + a_{20} \frac{100}{T} + p \left[ a_{11} \frac{T}{100} + a_{21} \frac{100}{T} \right] + p^2 \left[ a_{12} \frac{T}{100} + a_{22} \frac{100}{T} \right],
\] (1)
where \( T \) is the temperature in K, \( p \) is the pressure in MPa, and \( \lambda \) is the thermal conductivity in mW/(m K)\(^1\). The values of the \( a_{ij} \) coefficients are given in Table 2. The standard deviation of the obtained experimental data from equation (1) is within 0.5%.

### Table 2. Coefficient of equation (1).

| Coefficient indices, \( ij \) | 0     | 10    | 20    | 11    | 21    | 12    | 22    |
|------------------------------|-------|-------|-------|-------|-------|-------|-------|
| Coefficient value, \( a_{ij} \) | -32.809 | 11.161 | 38.640 | 0.175 | 0.203 | -0.234 | 3.783 |

The figure 1 presents the experimental values of the thermal conductivity reduced to the same temperatures (isotherms) and the data fitted according to equation (1). As can be seen in the figure 1 the thermal conductivity of the mixture under study increases in fact linearly along isotherms with the increase in pressure.

![Figure 1. Thermal conductivity of binary mixture of vapors of R-32/R-125 (40/60). The points are the experimental values; the lines are equation (1).](image)

Based on the experimental data, the thermal conductivity on the condensation line (\( \lambda_d \)) and thermal conductivity in an ideal gas state (\( \lambda_0 \) at a pressure \( p_0 = 0.101325 \) MPa) were determined. The calculations were performed by two ways. In the first, the thermal conductivity of the vapors of the R-32/R-125 (40.3/59.7) mixture on isotherms was extrapolated to the pressure on the condensation line and to \( p_0 \). In the second method, the calculations were performed according to the generalizing equation (1). The data on the dew line pressure required for the calculations were taken from [4]. A comparison of the calculations by these two methods has shown that the values coincide within the random error of 0.04–1.23% for \( \lambda_d \) and 0.07–0.15% for \( \lambda_0 \). In order to ensure the uniformity of the description of the properties within the whole parameter range the second calculation method was chosen.

The values obtained for \( \lambda_d \) were approximated by the following dependence

\[
\lambda_d = b_1 + b_2 T + b_3 T^2,
\]

where \( b_1 = 129.439, b_2 = -0.923, b_3 = 0.00182. \)
In the same way, the following dependence was obtained for $\lambda_0$

$$\lambda_0 = c_1 + c_2 T + c_3 / T,$$

(3)

where $c_1 = -32.809$, $c_2 = 0.1118$, $c_3 = 3869.9$. Figure 2 illustrates the thermal conductivity of binary mixture R-32/R-125 (40/60) in ideal-gas state.

![Figure 2. The thermal conductivity of mixture R-32/R-125 (40/60) in the ideal-gas state.](image)

The $\lambda_0$ value for the mixture under study was calculated in additive approximation on the basis of the experimental data according to the ideal-gas thermal conductivity of the pure components, R-32 [4] and R-125 [4] (figure 2). The relative deviations of the calculated values from the experimental ones were within 0.1–2.1%.

Conclusions
Experimental data on the thermal conductivity of binary mixture of R-32/R-125 (40/60) in the vapor state within the temperature range of 305–426 K and the pressure range of 0.1–1.8 MPa have been obtained for the first time. It was noted that the approximating equation (1) is valid for calculating the thermal conductivity of an R-32/R-125 (40/60) mixture in a wide range of the state parameters: from ideal gas to the dew line.

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