Vapor thermal conductivity of R-125/R-134a (84.6/15.4) mixture

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Abstract. The vapors thermal conductivity of binary mixture R-125/R134a (84.6/15.4) was measured with a coaxial cylinders method in the temperature range of 305–412 K and the pressure range of 0.1–1.7 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
Mixtures containing pentafluoroethane (R-125) and 1,1,1,2-tetrafluorethane (R-134a) are considered as alternatives to replace forbidden chlorine-containing refrigerants. The growing industrial interest to use of new mixtures has led to need to study their thermophysical properties. These properties are necessary for the practical use of such mixtures, and therefore are of particular importance for scientists and engineers involved in refrigeration technology.

The binary mixture studied in this work includes the constituents R-125 and R-134a with mass fractions of 84.6 and 15.4%, respectively. The values of the thermal conductivity for this mixture in the vapor phase were obtained experimentally, and the temperature dependence of the thermal conductivity in the state of ideal gas and on the dew line was calculated.

2. Experiments
Freon R-125 was supplied by China and was 99.5% pure. R-134a was from Forane (France) and had a purity of 99.9%. These components were used without further purification. The mixture was prepared by the weight technique. The limit weighing error was 0.1 g.

Thermal conductivity was measured with a stationary coaxial cylinders method. The apparatus and procedure have been 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 inner was 101.3 mm. Copper–constantan thermocouples were used to measure the temperature of the cylinders and the temperature difference between them. The influence of the free ends on the thermal conductivity values was accounted by entering the respective corrections [1]. Installation was calibrated against 99.998 vol. % pure argon. The measured values are in agreement with previously published data and we can conclude that the present apparatus operates within the total experimental error.

The setup was vacuumed up to a pressure of 1.5–2.0 Pa before the experiment. To avoid variations in the mixture composition, the measuring cell was filled up with the liquid phase [3]. The uncertainty
in the experimental data on the thermal conductivity, temperature and pressure were estimated to be within 1.5–2.5%, 0.05 K and 4 kPa, respectively.

3. Results
Experimental data on the thermal conductivity of binary mixture R-125/R134a (84.6/15.4) were obtained in the temperature range of 305–412 K and pressure range of 0.1–1.7 MPa. The thermal conductivity was measured in the vapor phase along six quasi-isotherms. Table 1 shows the experimental thermal conductivity.

Table 1. Experimental thermal conductivity of R-125a/R-134a mixture.

| T, K  | p, MPa | λ, mW/(mK) | T, K  | p, MPa | λ, mW/(mK) |
|-------|-------|------------|-------|-------|------------|
| 306.05| 0.151 | 13.41      | 349.42| 1.457 | 18.42      |
| 306.32| 0.158 | 13.44      | 372.35| 0.154 | 18.81      |
| 305.99| 0.247 | 13.52      | 372.29| 0.421 | 19.09      |
| 305.81| 0.274 | 13.47      | 372.30| 0.660 | 19.29      |
| 305.67| 0.370 | 13.79      | 371.84| 0.993 | 19.97      |
| 305.78| 0.392 | 13.64      | 372.09| 0.993 | 19.97      |
| 305.98| 0.393 | 13.66      | 372.03| 1.122 | 19.59      |
| 305.66| 0.495 | 13.95      | 372.18| 1.446 | 20.01      |
| 323.03| 0.247 | 14.99      | 372.17| 1.623 | 20.24      |
| 322.83| 0.491 | 15.28      | 396.40| 0.292 | 20.74      |
| 322.83| 0.614 | 15.39      | 396.31| 0.545 | 20.99      |
| 322.84| 0.614 | 15.40      | 396.66| 0.775 | 21.04      |
| 322.83| 0.635 | 15.42      | 396.50| 0.996 | 21.30      |
| 322.88| 0.857 | 15.62      | 396.53| 1.292 | 21.59      |
| 323.16| 1.062 | 15.99      | 396.46| 1.482 | 21.77      |
| 322.74| 1.309 | 16.32      | 396.40| 1.503 | 21.74      |
| 322.74| 1.447 | 16.62      | 396.32| 1.708 | 21.97      |
| 322.73| 1.447 | 16.65      | 411.81| 0.285 | 21.80      |
| 349.59| 0.153 | 17.04      | 411.80| 0.577 | 22.07      |
| 349.58| 0.398 | 17.24      | 411.77| 0.823 | 22.26      |
| 349.58| 0.614 | 17.44      | 411.75| 1.087 | 22.48      |
| 349.43| 1.018 | 17.88      | 411.82| 1.396 | 22.74      |
| 349.41| 1.268 | 18.19      | 411.73| 1.683 | 22.95      |

The measurement results were approximated by the empirical dependency [2, 3]:

\[
\lambda(T, p) = a_0 + a_{10} \frac{T}{100} + a_{20} \frac{100}{T} + p \left( a_{11} \frac{T}{100} + a_{21} \frac{100}{T} \right) + p^2 \left( a_{12} \frac{T}{100} + a_{22} \frac{100}{T} \right),
\]

where \( T \) is the temperature in K, \( p \) is the pressure in MPa, and \( \lambda \) is the thermal conductivity in mW/(mK). The values of the \( a_{ij} \) coefficients are presented in Table 2. The standard deviation of the obtained experimental data from those according to equation (1) is within 0.5%.

Table 2. Coefficient of equation (1).

| Coefficient indices, ij | 0  | 10 | 20 | 11 | 21 | 12 | 22 |
|-------------------------|----|----|----|----|----|----|----|
| Coefficient value, \( a_{ij} \) | 7.284 | 5.369 | –32.099 | 0.00104 | 3.633 | –0.0971 | 1.388 |
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 the thermal conductivity of the mixture under study along isotherms increases in fact linearly along isotherms with the increase in pressure.

![Figure 1](image.png)

**Figure 1.** The vapors thermal conductivity of binary mixture R-125/R134a (84.6/15.4): the points are the experimental values; the lines are equation (1).

The thermal conductivity on the condensation (dew) line, \( \lambda_d \), and the thermal conductivity in the ideal-gas state, \( \lambda_0 \) (at \( p_0 = 0.101325 \) MPa), were determinate by two methods. The first method was the extrapolation of the isotherms of the R-125/R-134a (84.6/15.4) vapor thermal conductivity to the dew line and the second was calculation according to the generalizing equation (1). The data on the vapor pressure on the condensation line were taken from [4]. The comparison of two methods showed that the thermal conductivity values coincide within the limits of random error of 0.4–2.3% for the \( \lambda_d \) and 0.03–0.75% for the \( \lambda_0 \). Thus to maintain the uniformity of the properties description within the whole parameter range the second calculation method was selected. It was obtained for \( \lambda_d \) that

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

where \( b_1 = 4.430, b_2 = -0.0689, b_3 = 3.410 \times 10^{-4} \). The vapor pressure and the thermal conductivity on the dew line are given in Table 3.

**Table 3.** R-125/R-134a (84.6/15.4) thermal conductivity on the dew line.

| \( T, \) K | \( p_{d\kappa}, \) MPa | \( \lambda_{d\kappa}, \) mW/(mK) |
|--------|----------------|----------------|
| 300    | 1.2428         | 14.46          |
| 310    | 1.6162         | 15.85          |
| 320    | 2.0688         | 17.31          |
| 330    | 2.6136         | 18.84          |
| 340    | 3.2712         | 20.44          |
From equation (1) for $\lambda_0$ following dependence was obtained

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

(3)

where $c_1 = 7.284$, $c_2 = 0.0537$, $c_3 = -3171.65$. Figure 2 illustrates the thermal conductivity of binary mixture R-125/R-134a (84.6/15.4) in ideal-gas state.

The value of $\lambda_0$ for the studied mixture was calculated in the additive approximation on the basis of the experimental data according to the ideal-gas thermal conductivity of the pure components, R-125 [4] and R-134a [4] (Figure 2). The differences in $\lambda_0$ between additive approximation and those from equation (3) averaged 1–3.5%.

**Conclusions**

Experimental data on the thermal conductivity of binary mixture R-125/R-134a (84.6/15.4) in the vapor state within the temperature range of 306–426 K and the pressure range of 0.1–1.6 MPa were obtained for the first time. It was established that the approximating equation (1) is suitable for calculating the thermal conductivity of an R-125/R-134a (84.6/15.4) mixture in a wide range of the state parameters: from ideal gas to the dew line.

**References**

[1] Verba O I and Gruzdev V A 2002 Thermophys. Aeromech. 9 445
[2] Verba O I, Raschektaeva E P and Stankus S V 2012 High Temp. 50 200
[3] Verba O I, Raschektaeva EP and Stankus SV 2014 High Temp 52 135
[4] Lemmon E W, McLinden M O and Huber M L 2002 NIST Standard Reference Database 23: Reference Fluid Thermodynamic and Transport Properties — REFPROP, Version 8.0. Standard Reference Data Program, Gaithersburg, Maryland, United States: National Institute of Standards and Technology