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**17584**

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## Refrigerant properties

*Propriétés des fluides frigorigènes*

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Reference number  
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## Foreword

ISO (the International Organization for Standardization) is a worldwide federation of national standards bodies (ISO member bodies). The work of preparing International Standards is normally carried out through ISO technical committees. Each member body interested in a subject for which a technical committee has been established has the right to be represented on that committee. International organizations, governmental and non-governmental, in liaison with ISO, also take part in the work. ISO collaborates closely with the International Electrotechnical Commission (IEC) on all matters of electrotechnical standardization.

The procedures used to develop this document and those intended for its further maintenance are described in the ISO/IEC Directives, Part 1. In particular, the different approval criteria needed for the different types of ISO documents should be noted. This document was drafted in accordance with the editorial rules of the ISO/IEC Directives, Part 2 (see [www.iso.org/directives](http://www.iso.org/directives)).

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights. Details of any patent rights identified during the development of the document will be in the Introduction and/or on the ISO list of patent declarations received (see [www.iso.org/patents](http://www.iso.org/patents)).

Any trade name used in this document is information given for the convenience of users and does not constitute an endorsement.

For an explanation of the voluntary nature of standards, the meaning of ISO specific terms and expressions related to conformity assessment, as well as information about ISO's adherence to the World Trade Organization (WTO) principles in the Technical Barriers to Trade (TBT), see [www.iso.org/iso/foreword.html](http://www.iso.org/iso/foreword.html).

This document was prepared by Technical Committee ISO/TC 86, *Refrigeration and air-conditioning*, Subcommittee SC 8, *Refrigerants and refrigeration lubricants*.

This second edition cancels and replaces the first edition (ISO 17584:2005), which has been technically revised.

The main changes are as follows:

- Addition of new refrigerants (R290, R600a, R1233zd(E), R1336mzz(Z), R1234yf, R1234ze(E));
- Update of Ammonia.

Any feedback or questions on this document should be directed to the user's national standards body. A complete listing of these bodies can be found at [www.iso.org/members.html](http://www.iso.org/members.html).

## Introduction

This document is consistent with and is intended to complement ISO 817. The purpose of this document is to address the differing performance ratings due to the differences between multiple property formulations, which is a problem especially in international trade. The fluids and properties included in this document represent those for which sufficient high-quality data were available.

This document allows for “alternative implementations” for the properties. These can take the form of simpler equations of state that may be applicable over limited ranges of conditions or simple correlations of single properties (e.g., expressions for vapour pressure or the enthalpy of the saturated vapour).

Tolerances in this document do not necessarily represent the uncertainty of the original experimental data or of the equation of state in fitting the data.

The tolerances are relative (i.e. plus or minus a percentage) for some properties and absolute for others (e.g. plus or minus a constant enthalpy value). Properties such as enthalpy and entropy, which can be negative, demand an absolute tolerance; any allowable percentage variation would be too strict at values near zero. The allowable tolerances for enthalpy and entropy are scaled by the enthalpy and entropy of vapourisation for each fluid. By scaling the tolerance to the vapourisation values, a greater tolerance is allowed for fluids, such as ammonia, with high heats of vapourisation.

The tolerances apply to individual thermodynamic states. In cycle and equipment analyses, it is the differences in enthalpy and/or entropy between two different states that are important. However, it is not possible to specify, in a simple way, allowable tolerances based on pairs of states because of the large number of possible pairs of interest.

The values of  $C_v$  and  $C_p$  approach infinity at the critical point, but the actual values returned by the equation of state are large numbers that vary from computer to computer due to round-off errors in the calculations. According to critical-region theory, the speed of sound is zero at the critical point; all traditional equations of state (including the ones in this document), however, do not reproduce this behaviour. Rather than list values that are inconsistent with either the theory or the specified equations of state, these points are not included as part of this document.

The values of the gas constant,  $R$ , vary from fluid to fluid. Similarly, the number of significant values given for the molecular mass,  $M$ , vary. The various values of  $R$  differ by less than  $5 \times 10^{-6}$  (equal to parts per million, a deprecated unit) from the currently accepted value of 8,314 462 618 J/(mol·K) and result in similarly small differences in the properties. The compositions of the refrigerant blends (R400- and R500-series) are defined on a mass basis, but the equations of state are given on a molar basis. The mass compositions have been converted to the equivalent molar basis and listed in [Clause 5](#); a large number of significant values are given for consistency with the tables of “verification values” given in [Annex D](#).

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# Refrigerant properties

## 1 Scope

This document specifies the thermophysical properties of several commonly used refrigerants and refrigerant blends.

This document is applicable to refrigerants R12, R22, R32, R123, R125, R134a, R143a, R152a, R290, R600a, R717 (ammonia), R744 (carbon dioxide), R1233zd(E), R1336mzz(Z), R1234yf and R1234ze(E) and to the refrigerant blends R404A, R407C, R410A, and R507A. The following properties are included: density, pressure, internal energy, enthalpy, entropy, heat capacity at constant pressure, heat capacity at constant volume, speed of sound, and the Joule-Thomson coefficient, in both single-phase states and along the liquid-vapour saturation boundary. The numerical designation of these refrigerants is that defined in ISO 817.

NOTE 1 R12, R22, R123 are controlled substances under the Montreal Protocol, [Annex A](#) (R12) or [Annex C](#) Group I (R22, R123).

NOTE 2 R32, R125, R134a, R143a, R152a, R404A, R407C, R410A, and R507A are controlled substances under the Montreal Protocol, Annex F or blend thereof.

## 2 Normative references

There are no normative references in this document.

## 3 Terms and definitions

For the purposes of this document, the following terms and definitions apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- ISO Online browsing platform: available at <https://www.iso.org/obp>
- IEC Electropedia: available at <https://www.electropedia.org/>

### 3.1

#### algorithm

procedure for the computation of refrigerant properties

Note 1 to entry: An algorithm is most often a computer program. An algorithm may also consist of one or more single-property correlations as allowed under [4.4](#).

### 3.2

#### blend

mixture of two or more chemical compounds

### 3.3

#### critical point

state at which the properties of the saturated liquid and those of the saturated vapour become equal

Note 1 to entry: Separate liquid and vapour phases do not exist above the critical point temperature for a pure fluid. This is more completely referred to as the “gas-liquid critical point” as other “critical points” can be defined.

### 3.4

#### **equation of state**

mathematical equation that is a complete and thermodynamically consistent representation of the thermodynamic properties of a fluid

Note 1 to entry: An equation of state most commonly expresses pressure or Helmholtz energy as a function of temperature, density, and (for a blend) composition. Other thermodynamic properties are obtained through integration and/or differentiation of the equation of state.

### 3.5

#### **fluid**

#### **refrigerant**

substance, present in liquid and/or gaseous states, used for heat transfer in a refrigerating system

Note 1 to entry: The fluid absorbs heat at a low temperature and low pressure, then releases the heat at a higher temperature and a higher pressure, usually through a change of state.

### 3.6

#### **liquid-vapour saturation**

state at which liquid and vapour phases of a fluid are in thermodynamic equilibrium with each other at a common temperature and pressure

Note 1 to entry: Such states exist from the triple point to the critical point.

### 3.7

#### **transport properties**

viscosity, thermal conductivity, and diffusion coefficient

### 3.8

#### **thermodynamic properties**

density, pressure, fugacity, internal energy, enthalpy, entropy, Gibbs and Helmholtz energies, heat capacities, speed of sound, and the Joule-Thomson coefficient, in both single-phase states and along the liquid-vapour saturation boundary

### 3.9

#### **thermophysical properties**

thermodynamic, transport, and other miscellaneous properties

### 3.10

#### **triple point**

state at which solid, liquid, and vapour phases of a substance are in thermodynamic equilibrium

## **4 Calculation of refrigerant properties**

### **4.1 General**

This document specifies properties for the refrigerants listed in [Clause 1](#). These properties are derived from experimental measurements.

The properties enumerated in this document are calculated from specified equations of state, although alternative algorithms are allowed. The properties themselves constitute this document. The equations of state serve as a convenient means to represent and reproduce the properties. The properties enumerated in the tables in this document thus represent only a subset of the properties specified by this document; the full range of conditions is given for each fluid in [Clause 5](#). An equation of state is a mathematical equation that is a complete and thermodynamically consistent representation of the thermodynamic properties of a fluid. These equations have been selected based on the following criteria:

- a) accuracy in reproducing the available experimental data;

- b) applicability over wide ranges of temperature, pressure, and density;
- c) proper behavior on extrapolation beyond the available experimental data; and
- d) preference has been given to fully documented and published formulations.

## 4.2 Pure-fluid equations of state

An equation of state for a pure fluid may express the reduced molar Helmholtz energy,  $A$ , as a function of temperature,  $T$ , and density. The equation of state is composed of separate terms arising from ideal-gas behaviour (subscript “id”) and a “residual” or “real-fluid” (subscript “r”) contribution as given in [Formula \(1\)](#):

$$\phi = \frac{A}{RT} = \phi_{\text{id}} + \phi_{\text{r}} \quad (1)$$

where  $R$  is the gas constant.

Formulae of this form may be written on either a molar basis or a mass basis. For a consistent representation in this document, the equations of state originally published on a mass basis have been converted to a molar basis. The “residual” or “real-fluid” contribution is given by [Formula \(2\)](#):

$$\phi_{\text{r}} = \sum_k N_k \tau^{t_k} \delta^{d_k} \exp[-\alpha_k (\delta - \varepsilon_k)^{l_k}] \exp[-\beta_k (\tau - \gamma_k)^{m_k}] \quad (2)$$

where

|                                                   |                                                                                                                                                                            |
|---------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| $\tau$                                            | is the dimensionless temperature variable $T^*/T$ ;                                                                                                                        |
| $T^*$                                             | is the reducing parameter that is often equal to the critical temperature;                                                                                                 |
| $\delta$                                          | is the dimensionless density variable $\rho/\rho^*$ ;                                                                                                                      |
| $\rho^*$                                          | is the reducing parameter that is often equal to the critical density;                                                                                                     |
| $N_k$                                             | are numerical coefficients fitted to experimental data;                                                                                                                    |
| $\alpha_k, \beta_k, \varepsilon_k$ and $\gamma_k$ | are parameters optimized for a particular fluid or group of fluids by a selection algorithm starting with a large bank of terms or by use of a non-linear fitting process; |
| $t_k, d_k, l_k$ and $m_k$                         | are exponents optimized for a particular fluid or group of fluids by a selection algorithm starting with a large bank of terms or by use of a non-linear fitting process.  |

The ideal-gas contribution can be represented in one of several ways. One representation is in terms of the heat capacity of the ideal-gas state, as given in [Formula \(3\)](#):

$$\phi_{\text{id}} = \frac{h_{\text{ref}}}{RT} - \frac{s_{\text{ref}}}{R} - 1 + \ln\left(\frac{RT\rho}{p_{\text{ref}}}\right) + \frac{1}{RT} \int_{T_{\text{ref}}}^T C_{p,\text{id}} dT - \frac{1}{R} \int_{T_{\text{ref}}}^T \frac{C_{p,\text{id}}}{T} dT \quad (3)$$

where

|                  |                                                                                                                                  |
|------------------|----------------------------------------------------------------------------------------------------------------------------------|
| $h_{\text{ref}}$ | is the arbitrary reference enthalpy for the ideal gas at the reference state specified by $T_{\text{ref}}$ ;                     |
| $s_{\text{ref}}$ | is the arbitrary reference entropy for the ideal gas at the reference state specified by $T_{\text{ref}}$ and $p_{\text{ref}}$ ; |

In this document, the  $h_{\text{ref}}$  and  $s_{\text{ref}}$  are chosen to yield a reference state for enthalpy of 200 kJ/kg and for entropy of 1 kJ/(kg·K), both for the saturated liquid at 0 °C. Such values of  $h_{\text{ref}}$  and  $s_{\text{ref}}$  are informative only; different values, corresponding to different reference state conventions, are acceptable.

The heat capacity of the ideal gas state,  $C_{p,\text{id}}$  may be represented as a function of temperature by the general form consisting of separate summations of polynomial (empirical) and exponential (theoretical) terms, as given in [Formula \(4\)](#):

$$\frac{C_{p,\text{id}}}{R} = c_0 + \sum_k c_k T^{t_k} + \sum_k a_k \frac{u_k^2 \exp(u_k)}{[\exp(u_k) - 1]^2} \quad (4)$$

where

$$u_k = \frac{b_k}{T}; \quad (5)$$

$c_k$ ,  $a_k$ ,  $b_k$  and  $t_k$  are numerical coefficients and exponents fitted to data or derived from theoretical calculations.

A second representation of the ideal-gas contribution is given directly in terms of the Helmholtz free energy, as shown in [Formula \(6\)](#):

$$\phi_{\text{id}} = d_1 + d_2 \tau + \ln \delta + d_3 \ln \tau + \sum_k d_k \tau^{t_k} + \sum_k a_k \ln[1 - \exp(-\tau \lambda_k)] \quad (6)$$

where

$d_1$  and  $d_2$  are adjusted to yield the desired reference state values for the enthalpy and entropy;

$d_3$ ,  $d_k$ ,  $a_k$ ,  $\lambda_k$  and  $t_k$  are either empirical or theoretical parameters.

[Formula \(6\)](#) is functionally equivalent to [Formulae \(3\) to \(5\)](#), and an ideal-gas contribution in the form of [Formula \(6\)](#) may be converted to the heat capacity form as given by [Formula \(7\)](#):

$$\frac{C_{p,\text{id}}}{R} = d_3 + 1 - \sum_k d_k t_k (t_k - 1) \left( \frac{T^*}{T} \right)^{t_k} + \sum_k a_k \frac{u_k^2 \exp(u_k)}{[\exp(u_k) - 1]^2} \quad (7)$$

where

$$u_k = \frac{\lambda_k T^*}{T} \quad (8)$$

The equations of state for certain fluids may also include special terms to represent the behaviour very close to the critical point. These are of the form of [Formula \(9\)](#):

$$\phi_{\text{crit}} = \sum_k N_k \delta \Delta^{b_k} \Psi \quad (9)$$

where

$$\Delta = \theta^2 + B_k [(\delta - 1)^2]^{a_k} \quad (10)$$

$$\theta = (1 - \tau) + A_k [(\delta - 1)^2]^{1/(2\beta_k)} \quad (11)$$

$$\Psi = \exp \left[ -C_k (\delta - 1)^2 - D_k (\tau - 1)^2 \right] \quad (12)$$

where  $N_k, A_k, B_k, C_k, D_k, \alpha_k$  and  $\beta_k$  are adjustable parameters fitted to data.

[Formula \(9\)](#) is added to the normal terms in [Formula \(1\)](#). Among the fluids in this document, only the equation of state for R744 (carbon dioxide) includes these critical region terms.

Alternately, an equation of state may express pressure as an explicit function of temperature and molar density. One form is that of a modified Benedict-Webb-Rubin (MBWR) equation of state, as given in [Formula \(13\)](#):

$$p = \sum_{k=1}^9 a_k \rho^k + \exp \left( -\rho^2 / \rho_{\text{crit}}^2 \right) \sum_{k=10}^{15} a_k \rho^{2k-17} \quad (13)$$

where the  $a_k$  are functions of temperature resulting in a total of 32 adjustable parameters that are fitted to the experimental data. For a complete description of the thermodynamic properties, the MBWR formula is combined with an expression for the ideal-gas heat capacity, such as [Formula \(4\)](#) or [\(5\)](#).

In this document, pressure-explicit equations of state [such as [Formula \(13\)](#)] are transformed into the Helmholtz-energy form to maintain a consistent representation. The pressure is related to the Helmholtz energy using the thermodynamic identity shown in [Formula \(14\)](#):

$$p = - \left( \frac{\partial A}{\partial V} \right)_T \quad (14)$$

Thus, the Helmholtz energy can be evaluated from the pressure by an integration over volume,  $V$ , using [Formula \(15\)](#):

$$\frac{A_r(T, \rho)}{RT} = \phi_r = - \int_V^\infty \left( \frac{p}{RT} - \rho \right) dV \quad (15)$$

[Formula \(15\)](#) is then combined with an ideal-gas contribution given by [Formulae \(3\)](#) to [\(5\)](#) to yield a complete description of the thermodynamic properties. Among the fluids in this document, the equations of state for R123 and R152a have been transformed in this manner.

An equation of state or the ideal-gas heat capacity may also be expressed in other forms, but the forms represented by [Formulae \(1\)](#) through [\(15\)](#) encompass all those specified in this document.

Methods for computing pure-fluid thermodynamic properties from an equation of state are given in [Annex B](#).

### 4.3 Mixture equation of state

Thermodynamic properties of mixtures are calculated by applying mixing rules to the Helmholtz energy of the mixture components together with a separate mixture function. The reduced Helmholtz energy of the mixture is a sum of ideal-gas and residual contributions as given by [Formula \(16\)](#):

$$\phi_{\text{mix}} = \frac{A}{RT} = \phi_{\text{mix,id}} + \phi_{\text{mix,r}} \quad (16)$$

The ideal gas part is given by [Formula \(17\)](#):

$$\phi_{\text{mix,id}} = \sum_{i=1}^n \left[ x_i \phi_{i,\text{id}} + x_i \ln x_i \right] + f_3 + f_4 / T \quad (17)$$

where

$x_i$  is the mole fraction of component  $i$  in the  $n$ -component mixture;

$x_i \ln x_i$  are terms arising from the entropy of mixing of ideal gases.

The parameters  $f_3$  and  $f_4$  are used to shift the thermodynamic surface such that the reference state for enthalpy is 200 kJ/kg and entropy is 1 kJ/(kg·K) at the saturated liquid at 0 °C, similar to that done for the pure fluids. Setting the parameters  $f_3$  and  $f_4$  to zero corresponds to a reference state based solely on the constituents of the mixture.

The residual part is given by [Formula \(18\)](#):

$$\phi_{\text{mix},r} = \sum_{i=1}^n x_i \phi_{i,r} + \sum_{i=1}^{n-1} \sum_{j=i+1}^n x_i x_j \phi_{ij,\text{excess}} \quad (18)$$

The first summation in this formula represents the ideal solution; it consists of the real fluid terms for each of the pure fluids multiplied by their respective compositions. The double summation accounts for the “excess” Helmholtz energy or “departure” from ideal solution. The  $\phi_{i,r}$  and  $\phi_{ij,\text{excess}}$  functions in [Formula \(18\)](#) are not evaluated at the temperature,  $T_{\text{mix}}$ , and density,  $\rho_{\text{mix}}$ , of the mixture, but, rather, at a reduced temperature,  $\tau$ , and density,  $\delta$ . The mixing rules for the reducing parameters are given by [Formulae \(19\)](#) and [\(20\)](#):

$$\tau = \frac{T^*}{T_{\text{mix}}} \quad (19)$$

where

$$T^* = \sum_{i=1}^n x_i T_i^* + \sum_{i=1}^{n-1} \sum_{j=i+1}^n x_i x_j \zeta_{ij}$$

and

$$\delta = \frac{\rho_{\text{mix}}}{\rho^*} \quad (20)$$

where

$$\frac{1}{\rho^*} = \sum_{i=1}^n \frac{x_i}{\rho_i^*} + \sum_{i=1}^{n-1} \sum_{j=i+1}^n x_i x_j \xi_{ij}$$

where

$\zeta_{ij}$  and  $\xi_{ij}$  are “interaction parameters”;

$T_i^*$  and  $\rho_i^*$  are the reducing parameters of the pure fluids.

The  $\phi_{ij,\text{excess}}$  function is of the general form of [Formula \(21\)](#):

$$\phi_{ij,\text{excess}} = F_{ij} \sum_k N_k \delta^{d_k} \tau^{t_k} \exp(-\delta^{l_k}) \quad (21)$$

The  $\phi_{ij,\text{excess}}$  function will, in general, vary from mixture to mixture (see [Annex E](#)), and the coefficients and exponents are tabulated in [Clause 5](#) for the refrigerant blends included in this document. In all cases, the pure-component contributions are those defined in [Clause 5](#) of this document.

Methods for computing thermodynamic properties from a mixture equation of state are given in [Annex C](#).

#### 4.4 Implementation

An algorithm shall directly implement one or more of the equations of state specified in [Clause 5](#) together with the methods of calculating the thermodynamic properties given in [Annex B](#) and is also demonstrate to reproduce, for the fluids implemented, the “verification values” given in [Annex D](#).

#### 4.5 Alternative implementation

An algorithm shall, by any method, reproduce the values of thermodynamic properties specified in this document for the fluids implemented. Such an algorithm is considered to be applicable to the full range of temperature, pressure, and density and to the full set of properties or to any subrange of conditions and/or subset of properties. Any algorithm shall state the fluids for which it is applicable and the applicable property(ies) and range(s). The allowable variations (tolerances) between the property values specified in this document and those of an alternative implementation vary from property to property and are defined in [Annex A](#).

#### 4.6 Testing implementations against requirements

Any computer program or other implementation of this document shall satisfy the requirements specified in [Annex A](#) before it can claim compliance with this document. These requirements shall be carried out by the developer of the particular implementation.

### 5 Specifications for individual refrigerants

#### 5.1 General

The following subclauses specify the equations of state used to calculate the properties of each of the refrigerants covered by this document and also tabulate the properties along the liquid-vapour saturation boundary. In the tabulations of coefficients and exponents, any terms not listed are zero.

#### 5.2 R744 — Carbon dioxide

##### 5.2.1 Range of validity

The coefficients are valid within the following ranges:

$$T_{\min} = 216,592 \text{ K}, T_{\max} = 1\,100 \text{ K}; p_{\max} = 800 \text{ MPa}; \rho_{\max} = 37,24 \text{ mol/l (1\,639 kg/m}^3\text{)}$$

Coefficients and exponents of the ideal-gas part are listed in [Table 1](#). Coefficients and exponents of the real-gas part are listed in [Table 2](#). Coefficients and exponents of the critical region terms are listed in [Table 3](#).

**Table 1 — Coefficients and exponents of the ideal-gas part [Formulae (3) to (5)]**

| $k$ | $a_k$           | $b_k$        | $c_k$ |
|-----|-----------------|--------------|-------|
| 0   | —               | —            | 3,5   |
| 1   | 1,994 270 42    | 958,499 56   | —     |
| 2   | 0,621 052 475   | 1 858,801 15 | —     |
| 3   | 0,411 952 928   | 2 061,101 14 | —     |
| 4   | 1,040 289 22    | 3 443,899 08 | —     |
| 5   | 0,083 276 775 3 | 8 238,200 35 | —     |

**Table 2 — Coefficients and exponents of the real-gas part [Formula (2)]**

| $k$ | $N_k$                                  | $t_k$ | $d_k$ | $l_k$ | $\alpha_k$ | $m_k$ | $\beta_k$ | $\gamma_k$ | $\varepsilon_k$ |
|-----|----------------------------------------|-------|-------|-------|------------|-------|-----------|------------|-----------------|
| 1   | 0,388 568 232 032                      | 0     | 1     | 0     | 0          | —     | —         | —          | —               |
| 2   | $0,293\,854\,759\,427 \times 10^1$     | 0,75  | 1     | 0     | 0          | —     | —         | —          | —               |
| 3   | $-0,558\,671\,885\,349 \times 10^1$    | 1     | 1     | 0     | 0          | —     | —         | —          | —               |
| 4   | -0,767 531 995 925                     | 2     | 1     | 0     | 0          | —     | —         | —          | —               |
| 5   | 0,317 290 055 804                      | 0,75  | 2     | 0     | 0          | —     | —         | —          | —               |
| 6   | 0,548 033 158 978                      | 2     | 2     | 0     | 0          | —     | —         | —          | —               |
| 7   | 0,122 794 112 203                      | 0,75  | 3     | 0     | 0          | —     | —         | —          | —               |
| 8   | $0,216\,589\,615\,432 \times 10^1$     | 1,5   | 1     | 1     | 1          | —     | —         | —          | —               |
| 9   | $0,158\,417\,351\,097 \times 10^1$     | 1,5   | 2     | 1     | 1          | —     | —         | —          | —               |
| 10  | -0,231 327 054 055                     | 2,5   | 4     | 1     | 1          | —     | —         | —          | —               |
| 11  | $0,581\,169\,164\,314 \times 10^{-1}$  | 0     | 5     | 1     | 1          | —     | —         | —          | —               |
| 12  | -0,553 691 372 054                     | 1,5   | 5     | 1     | 1          | —     | —         | —          | —               |
| 13  | 0,489 466 159 094                      | 2     | 5     | 1     | 1          | —     | —         | —          | —               |
| 14  | $-0,242\,757\,398\,435 \times 10^{-1}$ | 0     | 6     | 1     | 1          | —     | —         | —          | —               |
| 15  | $0,624\,947\,905\,017 \times 10^{-1}$  | 1     | 6     | 1     | 1          | —     | —         | —          | —               |
| 16  | -0,121 758 602 252                     | 2     | 6     | 1     | 1          | —     | —         | —          | —               |
| 17  | -0,370 556 852 701                     | 3     | 1     | 2     | 1          | —     | —         | —          | —               |
| 18  | $-0,167\,758\,797\,004 \times 10^{-1}$ | 6     | 1     | 2     | 1          | —     | —         | —          | —               |
| 19  | -0,119 607 366 380                     | 3     | 4     | 2     | 1          | —     | —         | —          | —               |
| 20  | $-0,456\,193\,625\,088 \times 10^{-1}$ | 6     | 4     | 2     | 1          | —     | —         | —          | —               |
| 21  | $0,356\,127\,892\,703 \times 10^{-1}$  | 8     | 4     | 2     | 1          | —     | —         | —          | —               |
| 22  | $-0,744\,277\,271\,321 \times 10^{-2}$ | 6     | 7     | 2     | 1          | —     | —         | —          | —               |
| 23  | $-0,173\,957\,049\,024 \times 10^{-2}$ | 0     | 8     | 2     | 1          | —     | —         | —          | —               |
| 24  | $-0,218\,101\,212\,895 \times 10^{-1}$ | 7     | 2     | 3     | 1          | —     | —         | —          | —               |
| 25  | $0,243\,321\,665\,592 \times 10^{-1}$  | 12    | 3     | 3     | 1          | —     | —         | —          | —               |
| 26  | $-0,374\,401\,334\,235 \times 10^{-1}$ | 16    | 3     | 3     | 1          | —     | —         | —          | —               |
| 27  | 0,143 387 157 569                      | 22    | 5     | 4     | 1          | —     | —         | —          | —               |
| 28  | -0,134 919 690 833                     | 24    | 5     | 4     | 1          | —     | —         | —          | —               |
| 29  | $-0,231\,512\,250\,535 \times 10^{-1}$ | 16    | 6     | 4     | 1          | —     | —         | —          | —               |
| 30  | $0,123\,631\,254\,929 \times 10^{-1}$  | 24    | 7     | 4     | 1          | —     | —         | —          | —               |
| 31  | $0,210\,583\,219\,729 \times 10^{-2}$  | 8     | 8     | 4     | 1          | —     | —         | —          | —               |
| 32  | $-0,339\,585\,190\,264 \times 10^{-3}$ | 2     | 10    | 4     | 1          | —     | —         | —          | —               |
| 33  | $0,559\,936\,517\,716 \times 10^{-2}$  | 28    | 4     | 5     | 1          | —     | —         | —          | —               |
| 34  | $-0,303\,351\,180\,556 \times 10^{-3}$ | 14    | 8     | 6     | 1          | —     | —         | —          | —               |
| 35  | $-0,213\,654\,886\,883 \times 10^3$    | 1     | 2     | 2     | 25         | 2     | 325       | 1,16       | 1               |
| 36  | $0,266\,415\,691\,493 \times 10^5$     | 0     | 2     | 2     | 25         | 2     | 300       | 1,19       | 1               |
| 37  | $-0,240\,272\,122\,046 \times 10^5$    | 1     | 2     | 2     | 25         | 2     | 300       | 1,19       | 1               |
| 38  | $-0,283\,416\,034\,240 \times 10^3$    | 3     | 3     | 2     | 15         | 2     | 275       | 1,25       | 1               |
| 39  | $0,212\,472\,844\,002 \times 10^3$     | 3     | 3     | 2     | 20         | 2     | 275       | 1,22       | 1               |

**Table 3 — Coefficients and exponents of the critical region terms [Formulae (9) to (12)]**

| $k$ | $N_k$              | $a_k$ | $b_k$ | $\beta_k$ | $A_k$ | $B_k$ | $C_k$ | $D_k$ |
|-----|--------------------|-------|-------|-----------|-------|-------|-------|-------|
| 40  | -0,666 422 765 408 | 3,5   | 0,875 | 0,3       | 0,7   | 0,3   | 10    | 275   |

Table 3 (continued)

| $k$ | $N_k$                              | $a_k$ | $b_k$ | $\beta_k$ | $A_k$ | $B_k$ | $C_k$ | $D_k$ |
|-----|------------------------------------|-------|-------|-----------|-------|-------|-------|-------|
| 41  | 0,726 086 323 499                  | 3,5   | 0,925 | 0,3       | 0,7   | 0,3   | 10    | 275   |
| 42  | 0,550 686 686 128 $\times 10^{-1}$ | 3     | 0,875 | 0,3       | 0,7   | 1     | 12,5  | 275   |

### 5.2.2 Reducing parameters, molar mass, and gas constant

$$T^* = 304,128 \text{ K}, \rho^* = 10,624 \text{ 906 3 mol/l}, M = 44,009 \text{ 8 g/mol}, R = 8,314 \text{ 51 J/(mol}\cdot\text{K)}$$

### 5.2.3 Reference state parameters

$$T_{\text{ref}} = 273,15 \text{ K}, p_{\text{ref}} = 1,0 \text{ kPa}, h_{\text{ref}} = 21 \text{ 389,328 J/mol}, s_{\text{ref}} = 155,741 \text{ 4 J/(mol}\cdot\text{K)}, f_1 = 5,805 \text{ 551 35}, f_2 = 1 \text{ 555,797 10}$$

R744 property values along the liquid-vapour saturation boundary are listed in [Table 4](#).

Table 4 — R744 property values along the liquid-vapour saturation boundary

|        | Temp.<br>°C         | Pressure<br>MPa | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|--------|---------------------|-----------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| liquid | −56,56 <sup>a</sup> | 0,518 0         | 1 178,5                      | 79,60                       | 80,04             | 0,521 3              | 0,974 7            | 1,953 2            | 975,8                 | −0,144 3                    |
| vapour |                     |                 | 13,761                       | 392,78                      | 430,42            | 2,139 0              | 0,629 2            | 0,908 7            | 222,78                | 26,17                       |
| liquid | −55,00              | 0,554 0         | 1 172,9                      | 82,62                       | 83,09             | 0,535 2              | 0,972 4            | 1,956 9            | 964,6                 | −0,138 7                    |
| vapour |                     |                 | 14,673                       | 393,23                      | 430,99            | 2,130 0              | 0,633 6            | 0,918 4            | 222,96                | 25,67                       |
| liquid | −50,00              | 0,682 3         | 1 154,6                      | 92,35                       | 92,94             | 0,579 4              | 0,965 5            | 1,971 2            | 928,5                 | −0,119 1                    |
| vapour |                     |                 | 17,925                       | 394,61                      | 432,68            | 2,101 8              | 0,648 3            | 0,951 9            | 223,39                | 24,14                       |
| liquid | −45,00              | 0,831 8         | 1 135,8                      | 102,14                      | 102,87            | 0,622 8              | 0,959 0            | 1,989 2            | 892,4                 | −0,096 3                    |
| vapour |                     |                 | 21,717                       | 395,83                      | 434,13            | 2,074 7              | 0,664 0            | 0,990 0            | 223,57                | 22,77                       |
| liquid | −40,00              | 1,004 5         | 1 116,4                      | 112,00                      | 112,90            | 0,665 6              | 0,952 9            | 2,011 7            | 856,3                 | −0,069 9                    |
| vapour |                     |                 | 26,121                       | 396,87                      | 435,32            | 2,048 5              | 0,680 7            | 1,033 3            | 223,50                | 21,51                       |
| liquid | −35,00              | 1,202 4         | 1 096,4                      | 121,95                      | 123,05            | 0,707 9              | 0,947 3            | 2,039 3            | 819,9                 | −0,039 1                    |
| vapour |                     |                 | 31,216                       | 397,71                      | 436,23            | 2,023 0              | 0,698 5            | 1,083 0            | 223,15                | 20,37                       |
| liquid | −30,00              | 1,427 8         | 1 075,7                      | 132,01                      | 133,34            | 0,749 8              | 0,942 2            | 2,073 1            | 783,2                 | −0,003 1                    |
| vapour |                     |                 | 37,098                       | 398,33                      | 436,82            | 1,998 0              | 0,717 4            | 1,140 6            | 222,54                | 19,32                       |
| liquid | −25,00              | 1,682 7         | 1 054,2                      | 142,20                      | 143,79            | 0,791 4              | 0,937 9            | 2,114 5            | 745,8                 | 0,039 4                     |
| vapour |                     |                 | 43,880                       | 398,71                      | 437,06            | 1,973 2              | 0,737 9            | 1,208 3            | 221,63                | 18,35                       |
| liquid | −20,00              | 1,969 6         | 1 031,7                      | 152,54                      | 154,45            | 0,832 8              | 0,934 4            | 2,165 3            | 707,5                 | 0,090 0                     |
| vapour |                     |                 | 51,700                       | 398,79                      | 436,89            | 1,948 5              | 0,760 2            | 1,289 3            | 220,41                | 17,44                       |
| liquid | −15,00              | 2,290 8         | 1 008,0                      | 163,07                      | 165,34            | 0,874 2              | 0,932 4            | 2,228 3            | 667,8                 | 0,150 9                     |
| vapour |                     |                 | 60,728                       | 398,55                      | 436,27            | 1,923 7              | 0,784 7            | 1,387 7            | 218,85                | 16,58                       |
| liquid | −10,00              | 2,648 7         | 982,9                        | 173,83                      | 176,52            | 0,915 7              | 0,933 0            | 2,307 2            | 626,1                 | 0,225 1                     |
| vapour |                     |                 | 71,185                       | 397,93                      | 435,14            | 1,898 5              | 0,811 3            | 1,509 1            | 216,94                | 15,77                       |
| liquid | −5,00               | 3,045 9         | 956,2                        | 184,86                      | 188,05            | 0,957 6              | 0,937 1            | 2,408 5            | 582,2                 | 0,316 8                     |
| vapour |                     |                 | 83,359                       | 396,84                      | 433,38            | 1,872 5              | 0,840 3            | 1,662 8            | 214,68                | 14,99                       |

<sup>a</sup> Triple point.

<sup>b</sup> The values of  $C_v$ ,  $C_p$ , and  $w$  at the critical point are not included as part of this document.

Table 4 (continued)

|          | Temp.<br>°C | Pressure<br>MPa | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|----------|-------------|-----------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| liquid   | 0,00        | 3,485 1         | 927,4                        | 196,24                      | 200,00            | 1,000 0              | 0,944 9            | 2,542 3            | 536,4                 | 0,432 5                     |
| vapour   |             |                 | 97,647                       | 395,20                      | 430,89            | 1,845 3              | 0,872 2            | 1,864 8            | 212,04                | 14,23                       |
| liquid   | 5,00        | 3,969 5         | 896,0                        | 208,07                      | 212,50            | 1,043 4              | 0,955 8            | 2,726 8            | 489,3                 | 0,582 4                     |
| vapour   |             |                 | 114,621                      | 392,85                      | 427,48            | 1,816 3              | 0,908 4            | 2,144 0            | 208,97                | 13,47                       |
| liquid   | 10,00       | 4,502 2         | 861,1                        | 220,50                      | 225,73            | 1,088 4              | 0,969 1            | 2,997 6            | 441,0                 | 0,783 6                     |
| vapour   |             |                 | 135,156                      | 389,57                      | 422,88            | 1,784 7              | 0,950 7            | 2,557 8            | 205,41                | 12,69                       |
| liquid   | 15,00       | 5,087 1         | 821,2                        | 233,79                      | 239,99            | 1,135 9              | 0,985 9            | 3,436 0            | 391,1                 | 1,067 0                     |
| vapour   |             |                 | 160,730                      | 384,99                      | 416,64            | 1,748 9              | 1,002 9            | 3,237 1            | 201,21                | 11,85                       |
| liquid   | 20,00       | 5,729 1         | 773,4                        | 248,46                      | 255,87            | 1,187 7              | 1,011 4            | 4,263 7            | 337,6                 | 1,497 3                     |
| vapour   |             |                 | 194,202                      | 378,36                      | 407,87            | 1,706 2              | 1,072 5            | 4,559 9            | 196,09                | 10,88                       |
| liquid   | 25,00       | 6,434 2         | 710,5                        | 265,73                      | 274,78            | 1,248 5              | 1,070 4            | 6,467 4            | 274,3                 | 2,256 5                     |
| vapour   |             |                 | 242,732                      | 367,92                      | 394,43            | 1,649 8              | 1,181 9            | 8,212 3            | 189,12                | 9,62                        |
| liquid   | 30,00       | 7,213 7         | 593,3                        | 292,40                      | 304,55            | 1,343 5              | 1,406 3            | 35,338 4           | 177,2                 | 4,278 9                     |
| vapour   |             |                 | 345,102                      | 344,23                      | 365,13            | 1,543 3              | 1,522 8            | 55,821 7           | 171,26                | 7,39                        |
| critical | 30,98       | 7,377 3         | 467,6                        | 316,47                      | 332,25            | 1,433 6              | <sup>b</sup>       | <sup>b</sup>       | <sup>b</sup>          | 5,866 5                     |

<sup>a</sup> Triple point.

<sup>b</sup> The values of  $C_v$ ,  $C_p$ , and  $w$  at the critical point are not included as part of this document.

### 5.3 R717 — Ammonia

#### 5.3.1 Range of validity

The coefficients are valid within the following ranges:

$$T_{\min} = 195,495 \text{ K}, T_{\max} = 725 \text{ K}; p_{\max} = 1\,000 \text{ MPa}; \rho_{\max} = 52,43 \text{ mol/l (893 kg/m}^3\text{)}$$

#### 5.3.2 Coefficients and exponents of the ideal-gas part [Formulae (3) to (5)]

Coefficients and exponents of the ideal-gas part are listed in Table 5 and Table 6. Coefficients and exponents of the real-gas part are listed in Table 7, Table 8 and Table 9.

Table 5 — Coefficients and exponents for  $k=0$ 

| $k$ | $c_k$ |
|-----|-------|
| 0   | 4,000 |

Table 6 — Coefficients and exponents for  $k = 1$  up to 3

| $k$ | $a_k$   | $b_k$ |
|-----|---------|-------|
| 1   | 2,224   | 1 646 |
| 2   | 3,148   | 3 965 |
| 3   | 0,957 9 | 7 231 |

#### 5.3.3 Coefficients and exponents of the real-gas part [Formula (2)]

Parameters not listed are zero.

**Table 7 — Coefficients and exponents for  $k = 1$  up to 5**

| $k$ | $N_k$         | $t_k$ | $d_k$ |
|-----|---------------|-------|-------|
| 1   | 0,006 132 232 | 1,0   | 4     |
| 2   | 1,739 586 6   | 0,382 | 1     |
| 3   | -2,226 179 2  | 1     | 1     |
| 4   | -0,301 275 53 | 1     | 2     |
| 5   | 0,089 670 23  | 0,677 | 3     |

**Table 8 — Coefficients and exponents for  $k = 6$  up to 18**

| $k$ | $N_k$          | $t_k$   | $d_k$ | $l_k$ | $\alpha_k$ | $m_k$ | $\beta_k$ | $\gamma_k$ | $\varepsilon_k$ |
|-----|----------------|---------|-------|-------|------------|-------|-----------|------------|-----------------|
| 6   | -0,076 387 037 | 2,915   | 3     | 2     | 1          | 1     | 0         | 1          | 0               |
| 7   | -0,840 639 63  | 3,51    | 2     | 2     | 1          | 1     | 0         | 1          | 0               |
| 8   | -0,270 263 27  | 1,063   | 3     | 1     | 1          | 1     | 0         | 1          | 0               |
| 9   | 6,212 578      | 0,655   | 1     | 2     | -0,427 76  | 2     | -1,708    | 1,036      | -0,072 6        |
| 10  | -5,784 435 7   | 1,3     | 1     | 2     | -0,642 4   | 2     | -1,486 5  | 1,277 7    | -0,127 4        |
| 11  | 2,481 754 2    | 3,1     | 1     | 2     | -0,817 5   | 2     | -2,091 5  | 1,083      | 0,752 7         |
| 12  | -2,373 916 8   | 1,439 5 | 2     | 2     | -0,799 5   | 2     | -2,43     | 1,290 6    | 0,57            |
| 13  | 0,014 936 97   | 1,623   | 2     | 2     | -0,91      | 2     | -0,488    | 0,928      | 2,2             |
| 14  | -3,774 926 4   | 0,643   | 1     | 2     | -0,357 4   | 2     | -1,1      | 0,934      | -0,243          |
| 15  | 0,000 625 435  | 1,13    | 3     | 2     | -1,21      | 2     | -0,85     | 0,919      | 2,96            |
| 16  | -0,000 017 359 | 4,5     | 3     | 2     | -4,14      | 2     | -1,14     | 1,852      | 3,02            |
| 17  | -0,134 620 33  | 1       | 1     | 2     | -22,56     | 2     | -945,64   | 1,058 97   | 0,957 4         |
| 18  | 0,077 490 728  | 4       | 1     | 2     | -22,68     | 2     | -993,85   | 1,052 77   | 0,957 6         |

For ammonia (R717), the final two terms in the summation of [Formula \(2\)](#) (i.e.,  $k= 19,20$ ) have a slightly different form, see [Formula \(22\)](#):

$$\phi_r = \sum_{k=19}^{20} N_k \tau^{t_k} \delta^{d_k} \exp[-\alpha_k (\delta - \varepsilon_k)^{l_k}] \exp\left[\frac{1}{\chi_k (\tau - \gamma_k)^{m_k} + b_k}\right] \quad (22)$$

**Table 9 — Coefficients and exponents for  $k = 19$  up to 20**

| $k$ | $N_k$        | $t_k$   | $d_k$ | $l_k$ | $\alpha_k$ | $m_k$ | $\chi_k$ | $\gamma_k$ | $\varepsilon_k$ | $b_k$   |
|-----|--------------|---------|-------|-------|------------|-------|----------|------------|-----------------|---------|
| 19  | -1,690 985 8 | 4,331 5 | 1     | 2     | -2,845 2   | 2     | 0,369 6  | 1,108      | 0,447 8         | 1,244   |
| 20  | 0,937 390 74 | 4,015   | 1     | 2     | -2,834 2   | 2     | 0,296 2  | 1,313      | 0,446 89        | 0,682 6 |

### 5.3.4 Reducing parameters, molar mass, and gas constant

$$T^* = 405,56 \text{ K}, \rho^* = 13,696 \text{ mol/l}, M = 17,030 52 \text{ g/mol}, R = 8,314 459 8 \text{ J/(mol}\cdot\text{K)}$$

### 5.3.5 Reference state parameters

$$T_{\text{ref}} = 273,15 \text{ K}, p_{\text{ref}} = 1,0 \text{ kPa}, h_{\text{ref}} = 28 044,796 \text{ J/mol}, s_{\text{ref}} = 156,239 4 \text{ J/(mol}\cdot\text{K)}$$

R717 property values along the liquid-vapour saturation boundary are listed in [Table 10](#).

Table 10 — R717 property values along the liquid-vapour saturation boundary

|        | Temp.<br>°C         | Pressure<br>MPa | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|--------|---------------------|-----------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| liquid | -77,66 <sup>a</sup> | 0,006 05        | 733,9                        | -145,67                     | -145,67           | -0,483 5             | 2,967 5            | 4,305 3            | 2 011,3               | -0,219 6                    |
| vapour |                     |                 | 0,063 7                      | 1 248,25                    | 1 343,27          | 7,132 9              | 1,516 2            | 2,022 9            | 355,26                | 180,96                      |
| liquid | -75,00              | 0,007 47        | 730,8                        | -134,21                     | -134,20           | -0,425 3             | 2,968 7            | 4,312 3            | 1 994,6               | -0,218 4                    |
| vapour |                     |                 | 0,077 6                      | 1 251,91                    | 1 348,16          | 7,055 7              | 1,522 5            | 2,031 9            | 357,48                | 169,43                      |
| liquid | -70,00              | 0,010 9         | 725                          | -112,62                     | -112,60           | -0,317 6             | 2,970 1            | 4,327 7            | 1 963,4               | -0,215 8                    |
| vapour |                     |                 | 0,111                        | 1 258,72                    | 1 357,25          | 6,917 7              | 1,535 6            | 2,050 7            | 361,55                | 150,11                      |
| liquid | -65,00              | 0,015 6         | 719,3                        | -90,94                      | -90,92            | -0,212 2             | 2,969 9            | 4,345 1            | 1 932,3               | -0,212 8                    |
| vapour |                     |                 | 0,155                        | 1 265,41                    | 1 366,19          | 6,788 1              | 1,550 5            | 2,072 6            | 365,49                | 133,43                      |
| liquid | -60,00              | 0,021 8         | 713,5                        | -69,17                      | -69,14            | -0,108 9             | 2,967 7            | 4,363 6            | 1 901,4               | -0,209 5                    |
| vapour |                     |                 | 0,212                        | 1 271,99                    | 1 374,98          | 6,666 3              | 1,567 5            | 2,097 5            | 369,29                | 118,99                      |
| liquid | -55,00              | 0,030 1         | 707,6                        | -47,31                      | -47,27            | -0,007 5             | 2,963 3            | 4,382 7            | 1 870,6               | -0,205 8                    |
| vapour |                     |                 | 0,286                        | 1 278,43                    | 1 383,58          | 6,551 5              | 1,586 5            | 2,125 9            | 372,93                | 106,44                      |
| liquid | -50,00              | 0,040 8         | 701,7                        | -25,35                      | -25,29            | 0,092                | 2,956 7            | 4,401 9            | 1 839,7               | -0,201 8                    |
| vapour |                     |                 | 0,38                         | 1 284,72                    | 1 391,98          | 6,443 3              | 1,607 7            | 2,157 8            | 376,41                | 95,48                       |
| liquid | -45,00              | 0,054 4         | 695,8                        | -3,30                       | -3,23             | 0,189 8              | 2,948              | 4,421              | 1 808,8               | -0,197 5                    |
| vapour |                     |                 | 0,498                        | 1 290,86                    | 1 400,17          | 6,341                | 1,631 1            | 2,193 4            | 379,73                | 85,9                        |
| liquid | -40,00              | 0,071 6         | 689,8                        | 18,84                       | 18,94             | 0,285 8              | 2,937 6            | 4,44               | 1 777,6               | -0,192 9                    |
| vapour |                     |                 | 0,644                        | 1 296,83                    | 1 408,14          | 6,244 1              | 1,656 7            | 2,232 8            | 382,86                | 77,48                       |
| liquid | -35,00              | 0,093           | 683,7                        | 41,07                       | 41,21             | 0,380 1              | 2,925 7            | 4,458 9            | 1 746,3               | -0,187 9                    |
| vapour |                     |                 | 0,822                        | 1 302,63                    | 1 415,86          | 6,152 3              | 1,684 4            | 2,276 1            | 385,81                | 70,08                       |
| liquid | -33,32 <sup>b</sup> | 0,101 3         | 681,6                        | 48,58                       | 48,73             | 0,411 5              | 2,921 4            | 4,465 3            | 1 735,6               | -0,186 1                    |
| vapour |                     |                 | 0,89                         | 1 304,55                    | 1 418,4           | 6,122 4              | 1,694 2            | 2,291 6            | 386,76                | 67,78                       |
| liquid | -30,00              | 0,119 4         | 677,5                        | 63,4                        | 63,57             | 0,472 9              | 2,912 7            | 4,478              | 1 714,6               | -0,182 6                    |
| vapour |                     |                 | 1,037                        | 1 308,25                    | 1 423,32          | 6,065 1              | 1,714 3            | 2,323 5            | 388,57                | 63,55                       |
| liquid | -25,00              | 0,151 4         | 671,3                        | 85,81                       | 86,04             | 0,564 1              | 2,899 1            | 4,497 4            | 1 682,5               | -0,176 8                    |
| vapour |                     |                 | 1,296                        | 1 313,68                    | 1 430,51          | 5,982 1              | 1,746 1            | 2,374 9            | 391,12                | 57,78                       |
| liquid | -20,00              | 0,19            | 665                          | 108,32                      | 108,6             | 0,654                | 2,885 2            | 4,517 3            | 1 650                 | -0,170 6                    |
| vapour |                     |                 | 1,604                        | 1 318,9                     | 1 437,41          | 5,903                | 1,779 8            | 2,430 5            | 393,47                | 52,68                       |
| liquid | -15,00              | 0,236 1         | 658,5                        | 130,92                      | 131,28            | 0,742 4              | 2,871 2            | 4,538 2            | 1 617,1               | -0,163 9                    |
| vapour |                     |                 | 1,966                        | 1 323,91                    | 1 444             | 5,827 5              | 1,815 2            | 2,490 2            | 395,61                | 48,17                       |
| liquid | -10,00              | 0,290 6         | 652                          | 153,62                      | 154,06            | 0,829 5              | 2,857 4            | 4,560 4            | 1 583,7               | -0,156 7                    |
| vapour |                     |                 | 2,391                        | 1 328,7                     | 1 450,27          | 5,755 2              | 1,852 3            | 2,554 3            | 397,53                | 44,16                       |
| liquid | -5,00               | 0,354 7         | 645,4                        | 176,42                      | 176,97            | 0,915 3              | 2,844 1            | 4,584 1            | 1 549,9               | -0,148 9                    |
| vapour |                     |                 | 2,885                        | 1 333,26                    | 1 456,2           | 5,685 9              | 1,890 7            | 2,622 9            | 399,23                | 40,61                       |
| liquid | 0                   | 0,429 2         | 638,6                        | 199,33                      | 200               | 1                    | 2,831 4            | 4,609 7            | 1 515,6               | -0,140 4                    |
| vapour |                     |                 | 3,456                        | 1 337,57                    | 1 461,77          | 5,619 3              | 1,930 4            | 2,696 2            | 400,7                 | 37,44                       |
| liquid | 5                   | 0,515 6         | 631,8                        | 222,36                      | 223,17            | 1,083 6              | 2,819 4            | 4,637 6            | 1 480,8               | -0,131 1                    |
| vapour |                     |                 | 4,113                        | 1 341,62                    | 1 466,96          | 5,555 2              | 1,971 4            | 2,774 5            | 401,94                | 34,61                       |
| liquid | 10                  | 0,614 8         | 624,8                        | 245,51                      | 246,49            | 1,166 1              | 2,808 3            | 4,668 2            | 1 445,5               | -0,120 9                    |
| vapour |                     |                 | 4,866                        | 1 345,38                    | 1 471,73          | 5,493 3              | 2,013 4            | 2,858 3            | 402,95                | 32,09                       |
| liquid | 15                  | 0,728 2         | 617,7                        | 268,8                       | 269,98            | 1,247 7              | 2,798              | 4,701 8            | 1 409,8               | -0,109 8                    |

<sup>a</sup> Triple point

<sup>b</sup> Normal boiling point

\* The values of  $C_v$ ,  $C_p$ , and  $w$  at the critical point are not included as part of this document.

Table 10 (continued)

|                                                                                                          | Temp.<br>°C | Pressure<br>MPa | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|----------------------------------------------------------------------------------------------------------|-------------|-----------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| vapour                                                                                                   |             |                 | 5,724                        | 1 348,84                    | 1 476,07          | 5,433 3              | 2,056 5            | 2,948 1            | 403,7                 | 29,82                       |
| liquid                                                                                                   | 20          | 0,857           | 610,4                        | 292,24                      | 293,64            | 1,328 4              | 2,788 6            | 4,738 9            | 1 373,6               | -0,097 6                    |
| vapour                                                                                                   |             |                 | 6,698                        | 1 351,99                    | 1 479,94          | 5,375 1              | 2,100 6            | 3,044 5            | 404,21                | 27,79                       |
| liquid                                                                                                   | 25          | 1,002 7         | 603                          | 315,84                      | 317,5             | 1,408 3              | 2,780 2            | 4,78               | 1 336,9               | -0,084 2                    |
| vapour                                                                                                   |             |                 | 7,801                        | 1 354,78                    | 1 483,32          | 5,318 4              | 2,145 8            | 3,148 6            | 404,46                | 25,96                       |
| liquid                                                                                                   | 30          | 1,166 5         | 595,4                        | 339,61                      | 341,57            | 1,487 4              | 2,772 7            | 4,825 7            | 1 299,7               | -0,069 4                    |
| vapour                                                                                                   |             |                 | 9,046                        | 1 357,2                     | 1 486,16          | 5,263 1              | 2,192 2            | 3,261 1            | 404,44                | 24,3                        |
| liquid                                                                                                   | 35          | 1,35            | 587,6                        | 363,58                      | 365,88            | 1,565 9              | 2,766 1            | 4,876 5            | 1 262,1               | -0,052 9                    |
| vapour                                                                                                   |             |                 | 10,448                       | 1 359,22                    | 1 488,44          | 5,208 8              | 2,239 6            | 3,383 6            | 404,15                | 22,79                       |
| liquid                                                                                                   | 40          | 1,554 5         | 579,6                        | 387,76                      | 390,45            | 1,643 9              | 2,760 4            | 4,933 3            | 1 223,9               | -0,034 6                    |
| vapour                                                                                                   |             |                 | 12,024                       | 1 360,81                    | 1 490,1           | 5,155 5              | 2,288 4            | 3,517 4            | 403,57                | 21,42                       |
| liquid                                                                                                   | 45          | 1,781 7         | 571,4                        | 412,18                      | 415,3             | 1,721 4              | 2,755 7            | 4,997              | 1 185,2               | -0,014 2                    |
| vapour                                                                                                   |             |                 | 13,792                       | 1 361,93                    | 1 491,11          | 5,102 8              | 2,338 5            | 3,664 6            | 402,68                | 20,16                       |
| liquid                                                                                                   | 50          | 2,033           | 563                          | 436,85                      | 440,46            | 1,798 5              | 2,752              | 5,068 8            | 1 146                 | 0,008 7                     |
| vapour                                                                                                   |             |                 | 15,775                       | 1 362,54                    | 1 491,41          | 5,050 7              | 2,390 2            | 3,827 4            | 401,49                | 19,01                       |
| liquid                                                                                                   | 55          | 2,31            | 554,3                        | 461,81                      | 465,97            | 1,875 3              | 2,749 2            | 5,149 9            | 1 106,1               | 0,034 4                     |
| vapour                                                                                                   |             |                 | 17,996                       | 1 362,59                    | 1 490,95          | 4,998 8              | 2,443 6            | 4,008 8            | 399,96                | 17,95                       |
| liquid                                                                                                   | 60          | 2,614 5         | 545,3                        | 487,08                      | 491,87            | 1,951 9              | 2,747 5            | 5,242 4            | 1 065,6               | 0,063 6                     |
| vapour                                                                                                   |             |                 | 20,484                       | 1 362,04                    | 1 489,67          | 4,947                | 2,498 9            | 4,212 6            | 398,09                | 16,97                       |
| liquid                                                                                                   | 65          | 2,948 1         | 536                          | 512,7                       | 518,2             | 2,028 5              | 2,747              | 5,348 6            | 1 024,4               | 0,096 8                     |
| vapour                                                                                                   |             |                 | 23,274                       | 1 360,81                    | 1 487,48          | 4,895                | 2,556 2            | 4,443 4            | 395,84                | 16,06                       |
| liquid                                                                                                   | 70          | 3,312 5         | 526,3                        | 538,72                      | 545,02            | 2,105 2              | 2,747 9            | 5,471 6            | 982,4                 | 0,135                       |
| vapour                                                                                                   |             |                 | 26,404                       | 1 358,86                    | 1 484,31          | 4,842 5              | 2,615 9            | 4,707 4            | 393,21                | 15,21                       |
| liquid                                                                                                   | 75          | 3,709 6         | 516,3                        | 565,19                      | 572,38            | 2,182 2              | 2,750 2            | 5,615 7            | 939,5                 | 0,179 1                     |
| vapour                                                                                                   |             |                 | 29,924                       | 1 356,08                    | 1 480,05          | 4,789 3              | 2,678 1            | 5,013              | 390,16                | 14,41                       |
| liquid                                                                                                   | 80          | 4,141 3         | 505,7                        | 592,18                      | 600,37            | 2,259 6              | 2,754 3            | 5,787              | 895,6                 | 0,230 7                     |
| vapour                                                                                                   |             |                 | 33,892                       | 1 352,38                    | 1 474,57          | 4,735 1              | 2,743 1            | 5,371 4            | 386,66                | 13,66                       |
| liquid                                                                                                   | 85          | 4,609 5         | 494,6                        | 619,77                      | 629,08            | 2,337 7              | 2,760 5            | 5,993 8            | 850,5                 | 0,291 6                     |
| vapour                                                                                                   |             |                 | 38,384                       | 1 347,63                    | 1 467,72          | 4,679 3              | 2,811 2            | 5,798 4            | 382,67                | 12,95                       |
| liquid                                                                                                   | 90          | 5,116 4         | 482,8                        | 648,06                      | 658,65            | 2,416 8              | 2,769 4            | 6,248 9            | 804,2                 | 0,364 5                     |
| vapour                                                                                                   |             |                 | 43,493                       | 1 341,68                    | 1 459,32          | 4,621 6              | 2,882 8            | 6,317              | 378,14                | 12,27                       |
| liquid                                                                                                   | 95          | 5,664 1         | 470,3                        | 677,19                      | 689,24            | 2,497 3              | 2,781 7            | 6,571 6            | 756,3                 | 0,453 2                     |
| vapour                                                                                                   |             |                 | 49,346                       | 1 334,32                    | 1 449,1           | 4,561 3              | 2,958 3            | 6,962              | 373,02                | 11,62                       |
| liquid                                                                                                   | 100         | 6,255 1         | 456,8                        | 707,37                      | 721,07            | 2,579 8              | 2,798 3            | 6,993 3            | 706,7                 | 0,563 1                     |
| vapour                                                                                                   |             |                 | 56,112                       | 1 325,26                    | 1 436,74          | 4,497 7              | 3,038 3            | 7,788 8            | 367,24                | 10,99                       |
| liquid                                                                                                   | 105         | 6,891 9         | 442,1                        | 738,88                      | 754,47            | 2,664 9              | 2,820 8            | 7,568 6            | 654,9                 | 0,702 7                     |
| vapour                                                                                                   |             |                 | 64,035                       | 1 314,12                    | 1 421,74          | 4,429 5              | 3,122 9            | 8,892 4            | 360,7                 | 10,38                       |
| liquid                                                                                                   | 110         | 7,577 5         | 425,7                        | 772,13                      | 789,93            | 2,753 9              | 2,851 5            | 8,4                | 600,8                 | 0,885 1                     |
| vapour                                                                                                   |             |                 | 73,481                       | 1 300,29                    | 1 403,41          | 4,355 1              | 3,212 8            | 10,454 7           | 353,3                 | 9,77                        |
| liquid                                                                                                   | 115         | 8,315 1         | 407,1                        | 807,81                      | 828,23            | 2,848 6              | 2,894 4            | 9,706 7            | 543,8                 | 1,132 6                     |
| vapour                                                                                                   |             |                 | 85,052                       | 1 282,79                    | 1 380,55          | 4,271 6              | 3,312 7            | 12,884 2           | 344,87                | 9,15                        |
| a Triple point                                                                                           |             |                 |                              |                             |                   |                      |                    |                    |                       |                             |
| b Normal boiling point                                                                                   |             |                 |                              |                             |                   |                      |                    |                    |                       |                             |
| * The values of $C_v$ , $C_p$ , and $w$ at the critical point are not included as part of this document. |             |                 |                              |                             |                   |                      |                    |                    |                       |                             |

Table 10 (continued)

|                                                                                                                                                                                       | Temp.<br>°C | Pressure<br>MPa | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|-----------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| liquid                                                                                                                                                                                | 120         | 9,108 8         | 385,1                        | 847,17                      | 870,82            | 2,952 5              | 2,957 5            | 12,060 4           | 483                   | 1,487 5                     |
| vapour                                                                                                                                                                                |             |                 | 99,866                       | 1 259,78                    | 1 350,99          | 4,173 8              | 3,441 6            | 17,313             | 334,87                | 8,47                        |
| liquid                                                                                                                                                                                | 125         | 9,963 8         | 357,1                        | 893,01                      | 920,91            | 3,073 3              | 3,072 6            | 17,636 5           | 414,5                 | 2,051 1                     |
| vapour                                                                                                                                                                                |             |                 | 120,494                      | 1 227,07                    | 1 309,76          | 4,049 9              | 3,667 7            | 28,268 5           | 321,42                | 7,64                        |
| liquid                                                                                                                                                                                | 130         | 10,888 3        | 313,4                        | 955,79                      | 990,53            | 3,240 1              | 3,557 2            | 50,546 8           | 313                   | 3,245                       |
| vapour                                                                                                                                                                                |             |                 | 156,733                      | 1 168,91                    | 1 238,38          | 3,854 9              | 4,384 7            | 96,671             | 294,02                | 6,36                        |
| critical                                                                                                                                                                              | 132,41      | 11,363 4        | 233,3                        | 1 053,41                    | 1 102,13          | 3,511 7              | *                  | *                  | *                     | 4,950 6                     |
| <sup>a</sup> Triple point<br><sup>b</sup> Normal boiling point<br><sup>*</sup> The values of $C_v$ , $C_p$ , and $w$ at the critical point are not included as part of this document. |             |                 |                              |                             |                   |                      |                    |                    |                       |                             |

## 5.4 R12 — Dichlorodifluoromethane

### 5.4.1 Range of validity

The coefficients are valid within the following ranges:

$$T_{\min} = 116,099 \text{ K}, T_{\max} = 525 \text{ K}; p_{\max} = 200 \text{ MPa}; \rho_{\max} = 15,13 \text{ mol/l (1 829 kg/m}^3\text{)}$$

Coefficients and exponents of the ideal-gas part are listed in [Table 11](#). Coefficients and exponents of the real-gas part are listed in [Table 12](#).

Table 11 — Coefficients and exponents of the ideal-gas part [Formulae (3) to (5)]

| $k$ | $c_k$         | $a_k$           | $b_k$       |
|-----|---------------|-----------------|-------------|
| 0   | 4,003 638 529 | —               | —           |
| 1   | —             | 3,160 638 395   | 1 433,434 2 |
| 2   | —             | 0,371 259 877 4 | 2 430,049 8 |
| 3   | —             | 3,562 277 099   | 685,659 52  |
| 4   | —             | 2,121 533 311   | 412,415 79  |

Table 12 — Coefficients and exponents of the real-gas part [Formula (2)]

| $k$ | $N_k$                             | $t_k$ | $d_k$ | $l_k$ | $\alpha_k$ |
|-----|-----------------------------------|-------|-------|-------|------------|
| 1   | $0,207 534 340 2 \times 10^1$     | 0,5   | 1     | 0     | 0          |
| 2   | $-0,296 252 599 6 \times 10^1$    | 1     | 1     | 0     | 0          |
| 3   | $0,100 158 961 6 \times 10^{-1}$  | 2     | 1     | 0     | 0          |
| 4   | $0,178 134 761 2 \times 10^{-1}$  | 2,5   | 2     | 0     | 0          |
| 5   | $0,255 692 915 7 \times 10^{-1}$  | -0,5  | 4     | 0     | 0          |
| 6   | $0,235 214 263 7 \times 10^{-2}$  | 0     | 6     | 0     | 0          |
| 7   | $-0,849 555 331 4 \times 10^{-4}$ | 0     | 8     | 0     | 0          |
| 8   | $-0,153 594 559 9 \times 10^{-1}$ | -0,5  | 1     | 1     | 1          |
| 9   | $-0,210 881 677 6$                | 1,5   | 1     | 1     | 1          |
| 10  | $-0,165 422 880 6 \times 10^{-1}$ | 2,5   | 5     | 1     | 1          |
| 11  | $-0,118 131 613 0 \times 10^{-1}$ | -0,5  | 7     | 1     | 1          |
| 12  | $-0,416 029 583 0 \times 10^{-4}$ | 0     | 12    | 1     | 1          |

Table 12 (continued)

| $k$ | $N_k$                                | $t_k$ | $d_k$ | $l_k$ | $\alpha_k$ |
|-----|--------------------------------------|-------|-------|-------|------------|
| 13  | $0,278\,486\,166\,4 \times 10^{-4}$  | 0,5   | 12    | 1     | 1          |
| 14  | $0,161\,868\,643\,3 \times 10^{-5}$  | -0,5  | 14    | 1     | 1          |
| 15  | -0,106 461 468 6                     | 4     | 1     | 2     | 1          |
| 16  | $0,936\,966\,520\,7 \times 10^{-3}$  | 4     | 9     | 2     | 1          |
| 17  | $0,259\,009\,544\,7 \times 10^{-1}$  | 2     | 1     | 3     | 1          |
| 18  | $-0,434\,702\,502\,5 \times 10^{-1}$ | 4     | 1     | 3     | 1          |
| 19  | 0,101 230 844 9                      | 12    | 3     | 3     | 1          |
| 20  | -0,110 000 343 8                     | 14    | 3     | 3     | 1          |
| 21  | $-0,336\,101\,200\,9 \times 10^{-2}$ | 0     | 5     | 3     | 1          |
| 22  | $0,378\,919\,000\,8 \times 10^{-3}$  | 14    | 9     | 4     | 1          |

#### 5.4.2 Reducing parameters, molar mass, and gas constant

$$T^* = 385,12 \text{ K}, \rho^* = 4,672\,781 \text{ mol/l}, M = 120,913 \text{ g/mol}, R = 8,314\,471 \text{ J/(mol}\cdot\text{K)}$$

#### 5.4.3 Reference state parameters

$$T_{\text{ref}} = 273,15 \text{ K}, p_{\text{ref}} = 1,0 \text{ kPa}, h_{\text{ref}} = 43\,261,068 \text{ J/mol}, s_{\text{ref}} = 237,753\,2 \text{ J/(mol}\cdot\text{K)}, \\ f_1 = 1,622\,697\,55, f_2 = 3\,621,284\,29$$

R12 property values along the liquid-vapour saturation boundary are listed in [Table 13](#).

Table 13 — R12 property values along the liquid-vapour saturation boundary

|                                                                                                                                                                                         | Temp.<br>°C          | Pressure<br>MPa        | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|------------------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| liquid                                                                                                                                                                                  | -157,05 <sup>a</sup> | $2,426 \times 10^{-7}$ | 1 828,8                      | 66,33                       | 66,33             | 0,278 0              | 0,572 5            | 0,856 1            | 1 310,0               | -0,530 5                    |
| vapour                                                                                                                                                                                  |                      |                        | $3,038 \times 10^{-5}$       | 275,23                      | 283,21            | 2,146 1              | 0,286 0            | 0,354 8            | 99,51                 | 532,60                      |
| liquid                                                                                                                                                                                  | -155,00              | $3,883 \times 10^{-7}$ | 1 823,4                      | 68,08                       | 68,08             | 0,293 0              | 0,567 4            | 0,851 0            | 1 299,6               | -0,533 3                    |
| vapour                                                                                                                                                                                  |                      |                        | $4,779 \times 10^{-5}$       | 275,82                      | 283,94            | 2,120 0              | 0,289 4            | 0,358 2            | 100,27                | 495,55                      |
| liquid                                                                                                                                                                                  | -150,00              | $1,135 \times 10^{-6}$ | 1 810,1                      | 72,31                       | 72,31             | 0,328 0              | 0,556 7            | 0,840 4            | 1 274,4               | -0,538 9                    |
| vapour                                                                                                                                                                                  |                      |                        | $1,340 \times 10^{-4}$       | 277,29                      | 285,75            | 2,061 2              | 0,297 8            | 0,366 5            | 102,10                | 418,14                      |
| liquid                                                                                                                                                                                  | -145,00              | $3,019 \times 10^{-6}$ | 1 796,9                      | 76,49                       | 76,49             | 0,361 3              | 0,548 2            | 0,832 1            | 1 249,5               | -0,543 0                    |
| vapour                                                                                                                                                                                  |                      |                        | $3,426 \times 10^{-4}$       | 278,80                      | 287,61            | 2,008 7              | 0,306 2            | 0,374 9            | 103,88                | 355,64                      |
| liquid                                                                                                                                                                                  | -140,00              | $7,387 \times 10^{-6}$ | 1 783,7                      | 80,63                       | 80,63             | 0,393 0              | 0,541 5            | 0,825 7            | 1 224,8               | -0,545 8                    |
| vapour                                                                                                                                                                                  |                      |                        | $8,068 \times 10^{-4}$       | 280,35                      | 289,50            | 1,961 7              | 0,314 6            | 0,383 3            | 105,63                | 304,78                      |
| liquid                                                                                                                                                                                  | -135,00              | $1,680 \times 10^{-5}$ | 1 770,6                      | 84,75                       | 84,75             | 0,423 4              | 0,536 3            | 0,821 0            | 1 200,3               | -0,547 3                    |
| vapour                                                                                                                                                                                  |                      |                        | $1,768 \times 10^{-3}$       | 281,94                      | 291,44            | 1,919 5              | 0,322 9            | 0,391 7            | 107,34                | 263,05                      |
| liquid                                                                                                                                                                                  | -130,00              | $3,577 \times 10^{-5}$ | 1 757,5                      | 88,85                       | 88,85             | 0,452 5              | 0,532 4            | 0,817 7            | 1 176,0               | -0,547 6                    |
| vapour                                                                                                                                                                                  |                      |                        | $3,635 \times 10^{-3}$       | 283,57                      | 293,42            | 1,881 6              | 0,331 3            | 0,400 1            | 109,02                | 228,57                      |
| liquid                                                                                                                                                                                  | -125,00              | $7,189 \times 10^{-5}$ | 1 744,5                      | 92,93                       | 92,93             | 0,480 5              | 0,529 6            | 0,815 7            | 1 152,0               | -0,546 9                    |
| vapour                                                                                                                                                                                  |                      |                        | $7,058 \times 10^{-3}$       | 285,25                      | 295,44            | 1,847 4              | 0,339 6            | 0,408 4            | 110,67                | 199,86                      |
| liquid                                                                                                                                                                                  | -120,00              | 0,000 137              | 1 731,4                      | 97,01                       | 97,01             | 0,507 6              | 0,527 7            | 0,814 6            | 1 128,1               | -0,545 3                    |
| <sup>a</sup> Triple point.<br><sup>b</sup> Normal boiling point.<br><sup>c</sup> The values of $C_v$ , $C_p$ , and $w$ at the critical point are not included as part of this document. |                      |                        |                              |                             |                   |                      |                    |                    |                       |                             |

Table 13 (continued)

|        | Temp.<br>°C         | Pressure<br>MPa | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | C <sub>v</sub><br>kJ/(kg·K) | C <sub>p</sub><br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|--------|---------------------|-----------------|------------------------------|-----------------------------|-------------------|----------------------|-----------------------------|-----------------------------|-----------------------|-----------------------------|
| vapour |                     |                 | 0,013 03                     | 286,96                      | 297,49            | 1,816 7              | 0,347 8                     | 0,416 6                     | 112,29                | 175,81                      |
| liquid | –115,00             | 0,000 250       | 1 718,4                      | 101,08                      | 101,08            | 0,533 8              | 0,526 6                     | 0,814 5                     | 1 104,5               | –0,542 8                    |
| vapour |                     |                 | 0,022 97                     | 288,72                      | 299,59            | 1,789 0              | 0,355 9                     | 0,424 8                     | 113,89                | 155,54                      |
| liquid | –110,00             | 0,000 436       | 1 705,3                      | 105,15                      | 105,15            | 0,559 1              | 0,526 3                     | 0,815 2                     | 1 081,1               | –0,539 5                    |
| vapour |                     |                 | 0,038 87                     | 290,51                      | 301,72            | 1,764 0              | 0,364 0                     | 0,433 0                     | 115,45                | 138,34                      |
| liquid | –105,00             | 0,000 732       | 1 692,2                      | 109,23                      | 109,23            | 0,583 8              | 0,526 5                     | 0,816 6                     | 1 058,0               | –0,535 5                    |
| vapour |                     |                 | 0,063 39                     | 292,34                      | 303,89            | 1,741 4              | 0,371 9                     | 0,441 0                     | 116,99                | 123,68                      |
| liquid | –100,00             | 0,001 19        | 1 679,1                      | 113,32                      | 113,32            | 0,607 7              | 0,527 2                     | 0,818 6                     | 1 035,0               | –0,530 8                    |
| vapour |                     |                 | 0,100 0                      | 294,20                      | 306,09            | 1,721 0              | 0,379 8                     | 0,449 1                     | 118,49                | 111,11                      |
| liquid | –95,00              | 0,001 87        | 1 666,0                      | 117,42                      | 117,42            | 0,631 0              | 0,528 3                     | 0,821 1                     | 1 012,2               | –0,525 4                    |
| vapour |                     |                 | 0,152 9                      | 296,10                      | 308,32            | 1,702 6              | 0,387 6                     | 0,457 1                     | 119,96                | 100,28                      |
| liquid | –90,00              | 0,002 86        | 1 652,8                      | 121,53                      | 121,53            | 0,653 8              | 0,529 8                     | 0,824 1                     | 989,7                 | –0,519 4                    |
| vapour |                     |                 | 0,227 5                      | 298,03                      | 310,59            | 1,686 1              | 0,395 3                     | 0,465 0                     | 121,39                | 90,92                       |
| liquid | –85,00              | 0,004 26        | 1 639,6                      | 125,66                      | 125,66            | 0,676 1              | 0,531 6                     | 0,827 5                     | 967,3                 | –0,512 8                    |
| vapour |                     |                 | 0,330 2                      | 299,98                      | 312,87            | 1,671 1              | 0,403 0                     | 0,473 0                     | 122,79                | 82,78                       |
| liquid | –80,00              | 0,006 19        | 1 626,3                      | 129,80                      | 129,81            | 0,697 8              | 0,533 7                     | 0,831 3                     | 945,2                 | –0,505 5                    |
| vapour |                     |                 | 0,468 3                      | 301,97                      | 315,19            | 1,657 6              | 0,410 5                     | 0,481 0                     | 124,14                | 75,69                       |
| liquid | –75,00              | 0,008 81        | 1 612,9                      | 133,97                      | 133,98            | 0,719 1              | 0,536 1                     | 0,835 5                     | 923,3                 | –0,497 7                    |
| vapour |                     |                 | 0,650 3                      | 303,98                      | 317,52            | 1,645 4              | 0,418 1                     | 0,489 0                     | 125,45                | 69,49                       |
| liquid | –70,00              | 0,012 3         | 1 599,5                      | 138,16                      | 138,17            | 0,740 0              | 0,538 6                     | 0,840 0                     | 901,5                 | –0,489 2                    |
| vapour |                     |                 | 0,886                        | 306,01                      | 319,87            | 1,634 4              | 0,425 5                     | 0,497 1                     | 126,71                | 64,05                       |
| liquid | –65,00              | 0,016 8         | 1 586,0                      | 142,37                      | 142,38            | 0,760 4              | 0,541 3                     | 0,844 8                     | 879,9                 | –0,480 1                    |
| vapour |                     |                 | 1,186                        | 308,07                      | 322,24            | 1,624 5              | 0,433 0                     | 0,505 2                     | 127,91                | 59,26                       |
| liquid | –60,00              | 0,022 6         | 1 572,3                      | 146,60                      | 146,62            | 0,780 6              | 0,544 2                     | 0,849 9                     | 858,5                 | –0,470 3                    |
| vapour |                     |                 | 1,563                        | 310,14                      | 324,61            | 1,615 6              | 0,440 3                     | 0,513 4                     | 129,06                | 55,03                       |
| liquid | –55,00              | 0,030 0         | 1 558,6                      | 150,87                      | 150,88            | 0,800 3              | 0,547 2                     | 0,855 3                     | 837,3                 | –0,459 8                    |
| vapour |                     |                 | 2,029                        | 312,23                      | 327,00            | 1,607 6              | 0,447 7                     | 0,521 8                     | 130,15                | 51,29                       |
| liquid | –50,00              | 0,039 1         | 1 544,7                      | 155,15                      | 155,18            | 0,819 7              | 0,550 3                     | 0,860 9                     | 816,2                 | –0,448 6                    |
| vapour |                     |                 | 2,598                        | 314,34                      | 329,39            | 1,600 4              | 0,455 0                     | 0,530 2                     | 131,17                | 47,97                       |
| liquid | –45,00              | 0,050 4         | 1 530,7                      | 159,47                      | 159,50            | 0,838 9              | 0,553 5                     | 0,866 8                     | 795,3                 | –0,436 6                    |
| vapour |                     |                 | 3,286                        | 316,45                      | 331,79            | 1,594 0              | 0,462 4                     | 0,538 9                     | 132,11                | 45,01                       |
| liquid | –40,00              | 0,064 1         | 1 516,5                      | 163,81                      | 163,86            | 0,857 7              | 0,556 8                     | 0,873 0                     | 774,5                 | –0,423 7                    |
| vapour |                     |                 | 4,108                        | 318,58                      | 334,18            | 1,588 2              | 0,469 7                     | 0,547 7                     | 132,99                | 42,38                       |
| liquid | –35,00              | 0,080 6         | 1 502,2                      | 168,19                      | 168,24            | 0,876 3              | 0,560 2                     | 0,879 5                     | 753,8                 | –0,409 9                    |
| vapour |                     |                 | 5,083                        | 320,71                      | 336,56            | 1,583 1              | 0,477 0                     | 0,556 8                     | 133,78                | 40,02                       |
| liquid | –30,00              | 0,100 3         | 1 487,7                      | 172,60                      | 172,67            | 0,894 6              | 0,563 6                     | 0,886 3                     | 733,3                 | –0,395 1                    |
| vapour |                     |                 | 6,228                        | 322,84                      | 338,94            | 1,578 4              | 0,484 3                     | 0,566 1                     | 134,49                | 37,90                       |
| liquid | –29,75 <sup>b</sup> | 0,101 3         | 1 487,0                      | 172,82                      | 172,89            | 0,895 5              | 0,563 7                     | 0,886 6                     | 732,3                 | –0,394 3                    |
| vapour |                     |                 | 6,289                        | 322,95                      | 339,06            | 1,578 2              | 0,484 7                     | 0,566 6                     | 134,52                | 37,81                       |
| liquid | –25,00              | 0,123 5         | 1 473,0                      | 177,04                      | 177,12            | 0,912 7              | 0,567 0                     | 0,893 4                     | 712,9                 | –0,379 2                    |
| vapour |                     |                 | 7,563                        | 324,98                      | 341,30            | 1,574 3              | 0,491 7                     | 0,575 7                     | 135,10                | 36,00                       |

<sup>a</sup> Triple point.<sup>b</sup> Normal boiling point.<sup>c</sup> The values of C<sub>v</sub>, C<sub>p</sub>, and w at the critical point are not included as part of this document.

Table 13 (continued)

|                                                                                                          | Temp.<br>°C | Pressure<br>MPa | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|----------------------------------------------------------------------------------------------------------|-------------|-----------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| liquid                                                                                                   | −20,00      | 0,150 7         | 1 458,1                      | 181,51                      | 181,62            | 0,930 5              | 0,570 5            | 0,900 7            | 692,5                 | −0,362 0                    |
| vapour                                                                                                   |             |                 | 9,109                        | 327,11                      | 343,65            | 1,570 6              | 0,499 0            | 0,585 7            | 135,63                | 34,29                       |
| liquid                                                                                                   | −15,00      | 0,182 3         | 1 443,0                      | 186,02                      | 186,15            | 0,948 2              | 0,574 1            | 0,908 5            | 672,3                 | −0,343 4                    |
| vapour                                                                                                   |             |                 | 10,889                       | 329,24                      | 345,98            | 1,567 3              | 0,506 4            | 0,596 0            | 136,05                | 32,75                       |
| liquid                                                                                                   | −10,00      | 0,218 8         | 1 427,6                      | 190,57                      | 190,72            | 0,965 6              | 0,577 6            | 0,916 6            | 652,1                 | −0,323 3                    |
| vapour                                                                                                   |             |                 | 12,925                       | 331,36                      | 348,29            | 1,564 4              | 0,513 9            | 0,606 8            | 136,38                | 31,35                       |
| liquid                                                                                                   | −5,00       | 0,260 6         | 1 412,0                      | 195,15                      | 195,34            | 0,982 9              | 0,581 2            | 0,925 1            | 632,0                 | −0,301 5                    |
| vapour                                                                                                   |             |                 | 15,244                       | 333,47                      | 350,56            | 1,561 8              | 0,521 3            | 0,618 0            | 136,59                | 30,09                       |
| liquid                                                                                                   | 0,00        | 0,308 1         | 1 396,1                      | 199,78                      | 200,00            | 1,000 0              | 0,584 9            | 0,934 1            | 611,9                 | −0,277 7                    |
| vapour                                                                                                   |             |                 | 17,873                       | 335,56                      | 352,81            | 1,559 4              | 0,528 9            | 0,629 8            | 136,69                | 28,94                       |
| liquid                                                                                                   | 5,00        | 0,362 0         | 1 379,8                      | 204,45                      | 204,71            | 1,016 9              | 0,588 5            | 0,943 6            | 591,9                 | −0,251 6                    |
| vapour                                                                                                   |             |                 | 20,842                       | 337,64                      | 355,01            | 1,557 3              | 0,536 5            | 0,642 3            | 136,68                | 27,91                       |
| liquid                                                                                                   | 10,00       | 0,422 7         | 1 363,2                      | 209,15                      | 209,46            | 1,033 7              | 0,592 2            | 0,953 7            | 571,8                 | −0,223 0                    |
| vapour                                                                                                   |             |                 | 24,184                       | 339,70                      | 357,18            | 1,555 4              | 0,544 1            | 0,655 5            | 136,54                | 26,97                       |
| liquid                                                                                                   | 15,00       | 0,490 6         | 1 346,3                      | 213,91                      | 214,27            | 1,050 4              | 0,596 0            | 0,964 5            | 551,8                 | −0,191 5                    |
| vapour                                                                                                   |             |                 | 27,935                       | 341,73                      | 359,30            | 1,553 7              | 0,551 9            | 0,669 6            | 136,28                | 26,11                       |
| liquid                                                                                                   | 20,00       | 0,566 4         | 1 328,9                      | 218,71                      | 219,14            | 1,066 9              | 0,599 7            | 0,976 1            | 531,7                 | −0,156 5                    |
| vapour                                                                                                   |             |                 | 32,135                       | 343,73                      | 361,36            | 1,552 1              | 0,559 7            | 0,684 6            | 135,88                | 25,34                       |
| liquid                                                                                                   | 25,00       | 0,650 6         | 1 311,0                      | 223,56                      | 224,06            | 1,083 4              | 0,603 6            | 0,988 5            | 511,5                 | −0,117 6                    |
| vapour                                                                                                   |             |                 | 36,828                       | 345,70                      | 363,37            | 1,550 6              | 0,567 6            | 0,700 8            | 135,34                | 24,65                       |
| liquid                                                                                                   | 30,00       | 0,743 7         | 1 292,7                      | 228,47                      | 229,04            | 1,099 7              | 0,607 5            | 1,002 1            | 491,3                 | −0,074 0                    |
| vapour                                                                                                   |             |                 | 42,066                       | 347,63                      | 365,31            | 1,549 2              | 0,575 7            | 0,718 4            | 134,65                | 24,02                       |
| liquid                                                                                                   | 35,00       | 0,846 2         | 1 273,8                      | 233,43                      | 234,10            | 1,116 0              | 0,611 4            | 1,016 9            | 471,0                 | −0,024 8                    |
| vapour                                                                                                   |             |                 | 47,906                       | 349,51                      | 367,18            | 1,547 8              | 0,583 8            | 0,737 7            | 133,82                | 23,46                       |
| liquid                                                                                                   | 40,00       | 0,958 8         | 1 254,3                      | 238,46                      | 239,22            | 1,132 2              | 0,615 5            | 1,033 2            | 450,5                 | 0,031 1                     |
| vapour                                                                                                   |             |                 | 54,416                       | 351,34                      | 368,96            | 1,546 5              | 0,592 1            | 0,758 9            | 132,82                | 22,96                       |
| liquid                                                                                                   | 45,00       | 1,082 1         | 1 234,0                      | 243,55                      | 244,42            | 1,148 4              | 0,619 7            | 1,051 4            | 429,7                 | 0,095 0                     |
| vapour                                                                                                   |             |                 | 61,673                       | 353,11                      | 370,66            | 1,545 1              | 0,600 6            | 0,782 7            | 131,65                | 22,52                       |
| liquid                                                                                                   | 50,00       | 1,216 6         | 1 213,0                      | 248,71                      | 249,71            | 1,164 5              | 0,624 2            | 1,071 9            | 408,8                 | 0,168 8                     |
| vapour                                                                                                   |             |                 | 69,771                       | 354,81                      | 372,24            | 1,543 7              | 0,609 3            | 0,809 5            | 130,30                | 22,14                       |
| liquid                                                                                                   | 55,00       | 1,363 0         | 1 191,1                      | 253,95                      | 255,10            | 1,180 7              | 0,628 8            | 1,095 3            | 387,5                 | 0,254 9                     |
| vapour                                                                                                   |             |                 | 78,823                       | 356,42                      | 373,72            | 1,542 1              | 0,618 2            | 0,840 4            | 128,76                | 21,81                       |
| liquid                                                                                                   | 60,00       | 1,521 9         | 1 168,1                      | 259,28                      | 260,58            | 1,196 9              | 0,633 8            | 1,122 5            | 365,9                 | 0,356 5                     |
| vapour                                                                                                   |             |                 | 88,966                       | 357,94                      | 375,05            | 1,540 4              | 0,627 4            | 0,876 3            | 127,02                | 21,54                       |
| liquid                                                                                                   | 65,00       | 1,694 1         | 1 144,0                      | 264,71                      | 266,19            | 1,213 1              | 0,639 1            | 1,154 5            | 343,9                 | 0,478 3                     |
| vapour                                                                                                   |             |                 | 100,375                      | 359,35                      | 376,23            | 1,538 5              | 0,637 0            | 0,919 1            | 125,07                | 21,31                       |
| liquid                                                                                                   | 70,00       | 1,880 2         | 1 118,3                      | 270,26                      | 271,94            | 1,229 5              | 0,645 0            | 1,193 1            | 321,3                 | 0,626 4                     |
| vapour                                                                                                   |             |                 | 113,272                      | 360,62                      | 377,22            | 1,536 3              | 0,647 1            | 0,971 4            | 122,88                | 21,14                       |
| liquid                                                                                                   | 75,00       | 2,081 1         | 1 090,9                      | 275,94                      | 277,84            | 1,246 1              | 0,651 7            | 1,241 0            | 298,1                 | 0,810 3                     |
| vapour                                                                                                   |             |                 | 127,952                      | 361,72                      | 377,99            | 1,533 7              | 0,657 8            | 1,037 0            | 120,44                | 21,01                       |
| liquid                                                                                                   | 80,00       | 2,297 5         | 1 061,4                      | 281,78                      | 283,94            | 1,262 9              | 0,659 4            | 1,302 4            | 274,1                 | 1,043 9                     |
| a Triple point.                                                                                          |             |                 |                              |                             |                   |                      |                    |                    |                       |                             |
| b Normal boiling point.                                                                                  |             |                 |                              |                             |                   |                      |                    |                    |                       |                             |
| c The values of $C_v$ , $C_p$ , and $w$ at the critical point are not included as part of this document. |             |                 |                              |                             |                   |                      |                    |                    |                       |                             |

Table 13 (continued)

|                                                                                                                                                                                         | Temp.<br>°C | Pressure<br>MPa | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|-----------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| vapour                                                                                                                                                                                  |             |                 | 144,822                      | 362,62                      | 378,48            | 1,530 6              | 0,669 3            | 1,122 5            | 117,73                | 20,92                       |
| liquid                                                                                                                                                                                  | 85,00       | 2,530 4         | 1 029,1                      | 287,82                      | 290,27            | 1,280 1              | 0,668 4            | 1,384 4            | 249,4                 | 1,349 5                     |
| vapour                                                                                                                                                                                  |             |                 | 164,464                      | 363,26                      | 378,64            | 1,526 8              | 0,681 9            | 1,239 4            | 114,73                | 20,85                       |
| liquid                                                                                                                                                                                  | 90,00       | 2,780 8         | 993,2                        | 294,11                      | 296,91            | 1,297 8              | 0,679 5            | 1,500 6            | 223,6                 | 1,763 6                     |
| vapour                                                                                                                                                                                  |             |                 | 187,766                      | 363,54                      | 378,35            | 1,522 0              | 0,696 1            | 1,410 1            | 111,41                | 20,79                       |
| liquid                                                                                                                                                                                  | 95,00       | 3,050 1         | 952,2                        | 300,75                      | 303,95            | 1,316 3              | 0,693 6            | 1,679 4            | 196,9                 | 2,351 8                     |
| vapour                                                                                                                                                                                  |             |                 | 216,208                      | 363,34                      | 377,45            | 1,515 9              | 0,712 7            | 1,683 5            | 107,75                | 20,68                       |
| liquid                                                                                                                                                                                  | 100,00      | 3,339 9         | 903,8                        | 307,89                      | 311,58            | 1,336 0              | 0,712 2            | 1,996 3            | 169,0                 | 3,247 0                     |
| vapour                                                                                                                                                                                  |             |                 | 252,577                      | 362,38                      | 375,60            | 1,507 6              | 0,733 2            | 2,192 4            | 103,73                | 20,41                       |
| liquid                                                                                                                                                                                  | 105,00      | 3,652 5         | 842,2                        | 315,90                      | 320,24            | 1,358 1              | 0,738 7            | 2,753 9            | 139,3                 | 4,787 2                     |
| vapour                                                                                                                                                                                  |             |                 | 303,473                      | 360,05                      | 372,08            | 1,495 2              | 0,761 0            | 3,457 9            | 99,28                 | 19,71                       |
| liquid                                                                                                                                                                                  | 110,00      | 3,992 4         | 742,7                        | 326,44                      | 331,82            | 1,387 4              | 0,787 0            | 7,806 1            | 105,3                 | 8,291 6                     |
| vapour                                                                                                                                                                                  |             |                 | 396,337                      | 353,88                      | 363,95            | 1,471 2              | 0,808 9            | 11,440 0           | 93,96                 | 17,60                       |
| critical                                                                                                                                                                                | 111,97      | 4,136 1         | 565,0                        | 340,44                      | 347,76            | 1,428 3              | c                  | c                  | c                     | 13,369 4                    |
| <sup>a</sup> Triple point.<br><sup>b</sup> Normal boiling point.<br><sup>c</sup> The values of $C_v$ , $C_p$ , and $w$ at the critical point are not included as part of this document. |             |                 |                              |                             |                   |                      |                    |                    |                       |                             |

## 5.5 R22 — Chlorodifluoromethane

### 5.5.1 Range of validity

The coefficients are valid within the following ranges:

$$T_{\min} = 115,73 \text{ K}, T_{\max} = 550 \text{ K}; p_{\max} = 60 \text{ MPa}; \rho_{\max} = 19,91 \text{ mol/l (1 722 kg/m}^3\text{)}$$

Coefficients and exponents of the ideal-gas part are listed in [Table 14](#). Coefficients and exponents of the real-gas part are listed in [Table 15](#).

Table 14 — Coefficients and exponents of the ideal-gas part [Formulae (3) to (5)]

| $k$ | $c_k$             | $t_k$ | $a_k$ | $b_k$        |
|-----|-------------------|-------|-------|--------------|
| 0   | 4,005 261 404 46  | —     | —     | —            |
| 1   | 0,000 120 662 553 | 1     | —     | —            |
| 2   | —                 | —     | 1,0   | 4 352,309 5  |
| 3   | —                 | —     | 1,0   | 1 935,159 1  |
| 4   | —                 | —     | 1,0   | 1 887,679 36 |
| 5   | —                 | —     | 1,0   | 1 694,882 84 |
| 6   | —                 | —     | 1,0   | 1 605,678 48 |
| 7   | —                 | —     | 1,0   | 1 162,534 24 |
| 8   | —                 | —     | 1,0   | 857,512 88   |
| 9   | —                 | —     | 1,0   | 605,726 38   |
| 10  | —                 | —     | 1,0   | 530,909 82   |

Table 15 — Coefficients and exponents of the real-gas part [Formula (2)]

| $k$ | $N_k$                                  | $t_k$ | $d_k$ | $l_k$ | $\alpha_k$ |
|-----|----------------------------------------|-------|-------|-------|------------|
| 1   | $0,695\,645\,445\,236 \times 10^{-1}$  | -1    | 1     | 0     | 0          |
| 2   | $0,252\,275\,419\,999 \times 10^2$     | 1,75  | 1     | 0     | 0          |
| 3   | $-0,202\,351\,148\,311 \times 10^3$    | 2,25  | 1     | 0     | 0          |
| 4   | $0,350\,063\,090\,302 \times 10^3$     | 2,5   | 1     | 0     | 0          |
| 5   | $-0,223\,134\,648\,863 \times 10^3$    | 2,75  | 1     | 0     | 0          |
| 6   | $0,488\,345\,904\,592 \times 10^2$     | 3     | 1     | 0     | 0          |
| 7   | $0,108\,874\,958\,556 \times 10^{-1}$  | 5,5   | 1     | 0     | 0          |
| 8   | 0,590 315 073 614                      | 1,5   | 2     | 0     | 0          |
| 9   | -0,689 043 767 432                     | 1,75  | 2     | 0     | 0          |
| 10  | 0,284 224 445 844                      | 3,5   | 2     | 0     | 0          |
| 11  | 0,125 436 457 897                      | 1     | 3     | 0     | 0          |
| 12  | $-0,113\,338\,666\,416 \times 10^{-1}$ | 4,5   | 3     | 0     | 0          |
| 13  | $-0,631\,388\,959\,17 \times 10^{-1}$  | 1,5   | 4     | 0     | 0          |
| 14  | $0,974\,021\,015\,232 \times 10^{-2}$  | 0,5   | 5     | 0     | 0          |
| 15  | $-0,408\,406\,844\,722 \times 10^{-3}$ | 4,5   | 6     | 0     | 0          |
| 16  | $0,741\,948\,773\,570 \times 10^{-3}$  | 1     | 7     | 0     | 0          |
| 17  | $0,315\,912\,525\,922 \times 10^{-3}$  | 4     | 7     | 0     | 0          |
| 18  | $0,876\,009\,723\,338 \times 10^{-5}$  | 5     | 7     | 0     | 0          |
| 19  | $-0,110\,343\,340\,301 \times 10^{-3}$ | -0,5  | 8     | 0     | 0          |
| 20  | $-0,705\,323\,356\,879 \times 10^{-4}$ | 3,5   | 8     | 0     | 0          |
| 21  | 0,235 850 731 510                      | 5     | 2     | 2     | 1          |
| 22  | -0,192 640 494 729                     | 7     | 2     | 2     | 1          |
| 23  | $0,375\,218\,008\,557 \times 10^{-2}$  | 12    | 2     | 2     | 1          |
| 24  | $-0,448\,926\,036\,678 \times 10^{-4}$ | 15    | 2     | 2     | 1          |
| 25  | $0,198\,120\,520\,635 \times 10^{-1}$  | 3,5   | 3     | 3     | 1          |
| 26  | $-0,356\,958\,425\,255 \times 10^{-1}$ | 3,5   | 4     | 2     | 1          |
| 27  | $0,319\,594\,161\,562 \times 10^{-1}$  | 8     | 4     | 2     | 1          |
| 28  | $0,260\,284\,291\,078 \times 10^{-5}$  | 15    | 4     | 2     | 1          |
| 29  | $-0,897\,629\,021\,967 \times 10^{-2}$ | 25    | 4     | 4     | 1          |
| 30  | $0,345\,482\,791\,645 \times 10^{-1}$  | 3     | 6     | 2     | 1          |
| 31  | $-0,411\,831\,711\,251 \times 10^{-2}$ | 9     | 6     | 2     | 1          |
| 32  | $0,567\,428\,536\,529 \times 10^{-2}$  | 19    | 6     | 4     | 1          |
| 33  | $-0,563\,368\,989\,908 \times 10^{-2}$ | 2     | 8     | 2     | 1          |
| 34  | $0,191\,384\,919\,423 \times 10^{-2}$  | 7     | 8     | 2     | 1          |
| 35  | $-0,178\,930\,036\,389 \times 10^{-2}$ | 13    | 8     | 4     | 1          |

### 5.5.2 Reducing parameters, molar mass, and gas constant

$$T^* = 369,295 \text{ K}, \rho^* = 6,058\,22 \text{ mol/l}, M = 86,468 \text{ g/mol}, R = 8,314\,51 \text{ J/(mol}\cdot\text{K)}$$

## 5.5.3 Reference state parameters

$$T_{\text{ref}} = 273,15 \text{ K}, p_{\text{ref}} = 1,0 \text{ kPa}, h_{\text{ref}} = 35\,874,594 \text{ J/mol}, s_{\text{ref}} = 205,291 \text{ J/(mol}\cdot\text{K)},$$

$$f_1 = 4,111\,053\,69, f_2 = 2\,986,449\,88$$

R22 property values along the liquid-vapour saturation boundary are listed in [Table 16](#).

Table 16 — R22 property values along the liquid-vapour saturation boundary

|        | Temp.<br>°C          | Pressure<br>MPa        | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|--------|----------------------|------------------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| liquid | −157,42 <sup>a</sup> | $3,795 \times 10^{-7}$ | 1 721,3                      | 29,60                       | 29,60             | 0,076 1              | 0,716 1            | 1,075 3            | 1 410,9               | −0,444 6                    |
| vapour |                      |                        | $3,410 \times 10^{-5}$       | 321,58                      | 332,71            | 2,695 2              | 0,329 2            | 0,425 3            | 119,91                | 398,80                      |
| liquid | −155,00              | $6,620 \times 10^{-7}$ | 1 714,9                      | 32,20                       | 32,20             | 0,098 3              | 0,713 9            | 1,073 5            | 1 398,2               | −0,445 0                    |
| vapour |                      |                        | $5,827 \times 10^{-5}$       | 322,38                      | 333,74            | 2,650 5              | 0,331 8            | 0,428 0            | 121,05                | 380,74                      |
| liquid | −150,00              | $1,934 \times 10^{-6}$ | 1 701,8                      | 37,56                       | 37,56             | 0,142 8              | 0,708 6            | 1,069 6            | 1 371,9               | −0,445 6                    |
| vapour |                      |                        | $1,633 \times 10^{-4}$       | 324,05                      | 335,90            | 2,565 3              | 0,337 5            | 0,433 6            | 123,35                | 344,75                      |
| liquid | −145,00              | $5,141 \times 10^{-6}$ | 1 688,8                      | 42,90                       | 42,90             | 0,185 3              | 0,702 7            | 1,066 3            | 1 346,3               | −0,445 6                    |
| vapour |                      |                        | $4,172 \times 10^{-4}$       | 325,76                      | 338,08            | 2,488 7              | 0,343 3            | 0,439 4            | 125,60                | 311,19                      |
| liquid | −140,00              | $1,258 \times 10^{-5}$ | 1 675,8                      | 48,22                       | 48,22             | 0,226 0              | 0,697 2            | 1,064 1            | 1 321,4               | −0,444 9                    |
| vapour |                      |                        | $9,826 \times 10^{-4}$       | 327,49                      | 340,29            | 2,419 5              | 0,349 2            | 0,445 4            | 127,78                | 280,46                      |
| liquid | −135,00              | $2,860 \times 10^{-5}$ | 1 662,8                      | 53,54                       | 53,54             | 0,265 2              | 0,692 3            | 1,062 8            | 1 296,8               | −0,443 6                    |
| vapour |                      |                        | $2,153 \times 10^{-3}$       | 329,25                      | 342,53            | 2,357 1              | 0,355 2            | 0,451 4            | 129,92                | 252,63                      |
| liquid | −130,00              | $6,091 \times 10^{-5}$ | 1 649,8                      | 58,85                       | 58,85             | 0,303 0              | 0,688 2            | 1,062 2            | 1 272,4               | −0,441 7                    |
| vapour |                      |                        | $4,426 \times 10^{-3}$       | 331,04                      | 344,80            | 2,300 5              | 0,361 4            | 0,457 6            | 132,01                | 227,61                      |
| liquid | −125,00              | 0,000 122              | 1 636,8                      | 64,16                       | 64,16             | 0,339 5              | 0,684 7            | 1,062 0            | 1 248,0               | −0,439 6                    |
| vapour |                      |                        | 0,008 59                     | 332,85                      | 347,10            | 2,249 2              | 0,367 6            | 0,463 9            | 134,05                | 205,23                      |
| liquid | −120,00              | 0,000 233              | 1 623,7                      | 69,47                       | 69,47             | 0,374 7              | 0,681 5            | 1,061 9            | 1 223,7               | −0,437 2                    |
| vapour |                      |                        | 0,015 85                     | 334,70                      | 349,42            | 2,202 7              | 0,373 9            | 0,470 3            | 136,04                | 185,26                      |
| liquid | −115,00              | 0,000 424              | 1 610,7                      | 74,78                       | 74,78             | 0,408 8              | 0,678 6            | 1,061 8            | 1 199,5               | −0,434 6                    |
| vapour |                      |                        | 0,027 92                     | 336,57                      | 351,77            | 2,160 3              | 0,380 3            | 0,476 8            | 137,99                | 167,49                      |
| liquid | −110,00              | 0,000 740              | 1 597,6                      | 80,09                       | 80,09             | 0,441 9              | 0,675 9            | 1,061 6            | 1 175,4               | −0,431 9                    |
| vapour |                      |                        | 0,047 19                     | 338,48                      | 354,15            | 2,121 7              | 0,386 8            | 0,483 4            | 139,90                | 151,69                      |
| liquid | −105,00              | 0,001 24               | 1 584,5                      | 85,40                       | 85,40             | 0,473 9              | 0,673 2            | 1,061 4            | 1 151,4               | −0,428 9                    |
| vapour |                      |                        | 0,076 8                      | 340,40                      | 356,55            | 2,086 5              | 0,393 4            | 0,490 2            | 141,76                | 137,65                      |
| liquid | −100,00              | 0,002 01               | 1 571,3                      | 90,70                       | 90,71             | 0,505 0              | 0,670 6            | 1,061 2            | 1 127,5               | −0,425 7                    |
| vapour |                      |                        | 0,121 0                      | 342,35                      | 358,97            | 2,054 3              | 0,400 0            | 0,497 2            | 143,57                | 125,17                      |
| liquid | −95,00               | 0,003 16               | 1 558,1                      | 96,01                       | 96,01             | 0,535 2              | 0,668 0            | 1,061 1            | 1 103,7               | −0,422 1                    |
| vapour |                      |                        | 0,184 7                      | 344,32                      | 361,40            | 2,024 9              | 0,406 7            | 0,504 4            | 145,34                | 114,07                      |
| liquid | −90,00               | 0,004 81               | 1 544,9                      | 101,31                      | 101,32            | 0,564 6              | 0,665 5            | 1,061 2            | 1 080,1               | −0,418 0                    |
| vapour |                      |                        | 0,274 4                      | 346,31                      | 363,85            | 1,998 0              | 0,413 6            | 0,511 8            | 147,05                | 104,20                      |
| liquid | −85,00               | 0,007 15               | 1 531,6                      | 106,62                      | 106,63            | 0,593 2              | 0,663 2            | 1,061 6            | 1 056,6               | −0,413 4                    |
| vapour |                      |                        | 0,397 3                      | 348,31                      | 366,31            | 1,973 4              | 0,420 6            | 0,519 5            | 148,70                | 95,41                       |
| liquid | −80,00               | 0,010 4                | 1 518,2                      | 111,93                      | 111,94            | 0,621 0              | 0,661 1            | 1,062 4            | 1 033,1               | −0,408 2                    |
| vapour |                      |                        | 0,562                        | 350,33                      | 368,77            | 1,950 8              | 0,427 7            | 0,527 6            | 150,29                | 87,58                       |
| liquid | −75,00               | 0,014 7                | 1 504,7                      | 117,24                      | 117,25            | 0,648 2              | 0,659 2            | 1,063 7            | 1 009,8               | −0,402 3                    |
| vapour |                      |                        | 0,779                        | 352,36                      | 371,24            | 1,930 0              | 0,435 0            | 0,535 9            | 151,82                | 80,60                       |
| liquid | −70,00               | 0,020 5                | 1 491,2                      | 122,56                      | 122,58            | 0,674 7              | 0,657 5            | 1,065 5            | 986,4                 | −0,395 6                    |

<sup>a</sup> Triple point.

<sup>b</sup> Normal boiling point.

<sup>c</sup> The values of  $C_v$ ,  $C_p$ , and  $w$  at the critical point are not included as part of this document.

Table 16 (continued)

|        | Temp.<br>°C         | Pressure<br>MPa | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|--------|---------------------|-----------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| vapour |                     |                 | 1,060                        | 354,39                      | 373,70            | 1,910 8              | 0,442 5            | 0,544 7            | 153,28                | 74,36                       |
| liquid | −65,00              | 0,027 9         | 1 477,5                      | 127,90                      | 127,91            | 0,700 6              | 0,656 2            | 1,067 9            | 963,2                 | −0,388 1                    |
| vapour |                     |                 | 1,416                        | 356,42                      | 376,15            | 1,893 2              | 0,450 2            | 0,553 9            | 154,66                | 68,78                       |
| liquid | −60,00              | 0,037 5         | 1 463,7                      | 133,24                      | 133,27            | 0,726 0              | 0,655 2            | 1,071 0            | 939,9                 | −0,379 6                    |
| vapour |                     |                 | 1,863                        | 358,46                      | 378,59            | 1,877 0              | 0,458 1            | 0,563 7            | 155,97                | 63,78                       |
| liquid | −55,00              | 0,049 6         | 1 449,7                      | 138,60                      | 138,63            | 0,750 9              | 0,654 6            | 1,074 8            | 916,6                 | −0,370 2                    |
| vapour |                     |                 | 2,414                        | 360,49                      | 381,02            | 1,861 9              | 0,466 2            | 0,573 9            | 157,18                | 59,29                       |
| liquid | −50,00              | 0,064 5         | 1 435,6                      | 143,98                      | 144,03            | 0,775 2              | 0,654 3            | 1,079 3            | 893,4                 | −0,359 7                    |
| vapour |                     |                 | 3,088                        | 362,52                      | 383,42            | 1,848 0              | 0,474 5            | 0,584 7            | 158,31                | 55,26                       |
| liquid | −45,00              | 0,082 9         | 1 421,3                      | 149,38                      | 149,44            | 0,799 2              | 0,654 4            | 1,084 5            | 870,1                 | −0,348 1                    |
| vapour |                     |                 | 3,901                        | 364,53                      | 385,79            | 1,835 1              | 0,483 1            | 0,596 2            | 159,33                | 51,63                       |
| liquid | −40,81 <sup>b</sup> | 0,101 3         | 1 409,2                      | 153,93                      | 154,00            | 0,818 9              | 0,654 8            | 1,089 5            | 850,6                 | −0,337 5                    |
| vapour |                     |                 | 4,704                        | 366,21                      | 387,75            | 1,825 0              | 0,490 4            | 0,606 3            | 160,11                | 48,85                       |
| liquid | −40,00              | 0,105 2         | 1 406,8                      | 154,81                      | 154,89            | 0,822 7              | 0,654 9            | 1,090 5            | 846,9                 | −0,335 3                    |
| vapour |                     |                 | 4,873                        | 366,53                      | 388,13            | 1,823 1              | 0,491 9            | 0,608 3            | 160,26                | 48,34                       |
| liquid | −30,00              | 0,163 9         | 1 377,2                      | 165,76                      | 165,88            | 0,868 7              | 0,657 0            | 1,104 9            | 800,3                 | −0,305 7                    |
| vapour |                     |                 | 7,379                        | 370,48                      | 392,69            | 1,801 5              | 0,510 3            | 0,634 9            | 161,78                | 42,68                       |
| liquid | −25,00              | 0,201 4         | 1 362,0                      | 171,29                      | 171,44            | 0,891 2              | 0,658 5            | 1,113 4            | 777,0                 | −0,288 7                    |
| vapour |                     |                 | 8,958                        | 372,42                      | 394,90            | 1,791 8              | 0,519 9            | 0,649 5            | 162,36                | 40,24                       |
| liquid | −20,00              | 0,245 3         | 1 346,5                      | 176,86                      | 177,04            | 0,913 5              | 0,660 4            | 1,122 7            | 753,6                 | −0,270 0                    |
| vapour |                     |                 | 10,790                       | 374,33                      | 397,06            | 1,782 6              | 0,529 9            | 0,665 0            | 162,82                | 38,01                       |
| liquid | −15,00              | 0,296 2         | 1 330,8                      | 182,47                      | 182,70            | 0,935 4              | 0,662 6            | 1,132 8            | 730,2                 | −0,249 5                    |
| vapour |                     |                 | 12,901                       | 376,20                      | 399,16            | 1,774 0              | 0,540 0            | 0,681 6            | 163,15                | 35,98                       |
| liquid | −10,00              | 0,354 8         | 1 314,7                      | 188,13                      | 188,40            | 0,957 2              | 0,665 1            | 1,143 9            | 706,8                 | −0,227 0                    |
| vapour |                     |                 | 15,322                       | 378,04                      | 401,20            | 1,765 8              | 0,550 5            | 0,699 4            | 163,35                | 34,13                       |
| liquid | −5,00               | 0,421 8         | 1 298,3                      | 193,85                      | 194,17            | 0,978 7              | 0,668 0            | 1,156 1            | 683,4                 | −0,202 3                    |
| vapour |                     |                 | 18,086                       | 379,84                      | 403,16            | 1,758 1              | 0,561 3            | 0,718 4            | 163,40                | 32,44                       |
| liquid | 0,00                | 0,498 0         | 1 281,5                      | 199,61                      | 200,00            | 1,000 0              | 0,671 1            | 1,169 2            | 659,9                 | −0,175 0                    |
| vapour |                     |                 | 21,229                       | 381,59                      | 405,05            | 1,750 7              | 0,572 3            | 0,739 0            | 163,31                | 30,89                       |
| liquid | 5,00                | 0,584 1         | 1 264,3                      | 205,44                      | 205,90            | 1,021 2              | 0,674 5            | 1,183 6            | 636,3                 | −0,144 8                    |
| vapour |                     |                 | 24,792                       | 383,29                      | 406,85            | 1,743 6              | 0,583 6            | 0,761 1            | 163,06                | 29,48                       |
| liquid | 10,00               | 0,680 9         | 1 246,7                      | 211,32                      | 211,87            | 1,042 2              | 0,678 2            | 1,199 3            | 612,7                 | −0,111 2                    |
| vapour |                     |                 | 28,820                       | 384,93                      | 408,56            | 1,736 8              | 0,595 3            | 0,785 2            | 162,65                | 28,18                       |
| liquid | 15,00               | 0,789 3         | 1 228,6                      | 217,28                      | 217,92            | 1,063 0              | 0,682 2            | 1,216 6            | 588,9                 | −0,073 7                    |
| vapour |                     |                 | 33,362                       | 386,51                      | 410,16            | 1,730 2              | 0,607 2            | 0,811 5            | 162,07                | 26,99                       |
| liquid | 20,00               | 0,910 0         | 1 209,9                      | 223,31                      | 224,06            | 1,083 8              | 0,686 4            | 1,235 6            | 565,1                 | −0,031 6                    |
| vapour |                     |                 | 38,477                       | 388,01                      | 411,66            | 1,723 8              | 0,619 5            | 0,840 4            | 161,32                | 25,90                       |
| liquid | 25,00               | 1,043 9         | 1 190,7                      | 229,41                      | 230,29            | 1,104 5              | 0,690 9            | 1,256 8            | 541,1                 | 0,016 1                     |
| vapour |                     |                 | 44,232                       | 389,43                      | 413,03            | 1,717 4              | 0,632 1            | 0,872 4            | 160,38                | 24,90                       |
| liquid | 30,00               | 1,191 9         | 1 170,7                      | 235,61                      | 236,62            | 1,125 2              | 0,695 6            | 1,280 7            | 516,8                 | 0,070 4                     |
| vapour |                     |                 | 50,705                       | 390,76                      | 414,26            | 1,711 1              | 0,645 0            | 0,908 1            | 159,25                | 23,98                       |
| liquid | 35,00               | 1,354 8         | 1 150,1                      | 241,89                      | 243,07            | 1,145 8              | 0,700 6            | 1,307 7            | 492,4                 | 0,133 1                     |
| vapour |                     |                 | 57,988                       | 391,98                      | 415,34            | 1,704 8              | 0,658 4            | 0,948 5            | 157,91                | 23,14                       |
| liquid | 40,00               | 1,533 6         | 1 128,5                      | 248,29                      | 249,65            | 1,166 5              | 0,705 9            | 1,338 9            | 467,6                 | 0,206 0                     |

<sup>a</sup> Triple point.<sup>b</sup> Normal boiling point.<sup>c</sup> The values of  $C_v$ ,  $C_p$ , and  $w$  at the critical point are not included as part of this document.

Table 16 (continued)

|                                                                                                                                                                                         | Temp.<br>°C | Pressure<br>MPa | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|-----------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| vapour                                                                                                                                                                                  |             |                 | 66,193                       | 393,08                      | 416,25            | 1,698 5              | 0,672 2            | 0,994 8            | 156,36                | 22,37                       |
| liquid                                                                                                                                                                                  | 45,00       | 1,729 2         | 1 106,0                      | 254,80                      | 256,36            | 1,187 2              | 0,711 6            | 1,375 5            | 442,5                 | 0,291 9                     |
| vapour                                                                                                                                                                                  |             |                 | 75,457                       | 394,04                      | 416,95            | 1,691 9              | 0,686 5            | 1,048 7            | 154,58                | 21,66                       |
| liquid                                                                                                                                                                                  | 50,00       | 1,942 7         | 1 082,3                      | 261,45                      | 263,25            | 1,208 0              | 0,717 6            | 1,419 1            | 417,0                 | 0,394 5                     |
| vapour                                                                                                                                                                                  |             |                 | 85,952                       | 394,83                      | 417,44            | 1,685 2              | 0,701 4            | 1,112 6            | 152,56                | 21,01                       |
| liquid                                                                                                                                                                                  | 55,00       | 2,175 1         | 1 057,2                      | 268,26                      | 270,32            | 1,229 1              | 0,724 0            | 1,472 4            | 390,9                 | 0,519 0                     |
| vapour                                                                                                                                                                                  |             |                 | 97,899                       | 395,43                      | 417,65            | 1,678 1              | 0,717 0            | 1,190 2            | 150,28                | 20,41                       |
| liquid                                                                                                                                                                                  | 60,00       | 2,427 5         | 1 030,4                      | 275,26                      | 277,61            | 1,250 4              | 0,730 8            | 1,539 2            | 364,3                 | 0,673 0                     |
| vapour                                                                                                                                                                                  |             |                 | 111,591                      | 395,80                      | 417,55            | 1,670 5              | 0,733 5            | 1,287 2            | 147,72                | 19,85                       |
| liquid                                                                                                                                                                                  | 65,00       | 2,701 2         | 1 001,4                      | 282,49                      | 285,18            | 1,272 2              | 0,738 4            | 1,625 9            | 337,0                 | 0,867 4                     |
| vapour                                                                                                                                                                                  |             |                 | 127,430                      | 395,87                      | 417,06            | 1,662 2              | 0,751 1            | 1,412 8            | 144,85                | 19,32                       |
| liquid                                                                                                                                                                                  | 70,00       | 2,997 4         | 969,7                        | 290,01                      | 293,10            | 1,294 5              | 0,746 7            | 1,743 4            | 308,8                 | 1,119 9                     |
| vapour                                                                                                                                                                                  |             |                 | 145,991                      | 395,56                      | 416,09            | 1,652 9              | 0,770 2            | 1,583 7            | 141,66                | 18,81                       |
| liquid                                                                                                                                                                                  | 75,00       | 3,317 7         | 934,4                        | 297,91                      | 301,46            | 1,317 7              | 0,756 3            | 1,912 7            | 279,6                 | 1,459 8                     |
| vapour                                                                                                                                                                                  |             |                 | 168,158                      | 394,76                      | 414,49            | 1,642 4              | 0,791 4            | 1,832 2            | 138,11                | 18,28                       |
| liquid                                                                                                                                                                                  | 80,00       | 3,663 8         | 893,7                        | 306,34                      | 310,44            | 1,342 3              | 0,768 0            | 2,181 4            | 248,8                 | 1,942 0                     |
| vapour                                                                                                                                                                                  |             |                 | 195,404                      | 393,26                      | 412,01            | 1,629 9              | 0,815 7            | 2,230 8            | 134,15                | 17,70                       |
| liquid                                                                                                                                                                                  | 85,00       | 4,037 8         | 844,8                        | 315,60                      | 320,38            | 1,369 0              | 0,784 0            | 2,682 1            | 215,3                 | 2,684 3                     |
| vapour                                                                                                                                                                                  |             |                 | 230,560                      | 390,67                      | 408,19            | 1,614 2              | 0,845 0            | 2,984 1            | 129,71                | 16,98                       |
| liquid                                                                                                                                                                                  | 90,00       | 4,442 3         | 780,1                        | 326,39                      | 332,09            | 1,400 1              | 0,811 5            | 3,981 1            | 177,0                 | 4,000 6                     |
| vapour                                                                                                                                                                                  |             |                 | 280,625                      | 386,04                      | 401,87            | 1,592 2              | 0,884 3            | 4,974 9            | 124,64                | 15,90                       |
| liquid                                                                                                                                                                                  | 95,00       | 4,882 4         | 662,9                        | 342,19                      | 349,56            | 1,446 2              | 0,891 8            | 17,312 0           | 128,0                 | 7,285 5                     |
| vapour                                                                                                                                                                                  |             |                 | 382,037                      | 374,50                      | 387,28            | 1,548 6              | 0,956 6            | 25,286 3           | 117,96                | 13,40                       |
| critical                                                                                                                                                                                | 96,15       | 4,990 0         | 523,8                        | 357,37                      | 366,90            | 1,492 7              | c                  | c                  | c                     | 10,366 1                    |
| <sup>a</sup> Triple point.<br><sup>b</sup> Normal boiling point.<br><sup>c</sup> The values of $C_v$ , $C_p$ , and $w$ at the critical point are not included as part of this document. |             |                 |                              |                             |                   |                      |                    |                    |                       |                             |

## 5.6 R32 — Difluoromethane

### 5.6.1 Range of validity

The coefficients are valid within the following ranges:

$$T_{\min} = 136,34 \text{ K}, T_{\max} = 435 \text{ K}; p_{\max} = 70 \text{ MPa}; \rho_{\max} = 27,473 4 \text{ mol/l (1 429 kg/m}^3\text{)}$$

Coefficients and exponents of the ideal-gas part are listed in [Table 17](#). Coefficients and exponents of the real-gas part are listed in [Table 18](#).

Table 17 — Coefficients and exponents of the ideal-gas part [Formulae (3) to (5)]

| $k$ | $c_k$     | $a_k$     | $b_k$  |
|-----|-----------|-----------|--------|
| 0   | 4,004 486 | —         | —      |
| 1   | —         | 1,160 761 | 798    |
| 2   | —         | 2,645 151 | 4 185  |
| 3   | —         | 5,794 987 | 1 806  |
| 4   | —         | 1,129 475 | 11 510 |

**Table 18 — Coefficients and exponents of the real-gas part [Formula (2)]**

| $k$ | $N_k$            | $t_k$ | $d_k$ | $l_k$ | $\alpha_k$ |
|-----|------------------|-------|-------|-------|------------|
| 1   | 1,046 634        | 0,25  | 1     | 0     | 0          |
| 2   | -0,545 116 5     | 1     | 2     | 0     | 0          |
| 3   | -0,002 448 595   | -0,25 | 5     | 0     | 0          |
| 4   | -0,048 770 02    | -1    | 1     | 0     | 0          |
| 5   | 0,035 201 58     | 2     | 1     | 0     | 0          |
| 6   | 0,001 622 75     | 2     | 3     | 0     | 0          |
| 7   | 0,000 023 772 25 | 0,75  | 8     | 0     | 0          |
| 8   | 0,029 149        | 0,25  | 4     | 0     | 0          |
| 9   | 0,003 386 203    | 18    | 4     | 4     | 1          |
| 10  | -0,004 202 444   | 26    | 4     | 3     | 1          |
| 11  | 0,000 478 202 5  | -1    | 8     | 1     | 1          |
| 12  | -0,005 504 323   | 25    | 3     | 4     | 1          |
| 13  | -0,024 183 96    | 1,75  | 5     | 1     | 1          |
| 14  | 0,420 903 4      | 4     | 1     | 2     | 1          |
| 15  | -0,461 653 7     | 5     | 1     | 2     | 1          |
| 16  | -1,200 513       | 1     | 3     | 1     | 1          |
| 17  | -2,591 55        | 1,5   | 1     | 1     | 1          |
| 18  | -1,400 145       | 1     | 2     | 1     | 1          |
| 19  | 0,826 301 7      | 0,5   | 3     | 1     | 1          |

**5.6.2 Reducing parameters, molar mass, and gas constant**

$$T^* = 351,255 \text{ K}, \rho^* = 8,150\,084\,6 \text{ mol/l}, M = 52,024 \text{ g/mol}, R = 8,314\,471 \text{ J/(mol}\cdot\text{K)}$$

**5.6.3 Reference state parameters**

$$T_{\text{ref}} = 273,15 \text{ K}, p_{\text{ref}} = 1,0 \text{ kPa}, h_{\text{ref}} = 28\,204,341 \text{ J/mol}, s_{\text{ref}} = 171,691\,3 \text{ J/(mol}\cdot\text{K)}, \\ f_1 = 7,254\,707\,84, f_2 = 2\,231,557\,35$$

R32 property values along the liquid-vapour saturation boundary are listed in [Table 19](#).

**Table 19 — R32 property values along the liquid-vapour saturation boundary**

|        | Temp.<br>°C          | Pressure<br>MPa        | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|--------|----------------------|------------------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| liquid | -136,81 <sup>a</sup> | 4,800×10 <sup>-5</sup> | 1 429,3                      | -19,07                      | -19,07            | -0,105 0             | 1,065 8            | 1,592 5            | 1 414,4               | -0,337 6                    |
| vapour |                      |                        | 2,203×10 <sup>-3</sup>       | 422,52                      | 444,31            | 3,293 7              | 0,499 5            | 0,659 7            | 169,60                | 881,12                      |
| liquid | -135,00              | 6,339×10 <sup>-5</sup> | 1 424,9                      | -16,19                      | -16,19            | -0,084 0             | 1,061 3            | 1,590 0            | 1 404,9               | -0,337 5                    |
| vapour |                      |                        | 2,872×10 <sup>-3</sup>       | 423,42                      | 445,49            | 3,257 9              | 0,500 7            | 0,660 9            | 170,67                | 823,35                      |
| liquid | -130,00              | 0,000 131              | 1 412,7                      | -8,26                       | -8,26             | -0,027 6             | 1,049 4            | 1,583 5            | 1 378,4               | -0,336 9                    |
| vapour |                      |                        | 0,005 74                     | 425,90                      | 448,77            | 3,165 1              | 0,504 1            | 0,664 6            | 173,59                | 686,24                      |
| liquid | -125,00              | 0,000 257              | 1 400,6                      | -0,36                       | -0,36             | 0,026 7              | 1,038 0            | 1,577 7            | 1 352,1               | -0,335 9                    |
| vapour |                      |                        | 0,010 85                     | 428,39                      | 452,05            | 3,080 4              | 0,508 0            | 0,668 9            | 176,44                | 576,21                      |

<sup>a</sup> Triple point.

<sup>b</sup> Normal boiling point.

<sup>c</sup> The values of  $C_v$ ,  $C_p$ , and  $w$  at the critical point are not included as part of this document.

Table 19 (continued)

|                                                                                                                                     | Temp.<br>°C         | Pressure<br>MPa | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | C <sub>v</sub><br>kJ/(kg·K) | C <sub>p</sub><br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|-------------------------------------------------------------------------------------------------------------------------------------|---------------------|-----------------|------------------------------|-----------------------------|-------------------|----------------------|-----------------------------|-----------------------------|-----------------------|-----------------------------|
| liquid                                                                                                                              | –120,00             | 0,000 478       | 1 388,4                      | 7,52                        | 7,52              | 0,079 0              | 1,027 4                     | 1,572 6                     | 1 325,8               | –0,334 5                    |
| vapour                                                                                                                              |                     |                 | 0,019 54                     | 430,88                      | 455,33            | 3,003 0              | 0,512 3                     | 0,673 8                     | 179,21                | 487,31                      |
| liquid                                                                                                                              | –115,00             | 0,000 850       | 1 376,1                      | 15,37                       | 15,37             | 0,129 4              | 1,017 3                     | 1,568 2                     | 1 299,5               | –0,332 7                    |
| vapour                                                                                                                              |                     |                 | 0,033 69                     | 433,37                      | 458,60            | 2,932 0              | 0,517 3                     | 0,679 6                     | 181,91                | 415,01                      |
| liquid                                                                                                                              | –110,00             | 0,001 45        | 1 363,8                      | 23,20                       | 23,20             | 0,178 2              | 1,007 9                     | 1,564 7                     | 1 273,4               | –0,330 4                    |
| vapour                                                                                                                              |                     |                 | 0,055 8                      | 435,85                      | 461,86            | 2,866 8              | 0,522 9                     | 0,686 3                     | 184,52                | 355,78                      |
| liquid                                                                                                                              | –105,00             | 0,002 39        | 1 351,5                      | 31,02                       | 31,02             | 0,225 4              | 0,999 1                     | 1,561 9                     | 1 247,3               | –0,327 7                    |
| vapour                                                                                                                              |                     |                 | 0,089 4                      | 438,32                      | 465,10            | 2,806 8              | 0,529 3                     | 0,694 0                     | 187,05                | 306,92                      |
| liquid                                                                                                                              | –100,00             | 0,003 81        | 1 339,0                      | 38,82                       | 38,83             | 0,271 1              | 0,991 0                     | 1,560 0                     | 1 221,2               | –0,324 4                    |
| vapour                                                                                                                              |                     |                 | 0,138 5                      | 440,77                      | 468,31            | 2,751 5              | 0,536 5                     | 0,703 0                     | 189,50                | 266,28                      |
| liquid                                                                                                                              | –95,00              | 0,005 90        | 1 326,5                      | 46,62                       | 46,62             | 0,315 5              | 0,983 4                     | 1,558 8                     | 1 195,3               | –0,320 5                    |
| vapour                                                                                                                              |                     |                 | 0,208 4                      | 443,20                      | 471,48            | 2,700 3              | 0,544 6                     | 0,713 4                     | 191,84                | 232,23                      |
| liquid                                                                                                                              | –90,00              | 0,008 87        | 1 313,9                      | 54,41                       | 54,42             | 0,358 6              | 0,976 4                     | 1,558 6                     | 1 169,3               | –0,316 0                    |
| vapour                                                                                                                              |                     |                 | 0,305 6                      | 445,59                      | 474,61            | 2,652 9              | 0,553 8                     | 0,725 4                     | 194,09                | 203,45                      |
| liquid                                                                                                                              | –85,00              | 0,013 0         | 1 301,2                      | 62,20                       | 62,21             | 0,400 6              | 0,970 0                     | 1,559 2                     | 1 143,4               | –0,310 9                    |
| vapour                                                                                                                              |                     |                 | 0,438                        | 447,96                      | 477,70            | 2,608 9              | 0,564 1                     | 0,739 0                     | 196,24                | 178,95                      |
| liquid                                                                                                                              | –80,00              | 0,018 7         | 1 288,4                      | 70,00                       | 70,02             | 0,441 5              | 0,964 1                     | 1,560 6                     | 1 117,5               | –0,305 1                    |
| vapour                                                                                                                              |                     |                 | 0,613                        | 450,29                      | 480,72            | 2,567 9              | 0,575 5                     | 0,754 3                     | 198,26                | 157,95                      |
| liquid                                                                                                                              | –75,00              | 0,026 2         | 1 275,4                      | 77,81                       | 77,83             | 0,481 4              | 0,958 8                     | 1,563 0                     | 1 091,7               | –0,298 6                    |
| vapour                                                                                                                              |                     |                 | 0,842                        | 452,57                      | 483,68            | 2,529 6              | 0,588 0                     | 0,771 4                     | 200,18                | 139,85                      |
| liquid                                                                                                                              | –70,00              | 0,036 1         | 1 262,4                      | 85,63                       | 85,66             | 0,520 4              | 0,954 0                     | 1,566 3                     | 1 065,8               | –0,291 3                    |
| vapour                                                                                                                              |                     |                 | 1,135                        | 454,81                      | 486,57            | 2,493 9              | 0,601 5                     | 0,790 3                     | 201,96                | 124,19                      |
| liquid                                                                                                                              | –65,00              | 0,048 8         | 1 249,1                      | 93,46                       | 93,50             | 0,558 5              | 0,949 7                     | 1,570 6                     | 1 039,9               | –0,283 1                    |
| vapour                                                                                                                              |                     |                 | 1,507                        | 456,99                      | 489,38            | 2,460 4              | 0,616 0                     | 0,811 0                     | 203,62                | 110,58                      |
| liquid                                                                                                                              | –60,00              | 0,065 0         | 1 235,7                      | 101,32                      | 101,38            | 0,595 8              | 0,946 0                     | 1,575 8                     | 1 014,1               | –0,274 0                    |
| vapour                                                                                                                              |                     |                 | 1,969                        | 459,12                      | 492,11            | 2,428 9              | 0,631 5                     | 0,833 5                     | 205,14                | 98,73                       |
| liquid                                                                                                                              | –55,00              | 0,085 2         | 1 222,1                      | 109,21                      | 109,28            | 0,632 4              | 0,942 7                     | 1,582 1                     | 988,2                 | –0,264 0                    |
| vapour                                                                                                                              |                     |                 | 2,538                        | 461,19                      | 494,74            | 2,399 3              | 0,647 7                     | 0,857 6                     | 206,52                | 88,40                       |
| liquid                                                                                                                              | –50,00              | 0,110 1         | 1 208,4                      | 117,13                      | 117,22            | 0,668 3              | 0,940 0                     | 1,589 5                     | 962,2                 | –0,252 8                    |
| vapour                                                                                                                              |                     |                 | 3,232                        | 463,19                      | 497,27            | 2,371 4              | 0,664 6                     | 0,883 5                     | 207,75                | 79,39                       |
| liquid                                                                                                                              | –51,65 <sup>b</sup> | 0,101 3         | 1 212,9                      | 114,51                      | 114,59            | 0,656 5              | 0,940 8                     | 1,586 9                     | 970,8                 | –0,256 6                    |
| vapour                                                                                                                              |                     |                 | 2,988                        | 462,54                      | 496,45            | 2,380 5              | 0,658 9                     | 0,874 8                     | 207,36                | 82,23                       |
| liquid                                                                                                                              | –45,00              | 0,140 6         | 1 194,4                      | 125,08                      | 125,20            | 0,703 5              | 0,937 7                     | 1,598 0                     | 936,3                 | –0,240 4                    |
| vapour                                                                                                                              |                     |                 | 4,067                        | 465,13                      | 499,70            | 2,345 0              | 0,682 0                     | 0,911 0                     | 208,83                | 71,52                       |
| liquid                                                                                                                              | –40,00              | 0,177 4         | 1 180,2                      | 133,08                      | 133,23            | 0,738 2              | 0,935 9                     | 1,607 7                     | 910,2                 | –0,226 7                    |
| vapour                                                                                                                              |                     |                 | 5,065                        | 466,99                      | 502,02            | 2,320 0              | 0,699 8                     | 0,940 1                     | 209,74                | 64,65                       |
| liquid                                                                                                                              | –35,00              | 0,221 4         | 1 165,7                      | 141,12                      | 141,31            | 0,772 3              | 0,934 6                     | 1,618 7                     | 884,0                 | –0,211 5                    |
| vapour                                                                                                                              |                     |                 | 6,248                        | 468,78                      | 504,21            | 2,296 2              | 0,718 0                     | 0,970 9                     | 210,49                | 58,63                       |
| liquid                                                                                                                              | –30,00              | 0,273 4         | 1 151,0                      | 149,21                      | 149,45            | 0,806 0              | 0,933 8                     | 1,631 1                     | 857,8                 | –0,194 7                    |
| vapour                                                                                                                              |                     |                 | 7,639                        | 470,48                      | 506,27            | 2,273 5              | 0,736 5                     | 1,003 5                     | 211,07                | 53,37                       |
| liquid                                                                                                                              | –25,00              | 0,334 6         | 1 135,9                      | 157,36                      | 157,66            | 0,839 2              | 0,933 4                     | 1,645 1                     | 831,4                 | –0,176 1                    |
| <sup>a</sup> Triple point.                                                                                                          |                     |                 |                              |                             |                   |                      |                             |                             |                       |                             |
| <sup>b</sup> Normal boiling point.                                                                                                  |                     |                 |                              |                             |                   |                      |                             |                             |                       |                             |
| <sup>c</sup> The values of C <sub>v</sub> , C <sub>p</sub> , and w at the critical point are not included as part of this document. |                     |                 |                              |                             |                   |                      |                             |                             |                       |                             |

Table 19 (continued)

|        | Temp.<br>°C | Pressure<br>MPa | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|--------|-------------|-----------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| vapour |             |                 | 9,266                        | 472,09                      | 508,20            | 2,251 8              | 0,755 2            | 1,038 0            | 211,47                | 48,75                       |
| liquid | −20,00      | 0,405 8         | 1 120,6                      | 165,58                      | 165,94            | 0,872 0              | 0,933 5            | 1,660 7            | 804,9                 | −0,155 3                    |
| vapour |             |                 | 11,157                       | 473,61                      | 509,97            | 2,231 0              | 0,774 0            | 1,074 7            | 211,68                | 44,70                       |
| liquid | −15,00      | 0,488 1         | 1 104,9                      | 173,86                      | 174,31            | 0,904 4              | 0,934 1            | 1,678 3            | 778,3                 | −0,132 2                    |
| vapour |             |                 | 13,346                       | 475,01                      | 511,58            | 2,210 9              | 0,793 0            | 1,113 9            | 211,69                | 41,13                       |
| liquid | −10,00      | 0,582 6         | 1 088,8                      | 182,23                      | 182,76            | 0,936 5              | 0,935 1            | 1,698 0            | 751,4                 | −0,106 3                    |
| vapour |             |                 | 15,870                       | 476,31                      | 513,02            | 2,191 5              | 0,812 1            | 1,156 0            | 211,50                | 37,98                       |
| liquid | −5,00       | 0,690 6         | 1 072,2                      | 190,68                      | 191,33            | 0,968 4              | 0,936 6            | 1,720 1            | 724,3                 | −0,077 2                    |
| vapour |             |                 | 18,769                       | 477,47                      | 514,26            | 2,172 7              | 0,831 5            | 1,201 5            | 211,10                | 35,20                       |
| liquid | 0,00        | 0,813 1         | 1 055,3                      | 199,23                      | 200,00            | 1,000 0              | 0,938 6            | 1,745 0            | 696,9                 | −0,044 4                    |
| vapour |             |                 | 22,091                       | 478,49                      | 515,30            | 2,154 3              | 0,851 0            | 1,251 1            | 210,48                | 32,72                       |
| liquid | 5,00        | 0,951 4         | 1 037,7                      | 207,88                      | 208,80            | 1,031 4              | 0,941 2            | 1,773 3            | 669,2                 | −0,007 1                    |
| vapour |             |                 | 25,891                       | 479,36                      | 516,11            | 2,136 3              | 0,870 9            | 1,305 8            | 209,63                | 30,51                       |
| liquid | 10,00       | 1,106 9         | 1 019,7                      | 216,66                      | 217,74            | 1,062 8              | 0,944 3            | 1,805 6            | 641,2                 | 0,035 4                     |
| vapour |             |                 | 30,232                       | 480,05                      | 516,66            | 2,118 5              | 0,891 1            | 1,366 7            | 208,54                | 28,54                       |
| liquid | 15,00       | 1,280 8         | 1 000,9                      | 225,56                      | 226,84            | 1,094 0              | 0,948 0            | 1,842 8            | 612,7                 | 0,084 3                     |
| vapour |             |                 | 35,190                       | 480,54                      | 516,93            | 2,100 8              | 0,911 8            | 1,435 3            | 207,20                | 26,76                       |
| liquid | 20,00       | 1,474 6         | 981,4                        | 234,62                      | 236,12            | 1,125 3              | 0,952 4            | 1,885 9            | 583,7                 | 0,141 0                     |
| vapour |             |                 | 40,856                       | 480,81                      | 516,90            | 2,083 1              | 0,933 1            | 1,513 6            | 205,60                | 25,16                       |
| liquid | 25,00       | 1,689 6         | 961,0                        | 243,84                      | 245,60            | 1,156 6              | 0,957 7            | 1,936 7            | 554,2                 | 0,207 6                     |
| vapour |             |                 | 47,339                       | 480,82                      | 516,51            | 2,065 2              | 0,955 0            | 1,604 5            | 203,72                | 23,69                       |
| liquid | 30,00       | 1,927 5         | 939,6                        | 253,27                      | 255,32            | 1,188 1              | 0,963 8            | 1,997 3            | 524,0                 | 0,286 5                     |
| vapour |             |                 | 54,776                       | 480,54                      | 515,72            | 2,047 1              | 0,977 9            | 1,711 8            | 201,54                | 22,36                       |
| liquid | 35,00       | 2,189 8         | 917,0                        | 262,92                      | 265,30            | 1,219 8              | 0,971 2            | 2,071 0            | 493,0                 | 0,381 5                     |
| vapour |             |                 | 63,343                       | 479,91                      | 514,48            | 2,028 5              | 1,001 9            | 1,841 2            | 199,04                | 21,13                       |
| liquid | 40,00       | 2,478 3         | 893,0                        | 272,84                      | 275,61            | 1,252 0              | 0,980 0            | 2,162 9            | 461,0                 | 0,497 6                     |
| vapour |             |                 | 73,268                       | 478,88                      | 512,71            | 2,009 1              | 1,027 2            | 2,001 2            | 196,19                | 19,98                       |
| liquid | 45,00       | 2,794 8         | 867,3                        | 283,09                      | 286,31            | 1,284 7              | 0,990 7            | 2,280 9            | 428,0                 | 0,642 8                     |
| vapour |             |                 | 84,859                       | 477,36                      | 510,29            | 1,988 8              | 1,054 2            | 2,205 6            | 192,96                | 18,90                       |
| liquid | 50,00       | 3,141 2         | 839,3                        | 293,74                      | 297,49            | 1,318 3              | 1,003 9            | 2,438 5            | 393,6                 | 0,828 8                     |
| vapour |             |                 | 98,550                       | 475,23                      | 507,10            | 1,967 0              | 1,083 4            | 2,477 3            | 189,31                | 17,86                       |
| liquid | 55,00       | 3,519 9         | 808,3                        | 304,93                      | 309,29            | 1,353 1              | 1,020 7            | 2,661 0            | 357,6                 | 1,075 1                     |
| vapour |             |                 | 114,989                      | 472,32                      | 502,93            | 1,943 2              | 1,115 6            | 2,859 4            | 185,16                | 16,85                       |
| liquid | 60,00       | 3,933 2         | 773,3                        | 316,84                      | 321,93            | 1,389 8              | 1,042 8            | 3,000 7            | 319,7                 | 1,415 7                     |
| vapour |             |                 | 135,213                      | 468,35                      | 497,44            | 1,916 6              | 1,151 9            | 3,441 2            | 180,43                | 15,83                       |
| liquid | 65,00       | 4,384 3         | 732,3                        | 329,81                      | 335,80            | 1,429 3              | 1,073 2            | 3,588 0            | 279,4                 | 1,916 0                     |
| vapour |             |                 | 161,092                      | 462,84                      | 490,05            | 1,885 5              | 1,194 7            | 4,446 2            | 174,95                | 14,75                       |
| liquid | 70,00       | 4,876 8         | 680,9                        | 344,57                      | 351,73            | 1,474 0              | 1,119 4            | 4,865 3            | 235,8                 | 2,723 3                     |
| vapour |             |                 | 196,688                      | 454,72                      | 479,52            | 1,846 4              | 1,248 8            | 6,638 8            | 168,40                | 13,49                       |
| liquid | 75,00       | 5,416 8         | 605,9                        | 363,45                      | 372,39            | 1,531 4              | 1,206 4            | 10,134 7           | 186,1                 | 4,309 3                     |
| vapour |             |                 | 255,587                      | 440,53                      | 461,72            | 1,788 0              | 1,331 0            | 15,601 6           | 159,64                | 11,74                       |

a Triple point.

b Normal boiling point.

c The values of  $C_v$ ,  $C_p$ , and  $w$  at the critical point are not included as part of this document.

Table 19 (continued)

|                                                                                                                                                                                         | Temp. | Pressure | Density           | Internal energy | Enthalpy | Entropy   | $C_v$     | $C_p$     | Sound speed | J-T coefficient |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------|----------|-------------------|-----------------|----------|-----------|-----------|-----------|-------------|-----------------|
|                                                                                                                                                                                         | °C    | MPa      | kg/m <sup>3</sup> | kJ/kg           | kJ/kg    | kJ/(kg·K) | kJ/(kg·K) | kJ/(kg·K) | m/s         | K/MPa           |
| critical                                                                                                                                                                                | 78,11 | 5,782 0  | 424,0             | 400,51          | 414,15   | 1,648 6   | c         | c         | c           | 8,073 1         |
| <sup>a</sup> Triple point.<br><sup>b</sup> Normal boiling point.<br><sup>c</sup> The values of $C_v$ , $C_p$ , and $w$ at the critical point are not included as part of this document. |       |          |                   |                 |          |           |           |           |             |                 |

## 5.7 R123 — 2,2-dichloro-1,1,1-trifluoroethane

### 5.7.1 Range of validity

The coefficients are valid within the following ranges:

$$T_{\min} = 166 \text{ K}, T_{\max} = 600 \text{ K}; p_{\max} = 40 \text{ MPa}; \rho_{\max} = 11,6 \text{ mol/l (1 774 kg/m}^3\text{)}$$

Coefficients and exponents of the ideal-gas part are listed in [Table 20](#). Coefficients and exponents of the real-gas part are listed in [Table 21](#).

Table 20 — Coefficients and exponents of the ideal-gas part [Formulae (3) to (5)]

| $k$ | $c_k$                       | $t_k$ |
|-----|-----------------------------|-------|
| 0   | 2,046 006                   | —     |
| 1   | $4,866 562 \times 10^{-2}$  | 1     |
| 2   | $-5,586 382 \times 10^{-5}$ | 2     |
| 3   | $2,823 279 \times 10^{-8}$  | 3     |

Table 21 — Coefficients and exponents of the real-gas part [Formula (2)]

| $k$ | $N_k$                               | $t_k$ | $d_k$ | $l_k$ | $\alpha_k$ |
|-----|-------------------------------------|-------|-------|-------|------------|
| 1   | $-0,100 242 647 494 \times 10^2$    | 3     | 0     | 0     | 0          |
| 2   | $-0,280 607 656 419$                | 4     | 0     | 0     | 0          |
| 3   | $0,206 814 471 606 \times 10^{-1}$  | 5     | 0     | 0     | 0          |
| 4   | $-0,284 379 431 451$                | 0     | 1     | 0     | 0          |
| 5   | $0,593 928 110 321 \times 10^1$     | 0,5   | 1     | 0     | 0          |
| 6   | $-0,936 560 389 528 \times 10^1$    | 1     | 1     | 0     | 0          |
| 7   | $0,416 660 793 675 \times 10^1$     | 2     | 1     | 0     | 0          |
| 8   | $-0,174 023 292 951 \times 10^1$    | 3     | 1     | 0     | 0          |
| 9   | $0,177 019 905 365$                 | 0     | 2     | 0     | 0          |
| 10  | $-0,154 721 692 26 \times 10^1$     | 1     | 2     | 0     | 0          |
| 11  | $0,161 820 495 59 \times 10^1$      | 2     | 2     | 0     | 0          |
| 12  | $0,288 903 529 383 \times 10^1$     | 3     | 2     | 0     | 0          |
| 13  | $-0,118 493 874 757$                | 0     | 3     | 0     | 0          |
| 14  | $0,130 952 266 209 \times 10^1$     | 1     | 3     | 0     | 0          |
| 15  | $-0,117 308 103 711 \times 10^1$    | 2     | 3     | 0     | 0          |
| 16  | $-0,128 125 131 950$                | 1     | 4     | 0     | 0          |
| 17  | $-0,786 087 387 513 \times 10^{-1}$ | 2     | 5     | 0     | 0          |
| 18  | $-0,816 000 499 305 \times 10^{-1}$ | 3     | 5     | 0     | 0          |
| 19  | $0,536 451 054 311 \times 10^{-1}$  | 2     | 6     | 0     | 0          |
| 20  | $-0,680 078 211 929 \times 10^{-2}$ | 2     | 7     | 0     | 0          |
| 21  | $0,701 264 082 191 \times 10^{-2}$  | 3     | 7     | 0     | 0          |
| 22  | $-0,901 762 397 311 \times 10^{-3}$ | 3     | 8     | 0     | 0          |

Table 21 (continued)

| $k$ | $N_k$                                  | $t_k$ | $d_k$ | $l_k$ | $\alpha_k$ |
|-----|----------------------------------------|-------|-------|-------|------------|
| 23  | $0,100\,242\,647\,494 \times 10^2$     | 3     | 0     | 2     | 1          |
| 24  | 0,280 607 656 419                      | 4     | 0     | 2     | 1          |
| 25  | $-0,206\,814\,471\,606 \times 10^{-1}$ | 5     | 0     | 2     | 1          |
| 26  | $0,798\,923\,878\,145 \times 10^1$     | 3     | 2     | 2     | 1          |
| 27  | -0,547 972 072 476                     | 4     | 2     | 2     | 1          |
| 28  | $-0,206\,814\,470\,584 \times 10^{-1}$ | 5     | 2     | 2     | 1          |
| 29  | $0,249\,142\,724\,365 \times 10^1$     | 3     | 4     | 2     | 1          |
| 30  | -0,273 986 034 884                     | 4     | 4     | 2     | 1          |
| 31  | 0,236 001 863 614                      | 5     | 4     | 2     | 1          |
| 32  | 0,540 528 251 211                      | 3     | 6     | 2     | 1          |
| 33  | $-0,600\,457\,561\,959 \times 10^{-1}$ | 4     | 6     | 2     | 1          |
| 34  | $0,786\,672\,874\,826 \times 10^{-1}$  | 5     | 6     | 2     | 1          |
| 35  | $0,708\,085\,874\,508 \times 10^{-1}$  | 3     | 8     | 2     | 1          |
| 36  | $-0,150\,114\,389\,748 \times 10^{-1}$ | 4     | 8     | 2     | 1          |
| 37  | $0,182\,205\,199\,477 \times 10^{-2}$  | 5     | 8     | 2     | 1          |
| 38  | $0,314\,978\,575\,163 \times 10^{-2}$  | 3     | 10    | 2     | 1          |
| 39  | $0,784\,455\,573\,794 \times 10^{-2}$  | 4     | 10    | 2     | 1          |
| 40  | $0,364\,410\,397\,155 \times 10^{-3}$  | 5     | 10    | 2     | 1          |

### 5.7.2 Reducing parameters, molar mass, and gas constant

$$T^* = 456,831 \text{ K}, \rho^* = 3,596\,417 \text{ mol/l}, M = 152,931 \text{ g/mol}, R = 8,314\,51 \text{ J/(mol}\cdot\text{K)}$$

### 5.7.3 Reference state parameters

$$T_{\text{ref}} = 273,15 \text{ K}, p_{\text{ref}} = 1,0 \text{ kPa}, h_{\text{ref}} = 58\,497,533 \text{ J/mol}, s_{\text{ref}} = 283,936\,5 \text{ J/(mol}\cdot\text{K)}, \\ f_1 = -8,106\,583\,79, f_2 = 5\,001,445\,51$$

R123 property values along the liquid-vapour saturation boundary are listed in [Table 22](#).

Table 22 — R123 property values along the liquid-vapour saturation boundary

|        | Temp.<br>°C          | Pressure<br>MPa        | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|--------|----------------------|------------------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| liquid | -107,15 <sup>a</sup> | $4,202 \times 10^{-6}$ | 1 771,0                      | 98,81                       | 98,81             | 0,531 1              | 0,629 5            | 0,928 9            | 1 243,8               | -0,475 5                    |
| vapour |                      |                        | $4,656 \times 10^{-4}$       | 313,47                      | 322,50            | 1,878 6              | 0,419 4            | 0,473 8            | 100,97                | 335,67                      |
| liquid | -105,00              | $5,765 \times 10^{-6}$ | 1 766,0                      | 100,80                      | 100,80            | 0,543 0              | 0,630 6            | 0,928 0            | 1 235,3               | -0,476 2                    |
| vapour |                      |                        | $6,306 \times 10^{-4}$       | 314,38                      | 323,52            | 1,867 5              | 0,423 2            | 0,477 6            | 101,57                | 319,10                      |
| liquid | -100,00              | $1,161 \times 10^{-5}$ | 1 754,5                      | 105,44                      | 105,44            | 0,570 2              | 0,632 1            | 0,926 1            | 1 215,3               | -0,477 2                    |
| vapour |                      |                        | $1,233 \times 10^{-3}$       | 316,51                      | 325,93            | 1,843 6              | 0,431 9            | 0,486 3            | 102,95                | 284,41                      |
| liquid | -95,00               | $2,233 \times 10^{-5}$ | 1 743,2                      | 110,07                      | 110,07            | 0,596 5              | 0,632 8            | 0,924 5            | 1 195,0               | -0,477 5                    |
| vapour |                      |                        | $2,306 \times 10^{-3}$       | 318,69                      | 328,38            | 1,822 0              | 0,440 5            | 0,494 9            | 104,31                | 254,37                      |
| liquid | -90,00               | $4,120 \times 10^{-5}$ | 1 732,0                      | 114,68                      | 114,68            | 0,622 1              | 0,633 3            | 0,923 5            | 1 174,6               | -0,477 1                    |
| vapour |                      |                        | $4,138 \times 10^{-3}$       | 320,92                      | 330,87            | 1,802 5              | 0,449 1            | 0,503 5            | 105,65                | 228,26                      |
| liquid | -85,00               | $7,317 \times 10^{-5}$ | 1 720,8                      | 119,30                      | 119,30            | 0,647 0              | 0,633 8            | 0,923 2            | 1 153,9               | -0,475 9                    |

<sup>a</sup> Triple point.

<sup>b</sup> Normal boiling point.

<sup>c</sup> The values of  $C_v$ ,  $C_p$ , and  $w$  at the critical point are not included as part of this document.

Table 22 (continued)

|        | Temp.<br>°C | Pressure<br>MPa | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | C <sub>v</sub><br>kJ/(kg·K) | C <sub>p</sub><br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|--------|-------------|-----------------|------------------------------|-----------------------------|-------------------|----------------------|-----------------------------|-----------------------------|-----------------------|-----------------------------|
| vapour |             |                 | 7,154×10 <sup>-3</sup>       | 323,18                      | 333,41            | 1,784 9              | 0,457 5                     | 0,511 9                     | 106,97                | 205,49                      |
| liquid | -80,00      | 0,000 125       | 1 709,6                      | 123,92                      | 123,92            | 0,671 2              | 0,634 6                     | 0,923 6                     | 1 133,1               | -0,474 0                    |
| vapour |             |                 | 0,011 95                     | 325,49                      | 335,98            | 1,769 1              | 0,465 8                     | 0,520 2                     | 108,27                | 185,55                      |
| liquid | -75,00      | 0,000 208       | 1 698,5                      | 128,54                      | 128,54            | 0,694 8              | 0,635 6                     | 0,924 7                     | 1 112,1               | -0,471 4                    |
| vapour |             |                 | 0,019 35                     | 327,83                      | 338,60            | 1,754 9              | 0,474 0                     | 0,528 5                     | 109,55                | 168,05                      |
| liquid | -70,00      | 0,000 336       | 1 687,4                      | 133,17                      | 133,17            | 0,717 9              | 0,637 1                     | 0,926 6                     | 1 091,1               | -0,468 1                    |
| vapour |             |                 | 0,030 45                     | 330,21                      | 341,25            | 1,742 2              | 0,482 1                     | 0,536 7                     | 110,81                | 152,63                      |
| liquid | -65,00      | 0,000 528       | 1 676,2                      | 137,80                      | 137,80            | 0,740 4              | 0,638 8                     | 0,929 0                     | 1 069,9               | -0,464 3                    |
| vapour |             |                 | 0,046 66                     | 332,63                      | 343,94            | 1,730 7              | 0,490 2                     | 0,544 8                     | 112,06                | 139,01                      |
| liquid | -60,00      | 0,000 808       | 1 665,1                      | 142,46                      | 142,46            | 0,762 5              | 0,641 0                     | 0,932 0                     | 1 048,7               | -0,459 9                    |
| vapour |             |                 | 0,069 77                     | 335,09                      | 346,66            | 1,720 6              | 0,498 2                     | 0,552 9                     | 113,27                | 126,94                      |
| liquid | -55,00      | 0,001 21        | 1 653,9                      | 147,13                      | 147,13            | 0,784 2              | 0,643 5                     | 0,935 4                     | 1 027,6               | -0,455 0                    |
| vapour |             |                 | 0,102 0                      | 337,58                      | 349,42            | 1,711 5              | 0,506 1                     | 0,561 0                     | 114,47                | 116,22                      |
| liquid | -50,00      | 0,001 77        | 1 642,6                      | 151,81                      | 151,81            | 0,805 4              | 0,646 2                     | 0,939 3                     | 1 006,4               | -0,449 6                    |
| vapour |             |                 | 0,146 1                      | 340,11                      | 352,21            | 1,703 4              | 0,513 9                     | 0,569 0                     | 115,64                | 106,68                      |
| liquid | -45,00      | 0,002 54        | 1 631,3                      | 156,52                      | 156,52            | 0,826 3              | 0,649 3                     | 0,943 5                     | 985,3                 | -0,443 7                    |
| vapour |             |                 | 0,205 2                      | 342,66                      | 355,03            | 1,696 4              | 0,521 7                     | 0,577 0                     | 116,78                | 98,17                       |
| liquid | -40,00      | 0,003 58        | 1 620,0                      | 161,25                      | 161,25            | 0,846 8              | 0,652 6                     | 0,948 0                     | 964,3                 | -0,437 5                    |
| vapour |             |                 | 0,283 1                      | 345,25                      | 357,88            | 1,690 1              | 0,529 5                     | 0,585 0                     | 117,90                | 90,55                       |
| liquid | -35,00      | 0,004 95        | 1 608,5                      | 166,00                      | 166,00            | 0,866 9              | 0,656 1                     | 0,952 8                     | 943,4                 | -0,430 9                    |
| vapour |             |                 | 0,384 3                      | 347,87                      | 360,75            | 1,684 7              | 0,537 2                     | 0,593 1                     | 118,98                | 83,73                       |
| liquid | -30,00      | 0,006 75        | 1 597,0                      | 170,77                      | 170,78            | 0,886 8              | 0,659 7                     | 0,957 8                     | 922,6                 | -0,423 9                    |
| vapour |             |                 | 0,513 6                      | 350,51                      | 363,65            | 1,680 0              | 0,544 8                     | 0,601 1                     | 120,03                | 77,60                       |
| liquid | -25,00      | 0,009 06        | 1 585,4                      | 175,58                      | 175,58            | 0,906 3              | 0,663 5                     | 0,962 9                     | 901,9                 | -0,416 6                    |
| vapour |             |                 | 0,676 7                      | 353,19                      | 366,57            | 1,676 0              | 0,552 5                     | 0,609 2                     | 121,04                | 72,09                       |
| liquid | -20,00      | 0,012 0         | 1 573,8                      | 180,40                      | 180,41            | 0,925 6              | 0,667 4                     | 0,968 2                     | 881,3                 | -0,408 8                    |
| vapour |             |                 | 0,880                        | 355,88                      | 369,52            | 1,672 6              | 0,560 1                     | 0,617 4                     | 122,01                | 67,13                       |
| liquid | -15,00      | 0,015 7         | 1 562,0                      | 185,26                      | 185,27            | 0,944 6              | 0,671 4                     | 0,973 5                     | 860,9                 | -0,400 7                    |
| vapour |             |                 | 1,130                        | 358,60                      | 372,47            | 1,669 8              | 0,567 7                     | 0,625 6                     | 122,94                | 62,65                       |
| liquid | -10,00      | 0,020 2         | 1 550,1                      | 190,14                      | 190,15            | 0,963 3              | 0,675 5                     | 0,979 0                     | 840,7                 | -0,392 3                    |
| vapour |             |                 | 1,435                        | 361,34                      | 375,45            | 1,667 5              | 0,575 3                     | 0,633 9                     | 123,82                | 58,60                       |
| liquid | -5,00       | 0,025 8         | 1 538,2                      | 195,04                      | 195,06            | 0,981 8              | 0,679 7                     | 0,984 6                     | 820,6                 | -0,383 4                    |
| vapour |             |                 | 1,802                        | 364,10                      | 378,44            | 1,665 6              | 0,582 8                     | 0,642 3                     | 124,66                | 54,93                       |
| liquid | 0,00        | 0,032 6         | 1 526,1                      | 199,98                      | 200,00            | 1,000 0              | 0,683 9                     | 0,990 2                     | 800,7                 | -0,374 0                    |
| vapour |             |                 | 2,242                        | 366,87                      | 381,44            | 1,664 2              | 0,590 4                     | 0,650 8                     | 125,44                | 51,61                       |
| liquid | 5,00        | 0,040 8         | 1 513,9                      | 204,94                      | 204,97            | 1,018 0              | 0,688 1                     | 0,995 9                     | 780,9                 | -0,364 3                    |
| vapour |             |                 | 2,762                        | 369,67                      | 384,44            | 1,663 3              | 0,597 9                     | 0,659 4                     | 126,17                | 48,60                       |
| liquid | 10,00       | 0,050 6         | 1 501,6                      | 209,93                      | 209,97            | 1,035 8              | 0,692 4                     | 1,001 7                     | 761,3                 | -0,354 0                    |
| vapour |             |                 | 3,374                        | 372,47                      | 387,46            | 1,662 6              | 0,605 5                     | 0,668 2                     | 126,84                | 45,86                       |
| liquid | 15,00       | 0,062 1         | 1 489,2                      | 214,95                      | 214,99            | 1,053 4              | 0,696 7                     | 1,007 6                     | 741,9                 | -0,343 1                    |
| vapour |             |                 | 4,088                        | 375,29                      | 390,48            | 1,662 4              | 0,613 0                     | 0,677 1                     | 127,45                | 43,37                       |

a Triple point.

b Normal boiling point.

c The values of C<sub>v</sub>, C<sub>p</sub>, and w at the critical point are not included as part of this document.

Table 22 (continued)

|                                                                                                                                                                                         | Temp.<br>°C        | Pressure<br>MPa | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|--------------------|-----------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| liquid                                                                                                                                                                                  | 20,00              | 0,075 6         | 1 476,6                      | 220,00                      | 220,05            | 1,070 7              | 0,701 1            | 1,013 5            | 722,6                 | −0,331 6                    |
| vapour                                                                                                                                                                                  |                    |                 | 4,917                        | 378,12                      | 393,49            | 1,662 4              | 0,620 6            | 0,686 1            | 127,99                | 41,10                       |
| liquid                                                                                                                                                                                  | 25,00              | 0,091 4         | 1 463,9                      | 225,08                      | 225,14            | 1,087 9              | 0,705 4            | 1,019 6            | 703,4                 | −0,319 5                    |
| vapour                                                                                                                                                                                  |                    |                 | 5,872                        | 380,95                      | 396,51            | 1,662 7              | 0,628 1            | 0,695 3            | 128,47                | 39,03                       |
| liquid                                                                                                                                                                                  | 27,82 <sup>b</sup> | 0,101 3         | 1 456,6                      | 227,96                      | 228,03            | 1,097 5              | 0,707 9            | 1,023 0            | 692,7                 | −0,312 3                    |
| vapour                                                                                                                                                                                  |                    |                 | 6,471                        | 382,56                      | 398,22            | 1,663 0              | 0,632 4            | 0,700 6            | 128,71                | 37,95                       |
| liquid                                                                                                                                                                                  | 30,00              | 0,109 6         | 1 451,0                      | 230,18                      | 230,26            | 1,104 9              | 0,709 7            | 1,025 7            | 684,4                 | −0,306 6                    |
| vapour                                                                                                                                                                                  |                    |                 | 6,966                        | 383,80                      | 399,53            | 1,663 3              | 0,635 7            | 0,704 7            | 128,88                | 37,15                       |
| liquid                                                                                                                                                                                  | 35,00              | 0,130 5         | 1 438,0                      | 235,32                      | 235,41            | 1,121 7              | 0,714 1            | 1,032 0            | 665,5                 | −0,292 9                    |
| vapour                                                                                                                                                                                  |                    |                 | 8,213                        | 386,64                      | 402,54            | 1,664 1              | 0,643 2            | 0,714 4            | 129,21                | 35,43                       |
| liquid                                                                                                                                                                                  | 40,00              | 0,154 5         | 1 424,8                      | 240,48                      | 240,59            | 1,138 3              | 0,718 5            | 1,038 5            | 646,8                 | −0,278 2                    |
| vapour                                                                                                                                                                                  |                    |                 | 9,630                        | 389,49                      | 405,54            | 1,665 1              | 0,650 8            | 0,724 3            | 129,46                | 33,86                       |
| liquid                                                                                                                                                                                  | 45,00              | 0,181 7         | 1 411,4                      | 245,68                      | 245,81            | 1,154 8              | 0,722 9            | 1,045 1            | 628,2                 | −0,262 5                    |
| vapour                                                                                                                                                                                  |                    |                 | 11,230                       | 392,35                      | 408,53            | 1,666 2              | 0,658 3            | 0,734 4            | 129,64                | 32,42                       |
| liquid                                                                                                                                                                                  | 50,00              | 0,212 5         | 1 397,8                      | 250,91                      | 251,06            | 1,171 1              | 0,727 3            | 1,051 9            | 609,6                 | −0,245 6                    |
| vapour                                                                                                                                                                                  |                    |                 | 13,031                       | 395,20                      | 411,50            | 1,667 6              | 0,665 9            | 0,744 8            | 129,73                | 31,11                       |
| liquid                                                                                                                                                                                  | 55,00              | 0,247 1         | 1 384,0                      | 256,17                      | 256,34            | 1,187 3              | 0,731 7            | 1,058 9            | 591,2                 | −0,227 4                    |
| vapour                                                                                                                                                                                  |                    |                 | 15,051                       | 398,04                      | 414,46            | 1,669 1              | 0,673 5            | 0,755 6            | 129,73                | 29,91                       |
| liquid                                                                                                                                                                                  | 60,00              | 0,285 9         | 1 370,0                      | 261,46                      | 261,67            | 1,203 3              | 0,736 2            | 1,066 3            | 572,9                 | −0,207 6                    |
| vapour                                                                                                                                                                                  |                    |                 | 17,311                       | 400,88                      | 417,40            | 1,670 7              | 0,681 1            | 0,766 7            | 129,64                | 28,82                       |
| liquid                                                                                                                                                                                  | 65,00              | 0,329 2         | 1 355,7                      | 266,78                      | 267,03            | 1,219 1              | 0,740 6            | 1,074 0            | 554,6                 | −0,186 1                    |
| vapour                                                                                                                                                                                  |                    |                 | 19,830                       | 403,72                      | 420,31            | 1,672 5              | 0,688 7            | 0,778 3            | 129,46                | 27,82                       |
| liquid                                                                                                                                                                                  | 70,00              | 0,377 2         | 1 341,2                      | 272,14                      | 272,42            | 1,234 9              | 0,745 1            | 1,082 0            | 536,4                 | −0,162 7                    |
| vapour                                                                                                                                                                                  |                    |                 | 22,632                       | 406,54                      | 423,20            | 1,674 3              | 0,696 3            | 0,790 4            | 129,17                | 26,92                       |
| liquid                                                                                                                                                                                  | 75,00              | 0,430 4         | 1 326,4                      | 277,54                      | 277,86            | 1,250 5              | 0,749 7            | 1,090 6            | 518,2                 | −0,137 0                    |
| vapour                                                                                                                                                                                  |                    |                 | 25,743                       | 409,34                      | 426,06            | 1,676 2              | 0,704 0            | 0,803 0            | 128,79                | 26,09                       |
| liquid                                                                                                                                                                                  | 80,00              | 0,489 1         | 1 311,2                      | 282,98                      | 283,35            | 1,266 0              | 0,754 2            | 1,099 6            | 500,0                 | −0,108 7                    |
| vapour                                                                                                                                                                                  |                    |                 | 29,188                       | 412,14                      | 428,89            | 1,678 1              | 0,711 7            | 0,816 2            | 128,30                | 25,34                       |
| liquid                                                                                                                                                                                  | 85,00              | 0,553 6         | 1 295,7                      | 288,45                      | 288,88            | 1,281 4              | 0,758 9            | 1,109 3            | 481,9                 | −0,077 3                    |
| vapour                                                                                                                                                                                  |                    |                 | 33,000                       | 414,91                      | 431,68            | 1,680 1              | 0,719 4            | 0,830 2            | 127,69                | 24,66                       |
| liquid                                                                                                                                                                                  | 90,00              | 0,624 2         | 1 279,9                      | 293,97                      | 294,45            | 1,296 7              | 0,763 6            | 1,119 7            | 463,8                 | −0,042 5                    |
| vapour                                                                                                                                                                                  |                    |                 | 37,213                       | 417,65                      | 434,43            | 1,682 2              | 0,727 2            | 0,845 0            | 126,97                | 24,05                       |
| liquid                                                                                                                                                                                  | 95,00              | 0,701 4         | 1 263,6                      | 299,53                      | 300,08            | 1,312 0              | 0,768 3            | 1,131 0            | 445,6                 | −0,003 6                    |
| vapour                                                                                                                                                                                  |                    |                 | 41,863                       | 420,37                      | 437,13            | 1,684 2              | 0,735 0            | 0,860 9            | 126,12                | 23,51                       |
| liquid                                                                                                                                                                                  | 100,00             | 0,785 5         | 1 246,9                      | 305,14                      | 305,77            | 1,327 1              | 0,773 1            | 1,143 3            | 427,5                 | 0,040 2                     |
| vapour                                                                                                                                                                                  |                    |                 | 46,996                       | 423,06                      | 439,77            | 1,686 2              | 0,742 9            | 0,878 0            | 125,14                | 23,03                       |
| liquid                                                                                                                                                                                  | 105,00             | 0,876 9         | 1 229,7                      | 310,80                      | 311,51            | 1,342 2              | 0,778 1            | 1,156 8            | 409,2                 | 0,089 6                     |
| vapour                                                                                                                                                                                  |                    |                 | 52,661                       | 425,71                      | 442,36            | 1,688 2              | 0,750 9            | 0,896 5            | 124,02                | 22,61                       |
| liquid                                                                                                                                                                                  | 110,00             | 0,976 0         | 1 211,9                      | 316,51                      | 317,32            | 1,357 2              | 0,783 1            | 1,171 7            | 391,0                 | 0,146 0                     |
| vapour                                                                                                                                                                                  |                    |                 | 58,914                       | 428,31                      | 444,88            | 1,690 2              | 0,759 0            | 0,916 8            | 122,76                | 22,24                       |
| liquid                                                                                                                                                                                  | 115,00             | 1,083 2         | 1 193,5                      | 322,28                      | 323,19            | 1,372 3              | 0,788 3            | 1,188 4            | 372,6                 | 0,210 6                     |
| <sup>a</sup> Triple point.<br><sup>b</sup> Normal boiling point.<br><sup>c</sup> The values of $C_v$ , $C_p$ , and $w$ at the critical point are not included as part of this document. |                    |                 |                              |                             |                   |                      |                    |                    |                       |                             |

Table 22 (continued)

|                                                                                                                                                                                         | Temp.<br>°C | Pressure<br>MPa | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|-----------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| vapour                                                                                                                                                                                  |             |                 | 65,824                       | 430,86                      | 447,32            | 1,692 0              | 0,767 2            | 0,939 2            | 121,34                | 21,94                       |
| liquid                                                                                                                                                                                  | 120,00      | 1,199 0         | 1 174,4                      | 328,13                      | 329,15            | 1,387 2              | 0,793 6            | 1,207 2            | 354,1                 | 0,285 4                     |
| vapour                                                                                                                                                                                  |             |                 | 73,471                       | 433,35                      | 449,67            | 1,693 8              | 0,775 5            | 0,964 3            | 119,76                | 21,69                       |
| liquid                                                                                                                                                                                  | 125,00      | 1,323 7         | 1 154,4                      | 334,04                      | 335,18            | 1,402 2              | 0,799 1            | 1,228 7            | 335,5                 | 0,372 8                     |
| vapour                                                                                                                                                                                  |             |                 | 81,950                       | 435,78                      | 451,93            | 1,695 5              | 0,784 0            | 0,992 8            | 118,00                | 21,51                       |
| liquid                                                                                                                                                                                  | 130,00      | 1,457 8         | 1 133,6                      | 340,03                      | 341,32            | 1,417 3              | 0,804 8            | 1,253 6            | 316,7                 | 0,475 9                     |
| vapour                                                                                                                                                                                  |             |                 | 91,379                       | 438,12                      | 454,07            | 1,696 9              | 0,792 7            | 1,025 7            | 116,05                | 21,38                       |
| liquid                                                                                                                                                                                  | 135,00      | 1,601 8         | 1 111,6                      | 346,12                      | 347,56            | 1,432 3              | 0,810 7            | 1,282 8            | 297,8                 | 0,599 2                     |
| vapour                                                                                                                                                                                  |             |                 | 101,904                      | 440,37                      | 456,08            | 1,698 2              | 0,801 7            | 1,064 3            | 113,89                | 21,32                       |
| liquid                                                                                                                                                                                  | 140,00      | 1,756 3         | 1 088,3                      | 352,31                      | 353,92            | 1,447 5              | 0,817 0            | 1,317 8            | 278,6                 | 0,748 7                     |
| vapour                                                                                                                                                                                  |             |                 | 113,711                      | 442,50                      | 457,94            | 1,699 2              | 0,811 0            | 1,110 6            | 111,51                | 21,32                       |
| liquid                                                                                                                                                                                  | 145,00      | 1,921 7         | 1 063,5                      | 358,62                      | 360,43            | 1,462 8              | 0,823 6            | 1,360 6            | 259,1                 | 0,933 4                     |
| vapour                                                                                                                                                                                  |             |                 | 127,044                      | 444,48                      | 459,61            | 1,700 0              | 0,820 7            | 1,167 7            | 108,88                | 21,39                       |
| liquid                                                                                                                                                                                  | 150,00      | 2,098 7         | 1 036,8                      | 365,08                      | 367,10            | 1,478 2              | 0,830 7            | 1,414 6            | 239,3                 | 1,166 4                     |
| vapour                                                                                                                                                                                  |             |                 | 142,231                      | 446,30                      | 461,05            | 1,700 3              | 0,830 9            | 1,240 5            | 105,99                | 21,53                       |
| liquid                                                                                                                                                                                  | 155,00      | 2,287 9         | 1 007,8                      | 371,72                      | 373,99            | 1,494 0              | 0,838 4            | 1,485 5            | 219,0                 | 1,468 6                     |
| vapour                                                                                                                                                                                  |             |                 | 159,735                      | 447,89                      | 462,22            | 1,700 0              | 0,841 7            | 1,337 1            | 102,80                | 21,75                       |
| liquid                                                                                                                                                                                  | 160,00      | 2,490 1         | 975,7                        | 378,58                      | 381,13            | 1,510 1              | 0,846 9            | 1,583 6            | 198,2                 | 1,874 8                     |
| vapour                                                                                                                                                                                  |             |                 | 180,242                      | 449,20                      | 463,01            | 1,699 1              | 0,853 4            | 1,472 8            | 99,29                 | 22,05                       |
| liquid                                                                                                                                                                                  | 165,00      | 2,706 2         | 939,4                        | 385,74                      | 388,62            | 1,526 7              | 0,856 5            | 1,730 3            | 176,6                 | 2,447 8                     |
| vapour                                                                                                                                                                                  |             |                 | 204,853                      | 450,11                      | 463,32            | 1,697 2              | 0,866 2            | 1,679 0            | 95,40                 | 22,41                       |
| liquid                                                                                                                                                                                  | 170,00      | 2,937 2         | 896,9                        | 393,33                      | 396,61            | 1,544 3              | 0,867 7            | 1,979 2            | 154,0                 | 3,314 7                     |
| vapour                                                                                                                                                                                  |             |                 | 235,543                      | 450,42                      | 462,89            | 1,693 9              | 0,880 6            | 2,033 2            | 91,07                 | 22,81                       |
| liquid                                                                                                                                                                                  | 175,00      | 3,184 5         | 843,9                        | 401,67                      | 405,44            | 1,563 5              | 0,881 7            | 2,510 2            | 129,6                 | 4,777 9                     |
| vapour                                                                                                                                                                                  |             |                 | 276,595                      | 449,73                      | 461,25            | 1,688 0              | 0,897 5            | 2,793 5            | 86,20                 | 23,12                       |
| liquid                                                                                                                                                                                  | 180,00      | 3,450 6         | 765,9                        | 411,72                      | 416,22            | 1,586 7              | 0,901 9            | 4,548 6            | 102,3                 | 7,810 6                     |
| vapour                                                                                                                                                                                  |             |                 | 341,950                      | 446,73                      | 456,82            | 1,676 3              | 0,919 4            | 5,661 3            | 80,62                 | 22,79                       |
| critical                                                                                                                                                                                | 183,68      | 3,661 8         | 550,0                        | 430,74                      | 437,39            | 1,632 5              | c                  | c                  | c                     | 16,565 8                    |
| <sup>a</sup> Triple point.<br><sup>b</sup> Normal boiling point.<br><sup>c</sup> The values of $C_v$ , $C_p$ , and $w$ at the critical point are not included as part of this document. |             |                 |                              |                             |                   |                      |                    |                    |                       |                             |

## 5.8 R125 — Pentafluoroethane

### 5.8.1 Range of validity

The coefficients are valid within the following ranges:

$$T_{\min} = 172,52 \text{ K}, T_{\max} = 500 \text{ K}; p_{\max} = 60 \text{ MPa}; \rho_{\max} = 14,09 \text{ mol/l (1 691 kg/m}^3\text{)}$$

Coefficients and exponents of the ideal-gas part are listed in [Table 23](#). Coefficients and exponents of the real-gas part are listed in [Table 24](#).

**Table 23 — Coefficients and exponents of the ideal-gas part [Formulae (3) to (5)]**

| $k$ | $c_k$   | $t_k$ | $a_k$ | $b_k$   |
|-----|---------|-------|-------|---------|
| 1   | 3,063 0 | 0,1   | —     | —       |
| 2   | —       | —     | 2,303 | 314,0   |
| 3   | —       | —     | 5,086 | 756,0   |
| 4   | —       | —     | 7,300 | 1 707,0 |

**Table 24 — Coefficients and exponents of the real-gas part [Formula (2)]**

| $k$ | $N_k$         | $t_k$ | $d_k$ | $l_k$ | $\alpha_k$ | $m_k$ | $\beta_k$ | $\gamma_k$ | $\varepsilon_k$ |
|-----|---------------|-------|-------|-------|------------|-------|-----------|------------|-----------------|
| 1   | 5,280 760     | 0,669 | 1     | 0     | 0          | —     | —         | —          | —               |
| 2   | −8,676 580    | 1,05  | 1     | 0     | 0          | —     | —         | —          | —               |
| 3   | 0,750 112 7   | 2,75  | 1     | 0     | 0          | —     | —         | —          | —               |
| 4   | 0,759 002 3   | 0,956 | 2     | 0     | 0          | —     | —         | —          | —               |
| 5   | 0,014 518 99  | 1,00  | 4     | 0     | 0          | —     | —         | —          | —               |
| 6   | 4,777 189     | 2,00  | 1     | 1     | 1          | —     | —         | —          | —               |
| 7   | −3,330 988    | 2,75  | 1     | 1     | 1          | —     | —         | —          | —               |
| 8   | 3,775 673     | 2,38  | 2     | 1     | 1          | —     | —         | —          | —               |
| 9   | −2,290 919    | 3,37  | 2     | 1     | 1          | —     | —         | —          | —               |
| 10  | 0,888 826 8   | 3,47  | 3     | 1     | 1          | —     | —         | —          | —               |
| 11  | −0,623 486 4  | 2,63  | 4     | 1     | 1          | —     | —         | —          | —               |
| 12  | −0,041 272 63 | 3,45  | 5     | 1     | 1          | —     | —         | —          | —               |
| 13  | −0,084 553 89 | 0,72  | 1     | 2     | 1          | —     | —         | —          | —               |
| 14  | −0,130 875 2  | 4,23  | 5     | 2     | 1          | —     | —         | —          | —               |
| 15  | 0,008 344 962 | 0,20  | 1     | 3     | 1          | —     | —         | —          | —               |
| 16  | −1,532 005    | 4,5   | 2     | 2     | 1          | 1,7   | 1         | 0          | 0               |
| 17  | −0,058 836 49 | 29,0  | 3     | 3     | 1          | 7,0   | 1         | 0          | 0               |
| 18  | 0,022 966 58  | 24,0  | 5     | 3     | 1          | 6,0   | 1         | 0          | 0               |

**5.8.2 Reducing parameters, molar mass, and gas constant**

$$T^* = 339,173 \text{ K}, \rho^* = 4,779 \text{ mol/l}, M = 120,021 4 \text{ g/mol}, R = 8,314 472 \text{ J/(mol·K)}$$

**5.8.3 Reference state parameters**

$$T_{\text{ref}} = 273,5 \text{ K}, p_{\text{ref}} = 1,0 \text{ kPa}, h_{\text{ref}} = 41 266,386 \text{ J/mol}, s_{\text{ref}} = 236,119 5 \text{ J/(mol·K)}, \\ f_1 = 29,876 674 5, f_2 = 3 013,226 7$$

R125 property values along the liquid-vapour saturation boundary are listed in [Table 25](#).

**Table 25 — R125 property values along the liquid-vapour saturation boundary**

|                                                                                                                                                                                         | Temp.<br>°C          | Pressure<br>MPa | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|-----------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| liquid                                                                                                                                                                                  | −100,63 <sup>a</sup> | 0,002 91        | 1 690,7                      | 87,13                       | 87,13             | 0,490 2              | 0,677 6            | 1,034 6            | 932,6                 | −0,383 7                    |
| <sup>a</sup> Triple point.<br><sup>b</sup> Normal boiling point.<br><sup>c</sup> The values of $C_v$ , $C_p$ , and $w$ at the critical point are not included as part of this document. |                      |                 |                              |                             |                   |                      |                    |                    |                       |                             |

Table 25 (continued)

|        | Temp.<br>°C         | Pressure<br>MPa | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|--------|---------------------|-----------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| vapour |                     |                 | 0,244 6                      | 265,48                      | 277,39            | 1,593 1              | 0,498 4            | 0,568 9            | 116,43                | 90,26                       |
| liquid | –100,00             | 0,003 09        | 1 688,7                      | 87,78                       | 87,78             | 0,494 0              | 0,678 1            | 1,035 1            | 929,2                 | –0,383 0                    |
| vapour |                     |                 | 0,258 3                      | 265,79                      | 277,74            | 1,591 1              | 0,499 7            | 0,570 3            | 116,61                | 89,08                       |
| liquid | –95,00              | 0,004 81        | 1 672,5                      | 92,97                       | 92,97             | 0,523 5              | 0,681 8            | 1,039 6            | 903,2                 | –0,376 6                    |
| vapour |                     |                 | 0,391 8                      | 268,25                      | 280,54            | 1,576 4              | 0,509 9            | 0,581 0            | 118,03                | 80,43                       |
| liquid | –90,00              | 0,007 29        | 1 656,2                      | 98,18                       | 98,18             | 0,552 4              | 0,686 0            | 1,045 0            | 877,5                 | –0,369 4                    |
| vapour |                     |                 | 0,577 9                      | 270,75                      | 283,36            | 1,563 4              | 0,520 1            | 0,591 9            | 119,39                | 72,87                       |
| liquid | –85,00              | 0,010 7         | 1 639,9                      | 103,42                      | 103,42            | 0,580 6              | 0,690 6            | 1,051 2            | 852,3                 | –0,361 4                    |
| vapour |                     |                 | 0,831                        | 273,28                      | 286,20            | 1,552 0              | 0,530 4            | 0,603 1            | 120,69                | 66,26                       |
| liquid | –80,00              | 0,015 5         | 1 623,4                      | 108,69                      | 108,70            | 0,608 2              | 0,695 5            | 1,058 1            | 827,5                 | –0,352 5                    |
| vapour |                     |                 | 1,169                        | 275,83                      | 289,06            | 1,542 1              | 0,540 9            | 0,614 6            | 121,92                | 60,44                       |
| liquid | –75,00              | 0,021 8         | 1 606,7                      | 114,00                      | 114,01            | 0,635 4              | 0,700 6            | 1,065 6            | 802,9                 | –0,342 8                    |
| vapour |                     |                 | 1,610                        | 278,41                      | 291,94            | 1,533 3              | 0,551 4            | 0,626 4            | 123,07                | 55,33                       |
| liquid | –70,00              | 0,030 1         | 1 589,9                      | 119,34                      | 119,36            | 0,662 0              | 0,706 0            | 1,073 6            | 778,6                 | –0,332 3                    |
| vapour |                     |                 | 2,177                        | 281,01                      | 294,83            | 1,525 7              | 0,562 0            | 0,638 5            | 124,13                | 50,81                       |
| liquid | –65,00              | 0,040 8         | 1 572,9                      | 124,73                      | 124,75            | 0,688 2              | 0,711 5            | 1,082 2            | 754,5                 | –0,320 8                    |
| vapour |                     |                 | 2,892                        | 283,62                      | 297,71            | 1,519 1              | 0,572 7            | 0,651 1            | 125,11                | 46,82                       |
| liquid | –60,00              | 0,054 3         | 1 555,7                      | 130,16                      | 130,19            | 0,714 0              | 0,717 1            | 1,091 2            | 730,6                 | –0,308 3                    |
| vapour |                     |                 | 3,783                        | 286,24                      | 300,60            | 1,513 5              | 0,583 6            | 0,664 1            | 125,98                | 43,28                       |
| liquid | –55,00              | 0,071 3         | 1 538,2                      | 135,63                      | 135,68            | 0,739 4              | 0,722 9            | 1,100 7            | 706,8                 | –0,294 7                    |
| vapour |                     |                 | 4,879                        | 288,88                      | 303,48            | 1,508 6              | 0,594 6            | 0,677 6            | 126,75                | 40,14                       |
| liquid | –50,00              | 0,092 2         | 1 520,5                      | 141,15                      | 141,21            | 0,764 4              | 0,728 8            | 1,110 7            | 683,2                 | –0,279 9                    |
| vapour |                     |                 | 6,211                        | 291,51                      | 306,35            | 1,504 4              | 0,605 8            | 0,691 6            | 127,41                | 37,35                       |
| liquid | –48,09 <sup>b</sup> | 0,101 3         | 1 513,6                      | 143,27                      | 143,34            | 0,773 9              | 0,731 1            | 1,114 6            | 674,2                 | –0,273 8                    |
| vapour |                     |                 | 6,790                        | 292,52                      | 307,44            | 1,503 0              | 0,610 1            | 0,697 1            | 127,63                | 36,36                       |
| liquid | –45,00              | 0,117 6         | 1 502,4                      | 146,72                      | 146,80            | 0,789 1              | 0,734 9            | 1,121 2            | 659,6                 | –0,263 6                    |
| vapour |                     |                 | 7,814                        | 294,15                      | 309,20            | 1,500 9              | 0,617 1            | 0,706 3            | 127,94                | 34,86                       |
| liquid | –40,00              | 0,148 3         | 1 484,0                      | 152,34                      | 152,44            | 0,813 4              | 0,741 0            | 1,132 3            | 636,1                 | –0,245 8                    |
| vapour |                     |                 | 9,725                        | 296,79                      | 312,03            | 1,498 0              | 0,628 6            | 0,721 6            | 128,35                | 32,65                       |
| liquid | –35,00              | 0,184 9         | 1 465,3                      | 158,01                      | 158,14            | 0,837 5              | 0,747 3            | 1,144 0            | 612,6                 | –0,226 2                    |
| vapour |                     |                 | 11,985                       | 299,41                      | 314,84            | 1,495 5              | 0,640 2            | 0,737 6            | 128,61                | 30,67                       |
| liquid | –30,00              | 0,228 1         | 1 446,1                      | 163,74                      | 163,90            | 0,861 4              | 0,753 7            | 1,156 5            | 589,1                 | –0,204 4                    |
| vapour |                     |                 | 14,639                       | 302,03                      | 317,61            | 1,493 5              | 0,652 0            | 0,754 5            | 128,73                | 28,91                       |
| liquid | –25,00              | 0,278 6         | 1 426,5                      | 169,53                      | 169,73            | 0,884 9              | 0,760 2            | 1,169 8            | 565,7                 | –0,180 3                    |
| vapour |                     |                 | 17,736                       | 304,63                      | 320,34            | 1,491 9              | 0,664 0            | 0,772 4            | 128,70                | 27,33                       |
| liquid | –20,00              | 0,337 3         | 1 406,4                      | 175,38                      | 175,62            | 0,908 3              | 0,766 8            | 1,184 0            | 542,2                 | –0,153 2                    |
| vapour |                     |                 | 21,331                       | 307,22                      | 323,03            | 1,490 6              | 0,676 1            | 0,791 2            | 128,50                | 25,91                       |
| liquid | –15,00              | 0,405 0         | 1 385,8                      | 181,30                      | 181,59            | 0,931 4              | 0,773 6            | 1,199 4            | 518,7                 | –0,122 8                    |
| vapour |                     |                 | 25,486                       | 309,78                      | 325,67            | 1,489 5              | 0,688 2            | 0,811 2            | 128,11                | 24,66                       |
| liquid | –10,00              | 0,482 5         | 1 364,5                      | 187,29                      | 187,64            | 0,954 4              | 0,780 5            | 1,216 1            | 495,2                 | –0,088 3                    |
| vapour |                     |                 | 30,271                       | 312,30                      | 328,24            | 1,488 7              | 0,700 3            | 0,832 4            | 127,54                | 23,55                       |

<sup>a</sup> Triple point.<sup>b</sup> Normal boiling point.<sup>c</sup> The values of  $C_v$ ,  $C_p$ , and  $w$  at the critical point are not included as part of this document.

Table 25 (continued)

|                                                                                                                                                                                         | Temp.<br>°C | Pressure<br>MPa | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|-----------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| liquid                                                                                                                                                                                  | −5,00       | 0,570 7         | 1 342,6                      | 193,35                      | 193,77            | 0,977 3              | 0,787 6            | 1,234 4            | 471,6                 | −0,048 9                    |
| vapour                                                                                                                                                                                  |             |                 | 35,768                       | 314,79                      | 330,74            | 1,488 1              | 0,712 2            | 0,855 0            | 126,77                | 22,61                       |
| liquid                                                                                                                                                                                  | 0,00        | 0,670 5         | 1 319,8                      | 199,49                      | 200,00            | 1,000 0              | 0,794 8            | 1,254 7            | 448,0                 | −0,003 6                    |
| vapour                                                                                                                                                                                  |             |                 | 42,070                       | 317,22                      | 333,16            | 1,487 5              | 0,724 0            | 0,879 7            | 125,80                | 21,81                       |
| liquid                                                                                                                                                                                  | 5,00        | 0,782 9         | 1 296,2                      | 205,72                      | 206,33            | 1,022 6              | 0,802 1            | 1,277 3            | 424,3                 | 0,049 2                     |
| vapour                                                                                                                                                                                  |             |                 | 49,291                       | 319,59                      | 335,47            | 1,486 9              | 0,735 9            | 0,907 3            | 124,60                | 21,15                       |
| liquid                                                                                                                                                                                  | 10,00       | 0,908 8         | 1 271,5                      | 212,05                      | 212,76            | 1,045 2              | 0,809 5            | 1,302 9            | 400,4                 | 0,111 3                     |
| vapour                                                                                                                                                                                  |             |                 | 57,564                       | 321,87                      | 337,66            | 1,486 3              | 0,748 3            | 0,939 2            | 123,17                | 20,61                       |
| liquid                                                                                                                                                                                  | 15,00       | 1,049 2         | 1 245,6                      | 218,48                      | 219,32            | 1,067 8              | 0,817 2            | 1,332 3            | 376,3                 | 0,185 1                     |
| vapour                                                                                                                                                                                  |             |                 | 67,054                       | 324,06                      | 339,71            | 1,485 6              | 0,761 7            | 0,977 0            | 121,49                | 20,18                       |
| liquid                                                                                                                                                                                  | 20,00       | 1,205 2         | 1 218,3                      | 225,03                      | 226,02            | 1,090 4              | 0,825 2            | 1,366 6            | 352,0                 | 0,274 2                     |
| vapour                                                                                                                                                                                  |             |                 | 77,966                       | 326,12                      | 341,58            | 1,484 6              | 0,776 4            | 1,023 0            | 119,55                | 19,83                       |
| liquid                                                                                                                                                                                  | 25,00       | 1,377 9         | 1 189,4                      | 231,71                      | 232,87            | 1,113 1              | 0,833 5            | 1,407 4            | 327,4                 | 0,383 5                     |
| vapour                                                                                                                                                                                  |             |                 | 90,557                       | 328,05                      | 343,26            | 1,483 4              | 0,792 8            | 1,079 8            | 117,32                | 19,53                       |
| liquid                                                                                                                                                                                  | 30,00       | 1,568 5         | 1 158,4                      | 238,55                      | 239,91            | 1,135 9              | 0,842 5            | 1,457 5            | 302,4                 | 0,520 2                     |
| vapour                                                                                                                                                                                  |             |                 | 105,170                      | 329,80                      | 344,71            | 1,481 7              | 0,811 1            | 1,151 7            | 114,78                | 19,29                       |
| liquid                                                                                                                                                                                  | 35,00       | 1,778 3         | 1 125,0                      | 245,57                      | 247,16            | 1,159 1              | 0,852 2            | 1,520 9            | 276,9                 | 0,695 6                     |
| vapour                                                                                                                                                                                  |             |                 | 122,270                      | 331,33                      | 345,88            | 1,479 4              | 0,831 5            | 1,245 2            | 111,88                | 19,08                       |
| liquid                                                                                                                                                                                  | 40,00       | 2,008 5         | 1 088,4                      | 252,82                      | 254,67            | 1,182 6              | 0,863 0            | 1,605 2            | 250,8                 | 0,928 2                     |
| vapour                                                                                                                                                                                  |             |                 | 142,522                      | 332,60                      | 346,69            | 1,476 4              | 0,854 2            | 1,371 6            | 108,58                | 18,91                       |
| liquid                                                                                                                                                                                  | 45,00       | 2,260 7         | 1 047,7                      | 260,36                      | 262,52            | 1,206 7              | 0,875 5            | 1,724 4            | 223,8                 | 1,250 1                     |
| vapour                                                                                                                                                                                  |             |                 | 166,954                      | 333,50                      | 347,05            | 1,472 4              | 0,879 6            | 1,553 5            | 104,82                | 18,78                       |
| liquid                                                                                                                                                                                  | 50,00       | 2,536 8         | 1 001,1                      | 268,29                      | 270,83            | 1,231 8              | 0,890 7            | 1,910 2            | 195,6                 | 1,724 7                     |
| vapour                                                                                                                                                                                  |             |                 | 197,293                      | 333,89                      | 346,75            | 1,466 7              | 0,908 3            | 1,842 5            | 100,51                | 18,67                       |
| liquid                                                                                                                                                                                  | 55,00       | 2,838 9         | 945,4                        | 276,82                      | 279,83            | 1,258 5              | 0,910 6            | 2,251 7            | 165,3                 | 2,494 8                     |
| vapour                                                                                                                                                                                  |             |                 | 236,916                      | 333,46                      | 345,44            | 1,458 4              | 0,942 1            | 2,386 0            | 95,57                 | 18,51                       |
| liquid                                                                                                                                                                                  | 60,00       | 3,170 3         | 872,1                        | 286,46                      | 290,10            | 1,288 4              | 0,941 1            | 3,139 2            | 131,5                 | 3,975 2                     |
| vapour                                                                                                                                                                                  |             |                 | 294,367                      | 331,44                      | 342,21            | 1,444 8              | 0,985 6            | 3,832 9            | 89,84                 | 18,06                       |
| liquid                                                                                                                                                                                  | 65,00       | 3,537 0         | 735,1                        | 300,06                      | 304,88            | 1,331 1              | 1,013 9            | 13,669 2           | 90,0                  | 8,295 5                     |
| vapour                                                                                                                                                                                  |             |                 | 416,565                      | 323,75                      | 332,24            | 1,412 0              | 1,060 4            | 20,073 5           | 82,63                 | 15,85                       |
| critical                                                                                                                                                                                | 66,02       | 3,617 7         | 573,6                        | 311,75                      | 318,06            | 1,369 6              | c                  | c                  | c                     | 12,360 8                    |
| <sup>a</sup> Triple point.<br><sup>b</sup> Normal boiling point.<br><sup>c</sup> The values of $C_v$ , $C_p$ , and $w$ at the critical point are not included as part of this document. |             |                 |                              |                             |                   |                      |                    |                    |                       |                             |

## 5.9 R134a — 1,1,1,2-tetrafluoroethane

### 5.9.1 Range of validity

The coefficients are valid within the following ranges:

$$T_{\min} = 169,85 \text{ K}, T_{\max} = 455 \text{ K}; p_{\max} = 70 \text{ MPa}; \rho_{\max} = 15,6 \text{ mol/l (1 592 kg/m}^3\text{)}$$

Coefficients and exponents of the ideal-gas part are listed in [Table 26](#). Coefficients and exponents of the real-gas part are listed in [Table 27](#).

**Table 26 — Coefficients and exponents of the ideal-gas part [Formulae (3) to (5)]**

| $k$ | $c_k$                          | $t_k$ |
|-----|--------------------------------|-------|
| 0   | -0,629 789                     | —     |
| 1   | $3,770\,180\,8 \times 10^{-1}$ | 0,5   |
| 2   | $6,058\,548\,9 \times 10^{-2}$ | 0,75  |

**Table 27 — Coefficients and exponents of the real-gas part [Formula (2)]**

| $k$ | $N_k$            | $t_k$ | $d_k$ | $l_k$ | $\alpha_k$ |
|-----|------------------|-------|-------|-------|------------|
| 1   | 0,055 868 17     | -0,5  | 2     | 0     | 0          |
| 2   | 0,498 223        | 0     | 1     | 0     | 0          |
| 3   | 0,024 586 98     | 0     | 3     | 0     | 0          |
| 4   | 0,000 857 014 5  | 0     | 6     | 0     | 0          |
| 5   | 0,000 478 858 4  | 1,5   | 6     | 0     | 0          |
| 6   | -1,800 808       | 1,5   | 1     | 0     | 0          |
| 7   | 0,267 164 1      | 2     | 1     | 0     | 0          |
| 8   | -0,047 816 52    | 2     | 2     | 0     | 0          |
| 9   | 0,014 239 87     | 1     | 5     | 1     | 1          |
| 10  | 0,332 406 2      | 3     | 2     | 1     | 1          |
| 11  | -0,007 485 907   | 5     | 2     | 1     | 1          |
| 12  | 0,000 101 726 3  | 1     | 4     | 2     | 1          |
| 13  | -0,518 456 7     | 5     | 1     | 2     | 1          |
| 14  | -0,086 922 88    | 5     | 4     | 2     | 1          |
| 15  | 0,205 714 4      | 6     | 1     | 2     | 1          |
| 16  | -0,005 000 457   | 10    | 2     | 2     | 1          |
| 17  | 0,000 460 326 2  | 10    | 4     | 2     | 1          |
| 18  | -0,003 497 836   | 10    | 1     | 3     | 1          |
| 19  | 0,006 995 038    | 18    | 5     | 3     | 1          |
| 20  | -0,014 521 84    | 22    | 3     | 3     | 1          |
| 21  | -0,000 128 545 8 | 50    | 10    | 4     | 1          |

### 5.9.2 Reducing parameters, molar mass, and gas constant

$$T^* = 374,18 \text{ K}, \rho^* = 4,978\,830\,171 \text{ mol/l}, M = 102,032 \text{ g/mol}, R = 8,314\,471 \text{ J/(mol}\cdot\text{K)}$$

### 5.9.3 Reference state parameters

$$T_{\text{ref}} = 273,15 \text{ K}, p_{\text{ref}} = 1,0 \text{ kPa}, h_{\text{ref}} = 41\,433,397 \text{ J/mol}, s_{\text{ref}} = 225,535\,3 \text{ J/(mol}\cdot\text{K)}, \\ f_1 = -12,280\,800\,2, f_2 = 3\,385,257\,07$$

R134a property values along the liquid-vapour saturation boundary are listed in [Table 28](#).

Table 28 — R134a property values along the liquid-vapour saturation boundary

|                                                                                                                                                                                         | Temp.<br>°C          | Pressure<br>MPa | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|-----------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| liquid                                                                                                                                                                                  | −103,30 <sup>a</sup> | 0,000 390       | 1 591,1                      | 71,45                       | 71,46             | 0,412 6              | 0,792 2            | 1,183 8            | 1 120,0               | −0,381 5                    |
| vapour                                                                                                                                                                                  |                      |                 | 0,028 17                     | 321,11                      | 334,94            | 1,963 9              | 0,503 0            | 0,585 3            | 126,79                | 373,57                      |
| liquid                                                                                                                                                                                  | −100,00              | 0,000 559       | 1 582,4                      | 75,36                       | 75,36             | 0,435 4              | 0,791 2            | 1,184 2            | 1 103,2               | −0,379 3                    |
| vapour                                                                                                                                                                                  |                      |                 | 0,039 69                     | 322,76                      | 336,85            | 1,945 6              | 0,510 7            | 0,593 2            | 127,87                | 318,13                      |
| liquid                                                                                                                                                                                  | −95,00               | 0,000 939       | 1 569,1                      | 81,29                       | 81,29             | 0,469 1              | 0,791 0            | 1,186 1            | 1 077,7               | −0,375 3                    |
| vapour                                                                                                                                                                                  |                      |                 | 0,064 79                     | 325,29                      | 339,78            | 1,920 1              | 0,522 4            | 0,605 2            | 129,47                | 253,65                      |
| liquid                                                                                                                                                                                  | −90,00               | 0,001 52        | 1 555,8                      | 87,22                       | 87,23             | 0,502 0              | 0,792 0            | 1,189 2            | 1 052,3               | −0,370 7                    |
| vapour                                                                                                                                                                                  |                      |                 | 0,102 4                      | 327,87                      | 342,76            | 1,897 2              | 0,534 1            | 0,617 3            | 131,03                | 206,26                      |
| liquid                                                                                                                                                                                  | −85,00               | 0,002 40        | 1 542,5                      | 93,18                       | 93,18             | 0,534 1              | 0,794 0            | 1,193 3            | 1 027,0               | −0,365 6                    |
| vapour                                                                                                                                                                                  |                      |                 | 0,157 0                      | 330,49                      | 345,77            | 1,876 6              | 0,545 7            | 0,629 4            | 132,56                | 170,88                      |
| liquid                                                                                                                                                                                  | −80,00               | 0,003 67        | 1 529,0                      | 99,16                       | 99,16             | 0,565 4              | 0,796 8            | 1,198 1            | 1 001,8               | −0,359 9                    |
| vapour                                                                                                                                                                                  |                      |                 | 0,234 3                      | 333,15                      | 348,83            | 1,858 0              | 0,557 3            | 0,641 7            | 134,04                | 144,05                      |
| liquid                                                                                                                                                                                  | −75,00               | 0,005 48        | 1 515,5                      | 105,16                      | 105,17            | 0,596 1              | 0,800 2            | 1,203 6            | 976,8                 | −0,353 6                    |
| vapour                                                                                                                                                                                  |                      |                 | 0,341 2                      | 335,85                      | 351,91            | 1,841 4              | 0,568 9            | 0,654 0            | 135,47                | 123,38                      |
| liquid                                                                                                                                                                                  | −70,00               | 0,007 98        | 1 501,9                      | 111,19                      | 111,20            | 0,626 2              | 0,804 0            | 1,209 6            | 952,0                 | −0,346 9                    |
| vapour                                                                                                                                                                                  |                      |                 | 0,485 7                      | 338,59                      | 355,02            | 1,826 4              | 0,580 6            | 0,666 5            | 136,84                | 107,19                      |
| liquid                                                                                                                                                                                  | −65,00               | 0,011 4         | 1 488,2                      | 117,26                      | 117,26            | 0,655 7              | 0,808 2            | 1,216 1            | 927,4                 | −0,339 6                    |
| vapour                                                                                                                                                                                  |                      |                 | 0,677                        | 341,35                      | 358,16            | 1,813 0              | 0,592 3            | 0,679 3            | 138,16                | 94,32                       |
| liquid                                                                                                                                                                                  | −60,00               | 0,015 9         | 1 474,3                      | 123,35                      | 123,36            | 0,684 6              | 0,812 7            | 1,223 0            | 903,0                 | −0,331 8                    |
| vapour                                                                                                                                                                                  |                      |                 | 0,927                        | 344,15                      | 361,31            | 1,801 0              | 0,604 0            | 0,692 4            | 139,41                | 83,91                       |
| liquid                                                                                                                                                                                  | −55,00               | 0,021 8         | 1 460,4                      | 129,48                      | 129,50            | 0,713 1              | 0,817 5            | 1,230 4            | 878,8                 | −0,323 4                    |
| vapour                                                                                                                                                                                  |                      |                 | 1,246                        | 346,96                      | 364,48            | 1,790 2              | 0,615 9            | 0,705 8            | 140,59                | 75,36                       |
| liquid                                                                                                                                                                                  | −50,00               | 0,029 5         | 1 446,3                      | 135,65                      | 135,67            | 0,741 0              | 0,822 4            | 1,238 1            | 854,7                 | −0,314 3                    |
| vapour                                                                                                                                                                                  |                      |                 | 1,650                        | 349,80                      | 367,65            | 1,780 6              | 0,628 0            | 0,719 7            | 141,69                | 68,25                       |
| liquid                                                                                                                                                                                  | −45,00               | 0,039 1         | 1 432,1                      | 141,86                      | 141,89            | 0,768 5              | 0,827 6            | 1,246 2            | 830,9                 | −0,304 6                    |
| vapour                                                                                                                                                                                  |                      |                 | 2,152                        | 352,65                      | 370,83            | 1,772 0              | 0,640 2            | 0,734 1            | 142,70                | 62,23                       |
| liquid                                                                                                                                                                                  | −40,00               | 0,051 2         | 1 417,7                      | 148,11                      | 148,14            | 0,795 6              | 0,832 8            | 1,254 6            | 807,2                 | −0,294 1                    |
| vapour                                                                                                                                                                                  |                      |                 | 2,769                        | 355,51                      | 374,00            | 1,764 3              | 0,652 6            | 0,749 0            | 143,63                | 57,08                       |
| liquid                                                                                                                                                                                  | −35,00               | 0,066 1         | 1 403,1                      | 154,40                      | 154,44            | 0,822 3              | 0,838 2            | 1,263 5            | 783,7                 | −0,282 8                    |
| vapour                                                                                                                                                                                  |                      |                 | 3,521                        | 358,38                      | 377,17            | 1,757 5              | 0,665 2            | 0,764 6            | 144,45                | 52,63                       |
| liquid                                                                                                                                                                                  | −30,00               | 0,084 4         | 1 388,4                      | 160,73                      | 160,79            | 0,848 6              | 0,843 8            | 1,272 9            | 760,3                 | −0,270 6                    |
| vapour                                                                                                                                                                                  |                      |                 | 4,426                        | 361,25                      | 380,32            | 1,751 5              | 0,678 1            | 0,780 9            | 145,18                | 48,74                       |
| liquid                                                                                                                                                                                  | −26,07 <sup>b</sup>  | 0,101 3         | 1 376,7                      | 165,74                      | 165,81            | 0,869 0              | 0,848 2            | 1,280 5            | 742,0                 | −0,260 2                    |
| vapour                                                                                                                                                                                  |                      |                 | 5,258                        | 363,51                      | 382,78            | 1,747 2              | 0,688 4            | 0,794 2            | 145,67                | 46,01                       |
| liquid                                                                                                                                                                                  | −25,00               | 0,106 4         | 1 373,4                      | 167,11                      | 167,19            | 0,874 6              | 0,849 4            | 1,282 7            | 737,0                 | −0,257 3                    |
| vapour                                                                                                                                                                                  |                      |                 | 5,506                        | 364,12                      | 383,45            | 1,746 1              | 0,691 2            | 0,797 9            | 145,79                | 45,31                       |
| liquid                                                                                                                                                                                  | −20,00               | 0,132 7         | 1 358,3                      | 173,54                      | 173,64            | 0,900 2              | 0,855 1            | 1,293 0            | 713,8                 | −0,242 8                    |
| vapour                                                                                                                                                                                  |                      |                 | 6,784                        | 366,99                      | 386,55            | 1,741 3              | 0,704 6            | 0,815 8            | 146,28                | 42,26                       |
| liquid                                                                                                                                                                                  | −15,00               | 0,163 9         | 1 342,8                      | 180,02                      | 180,14            | 0,925 6              | 0,860 9            | 1,304 0            | 690,7                 | −0,227 0                    |
| vapour                                                                                                                                                                                  |                      |                 | 8,287                        | 369,85                      | 389,63            | 1,737 1              | 0,718 3            | 0,834 6            | 146,65                | 39,54                       |
| liquid                                                                                                                                                                                  | −10,00               | 0,200 6         | 1 327,1                      | 186,55                      | 186,70            | 0,950 6              | 0,866 9            | 1,315 6            | 667,6                 | −0,209 6                    |
| <sup>a</sup> Triple point.<br><sup>b</sup> Normal boiling point.<br><sup>c</sup> The values of $C_v$ , $C_p$ , and $w$ at the critical point are not included as part of this document. |                      |                 |                              |                             |                   |                      |                    |                    |                       |                             |

Table 28 (continued)

|        | Temp.<br>°C | Pressure<br>MPa | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|--------|-------------|-----------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| vapour |             |                 | 10,041                       | 372,69                      | 392,66            | 1,733 4              | 0,732 2            | 0,854 4            | 146,89                | 37,11                       |
| liquid | −5,00       | 0,243 3         | 1 311,1                      | 193,13                      | 193,32            | 0,975 4              | 0,872 9            | 1,327 9            | 644,6                 | −0,190 5                    |
| vapour |             |                 | 12,077                       | 375,51                      | 395,66            | 1,730 0              | 0,746 4            | 0,875 2            | 146,99                | 34,92                       |
| liquid | 0,00        | 0,292 8         | 1 294,8                      | 199,77                      | 200,00            | 1,000 0              | 0,879 1            | 1,341 0            | 621,6                 | −0,169 5                    |
| vapour |             |                 | 14,428                       | 378,31                      | 398,60            | 1,727 1              | 0,760 8            | 0,897 2            | 146,94                | 32,95                       |
| liquid | 5,00        | 0,349 7         | 1 278,1                      | 206,48                      | 206,75            | 1,024 3              | 0,885 4            | 1,355 2            | 598,7                 | −0,146 1                    |
| vapour |             |                 | 17,131                       | 381,08                      | 401,49            | 1,724 5              | 0,775 5            | 0,920 6            | 146,74                | 31,17                       |
| liquid | 10,00       | 0,414 6         | 1 261,0                      | 213,25                      | 213,58            | 1,048 5              | 0,891 8            | 1,370 4            | 575,7                 | −0,120 0                    |
| vapour |             |                 | 20,226                       | 383,82                      | 404,32            | 1,722 1              | 0,790 4            | 0,945 5            | 146,38                | 29,57                       |
| liquid | 15,00       | 0,488 4         | 1 243,4                      | 220,09                      | 220,48            | 1,072 4              | 0,898 3            | 1,386 9            | 552,7                 | −0,090 7                    |
| vapour |             |                 | 23,758                       | 386,52                      | 407,07            | 1,720 0              | 0,805 6            | 0,972 1            | 145,85                | 28,12                       |
| liquid | 20,00       | 0,571 7         | 1 225,3                      | 227,00                      | 227,47            | 1,096 2              | 0,905 0            | 1,404 9            | 529,6                 | −0,057 8                    |
| vapour |             |                 | 27,780                       | 389,17                      | 409,75            | 1,718 0              | 0,821 0            | 1,000 7            | 145,15                | 26,81                       |
| liquid | 25,00       | 0,665 4         | 1 206,7                      | 233,99                      | 234,55            | 1,119 9              | 0,911 9            | 1,424 6            | 506,5                 | −0,020 4                    |
| vapour |             |                 | 32,350                       | 391,77                      | 412,33            | 1,716 2              | 0,836 7            | 1,031 6            | 144,26                | 25,64                       |
| liquid | 30,00       | 0,770 2         | 1 187,5                      | 241,07                      | 241,72            | 1,143 5              | 0,918 9            | 1,446 5            | 483,2                 | 0,022 3                     |
| vapour |             |                 | 37,535                       | 394,30                      | 414,82            | 1,714 5              | 0,852 7            | 1,065 5            | 143,16                | 24,58                       |
| liquid | 35,00       | 0,887 0         | 1 167,5                      | 248,25                      | 249,01            | 1,167 0              | 0,926 2            | 1,470 9            | 459,9                 | 0,071 4                     |
| vapour |             |                 | 43,416                       | 396,76                      | 417,19            | 1,712 8              | 0,869 1            | 1,102 8            | 141,86                | 23,63                       |
| liquid | 40,00       | 1,016 6         | 1 146,7                      | 255,52                      | 256,41            | 1,190 5              | 0,933 6            | 1,498 4            | 436,4                 | 0,128 5                     |
| vapour |             |                 | 50,085                       | 399,13                      | 419,43            | 1,711 1              | 0,885 8            | 1,144 5            | 140,34                | 22,78                       |
| liquid | 45,00       | 1,159 9         | 1 125,1                      | 262,91                      | 263,94            | 1,213 9              | 0,941 4            | 1,529 8            | 412,8                 | 0,195 3                     |
| vapour |             |                 | 57,657                       | 401,40                      | 421,52            | 1,709 2              | 0,902 9            | 1,191 7            | 138,57                | 22,02                       |
| liquid | 50,00       | 1,317 9         | 1 102,3                      | 270,43                      | 271,62            | 1,237 5              | 0,949 4            | 1,566 1            | 389,0                 | 0,274 6                     |
| vapour |             |                 | 66,272                       | 403,55                      | 423,44            | 1,707 2              | 0,920 5            | 1,246 1            | 136,55                | 21,36                       |
| liquid | 55,00       | 1,491 5         | 1 078,3                      | 278,09                      | 279,47            | 1,261 1              | 0,957 9            | 1,608 9            | 364,9                 | 0,369 8                     |
| vapour |             |                 | 76,104                       | 405,55                      | 425,15            | 1,705 0              | 0,938 7            | 1,309 9            | 134,25                | 20,77                       |
| liquid | 60,00       | 1,681 8         | 1 052,9                      | 285,91                      | 287,50            | 1,284 8              | 0,966 8            | 1,660 2            | 340,5                 | 0,486 1                     |
| vapour |             |                 | 87,379                       | 407,38                      | 426,63            | 1,702 4              | 0,957 7            | 1,386 8            | 131,66                | 20,27                       |
| liquid | 65,00       | 1,889 8         | 1 025,6                      | 293,92                      | 295,76            | 1,308 8              | 0,976 4            | 1,723 4            | 315,7                 | 0,630 8                     |
| vapour |             |                 | 100,398                      | 408,99                      | 427,82            | 1,699 3              | 0,977 5            | 1,482 2            | 128,74                | 19,83                       |
| liquid | 70,00       | 2,116 8         | 996,2                        | 302,16                      | 304,28            | 1,333 2              | 0,986 9            | 1,803 9            | 290,3                 | 0,815 7                     |
| vapour |             |                 | 115,572                      | 410,33                      | 428,65            | 1,695 6              | 0,998 6            | 1,605 1            | 125,46                | 19,46                       |
| liquid | 75,00       | 2,364 1         | 964,1                        | 310,68                      | 313,13            | 1,358 0              | 0,998 8            | 1,911 5            | 264,1                 | 1,059 9                     |
| vapour |             |                 | 133,494                      | 411,32                      | 429,03            | 1,690 9              | 1,021 2            | 1,771 4            | 121,80                | 19,14                       |
| liquid | 80,00       | 2,633 2         | 928,2                        | 319,55                      | 322,39            | 1,383 6              | 1,012 9            | 2,064 8            | 236,6                 | 1,397 3                     |
| vapour |             |                 | 155,078                      | 411,83                      | 428,81            | 1,685 0              | 1,046 0            | 2,012 2            | 117,69                | 18,86                       |
| liquid | 85,00       | 2,925 8         | 887,2                        | 328,93                      | 332,22            | 1,410 4              | 1,030 8            | 2,306 4            | 207,4                 | 1,893 6                     |
| vapour |             |                 | 181,853                      | 411,67                      | 427,76            | 1,677 1              | 1,073 9            | 2,397 1            | 113,09                | 18,57                       |
| liquid | 90,00       | 3,244 2         | 837,8                        | 339,06                      | 342,93            | 1,439 0              | 1,055 6            | 2,755 9            | 175,9                 | 2,693 6                     |
| vapour |             |                 | 216,761                      | 410,45                      | 425,42            | 1,666 2              | 1,106 8            | 3,120 7            | 107,90                | 18,20                       |

a Triple point.

b Normal boiling point.

c The values of  $C_v$ ,  $C_p$ , and  $w$  at the critical point are not included as part of this document.

Table 28 (continued)

|                                                                                                                                                                                         | Temp.<br>°C | Pressure<br>MPa | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|-----------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| liquid                                                                                                                                                                                  | 95,00       | 3,591 2         | 772,7                        | 350,60                      | 355,25            | 1,471 5              | 1,093 8            | 3,938 5            | 141,2                 | 4,191 6                     |
| vapour                                                                                                                                                                                  |             |                 | 267,139                      | 407,23                      | 420,67            | 1,649 2              | 1,148 9            | 5,019 5            | 101,91                | 17,51                       |
| liquid                                                                                                                                                                                  | 100,00      | 3,972 4         | 651,2                        | 367,20                      | 373,30            | 1,518 8              | 1,173 7            | 17,591 5           | 101,0                 | 8,198 5                     |
| vapour                                                                                                                                                                                  |             |                 | 373,011                      | 397,03                      | 407,68            | 1,610 9              | 1,218 0            | 25,350 3           | 93,95                 | 15,30                       |
| critical                                                                                                                                                                                | 101,06      | 4,059 3         | 511,9                        | 381,71                      | 389,64            | 1,562 1              | c                  | c                  | c                     | 11,931 2                    |
| <sup>a</sup> Triple point.<br><sup>b</sup> Normal boiling point.<br><sup>c</sup> The values of $C_v$ , $C_p$ , and $w$ at the critical point are not included as part of this document. |             |                 |                              |                             |                   |                      |                    |                    |                       |                             |

## 5.10 R143a — 1,1,1-trifluoroethane

### 5.10.1 Range of validity

The coefficients are valid within the following ranges:

$$T_{\min} = 161,34 \text{ K}, T_{\max} = 650 \text{ K}; p_{\max} = 100 \text{ MPa}; \rho_{\max} = 15,85 \text{ mol/l (1 332 kg/m}^3\text{)}$$

Coefficients and exponents of the ideal-gas part are listed in Table 29. Coefficients and exponents of the real-gas part are listed in Table 30.

Table 29 — Coefficients and exponents of the ideal-gas part [Formulae (3) to (5)]

| $k$ | $c_k$   | $t_k$ | $a_k$   | $b_k$ |
|-----|---------|-------|---------|-------|
| 1   | 1,057 8 | 0,33  | —       | —     |
| 2   | —       | —     | 4,440 2 | 1 791 |
| 3   | —       | —     | 3,751 5 | 823   |

Table 30 — Coefficients and exponents of the real-gas part [Formula (2)]

| $k$ | $N_k$           | $t_k$ | $d_k$ | $l_k$ | $\alpha_k$ |
|-----|-----------------|-------|-------|-------|------------|
| 1   | 7,773 644 3     | 0,67  | 1     | 0     | 0          |
| 2   | −8,701 85       | 0,833 | 1     | 0     | 0          |
| 3   | −0,277 797 99   | 1,7   | 1     | 0     | 0          |
| 4   | 0,146 092 2     | 1,82  | 2     | 0     | 0          |
| 5   | 0,008 958 161 6 | 0,35  | 5     | 0     | 0          |
| 6   | −0,205 521 16   | 3,9   | 1     | 1     | 1          |
| 7   | 0,106 532 58    | 0,95  | 3     | 1     | 1          |
| 8   | 0,023 270 816   | 0     | 5     | 1     | 1          |
| 9   | −0,013 247 542  | 1,19  | 7     | 1     | 1          |
| 10  | −0,042 793 87   | 7,2   | 1     | 2     | 1          |
| 11  | 0,362 216 85    | 5,9   | 2     | 2     | 1          |
| 12  | −0,256 718 99   | 7,65  | 2     | 2     | 1          |
| 13  | −0,092 326 113  | 7,5   | 3     | 2     | 1          |
| 14  | 0,083 774 837   | 7,45  | 4     | 2     | 1          |
| 15  | 0,017 128 445   | 15,5  | 2     | 3     | 1          |
| 16  | −0,017 256 11   | 22    | 3     | 3     | 1          |

Table 30 (continued)

| $k$ | $N_k$           | $t_k$ | $d_k$ | $l_k$ | $\alpha_k$ |
|-----|-----------------|-------|-------|-------|------------|
| 17  | 0,004 908 049 2 | 19    | 5     | 3     | 1          |

### 5.10.2 Reducing parameters, molar mass, and gas constant

$$T^* = 345,857 \text{ K}, \rho^* = 5,128 45 \text{ mol/l}, M = 84,041 \text{ g/mol}, R = 8,314 472 \text{ J/(mol}\cdot\text{K)}$$

### 5.10.3 Reference state parameters

$$T_{\text{ref}} = 273,15 \text{ K}, p_{\text{ref}} = 1,0 \text{ kPa}, h_{\text{ref}} = 33 936,397 \text{ J/mol}, s_{\text{ref}} = 198,961 3 \text{ J/(mol}\cdot\text{K)}, \\ f_1 = -1,577 780 74, f_2 = 2 527,263 78$$

R143a property values along the liquid-vapour saturation boundary are listed in [Table 31](#).

Table 31 — R143a property values along the liquid-vapour saturation boundary

|        | Temp.<br>°C          | Pressure<br>MPa | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|--------|----------------------|-----------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| liquid | -111,81 <sup>a</sup> | 0,001 07        | 1 330,5                      | 52,52                       | 52,52             | 0,314 2              | 0,813 8            | 1,211 2            | 1 058,1               | -0,439 4                    |
| vapour |                      |                 | 0,067 5                      | 303,67                      | 319,59            | 1,969 5              | 0,528 3            | 0,629 9            | 137,57                | 385,09                      |
| liquid | -110,00              | 0,001 29        | 1 326,2                      | 54,71                       | 54,71             | 0,327 7              | 0,812 8            | 1,211 9            | 1 049,4               | -0,437 5                    |
| vapour |                      |                 | 0,080 5                      | 304,59                      | 320,68            | 1,957 9              | 0,533 1            | 0,635 0            | 138,22                | 354,60                      |
| liquid | -105,00              | 0,002 11        | 1 314,1                      | 60,78                       | 60,78             | 0,364 3              | 0,811 4            | 1,215 1            | 1 025,5               | -0,431 6                    |
| vapour |                      |                 | 0,127 4                      | 307,17                      | 323,73            | 1,928 1              | 0,546 7            | 0,649 5            | 139,98                | 284,35                      |
| liquid | -100,00              | 0,003 33        | 1 301,9                      | 66,87                       | 66,87             | 0,400 0              | 0,811 5            | 1,219 9            | 1 001,7               | -0,424 7                    |
| vapour |                      |                 | 0,195 6                      | 309,78                      | 326,81            | 1,901 2              | 0,560 4            | 0,664 2            | 141,68                | 230,56                      |
| liquid | -95,00               | 0,005 10        | 1 289,6                      | 72,98                       | 72,98             | 0,434 8              | 0,813 1            | 1,226 0            | 977,9                 | -0,417 1                    |
| vapour |                      |                 | 0,291 7                      | 312,43                      | 329,92            | 1,877 0              | 0,574 2            | 0,679 2            | 143,32                | 189,21                      |
| liquid | -90,00               | 0,007 61        | 1 277,2                      | 79,13                       | 79,13             | 0,468 8              | 0,815 7            | 1,233 3            | 954,2                 | -0,408 6                    |
| vapour |                      |                 | 0,423 8                      | 315,11                      | 333,06            | 1,855 3              | 0,588 1            | 0,694 4            | 144,89                | 157,26                      |
| liquid | -85,00               | 0,011 1         | 1 264,8                      | 85,31                       | 85,32             | 0,502 1              | 0,819 4            | 1,241 5            | 930,4                 | -0,399 4                    |
| vapour |                      |                 | 0,601                        | 317,83                      | 336,22            | 1,835 7              | 0,602 1            | 0,710 0            | 146,39                | 132,44                      |
| liquid | -80,00               | 0,015 7         | 1 252,2                      | 91,54                       | 91,55             | 0,534 8              | 0,823 8            | 1,250 4            | 906,6                 | -0,389 5                    |
| vapour |                      |                 | 0,835                        | 320,58                      | 339,40            | 1,818 0              | 0,616 2            | 0,725 8            | 147,81                | 113,01                      |
| liquid | -75,00               | 0,021 9         | 1 239,5                      | 97,81                       | 97,83             | 0,566 9              | 0,828 8            | 1,260 1            | 882,8                 | -0,378 9                    |
| vapour |                      |                 | 1,138                        | 323,36                      | 342,60            | 1,802 1              | 0,630 4            | 0,742 1            | 149,13                | 97,68                       |
| liquid | -70,00               | 0,029 9         | 1 226,7                      | 104,14                      | 104,16            | 0,598 4              | 0,834 4            | 1,270 4            | 859,1                 | -0,367 4                    |
| vapour |                      |                 | 1,523                        | 326,16                      | 345,80            | 1,787 9              | 0,644 8            | 0,758 9            | 150,37                | 85,45                       |
| liquid | -65,00               | 0,040 2         | 1 213,7                      | 110,51                      | 110,54            | 0,629 4              | 0,840 5            | 1,281 3            | 835,3                 | -0,355 1                    |
| vapour |                      |                 | 2,005                        | 328,98                      | 349,01            | 1,775 0              | 0,659 3            | 0,776 3            | 151,50                | 75,60                       |
| liquid | -60,00               | 0,053 1         | 1 200,6                      | 116,94                      | 116,99            | 0,659 9              | 0,847 0            | 1,292 8            | 811,5                 | -0,341 9                    |
| vapour |                      |                 | 2,601                        | 331,81                      | 352,21            | 1,763 5              | 0,674 1            | 0,794 4            | 152,51                | 67,57                       |
| liquid | -55,00               | 0,069 1         | 1 187,3                      | 123,43                      | 123,49            | 0,690 0              | 0,853 8            | 1,304 9            | 787,7                 | -0,327 7                    |
| vapour |                      |                 | 3,329                        | 334,66                      | 355,41            | 1,753 1              | 0,689 2            | 0,813 3            | 153,41                | 60,93                       |

<sup>a</sup> Triple point.

<sup>b</sup> Normal boiling point.

<sup>c</sup> The values of  $C_v$ ,  $C_p$ , and  $w$  at the critical point are not included as part of this document.

Table 31 (continued)

|                                                                                                          | Temp.<br>°C         | Pressure<br>MPa | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|----------------------------------------------------------------------------------------------------------|---------------------|-----------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| liquid                                                                                                   | –50,00              | 0,088 7         | 1 173,9                      | 129,97                      | 130,05            | 0,719 7              | 0,860 8            | 1,317 5            | 763,9                 | –0,312 3                    |
| vapour                                                                                                   |                     |                 | 4,210                        | 337,51                      | 358,58            | 1,743 8              | 0,704 6            | 0,833 1            | 154,19                | 55,38                       |
| liquid                                                                                                   | –47,24 <sup>b</sup> | 0,101 3         | 1 166,4                      | 133,61                      | 133,70            | 0,735 9              | 0,864 8            | 1,324 8            | 750,8                 | –0,303 2                    |
| vapour                                                                                                   |                     |                 | 4,769                        | 339,08                      | 360,33            | 1,739 1              | 0,713 2            | 0,844 4            | 154,55                | 52,70                       |
| liquid                                                                                                   | –45,00              | 0,112 5         | 1 160,3                      | 136,58                      | 136,68            | 0,749 0              | 0,868 1            | 1,330 9            | 740,1                 | –0,295 6                    |
| vapour                                                                                                   |                     |                 | 5,264                        | 340,36                      | 361,74            | 1,735 4              | 0,720 3            | 0,853 9            | 154,82                | 50,69                       |
| liquid                                                                                                   | –40,00              | 0,141 1         | 1 146,4                      | 143,26                      | 143,38            | 0,777 9              | 0,875 6            | 1,344 8            | 716,3                 | –0,277 4                    |
| vapour                                                                                                   |                     |                 | 6,514                        | 343,20                      | 364,86            | 1,727 9              | 0,736 3            | 0,875 8            | 155,31                | 46,68                       |
| liquid                                                                                                   | –35,00              | 0,175 0         | 1 132,3                      | 150,00                      | 150,15            | 0,806 5              | 0,883 3            | 1,359 6            | 692,5                 | –0,257 6                    |
| vapour                                                                                                   |                     |                 | 7,988                        | 346,04                      | 367,95            | 1,721 1              | 0,752 6            | 0,898 9            | 155,65                | 43,21                       |
| liquid                                                                                                   | –30,00              | 0,214 9         | 1 117,9                      | 156,81                      | 157,00            | 0,834 8              | 0,891 1            | 1,375 2            | 668,6                 | –0,235 8                    |
| vapour                                                                                                   |                     |                 | 9,711                        | 348,86                      | 370,99            | 1,714 9              | 0,769 3            | 0,923 3            | 155,84                | 40,20                       |
| liquid                                                                                                   | –25,00              | 0,261 4         | 1 103,3                      | 163,70                      | 163,93            | 0,862 9              | 0,899 1            | 1,391 8            | 644,7                 | –0,211 8                    |
| vapour                                                                                                   |                     |                 | 11,716                       | 351,67                      | 373,98            | 1,709 3              | 0,786 3            | 0,949 2            | 155,85                | 37,55                       |
| liquid                                                                                                   | –20,00              | 0,315 4         | 1 088,3                      | 170,66                      | 170,95            | 0,890 7              | 0,907 2            | 1,409 4            | 620,8                 | –0,185 2                    |
| vapour                                                                                                   |                     |                 | 14,036                       | 354,44                      | 376,91            | 1,704 3              | 0,803 5            | 0,976 7            | 155,68                | 35,22                       |
| liquid                                                                                                   | –15,00              | 0,377 4         | 1 072,9                      | 177,71                      | 178,06            | 0,918 3              | 0,915 4            | 1,428 3            | 596,8                 | –0,155 5                    |
| vapour                                                                                                   |                     |                 | 16,709                       | 357,18                      | 379,76            | 1,699 6              | 0,821 1            | 1,006 1            | 155,33                | 33,16                       |
| liquid                                                                                                   | –10,00              | 0,448 2         | 1 057,2                      | 184,84                      | 185,27            | 0,945 7              | 0,923 7            | 1,448 7            | 572,8                 | –0,122 3                    |
| vapour                                                                                                   |                     |                 | 19,778                       | 359,88                      | 382,54            | 1,695 3              | 0,839 0            | 1,037 7            | 154,78                | 31,33                       |
| liquid                                                                                                   | –5,00               | 0,528 7         | 1 041,0                      | 192,07                      | 192,58            | 0,972 9              | 0,932 2            | 1,470 9            | 548,6                 | –0,084 7                    |
| vapour                                                                                                   |                     |                 | 23,292                       | 362,53                      | 385,23            | 1,691 3              | 0,857 1            | 1,071 7            | 154,03                | 29,69                       |
| liquid                                                                                                   | 0,00                | 0,619 7         | 1 024,3                      | 199,40                      | 200,00            | 1,000 0              | 0,940 8            | 1,495 1            | 524,3                 | –0,042 0                    |
| vapour                                                                                                   |                     |                 | 27,306                       | 365,11                      | 387,81            | 1,687 6              | 0,875 6            | 1,108 7            | 153,06                | 28,24                       |
| liquid                                                                                                   | 5,00                | 0,721 9         | 1 007,0                      | 206,83                      | 207,54            | 1,027 0              | 0,949 5            | 1,521 9            | 499,8                 | 0,006 9                     |
| vapour                                                                                                   |                     |                 | 31,885                       | 367,63                      | 390,27            | 1,683 9              | 0,894 4            | 1,149 2            | 151,87                | 26,94                       |
| liquid                                                                                                   | 10,00               | 0,836 3         | 989,1                        | 214,37                      | 215,22            | 1,053 9              | 0,958 5            | 1,551 7            | 475,1                 | 0,063 5                     |
| vapour                                                                                                   |                     |                 | 37,107                       | 370,06                      | 392,60            | 1,680 4              | 0,913 5            | 1,194 2            | 150,43                | 25,79                       |
| liquid                                                                                                   | 15,00               | 0,963 7         | 970,4                        | 222,05                      | 223,04            | 1,080 9              | 0,967 8            | 1,585 4            | 450,2                 | 0,129 5                     |
| vapour                                                                                                   |                     |                 | 43,062                       | 372,39                      | 394,77            | 1,676 8              | 0,933 1            | 1,244 7            | 148,74                | 24,76                       |
| liquid                                                                                                   | 20,00               | 1,105 2         | 950,8                        | 229,86                      | 231,02            | 1,107 8              | 0,977 3            | 1,623 9            | 425,0                 | 0,207 5                     |
| vapour                                                                                                   |                     |                 | 49,864                       | 374,60                      | 396,76            | 1,673 2              | 0,953 1            | 1,302 4            | 146,77                | 23,84                       |
| liquid                                                                                                   | 25,00               | 1,261 6         | 930,2                        | 237,83                      | 239,19            | 1,134 9              | 0,987 3            | 1,668 7            | 399,5                 | 0,300 7                     |
| vapour                                                                                                   |                     |                 | 57,653                       | 376,66                      | 398,54            | 1,669 3              | 0,973 7            | 1,369 5            | 144,51                | 23,04                       |
| liquid                                                                                                   | 30,00               | 1,434 0         | 908,4                        | 245,98                      | 247,56            | 1,162 1              | 0,997 8            | 1,721 8            | 373,5                 | 0,414 0                     |
| vapour                                                                                                   |                     |                 | 66,605                       | 378,54                      | 400,07            | 1,665 2              | 0,995 1            | 1,449 4            | 141,93                | 22,33                       |
| liquid                                                                                                   | 35,00               | 1,623 6         | 885,2                        | 254,33                      | 256,16            | 1,189 5              | 1,009 1            | 1,786 3            | 347,0                 | 0,554 3                     |
| vapour                                                                                                   |                     |                 | 76,954                       | 380,21                      | 401,31            | 1,660 6              | 1,017 3            | 1,547 2            | 139,02                | 21,71                       |
| liquid                                                                                                   | 40,00               | 1,831 4         | 860,3                        | 262,91                      | 265,04            | 1,217 4              | 1,021 3            | 1,867 0            | 319,8                 | 0,731 9                     |
| vapour                                                                                                   |                     |                 | 89,018                       | 381,61                      | 402,19            | 1,655 3              | 1,040 8            | 1,671 5            | 135,73                | 21,17                       |
| liquid                                                                                                   | 45,00               | 2,058 9         | 833,1                        | 271,79                      | 274,26            | 1,245 7              | 1,035 0            | 1,972 5            | 291,8                 | 0,963 6                     |
| a Triple point.                                                                                          |                     |                 |                              |                             |                   |                      |                    |                    |                       |                             |
| b Normal boiling point.                                                                                  |                     |                 |                              |                             |                   |                      |                    |                    |                       |                             |
| c The values of $C_v$ , $C_p$ , and $w$ at the critical point are not included as part of this document. |                     |                 |                              |                             |                   |                      |                    |                    |                       |                             |

Table 31 (continued)

|                                                                                                                                                                                                      | Temp.<br>°C | Pressure<br>MPa | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|-----------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| vapour                                                                                                                                                                                               |             |                 | 103,245                      | 382,66                      | 402,61            | 1,649 1              | 1,065 9            | 1,836 6            | 132,04                | 20,69                       |
| liquid                                                                                                                                                                                               | 50,00       | 2,307 3         | 803,0                        | 281,02                      | 283,90            | 1,274 8              | 1,050 9            | 2,118 1            | 262,7                 | 1,277 7                     |
| vapour                                                                                                                                                                                               |             |                 | 120,307                      | 383,25                      | 402,43            | 1,641 6              | 1,093 2            | 2,070 0            | 127,89                | 20,26                       |
| liquid                                                                                                                                                                                               | 55,00       | 2,578 5         | 768,9                        | 290,74                      | 294,09            | 1,305 1              | 1,070 2            | 2,336 9            | 232,2                 | 1,727 3                     |
| vapour                                                                                                                                                                                               |             |                 | 141,302                      | 383,20                      | 401,44            | 1,632 2              | 1,123 7            | 2,430 2            | 123,22                | 19,84                       |
| liquid                                                                                                                                                                                               | 60,00       | 2,874 4         | 728,9                        | 301,15                      | 305,09            | 1,337 1              | 1,095 1            | 2,714 3            | 199,5                 | 2,423 7                     |
| vapour                                                                                                                                                                                               |             |                 | 168,236                      | 382,16                      | 399,24            | 1,619 7              | 1,159 5            | 3,068 5            | 117,93                | 19,37                       |
| liquid                                                                                                                                                                                               | 65,00       | 3,197 7         | 678,3                        | 312,73                      | 317,45            | 1,372 6              | 1,131 2            | 3,563 5            | 163,8                 | 3,652 9                     |
| vapour                                                                                                                                                                                               |             |                 | 205,645                      | 379,39                      | 394,94            | 1,601 8              | 1,204 4            | 4,532 3            | 101,84                | 18,67                       |
| liquid                                                                                                                                                                                               | 70,00       | 3,552 7         | 600,8                        | 327,28                      | 333,19            | 1,417 2              | 1,198 4            | 7,719 7            | 122,4                 | 6,473 3                     |
| vapour                                                                                                                                                                                               |             |                 | 270,096                      | 372,27                      | 385,42            | 1,569 4              | 1,272 0            | 11,500 8           | 104,25                | 17,07                       |
| critical                                                                                                                                                                                             | 72,71       | 3,761 0         | 431,0                        | 350,18                      | 358,91            | 1,490 6              | c                  | c                  | c                     | 12,396 9                    |
| <p>a Triple point.</p> <p>b Normal boiling point.</p> <p>c The values of <math>C_v</math>, <math>C_p</math>, and <math>w</math> at the critical point are not included as part of this document.</p> |             |                 |                              |                             |                   |                      |                    |                    |                       |                             |

## 5.11 R152a — 1,1-difluoroethane

### 5.11.1 Range of validity

The coefficients are valid within the following ranges:

$$T_{\min} = 154,5 \text{ K}, T_{\max} = 500 \text{ K}; p_{\max} = 60 \text{ MPa}; \rho_{\max} = 18,07 \text{ mol/l (1 194 kg/m}^3\text{)}$$

Coefficients and exponents of the ideal-gas part are listed in [Table 32](#). Coefficients and exponents of the real-gas part are listed in [Table 33](#).

Table 32 — Coefficients and exponents of the ideal-gas part [Formulae (3) to (5)]

| $k$ | $c_k$                       | $t_k$ |
|-----|-----------------------------|-------|
| 0   | 3,354 952                   | —     |
| 1   | $1,098 649 \times 10^{-2}$  | 1     |
| 2   | $2,501 616 \times 10^{-5}$  | 2     |
| 3   | $-2,787 445 \times 10^{-8}$ | 3     |

Table 33 — Coefficients and exponents of the real-gas part [Formula (2)]

| $k$ | $N_k$                              | $t_k$ | $d_k$ | $l_k$ | $\alpha_k$ |
|-----|------------------------------------|-------|-------|-------|------------|
| 1   | $-0,354 657 949 982 \times 10^1$   | 3     | 0     | 0     | 0          |
| 2   | $-0,364 631 280 620$               | 4     | 0     | 0     | 0          |
| 3   | $0,333 233 335 558 \times 10^{-1}$ | 5     | 0     | 0     | 0          |
| 4   | $-0,680 968 435 117$               | 0     | 1     | 0     | 0          |
| 5   | $0,735 212 646 801 \times 10^1$    | 0,5   | 1     | 0     | 0          |
| 6   | $-0,112 473 063 838 \times 10^2$   | 1     | 1     | 0     | 0          |
| 7   | $0,549 916 715 657 \times 10^1$    | 2     | 1     | 0     | 0          |
| 8   | $-0,240 186 327 322 \times 10^1$   | 3     | 1     | 0     | 0          |

Table 33 (continued)

| $k$ | $N_k$                                  | $t_k$ | $d_k$ | $l_k$ | $\alpha_k$ |
|-----|----------------------------------------|-------|-------|-------|------------|
| 9   | $-0,709\,036\,447\,042 \times 10^{-1}$ | 0     | 2     | 0     | 0          |
| 10  | $-0,213\,200\,886\,814$                | 1     | 2     | 0     | 0          |
| 11  | $0,197\,839\,736\,368$                 | 2     | 2     | 0     | 0          |
| 12  | $0,182\,494\,769\,909 \times 10^1$     | 3     | 2     | 0     | 0          |
| 13  | $-0,860\,546\,479\,693 \times 10^{-1}$ | 0     | 3     | 0     | 0          |
| 14  | $0,888\,137\,366\,540$                 | 1     | 3     | 0     | 0          |
| 15  | $-0,966\,127\,346\,370$                | 2     | 3     | 0     | 0          |
| 16  | $-0,985\,223\,479\,324 \times 10^{-1}$ | 1     | 4     | 0     | 0          |
| 17  | $0,183\,419\,368\,472 \times 10^{-1}$  | 2     | 5     | 0     | 0          |
| 18  | $-0,338\,550\,204\,252 \times 10^{-1}$ | 3     | 5     | 0     | 0          |
| 19  | $0,124\,921\,101\,016 \times 10^{-1}$  | 2     | 6     | 0     | 0          |
| 20  | $-0,221\,056\,706\,423 \times 10^{-2}$ | 2     | 7     | 0     | 0          |
| 21  | $0,216\,879\,133\,161 \times 10^{-2}$  | 3     | 7     | 0     | 0          |
| 22  | $-0,233\,597\,690\,478 \times 10^{-3}$ | 3     | 8     | 0     | 0          |
| 23  | $0,354\,657\,949\,982 \times 10^1$     | 3     | 0     | 2     | 1          |
| 24  | $0,364\,631\,280\,620$                 | 4     | 0     | 2     | 1          |
| 25  | $-0,333\,233\,335\,558 \times 10^{-1}$ | 5     | 0     | 2     | 1          |
| 26  | $0,276\,133\,830\,254 \times 10^1$     | 3     | 2     | 2     | 1          |
| 27  | $-0,691\,185\,711\,880 \times 10^{-1}$ | 4     | 2     | 2     | 1          |
| 28  | $-0,333\,233\,335\,558 \times 10^{-1}$ | 5     | 2     | 2     | 1          |
| 29  | $0,782\,761\,327\,717$                 | 3     | 4     | 2     | 1          |
| 30  | $-0,345\,592\,855\,940 \times 10^{-1}$ | 4     | 4     | 2     | 1          |
| 31  | $0,137\,813\,531\,906$                 | 5     | 4     | 2     | 1          |
| 32  | $0,186\,173\,126\,153$                 | 3     | 6     | 2     | 1          |
| 33  | $-0,341\,119\,393\,297 \times 10^{-1}$ | 4     | 6     | 2     | 1          |
| 34  | $0,459\,378\,439\,687 \times 10^{-1}$  | 5     | 6     | 2     | 1          |
| 35  | $0,216\,470\,012\,607 \times 10^{-1}$  | 3     | 8     | 2     | 1          |
| 36  | $-0,852\,798\,483\,242 \times 10^{-2}$ | 4     | 8     | 2     | 1          |
| 37  | $0,620\,394\,038\,634 \times 10^{-2}$  | 5     | 8     | 2     | 1          |
| 38  | $0,185\,210\,290\,813 \times 10^{-2}$  | 3     | 10    | 2     | 1          |
| 39  | $0,101\,674\,662\,734 \times 10^{-2}$  | 4     | 10    | 2     | 1          |
| 40  | $0,124\,078\,807\,727 \times 10^{-2}$  | 5     | 10    | 2     | 1          |

### 5.11.2 Reducing parameters, molar mass, and gas constant

$$T^* = 386,411 \text{ K}, \rho^* = 5,571\,45 \text{ mol/l}, M = 66,051 \text{ g/mol}, R = 8,314\,471 \text{ J/(mol}\cdot\text{K)}$$

### 5.11.3 Reference state parameters

$$T_{\text{ref}} = 273,15 \text{ K}, p_{\text{ref}} = 1,0 \text{ kPa}, h_{\text{ref}} = 34\,189,811 \text{ J/mol}, s_{\text{ref}} = 188,564\,6 \text{ J/(mol}\cdot\text{K)}, \\ f_1 = 4,360\,056, f_2 = 2\,654,673\,62$$

R152a property values along the liquid-vapour saturation boundary are listed in [Table 34](#).

Table 34 — R152a property values along the liquid-vapour saturation boundary

|        | Temp.<br>°C          | Pressure<br>MPa        | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | C <sub>v</sub><br>kJ/(kg·K) | C <sub>p</sub><br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|--------|----------------------|------------------------|------------------------------|-----------------------------|-------------------|----------------------|-----------------------------|-----------------------------|-----------------------|-----------------------------|
| liquid | -118,59 <sup>a</sup> | 6,414×10 <sup>-5</sup> | 1 192,9                      | 13,79                       | 13,79             | 0,111 9              | 0,994 8                     | 1,477 4                     | 1 400,9               | -0,432 6                    |
| vapour |                      |                        | 3,297×10 <sup>-3</sup>       | 399,87                      | 419,32            | 2,735 7              | 0,572 6                     | 0,698 7                     | 154,04                | 336,54                      |
| liquid | -115,00              | 0,000 103              | 1 186,3                      | 19,13                       | 19,13             | 0,146 0              | 1,009 0                     | 1,492 1                     | 1 372,8               | -0,426 6                    |
| vapour |                      |                        | 0,005 16                     | 401,93                      | 421,84            | 2,692 4              | 0,580 3                     | 0,706 4                     | 155,63                | 308,12                      |
| liquid | -110,00              | 0,000 191              | 1 177,1                      | 26,62                       | 26,62             | 0,192 7              | 1,021 0                     | 1,505 3                     | 1 337,3               | -0,420 3                    |
| vapour |                      |                        | 0,009 28                     | 404,85                      | 425,38            | 2,636 8              | 0,591 1                     | 0,717 3                     | 157,80                | 273,32                      |
| liquid | -105,00              | 0,000 339              | 1 167,9                      | 34,17                       | 34,17             | 0,238 3              | 1,027 1                     | 1,513 1                     | 1 305,0               | -0,415 4                    |
| vapour |                      |                        | 0,016 00                     | 407,81                      | 428,96            | 2,586 1              | 0,602 0                     | 0,728 4                     | 159,93                | 243,29                      |
| liquid | -100,00              | 0,000 579              | 1 158,7                      | 41,75                       | 41,75             | 0,282 7              | 1,029 7                     | 1,517 8                     | 1 274,9               | -0,411 2                    |
| vapour |                      |                        | 0,026 58                     | 410,82                      | 432,59            | 2,539 9              | 0,613 1                     | 0,739 8                     | 162,01                | 217,25                      |
| liquid | -95,00               | 0,000 956              | 1 149,4                      | 49,35                       | 49,35             | 0,325 9              | 1,030 5                     | 1,521 0                     | 1 246,3               | -0,407 2                    |
| vapour |                      |                        | 0,042 68                     | 413,87                      | 436,26            | 2,497 8              | 0,624 4                     | 0,751 4                     | 164,04                | 194,62                      |
| liquid | -90,00               | 0,001 53               | 1 140,1                      | 56,96                       | 56,96             | 0,368 1              | 1,030 4                     | 1,523 7                     | 1 218,9               | -0,403 0                    |
| vapour |                      |                        | 0,066 4                      | 416,96                      | 439,97            | 2,459 3              | 0,635 8                     | 0,763 4                     | 166,02                | 174,86                      |
| liquid | -85,00               | 0,002 37               | 1 130,7                      | 64,58                       | 64,59             | 0,409 1              | 1,030 2                     | 1,526 5                     | 1 192,3               | -0,398 6                    |
| vapour |                      |                        | 0,100 5                      | 420,10                      | 443,71            | 2,424 2              | 0,647 5                     | 0,775 8                     | 167,95                | 157,56                      |
| liquid | -80,00               | 0,003 59               | 1 121,3                      | 72,22                       | 72,23             | 0,449 2              | 1,030 2                     | 1,529 8                     | 1 166,3               | -0,393 7                    |
| vapour |                      |                        | 0,148 3                      | 423,26                      | 447,48            | 2,392 0              | 0,659 5                     | 0,788 6                     | 169,81                | 142,37                      |
| liquid | -75,00               | 0,005 30               | 1 111,9                      | 79,88                       | 79,89             | 0,488 4              | 1,030 7                     | 1,533 9                     | 1 140,7               | -0,388 3                    |
| vapour |                      |                        | 0,213 6                      | 426,46                      | 451,27            | 2,362 6              | 0,671 8                     | 0,801 9                     | 171,62                | 128,99                      |
| liquid | -70,00               | 0,007 65               | 1 102,4                      | 87,56                       | 87,57             | 0,526 6              | 1,031 7                     | 1,538 8                     | 1 115,5               | -0,382 4                    |
| vapour |                      |                        | 0,301 2                      | 429,69                      | 455,08            | 2,335 7              | 0,684 3                     | 0,815 7                     | 173,36                | 117,18                      |
| liquid | -65,00               | 0,010 8                | 1 092,8                      | 95,27                       | 95,28             | 0,564 1              | 1,033 4                     | 1,544 6                     | 1 090,4               | -0,375 8                    |
| vapour |                      |                        | 0,416                        | 432,94                      | 458,90            | 2,311 1              | 0,697 2                     | 0,830 1                     | 175,03                | 106,73                      |
| liquid | -60,00               | 0,015 0                | 1 083,2                      | 103,01                      | 103,02            | 0,600 9              | 1,035 7                     | 1,551 3                     | 1 065,6               | -0,368 5                    |
| vapour |                      |                        | 0,566                        | 436,21                      | 462,74            | 2,288 5              | 0,710 4                     | 0,845 2                     | 176,62                | 97,46                       |
| liquid | -55,00               | 0,020 4                | 1 073,5                      | 110,78                      | 110,80            | 0,636 9              | 1,038 7                     | 1,558 9                     | 1 040,9               | -0,360 6                    |
| vapour |                      |                        | 0,755                        | 439,50                      | 466,57            | 2,267 7              | 0,724 0                     | 0,860 9                     | 178,12                | 89,21                       |
| liquid | -50,00               | 0,027 4                | 1 063,7                      | 118,59                      | 118,62            | 0,672 3              | 1,042 2                     | 1,567 4                     | 1 016,4               | -0,352 0                    |
| vapour |                      |                        | 0,994                        | 442,80                      | 470,40            | 2,248 7              | 0,737 9                     | 0,877 4                     | 179,54                | 81,87                       |
| liquid | -45,00               | 0,036 2                | 1 053,8                      | 126,45                      | 126,48            | 0,707 1              | 1,046 3                     | 1,576 8                     | 991,8                 | -0,342 7                    |
| vapour |                      |                        | 1,289                        | 446,10                      | 474,21            | 2,231 3              | 0,752 2                     | 0,894 6                     | 180,86                | 75,31                       |
| liquid | -40,00               | 0,047 2                | 1 043,8                      | 134,35                      | 134,40            | 0,741 4              | 1,050 9                     | 1,587 0                     | 967,4                 | -0,332 6                    |
| vapour |                      |                        | 1,651                        | 449,41                      | 478,02            | 2,215 2              | 0,766 9                     | 0,912 7                     | 182,08                | 69,45                       |
| liquid | -35,00               | 0,060 7                | 1 033,7                      | 142,31                      | 142,37            | 0,775 2              | 1,055 8                     | 1,597 9                     | 943,0                 | -0,321 6                    |
| vapour |                      |                        | 2,089                        | 452,72                      | 481,79            | 2,200 4              | 0,782 0                     | 0,931 7                     | 183,19                | 64,20                       |
| liquid | -30,00               | 0,077 2                | 1 023,5                      | 150,32                      | 150,39            | 0,808 5              | 1,061 2                     | 1,609 7                     | 918,6                 | -0,309 8                    |
| vapour |                      |                        | 2,615                        | 456,03                      | 485,55            | 2,186 8              | 0,797 5                     | 0,951 6                     | 184,18                | 59,49                       |
| liquid | -25,00               | 0,097 0                | 1 013,2                      | 158,39                      | 158,48            | 0,841 3              | 1,066 9                     | 1,622 2                     | 894,2                 | -0,297 0                    |
| vapour |                      |                        | 3,241                        | 459,33                      | 489,26            | 2,174 3              | 0,813 3                     | 0,972 4                     | 185,06                | 55,26                       |
| liquid | -24,02 <sup>b</sup>  | 0,101 3                | 1 011,2                      | 159,97                      | 160,07            | 0,847 7              | 1,068 1                     | 1,624 7                     | 889,5                 | -0,294 4                    |

<sup>a</sup> Triple point.<sup>b</sup> Normal boiling point.<sup>c</sup> The values of C<sub>p</sub>, C<sub>v</sub>, and w at the critical point are not included as part of this document.

Table 34 (continued)

|                                                                                                          | Temp.<br>°C | Pressure<br>MPa | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|----------------------------------------------------------------------------------------------------------|-------------|-----------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| vapour                                                                                                   |             |                 | 3,376                        | 459,97                      | 489,98            | 2,171 9              | 0,816 4            | 0,976 6            | 185,21                | 54,48                       |
| liquid                                                                                                   | −20,00      | 0,120 7         | 1 002,7                      | 166,52                      | 166,64            | 0,873 7              | 1,073 0            | 1,635 5            | 869,9                 | −0,283 2                    |
| vapour                                                                                                   |             |                 | 3,979                        | 462,61                      | 492,94            | 2,162 7              | 0,829 5            | 0,994 3            | 185,80                | 51,45                       |
| liquid                                                                                                   | −15,00      | 0,148 7         | 992,1                        | 174,71                      | 174,86            | 0,905 8              | 1,079 3            | 1,649 6            | 845,5                 | −0,268 2                    |
| vapour                                                                                                   |             |                 | 4,844                        | 465,88                      | 496,57            | 2,152 0              | 0,846 0            | 1,017 2            | 186,41                | 48,02                       |
| liquid                                                                                                   | −10,00      | 0,181 5         | 981,3                        | 182,98                      | 183,16            | 0,937 5              | 1,085 9            | 1,664 5            | 821,0                 | −0,252 0                    |
| vapour                                                                                                   |             |                 | 5,852                        | 469,12                      | 500,15            | 2,142 1              | 0,862 9            | 1,041 4            | 186,88                | 44,93                       |
| liquid                                                                                                   | −5,00       | 0,219 8         | 970,3                        | 191,31                      | 191,54            | 0,968 9              | 1,092 7            | 1,680 4            | 796,6                 | −0,234 3                    |
| vapour                                                                                                   |             |                 | 7,017                        | 472,34                      | 503,66            | 2,132 9              | 0,880 2            | 1,066 7            | 187,20                | 42,13                       |
| liquid                                                                                                   | 0,00        | 0,264 0         | 959,1                        | 199,72                      | 200,00            | 1,000 0              | 1,099 7            | 1,697 2            | 772,0                 | −0,214 9                    |
| vapour                                                                                                   |             |                 | 8,359                        | 475,53                      | 507,11            | 2,124 3              | 0,897 8            | 1,093 5            | 187,37                | 39,60                       |
| liquid                                                                                                   | 5,00        | 0,314 8         | 947,7                        | 208,22                      | 208,55            | 1,030 8              | 1,106 9            | 1,715 1            | 747,4                 | −0,193 8                    |
| vapour                                                                                                   |             |                 | 9,896                        | 478,68                      | 510,49            | 2,116 4              | 0,915 7            | 1,121 8            | 187,37                | 37,31                       |
| liquid                                                                                                   | 10,00       | 0,372 8         | 936,1                        | 216,79                      | 217,19            | 1,061 4              | 1,114 4            | 1,734 2            | 722,7                 | −0,170 6                    |
| vapour                                                                                                   |             |                 | 11,651                       | 481,79                      | 513,78            | 2,108 9              | 0,933 9            | 1,151 7            | 187,21                | 35,23                       |
| liquid                                                                                                   | 15,00       | 0,438 6         | 924,2                        | 225,45                      | 225,93            | 1,091 7              | 1,122 0            | 1,754 6            | 697,9                 | −0,144 9                    |
| vapour                                                                                                   |             |                 | 13,647                       | 484,85                      | 516,99            | 2,101 8              | 0,952 5            | 1,183 4            | 186,87                | 33,35                       |
| liquid                                                                                                   | 20,00       | 0,512 9         | 912,0                        | 234,21                      | 234,77            | 1,121 9              | 1,129 9            | 1,776 5            | 673,0                 | −0,116 5                    |
| vapour                                                                                                   |             |                 | 15,910                       | 487,85                      | 520,09            | 2,095 2              | 0,971 4            | 1,217 3            | 186,36                | 31,64                       |
| liquid                                                                                                   | 25,00       | 0,596 4         | 899,5                        | 243,07                      | 243,73            | 1,151 9              | 1,137 9            | 1,800 1            | 647,9                 | −0,084 9                    |
| vapour                                                                                                   |             |                 | 18,469                       | 490,79                      | 523,09            | 2,088 8              | 0,990 6            | 1,253 6            | 185,65                | 30,09                       |
| liquid                                                                                                   | 30,00       | 0,689 8         | 886,6                        | 252,03                      | 252,80            | 1,181 7              | 1,146 2            | 1,825 8            | 622,7                 | −0,049 5                    |
| vapour                                                                                                   |             |                 | 21,357                       | 493,66                      | 525,96            | 2,082 8              | 1,010 1            | 1,292 6            | 184,74                | 28,69                       |
| liquid                                                                                                   | 35,00       | 0,793 9         | 873,4                        | 261,10                      | 262,01            | 1,211 4              | 1,154 8            | 1,853 9            | 597,3                 | −0,009 6                    |
| vapour                                                                                                   |             |                 | 24,613                       | 496,44                      | 528,70            | 2,076 9              | 1,030 0            | 1,334 9            | 183,63                | 27,41                       |
| liquid                                                                                                   | 40,00       | 0,909 3         | 859,7                        | 270,29                      | 271,35            | 1,241 1              | 1,163 6            | 1,884 7            | 571,7                 | 0,035 7                     |
| vapour                                                                                                   |             |                 | 28,280                       | 499,13                      | 531,28            | 2,071 1              | 1,050 2            | 1,381 1            | 182,30                | 26,25                       |
| liquid                                                                                                   | 45,00       | 1,036 8         | 845,5                        | 279,62                      | 280,84            | 1,270 7              | 1,172 8            | 1,919 0            | 545,9                 | 0,087 3                     |
| vapour                                                                                                   |             |                 | 32,408                       | 501,71                      | 533,70            | 2,065 5              | 1,070 7            | 1,432 0            | 180,74                | 25,20                       |
| liquid                                                                                                   | 50,00       | 1,177 4         | 830,8                        | 289,08                      | 290,50            | 1,300 3              | 1,182 3            | 1,957 4            | 519,9                 | 0,146 8                     |
| vapour                                                                                                   |             |                 | 37,058                       | 504,16                      | 535,93            | 2,059 8              | 1,091 7            | 1,488 7            | 178,94                | 24,24                       |
| liquid                                                                                                   | 55,00       | 1,331 7         | 815,4                        | 298,70                      | 300,34            | 1,329 9              | 1,192 2            | 2,000 9            | 493,5                 | 0,215 9                     |
| vapour                                                                                                   |             |                 | 42,300                       | 506,47                      | 537,95            | 2,054 0              | 1,113 1            | 1,552 6            | 176,89                | 23,38                       |
| liquid                                                                                                   | 60,00       | 1,500 7         | 799,4                        | 308,50                      | 310,38            | 1,359 6              | 1,202 6            | 2,051 0            | 466,9                 | 0,297 0                     |
| vapour                                                                                                   |             |                 | 48,222                       | 508,60                      | 539,72            | 2,048 0              | 1,135 0            | 1,625 7            | 174,57                | 22,60                       |
| liquid                                                                                                   | 65,00       | 1,685 3         | 782,5                        | 318,49                      | 320,64            | 1,389 5              | 1,213 5            | 2,109 4            | 440,0                 | 0,393 4                     |
| vapour                                                                                                   |             |                 | 54,933                       | 510,53                      | 541,21            | 2,041 8              | 1,157 5            | 1,710 9            | 171,96                | 21,90                       |
| liquid                                                                                                   | 70,00       | 1,886 4         | 764,6                        | 328,70                      | 331,16            | 1,419 6              | 1,225 1            | 2,178 9            | 412,6                 | 0,509 6                     |
| vapour                                                                                                   |             |                 | 62,569                       | 512,22                      | 542,37            | 2,035 1              | 1,180 6            | 1,812 2            | 169,04                | 21,27                       |
| liquid                                                                                                   | 75,00       | 2,105 1         | 745,6                        | 339,16                      | 341,98            | 1,450 1              | 1,237 5            | 2,263 7            | 384,8                 | 0,652 2                     |
| vapour                                                                                                   |             |                 | 71,312                       | 513,62                      | 543,14            | 2,027 9              | 1,204 5            | 1,936 0            | 165,79                | 20,71                       |
| a Triple point.                                                                                          |             |                 |                              |                             |                   |                      |                    |                    |                       |                             |
| b Normal boiling point.                                                                                  |             |                 |                              |                             |                   |                      |                    |                    |                       |                             |
| c The values of $C_v$ , $C_p$ , and $w$ at the critical point are not included as part of this document. |             |                 |                              |                             |                   |                      |                    |                    |                       |                             |

Table 34 (continued)

|                                                                                                                                                                                         | Temp.<br>°C | Pressure<br>MPa | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|-----------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| liquid                                                                                                                                                                                  | 80,00       | 2,342 4         | 725,2                        | 349,92                      | 353,15            | 1,481 0              | 1,250 9            | 2,370 3            | 356,4                 | 0,830 9                     |
| vapour                                                                                                                                                                                  |             |                 | 81,403                       | 514,66                      | 543,43            | 2,019 8              | 1,229 4            | 2,092 4            | 162,17                | 20,20                       |
| liquid                                                                                                                                                                                  | 85,00       | 2,599 6         | 703,0                        | 361,04                      | 364,74            | 1,512 6              | 1,265 5            | 2,509 9            | 327,4                 | 1,060 9                     |
| vapour                                                                                                                                                                                  |             |                 | 93,185                       | 515,23                      | 543,13            | 2,010 7              | 1,255 5            | 2,298 5            | 158,15                | 19,74                       |
| liquid                                                                                                                                                                                  | 90,00       | 2,878 0         | 678,5                        | 372,63                      | 376,87            | 1,545 1              | 1,281 8            | 2,703 4            | 297,4                 | 1,367 5                     |
| vapour                                                                                                                                                                                  |             |                 | 107,172                      | 515,21                      | 542,06            | 2,000 0              | 1,283 2            | 2,586 3            | 153,69                | 19,32                       |
| liquid                                                                                                                                                                                  | 95,00       | 3,179 1         | 650,9                        | 384,82                      | 389,71            | 1,579 0              | 1,300 4            | 2,994 7            | 266,3                 | 1,796 1                     |
| vapour                                                                                                                                                                                  |             |                 | 124,192                      | 514,35                      | 539,95            | 1,987 1              | 1,313 0            | 3,022 8            | 148,70                | 18,90                       |
| liquid                                                                                                                                                                                  | 100,00      | 3,505 0         | 618,5                        | 397,93                      | 403,59            | 1,615 1              | 1,322 3            | 3,495 1            | 233,5                 | 2,437 8                     |
| vapour                                                                                                                                                                                  |             |                 | 145,754                      | 512,23                      | 536,28            | 1,970 7              | 1,345 9            | 3,775 9            | 143,11                | 18,43                       |
| liquid                                                                                                                                                                                  | 105,00      | 3,858 3         | 578,1                        | 412,57                      | 419,25            | 1,655 2              | 1,350 2            | 4,594 7            | 198,0                 | 3,508 2                     |
| vapour                                                                                                                                                                                  |             |                 | 175,224                      | 507,95                      | 529,97            | 1,947 9              | 1,383 8            | 5,424 5            | 136,73                | 17,78                       |
| liquid                                                                                                                                                                                  | 110,00      | 4,243 2         | 517,4                        | 431,02                      | 439,22            | 1,705 8              | 1,392 1            | 9,261 4            | 157,9                 | 5,710 4                     |
| vapour                                                                                                                                                                                  |             |                 | 224,256                      | 498,39                      | 517,31            | 1,909 6              | 1,431 7            | 12,215 0           | 129,14                | 16,42                       |
| critical                                                                                                                                                                                | 113,26      | 4,516 8         | 368,0                        | 465,28                      | 477,55            | 1,803 7              | c                  | c                  | c                     | 11,292 0                    |
| <sup>a</sup> Triple point.<br><sup>b</sup> Normal boiling point.<br><sup>c</sup> The values of $C_v$ , $C_p$ , and $w$ at the critical point are not included as part of this document. |             |                 |                              |                             |                   |                      |                    |                    |                       |                             |

## 5.12 R404A — R125/143a/134a (44/52/4)

### 5.12.1 Composition of R404A

The Composition of R404A is listed in Table 35.

Table 35 — Composition of R404A

| <i>i</i>                      | Component | Mass fraction | Mole fraction |
|-------------------------------|-----------|---------------|---------------|
| 1                             | R125      | 0,44          | 0,357 816 78  |
| 2                             | R143a     | 0,52          | 0,603 919 22  |
| 3                             | R134a     | 0,04          | 0,038 264 00  |
| $M = 97,604\ 0\ \text{g/mol}$ |           |               |               |

### 5.12.2 Range of validity

The coefficients are valid within the following ranges:

$$T_{\min} = 172,52\ \text{K}, T_{\max} = 455\ \text{K}; p_{\max} = 60\ \text{MPa}; \rho_{\max} = 15,04\ \text{mol/l} (1\ 468\ \text{kg/m}^3)$$

### 5.12.3 Interaction parameters (Formulae 19 and 20)

$$\zeta_{12} = 5,551; \zeta_{12} = -0,000\ 445\ 2; \zeta_{13} = -0,432\ 6; \zeta_{13} = -0,000\ 345\ 3; \zeta_{23} = 2,324; \zeta_{23} = 0,000\ 618\ 2$$

### 5.12.4 Coefficients and exponents of the excess functions (Formula 21)

Coefficients and exponents of the excess functions of R125/134a binary pair and R143a/134a binary pair are listed in Table 36.

**Table 36 — Coefficients and exponents of the excess functions,  $i = 1; j = 2$  (R125/143a binary pair)**

| R125/134a binary pair <sup>a</sup> and R143a/134a binary pair <sup>b</sup>                                                                                  |                 |       |       |       |
|-------------------------------------------------------------------------------------------------------------------------------------------------------------|-----------------|-------|-------|-------|
| $k$                                                                                                                                                         | $N_k$           | $t_k$ | $d_k$ | $l_k$ |
| 1                                                                                                                                                           | −0,013 073      | 7,4   | 1     | 1     |
| 2                                                                                                                                                           | 0,018 259       | 0,35  | 3     | 1     |
| 3                                                                                                                                                           | 0,000 008 129 9 | 10,0  | 11    | 2     |
| 4                                                                                                                                                           | 0,007 849 6     | 5,3   | 2     | 3     |
| $F_{12} = 1,169 7$                                                                                                                                          |                 |       |       |       |
| <sup>a</sup> $i = 1; j = 3$ : $F_{13} = 1,00$ ; the $\phi_{ij,excess}$ function for the R125/134a pair is identical to that for the R125/143a pair.         |                 |       |       |       |
| <sup>b</sup> For $i = 2; j = 3$ : $F_{23} = 0,555 7$ ; the $\phi_{ij,excess}$ function for the R143a/134a pair is identical to that for the R125/143a pair. |                 |       |       |       |

**5.12.5 Reference state parameters**

$$f_3 = 0,753\,387\,285, f_4 = 17,495\,997\,7$$

R404A property values of liquid on the bubble line and vapour on the dew line are listed in [Table 37](#).

**Table 37 — R404A property values of liquid on the bubble line and vapour on the dew line**

|                                                                                                                     | Pressure             | Temp.  | Density           | Internal energy | Enthalpy | Entropy   | $C_v$     | $C_p$     | Sound speed | J-T coefficient |
|---------------------------------------------------------------------------------------------------------------------|----------------------|--------|-------------------|-----------------|----------|-----------|-----------|-----------|-------------|-----------------|
|                                                                                                                     | MPa                  | °C     | kg/m <sup>3</sup> | kJ/kg           | kJ/kg    | kJ/(kg·K) | kJ/(kg·K) | kJ/(kg·K) | m/s         | K/MPa           |
| bubble                                                                                                              | 0,010 0              | −84,93 | 1 421,3           | 91,82           | 91,83    | 0,529 6   | 0,771 0   | 1,213 8   | 932,6       | −0,354 5        |
| dew                                                                                                                 |                      | −83,84 | 0,626             | 300,87          | 316,83   | 1,722 9   | 0,571 9   | 0,663 5   | 135,39      | 113,71          |
| bubble                                                                                                              | 0,015 0              | −79,30 | 1 404,8           | 98,65           | 98,66    | 0,565 4   | 0,779 5   | 1,213 7   | 895,9       | −0,349 5        |
| dew                                                                                                                 |                      | −78,28 | 0,916             | 303,83          | 320,21   | 1,706 4   | 0,586 0   | 0,679 3   | 136,88      | 96,75           |
| bubble                                                                                                              | 0,020 0              | −75,05 | 1 392,4           | 103,80          | 103,81   | 0,591 7   | 0,785 4   | 1,215 2   | 870,1       | −0,344 4        |
| dew                                                                                                                 |                      | −74,08 | 1,199             | 306,10          | 322,78   | 1,695 3   | 0,596 8   | 0,691 5   | 137,93      | 86,40           |
| bubble                                                                                                              | 0,025 0              | −71,61 | 1 382,3           | 107,99          | 108,01   | 0,612 6   | 0,789 9   | 1,217 3   | 850,1       | −0,339 6        |
| dew                                                                                                                 |                      | −70,66 | 1,477             | 307,94          | 324,87   | 1,687 0   | 0,605 5   | 0,701 6   | 138,74      | 79,22           |
| bubble                                                                                                              | 0,030 0              | −68,68 | 1 373,7           | 111,56          | 111,58   | 0,630 2   | 0,793 7   | 1,219 7   | 833,7       | −0,334 9        |
| dew                                                                                                                 |                      | −67,76 | 1,752             | 309,52          | 326,65   | 1,680 5   | 0,613 0   | 0,710 4   | 139,39      | 73,86           |
| bubble                                                                                                              | 0,040 0              | −63,85 | 1 359,4           | 117,45          | 117,48   | 0,658 7   | 0,799 8   | 1,224 6   | 807,5       | −0,326 2        |
| dew                                                                                                                 |                      | −62,97 | 2,293             | 312,13          | 329,58   | 1,670 7   | 0,625 5   | 0,725 2   | 140,40      | 66,23           |
| bubble                                                                                                              | 0,050 0              | −59,92 | 1 347,7           | 122,28          | 122,31   | 0,681 5   | 0,804 6   | 1,229 5   | 786,8       | −0,318 1        |
| dew                                                                                                                 |                      | −59,07 | 2,825             | 314,28          | 331,97   | 1,663 5   | 0,635 9   | 0,737 7   | 141,14      | 60,94           |
| bubble                                                                                                              | 0,060 0              | −56,57 | 1 337,7           | 126,40          | 126,44   | 0,700 7   | 0,808 8   | 1,234 2   | 769,6       | −0,310 6        |
| dew                                                                                                                 |                      | −55,75 | 3,351             | 316,10          | 334,00   | 1,657 8   | 0,644 7   | 0,748 7   | 141,72      | 56,99           |
| bubble                                                                                                              | 0,080 0              | −51,03 | 1 321,0           | 133,25          | 133,31   | 0,732 0   | 0,815 6   | 1,243 0   | 741,6       | −0,296 7        |
| dew                                                                                                                 |                      | −50,25 | 4,390             | 319,13          | 337,36   | 1,649 4   | 0,659 6   | 0,767 5   | 142,57      | 51,36           |
| bubble                                                                                                              | 0,100 0              | −46,50 | 1 307,1           | 138,89          | 138,97   | 0,757 1   | 0,821 2   | 1,251 1   | 719,2       | −0,283 9        |
| dew                                                                                                                 |                      | −45,74 | 5,415             | 321,62          | 340,08   | 1,643 4   | 0,672 0   | 0,783 6   | 143,16      | 47,44           |
| bubble                                                                                                              | 0,101 3 <sup>a</sup> | −46,22 | 1 306,3           | 139,24          | 139,31   | 0,758 6   | 0,821 5   | 1,251 6   | 717,9       | −0,283 1        |
| dew                                                                                                                 |                      | −45,47 | 5,483             | 321,77          | 340,25   | 1,643 0   | 0,672 8   | 0,784 6   | 143,19      | 47,22           |
| bubble                                                                                                              | 0,120 0              | −42,63 | 1 295,1           | 143,74          | 143,83   | 0,778 3   | 0,826 0   | 1,258 7   | 700,4       | −0,272 0        |
| dew                                                                                                                 |                      | −41,90 | 6,430             | 323,74          | 342,40   | 1,638 7   | 0,682 8   | 0,797 8   | 143,57      | 44,50           |
| bubble                                                                                                              | 0,140 0              | −39,24 | 1 284,5           | 148,01          | 148,12   | 0,796 7   | 0,830 3   | 1,265 8   | 684,0       | −0,260 6        |
| <sup>a</sup> Bubble point and dew point at one standard atmosphere.                                                 |                      |        |                   |                 |          |           |           |           |             |                 |
| <sup>b</sup> The values of $C_v$ , $C_p$ , and $w$ at the critical point are not included as part of this document. |                      |        |                   |                 |          |           |           |           |             |                 |

Table 37 (continued)

|        | Pressure<br>MPa | Temp.<br>°C | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|--------|-----------------|-------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| dew    |                 | -38,53      | 7,439                        | 325,59                      | 344,41            | 1,634 9              | 0,692 3            | 0,810 8            | 143,86                | 42,18                       |
| bubble | 0,160 0         | -36,20      | 1 275,0                      | 151,85                      | 151,97            | 0,813 0              | 0,834 1            | 1,272 6            | 669,4                 | -0,249 8                    |
| dew    |                 | -35,51      | 8,442                        | 327,25                      | 346,20            | 1,631 8              | 0,700 9            | 0,822 8            | 144,07                | 40,29                       |
| bubble | 0,180 0         | -33,45      | 1 266,2                      | 155,35                      | 155,49            | 0,827 7              | 0,837 7            | 1,279 0            | 656,2                 | -0,239 3                    |
| dew    |                 | -32,78      | 9,441                        | 328,75                      | 347,81            | 1,629 2              | 0,708 8            | 0,833 9            | 144,21                | 38,70                       |
| bubble | 0,200 0         | -30,93      | 1 258,0                      | 158,57                      | 158,73            | 0,841 1              | 0,840 9            | 1,285 2            | 644,2                 | -0,229 1                    |
| dew    |                 | -30,27      | 10,437                       | 330,12                      | 349,28            | 1,627 0              | 0,716 1            | 0,844 5            | 144,29                | 37,34                       |
| bubble | 0,250 0         | -25,38      | 1 239,9                      | 165,72                      | 165,92            | 0,870 3              | 0,848 2            | 1,299 8            | 617,8                 | -0,204 6                    |
| dew    |                 | -24,75      | 12,920                       | 333,12                      | 352,47            | 1,622 5              | 0,732 4            | 0,868 8            | 144,34                | 34,66                       |
| bubble | 0,300 0         | -20,62      | 1 223,9                      | 171,90                      | 172,14            | 0,895 0              | 0,854 6            | 1,313 4            | 595,2                 | -0,181 1                    |
| dew    |                 | -20,02      | 15,399                       | 335,67                      | 355,15            | 1,619 0              | 0,746 5            | 0,890 9            | 144,22                | 32,64                       |
| bubble | 0,350 0         | -16,44      | 1 209,6                      | 177,38                      | 177,67            | 0,916 6              | 0,860 4            | 1,326 4            | 575,4                 | -0,158 1                    |
| dew    |                 | -15,86      | 17,881                       | 337,90                      | 357,47            | 1,616 3              | 0,759 2            | 0,911 4            | 143,99                | 31,04                       |
| bubble | 0,400 0         | -12,69      | 1 196,5                      | 182,35                      | 182,68            | 0,935 8              | 0,865 6            | 1,338 8            | 557,6                 | -0,135 5                    |
| dew    |                 | -12,12      | 20,369                       | 339,87                      | 359,51            | 1,614 1              | 0,770 6            | 0,930 7            | 143,66                | 29,75                       |
| bubble | 0,450 0         | -9,28       | 1 184,4                      | 186,89                      | 187,27            | 0,953 1              | 0,870 4            | 1,350 9            | 541,4                 | -0,113 0                    |
| dew    |                 | -8,73       | 22,867                       | 341,65                      | 361,33            | 1,612 2              | 0,781 1            | 0,949 2            | 143,28                | 28,67                       |
| bubble | 0,500 0         | -6,15       | 1 173,0                      | 191,11                      | 191,53            | 0,969 0              | 0,875 0            | 1,362 7            | 526,5                 | -0,090 5                    |
| dew    |                 | -5,61       | 25,378                       | 343,26                      | 362,96            | 1,610 5              | 0,790 7            | 0,967 0            | 142,84                | 27,75                       |
| bubble | 0,550 0         | -3,24       | 1 162,3                      | 195,04                      | 195,51            | 0,983 7              | 0,879 2            | 1,374 4            | 512,7                 | -0,067 9                    |
| dew    |                 | -2,72       | 27,905                       | 344,74                      | 364,45            | 1,609 1              | 0,799 7            | 0,984 2            | 142,36                | 26,97                       |
| bubble | 0,600 0         | -0,53       | 1 152,0                      | 198,74                      | 199,26            | 0,997 3              | 0,883 2            | 1,385 9            | 499,7                 | -0,045 2                    |
| dew    |                 | -0,02       | 30,449                       | 346,11                      | 365,81            | 1,607 8              | 0,808 2            | 1,001 1            | 141,85                | 26,28                       |
| bubble | 0,650 0         | 2,02        | 1 142,3                      | 202,24                      | 202,81            | 1,010 1              | 0,887 1            | 1,397 3            | 487,5                 | -0,022 2                    |
| dew    |                 | 2,52        | 33,012                       | 347,37                      | 367,06            | 1,606 6              | 0,816 1            | 1,017 7            | 141,31                | 25,68                       |
| bubble | 0,700 0         | 4,42        | 1 132,9                      | 205,57                      | 206,18            | 1,022 2              | 0,890 8            | 1,408 7            | 476,0                 | 0,001 1                     |
| dew    |                 | 4,91        | 35,595                       | 348,55                      | 368,21            | 1,605 5              | 0,823 7            | 1,034 2            | 140,75                | 25,16                       |
| bubble | 0,750 0         | 6,70        | 1 123,8                      | 208,74                      | 209,41            | 1,033 6              | 0,894 3            | 1,420 1            | 465,0                 | 0,024 8                     |
| dew    |                 | 7,18        | 38,201                       | 349,65                      | 369,28            | 1,604 4              | 0,830 9            | 1,050 6            | 140,17                | 24,69                       |
| bubble | 0,800 0         | 8,87        | 1 115,1                      | 211,78                      | 212,49            | 1,044 4              | 0,897 7            | 1,431 6            | 454,5                 | 0,048 9                     |
| dew    |                 | 9,34        | 40,831                       | 350,68                      | 370,27            | 1,603 5              | 0,837 8            | 1,067 0            | 139,58                | 24,27                       |
| bubble | 0,850 0         | 10,94       | 1 106,5                      | 214,70                      | 215,46            | 1,054 7              | 0,900 9            | 1,443 1            | 444,5                 | 0,073 5                     |
| dew    |                 | 11,40       | 43,485                       | 351,64                      | 371,19            | 1,602 5              | 0,844 5            | 1,083 5            | 138,96                | 23,89                       |
| bubble | 0,900 0         | 12,92       | 1 098,2                      | 217,51                      | 218,32            | 1,064 6              | 0,904 1            | 1,454 7            | 434,9                 | 0,098 6                     |
| dew    |                 | 13,37       | 46,167                       | 352,55                      | 372,05            | 1,601 6              | 0,851 0            | 1,100 1            | 138,34                | 23,55                       |
| bubble | 0,950 0         | 14,81       | 1 090,2                      | 220,22                      | 221,09            | 1,074 1              | 0,907 2            | 1,466 5            | 425,6                 | 0,124 4                     |
| dew    |                 | 15,26       | 48,876                       | 353,41                      | 372,85            | 1,600 7              | 0,857 3            | 1,116 9            | 137,70                | 23,24                       |
| bubble | 1,000 0         | 16,64       | 1 082,2                      | 222,84                      | 223,77            | 1,083 2              | 0,910 2            | 1,478 4            | 416,7                 | 0,150 7                     |
| dew    |                 | 17,08       | 51,614                       | 354,22                      | 373,59            | 1,599 9              | 0,863 4            | 1,134 0            | 137,05                | 22,95                       |
| bubble | 1,200 0         | 23,32       | 1 052,0                      | 232,60                      | 233,75            | 1,116 6              | 0,921 7            | 1,528 0            | 383,5                 | 0,263 3                     |
| dew    |                 | 23,73       | 62,884                       | 357,03                      | 376,12            | 1,596 5              | 0,886 9            | 1,205 8            | 134,36                | 22,03                       |
| bubble | 1,400 0         | 29,22       | 1 023,4                      | 241,44                      | 242,81            | 1,146 2              | 0,932 5            | 1,582 1            | 353,8                 | 0,390 1                     |

<sup>a</sup> Bubble point and dew point at one standard atmosphere.

<sup>b</sup> The values of  $C_v$ ,  $C_p$ , and  $w$  at the critical point are not included as part of this document.

Table 37 (continued)

|                                                                                                          | Pressure | Temp. | Density           | Internal energy | Enthalpy | Entropy   | $C_v$     | $C_p$     | Sound speed | J-T coefficient |
|----------------------------------------------------------------------------------------------------------|----------|-------|-------------------|-----------------|----------|-----------|-----------|-----------|-------------|-----------------|
|                                                                                                          | MPa      | °C    | kg/m <sup>3</sup> | kJ/kg           | kJ/kg    | kJ/(kg·K) | kJ/(kg·K) | kJ/(kg·K) | m/s         | K/MPa           |
| dew                                                                                                      |          | 29,60 | 74,728            | 359,29          | 378,02   | 1,593 2   | 0,909 1   | 1,285 3   | 131,56      | 21,35           |
| bubble                                                                                                   | 1,600 0  | 34,51 | 995,7             | 249,58          | 251,19   | 1,173 0   | 0,943 1   | 1,642 7   | 326,5       | 0,535 1         |
| dew                                                                                                      |          | 34,87 | 87,247            | 361,08          | 379,42   | 1,589 6   | 0,930 6   | 1,375 7   | 128,65      | 20,82           |
| bubble                                                                                                   | 1,800 0  | 39,33 | 968,6             | 257,19          | 259,05   | 1,197 7   | 0,953 5   | 1,712 2   | 301,2       | 0,703 3         |
| dew                                                                                                      |          | 39,67 | 100,56            | 362,48          | 380,38   | 1,585 8   | 0,951 8   | 1,481 0   | 125,66      | 20,41           |
| bubble                                                                                                   | 2,000 0  | 43,75 | 941,6             | 264,40          | 266,52   | 1,220 8   | 0,964 3   | 1,794 1   | 277,3       | 0,901 5         |
| dew                                                                                                      |          | 44,07 | 114,81            | 363,51          | 380,92   | 1,581 7   | 0,972 8   | 1,607 1   | 122,58      | 20,07           |
| bubble                                                                                                   | 2,200 0  | 47,85 | 914,4             | 271,29          | 273,70   | 1,242 7   | 0,975 5   | 1,893 5   | 254,5       | 1,139 2         |
| dew                                                                                                      |          | 48,15 | 130,20            | 364,18          | 381,08   | 1,577 0   | 0,993 9   | 1,762 8   | 119,43      | 19,79           |
| bubble                                                                                                   | 2,400 0  | 51,68 | 886,5             | 277,96          | 280,66   | 1,263 5   | 0,987 5   | 2,018 5   | 232,5       | 1,430 1         |
| dew                                                                                                      |          | 51,95 | 146,99            | 364,50          | 380,83   | 1,571 8   | 1,015 3   | 1,962 0   | 116,19      | 19,55           |
| bubble                                                                                                   | 2,600 0  | 55,26 | 857,5             | 284,47          | 287,50   | 1,283 7   | 1,000 9   | 2,183 2   | 211,1       | 1,795 0         |
| dew                                                                                                      |          | 55,51 | 165,54            | 364,44          | 380,15   | 1,565 8   | 1,037 5   | 2,229 1   | 112,87      | 19,31           |
| bubble                                                                                                   | 2,800 0  | 58,63 | 826,8             | 290,90          | 294,29   | 1,303 6   | 1,016 1   | 2,413 6   | 190,0       | 2,267 1         |
| dew                                                                                                      |          | 58,86 | 186,43            | 363,94          | 378,96   | 1,558 7   | 1,060 9   | 2,609 1   | 109,47      | 19,06           |
| bubble                                                                                                   | 3,000 0  | 61,81 | 793,4             | 297,36          | 301,15   | 1,323 4   | 1,034 3   | 2,765 3   | 169,0       | 2,902 8         |
| dew                                                                                                      |          | 62,01 | 210,55            | 362,90          | 377,15   | 1,550 3   | 1,086 2   | 3,197 3   | 105,97      | 18,74           |
| bubble                                                                                                   | 3,200 0  | 64,82 | 755,6             | 304,02          | 308,25   | 1,343 8   | 1,057 0   | 3,381 2   | 147,8       | 3,806 8         |
| dew                                                                                                      |          | 64,99 | 239,56            | 361,13          | 374,49   | 1,539 7   | 1,114 8   | 4,233 3   | 102,35      | 18,29           |
| critical                                                                                                 | 3,728 9  | 72,05 | 486,5             | 336,26          | 343,92   | 1,445 5   | b         | b         | b           | 12,334 7        |
| a Bubble point and dew point at one standard atmosphere                                                  |          |       |                   |                 |          |           |           |           |             |                 |
| b The values of $C_v$ , $C_p$ , and $w$ at the critical point are not included as part of this document. |          |       |                   |                 |          |           |           |           |             |                 |

### 5.13 R407C — R32/125/134a (23/25/52)

The composition of R407C is listed in [Table 38](#).

Table 38 — Composition of R407C

| <i>i</i>             | Component | Mass fraction | Mole fraction |
|----------------------|-----------|---------------|---------------|
| 1                    | R32       | 0,23          | 0,381 109 42  |
| 2                    | R125      | 0,25          | 0,179 558 89  |
| 3                    | R134a     | 0,52          | 0,439 331 69  |
| $M = 86,203 7$ g/mol |           |               |               |

#### 5.13.1 Range of validity

The coefficients are valid within the following ranges:

$$T_{\min} = 172,52 \text{ K}, T_{\max} = 435 \text{ K}; p_{\max} = 60 \text{ MPa}; \rho_{\max} = 17,96 \text{ mol/l (1 548 kg/m}^3\text{)}$$

#### 5.13.2 Interaction parameters ([Formulae 19](#) and [20](#))

$$\zeta_{12} = 28,95; \zeta_{12} = -0,006 008; \zeta_{13} = 7,909; \zeta_{13} = -0,002 039; \zeta_{23} = -0,432 6; \zeta_{23} = -0,000 345 3$$

Coefficients and exponents of the excess functions are listed in [Table 39](#).

Table 39 — Coefficients and exponents of the excess functions [Formula (21)]

| R32/125 binary pair <sup>a</sup>                                                                                                             |                 |       |       |       |
|----------------------------------------------------------------------------------------------------------------------------------------------|-----------------|-------|-------|-------|
| $k$                                                                                                                                          | $N_k$           | $t_k$ | $d_k$ | $l_k$ |
| 1                                                                                                                                            | -0,007 295 5    | 4,50  | 2     | 1     |
| 2                                                                                                                                            | 0,078 035       | 0,57  | 5     | 1     |
| 3                                                                                                                                            | 0,610 07        | 1,90  | 1     | 2     |
| 4                                                                                                                                            | 0,642 46        | 1,20  | 3     | 2     |
| 5                                                                                                                                            | 0,014 965       | 0,50  | 9     | 2     |
| 6                                                                                                                                            | -0,340 49       | 2,60  | 2     | 3     |
| 7                                                                                                                                            | 0,085 658       | 11,40 | 3     | 3     |
| 8                                                                                                                                            | -0,064 429      | 4,50  | 6     | 3     |
| R32/134a binary pair <sup>b</sup>                                                                                                            |                 |       |       |       |
| 1                                                                                                                                            | 0,229 09        | 1,9   | 1     | 1     |
| 2                                                                                                                                            | 0,094 074       | 0,25  | 3     | 1     |
| 3                                                                                                                                            | 0,000 398 76    | 0,07  | 8     | 1     |
| 4                                                                                                                                            | 0,021 133       | 2,0   | 1     | 2     |
| R125/134a binary pair <sup>c</sup>                                                                                                           |                 |       |       |       |
| 1                                                                                                                                            | -0,013 073      | 7,4   | 1     | 1     |
| 2                                                                                                                                            | 0,018 259       | 0,35  | 3     | 1     |
| 3                                                                                                                                            | 0,000 008 129 9 | 10,0  | 11    | 2     |
| 4                                                                                                                                            | 0,007 849 6     | 5,3   | 2     | 3     |
| <sup>a</sup> $i = 1; j = 2; F_{12} = 1,00$ .<br><sup>b</sup> $i = 1; j = 3; F_{13} = 1,00$ .<br><sup>c</sup> $i = 2; j = 3; F_{23} = 1,00$ . |                 |       |       |       |

## 5.13.3 Reference state parameters

$$f_3 = 1,043\,708\,79, f_4 = -8,741\,068\,03$$

R407C property values of liquid on the bubble line and vapour on the dew line are listed in Table 40.

Table 40 — R407C property values of liquid on the bubble line and vapour on the dew line

|                                                                                                                                                                                            | Pressure | Temp.  | Density           | Internal energy | Enthalpy | Entropy   | $C_v$     | $C_p$     | Sound speed | J-T coefficient |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------|--------|-------------------|-----------------|----------|-----------|-----------|-----------|-------------|-----------------|
|                                                                                                                                                                                            | MPa      | °C     | kg/m <sup>3</sup> | kJ/kg           | kJ/kg    | kJ/(kg·K) | kJ/(kg·K) | kJ/(kg·K) | m/s         | K/MPa           |
| bubble                                                                                                                                                                                     | 0,010 0  | -82,45 | 1 495,5           | 90,48           | 90,48    | 0,525 9   | 0,820 0   | 1,281 5   | 1 008,4     | -0,329 9        |
| dew                                                                                                                                                                                        |          | -74,81 | 0,527             | 347,81          | 366,78   | 1,947 1   | 0,565 4   | 0,668 1   | 149,08      | 115,10          |
| bubble                                                                                                                                                                                     | 0,015 0  | -76,77 | 1 479,1           | 97,75           | 97,76    | 0,563 4   | 0,821 9   | 1,282 0   | 976,2       | -0,324 6        |
| dew                                                                                                                                                                                        |          | -69,22 | 0,771             | 350,74          | 370,19   | 1,925 3   | 0,578 1   | 0,682 6   | 150,70      | 100,56          |
| bubble                                                                                                                                                                                     | 0,020 0  | -72,50 | 1 466,7           | 103,23          | 103,24   | 0,591 0   | 0,823 5   | 1,283 5   | 952,7       | -0,319 8        |
| dew                                                                                                                                                                                        |          | -65,02 | 1,010             | 352,95          | 372,75   | 1,910 4   | 0,587 9   | 0,694 1   | 151,85      | 91,36           |
| bubble                                                                                                                                                                                     | 0,025 0  | -69,03 | 1 456,6           | 107,68          | 107,70   | 0,613 0   | 0,825 0   | 1,285 3   | 934,1       | -0,315 4        |
| dew                                                                                                                                                                                        |          | -61,61 | 1,245             | 354,75          | 374,83   | 1,899 1   | 0,596 0   | 0,703 8   | 152,74      | 84,79           |
| bubble                                                                                                                                                                                     | 0,030 0  | -66,09 | 1 448,0           | 111,46          | 111,48   | 0,631 4   | 0,826 3   | 1,287 2   | 918,5       | -0,311 3        |
| dew                                                                                                                                                                                        |          | -58,72 | 1,477             | 356,27          | 376,59   | 1,890 0   | 0,603 1   | 0,712 3   | 153,46      | 79,75           |
| <sup>a</sup> Bubble point and dew point at one standard atmosphere.<br><sup>b</sup> The values of $C_v$ , $C_p$ , and $w$ at the critical point are not included as part of this document. |          |        |                   |                 |          |           |           |           |             |                 |

Table 40 (continued)

|        | Pressure             | Temp.  | Density           | Internal energy | Enthalpy | Entropy   | $C_v$     | $C_p$     | Sound speed | J-T coefficient |
|--------|----------------------|--------|-------------------|-----------------|----------|-----------|-----------|-----------|-------------|-----------------|
|        | MPa                  | °C     | kg/m <sup>3</sup> | kJ/kg           | kJ/kg    | kJ/(kg·K) | kJ/(kg·K) | kJ/(kg·K) | m/s         | K/MPa           |
| bubble | 0,040 0              | −61,25 | 1 433,7           | 117,70          | 117,72   | 0,661 2   | 0,828 7   | 1,291 2   | 893,3       | −0,303 9        |
| dew    |                      | −53,95 | 1,934             | 358,79          | 379,47   | 1,876 1   | 0,614 9   | 0,726 9   | 154,58      | 72,38           |
| bubble | 0,050 0              | −57,31 | 1 422,0           | 122,79          | 122,82   | 0,685 0   | 0,830 8   | 1,295 0   | 873,1       | −0,297 2        |
| dew    |                      | −50,08 | 2,384             | 360,83          | 381,80   | 1,865 6   | 0,624 8   | 0,739 3   | 155,43      | 67,09           |
| bubble | 0,060 0              | −53,96 | 1 412,0           | 127,13          | 127,17   | 0,705 0   | 0,832 7   | 1,298 7   | 856,1       | −0,291 1        |
| dew    |                      | −46,79 | 2,829             | 362,56          | 383,77   | 1,857 3   | 0,633 4   | 0,750 2   | 156,10      | 63,04           |
| bubble | 0,080 0              | −48,42 | 1 395,3           | 134,33          | 134,39   | 0,737 4   | 0,836 1   | 1,305 6   | 828,3       | −0,279 9        |
| dew    |                      | −41,34 | 3,707             | 365,41          | 386,99   | 1,844 5   | 0,647 9   | 0,769 2   | 157,10      | 57,08           |
| bubble | 0,100 0              | −43,90 | 1 381,5           | 140,24          | 140,31   | 0,763 5   | 0,839 1   | 1,312 1   | 805,8       | −0,269 8        |
| dew    |                      | −36,90 | 4,574             | 367,73          | 389,59   | 1,834 9   | 0,660 1   | 0,785 5   | 157,81      | 52,81           |
| bubble | 0,101 3 <sup>a</sup> | −43,63 | 1 380,7           | 140,60          | 140,67   | 0,765 0   | 0,839 3   | 1,312 5   | 804,5       | −0,269 1        |
| dew    |                      | −36,63 | 4,631             | 367,87          | 389,75   | 1,834 3   | 0,660 9   | 0,786 5   | 157,85      | 52,57           |
| bubble | 0,120 0              | −40,05 | 1 369,7           | 145,30          | 145,39   | 0,785 4   | 0,841 8   | 1,318 1   | 786,8       | −0,260 4        |
| dew    |                      | −33,11 | 5,432             | 369,69          | 391,78   | 1,827 3   | 0,670 7   | 0,800 1   | 158,34      | 49,54           |
| bubble | 0,140 0              | −36,67 | 1 359,1           | 149,75          | 149,86   | 0,804 3   | 0,844 3   | 1,323 8   | 770,2       | −0,251 5        |
| dew    |                      | −29,79 | 6,283             | 371,40          | 393,68   | 1,821 0   | 0,680 2   | 0,813 3   | 158,74      | 46,91           |
| bubble | 0,160 0              | −33,65 | 1 349,7           | 153,75          | 153,86   | 0,821 1   | 0,846 6   | 1,329 2   | 755,4       | −0,243 1        |
| dew    |                      | −26,83 | 7,130             | 372,92          | 395,36   | 1,815 6   | 0,688 7   | 0,825 5   | 159,05      | 44,74           |
| bubble | 0,180 0              | −30,92 | 1 341,0           | 157,38          | 157,51   | 0,836 2   | 0,848 8   | 1,334 4   | 742,1       | −0,235 0        |
| dew    |                      | −24,15 | 7,973             | 374,29          | 396,86   | 1,811 0   | 0,696 5   | 0,836 9   | 159,29      | 42,90           |
| bubble | 0,200 0              | −28,41 | 1 333,0           | 160,72          | 160,87   | 0,849 9   | 0,850 8   | 1,339 4   | 729,9       | −0,227 2        |
| dew    |                      | −21,69 | 8,813             | 375,53          | 398,22   | 1,806 9   | 0,703 8   | 0,847 6   | 159,47      | 41,32           |
| bubble | 0,250 0              | −22,90 | 1 315,1           | 168,11          | 168,30   | 0,879 8   | 0,855 5   | 1,351 3   | 703,1       | −0,208 4        |
| dew    |                      | −16,28 | 10 904            | 378,24          | 401,17   | 1,798 4   | 0,720 0   | 0,872 2   | 159,74      | 38,14           |
| bubble | 0,300 0              | −18,19 | 1 299,5           | 174,48          | 174,71   | 0,905 0   | 0,859 8   | 1,362 4   | 680,1       | −0,190 6        |
| dew    |                      | −11,66 | 12,989            | 380,52          | 403,62   | 1,791 7   | 0,734 0   | 0,894 5   | 159,82      | 35,72           |
| bubble | 0,350 0              | −14,04 | 1 285,5           | 180,12          | 180,39   | 0,926 9   | 0,863 7   | 1,373 1   | 660,0       | −0,173 3        |
| dew    |                      | −7,61  | 15,071            | 382,49          | 405,72   | 1,786 1   | 0,746 5   | 0,915 1   | 159,79      | 33,80           |
| bubble | 0,400 0              | −10,33 | 1 272,8           | 185,20          | 185,52   | 0,946 5   | 0,867 3   | 1,383 4   | 641,9       | −0,156 4        |
| dew    |                      | −3,97  | 17,154            | 384,24          | 407,55   | 1,781 4   | 0,757 8   | 0,934 5   | 159,66      | 32,22           |
| bubble | 0,450 0              | −6,95  | 1 261,1           | 189,86          | 190,21   | 0,964 1   | 0,870 7   | 1,393 4   | 625,5       | −0,139 8        |
| dew    |                      | −0,67  | 19,241            | 385,79          | 409,18   | 1,777 2   | 0,768 2   | 0,952 8   | 159,46      | 30,89           |
| bubble | 0,500 0              | −3,85  | 1 250,1           | 194,16          | 194,56   | 0,980 1   | 0,874 0   | 1,403 2   | 610,4       | −0,123 3        |
| dew    |                      | 2,36   | 21,334            | 387,20          | 410,64   | 1,773 5   | 0,777 9   | 0,970 4   | 159,20      | 29,76           |
| bubble | 0,550 0              | −0,98  | 1 239,8           | 198,17          | 198,61   | 0,995 0   | 0,877 1   | 1,412 9   | 596,3       | −0,106 9        |
| dew    |                      | 5,17   | 23,435            | 388,48          | 411,95   | 1,770 2   | 0,786 8   | 0,987 5   | 158,91      | 28,77           |
| bubble | 0,600 0              | 1,70   | 1 230,0           | 201,93          | 202,42   | 1,008 7   | 0,880 1   | 1,422 4   | 583,2       | −0,090 5        |
| dew    |                      | 7,79   | 25,545            | 389,66          | 413,15   | 1,767 2   | 0,795 3   | 1,004 0   | 158,58      | 27,91           |
| bubble | 0,650 0              | 4,22   | 1 220,7           | 205,49          | 206,02   | 1,021 6   | 0,883 0   | 1,431 9   | 570,8       | −0,074 1        |
| dew    |                      | 10,24  | 27,665            | 390,75          | 414,25   | 1,764 4   | 0,803 2   | 1,020 1   | 158,22      | 27,14           |
| bubble | 0,700 0              | 6,60   | 1 211,7           | 208,87          | 209,44   | 1,033 8   | 0,885 7   | 1,441 3   | 559,1       | −0,057 6        |
| dew    |                      | 12,56  | 29,796            | 391,76          | 415,25   | 1,761 8   | 0,810 8   | 1,036 0   | 157,83      | 26,46           |

<sup>a</sup> Bubble point and dew point at one standard atmosphere.<sup>b</sup> The values of  $C_v$ ,  $C_p$ , and  $w$  at the critical point are not included as part of this document.

Table 40 (continued)

|            | Pressure | Temp.          | Density           | Internal energy  | Enthalpy         | Entropy            | $C_v$              | $C_p$              | Sound speed     | J-T coefficient   |
|------------|----------|----------------|-------------------|------------------|------------------|--------------------|--------------------|--------------------|-----------------|-------------------|
|            | MPa      | °C             | kg/m <sup>3</sup> | kJ/kg            | kJ/kg            | kJ/(kg·K)          | kJ/(kg·K)          | kJ/(kg·K)          | m/s             | K/MPa             |
| bubble dew | 0,750 0  | 8,85<br>14,76  | 1 203,1<br>31,940 | 212,08<br>392,70 | 212,71<br>416,18 | 1,045 2<br>1,759 4 | 0,888 4<br>0,817 9 | 1,450 7<br>1,051 6 | 548,0<br>157,42 | −0,041 0<br>25,84 |
| bubble dew | 0,800 0  | 11,00<br>16,85 | 1 194,9<br>34,098 | 215,16<br>393,57 | 215,83<br>417,03 | 1,056 1<br>1,757 1 | 0,891 1<br>0,824 8 | 1,460 0<br>1,067 0 | 537,4<br>157,00 | −0,024 2<br>25,29 |
| bubble dew | 0,900 0  | 15,00<br>20,74 | 1 179,1<br>38,456 | 220,95<br>395,16 | 221,71<br>418,57 | 1,076 4<br>1,752 9 | 0,896 1<br>0,837 8 | 1,478 9<br>1,097 6 | 517,6<br>156,11 | 0,009 8<br>24,32  |
| bubble dew | 1,000 0  | 18,69<br>24,32 | 1 164,1<br>42,877 | 226,33<br>396,57 | 227,19<br>419,89 | 1,095 0<br>1,749 1 | 0,901 0<br>0,849 9 | 1,497 9<br>1,128 2 | 499,2<br>155,16 | 0,044 7<br>23,50  |
| bubble dew | 1,200 0  | 25,30<br>30,73 | 1 136,2<br>51,932 | 236,14<br>398,92 | 237,20<br>422,03 | 1,128 3<br>1,742 1 | 0,910 2<br>0,872 1 | 1,537 0<br>1,190 2 | 466,0<br>153,16 | 0,118 0<br>22,18  |
| bubble dew | 1,400 0  | 31,14<br>36,37 | 1 110,2<br>61,306 | 244,98<br>400,79 | 246,24<br>423,63 | 1,157 7<br>1,735 8 | 0,919 0<br>0,892 6 | 1,578 0<br>1,254 9 | 436,4<br>151,05 | 0,196 8<br>21,17  |
| bubble dew | 1,600 0  | 36,39<br>41,43 | 1 085,5<br>71,047 | 253,09<br>402,28 | 254,57<br>424,80 | 1,184 3<br>1,729 8 | 0,927 4<br>0,912 0 | 1,621 9<br>1,324 2 | 409,4<br>148,85 | 0,282 6<br>20,36  |
| bubble dew | 1,800 0  | 41,18<br>46,03 | 1 061,7<br>81,203 | 260,64<br>403,44 | 262,33<br>425,61 | 1,208 6<br>1,724 1 | 0,935 8<br>0,930 5 | 1,669 5<br>1,399 6 | 384,5<br>146,57 | 0,376 9<br>19,69  |
| bubble dew | 2,000 0  | 45,59<br>50,25 | 1 038,5<br>91,831 | 267,74<br>404,32 | 269,66<br>426,10 | 1,231 1<br>1,718 4 | 0,944 1<br>0,948 4 | 1,721 8<br>1,483 1 | 361,3<br>144,24 | 0,481 5<br>19,13  |
| bubble dew | 2,200 0  | 49,68<br>54,15 | 1 015,7<br>103,00 | 274,47<br>404,93 | 276,64<br>426,29 | 1,252 2<br>1,712 6 | 0,952 6<br>0,966 0 | 1,780 4<br>1,577 0 | 339,3<br>141,84 | 0,598 7<br>18,64  |
| bubble dew | 2,400 0  | 53,51<br>57,79 | 993,1<br>114,78   | 280,92<br>405,29 | 283,34<br>426,20 | 1,272 3<br>1,706 8 | 0,961 3<br>0,983 4 | 1,847 0<br>1,684 5 | 318,4<br>139,40 | 0,731 5<br>18,22  |
| bubble dew | 2,600 0  | 57,11<br>61,19 | 970,5<br>127,27   | 287,14<br>405,42 | 289,82<br>425,85 | 1,291 4<br>1,700 7 | 0,970 5<br>1,000 8 | 1,924 4<br>1,809 6 | 298,2<br>136,90 | 0,883 8<br>17,84  |
| bubble dew | 2,800 0  | 60,51<br>64,38 | 947,5<br>140,60   | 293,17<br>405,30 | 296,12<br>425,21 | 1,309 7<br>1,694 4 | 0,980 2<br>1,018 3 | 2,016 1<br>1,958 2 | 278,6<br>134,35 | 1,060 7<br>17,48  |
| bubble dew | 3,000 0  | 63,73<br>67,40 | 924,1<br>154,93   | 299,07<br>404,93 | 302,31<br>424,29 | 1,327 6<br>1,687 7 | 0,990 9<br>1,036 0 | 2,127 9<br>2,139 0 | 259,4<br>131,75 | 1,269 5<br>17,15  |
| bubble dew | 3,200 0  | 66,80<br>70,25 | 899,9<br>170,45   | 304,88<br>404,28 | 308,43<br>423,06 | 1,345 0<br>1,680 5 | 1,002 8<br>1,054 3 | 2,268 2<br>2,364 8 | 240,4<br>129,09 | 1,520 1<br>16,83  |
| bubble dew | 3,400 0  | 69,73<br>72,94 | 874,6<br>187,47   | 310,65<br>403,33 | 314,54<br>421,46 | 1,362 2<br>1,672 6 | 1,016 4<br>1,073 4 | 2,451 1<br>2,656 7 | 221,6<br>126,38 | 1,826 8<br>16,49  |
| bubble dew | 3,600 0  | 72,53<br>75,50 | 847,6<br>206,40   | 316,46<br>402,01 | 320,71<br>419,45 | 1,379 5<br>1,663 9 | 1,032 2<br>1,093 7 | 2,701 1<br>3,050 4 | 202,7<br>123,59 | 2,210 7<br>16,14  |
| bubble dew | 3,800 0  | 75,22<br>77,92 | 818,1<br>227,89   | 322,38<br>400,24 | 327,02<br>416,91 | 1,397 0<br>1,654 0 | 1,051 2<br>1,115 6 | 3,065 3<br>3,613 2 | 183,8<br>120,73 | 2,704 3<br>15,74  |
| bubble dew | 4,000 0  | 77,82<br>80,21 | 785,1<br>253,04   | 328,54<br>397,85 | 333,64<br>413,66 | 1,415 2<br>1,642 4 | 1,074 7<br>1,140 1 | 3,646 9<br>4,486 3 | 164,8<br>117,75 | 3,360 4<br>15,26  |
| bubble dew | 4,200 0  | 80,32<br>82,37 | 746,0<br>284,01   | 335,20<br>394,55 | 340,83<br>409,34 | 1,434 8<br>1,628 1 | 1,105 0<br>1,168 7 | 4,726 1<br>6,028 9 | 145,6<br>114,58 | 4,274 2<br>14,63  |
| critical   | 4,629 8  | 86,03          | 484,2             | 368,92           | 378,48           | 1,538 4            | b                  | b                  | b               | 10,392 2          |

<sup>a</sup> Bubble point and dew point at one standard atmosphere.

<sup>b</sup> The values of  $C_v$ ,  $C_p$ , and  $w$  at the critical point are not included as part of this document.

### 5.14 R410A — R32/125 (50/50)

The composition of R410A is listed in [Table 41](#).

**Table 41 — Composition of R410A**

| <i>i</i>                  | Component | Mass fraction | Mole fraction |
|---------------------------|-----------|---------------|---------------|
| 1                         | R32       | 0,50          | 0,697 614 70  |
| 2                         | R125      | 0,50          | 0,302 385 30  |
| <i>M</i> = 72,585 5 g/mol |           |               |               |

#### 5.14.1 Range of validity

The coefficients are valid within the following ranges:

$$T_{\min} = 172,52 \text{ K}, T_{\max} = 435 \text{ K}; p_{\max} = 60 \text{ MPa}; \rho_{\max} = 20,2 \text{ mol/l} (1\,496 \text{ kg/m}^3)$$

#### 5.14.2 Interaction parameters (Formulae 9 and 20)

$$\zeta_{12} = 28,95; \zeta_{12} = -0,006\,008$$

Coefficients and exponents of the excess functions are listed in [Table 42](#).

**Table 42 — Coefficients and exponents of the excess functions [Formula (21)]**

| R32/125 binary pair <sup>a</sup>                                        |                      |                      |                      |                      |
|-------------------------------------------------------------------------|----------------------|----------------------|----------------------|----------------------|
| <i>k</i>                                                                | <i>N<sub>k</sub></i> | <i>t<sub>k</sub></i> | <i>d<sub>k</sub></i> | <i>l<sub>k</sub></i> |
| 1                                                                       | −0,007 295 5         | 4,50                 | 2                    | 1                    |
| 2                                                                       | 0,078 035            | 0,57                 | 5                    | 1                    |
| 3                                                                       | 0,610 07             | 1,90                 | 1                    | 2                    |
| 4                                                                       | 0,642 46             | 1,20                 | 3                    | 2                    |
| 5                                                                       | 0,014 965            | 0,50                 | 9                    | 2                    |
| 6                                                                       | −0,340 49            | 2,60                 | 2                    | 3                    |
| 7                                                                       | 0,085 658            | 11,40                | 3                    | 3                    |
| 8                                                                       | −0,064 429           | 4,50                 | 6                    | 3                    |
| <sup>a</sup> <i>F</i> <sub>12</sub> = 1,00; <i>i</i> = 1; <i>j</i> = 2. |                      |                      |                      |                      |

#### 5.14.3 Reference state parameters

$$f_3 = 0,617\,469\,323, f_4 = -0,596\,795$$

R410A property values of liquid on the bubble line and vapour on the dew line are listed in [Table 43](#).

**Table 43 — R410A property values of liquid on the bubble line and vapour on the dew line**

|                                                                                                                                                        | Pressure | Temp.  | Density           | Internal energy | Enthalpy | Entropy   | <i>C<sub>v</sub></i> | <i>C<sub>p</sub></i> | Sound speed | J-T coefficient |
|--------------------------------------------------------------------------------------------------------------------------------------------------------|----------|--------|-------------------|-----------------|----------|-----------|----------------------|----------------------|-------------|-----------------|
|                                                                                                                                                        | MPa      | °C     | kg/m <sup>3</sup> | kJ/kg           | kJ/kg    | kJ/(kg·K) | kJ/(kg·K)            | kJ/(kg·K)            | m/s         | K/MPa           |
| bubble                                                                                                                                                 | 0,010 0  | −88,23 | 1 460,6           | 76,55           | 76,56    | 0,458 8   | 0,866 2              | 1,344 1              | 1 004,0     | −0,321 5        |
| dew                                                                                                                                                    |          | −88,14 | 0,476             | 357,77          | 378,76   | 2,092 7   | 0,544 2              | 0,668 0              | 159,71      | 156,70          |
| <sup>a</sup> Bubble point and dew point at one standard atmosphere.                                                                                    |          |        |                   |                 |          |           |                      |                      |             |                 |
| <sup>b</sup> The values of <i>C<sub>v</sub></i> , <i>C<sub>p</sub></i> , and <i>w</i> at the critical point are not included as part of this document. |          |        |                   |                 |          |           |                      |                      |             |                 |

Table 43 (continued)

|        | Pressure             | Temp.  | Density           | Internal energy | Enthalpy | Entropy   | $C_v$     | $C_p$     | Sound speed | J-T coefficient |
|--------|----------------------|--------|-------------------|-----------------|----------|-----------|-----------|-----------|-------------|-----------------|
|        | MPa                  | °C     | kg/m <sup>3</sup> | kJ/kg           | kJ/kg    | kJ/(kg·K) | kJ/(kg·K) | kJ/(kg·K) | m/s         | K/MPa           |
| bubble | 0,015 0              | −82,84 | 1 444,9           | 83,79           | 83,80    | 0,497 4   | 0,862 0   | 1,344 4   | 977,6       | −0,315 6        |
| dew    |                      | −82,75 | 0,697             | 360,37          | 381,90   | 2,063 5   | 0,556 9   | 0,683 6   | 161,51      | 137,58          |
| bubble | 0,020 0              | −78,79 | 1 432,9           | 89,24           | 89,26    | 0,525 8   | 0,859 6   | 1,345 5   | 957,8       | −0,310 5        |
| dew    |                      | −78,70 | 0,912             | 362,31          | 384,25   | 2,043 2   | 0,567 0   | 0,696 4   | 162,79      | 125,06          |
| bubble | 0,025 0              | −75,50 | 1 423,1           | 93,67           | 93,69    | 0,548 4   | 0,858 0   | 1,346 8   | 941,8       | −0,306 0        |
| dew    |                      | −75,41 | 1,124             | 363,88          | 386,13   | 2,027 6   | 0,575 7   | 0,707 4   | 163,78      | 115,92          |
| bubble | 0,030 0              | −72,71 | 1 414,8           | 97,42           | 97,44    | 0,567 2   | 0,856 9   | 1,348 3   | 928,2       | −0,301 8        |
| dew    |                      | −72,63 | 1,333             | 365,21          | 387,71   | 2,015 1   | 0,583 3   | 0,717 2   | 164,59      | 108,80          |
| bubble | 0,040 0              | −68,12 | 1 401,1           | 103,61          | 103,64   | 0,597 8   | 0,855 5   | 1,351 5   | 905,8       | −0,294 4        |
| dew    |                      | −68,04 | 1,745             | 367,37          | 390,29   | 1,995 6   | 0,596 4   | 0,734 4   | 165,84      | 98,17           |
| bubble | 0,050 0              | −64,39 | 1 389,7           | 108,66          | 108,70   | 0,622 2   | 0,854 8   | 1,354 6   | 887,6       | −0,287 8        |
| dew    |                      | −64,31 | 2,151             | 369,11          | 392,36   | 1,980 7   | 0,607 5   | 0,749 2   | 166,78      | 90,44           |
| bubble | 0,060 0              | −61,22 | 1 380,0           | 112,96          | 113,00   | 0,642 6   | 0,854 4   | 1,357 7   | 872,1       | −0,281 8        |
| dew    |                      | −61,14 | 2,551             | 370,58          | 394,10   | 1,968 7   | 0,617 2   | 0,762 4   | 167,53      | 84,44           |
| bubble | 0,080 0              | −55,98 | 1 363,9           | 120,08          | 120,14   | 0,675 8   | 0,854 3   | 1,363 6   | 846,5       | −0,270 8        |
| dew    |                      | −55,90 | 3,342             | 372,99          | 396,92   | 1,950 0   | 0,633 8   | 0,785 5   | 168,66      | 75,56           |
| bubble | 0,100 0              | −51,70 | 1 350,5           | 125,92          | 125,99   | 0,702 4   | 0,854 6   | 1,369 3   | 825,6       | −0,260 9        |
| dew    |                      | −51,62 | 4,123             | 374,92          | 399,17   | 1,935 8   | 0,647 7   | 0,805 4   | 169,47      | 69,16           |
| bubble | 0,101 3 <sup>a</sup> | −51,44 | 1 349,7           | 126,27          | 126,34   | 0,704 0   | 0,854 7   | 1,369 7   | 824,3       | −0,260 2        |
| dew    |                      | −51,36 | 4,174             | 375,03          | 399,31   | 1,935 0   | 0,648 6   | 0,806 6   | 169,52      | 68,80           |
| bubble | 0,120 0              | −48,06 | 1 339,0           | 130,90          | 130,99   | 0,724 7   | 0,855 2   | 1,374 7   | 807,7       | −0,251 6        |
| dew    |                      | −47,98 | 4,895             | 376,54          | 401,05   | 1,924 3   | 0,659 9   | 0,823 1   | 170,08      | 64,24           |
| bubble | 0,140 0              | −44,87 | 1 328,8           | 135,29          | 135,39   | 0,744 1   | 0,855 9   | 1,379 9   | 792,0       | −0,243 0        |
| dew    |                      | −44,79 | 5,662             | 377,95          | 402,67   | 1,914 7   | 0,670 6   | 0,839 1   | 170,56      | 60,30           |
| bubble | 0,160 0              | −42,02 | 1 319,6           | 139,22          | 139,34   | 0,761 2   | 0,856 7   | 1,385 0   | 777,9       | −0,234 7        |
| dew    |                      | −41,94 | 6,425             | 379,19          | 404,09   | 1,906 5   | 0,680 4   | 0,853 9   | 170,93      | 57,05           |
| bubble | 0,180 0              | −39,44 | 1 311,2           | 142,79          | 142,93   | 0,776 6   | 0,857 6   | 1,389 9   | 765,2       | −0,226 7        |
| dew    |                      | −39,36 | 7,183             | 380,30          | 405,36   | 1,899 3   | 0,689 2   | 0,867 7   | 171,22      | 54,30           |
| bubble | 0,200 0              | −37,07 | 1 303,4           | 146,07          | 146,23   | 0,790 5   | 0,858 5   | 1,394 6   | 753,4       | −0,219 0        |
| dew    |                      | −36,99 | 7,940             | 381,31          | 406,50   | 1,892 8   | 0,697 4   | 0,880 6   | 171,45      | 51,94           |
| bubble | 0,250 0              | −31,88 | 1 286,1           | 153,32          | 153,51   | 0,820 9   | 0,860 8   | 1,406 1   | 727,5       | −0,200 6        |
| dew    |                      | −31,79 | 9,822             | 383,48          | 408,93   | 1,879 4   | 0,715 5   | 0,910 0   | 171,83      | 47,24           |
| bubble | 0,300 0              | −27,44 | 1 271,1           | 159,56          | 159,80   | 0,846 6   | 0,863 1   | 1,417 2   | 705,3       | −0,183 0        |
| dew    |                      | −27,35 | 11,697            | 385,29          | 410,94   | 1,868 5   | 0,731 0   | 0,936 5   | 172,01      | 43,70           |
| bubble | 0,350 0              | −23,54 | 1 257,6           | 165,08          | 165,36   | 0,868 9   | 0,865 5   | 1,427 9   | 685,6       | −0,166 0        |
| dew    |                      | −23,45 | 13,569            | 386,84          | 412,64   | 1,859 3   | 0,744 7   | 0,960 8   | 172,06      | 40,90           |
| bubble | 0,400 0              | −20,04 | 1 245,3           | 170,05          | 170,38   | 0,888 7   | 0,867 8   | 1,438 4   | 667,8       | −0,149 3        |
| dew    |                      | −19,95 | 15,442            | 388,20          | 414,10   | 1,851 4   | 0,757 0   | 0,983 4   | 172,00      | 38,62           |
| bubble | 0,450 0              | −16,87 | 1 233,9           | 174,60          | 174,96   | 0,906 5   | 0,870 2   | 1,448 7   | 651,6       | −0,132 9        |
| dew    |                      | −16,78 | 17,318            | 389,40          | 415,39   | 1,844 5   | 0,768 2   | 1,004 9   | 171,87      | 36,72           |
| bubble | 0,500 0              | −13,96 | 1 223,3           | 178,80          | 179,21   | 0,922 8   | 0,872 5   | 1,458 9   | 636,7       | −0,116 6        |
| dew    |                      | −13,86 | 19,198            | 390,48          | 416,53   | 1,838 3   | 0,778 6   | 1,025 3   | 171,68      | 35,10           |

<sup>a</sup> Bubble point and dew point at one standard atmosphere.<sup>b</sup> The values of  $C_v$ ,  $C_p$ , and  $w$  at the critical point are not included as part of this document.

Table 43 (continued)

|        | Pressure | Temp.  | Density           | Internal energy | Enthalpy | Entropy   | $C_v$     | $C_p$     | Sound speed | J-T coefficient |
|--------|----------|--------|-------------------|-----------------|----------|-----------|-----------|-----------|-------------|-----------------|
|        | MPa      | °C     | kg/m <sup>3</sup> | kJ/kg           | kJ/kg    | kJ/(kg·K) | kJ/(kg·K) | kJ/(kg·K) | m/s         | K/MPa           |
| bubble | 0,550 0  | −11,26 | 1 213,4           | 182,72          | 183,17   | 0,937 9   | 0,874 7   | 1,469 0   | 622,7       | −0,100 4        |
| dew    |          | −11,16 | 21,085            | 391,46          | 417,54   | 1,832 6   | 0,788 1   | 1,045 0   | 171,44      | 33,70           |
| bubble | 0,600 0  | −8,74  | 1 203,9           | 186,39          | 186,89   | 0,951 8   | 0,877 0   | 1,479 1   | 609,6       | −0,084 3        |
| dew    |          | −8,64  | 22,979            | 392,34          | 418,46   | 1,827 5   | 0,797 0   | 1,064 1   | 171,16      | 32,48           |
| bubble | 0,650 0  | −6,38  | 1 194,9           | 189,86          | 190,40   | 0,964 9   | 0,879 2   | 1,489 1   | 597,3       | −0,068 1        |
| dew    |          | −6,28  | 24,882            | 393,16          | 419,28   | 1,822 7   | 0,805 4   | 1,082 7   | 170,85      | 31,40           |
| bubble | 0,700 0  | −4,15  | 1 186,3           | 193,15          | 193,74   | 0,977 2   | 0,881 5   | 1,499 1   | 585,6       | −0,051 9        |
| dew    |          | −4,05  | 26,795            | 393,90          | 420,03   | 1,818 3   | 0,813 3   | 1,100 8   | 170,52      | 30,44           |
| bubble | 0,750 0  | −2,04  | 1 178,1           | 196,28          | 196,92   | 0,988 8   | 0,883 7   | 1,509 2   | 574,5       | −0,035 5        |
| dew    |          | −1,93  | 28,718            | 394,59          | 420,71   | 1,814 1   | 0,820 7   | 1,118 6   | 170,16      | 29,58           |
| bubble | 0,800 0  | −0,03  | 1 170,1           | 199,27          | 199,96   | 0,999 8   | 0,885 9   | 1,519 3   | 563,9       | −0,019 1        |
| dew    |          | 0,08   | 30,652            | 395,23          | 421,33   | 1,810 2   | 0,827 8   | 1,136 2   | 169,78      | 28,80           |
| bubble | 0,900 0  | 3,72   | 1 154,9           | 204,91          | 205,69   | 1,020 4   | 0,890 2   | 1,539 6   | 543,9       | 0,014 2         |
| dew    |          | 3,83   | 34,557            | 396,37          | 422,41   | 1,803 0   | 0,840 9   | 1,170 8   | 168,98      | 27,45           |
| bubble | 1,000 0  | 7,17   | 1 140,5           | 210,15          | 211,02   | 1,039 2   | 0,894 5   | 1,560 2   | 525,4       | 0,048 2         |
| dew    |          | 7,27   | 38,515            | 397,35          | 423,31   | 1,796 4   | 0,852 9   | 1,205 1   | 168,13      | 26,32           |
| bubble | 1,200 0  | 13,34  | 1 113,7           | 219,69          | 220,76   | 1,073 0   | 0,903 0   | 1,602 5   | 491,9       | 0,119 0         |
| dew    |          | 13,46  | 46,611            | 398,94          | 424,68   | 1,784 6   | 0,874 6   | 1,274 3   | 166,32      | 24,52           |
| bubble | 1,400 0  | 18,79  | 1 088,8           | 228,27          | 229,56   | 1,102 7   | 0,911 4   | 1,646 9   | 462,0       | 0,194 3         |
| dew    |          | 18,91  | 54,978            | 400,12          | 425,59   | 1,774 1   | 0,894 3   | 1,346 6   | 164,40      | 23,14           |
| bubble | 1,600 0  | 23,68  | 1 065,2           | 236,15          | 237,65   | 1,129 6   | 0,919 9   | 1,694 1   | 434,7       | 0,275 1         |
| dew    |          | 23,80  | 63,652            | 400,97          | 426,11   | 1,764 4   | 0,912 8   | 1,424 1   | 162,40      | 22,03           |
| bubble | 1,800 0  | 28,13  | 1 042,6           | 243,46          | 245,19   | 1,154 2   | 0,928 5   | 1,744 7   | 409,5       | 0,362 8         |
| dew    |          | 28,25  | 72,672            | 401,54          | 426,31   | 1,755 2   | 0,930 8   | 1,509 0   | 160,33      | 21,11           |
| bubble | 2,000 0  | 32,22  | 1 020,7           | 250,33          | 252,29   | 1,176 9   | 0,937 4   | 1,799 8   | 386,0       | 0,458 6         |
| dew    |          | 32,34  | 82,083            | 401,87          | 426,24   | 1,746 4   | 0,948 5   | 1,603 3   | 158,20      | 20,33           |
| bubble | 2,200 0  | 36,02  | 999,2             | 256,85          | 259,05   | 1,198 3   | 0,946 5   | 1,860 8   | 363,8       | 0,564 3         |
| dew    |          | 36,14  | 91,932            | 401,97          | 425,90   | 1,737 9   | 0,966 3   | 1,709 4   | 156,01      | 19,64           |
| bubble | 2,400 0  | 39,56  | 978,0             | 263,07          | 265,52   | 1,218 5   | 0,956 0   | 1,929 5   | 342,7       | 0,682 1         |
| dew    |          | 39,68  | 102,28            | 401,86          | 425,33   | 1,729 4   | 0,984 3   | 1,830 6   | 153,77      | 19,03           |
| bubble | 2,600 0  | 42,89  | 957,0             | 269,05          | 271,77   | 1,237 7   | 0,966 0   | 2,008 2   | 322,4       | 0,815 0         |
| dew    |          | 43,00  | 113,19            | 401,54          | 424,51   | 1,720 9   | 1,002 5   | 1,970 8   | 151,48      | 18,47           |
| bubble | 2,800 0  | 46,02  | 935,8             | 274,85          | 277,84   | 1,256 1   | 0,976 7   | 2,100 5   | 302,9       | 0,966 5         |
| dew    |          | 46,14  | 124,76            | 401,02          | 423,47   | 1,712 3   | 1,021 2   | 2,135 7   | 149,12      | 17,96           |
| bubble | 3,000 0  | 48,99  | 914,5             | 280,50          | 283,78   | 1,274 0   | 0,988 1   | 2,211 2   | 283,8       | 1,141 6         |
| dew    |          | 49,10  | 137,09            | 400,29          | 422,18   | 1,703 5   | 1,040 4   | 2,333 1   | 146,70      | 17,47           |
| bubble | 3,200 0  | 51,81  | 892,6             | 286,04          | 289,62   | 1,291 3   | 1,000 5   | 2,347 9   | 265,2       | 1,346 9         |
| dew    |          | 51,91  | 150,31            | 399,33          | 420,62   | 1,694 4   | 1,060 2   | 2,575 0   | 144,22      | 17,01           |
| bubble | 3,400 0  | 54,49  | 870,0             | 291,52          | 295,43   | 1,308 5   | 1,014 1   | 2,521 8   | 246,8       | 1,591 3         |
| dew    |          | 54,59  | 164,62            | 398,12          | 418,78   | 1,684 9   | 1,081 0   | 2,879 3   | 141,67      | 16,55           |
| bubble | 3,600 0  | 57,05  | 846,3             | 297,00          | 301,26   | 1,325 4   | 1,029 5   | 2,751 7   | 228,5       | 1,887 4         |
| dew    |          | 57,15  | 180,26            | 396,63          | 416,60   | 1,674 7   | 1,103 1   | 3,275 7   | 139,03      | 16,09           |

<sup>a</sup> Bubble point and dew point at one standard atmosphere.

<sup>b</sup> The values of  $C_v$ ,  $C_p$ , and  $w$  at the critical point are not included as part of this document.

Table 43 (continued)

|                                                                                                                     | Pressure | Temp. | Density           | Internal energy | Enthalpy | Entropy   | $C_v$     | $C_p$     | Sound speed | J-T coefficient |
|---------------------------------------------------------------------------------------------------------------------|----------|-------|-------------------|-----------------|----------|-----------|-----------|-----------|-------------|-----------------|
|                                                                                                                     | MPa      | °C    | kg/m <sup>3</sup> | kJ/kg           | kJ/kg    | kJ/(kg·K) | kJ/(kg·K) | kJ/(kg·K) | m/s         | K/MPa           |
| bubble                                                                                                              | 3,800 0  | 59,50 | 821,0             | 302,53          | 307,16   | 1,342 5   | 1,047 2   | 3,070 4   | 210,3       | 2,253 4         |
| dew                                                                                                                 |          | 59,59 | 197,60            | 394,80          | 414,03   | 1,663 8   | 1,126 7   | 3,815 4   | 136,29      | 15,61           |
| bubble                                                                                                              | 4,000 0  | 61,85 | 793,5             | 308,20          | 313,24   | 1,360 0   | 1,068 4   | 3,541 3   | 191,9       | 2,716 9         |
| dew                                                                                                                 |          | 61,93 | 217,17            | 392,55          | 410,97   | 1,651 7   | 1,152 7   | 4,595 7   | 133,43      | 15,10           |
| bubble                                                                                                              | 4,200 0  | 64,10 | 762,6             | 314,14          | 319,65   | 1,378 3   | 1,095 0   | 4,305 8   | 173,3       | 3,322 4         |
| dew                                                                                                                 |          | 64,17 | 239,86            | 389,73          | 407,24   | 1,638 0   | 1,182 0   | 5,826 3   | 130,40      | 14,53           |
| critical                                                                                                            | 4,902 6  | 71,36 | 459,5             | 357,88          | 368,55   | 1,518 1   | b         | b         | b           | 9,747 7         |
| <sup>a</sup> Bubble point and dew point at one standard atmosphere.                                                 |          |       |                   |                 |          |           |           |           |             |                 |
| <sup>b</sup> The values of $C_v$ , $C_p$ , and $w$ at the critical point are not included as part of this document. |          |       |                   |                 |          |           |           |           |             |                 |

## 5.15 R507A — R125/143a (50/50)

The composition of R507A is listed in [Table 44](#).

Table 44 — Composition of R507A

| <i>i</i>                      | Component | Mass fraction | Mole fraction |
|-------------------------------|-----------|---------------|---------------|
| 1                             | R125      | 0,50          | 0,411 839 71  |
| 2                             | R143a     | 0,50          | 0,588 160 29  |
| $M = 98,859\ 4\ \text{g/mol}$ |           |               |               |

### 5.15.1 Range of validity

The coefficients are valid within the following ranges:

$$T_{\min} = 172,52\ \text{K}, T_{\max} = 500\ \text{K}; p_{\max} = 60\ \text{MPa}; \rho_{\max} = 14,96\ \text{mol/l}\ (1\ 468\ \text{kg/m}^3)$$

### 5.15.2 Interaction parameters [Formulae (19) and (20)]

$$\zeta_{12} = 5,551; \zeta_{12} = -0,000\ 445\ 2$$

Coefficients and exponents of the excess functions are listed in [Table 45](#).

Table 45 — Coefficients and exponents of the excess functions [Formula (21)]

| R125/143a binary pair <sup>a</sup>               |                 |       |       |       |
|--------------------------------------------------|-----------------|-------|-------|-------|
| <i>k</i>                                         | $N_k$           | $t_k$ | $d_k$ | $l_k$ |
| 1                                                | -0,013 073      | 7,4   | 1     | 1     |
| 2                                                | 0,018 259       | 0,35  | 3     | 1     |
| 3                                                | 0,000 008 129 9 | 10,0  | 11    | 2     |
| 4                                                | 0,007 849 6     | 5,3   | 2     | 3     |
| <sup>a</sup> $i = 1; j = 2; F_{12} = 1,169\ 7$ . |                 |       |       |       |

## 5.15.3 Reference state parameters

$$f_3 = 0,630\,988\,493, f_4 = 19,345\,427$$

R507A property values of liquid on the bubble line and vapour on the dew line are listed in [Table 46](#).

**Table 46 — R507A property values of liquid on the bubble line and vapour on the dew line**

|                                                                                                                     | Pressure             | Temp.  | Density           | Internal energy | Enthalpy | Entropy   | $C_v$     | $C_p$     | Sound speed | J-T coefficient |
|---------------------------------------------------------------------------------------------------------------------|----------------------|--------|-------------------|-----------------|----------|-----------|-----------|-----------|-------------|-----------------|
|                                                                                                                     | MPa                  | °C     | kg/m <sup>3</sup> | kJ/kg           | kJ/kg    | kJ/(kg·K) | kJ/(kg·K) | kJ/(kg·K) | m/s         | K/MPa           |
| bubble                                                                                                              | 0,010 0              | −85,26 | 1 432,7           | 92,21           | 92,21    | 0,531 0   | 0,763 3   | 1,202 6   | 926,5       | −0,354 5        |
| dew                                                                                                                 |                      | −85,24 | 0,639             | 297,04          | 312,68   | 1,704 4   | 0,566 9   | 0,657 3   | 133,98      | 112,99          |
| bubble                                                                                                              | 0,015 0              | −79,66 | 1 416,1           | 98,94           | 98,95    | 0,566 3   | 0,772 0   | 1,202 8   | 889,9       | −0,349 4        |
| dew                                                                                                                 |                      | −79,65 | 0,934             | 300,00          | 316,06   | 1,688 4   | 0,580 9   | 0,673 0   | 135,47      | 96,12           |
| bubble                                                                                                              | 0,020 0              | −75,44 | 1 403,6           | 104,02          | 104,04   | 0,592 3   | 0,778 0   | 1,204 4   | 864,2       | −0,344 2        |
| dew                                                                                                                 |                      | −75,43 | 1,223             | 302,26          | 318,61   | 1,677 6   | 0,591 6   | 0,685 1   | 136,53      | 85,83           |
| bubble                                                                                                              | 0,025 0              | −72,01 | 1 393,4           | 108,16          | 108,17   | 0,613 0   | 0,782 6   | 1,206 7   | 844,3       | −0,339 3        |
| dew                                                                                                                 |                      | −72,00 | 1,506             | 304,10          | 320,70   | 1,669 6   | 0,600 3   | 0,695 1   | 137,34      | 78,70           |
| bubble                                                                                                              | 0,030 0              | −69,10 | 1 384,7           | 111,67          | 111,69   | 0,630 4   | 0,786 5   | 1,209 1   | 827,9       | −0,334 6        |
| dew                                                                                                                 |                      | −69,09 | 1,786             | 305,67          | 322,47   | 1,663 3   | 0,607 7   | 0,703 9   | 137,99      | 73,37           |
| bubble                                                                                                              | 0,040 0              | −64,29 | 1 370,4           | 117,49          | 117,52   | 0,658 6   | 0,792 6   | 1,214 1   | 801,8       | −0,325 8        |
| dew                                                                                                                 |                      | −64,29 | 2,337             | 308,28          | 325,39   | 1,653 8   | 0,620 1   | 0,718 6   | 139,00      | 65,80           |
| bubble                                                                                                              | 0,050 0              | −60,37 | 1 358,6           | 122,25          | 122,29   | 0,681 2   | 0,797 6   | 1,219 1   | 781,2       | −0,317 6        |
| dew                                                                                                                 |                      | −60,37 | 2,880             | 310,41          | 327,77   | 1,646 9   | 0,630 4   | 0,731 0   | 139,75      | 60,55           |
| bubble                                                                                                              | 0,060 0              | −57,04 | 1 348,5           | 126,32          | 126,36   | 0,700 1   | 0,801 7   | 1,223 8   | 764,1       | −0,310 0        |
| dew                                                                                                                 |                      | −57,04 | 3,416             | 312,23          | 329,79   | 1,641 5   | 0,639 2   | 0,741 8   | 140,33      | 56,62           |
| bubble                                                                                                              | 0,080 0              | −51,53 | 1 331,6           | 133,08          | 133,14   | 0,731 0   | 0,808 5   | 1,232 6   | 736,3       | −0,296 0        |
| dew                                                                                                                 |                      | −51,53 | 4,474             | 315,25          | 333,13   | 1,633 4   | 0,654 0   | 0,760 5   | 141,18      | 51,02           |
| bubble                                                                                                              | 0,100 0              | −47,01 | 1 317,6           | 138,65          | 138,73   | 0,755 9   | 0,814 1   | 1,240 8   | 714,0       | −0,283 2        |
| dew                                                                                                                 |                      | −47,01 | 5,517             | 317,72          | 335,85   | 1,627 6   | 0,666 2   | 0,776 4   | 141,76      | 47,13           |
| bubble                                                                                                              | 0,101 3 <sup>a</sup> | −46,74 | 1 316,8           | 138,99          | 139,07   | 0,757 4   | 0,814 5   | 1,241 3   | 712,7       | −0,282 4        |
| dew                                                                                                                 |                      | −46,74 | 5,586             | 317,87          | 336,01   | 1,627 3   | 0,667 0   | 0,777 4   | 141,79      | 46,91           |
| bubble                                                                                                              | 0,120 0              | −43,16 | 1 305,6           | 143,44          | 143,53   | 0,776 9   | 0,819 0   | 1,248 3   | 695,2       | −0,271 2        |
| dew                                                                                                                 |                      | −43,16 | 6,551             | 319,83          | 338,15   | 1,623 1   | 0,676 9   | 0,790 5   | 142,17      | 44,21           |
| bubble                                                                                                              | 0,140 0              | −39,79 | 1 294,9           | 147,65          | 147,76   | 0,795 1   | 0,823 2   | 1,255 5   | 678,9       | −0,259 8        |
| dew                                                                                                                 |                      | −39,79 | 7,578             | 321,68          | 340,15   | 1,619 5   | 0,686 3   | 0,803 3   | 142,47      | 41,91           |
| bubble                                                                                                              | 0,160 0              | −36,77 | 1 285,2           | 151,44          | 151,57   | 0,811 3   | 0,827 1   | 1,262 2   | 664,3       | −0,248 8        |
| dew                                                                                                                 |                      | −36,77 | 8,599             | 323,33          | 341,93   | 1,616 6   | 0,694 8   | 0,815 2   | 142,67      | 40,03           |
| bubble                                                                                                              | 0,180 0              | −34,03 | 1 276,4           | 154,90          | 155,04   | 0,825 8   | 0,830 6   | 1,268 6   | 651,2       | −0,238 3        |
| dew                                                                                                                 |                      | −34,03 | 9,616             | 324,82          | 343,54   | 1,614 1   | 0,702 6   | 0,826 2   | 142,82      | 38,45           |
| bubble                                                                                                              | 0,200 0              | −31,52 | 1 268,2           | 158,08          | 158,24   | 0,839 0   | 0,833 9   | 1,274 8   | 639,2       | −0,228 0        |
| dew                                                                                                                 |                      | −31,51 | 10,631            | 326,19          | 345,00   | 1,611 9   | 0,709 8   | 0,836 7   | 142,90      | 37,11           |
| bubble                                                                                                              | 0,250 0              | −25,99 | 1 249,8           | 165,14          | 165,34   | 0,867 9   | 0,841 1   | 1,289 3   | 612,9       | −0,203 4        |
| dew                                                                                                                 |                      | −25,99 | 13,159            | 329,18          | 348,18   | 1,607 7   | 0,725 9   | 0,860 7   | 142,96      | 34,44           |
| bubble                                                                                                              | 0,300 0              | −21,26 | 1 233,7           | 171,24          | 171,48   | 0,892 4   | 0,847 5   | 1,302 9   | 590,5       | −0,179 7        |
| dew                                                                                                                 |                      | −21,25 | 15,682            | 331,72          | 350,85   | 1,604 4   | 0,739 9   | 0,882 5   | 142,84      | 32,43           |
| bubble                                                                                                              | 0,350 0              | −17,10 | 1 219,3           | 176,66          | 176,95   | 0,913 7   | 0,853 2   | 1,315 8   | 570,7       | −0,156 5        |
| <sup>a</sup> Bubble point and dew point at one standard atmosphere.                                                 |                      |        |                   |                 |          |           |           |           |             |                 |
| <sup>b</sup> The values of $C_v$ , $C_p$ , and $w$ at the critical point are not included as part of this document. |                      |        |                   |                 |          |           |           |           |             |                 |

Table 46 (continued)

|        | Pressure | Temp.  | Density           | Internal energy | Enthalpy | Entropy   | $C_v$     | $C_p$     | Sound speed | J-T coefficient |
|--------|----------|--------|-------------------|-----------------|----------|-----------|-----------|-----------|-------------|-----------------|
|        | MPa      | °C     | kg/m <sup>3</sup> | kJ/kg           | kJ/kg    | kJ/(kg·K) | kJ/(kg·K) | kJ/(kg·K) | m/s         | K/MPa           |
| dew    |          | -17,08 | 18,208            | 333,93          | 353,15   | 1,601 9   | 0,752 4   | 0,902 8   | 142,60      | 30,85           |
| bubble | 0,400 0  | -13,36 | 1 206,1           | 181,56          | 181,89   | 0,932 7   | 0,858 4   | 1,328 2   | 553,0       | -0,133 7        |
| dew    |          | -13,35 | 20,741            | 335,90          | 355,18   | 1,599 8   | 0,763 7   | 0,921 9   | 142,28      | 29,57           |
| bubble | 0,450 0  | -9,97  | 1 193,8           | 186,05          | 186,43   | 0,949 9   | 0,863 3   | 1,340 3   | 536,9       | -0,111 1        |
| dew    |          | -9,95  | 23,284            | 337,67          | 356,99   | 1,598 0   | 0,774 1   | 0,940 1   | 141,89      | 28,49           |
| bubble | 0,500 0  | -6,85  | 1 182,3           | 190,21          | 190,63   | 0,965 7   | 0,867 8   | 1,352 0   | 522,0       | -0,088 4        |
| dew    |          | -6,83  | 25,841            | 339,28          | 358,63   | 1,596 5   | 0,783 6   | 0,957 7   | 141,45      | 27,59           |
| bubble | 0,550 0  | -3,96  | 1 171,5           | 194,10          | 194,57   | 0,980 2   | 0,872 0   | 1,363 6   | 508,3       | -0,065 7        |
| dew    |          | -3,94  | 28,413            | 340,75          | 360,11   | 1,595 1   | 0,792 4   | 0,974 7   | 140,98      | 26,81           |
| bubble | 0,600 0  | -1,26  | 1 161,2           | 197,75          | 198,27   | 0,993 7   | 0,876 0   | 1,375 1   | 495,3       | -0,042 7        |
| dew    |          | -1,24  | 31,003            | 342,11          | 361,47   | 1,593 9   | 0,800 7   | 0,991 3   | 140,47      | 26,14           |
| bubble | 0,650 0  | 1,28   | 1 151,3           | 201,21          | 201,77   | 1,006 4   | 0,879 8   | 1,386 5   | 483,2       | -0,019 5        |
| dew    |          | 1,30   | 33,612            | 343,37          | 362,71   | 1,592 8   | 0,808 6   | 1,007 7   | 139,93      | 25,55           |
| bubble | 0,700 0  | 3,67   | 1 141,8           | 204,49          | 205,11   | 1,018 3   | 0,883 5   | 1,397 9   | 471,7       | 0,004 0         |
| dew    |          | 3,70   | 36,243            | 344,55          | 363,86   | 1,591 8   | 0,816 0   | 1,024 0   | 139,37      | 25,03           |
| bubble | 0,750 0  | 5,94   | 1 132,7           | 207,63          | 208,29   | 1,029 6   | 0,887 0   | 1,409 3   | 460,7       | 0,027 9         |
| dew    |          | 5,97   | 38,897            | 345,64          | 364,92   | 1,590 8   | 0,823 0   | 1,040 1   | 138,79      | 24,57           |
| bubble | 0,800 0  | 8,10   | 1 123,8           | 210,63          | 211,34   | 1,040 4   | 0,890 3   | 1,420 7   | 450,3       | 0,052 3         |
| dew    |          | 8,13   | 41,575            | 346,67          | 365,91   | 1,589 9   | 0,829 8   | 1,056 3   | 138,19      | 24,15           |
| bubble | 0,900 0  | 12,13  | 1 106,8           | 216,29          | 217,10   | 1,060 4   | 0,896 8   | 1,443 8   | 430,7       | 0,102 5         |
| dew    |          | 12,16  | 47,010            | 348,54          | 367,68   | 1,588 2   | 0,842 7   | 1,089 1   | 136,95      | 23,45           |
| bubble | 1,000 0  | 15,84  | 1 090,6           | 221,56          | 222,48   | 1,078 8   | 0,902 9   | 1,467 4   | 412,5       | 0,155 1         |
| dew    |          | 15,87  | 52,559            | 350,20          | 369,22   | 1,586 5   | 0,855 0   | 1,122 7   | 135,67      | 22,87           |
| bubble | 1,200 0  | 22,49  | 1 060,0           | 231,21          | 232,34   | 1,111 9   | 0,914 3   | 1,517 0   | 379,5       | 0,269 1         |
| dew    |          | 22,53  | 64,044            | 353,00          | 371,74   | 1,583 4   | 0,878 1   | 1,194 1   | 132,98      | 21,98           |
| bubble | 1,400 0  | 28,36  | 1 031,0           | 239,93          | 241,29   | 1,141 2   | 0,925 0   | 1,571 3   | 349,9       | 0,397 7         |
| dew    |          | 28,40  | 76,121            | 355,25          | 373,64   | 1,580 2   | 0,900 1   | 1,273 6   | 130,18      | 21,31           |
| bubble | 1,600 0  | 33,63  | 1 003,0           | 247,98          | 249,58   | 1,167 8   | 0,935 5   | 1,632 1   | 322,7       | 0,544 9         |
| dew    |          | 33,67  | 88,893            | 357,04          | 375,04   | 1,576 7   | 0,921 6   | 1,364 4   | 127,27      | 20,81           |
| bubble | 1,800 0  | 38,43  | 975,6             | 255,51          | 257,35   | 1,192 3   | 0,946 0   | 1,702 0   | 297,4       | 0,716 1         |
| dew    |          | 38,46  | 102,48            | 358,42          | 375,99   | 1,573 1   | 0,942 8   | 1,470 7   | 124,28      | 20,41           |
| bubble | 2,000 0  | 42,83  | 948,2             | 262,63          | 264,74   | 1,215 2   | 0,956 7   | 1,784 6   | 273,5       | 0,918 3         |
| dew    |          | 42,87  | 117,05            | 359,45          | 376,53   | 1,569 0   | 0,964 0   | 1,598 5   | 121,20      | 20,08           |
| bubble | 2,200 0  | 46,91  | 920,5             | 269,45          | 271,84   | 1,236 8   | 0,967 9   | 1,885 4   | 250,8       | 1,161 5         |
| dew    |          | 46,95  | 132,79            | 360,12          | 376,68   | 1,564 4   | 0,985 2   | 1,756 9   | 118,04      | 19,81           |
| bubble | 2,400 0  | 50,72  | 892,1             | 276,04          | 278,73   | 1,257 6   | 0,980 0   | 2,012 8   | 228,9       | 1,460 0         |
| dew    |          | 50,75  | 149,99            | 360,43          | 376,43   | 1,559 2   | 1,006 9   | 1,961 0   | 114,80      | 19,58           |
| bubble | 2,600 0  | 54,28  | 862,6             | 282,49          | 285,50   | 1,277 7   | 0,993 4   | 2,181 8   | 207,5       | 1,836 0         |
| dew    |          | 54,32  | 169,04            | 360,36          | 375,74   | 1,553 2   | 1,029 4   | 2,236 8   | 111,48      | 19,35           |
| bubble | 2,800 0  | 57,63  | 831,2             | 288,87          | 292,23   | 1,297 4   | 1,008 8   | 2,420 6   | 186,4       | 2,325 2         |
| dew    |          | 57,67  | 190,55            | 359,84          | 374,53   | 1,546 2   | 1,053 1   | 2,633 8   | 108,06      | 19,09           |
| bubble | 3,000 0  | 60,80  | 796,9             | 295,28          | 299,05   | 1,317 2   | 1,027 1   | 2,791 0   | 165,4       | 2,989 0         |

<sup>a</sup> Bubble point and dew point at one standard atmosphere.

<sup>b</sup> The values of  $C_v$ ,  $C_p$ , and  $w$  at the critical point are not included as part of this document.

Table 46 (continued)

|                                                                                                                     | Pressure<br>MPa | Temp.<br>°C | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|---------------------------------------------------------------------------------------------------------------------|-----------------|-------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| dew                                                                                                                 |                 | 60,82       | 215,50                       | 358,77                      | 372,69            | 1,537 7              | 1,079 0            | 3,259 2            | 104,54                | 18,77                       |
| bubble                                                                                                              | 3,200 0         | 63,78       | 757,9                        | 301,91                      | 306,13            | 1,337 5              | 1,050 4            | 3,458 1            | 144,1                 | 3,944 0                     |
| dew                                                                                                                 |                 | 63,81       | 245,74                       | 356,93                      | 369,95            | 1,526 9              | 1,108 3            | 4,394 1            | 100,89                | 18,30                       |
| bubble                                                                                                              | 3,400 0         | 66,61       | 709,9                        | 309,11                      | 313,90            | 1,359 6              | 1,082 8            | 5,054 8            | 122,2                 | 5,443 2                     |
| dew                                                                                                                 |                 | 66,63       | 285,53                       | 353,82                      | 365,73            | 1,512 2              | 1,143 9            | 7,076 0            | 97,03                 | 17,52                       |
| bubble                                                                                                              | 3,600 0         | 68,45       | 657,9                        | 315,53                      | 320,89            | 1,379 6              | 1,123 7            | 10,265 7           | 103,6                 | 7,484 7                     |
| dew                                                                                                                 |                 | 68,55       | 679,05                       | 313,87                      | 319,13            | 1,374 3              | 1,102 4            | 6,504 8            | 112,80                | 6,40                        |
| critical                                                                                                            | 3,705 0         | 70,62       | 490,8                        | 332,90                      | 340,45            | 1,435 8              | b                  | b                  | b                     | 12,383 5                    |
| <sup>a</sup> Bubble point and dew point at one standard atmosphere.                                                 |                 |             |                              |                             |                   |                      |                    |                    |                       |                             |
| <sup>b</sup> The values of $C_v$ , $C_p$ , and $w$ at the critical point are not included as part of this document. |                 |             |                              |                             |                   |                      |                    |                    |                       |                             |

## 5.16 R290 — Propane

### 5.16.1 Range of validity

The coefficients are valid within the following ranges:

$$T_{\min} = 85,525 \text{ K}, T_{\max} = 650 \text{ K}; p_{\max} = 1\,000 \text{ MPa}; \rho_{\max} = 20,6 \text{ mol/l (908,4 kg/m}^3\text{)}$$

### 5.16.2 Coefficients and exponents of the ideal-gas part (Formulae 3 to 5)

Coefficients and exponents of the ideal-gas part are listed in Table 47 and Table 48. Coefficients and exponents of the real-gas part are listed in Table 49 and Table 50.

Table 47 — Coefficients and exponents for  $k = 0$ 

| $k$ | $c_k$   |
|-----|---------|
| 0   | 4,000 0 |

Table 48 — Coefficients and exponents for  $k = 1$  up to 3

| $k$ | $a_k$ | $b_k$   |
|-----|-------|---------|
| 1   | 3,043 | 393,0   |
| 2   | 5,874 | 1 237,0 |
| 3   | 9,337 | 1 984,0 |
| 4   | 7,922 | 4 351,0 |

### 5.16.3 Coefficients and exponents of the real-gas part (Formula 2)

Table 49 — Coefficients and exponents for  $k = 1$  up to 11

| $k$ | $N_k$         | $t_k$ | $d_k$ | $l_k$ | $\alpha_k$ |
|-----|---------------|-------|-------|-------|------------|
| 1   | 0,042 910 051 | 1,00  | 4     | 0     | 0          |
| 2   | 1,731 367 1   | 0,33  | 1     | 0     | 0          |
| 3   | -2,451 652 4  | 0,80  | 1     | 0     | 0          |
| 4   | 0,341 574 66  | 0,43  | 2     | 0     | 0          |
| 5   | -0,460 478 98 | 0,90  | 2     | 0     | 0          |

Table 49 (continued)

| $k$ | $N_k$         | $t_k$ | $d_k$ | $l_k$ | $\alpha_k$ |
|-----|---------------|-------|-------|-------|------------|
| 6   | -0,668 472 95 | 2,46  | 1     | 1     | 0          |
| 7   | 0,208 897 05  | 2,09  | 3     | 1     | 0          |
| 8   | 0,194 213 81  | 0,88  | 6     | 1     | 0          |
| 9   | -0,229 178 51 | 1,09  | 6     | 1     | 0          |
| 10  | -0,604 058 66 | 3,25  | 2     | 2     | 0          |
| 11  | 0,066 680 654 | 4,62  | 3     | 2     | 0          |

Table 50 — Coefficients and exponents for  $k = 12$  up to 18

| $k$ | $N_k$          | $t_k$ | $d_k$ | $l_k$ | $\alpha_k$ | $m_k$ | $\beta_k$ | $\gamma_k$ | $\varepsilon_k$ |
|-----|----------------|-------|-------|-------|------------|-------|-----------|------------|-----------------|
| 12  | 0,017 534 618  | 0,76  | 1     | 2     | 2          | 0,963 | 2,33      | 0,684      | 1,283           |
| 13  | 0,338 742 42   | 2,5   | 1     | 2     | 2          | 1,977 | 3,47      | 0,829      | 0,693 6         |
| 14  | 0,222 287 77   | 2,75  | 1     | 2     | 2          | 1,917 | 3,15      | 1,419      | 0,788           |
| 15  | -0,232 190 62  | 3,05  | 2     | 2     | 2          | 2,307 | 3,19      | 0,817      | 0,473           |
| 16  | -0,092 206 94  | 2,55  | 2     | 2     | 2          | 2,546 | 0,92      | 1,500      | 0,857 7         |
| 17  | -0,475 757 18  | 8,40  | 4     | 2     | 2          | 3,28  | 18,8      | 1,426      | 0,271           |
| 18  | -0,017 486 824 | 6,75  | 1     | 2     | 2          | 14,6  | 547,8     | 1,093      | 0,948           |

#### 5.16.4 Reducing parameters, molar mass, and gas constant

$$T^* = 369,89 \text{ K}, \rho^* = 5,000 \text{ 00 mol/l}, M = 44,095 \text{ 62 g/mol}, R = 8,314 \text{ 459 8 J/(mol}\cdot\text{K)}$$

#### 5.16.5 Reference state parameters

$$T_{\text{ref}} = 273,15 \text{ K}, p_{\text{ref}} = 1,0 \text{ kPa}, h_{\text{ref}} = 26 \text{ 148,457 J/mol}, s_{\text{ref}} = 157,910 \text{ 3 J/(mol}\cdot\text{K)}$$

R290 (propane) Property values along the liquid-vapour saturation boundary are listed in [Table 51](#).

Table 51 — R290 (propane) Property values along the liquid-vapour saturation boundary

|        | Temp.<br>°C          | Pressure<br>MPa         | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|--------|----------------------|-------------------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| liquid | -187,62 <sup>a</sup> | $1,720 \times 10^{-10}$ | 733,1                        | -196,64                     | -196,64           | -1,395 9             | 1,355 3            | 1,915 8            | 2 136,4               | -0,625 2                    |
| vapour |                      |                         | $1,067 \times 10^{-8}$       | 350,13                      | 366,26            | 5,185 8              | 0,690 7            | 0,879 2            | 143,28                | 491,93                      |
| liquid | -185                 | $4,853 \times 10^{-10}$ | 730,4                        | -191,61                     | -191,61           | -1,338               | 1,351 8            | 1,917 9            | 2 118,6               | -0,624 2                    |
| vapour |                      |                         | $2,920 \times 10^{-8}$       | 351,96                      | 368,58            | 5,017                | 0,701              | 0,889 6            | 145,23                | 453,64                      |
| liquid | -180                 | $2,939 \times 10^{-9}$  | 725,2                        | -182,01                     | -182,01           | -1,232               | 1,346 5            | 1,922 7            | 2 084,6               | -0,621 9                    |
| vapour |                      |                         | $1,673 \times 10^{-7}$       | 355,51                      | 373,08            | 4,727                | 0,720 8            | 0,909 3            | 148,86                | 391,26                      |
| liquid | -175                 | $1,460 \times 10^{-8}$  | 720                          | -172,38                     | -172,38           | -1,131 4             | 1,342 6            | 1,928 2            | 2 050,4               | -0,619 3                    |
| vapour |                      |                         | $7,887 \times 10^{-7}$       | 359,16                      | 377,67            | 4,472 9              | 0,740 4            | 0,928 9            | 152,38                | 340,14                      |
| liquid | -170                 | $6,126 \times 10^{-8}$  | 714,9                        | -162,73                     | -162,73           | -1,035 4             | 1,339 7            | 1,934 2            | 2 016,2               | -0,616 5                    |
| vapour |                      |                         | $3,149 \times 10^{-6}$       | 362,91                      | 382,36            | 4,249 1              | 0,759 6            | 0,948 1            | 155,81                | 297,85                      |
| liquid | -165                 | $2,225 \times 10^{-7}$  | 709,8                        | -153,04                     | -153,04           | -0,943 7             | 1,337 6            | 1,940 6            | 1 982                 | -0,613 3                    |

<sup>a</sup> Triple point

<sup>b</sup> Normal boiling point

\* The values of  $C_v$ ,  $C_p$ , and  $w$  at the critical point are not included as part of this document.

Table 51 (continued)

|                                                                                                                          | Temp.<br>°C | Pressure<br>MPa          | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | C <sub>v</sub><br>kJ/(kg·K) | C <sub>p</sub><br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|--------------------------------------------------------------------------------------------------------------------------|-------------|--------------------------|------------------------------|-----------------------------|-------------------|----------------------|-----------------------------|-----------------------------|-----------------------|-----------------------------|
| vapour                                                                                                                   |             |                          | 1,09 × 10 <sup>-5</sup>      | 366,76                      | 387,15            | 4,051 2              | 0,778 4                     | 0,966 9                     | 159,16                | 262,59                      |
| liquid                                                                                                                   | -160        | 7,137 × 10 <sup>-7</sup> | 704,7                        | -143,32                     | -143,32           | -0,855 8             | 1,336 1                     | 1,947 3                     | 1 947,9               | -0,609 9                    |
| vapour                                                                                                                   |             |                          | 3,35 × 10 <sup>-5</sup>      | 370,7                       | 392,03            | 3,875 5              | 0,796 7                     | 0,985 2                     | 162,43                | 232,95                      |
| liquid                                                                                                                   | -155        | 2,054 × 10 <sup>-6</sup> | 699,7                        | -133,57                     | -133,57           | -0,771 5             | 1,335 1                     | 1,954 3                     | 1 913,9               | -0,606 3                    |
| vapour                                                                                                                   |             |                          | 9,22 × 10 <sup>-5</sup>      | 374,73                      | 397               | 3,719 2              | 0,814 5                     | 1,003 1                     | 165,63                | 207,84                      |
| liquid                                                                                                                   | -150        | 5,380 × 10 <sup>-6</sup> | 694,6                        | -123,78                     | -123,78           | -0,690 3             | 1,334 5                     | 1,961 6                     | 1 880                 | -0,602 4                    |
| vapour                                                                                                                   |             |                          | 2,317 × 10 <sup>-4</sup>     | 378,84                      | 402,06            | 3,579 6              | 0,831 9                     | 1,020 5                     | 168,77                | 186,44                      |
| liquid                                                                                                                   | -145        | 1,297 × 10 <sup>-5</sup> | 689,6                        | -113,95                     | -113,95           | -0,612 1             | 1,334 3                     | 1,969 1                     | 1 846,2               | -0,598 2                    |
| vapour                                                                                                                   |             |                          | 5,366 × 10 <sup>-4</sup>     | 383,04                      | 407,21            | 3,454 6              | 0,848 9                     | 1,037 4                     | 171,84                | 168,1                       |
| liquid                                                                                                                   | -140        | 2,904 × 10 <sup>-5</sup> | 684,5                        | -104,09                     | -104,09           | -0,536 6             | 1,334 4                     | 1,977                       | 1 812,5               | -0,593 8                    |
| vapour                                                                                                                   |             |                          | 1,157 × 10 <sup>-3</sup>     | 3 387,33                    | 412,43            | 3,342 6              | 0,865 5                     | 1,054 1                     | 174,85                | 152,32                      |
| liquid                                                                                                                   | -135        | 6,095 × 10 <sup>-5</sup> | 679,5                        | -94,18                      | -94,18            | -0,463 6             | 1,334 9                     | 1,985 2                     | 1 779                 | -0,589 1                    |
| vapour                                                                                                                   |             |                          | 2,340 × 10 <sup>-3</sup>     | 391,69                      | 417,74            | 3,241 9              | 0,881 8                     | 1,070 4                     | 177,81                | 138,68                      |
| liquid                                                                                                                   | -130        | 0,000 121                | 674,4                        | -84,23                      | -84,23            | -0,392 9             | 1,335 7                     | 1,993 7                     | 1 745,5               | -0,584                      |
| vapour                                                                                                                   |             |                          | 0,004 47                     | 396,14                      | 423,12            | 3,151 4              | 0,897 9                     | 1,086 6                     | 180,7                 | 126,85                      |
| liquid                                                                                                                   | -125        | 0,000 227                | 669,3                        | -74,24                      | -74,24            | -0,324 3             | 1,337                       | 2,002 6                     | 1 712                 | -0,578 6                    |
| vapour                                                                                                                   |             |                          | 0,008 13                     | 400,66                      | 428,58            | 3,069 8              | 0,913 8                     | 1,102 6                     | 183,53                | 116,55                      |
| liquid                                                                                                                   | -120        | 0,000 408                | 664,3                        | -64,21                      | -64,21            | -0,257 6             | 1,338 6                     | 2,011 9                     | 1 678,6               | -0,572 8                    |
| vapour                                                                                                                   |             |                          | 0,014 13                     | 405,25                      | 434,11            | 2,996 2              | 0,929 7                     | 1,118 6                     | 186,31                | 107,51                      |
| liquid                                                                                                                   | -115        | 0,000 702                | 659,2                        | -54,12                      | -54,12            | -0,192 8             | 1,340 7                     | 2,021 7                     | 1 645,2               | -0,566 6                    |
| vapour                                                                                                                   |             |                          | 0,023 57                     | 409,92                      | 439,71            | 2,929 7              | 0,945 5                     | 1,134 7                     | 189,02                | 99,51                       |
| liquid                                                                                                                   | -110        | 0,001 16                 | 654                          | -43,99                      | -43,99            | -0,129 8             | 1,343 3                     | 2,031 8                     | 1 611,8               | -0,56                       |
| vapour                                                                                                                   |             |                          | 0,037 9                      | 414,65                      | 445,37            | 2,869 7              | 0,961 4                     | 1,151                       | 191,67                | 92,38                       |
| liquid                                                                                                                   | -105        | 0,001 87                 | 648,9                        | -33,8                       | -33,8             | -0,068 3             | 1,346 4                     | 2,042 6                     | 1 578,4               | -0,553                      |
| vapour                                                                                                                   |             |                          | 0,059                        | 419,45                      | 451,1             | 2,815 5              | 0,977 5                     | 1,167 5                     | 194,24                | 85,93                       |
| liquid                                                                                                                   | -100        | 0,002 9                  | 643,7                        | -23,56                      | -23,56            | -0,008 3             | 1,350 2                     | 2,053 8                     | 1 544,9               | -0,545 6                    |
| vapour                                                                                                                   |             |                          | 0,089                        | 424,32                      | 456,88            | 2,766 4              | 0,993 7                     | 1,184 5                     | 196,75                | 80,06                       |
| liquid                                                                                                                   | -95         | 0,004 38                 | 638,5                        | -13,27                      | -13,26            | 0,050 4              | 1,354 6                     | 2,065 7                     | 1 511,5               | -0,537 7                    |
| vapour                                                                                                                   |             |                          | 0,130 9                      | 429,24                      | 462,71            | 2,722 1              | 1,010 3                     | 1,201 9                     | 199,18                | 74,67                       |
| liquid                                                                                                                   | -90         | 0,006 45                 | 633,3                        | -2,91                       | -2,9              | 0,107 7              | 1,359 8                     | 2,078 3                     | 1 478                 | -0,529 2                    |
| vapour                                                                                                                   |             |                          | 0,187 6                      | 434,22                      | 468,58            | 2,682                | 1,027 2                     | 1,22                        | 201,53                | 69,69                       |
| liquid                                                                                                                   | -85         | 0,009 27                 | 628,1                        | 7,52                        | 7,53              | 0,163 9              | 1,365 7                     | 2,091 7                     | 1 444,6               | -0,520 2                    |
| vapour                                                                                                                   |             |                          | 0,263                        | 439,25                      | 474,49            | 2,645 7              | 1,044 6                     | 1,238 7                     | 203,78                | 65,08                       |
| liquid                                                                                                                   | -80         | 0,013                    | 622,8                        | 18,01                       | 18,03             | 0,218 9              | 1,372 3                     | 2,105 9                     | 1 411,2               | -0,510 6                    |
| vapour                                                                                                                   |             |                          | 0,361                        | 444,32                      | 480,44            | 2,613                | 1,062 5                     | 1,258 3                     | 205,94                | 60,81                       |
| liquid                                                                                                                   | -75         | 0,018                    | 617,4                        | 28,57                       | 28,6              | 0,272 9              | 1,379 7                     | 2,120 9                     | 1 377,8               | -0,500 3                    |
| vapour                                                                                                                   |             |                          | 0,487                        | 449,45                      | 486,41            | 2,583 3              | 1,081                       | 1,278 9                     | 207,99                | 56,85                       |
| liquid                                                                                                                   | -70         | 0,024 4                  | 612                          | 39,21                       | 39,25             | 0,325 9              | 1,387 8                     | 2,136 9                     | 1 344,6               | -0,489 3                    |
| vapour                                                                                                                   |             |                          | 0,646                        | 454,61                      | 492,41            | 2,556 6              | 1,100 1                     | 1,300 3                     | 209,94                | 53,19                       |
| liquid                                                                                                                   | -65         | 0,032 5                  | 606,6                        | 49,93                       | 49,99             | 0,378 1              | 1,396 7                     | 2,154                       | 1 311,4               | -0,477 6                    |
| vapour                                                                                                                   |             |                          | 0,843                        | 459,82                      | 498,42            | 2,532 4              | 1,119 7                     | 1,322 9                     | 211,76                | 49,82                       |
| a Triple point                                                                                                           |             |                          |                              |                             |                   |                      |                             |                             |                       |                             |
| b Normal boiling point                                                                                                   |             |                          |                              |                             |                   |                      |                             |                             |                       |                             |
| * The values of C <sub>v</sub> , C <sub>p</sub> , and w at the critical point are not included as part of this document. |             |                          |                              |                             |                   |                      |                             |                             |                       |                             |

Table 51 (continued)

|        | Temp.<br>°C         | Pressure<br>MPa | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | C <sub>v</sub><br>kJ/(kg·K) | C <sub>p</sub><br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|--------|---------------------|-----------------|------------------------------|-----------------------------|-------------------|----------------------|-----------------------------|-----------------------------|-----------------------|-----------------------------|
| liquid | -60                 | 0,042 7         | 601,1                        | 60,74                       | 60,81             | 0,429 4              | 1,406 3                     | 2,172                       | 1 278,4               | -0,465 1                    |
| vapour |                     |                 | 1,084                        | 465,05                      | 504,44            | 2,510 7              | 1,14                        | 1,346 5                     | 213,46                | 46,72                       |
| liquid | -55                 | 0,055 2         | 595,5                        | 71,64                       | 71,73             | 0,479 9              | 1,416 6                     | 2,191 2                     | 1 245,4               | -0,451 8                    |
| vapour |                     |                 | 1,376                        | 470,32                      | 510,46            | 2,491                | 1,160 8                     | 1,371 2                     | 215,03                | 43,88                       |
| liquid | -50                 | 0,070 6         | 589,9                        | 82,63                       | 82,75             | 0,529 8              | 1,427 6                     | 2,211 5                     | 1 212,5               | -0,437 4                    |
| vapour |                     |                 | 1,727                        | 475,61                      | 516,48            | 2,473 4              | 1,182 3                     | 1,397 1                     | 216,45                | 41,27                       |
| liquid | -45                 | 0,089 1         | 584,2                        | 93,73                       | 93,88             | 0,578 9              | 1,439 3                     | 2,233                       | 1 179,7               | -0,422 1                    |
| vapour |                     |                 | 2,143                        | 480,93                      | 522,49            | 2,457 5              | 1,204 3                     | 1,424 2                     | 217,73                | 38,9                        |
| liquid | -42,11 <sup>b</sup> | 0,101 3         | 580,9                        | 100,18                      | 100,36            | 0,607                | 1,446 3                     | 2,246                       | 1 160,8               | -0,412 8                    |
| vapour |                     |                 | 2,416                        | 484,01                      | 525,95            | 2,449 1              | 1,217 3                     | 1,440 4                     | 218,4                 | 37,63                       |
| liquid | -40                 | 0,111 1         | 578,4                        | 104,93                      | 105,12            | 0,627 5              | 1,451 5                     | 2,255 8                     | 1 147                 | -0,405 7                    |
| vapour |                     |                 | 2,633                        | 486,27                      | 528,48            | 2,443 3              | 1,226 9                     | 1,452 6                     | 218,85                | 36,74                       |
| liquid | -35                 | 0,137 2         | 572,6                        | 116,25                      | 116,49            | 0,675 5              | 1,464 4                     | 2,279 9                     | 1 114,4               | -0,388                      |
| vapour |                     |                 | 3,204                        | 491,62                      | 534,45            | 2,430 6              | 1,25                        | 1,482 2                     | 219,81                | 34,77                       |
| liquid | -30                 | 0,167 8         | 566,6                        | 127,68                      | 127,97            | 0,723 1              | 1,477 9                     | 2,305 4                     | 1 081,7               | -0,369 1                    |
| vapour |                     |                 | 3,867                        | 496,98                      | 540,38            | 2,419 2              | 1,273 6                     | 1,513 3                     | 220,6                 | 32,98                       |
| liquid | -25                 | 0,203 4         | 560,6                        | 139,24                      | 139,6             | 0,770 1              | 1,492                       | 2,332 3                     | 1 049,1               | -0,348 6                    |
| vapour |                     |                 | 4,63                         | 502,35                      | 546,28            | 2,409                | 1,297 8                     | 1,546                       | 221,21                | 31,35                       |
| liquid | -20                 | 0,244 5         | 554,5                        | 150,92                      | 151,36            | 0,816 8              | 1,506 8                     | 2,360 8                     | 1 016,5               | -0,326 5                    |
| vapour |                     |                 | 5,505                        | 507,71                      | 552,13            | 2,399 9              | 1,322 5                     | 1,580 3                     | 221,64                | 29,88                       |
| liquid | -15                 | 0,291 6         | 548,2                        | 162,74                      | 163,28            | 0,863                | 1,522 1                     | 2,391                       | 983,8                 | -0,302 6                    |
| vapour |                     |                 | 6,501                        | 513,07                      | 557,93            | 2,391 8              | 1,347 8                     | 1,616 5                     | 221,87                | 28,54                       |
| liquid | -10                 | 0,345 3         | 541,8                        | 174,71                      | 175,35            | 0,909                | 1,538 1                     | 2,423                       | 951,1                 | -0,276 7                    |
| vapour |                     |                 | 7,632                        | 518,41                      | 563,65            | 2,384 6              | 1,373 7                     | 1,654 8                     | 221,89                | 27,33                       |
| liquid | -5                  | 0,406           | 535,3                        | 186,83                      | 187,59            | 0,954 6              | 1,554 6                     | 2,457                       | 918,3                 | -0,248 4                    |
| vapour |                     |                 | 8,91                         | 523,73                      | 569,3             | 2,378 1              | 1,400 2                     | 1,695 4                     | 221,7                 | 26,23                       |
| liquid | 0                   | 0,474 5         | 528,6                        | 199,1                       | 200               | 1                    | 1,571 8                     | 2,493 2                     | 885,5                 | -0,217 4                    |
| vapour |                     |                 | 10,351                       | 529,03                      | 574,87            | 2,372 4              | 1,427 4                     | 1,738 7                     | 221,3                 | 25,24                       |
| liquid | 5                   | 0,551 1         | 521,8                        | 211,54                      | 212,6             | 1,045 2              | 1,589 6                     | 2,531 8                     | 852,5                 | -0,183 3                    |
| vapour |                     |                 | 11,969                       | 534,28                      | 580,33            | 2,367 2              | 1,455 3                     | 1,785 2                     | 220,65                | 24,35                       |
| liquid | 10                  | 0,636 6         | 514,7                        | 224,16                      | 225,4             | 1,090 2              | 1,608 1                     | 2,573 3                     | 819,4                 | -0,145 7                    |
| vapour |                     |                 | 13,783                       | 539,48                      | 585,67            | 2,362 6              | 1,484 1                     | 1,835 3                     | 219,77                | 23,55                       |
| liquid | 15                  | 0,731 5         | 507,5                        | 236,96                      | 238,4             | 1,135 1              | 1,627 1                     | 2,617 9                     | 786,2                 | -0,103 9                    |
| vapour |                     |                 | 15,813                       | 544,63                      | 590,89            | 2,358 3              | 1,513 7                     | 1,889 7                     | 218,63                | 22,83                       |
| liquid | 20                  | 0,836 5         | 500,1                        | 249,96                      | 251,64            | 1,179 9              | 1,646 8                     | 2,666 2                     | 752,9                 | -0,057                      |
| vapour |                     |                 | 18,082                       | 549,69                      | 595,95            | 2,354 4              | 1,544 2                     | 1,949 2                     | 217,22                | 22,19                       |
| liquid | 25                  | 0,952 1         | 492,4                        | 263,17                      | 265,11            | 1,224 7              | 1,667 1                     | 2,718 9                     | 719,3                 | -0,004 3                    |
| vapour |                     |                 | 20,618                       | 554,66                      | 600,84            | 2,350 7              | 1,575 9                     | 2,014 7                     | 215,53                | 21,61                       |
| liquid | 30                  | 1,079           | 484,4                        | 276,61                      | 278,83            | 1,269 5              | 1,688 1                     | 2,776 7                     | 685,5                 | 0,055 6                     |
| vapour |                     |                 | 23,451                       | 559,53                      | 605,54            | 2,347 1              | 1,608 6                     | 2,087 7                     | 213,53                | 21,1                        |
| liquid | 35                  | 1,217 9         | 476,1                        | 290,28                      | 292,84            | 1,314 3              | 1,709 7                     | 2,840 8                     | 651,4                 | 0,124 4                     |

<sup>a</sup> Triple point

<sup>b</sup> Normal boiling point

\* The values of C<sub>v</sub>, C<sub>p</sub>, and w at the critical point are not included as part of this document.

Table 51 (continued)

|                                                                                                          | Temp.<br>°C | Pressure<br>MPa | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|----------------------------------------------------------------------------------------------------------|-------------|-----------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| vapour                                                                                                   |             |                 | 26,618                       | 564,25                      | 610,01            | 2,343 6              | 1,642 6            | 2,169 7            | 211,22                | 20,66                       |
| liquid                                                                                                   | 40          | 1,369 4         | 467,5                        | 304,22                      | 307,15            | 1,359 4              | 1,732 2            | 2,912 7            | 617                   | 0,204 1                     |
| vapour                                                                                                   |             |                 | 30,165                       | 568,82                      | 614,21            | 2,339 9              | 1,677 9            | 2,263 2            | 208,57                | 20,27                       |
| liquid                                                                                                   | 45          | 1,534 3         | 458,4                        | 318,44                      | 321,79            | 1,404 6              | 1,755 5            | 2,994 6            | 582,1                 | 0,297 7                     |
| vapour                                                                                                   |             |                 | 34,146                       | 573,18                      | 618,12            | 2,336                | 1,714 8            | 2,371 3            | 205,56                | 19,94                       |
| liquid                                                                                                   | 50          | 1,713 3         | 448,9                        | 332,98                      | 336,8             | 1,450 2              | 1,779 8            | 3,089 3            | 546,8                 | 0,409 1                     |
| vapour                                                                                                   |             |                 | 38,63                        | 577,31                      | 621,66            | 2,331 7              | 1,753 4            | 2,498 7            | 202,17                | 19,66                       |
| liquid                                                                                                   | 55          | 1,907 2         | 438,8                        | 347,88                      | 352,23            | 1,496 2              | 1,805 3            | 3,201 3            | 510,9                 | 0,544 1                     |
| vapour                                                                                                   |             |                 | 43,706                       | 581,14                      | 624,77            | 2,326 8              | 1,793 8            | 2,651 9            | 198,35                | 19,44                       |
| liquid                                                                                                   | 60          | 2,116 7         | 428                          | 363,19                      | 368,14            | 1,542 9              | 1,832 3            | 3,337 5            | 474,2                 | 0,710 9                     |
| vapour                                                                                                   |             |                 | 49,493                       | 584,59                      | 627,36            | 2,321                | 1,835 9            | 2,841 4            | 194,07                | 19,27                       |
| liquid                                                                                                   | 65          | 2,342 9         | 416,3                        | 378,98                      | 384,6             | 1,590 3              | 1,861              | 3,508 9            | 436,6                 | 0,922 3                     |
| vapour                                                                                                   |             |                 | 56,152                       | 587,56                      | 629,29            | 2,313 9              | 1,880 4            | 3,086 3            | 189,32                | 19,16                       |
| liquid                                                                                                   | 70          | 2,586 8         | 403,6                        | 395,34                      | 401,75            | 1,638 9              | 1,892 3            | 3,734 9            | 397,9                 | 1,199 1                     |
| vapour                                                                                                   |             |                 | 63,916                       | 589,9                       | 630,37            | 2,305 2              | 1,929 6            | 3,421 4            | 184,05                | 19,1                        |
| liquid                                                                                                   | 75          | 2,849 3         | 389,5                        | 412,45                      | 419,76            | 1,689 1              | 1,927 2            | 4,052 9            | 357,5                 | 1,577                       |
| vapour                                                                                                   |             |                 | 73,14                        | 591,37                      | 630,33            | 2,293 9              | 1,987 1            | 3,914              | 178,18                | 19,04                       |
| liquid                                                                                                   | 80          | 3,131 9         | 373,3                        | 430,54                      | 438,93            | 1,741 7              | 1,968 8            | 4,544 5            | 314,9                 | 2,123 1                     |
| vapour                                                                                                   |             |                 | 84,406                       | 591,62                      | 628,73            | 2,279 1              | 2,057 1            | 4,706 7            | 171,59                | 18,95                       |
| liquid                                                                                                   | 85          | 3,436 1         | 354                          | 450,1                       | 459,81            | 1,798                | 2,023 1            | 5,432 8            | 269,1                 | 2,98                        |
| vapour                                                                                                   |             |                 | 98,818                       | 589,98                      | 624,75            | 2,258 5              | 2,144 2            | 6,182 4            | 164,14                | 18,73                       |
| liquid                                                                                                   | 90          | 3,764 1         | 328,8                        | 472,26                      | 483,71            | 1,861 6              | 2,107              | 7,623 3            | 218,3                 | 4,519 8                     |
| vapour                                                                                                   |             |                 | 118,995                      | 584,84                      | 616,47            | 2,227 2              | 2,260 3            | 9,887 6            | 155,53                | 18,17                       |
| liquid                                                                                                   | 95          | 4,119 5         | 286,5                        | 501,95                      | 516,33            | 1,947 6              | 2,302 4            | 23,59 4            | 158,1                 | 8,238 5                     |
| vapour                                                                                                   |             |                 | 156,308                      | 569,45                      | 595,81            | 2,163 5              | 2,467 5            | 36,065 7           | 144,07                | 16,38                       |
| critical                                                                                                 | 96,74       | 4,251 2         | 220,5                        | 535,95                      | 555,23            | 2,051 6              | *                  | *                  | *                     | 12,899 5                    |
| a Triple point                                                                                           |             |                 |                              |                             |                   |                      |                    |                    |                       |                             |
| b Normal boiling point                                                                                   |             |                 |                              |                             |                   |                      |                    |                    |                       |                             |
| * The values of $C_v$ , $C_p$ , and $w$ at the critical point are not included as part of this document. |             |                 |                              |                             |                   |                      |                    |                    |                       |                             |

## 5.17 R600a – Isobutane

### 5.17.1 Range of validity

$$T_{\min} = 113,73 \text{ K}, T_{\max} = 575 \text{ K}; p_{\max} = 35 \text{ MPa}; \rho_{\max} = 12,9 \text{ mol/l (749,8 kg/m}^3\text{)}$$

### 5.17.2 Coefficients and exponents of the ideal-gas part (Formulae 3 to 5)

Coefficients and exponents of the ideal-gas part are listed in Table 52 and Table 53. Coefficients and exponents of the real-gas part are listed in Table 54 and Table 55.

Table 52 — Coefficients and exponents for  $k = 0$ 

| $k$ | $c_k$        |
|-----|--------------|
| 0   | 4,059 566 19 |

**Table 53 — Coefficients and exponents for  $k = 1$  up to 4**

| $k$ | $a_k$        | $b_k$        |
|-----|--------------|--------------|
| 1   | 4,946 410 14 | 387,940 64   |
| 2   | 4,094 751 97 | 973,807 82   |
| 3   | 15,663 282 4 | 1 772,711 03 |
| 4   | 9,739 181 22 | 4 228,524 24 |

**5.17.3 Coefficients and exponents of the real-gas part (Formula 2)****Table 54 — Coefficients and exponents for  $k = 1$  up to 23**

| $k$ | $N_k$          | $t_k$ | $d_k$ | $l_k$ | $\alpha_k$ |
|-----|----------------|-------|-------|-------|------------|
| 1   | 2,068 682 073  | 0,5   | 1     | 0     | 0          |
| 2   | -3,640 009 862 | 1     | 1     | 0     | 0          |
| 3   | 0,519 687 544  | 1,5   | 1     | 0     | 0          |
| 4   | 0,177 458 459  | 0     | 2     | 0     | 0          |
| 5   | -0,123 618 079 | 0,5   | 3     | 0     | 0          |
| 6   | 0,045 145 314  | 0,5   | 4     | 0     | 0          |
| 7   | 0,030 476 48   | 0,75  | 4     | 0     | 0          |
| 8   | 0,755 083 877  | 2     | 1     | 1     | 0          |
| 9   | -0,858 853 81  | 2,5   | 1     | 1     | 0          |
| 10  | 0,036 324 01   | 2,5   | 2     | 1     | 0          |
| 11  | -0,019 548 799 | 1,5   | 7     | 1     | 0          |
| 12  | -0,004 445 239 | 1     | 8     | 1     | 0          |
| 13  | 0,004 641 076  | 1,5   | 8     | 1     | 0          |
| 14  | -0,071 444 098 | 4     | 1     | 2     | 0          |
| 15  | -0,080 765 06  | 7     | 2     | 2     | 0          |
| 16  | 0,155 604 609  | 3     | 3     | 2     | 0          |
| 17  | 0,002 031 875  | 7     | 3     | 2     | 0          |
| 18  | -0,106 248 836 | 3     | 4     | 2     | 0          |
| 19  | 0,039 807 691  | 1     | 5     | 2     | 0          |
| 20  | 0,016 371 431  | 6     | 5     | 2     | 0          |
| 21  | 0,000 532 122  | 0     | 10    | 2     | 0          |
| 22  | -0,007 868 156 | 6     | 2     | 3     | 0          |
| 23  | -0,003 098 119 | 13    | 6     | 3     | 0          |

**Table 55 — Coefficients and exponents for  $k = 24$  up to 25**

| $k$ | $N_k$          | $t_k$ | $d_k$ | $l_k$ | $\alpha_k$ | $m_k$ | $\beta_k$ | $\gamma_k$ | $\varepsilon_k$ |
|-----|----------------|-------|-------|-------|------------|-------|-----------|------------|-----------------|
| 24  | -0,042 276 037 | 2     | 1     | 2     | 2          | -10   | -150      | 1,16       | 0,85            |
| 25  | -0,005 300 104 | 0     | 2     | 2     | 2          | -10   | -200      | 1,13       | 1               |

**5.17.4 Reducing parameters, molar mass, and gas constant**

$$T^* = 407,81 \text{ K}, \rho^* = 3,879\,756\,788 \text{ mol/l}, M = 58,122\,2 \text{ g/mol}, R = 8,314\,459\,8 \text{ J/(mol}\cdot\text{K)}$$

## 5.17.5 Reference state parameters

$$T_{\text{ref}} = 273,15 \text{ K}, p_{\text{ref}} = 1,0 \text{ kPa}, h_{\text{ref}} = 32\,638,234 \text{ J/mol}, s_{\text{ref}} = 176,637 \text{ J/(mol}\cdot\text{K)}$$

R600a (isobutane) Property values along the liquid-vapour saturation boundary are listed in [Table 56](#).

**Table 56 — R600a (isobutane) Property values along the liquid-vapour saturation boundary**

|        | Temp.<br>°C          | Pressure<br>MPa        | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|--------|----------------------|------------------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| liquid | -159,42 <sup>a</sup> | $2,289 \times 10^{-8}$ | 740,3                        | -112,38                     | -112,38           | -0,679 8             | 1,174 1            | 1,688 8            | 1 999,8               | -0,683 8                    |
| vapour |                      |                        | $1,407 \times 10^{-6}$       | 352,05                      | 368,32            | 3,546 8              | 0,736 6            | 0,879 6            | 139,39                | 577,37                      |
| liquid | -155                 | $6,886 \times 10^{-8}$ | 736,2                        | -104,88                     | -104,88           | -0,615 2             | 1,183 2            | 1,702 7            | 1 961,2               | -0,676 9                    |
| vapour |                      |                        | $4,074 \times 10^{-6}$       | 355,35                      | 372,25            | 3,423 2              | 0,757 1            | 0,900 1            | 141,76                | 498,97                      |
| liquid | -150                 | $2,156 \times 10^{-7}$ | 731,4                        | -96,33                      | -96,33            | -0,544 3             | 1,193 9            | 1,718 7            | 1 918,9               | -0,669                      |
| vapour |                      |                        | $1,224 \times 10^{-5}$       | 359,19                      | 376,81            | 3,297 7              | 0,779 8            | 0,922 9            | 144,39                | 426,39                      |
| liquid | -145                 | $6,122 \times 10^{-7}$ | 726,7                        | -87,69                      | -87,69            | -0,475 6             | 1,204 7            | 1,734 9            | 1 878,1               | -0,661 1                    |
| vapour |                      |                        | $3,339 \times 10^{-5}$       | 363,15                      | 381,48            | 3,185 6              | 0,802              | 0,945 1            | 146,98                | 367,2                       |
| liquid | -140                 | $1,594 \times 10^{-6}$ | 722,0                        | -78,98                      | -78,98            | -0,408 9             | 1,215 5            | 1,751              | 1 838,8               | -0,653 1                    |
| vapour |                      |                        | $8,369 \times 10^{-5}$       | 367,21                      | 386,26            | 3,085 2              | 0,823 8            | 0,966 9            | 149,51                | 318,49                      |
| liquid | -135                 | $3,845 \times 10^{-6}$ | 717,3                        | -70,18                      | -70,18            | -0,344               | 1,226 2            | 1,767              | 1 800,6               | -0,645 2                    |
| vapour |                      |                        | $1,945 \times 10^{-4}$       | 371,39                      | 391,15            | 2,995 3              | 0,845 1            | 0,988 2            | 152,01                | 278,06                      |
| liquid | -130                 | $8,660 \times 10^{-6}$ | 712,5                        | -61,31                      | -61,31            | -0,280 9             | 1,236 8            | 1,783              | 1 763,6               | -0,637 3                    |
| vapour |                      |                        | $4,229 \times 10^{-4}$       | 375,66                      | 396,14            | 2,914 7              | 0,866 1            | 1,009 2            | 154,46                | 244,24                      |
| liquid | -125                 | $1,835 \times 10^{-5}$ | 707,8                        | -52,35                      | -52,35            | -0,219 4             | 1,247 3            | 1,798 8            | 1 727,5               | -0,629 3                    |
| vapour |                      |                        | $8,658 \times 10^{-4}$       | 380,04                      | 401,24            | 2,842 3              | 0,886 8            | 1,029 9            | 156,88                | 215,75                      |
| liquid | -120                 | $3,679 \times 10^{-5}$ | 703,0                        | -43,32                      | -43,32            | -0,159 5             | 1,257 8            | 1,814 7            | 1 692,3               | -0,621 4                    |
| vapour |                      |                        | $1,680 \times 10^{-3}$       | 384,53                      | 406,43            | 2,777 2              | 0,907 2            | 1,050 3            | 159,25                | 191,58                      |
| liquid | -115                 | $7,023 \times 10^{-5}$ | 698,3                        | -34,21                      | -34,21            | -0,100 9             | 1,268 3            | 1,830 4            | 1 657,8               | -0,613 3                    |
| vapour |                      |                        | $3,105 \times 10^{-3}$       | 389,11                      | 411,73            | 2,718 8              | 0,927 4            | 1,070 5            | 161,58                | 170,94                      |
| liquid | -110                 | 0,000 128              | 693,5                        | -25,02                      | -25,02            | -0,043 7             | 1,278 8            | 1,846 3            | 1 624                 | -0,605 2                    |
| vapour |                      |                        | 0,005 49                     | 393,79                      | 417,12            | 2,666 3              | 0,947 4            | 1,090 6            | 163,87                | 153,22                      |
| liquid | -105                 | 0,000 225              | 688,7                        | -15,75                      | -15,75            | 0,012 3              | 1,289 5            | 1,862 1            | 1 590,8               | -0,597                      |
| vapour |                      |                        | 0,009 34                     | 398,56                      | 422,61            | 2,619 2              | 0,967 3            | 1,110 7            | 166,12                | 137,92                      |
| liquid | -100                 | 0,000 379              | 683,9                        | -6,4                        | -6,39             | 0,067 1              | 1,300 3            | 1,878 1            | 1 558,1               | -0,588 6                    |
| vapour |                      |                        | 0,015 33                     | 403,44                      | 428,19            | 2,577                | 0,987 2            | 1,130 7            | 168,33                | 124,65                      |
| liquid | -95                  | 0,000 62               | 679,1                        | 3,04                        | 3,04              | 0,120 8              | 1,311 3            | 1,894 3            | 1 525,8               | -0,580 1                    |
| vapour |                      |                        | 0,024 34                     | 408,4                       | 433,86            | 2,539 1              | 1,007 1            | 1,150 8            | 170,5                 | 113,08                      |
| liquid | -90                  | 0,000 982              | 674,2                        | 12,55                       | 12,55             | 0,173 4              | 1,322 6            | 1,910 6            | 1 494                 | -0,571 3                    |
| vapour |                      |                        | 0,037 53                     | 413,45                      | 439,62            | 2,505 2              | 1,027              | 1,171              | 172,62                | 102,95                      |
| liquid | -85                  | 0,001 51               | 669,4                        | 22,14                       | 22,14             | 0,225 1              | 1,334 1            | 1,927 2            | 1 462,5               | -0,562 4                    |
| vapour |                      |                        | 0,056 3                      | 418,6                       | 445,46            | 2,475                | 1,047 1            | 1,191 4            | 174,69                | 94,04                       |
| liquid | -80                  | 0,002 27               | 664,5                        | 31,82                       | 31,82             | 0,275 9              | 1,345 9            | 1,944 1            | 1 431,3               | -0,553 2                    |
| vapour |                      |                        | 0,082 4                      | 423,83                      | 451,39            | 2,448 1              | 1,067 3            | 1,212 1            | 176,71                | 86,19                       |
| liquid | -75                  | 0,003 33               | 659,5                        | 41,58                       | 41,59             | 0,325 8              | 1,358              | 1,961 3            | 1 400,5               | -0,543 7                    |
| vapour |                      |                        | 0,117 8                      | 429,14                      | 457,4             | 2,424 2              | 1,087 6            | 1,233              | 178,67                | 79,24                       |

<sup>a</sup> Triple point

<sup>b</sup> Normal boiling point

\* The values of  $C_v$ ,  $C_p$ , and  $w$  at the critical point are not included as part of this document.

Table 56 (continued)

|        | Temp.<br>°C         | Pressure<br>MPa | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | C <sub>v</sub><br>kJ/(kg·K) | C <sub>p</sub><br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|--------|---------------------|-----------------|------------------------------|-----------------------------|-------------------|----------------------|-----------------------------|-----------------------------|-----------------------|-----------------------------|
| liquid | -70                 | 0,004 78        | 654,6                        | 51,43                       | 51,44             | 0,374 9              | 1,370 5                     | 1,978 9                     | 1 369,9               | -0,533 9                    |
| vapour |                     |                 | 0,165                        | 434,54                      | 463,48            | 2,403 1              | 1,108 2                     | 1,254 3                     | 180,57                | 73,07                       |
| liquid | -65                 | 0,006 71        | 649,6                        | 61,37                       | 61,38             | 0,423 2              | 1,383 4                     | 1,996 9                     | 1 339,5               | -0,523 8                    |
| vapour |                     |                 | 0,226 8                      | 440,02                      | 469,63            | 2,384 5              | 1,129 1                     | 1,276 1                     | 182,41                | 67,57                       |
| liquid | -60                 | 0,009 27        | 644,6                        | 71,4                        | 71,41             | 0,470 8              | 1,396 7                     | 2,015 3                     | 1 309,4               | -0,513 4                    |
| vapour |                     |                 | 0,306 2                      | 445,58                      | 475,85            | 2,368 3              | 1,150 2                     | 1,298 3                     | 184,18                | 62,66                       |
| liquid | -55                 | 0,012 6         | 639,5                        | 81,52                       | 81,54             | 0,517 7              | 1,410 3                     | 2,034 2                     | 1 279,6               | -0,502 5                    |
| vapour |                     |                 | 0,407                        | 451,22                      | 482,14            | 2,354 1              | 1,171 7                     | 1,321 1                     | 185,88                | 58,26                       |
| liquid | -50                 | 0,016 8         | 634,4                        | 91,74                       | 91,76             | 0,564                | 1,424 3                     | 2,053 6                     | 1 249,9               | -0,491 2                    |
| vapour |                     |                 | 0,532                        | 456,92                      | 488,49            | 2,341 9              | 1,193 5                     | 1,344 4                     | 187,49                | 54,31                       |
| liquid | -45                 | 0,022 1         | 629,3                        | 102,05                      | 102,09            | 0,609 8              | 1,438 8                     | 2,073 5                     | 1 220,4               | -0,479 5                    |
| vapour |                     |                 | 0,687                        | 462,7                       | 494,89            | 2,331 5              | 1,215 6                     | 1,368 3                     | 189,01                | 50,76                       |
| liquid | -40                 | 0,028 7         | 624,1                        | 112,47                      | 112,51            | 0,654 9              | 1,453 7                     | 2,094                       | 1 191,1               | -0,467 2                    |
| vapour |                     |                 | 0,875                        | 468,55                      | 501,35            | 2,322 7              | 1,238 2                     | 1,392 9                     | 190,45                | 47,55                       |
| liquid | -35                 | 0,036 8         | 618,9                        | 122,98                      | 123,04            | 0,699 5              | 1,469                       | 2,115 2                     | 1 161,9               | -0,454 4                    |
| vapour |                     |                 | 1,102                        | 474,46                      | 507,85            | 2,315 4              | 1,261 1                     | 1,418 3                     | 191,79                | 44,66                       |
| liquid | -30                 | 0,046 6         | 613,6                        | 133,61                      | 133,68            | 0,743 7              | 1,484 7                     | 2,136 9                     | 1 132,9               | -0,441                      |
| vapour |                     |                 | 1,373                        | 480,44                      | 514,4             | 2,309 5              | 1,284 4                     | 1,444 3                     | 193,02                | 42,04                       |
| liquid | -25                 | 0,058 4         | 608,3                        | 144,34                      | 144,43            | 0,787 4              | 1,500 8                     | 2,159 3                     | 1 104                 | -0,427                      |
| vapour |                     |                 | 1,693                        | 486,48                      | 520,99            | 2,304 8              | 1,308 1                     | 1,471 2                     | 194,14                | 39,67                       |
| liquid | -20                 | 0,072 5         | 602,9                        | 155,18                      | 155,3             | 0,830 6              | 1,517 3                     | 2,182 4                     | 1 075,3               | -0,412 2                    |
| vapour |                     |                 | 2,069                        | 492,57                      | 527,61            | 2,301 3              | 1,332 3                     | 1,498 9                     | 195,14                | 37,51                       |
| liquid | -15                 | 0,089 1         | 597,4                        | 166,14                      | 166,29            | 0,873 5              | 1,534 2                     | 2,206 3                     | 1 046,7               | -0,396 6                    |
| vapour |                     |                 | 2,506                        | 498,72                      | 534,26            | 2,298 9              | 1,356 8                     | 1,527 5                     | 196,03                | 35,55                       |
| liquid | -11,75 <sup>b</sup> | 0,101 3         | 593,8                        | 173,32                      | 173,5             | 0,901 2              | 1,545 4                     | 2,222 2                     | 1 028,1               | -0,386 1                    |
| vapour |                     |                 | 2,827                        | 502,75                      | 538,59            | 2,297 9              | 1,373                       | 1,546 6                     | 196,53                | 34,37                       |
| liquid | -10                 | 0,108 4         | 591,9                        | 177,21                      | 177,4             | 0,916                | 1,551 5                     | 2,230 9                     | 1 018,2               | -0,380 2                    |
| vapour |                     |                 | 3,012                        | 504,92                      | 540,93            | 2,297 5              | 1,381 8                     | 1,557                       | 196,78                | 33,76                       |
| liquid | -5                  | 0,131 0         | 586,3                        | 188,41                      | 188,63            | 0,958 2              | 1,569 2                     | 2,256 4                     | 989,8                 | -0,362 8                    |
| vapour |                     |                 | 3,593                        | 511,17                      | 547,63            | 2,296 9              | 1,407 2                     | 1,587 5                     | 197,4                 | 32,13                       |
| liquid | 0                   | 0,157 0         | 580,6                        | 199,73                      | 200               | 1                    | 1,587 3                     | 2,282 7                     | 961,5                 | -0,344 4                    |
| vapour |                     |                 | 4,257                        | 517,47                      | 554,34            | 2,297 2              | 1,432 9                     | 1,619                       | 197,87                | 30,65                       |
| liquid | 5                   | 0,186 7         | 574,8                        | 211,18                      | 211,5             | 1,041 5              | 1,605 7                     | 2,31                        | 933,2                 | -0,324 7                    |
| vapour |                     |                 | 5,012                        | 523,8                       | 561,06            | 2,298 2              | 1,459 1                     | 1,651 7                     | 198,2                 | 29,29                       |
| liquid | 10                  | 0,220 6         | 568,9                        | 222,76                      | 223,15            | 1,082 8              | 1,624 5                     | 2,338 2                     | 905                   | -0,303 7                    |
| vapour |                     |                 | 5,867                        | 530,17                      | 567,78            | 2,3                  | 1,485 7                     | 1,685 6                     | 198,38                | 28,06                       |
| liquid | 15                  | 0,259 0         | 562,9                        | 234,48                      | 234,94            | 1,123 9              | 1,643 6                     | 2,367 6                     | 876,9                 | -0,281 2                    |
| vapour |                     |                 | 6,831                        | 536,58                      | 574,5             | 2,302 3              | 1,512 6                     | 1,720 8                     | 198,39                | 26,93                       |
| liquid | 20                  | 0,302 2         | 556,9                        | 246,34                      | 246,88            | 1,164 7              | 1,663 1                     | 2,398 2                     | 848,8                 | -0,257                      |
| vapour |                     |                 | 7,913                        | 543,02                      | 581,21            | 2,305 1              | 1,54                        | 1,757 3                     | 198,24                | 25,9                        |
| liquid | 25                  | 0,350 7         | 550,7                        | 258,34                      | 258,98            | 1,205 3              | 1,682 9                     | 2,43                        | 820,7                 | -0,230 8                    |

<sup>a</sup> Triple point<sup>b</sup> Normal boiling point\* The values of C<sub>v</sub>, C<sub>p</sub>, and w at the critical point are not included as part of this document.

Table 56 (continued)

|                                                                                                                          | Temp.<br>°C | Pressure<br>MPa | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | C <sub>v</sub><br>kJ/(kg·K) | C <sub>p</sub><br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|--------------------------------------------------------------------------------------------------------------------------|-------------|-----------------|------------------------------|-----------------------------|-------------------|----------------------|-----------------------------|-----------------------------|-----------------------|-----------------------------|
| vapour                                                                                                                   |             |                 | 9,126                        | 549,47                      | 587,9             | 2,308 5              | 1,567 7                     | 1,795 4                     | 197,9                 | 24,97                       |
| liquid                                                                                                                   | 30          | 0,404 7         | 544,3                        | 270,5                       | 271,24            | 1,245 8              | 1,703                       | 2,463 3                     | 792,5                 | -0,202 4                    |
| vapour                                                                                                                   |             |                 | 10,48                        | 555,95                      | 594,57            | 2,312 3              | 1,595 8                     | 1,835 3                     | 197,39                | 24,11                       |
| liquid                                                                                                                   | 35          | 0,464 8         | 537,8                        | 282,81                      | 283,67            | 1,286 1              | 1,723 4                     | 2,498 2                     | 764,4                 | -0,171 5                    |
| vapour                                                                                                                   |             |                 | 11,988                       | 562,44                      | 601,21            | 2,316 5              | 1,624 3                     | 1,877 1                     | 196,68                | 23,34                       |
| liquid                                                                                                                   | 40          | 0,531 2         | 531,2                        | 295,28                      | 296,28            | 1,326 3              | 1,744 2                     | 2,534 9                     | 736,2                 | -0,137 5                    |
| vapour                                                                                                                   |             |                 | 13,666                       | 568,93                      | 607,8             | 2,321 1              | 1,653 3                     | 1,921                       | 195,77                | 22,64                       |
| liquid                                                                                                                   | 45          | 0,604 4         | 524,4                        | 307,92                      | 309,07            | 1,366 4              | 1,765 3                     | 2,573 7                     | 707,9                 | -0,100 1                    |
| vapour                                                                                                                   |             |                 | 15,529                       | 575,42                      | 614,34            | 2,325 9              | 1,682 6                     | 1,967 5                     | 194,64                | 22,01                       |
| liquid                                                                                                                   | 50          | 0,684 9         | 517,4                        | 320,74                      | 322,06            | 1,406 4              | 1,786 8                     | 2,614 8                     | 679,6                 | -0,058 5                    |
| vapour                                                                                                                   |             |                 | 17,595                       | 581,9                       | 620,82            | 2,330 9              | 1,712 3                     | 2,016 7                     | 193,29                | 21,45                       |
| liquid                                                                                                                   | 55          | 0,773 0         | 510,2                        | 333,74                      | 335,25            | 1,446 4              | 1,808 5                     | 2,658 7                     | 651,1                 | -0,012 1                    |
| vapour                                                                                                                   |             |                 | 19,886                       | 588,35                      | 627,22            | 2,336 1              | 1,742 3                     | 2,069 2                     | 191,7                 | 20,95                       |
| liquid                                                                                                                   | 60          | 0,869 2         | 502,7                        | 346,93                      | 348,66            | 1,486 3              | 1,830 7                     | 2,705 8                     | 622,4                 | 0,040 2                     |
| vapour                                                                                                                   |             |                 | 22,426                       | 594,77                      | 633,53            | 2,341 4              | 1,772 4                     | 2,125 3                     | 189,86                | 20,51                       |
| liquid                                                                                                                   | 65          | 0,973 9         | 495                          | 360,32                      | 362,29            | 1,526 3              | 1,853 3                     | 2,756 7                     | 593,5                 | 0,099 5                     |
| vapour                                                                                                                   |             |                 | 25,242                       | 601,14                      | 639,72            | 2,346 7              | 1,802 4                     | 2,185 8                     | 187,75                | 20,15                       |
| liquid                                                                                                                   | 70          | 1,087 5         | 487                          | 373,94                      | 376,17            | 1,566 4              | 1,876 3                     | 2,812 3                     | 564,4                 | 0,167 5                     |
| vapour                                                                                                                   |             |                 | 28,369                       | 607,43                      | 645,77            | 2,352                | 1,832 6                     | 2,251 9                     | 185,36                | 19,86                       |
| liquid                                                                                                                   | 75          | 1,210 7         | 478,6                        | 387,78                      | 390,31            | 1,606 5              | 1,899 8                     | 2,873 6                     | 534,9                 | 0,246 3                     |
| vapour                                                                                                                   |             |                 | 31,846                       | 613,63                      | 651,64            | 2,357 2              | 1,863                       | 2,325 5                     | 182,67                | 19,64                       |
| liquid                                                                                                                   | 80          | 1,343 8         | 469,9                        | 401,87                      | 404,73            | 1,646 9              | 1,923 8                     | 2,942 1                     | 505,1                 | 0,338 6                     |
| vapour                                                                                                                   |             |                 | 35,721                       | 619,69                      | 657,31            | 2,362 1              | 1,894 2                     | 2,409 4                     | 179,65                | 19,49                       |
| liquid                                                                                                                   | 85          | 1,487 4         | 460,7                        | 416,24                      | 419,46            | 1,687 4              | 1,948 5                     | 3,019 9                     | 474,9                 | 0,448 3                     |
| vapour                                                                                                                   |             |                 | 40,057                       | 625,6                       | 662,73            | 2,366 7              | 1,926 8                     | 2,507 4                     | 176,29                | 19,42                       |
| liquid                                                                                                                   | 90          | 1,642 0         | 451,1                        | 430,9                       | 434,54            | 1,728 3              | 1,974                       | 3,11                        | 444,2                 | 0,581                       |
| vapour                                                                                                                   |             |                 | 44,927                       | 631,31                      | 667,86            | 2,370 8              | 1,961 5                     | 2,624 8                     | 172,56                | 19,42                       |
| liquid                                                                                                                   | 95          | 1,808 1         | 440,7                        | 445,9                       | 450               | 1,769 6              | 2,000 5                     | 3,216 8                     | 412,8                 | 0,744 5                     |
| vapour                                                                                                                   |             |                 | 50,43                        | 636,76                      | 672,62            | 2,374 3              | 1,998 9                     | 2,768 9                     | 168,42                | 19,49                       |
| liquid                                                                                                                   | 100         | 1,986 5         | 429,6                        | 461,28                      | 465,9             | 1,811 4              | 2,028 2                     | 3,347 3                     | 380,7                 | 0,951                       |
| vapour                                                                                                                   |             |                 | 56,697                       | 641,9                       | 676,94            | 2,376 9              | 2,039 4                     | 2,951                       | 163,83                | 19,62                       |
| liquid                                                                                                                   | 105         | 2,177 8         | 417,6                        | 477,11                      | 482,33            | 1,853 9              | 2,057 7                     | 3,513 5                     | 347,6                 | 1,219 6                     |
| vapour                                                                                                                   |             |                 | 63,91                        | 646,62                      | 680,7             | 2,378 5              | 2,083 5                     | 3,189 3                     | 158,74                | 19,82                       |
| liquid                                                                                                                   | 110         | 2,382 6         | 404,3                        | 493,5                       | 499,39            | 1,897 4              | 2,089 7                     | 3,736 5                     | 313,3                 | 1,582 1                     |
| vapour                                                                                                                   |             |                 | 72,331                       | 650,8                       | 683,74            | 2,378 5              | 2,131 8                     | 3,517 3                     | 153,11                | 20,1                        |
| liquid                                                                                                                   | 115         | 2,601 9         | 389,4                        | 510,58                      | 517,26            | 1,942 3              | 2,125 7                     | 4,059 4                     | 277,6                 | 2,096                       |
| vapour                                                                                                                   |             |                 | 82,372                       | 654,22                      | 685,81            | 2,376 5              | 2,185 3                     | 4,002 4                     | 146,86                | 20,44                       |
| liquid                                                                                                                   | 120         | 2,836 6         | 372                          | 528,63                      | 536,26            | 1,989 3              | 2,168 5                     | 4,584 6                     | 240                   | 2,875 7                     |
| vapour                                                                                                                   |             |                 | 94,741                       | 656,52                      | 686,46            | 2,371 4              | 2,246 5                     | 4,806                       | 139,9                 | 20,84                       |
| liquid                                                                                                                   | 125         | 3,088 0         | 350,6                        | 548,2                       | 557,01            | 2,04                 | 2,223 8                     | 5,628 6                     | 200                   | 4,186 3                     |
| vapour                                                                                                                   |             |                 | 110,866                      | 656,96                      | 684,81            | 2,361                | 2,320 8                     | 6,428 2                     | 132,07                | 21,21                       |
| a Triple point                                                                                                           |             |                 |                              |                             |                   |                      |                             |                             |                       |                             |
| b Normal boiling point                                                                                                   |             |                 |                              |                             |                   |                      |                             |                             |                       |                             |
| * The values of C <sub>v</sub> , C <sub>p</sub> , and w at the critical point are not included as part of this document. |             |                 |                              |                             |                   |                      |                             |                             |                       |                             |

Table 56 (continued)

|                                                                                                                                                                            | Temp.<br>°C | Pressure<br>MPa | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|-----------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| liquid                                                                                                                                                                     | 130         | 3,357 8         | 321                          | 570,79                      | 581,25            | 2,098 5              | 2,309 3            | 8,908 1            | 156,3                 | 6,819 8                     |
| vapour                                                                                                                                                                     |             |                 | 134,723                      | 653,51                      | 678,44            | 2,339 6              | 2,424 3            | 11,556 8           | 123,05                | 21,22                       |
| critical                                                                                                                                                                   | 134,66      | 3,629 0         | 225,5                        | 617,84                      | 633,94            | 2,225 9              | *                  | *                  | *                     | 16,282 2                    |
| <sup>a</sup> Triple point<br><sup>b</sup> Normal boiling point<br>* The values of $C_v$ , $C_p$ , and $w$ at the critical point are not included as part of this document. |             |                 |                              |                             |                   |                      |                    |                    |                       |                             |

## 5.18 R1336mzz(Z) – (cis-1,1,1,4,4,4-hexafluorobutene)

### 5.18.1 Range of validity

$T_{\min} = 230,0 \text{ K}$ ,  $T_{\max} = 500 \text{ K}$ ;  $p_{\max} = 46 \text{ MPa}$ ;  $\rho_{\max} = 9,725 \text{ mol/l}$  (1 595,5 kg/m<sup>3</sup>)

### 5.18.2 Coefficients and exponents of the ideal-gas part (Formulae 3 to 5)

Coefficients and exponents of the ideal-gas part are listed in Table 57 and Table 58. Coefficients and exponents of the real-gas part are listed in Table 59 and Table 60.

Table 57 — Coefficients and exponents for  $k = 0$ 

| $k$ | $c_k$ |
|-----|-------|
| 0   | 4,00  |

Table 58 — Coefficients and exponents for  $k = 1$  up to 2

| $k$ | $a_k$ | $b_k$   |
|-----|-------|---------|
| 1   | 20,2  | 736,0   |
| 2   | 5,275 | 2 299,0 |

### 5.18.3 Coefficients and exponents of the real-gas part (Formula 2)

Table 59 — Coefficients and exponents for  $k = 1$  up to 10

| $k$ | $N_k$          | $t_k$ | $d_k$ | $l_k$ | $\alpha_k$ |
|-----|----------------|-------|-------|-------|------------|
| 1   | 0,036 673 095  | 1     | 4     | 0     | 1          |
| 2   | 1,195 661 9    | 0,26  | 1     | 0     | 1          |
| 3   | -1,846 237 6   | 1     | 1     | 0     | 1          |
| 4   | -0,605 992 97  | 1     | 2     | 0     | 1          |
| 5   | 0,249 738 33   | 0,515 | 3     | 0     | 1          |
| 6   | -1,254 827 8   | 2,6   | 1     | 2     | 1          |
| 7   | -1,438 961 2   | 3     | 3     | 2     | 1          |
| 8   | 0,351 688 87   | 0,74  | 2     | 1     | 1          |
| 9   | -0,821 040 51  | 2,68  | 2     | 2     | 1          |
| 10  | -0,031 747 538 | 0,96  | 7     | 1     | 1          |

**Table 60 — Coefficients and exponents for  $k = 11$  up to 18**

| $k$ | $N_k$          | $t_k$ | $d_k$ | $l_k$ | $\alpha_k$ | $m_k$    | $\beta_k$ | $\gamma_k$ | $\varepsilon_k$ |
|-----|----------------|-------|-------|-------|------------|----------|-----------|------------|-----------------|
| 11  | 1,028 138 8    | 1,06  | 1     | 2     | 2          | -0,746   | -1,118    | 0,962      | 1,225           |
| 12  | 0,210 940 74   | 3,4   | 1     | 2     | 2          | -2,406   | -3,065    | 1,111      | 0,161           |
| 13  | 0,701 701      | 1,617 | 3     | 2     | 2          | -0,780 4 | -0,727 4  | 1,135      | 1,231           |
| 14  | 0,246 385 28   | 1,865 | 2     | 2     | 2          | -1,25    | -0,843 5  | 1,163      | 1,395           |
| 15  | -1,529 503 4   | 1,737 | 3     | 2     | 2          | -0,682 6 | -0,675 4  | 0,969      | 0,907 2         |
| 16  | 0,334 249 78   | 3,29  | 2     | 2     | 2          | -1,677   | -0,436    | 1,286      | 0,958           |
| 17  | 1,011 324      | 1,242 | 2     | 2     | 2          | -1,762   | -3,808    | 1,274      | 0,412           |
| 18  | -0,023 457 179 | 2     | 1     | 2     | 2          | -21      | -1 888    | 1,056      | 0,944           |

**5.18.4 Reducing parameters, molar mass, and gas constant**

$$T^* = 444,5 \text{ K}, \rho^* = 3,044 \text{ mol/l}, M = 164,056 \text{ g/mol}, R = 8,314 459 8 \text{ J/(mol}\cdot\text{K)}$$

**5.18.5 Reference state parameters**

$$T_{\text{ref}} = 273,15 \text{ K}, p_{\text{ref}} = 1,0 \text{ kPa}, h_{\text{ref}} = 62 425,495 \text{ J/mol}, s_{\text{ref}} = 298,993 7 \text{ J/(mol}\cdot\text{K)}$$

Property values along the liquid-vapour saturation boundary are listed in [Table 61](#).

**Table 61 — R1336mzz(Z) (cis-1,1,1,4,4,4-hexafluorobutene) — Property values along the liquid-vapour saturation boundary**

|        | Temp. | Pressure | Density           | Internal energy | Enthalpy | Entropy   | $C_v$     | $C_p$     | Sound speed | J-T coefficient |
|--------|-------|----------|-------------------|-----------------|----------|-----------|-----------|-----------|-------------|-----------------|
|        | °C    | MPa      | kg/m <sup>3</sup> | kJ/kg           | kJ/kg    | kJ/(kg·K) | kJ/(kg·K) | kJ/(kg·K) | m/s         | K/MPa           |
| liquid | -40   | 0,002 35 | 1 522,9           | 154,9           | 154,9    | 0,821 7   | 0,785 9   | 1,084 2   | 874,9       | -0,391 3        |
| vapour |       |          | 0,199 2           | 339,26          | 351,04   | 1,663     | 0,627 6   | 0,679 2   | 112,71      | 92,58           |
| liquid | -35   | 0,003 32 | 1 511,3           | 160,35          | 160,35   | 0,844 8   | 0,795 8   | 1,095 1   | 854,6       | -0,382 7        |
| vapour |       |          | 0,276 5           | 342,4           | 354,42   | 1,659 7   | 0,642 5   | 0,694 4   | 113,72      | 86,39           |
| liquid | -30   | 0,004 62 | 1 499,7           | 165,85          | 165,86   | 0,867 7   | 0,805 6   | 1,106     | 834,4       | -0,374 1        |
| vapour |       |          | 0,377 4           | 345,6           | 357,85   | 1,657 3   | 0,657     | 0,709 3   | 114,69      | 80,71           |
| liquid | -25   | 0,006 33 | 1 487,9           | 171,41          | 171,41   | 0,890 3   | 0,815 2   | 1,116 8   | 814,6       | -0,365 3        |
| vapour |       |          | 0,507 1           | 348,85          | 361,34   | 1,655 7   | 0,671 3   | 0,724     | 115,64      | 75,47           |
| liquid | -20   | 0,008 54 | 1 476,1           | 177,02          | 177,03   | 0,912 7   | 0,824 6   | 1,127 4   | 795         | -0,356 2        |
| vapour |       |          | 0,671 6           | 352,16          | 364,88   | 1,654 8   | 0,685 3   | 0,738 6   | 116,54      | 70,63           |
| liquid | -15   | 0,011 4  | 1 464,2           | 182,68          | 182,69   | 0,934 9   | 0,833 9   | 1,138     | 775,5       | -0,346 9        |
| vapour |       |          | 0,878             | 355,52          | 368,46   | 1,654 5   | 0,699     | 0,753     | 117,41      | 66,16           |
| liquid | -10   | 0,014 9  | 1 452,2           | 188,4           | 188,41   | 0,956 8   | 0,843 1   | 1,148 5   | 756,3       | -0,337 3        |
| vapour |       |          | 1,133             | 358,93          | 372,09   | 1,654 8   | 0,712 6   | 0,767 4   | 118,22      | 62,03           |
| liquid | -5    | 0,019 3  | 1 440,1           | 194,16          | 194,18   | 0,978 5   | 0,852     | 1,158 9   | 737,3       | -0,327 4        |
| vapour |       |          | 1,445             | 362,39          | 375,76   | 1,655 7   | 0,726     | 0,781 7   | 118,99      | 58,22           |
| liquid | 0     | 0,024 7  | 1 427,8           | 199,98          | 200      | 1         | 0,860 9   | 1,169 2   | 718,5       | -0,317          |
| vapour |       |          | 1,823             | 365,88          | 379,46   | 1,657     | 0,739 2   | 0,795 9   | 119,7       | 54,69           |
| liquid | 5     | 0,031 4  | 1 415,5           | 205,85          | 205,87   | 1,021 3   | 0,869 6   | 1,179 6   | 699,9       | -0,306 3        |
| vapour |       |          | 2,277             | 369,42          | 383,19   | 1,658 8   | 0,752 2   | 0,810 2   | 120,36      | 51,43           |

<sup>b</sup> Normal boiling point

\* The values of  $C_v$ ,  $C_p$ , and  $w$  at the critical point are not included as part of this document.

Table 61 (continued)

|        | Temp.              | Pressure | Density           | Internal energy | Enthalpy | Entropy   | $C_v$     | $C_p$     | Sound speed | J-T coefficient |
|--------|--------------------|----------|-------------------|-----------------|----------|-----------|-----------|-----------|-------------|-----------------|
|        | °C                 | MPa      | kg/m <sup>3</sup> | kJ/kg           | kJ/kg    | kJ/(kg·K) | kJ/(kg·K) | kJ/(kg·K) | m/s         | K/MPa           |
| liquid | 10                 | 0,039 4  | 1 403             | 211,77          | 211,8    | 1,042 4   | 0,878 1   | 1,189 8   | 681,4       | -0,295          |
| vapour |                    |          | 2,818             | 372,99          | 386,95   | 1,661     | 0,765 2   | 0,824 5   | 120,95      | 48,43           |
| liquid | 15                 | 0,048 9  | 1 390,4           | 217,74          | 217,78   | 1,063 3   | 0,886 5   | 1,200 1   | 663,1       | -0,283 2        |
| vapour |                    |          | 3,458             | 376,6           | 390,74   | 1,663 5   | 0,778     | 0,838 9   | 121,47      | 45,67           |
| liquid | 20                 | 0,060 2  | 1 377,6           | 223,77          | 223,81   | 1,084     | 0,894 7   | 1,210 4   | 644,9       | -0,270 7        |
| vapour |                    |          | 4,207             | 380,23          | 394,55   | 1,666 4   | 0,790 7   | 0,853 4   | 121,93      | 43,13           |
| liquid | 25                 | 0,073 6  | 1 364,7           | 229,84          | 229,89   | 1,104 6   | 0,902 8   | 1,220 7   | 626,9       | -0,257 4        |
| vapour |                    |          | 5,081             | 383,89          | 398,37   | 1,669 6   | 0,803 3   | 0,867 9   | 122,31      | 40,79           |
| liquid | 30                 | 0,089 1  | 1 351,6           | 235,96          | 236,03   | 1,124 9   | 0,910 8   | 1,231 1   | 608,9       | -0,243 4        |
| vapour |                    |          | 6,092             | 387,57          | 402,2    | 1,673 1   | 0,815 8   | 0,882 7   | 122,61      | 38,66           |
| liquid | 33,45 <sup>b</sup> | 0,101 3  | 1 342,4           | 240,22          | 240,29   | 1,138 9   | 0,916 2   | 1,238 3   | 596,6       | -0,233 2        |
| vapour |                    |          | 6,88              | 390,13          | 404,86   | 1,675 6   | 0,824 4   | 0,893     | 122,77      | 37,29           |
| liquid | 35                 | 0,107 2  | 1 338,3           | 242,13          | 242,21   | 1,145 1   | 0,918 6   | 1,241 5   | 591,1       | -0,228 4        |
| vapour |                    |          | 7,258             | 391,28          | 406,05   | 1,676 8   | 0,828 2   | 0,897 6   | 122,83      | 36,7            |
| liquid | 40                 | 0,128    | 1 324,8           | 248,36          | 248,45   | 1,165 2   | 0,926 3   | 1,252 1   | 573,3       | -0,212 4        |
| vapour |                    |          | 8,593             | 395             | 409,9    | 1,680 7   | 0,840 5   | 0,912 7   | 122,96      | 34,91           |
| liquid | 45                 | 0,151 9  | 1 311             | 254,63          | 254,75   | 1,185     | 0,933 8   | 1,262 8   | 555,7       | -0,195 1        |
| vapour |                    |          | 10,117            | 398,74          | 413,75   | 1,684 8   | 0,852 8   | 0,928 1   | 123         | 33,28           |
| liquid | 50                 | 0,179 1  | 1 297,1           | 260,95          | 261,09   | 1,204 8   | 0,941 3   | 1,273 7   | 538,1       | -0,176 5        |
| vapour |                    |          | 11,848            | 402,49          | 417,61   | 1,689 1   | 0,864 9   | 0,943 7   | 122,94      | 31,79           |
| liquid | 55                 | 0,209 9  | 1 282,9           | 267,33          | 267,5    | 1,224 4   | 0,948 6   | 1,284 8   | 520,6       | -0,156 2        |
| vapour |                    |          | 13,808            | 406,25          | 421,45   | 1,693 5   | 0,877     | 0,959 7   | 122,77      | 30,45           |
| liquid | 60                 | 0,244 7  | 1 268,4           | 273,76          | 273,95   | 1,243 8   | 0,955 9   | 1,296 2   | 503,1       | -0,134 2        |
| vapour |                    |          | 16,02             | 410,01          | 425,29   | 1,698 1   | 0,889     | 0,976 1   | 122,5       | 29,22           |
| liquid | 65                 | 0,283 7  | 1 253,6           | 280,24          | 280,47   | 1,263 1   | 0,963     | 1,307 9   | 485,7       | -0,110 1        |
| vapour |                    |          | 18,508            | 413,78          | 429,11   | 1,702 7   | 0,900 9   | 0,992 9   | 122,12      | 28,12           |
| liquid | 70                 | 0,327 4  | 1 238,5           | 286,78          | 287,05   | 1,282 3   | 0,970 1   | 1,320 1   | 468,3       | -0,083 6        |
| vapour |                    |          | 21,303            | 417,54          | 432,91   | 1,707 4   | 0,912 7   | 1,010 4   | 121,61      | 27,12           |
| liquid | 75                 | 0,376    | 1 223             | 293,38          | 293,68   | 1,301 4   | 0,977 2   | 1,332 8   | 450,9       | -0,054 3        |
| vapour |                    |          | 24,433            | 421,3           | 436,68   | 1,712 2   | 0,924 5   | 1,028 5   | 120,98      | 26,23           |
| liquid | 80                 | 0,429 9  | 1 207,1           | 300,03          | 300,38   | 1,320 4   | 0,984 2   | 1,346 1   | 433,4       | -0,021 7        |
| vapour |                    |          | 27,934            | 425,04          | 440,43   | 1,717     | 0,936 2   | 1,047 5   | 120,22      | 25,43           |
| liquid | 85                 | 0,489 5  | 1 190,8           | 306,74          | 307,15   | 1,339 3   | 0,991 1   | 1,360 2   | 416         | 0,014 7         |
| vapour |                    |          | 31,847            | 428,77          | 444,14   | 1,721 8   | 0,947 9   | 1,067 5   | 119,31      | 24,73           |
| liquid | 90                 | 0,555 2  | 1 174,1           | 313,51          | 313,98   | 1,358 1   | 0,998     | 1,375 2   | 398,6       | 0,055 7         |
| vapour |                    |          | 36,215            | 432,47          | 447,8    | 1,726 6   | 0,959 6   | 1,088 7   | 118,26      | 24,11           |
| liquid | 95                 | 0,627 3  | 1 156,8           | 320,35          | 320,89   | 1,376 8   | 1,005     | 1,391 3   | 381,1       | 0,102 1         |
| vapour |                    |          | 41,091            | 436,14          | 451,41   | 1,731 3   | 0,971 2   | 1,111 5   | 117,05      | 23,57           |
| liquid | 100                | 0,706 3  | 1 138,9           | 327,26          | 327,88   | 1,395 5   | 1,012     | 1,408 7   | 363,5       | 0,155 2         |
| vapour |                    |          | 46,534            | 439,77          | 454,95   | 1,736     | 0,983     | 1,136 2   | 115,68      | 23,11           |
| liquid | 105                | 0,792 7  | 1 120,4           | 334,24          | 334,94   | 1,414 1   | 1,019     | 1,427 9   | 345,8       | 0,216 3         |
| vapour |                    |          | 52,617            | 443,36          | 458,42   | 1,740 6   | 0,994 8   | 1,163 3   | 114,13      | 22,73           |

<sup>b</sup> Normal boiling point\* The values of  $C_v$ ,  $C_p$ , and  $w$  at the critical point are not included as part of this document.

Table 61 (continued)

|          | Temp.  | Pressure | Density           | Internal energy | Enthalpy | Entropy   | $C_v$     | $C_p$     | Sound speed | J-T coefficient |
|----------|--------|----------|-------------------|-----------------|----------|-----------|-----------|-----------|-------------|-----------------|
|          | °C     | MPa      | kg/m <sup>3</sup> | kJ/kg           | kJ/kg    | kJ/(kg·K) | kJ/(kg·K) | kJ/(kg·K) | m/s         | K/MPa           |
| liquid   | 110    | 0,886 8  | 1 101,1           | 341,3           | 342,1    | 1,432 6   | 1,026 1   | 1,449 1   | 328         | 0,287 5         |
| vapour   |        |          | 59,423            | 446,89          | 461,81   | 1,745 1   | 1,006 7   | 1,193 4   | 112,38      | 22,43           |
| liquid   | 115    | 0,989 1  | 1 081             | 348,44          | 349,36   | 1,451 2   | 1,033 3   | 1,473 1   | 310         | 0,371 2         |
| vapour   |        |          | 67,055            | 450,35          | 465,1    | 1,749 4   | 1,018 9   | 1,227 4   | 110,44      | 22,21           |
| liquid   | 120    | 1,100 1  | 1 059,9           | 355,68          | 356,72   | 1,469 8   | 1,040 8   | 1,500 5   | 291,8       | 0,471 1         |
| vapour   |        |          | 75,641            | 453,73          | 468,27   | 1,753 5   | 1,031 2   | 1,266 6   | 108,27      | 22,06           |
| liquid   | 125    | 1,220 4  | 1 037,7           | 363,03          | 364,2    | 1,488 4   | 1,048 5   | 1,532 5   | 273,4       | 0,592 1         |
| vapour   |        |          | 85,339            | 457             | 471,3    | 1,757 4   | 1,043 9   | 1,312 6   | 105,86      | 22              |
| liquid   | 130    | 1,350 4  | 1 014,1           | 370,49          | 371,82   | 1,507 1   | 1,056 5   | 1,570 8   | 254,6       | 0,741 4         |
| vapour   |        |          | 96,355            | 460,15          | 474,16   | 1,761     | 1,057     | 1,368     | 103,19      | 22,02           |
| liquid   | 135    | 1,490 9  | 988,9             | 378,1           | 379,6    | 1,526     | 1,065 1   | 1,617 9   | 235,3       | 0,929 9         |
| vapour   |        |          | 108,962           | 463,14          | 476,82   | 1,764 2   | 1,070 7   | 1,436 8   | 100,23      | 22,15           |
| liquid   | 140    | 1,642 3  | 961,7             | 385,87          | 387,58   | 1,545     | 1,074 3   | 1,678     | 215,6       | 1,174 6         |
| vapour   |        |          | 123,535           | 465,94          | 479,23   | 1,766 8   | 1,085 2   | 1,525 6   | 96,95       | 22,38           |
| liquid   | 145    | 1,805 6  | 931,8             | 393,85          | 395,78   | 1,564 3   | 1,084 4   | 1,758 5   | 195,2       | 1,503 8         |
| vapour   |        |          | 140,616           | 468,48          | 481,32   | 1,768 9   | 1,100 5   | 1,645 9   | 93,29       | 22,73           |
| liquid   | 150    | 1,981 4  | 898,5             | 402,09          | 404,29   | 1,584 1   | 1,095 9   | 1,873 4   | 173,9       | 1,968 1         |
| vapour   |        |          | 161,044           | 470,67          | 482,97   | 1,77      | 1,117 2   | 1,821 1   | 89,21       | 23,22           |
| liquid   | 155    | 2,170 8  | 860,2             | 410,7           | 413,22   | 1,604 6   | 1,109 6   | 2,054 4   | 151,5       | 2,667 4         |
| vapour   |        |          | 186,228           | 472,36          | 484,02   | 1,769 9   | 1,136 9   | 2,106 9   | 84,65       | 23,87           |
| liquid   | 160    | 2,374 9  | 814,1             | 419,87          | 422,78   | 1,626 2   | 1,127     | 2,389 6   | 127,5       | 3,828 2         |
| vapour   |        |          | 218,866           | 473,28          | 484,13   | 1,767 8   | 1,163 5   | 2,656 1   | 79,51       | 24,56           |
| liquid   | 165    | 2,595 3  | 753,1             | 430,07          | 433,52   | 1,650 2   | 1,153     | 3,251 9   | 101,1       | 6,092 7         |
| vapour   |        |          | 265,561           | 472,74          | 482,52   | 1,762     | 1,202 2   | 4,097 3   | 73,6        | 25,04           |
| liquid   | 170    | 2,834 9  | 644,4             | 443,57          | 447,97   | 1,682 2   | 1,22      | 11,053 3  | 70,3        | 12,409 7        |
| vapour   |        |          | 357,94            | 467,66          | 475,58   | 1,744 5   | 1,281 5   | 16,701 1  | 66,14       | 23,7            |
| critical | 171,35 | 2,903    | 499,4             | 455,8           | 461,61   | 1,712 7   | *         | *         | *           | 19,180 3        |

<sup>b</sup> Normal boiling point

\* The values of  $C_v$ ,  $C_p$ , and  $w$  at the critical point are not included as part of this document.

## 5.19 R1234ze(E) — trans-1,3,3,3-tetrafluoropropene

### 5.19.1 Range of validity

$$T_{\min} = 169,0 \text{ K}, T_{\max} = 420 \text{ K}; p_{\max} = 1\,000 \text{ MPa}; \rho_{\max} = 13,25 \text{ mol/l (1 511 kg/m}^3\text{)}$$

### 5.19.2 Coefficients and exponents of the ideal-gas part (Formulae 3 to 5)

Coefficients and exponents of the ideal-gas part are listed in [Table 62](#) and [Table 63](#). Coefficients and exponents of the real-gas part are listed in [Table 64](#) and [Table 65](#).

Table 62 — Coefficients and exponents for  $k = 0$ 

| $k$ | $c_k$ |
|-----|-------|
| 0   | 4,000 |

**Table 63 — Coefficients and exponents for  $k = 1$  up to 2**

| $k$ | $a_k$   | $b_k$ |
|-----|---------|-------|
| 1   | 9,357 5 | 513   |
| 2   | 10,717  | 1 972 |

**5.19.3 Coefficients and exponents of the real-gas part (Formula 2)**

Parameters not listed are zero.

**Table 64 — Coefficients and exponents for  $k = 1$  up to 5**

| $k$ | $N_k$        | $t_k$ | $d_k$ |
|-----|--------------|-------|-------|
| 1   | 0,039 827 97 | 1     | 4     |
| 2   | 1,812 227    | 0,223 | 1     |
| 3   | -2,537 512   | 0,755 | 1     |
| 4   | -0,533 325 4 | 1,24  | 2     |
| 5   | 0,167 703 1  | 0,44  | 3     |

**Table 65 — Coefficients and exponents for  $k = 6$  up to 16**

| $k$ | $N_k$          | $t_k$ | $d_k$ | $l_k$ | $\alpha_k$ | $m_k$ | $\beta_k$ | $\gamma_k$ | $\varepsilon_k$ |
|-----|----------------|-------|-------|-------|------------|-------|-----------|------------|-----------------|
| 6   | -1,323 801     | 2     | 1     | 2     | 1          | 1     | 0         | 1          | 0               |
| 7   | -0,669 465 4   | 2,2   | 3     | 2     | 1          | 1     | 0         | 1          | 0               |
| 8   | 0,807 271 8    | 1,2   | 2     | 1     | 1          | 1     | 0         | 1          | 0               |
| 9   | -0,774 022 9   | 1,5   | 2     | 2     | 1          | 1     | 0         | 1          | 0               |
| 10  | -0,018 438 46  | 0,9   | 7     | 1     | 1          | 1     | 0         | 1          | 0               |
| 11  | 1,407 916      | 1,33  | 1     | 2     | 2          | -1,00 | -1,21     | 0,943      | 0,728           |
| 12  | -0,423 708 2   | 1,75  | 1     | 2     | 2          | -1,61 | -1,37     | 0,642      | 0,87            |
| 13  | -0,227 006 8   | 2,11  | 3     | 2     | 2          | -1,24 | -0,98     | 0,59       | 0,855           |
| 14  | -0,805 213     | 1     | 3     | 2     | 2          | -9,34 | -171      | 1,2        | 0,79            |
| 15  | 0,009 943 18   | 1,5   | 2     | 2     | 2          | -5,78 | -47,4     | 1,33       | 1,3             |
| 16  | -0,008 798 793 | 1     | 1     | 2     | 2          | -3,08 | -15,4     | 0,64       | 0,71            |

**5.19.4 Reducing parameters, molar mass, and gas constant**

$$T^* = 382,513 \text{ K}, \rho^* = 4,29 \text{ mol/l}, M = 114,041 \text{ g/mol}, R = 8,314 \text{ 462 1 J/(mol}\cdot\text{K)}$$

**5.19.5 Reference state parameters**

$$T_{\text{ref}} = 273,15 \text{ K}, p_{\text{ref}} = 1,0 \text{ kPa}, h_{\text{ref}} = 44 \text{ 375,837 J/mol}, s_{\text{ref}} = 237,138 \text{ 3 J/(mol}\cdot\text{K)}$$

Property values along the liquid-vapour saturation boundary are listed in [Table 66](#).

**Table 66 — R1234ze(E) — trans-1,3,3,3-tetrafluoropropene — Property values along the liquid-vapour saturation boundary**

|        | Temp.<br>°C          | Pressure<br>MPa | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|--------|----------------------|-----------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| liquid | −104,15 <sup>a</sup> | 0,000 229       | 1 510,8                      | 69,95                       | 69,95             | 0,403                | 0,824 6            | 1,218              | 1 122                 | −0,391 7                    |
| vapour |                      |                 | 0,018 56                     | 299,8                       | 312,12            | 1,836                | 0,553              | 0,626              | 118,06                | 89,18                       |
| liquid | −100,00              | 0,000 365       | 1 500,4                      | 75                          | 75                | 0,432 6              | 0,824 4            | 1,217 1            | 1 101,8               | −0,390 1                    |
| vapour |                      |                 | 0,028 95                     | 302,12                      | 314,73            | 1,817 1              | 0,564              | 0,637 1            | 119,35                | 84,27                       |
| liquid | −95,00               | 0,000 621       | 1 488                        | 81,09                       | 81,09             | 0,467 2              | 0,824 7            | 1,216 6            | 1 077,6               | −0,387 9                    |
| vapour |                      |                 | 0,047 83                     | 304,96                      | 317,94            | 1,796 7              | 0,576 9            | 0,65               | 120,88                | 78,85                       |
| liquid | −90,00               | 0,001 02        | 1 475,5                      | 87,17                       | 87,17             | 0,500 9              | 0,825 5            | 1,216 8            | 1 053,5               | −0,385 1                    |
| vapour |                      |                 | 0,076 4                      | 307,86                      | 321,2             | 1,778 7              | 0,589 3            | 0,662 6            | 122,38                | 73,89                       |
| liquid | −85,00               | 0,001 62        | 1 463,1                      | 93,25                       | 93,26             | 0,533 7              | 0,826 7            | 1,217 7            | 1 029,7               | −0,381 8                    |
| vapour |                      |                 | 0,118 3                      | 310,82                      | 324,52            | 1,762 8              | 0,601 3            | 0,674 8            | 123,85                | 69,34                       |
| liquid | −80,00               | 0,002 5         | 1 450,7                      | 99,35                       | 99,35             | 0,565 6              | 0,828 4            | 1,219 3            | 1 006                 | −0,378 0                    |
| vapour |                      |                 | 0,178 1                      | 313,83                      | 327,88            | 1,748 8              | 0,612 9            | 0,686 7            | 125,29                | 65,14                       |
| liquid | −75,00               | 0,003 76        | 1 438,2                      | 105,45                      | 105,45            | 0,596 8              | 0,830 5            | 1,221 4            | 982,4                 | −0,373 7                    |
| vapour |                      |                 | 0,261 4                      | 316,89                      | 331,29            | 1,736 5              | 0,624 2            | 0,698 3            | 126,68                | 61,27                       |
| liquid | −70,00               | 0,005 53        | 1 425,7                      | 111,56                      | 111,56            | 0,627 3              | 0,832 8            | 1,224 1            | 959,1                 | −0,368 8                    |
| vapour |                      |                 | 0,374 9                      | 319,99                      | 334,73            | 1,725 8              | 0,635 2            | 0,709 7            | 128,04                | 57,68                       |
| liquid | −65,00               | 0,007 94        | 1 413,2                      | 117,69                      | 117,69            | 0,657 1              | 0,835 5            | 1,227 3            | 935,8                 | −0,363 3                    |
| vapour |                      |                 | 0,526 2                      | 323,13                      | 338,21            | 1,716 5              | 0,645 9            | 0,720 9            | 129,34                | 54,35                       |
| liquid | −60,00               | 0,011 2         | 1 400,6                      | 123,83                      | 123,84            | 0,686 3              | 0,838 5            | 1,231 1            | 912,8                 | −0,357 2                    |
| vapour |                      |                 | 0,724                        | 326,31                      | 341,72            | 1,708 5              | 0,656 4            | 0,732 1            | 130,58                | 51,27                       |
| liquid | −55,00               | 0,015 4         | 1 388                        | 130                         | 130,01            | 0,714 8              | 0,841 7            | 1,235 4            | 889,9                 | −0,350 5                    |
| vapour |                      |                 | 0,979                        | 329,51                      | 345,25            | 1,701 5              | 0,666 8            | 0,743 3            | 131,77                | 48,4                        |
| liquid | −50,00               | 0,020 9         | 1 375,3                      | 136,19                      | 136,2             | 0,742 9              | 0,845 1            | 1,240 3            | 867,1                 | −0,343 1                    |
| vapour |                      |                 | 1,303                        | 332,75                      | 348,81            | 1,695 6              | 0,677              | 0,754 5            | 132,89                | 45,75                       |
| liquid | −45,00               | 0,027 9         | 1 362,4                      | 142,4                       | 142,42            | 0,770 4              | 0,848 7            | 1,245 6            | 844,5                 | −0,334 9                    |
| vapour |                      |                 | 1,707                        | 336                         | 352,37            | 1,690 7              | 0,687 1            | 0,765 8            | 133,94                | 43,29                       |
| liquid | −40,00               | 0,036 7         | 1 349,5                      | 148,64                      | 148,66            | 0,797 5              | 0,852 5            | 1,251 5            | 822                   | −0,325 9                    |
| vapour |                      |                 | 2,206                        | 339,28                      | 355,94            | 1,686 5              | 0,697 2            | 0,777 4            | 134,9                 | 41,01                       |
| liquid | −35,00               | 0,047 7         | 1 336,5                      | 154,91                      | 154,94            | 0,824 1              | 0,856 5            | 1,257 9            | 799,6                 | −0,316 1                    |
| vapour |                      |                 | 2,814                        | 342,57                      | 359,51            | 1,683 1              | 0,707 2            | 0,789 1            | 135,79                | 38,9                        |
| liquid | −30,00               | 0,061 1         | 1 323,3                      | 161,21                      | 161,25            | 0,850 3              | 0,860 6            | 1,264 8            | 777,2                 | −0,305 3                    |
| vapour |                      |                 | 3,549                        | 345,87                      | 363,09            | 1,680 3              | 0,717 3            | 0,801 2            | 136,58                | 36,94                       |
| liquid | −25,00               | 0,077 4         | 1 309,9                      | 167,54                      | 167,6             | 0,876 1              | 0,864 9            | 1,272 3            | 754,9                 | −0,293 5                    |
| vapour |                      |                 | 4,428                        | 349,18                      | 366,65            | 1,678 2              | 0,727 4            | 0,813 6            | 137,27                | 35,14                       |
| liquid | −20,00               | 0,096 9         | 1 296,4                      | 173,92                      | 173,99            | 0,901 5              | 0,869 3            | 1,280 3            | 732,7                 | −0,280 6                    |
| vapour |                      |                 | 5,47                         | 352,49                      | 370,2             | 1,676 6              | 0,737 6            | 0,826 5            | 137,87                | 33,47                       |
| liquid | −18,97 <sup>b</sup>  | 0,101 3         | 1 293,6                      | 175,23                      | 175,31            | 0,906 7              | 0,870 2            | 1,282 1            | 728,1                 | −0,277 8                    |
| vapour |                      |                 | 5,706                        | 353,17                      | 370,93            | 1,676 3              | 0,739 8            | 0,829 2            | 137,97                | 33,14                       |
| liquid | −15,00               | 0,120 1         | 1 282,7                      | 180,33                      | 180,42            | 0,926 6              | 0,873 9            | 1,288 9            | 710,5                 | −0,266 4                    |
| vapour |                      |                 | 6,696                        | 355,8                       | 373,74            | 1,675 4              | 0,748              | 0,839 8            | 138,35                | 31,93                       |

<sup>a</sup> Triple point.<sup>b</sup> Normal boiling point.\* The values of  $C_v$ ,  $C_p$ , and  $w$  at the critical point are not included as part of this International Standard.

Table 66 (continued)

|        | Temp.<br>°C | Pressure<br>MPa | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | C <sub>v</sub><br>kJ/(kg·K) | C <sub>p</sub><br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|--------|-------------|-----------------|------------------------------|-----------------------------|-------------------|----------------------|-----------------------------|-----------------------------|-----------------------|-----------------------------|
| liquid | −10,00      | 0,147 4         | 1 268,7                      | 186,78                      | 186,9             | 0,951 3              | 0,878 6                     | 1,298 1                     | 688,3                 | −0,250 9                    |
| vapour |             |                 | 8,129                        | 359,11                      | 377,25            | 1,674 7              | 0,758 4                     | 0,853 8                     | 138,71                | 30,52                       |
| liquid | −5,00       | 0,179 4         | 1 254,6                      | 193,28                      | 193,42            | 0,975 8              | 0,883 5                     | 1,307 9                     | 666,2                 | −0,233 9                    |
| vapour |             |                 | 9,793                        | 362,41                      | 380,73            | 1,674 3              | 0,769                       | 0,868 4                     | 138,95                | 29,21                       |
| liquid | 0           | 0,216 5         | 1 240,1                      | 199,83                      | 200               | 1                    | 0,888 5                     | 1,318 5                     | 644,1                 | −0,215 2                    |
| vapour |             |                 | 11,714                       | 365,69                      | 384,18            | 1,674 3              | 0,779 7                     | 0,883 7                     | 139,06                | 28,02                       |
| liquid | 5           | 0,259 3         | 1 225,4                      | 206,42                      | 206,63            | 1,023 9              | 0,893 8                     | 1,329 8                     | 622                   | −0,194 6                    |
| vapour |             |                 | 13,923                       | 368,96                      | 387,59            | 1,674 5              | 0,790 7                     | 0,899 9                     | 139,04                | 26,93                       |
| liquid | 10          | 0,308 4         | 1 210,4                      | 213,07                      | 213,32            | 1,047 6              | 0,899 2                     | 1,342                       | 600                   | −0,171 8                    |
| vapour |             |                 | 16,45                        | 372,21                      | 390,96            | 1,675                | 0,801 8                     | 0,917                       | 138,87                | 25,93                       |
| liquid | 15          | 0,364 2         | 1 195                        | 219,77                      | 220,08            | 1,071 1              | 0,904 9                     | 1,355 3                     | 578                   | −0,146 4                    |
| vapour |             |                 | 19,332                       | 375,43                      | 394,27            | 1,675 6              | 0,813 1                     | 0,935 3                     | 138,55                | 25,01                       |
| liquid | 20          | 0,427 3         | 1 179,3                      | 226,54                      | 226,9             | 1,094 4              | 0,910 6                     | 1,369 8                     | 556                   | −0,118 1                    |
| vapour |             |                 | 22,607                       | 378,62                      | 397,53            | 1,676 5              | 0,824 7                     | 0,954 8                     | 138,08                | 24,19                       |
| liquid | 25          | 0,498 5         | 1 163,1                      | 233,37                      | 233,8             | 1,117 5              | 0,916 4                     | 1,385 6                     | 534,1                 | −0,086 2                    |
| vapour |             |                 | 26,321                       | 381,78                      | 400,72            | 1,677 4              | 0,836 5                     | 0,975 8                     | 137,43                | 23,44                       |
| liquid | 30          | 0,578 3         | 1 146,4                      | 240,27                      | 240,78            | 1,140 5              | 0,922 2                     | 1,402 9                     | 512,1                 | −0,050 1                    |
| vapour |             |                 | 30,523                       | 384,89                      | 403,83            | 1,678 4              | 0,848 5                     | 0,998 6                     | 136,61                | 22,76                       |
| liquid | 35          | 0,667 4         | 1 129,3                      | 247,25                      | 247,84            | 1,163 4              | 0,928                       | 1,422                       | 490,1                 | −0,009 0                    |
| vapour |             |                 | 35,272                       | 387,95                      | 406,87            | 1,679 4              | 0,860 8                     | 1,023 4                     | 135,6                 | 22,16                       |
| liquid | 40          | 0,766 4         | 1 111,5                      | 254,31                      | 255               | 1,186 1              | 0,933 8                     | 1,443 1                     | 467,9                 | 0,038 1                     |
| vapour |             |                 | 40,636                       | 390,94                      | 409,8             | 1,680 5              | 0,873 3                     | 1,050 7                     | 134,4                 | 21,64                       |
| liquid | 45          | 0,876 1         | 1 093,1                      | 261,46                      | 262,27            | 1,208 8              | 0,939 5                     | 1,466 7                     | 445,5                 | 0,092 7                     |
| vapour |             |                 | 46,693                       | 393,86                      | 412,63            | 1,681 5              | 0,886 1                     | 1,081 2                     | 132,99                | 21,19                       |
| liquid | 50          | 0,997 2         | 1 073,8                      | 268,71                      | 269,64            | 1,231 5              | 0,945 3                     | 1,493 2                     | 422,8                 | 0,156 5                     |
| vapour |             |                 | 53,538                       | 396,7                       | 415,33            | 1,682 3              | 0,899 3                     | 1,115 9                     | 131,36                | 20,81                       |
| liquid | 55          | 1,130 4         | 1 058,7                      | 276,07                      | 277,14            | 1,254 1              | 0,951 2                     | 1,523 4                     | 399,7                 | 0,231 8                     |
| vapour |             |                 | 61,286                       | 399,44                      | 417,88            | 1,683                | 0,913 2                     | 1,156                       | 129,49                | 20,51                       |
| liquid | 60          | 1,276 6         | 1 032,5                      | 283,55                      | 284,78            | 1,276 8              | 0,957 4                     | 1,558 3                     | 376,1                 | 0,321 8                     |
| vapour |             |                 | 70,078                       | 402,05                      | 420,26            | 1,683 5              | 0,928                       | 1,203 6                     | 127,38                | 20,27                       |
| liquid | 65          | 1,436 5         | 1 010,1                      | 291,16                      | 292,58            | 1,299 6              | 0,964 1                     | 1,599 5                     | 351,9                 | 0,431                       |
| vapour |             |                 | 80,093                       | 404,51                      | 422,45            | 1,683 6              | 0,944                       | 1,261 3                     | 125                   | 20,09                       |
| liquid | 70          | 1,611           | 986,2                        | 298,92                      | 300,56            | 1,322 5              | 0,971 5                     | 1,649 3                     | 327,2                 | 0,566                       |
| vapour |             |                 | 91,563                       | 406,8                       | 424,4             | 1,683 4              | 0,961 4                     | 1,332 9                     | 122,32                | 19,97                       |
| liquid | 75          | 1,801           | 960,6                        | 306,87                      | 308,74            | 1,345 6              | 0,979 9                     | 1,711 3                     | 301,6                 | 0,736 6                     |
| vapour |             |                 | 104,797                      | 408,88                      | 426,06            | 1,682 6              | 0,980 5                     | 1,424 1                     | 119,32                | 19,9                        |
| liquid | 80          | 2,007 7         | 932,7                        | 315,03                      | 317,19            | 1,369 1              | 0,989 6                     | 1,791 6                     | 275,3                 | 0,958 2                     |
| vapour |             |                 | 120,226                      | 410,68                      | 427,38            | 1,681 1              | 1,001 5                     | 1,544 6                     | 115,96                | 19,87                       |
| liquid | 85          | 2,232 1         | 901,9                        | 323,47                      | 325,95            | 1,393                | 1,001 2                     | 1,901 2                     | 248                   | 1,256 9                     |
| vapour |             |                 | 138,484                      | 412,13                      | 428,25            | 1,678 7              | 1,024 7                     | 1,712 2                     | 112,2                 | 19,89                       |
| liquid | 90          | 2,475 5         | 867,2                        | 332,27                      | 335,12            | 1,417 7              | 1,015 6                     | 2,062 2                     | 219,4                 | 1,679 4                     |

<sup>a</sup> Triple point.<sup>b</sup> Normal boiling point.\* The values of C<sub>v</sub>, C<sub>p</sub>, and w at the critical point are not included as part of this International Standard.

Table 66 (continued)

|                                                                                                                                                                                            | Temp.<br>°C | Pressure<br>MPa | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|--------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|-----------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| vapour                                                                                                                                                                                     |             |                 | 160,57                       | 413,11                      | 428,52            | 1,674 9              | 1,051              | 1,963 4            | 107,99                | 19,94                       |
| liquid                                                                                                                                                                                     | 95          | 2,739 5         | 826,9                        | 341,58                      | 344,89            | 1,443 5              | 1,034 4            | 2,327 1            | 189,4                 | 2,319 6                     |
| vapour                                                                                                                                                                                     |             |                 | 188,222                      | 413,38                      | 427,93            | 1,669 1              | 1,082              | 2,386 3            | 103,27                | 19,96                       |
| liquid                                                                                                                                                                                     | 100         | 3,026           | 777,3                        | 351,7                       | 355,59            | 1,471 5              | 1,061 3            | 2,859 3            | 157,2                 | 3,399 5                     |
| vapour                                                                                                                                                                                     |             |                 | 225,006                      | 412,5                       | 425,95            | 1,66                 | 1,121 6            | 3,258 1            | 97,93                 | 19,83                       |
| liquid                                                                                                                                                                                     | 105         | 3,337 8         | 708,1                        | 363,52                      | 368,23            | 1,504                | 1,108 9            | 4,573 3            | 121,1                 | 5,619 5                     |
| vapour                                                                                                                                                                                     |             |                 | 281,016                      | 409,24                      | 421,12            | 1,643 8              | 1,182              | 6,121 7            | 91,7                  | 19,14                       |
| critical                                                                                                                                                                                   | 109,36      | 3,634 9         | 489,2                        | 388,11                      | 395,54            | 1,574 4              | *                  | *                  | *                     | 0,000                       |
| <sup>a</sup> Triple point.<br><sup>b</sup> Normal boiling point.<br>* The values of $C_v$ , $C_p$ , and $w$ at the critical point are not included as part of this International Standard. |             |                 |                              |                             |                   |                      |                    |                    |                       |                             |

## 5.20 R1234yf — 2,3,3,3-tetrafluoropropene

### 5.20.1 Range of validity

$$T_{\min} = 122,77 \text{ K}, T_{\max} = 410 \text{ K}; p_{\max} = 30 \text{ MPa}; \rho_{\max} = 13,81 \text{ mol/l (1 575 kg/m}^3\text{)}$$

### 5.20.2 Coefficients and exponents of the ideal-gas part (Formulae 3 to 5)

Coefficients and exponents of the ideal-gas part are listed in Table 67 and Table 68. Coefficients and exponents of the real-gas part are listed in Table 69 and Table 70.

Table 67 — Coefficients and exponents for  $k = 0$ 

| $k$ | $c_k$ |
|-----|-------|
| 0   | 4,000 |

Table 68 — Coefficients and exponents for  $k = 1$  up to 2

| $k$ | $a_k$ | $b_k$ |
|-----|-------|-------|
| 1   | 8,65  | 512   |
| 2   | 9,75  | 1 570 |
| 3   | 2,11  | 4 500 |

### 5.20.3 Coefficients and exponents of the real-gas part (Formula 2)

Parameters not listed are zero.

Table 69 — Coefficients and exponents for  $k = 1$  up to 5

| $k$ | $N_k$        | $t_k$ | $d_k$ |
|-----|--------------|-------|-------|
| 1   | 0,034 038 7  | 1     | 4     |
| 2   | 1,912 859    | 0,222 | 1     |
| 3   | -2,198 472   | 0,61  | 1     |
| 4   | -0,814 764 5 | 1,122 | 2     |
| 5   | 0,228 828 2  | 0,5   | 3     |

**Table 70 — Coefficients and exponents for  $k = 6$  up to 16**

| $k$ | $N_k$        | $t_k$ | $d_k$ | $l_k$ | $\alpha_k$ | $m_k$  | $\beta_k$ | $\gamma_k$ | $\varepsilon_k$ |
|-----|--------------|-------|-------|-------|------------|--------|-----------|------------|-----------------|
| 6   | -1,654 36    | 2,14  | 1     | 2     | 1          | 1      | 0         | 1          | 0               |
| 7   | -1,446 628   | 2,284 | 3     | 2     | 1          | 1      | 0         | 1          | 0               |
| 8   | 0,596 172 2  | 1,05  | 2     | 1     | 1          | 1      | 0         | 1          | 0               |
| 9   | -0,614 820 9 | 2,33  | 2     | 2     | 1          | 1      | 0         | 1          | 0               |
| 10  | -0,018 006 9 | 0,778 | 7     | 1     | 1          | 1      | 0         | 1          | 0               |
| 11  | 0,284 527 5  | 1     | 1     | 2     | 2          | -28,1  | -1 016    | 1,061      | 0,96            |
| 12  | -0,305 080 9 | 2     | 1     | 2     | 2          | -28    | -1 000    | 1,062      | 0,96            |
| 13  | 2,198 935    | 1,236 | 1     | 2     | 2          | -1,307 | -1,16     | 1,3        | 0,853           |
| 14  | -0,427 032 9 | 1,6   | 1     | 2     | 2          | -1,96  | -1,2      | 1,04       | 1,15            |
| 15  | -0,401 558 1 | 1,85  | 1     | 2     | 2          | -1,25  | -1,26     | 1          | 1,3             |
| 16  | 0,117 958 7  | 0,7   | 1     | 2     | 2          | -1     | -1,6      | 1,14       | 1,5             |
| 17  | -0,314 100 2 | 1,75  | 1     | 2     | 2          | -2,2   | -0,87     | 1,1        | 0,762           |

**5.20.4 Reducing parameters, molar mass, and gas constant**

$$T^* = 367,85 \text{ K}, \rho^* = 4,18 \text{ mol/l}, M = 114,041 6 \text{ g/mol}, R = 8,314 462 618 \text{ J/(mol}\cdot\text{K)}$$

**5.20.5 Reference state parameters**

$$T_{\text{ref}} = 273,15 \text{ K}, p_{\text{ref}} = 1,0 \text{ kPa}, h_{\text{ref}} = 42 251,666 \text{ J/mol}, s_{\text{ref}} = 232,282 1 \text{ J/(mol}\cdot\text{K)}$$

Property values along the liquid-vapour saturation boundary are listed in [Table 71](#).

**Table 71 — R1234yf - 2,3,3,3-tetrafluoropropene — Property values along the liquid-vapour saturation boundary**

|                                                                                                          | Temp.<br>°C          | Pressure<br>MPa        | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|----------------------------------------------------------------------------------------------------------|----------------------|------------------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| liquid                                                                                                   | -150,38 <sup>a</sup> | 5,363×10 <sup>-7</sup> | 1 574,7                      | 26,33                       | 26,33             | 0,087 5              | 0,729 5            | 1,103 1            | 1 274,5               | -0,456 7                    |
| vapour                                                                                                   |                      |                        | 5,991×10 <sup>-5</sup>       | 260,66                      | 269,61            | 2,069 1              | 0,393 8            | 0,466 7            | 102,99                | 266,05                      |
| liquid                                                                                                   | -150                 | 5,831×10 <sup>-7</sup> | 1 573,7                      | 26,75                       | 26,75             | 0,090 9              | 0,729 3            | 1,102 8            | 1 272,5               | -0,456 8                    |
| vapour                                                                                                   |                      |                        | 6,495×10 <sup>-5</sup>       | 260,81                      | 269,79            | 2,064 4              | 0,395 1            | 0,468              | 103,13                | 263,78                      |
| liquid                                                                                                   | -140                 | 4,342×10 <sup>-6</sup> | 1 547,5                      | 37,74                       | 37,74             | 0,176 7              | 0,726 8            | 1,095 7            | 1 220,4               | -0,458 2                    |
| vapour                                                                                                   |                      |                        | 4,473×10 <sup>-4</sup>       | 264,92                      | 274,63            | 1,955 9              | 0,427 6            | 0,500 6            | 106,59                | 212,9                       |
| liquid                                                                                                   | -130                 | 2,340×10 <sup>-5</sup> | 1 521,8                      | 48,68                       | 48,68             | 0,255 9              | 0,727 6            | 1,093 3            | 1 169                 | -0,456 8                    |
| vapour                                                                                                   |                      |                        | 2,242×10 <sup>-4</sup>       | 269,36                      | 279,79            | 1,870 4              | 0,459              | 0,531 9            | 109,97                | 175,09                      |
| liquid                                                                                                   | -120                 | 9,770×10 <sup>-5</sup> | 1 496,5                      | 59,61                       | 59,61             | 0,329 8              | 0,730 5            | 1,094 1            | 1 118,5               | -0,453 1                    |
| vapour                                                                                                   |                      |                        | 8,752×10 <sup>-4</sup>       | 274,09                      | 285,26            | 1,803 1              | 0,489              | 0,561 9            | 113,26                | 145,85                      |
| liquid                                                                                                   | -110                 | 0,000 333              | 1 471,3                      | 70,57                       | 70,57             | 0,399 1              | 0,735 3            | 1,097 6            | 1 068,6               | -0,447 1                    |
| vapour                                                                                                   |                      |                        | 0,027 98                     | 279,11                      | 291               | 1,750 2              | 0,517 4            | 0,590 6            | 116,45                | 122,47                      |
| liquid                                                                                                   | -100                 | 0,000 959              | 1 446,3                      | 81,57                       | 81,57             | 0,464 5              | 0,742              | 1,103 8            | 1 019,2               | -0,438 8                    |
| vapour                                                                                                   |                      |                        | 0,076 1                      | 284,4                       | 297               | 1,708 7              | 0,544 6            | 0,618              | 119,52                | 103,39                      |
| liquid                                                                                                   | -90                  | 0,002 42               | 1 421,3                      | 92,65                       | 92,66             | 0,526 7              | 0,750 7            | 1,112 8            | 970,4                 | -0,427 9                    |
| <sup>a</sup> Triple point.                                                                               |                      |                        |                              |                             |                   |                      |                    |                    |                       |                             |
| <sup>b</sup> Normal boiling point.                                                                       |                      |                        |                              |                             |                   |                      |                    |                    |                       |                             |
| * The values of $C_v$ , $C_p$ , and $w$ at the critical point are not included as part of this document. |                      |                        |                              |                             |                   |                      |                    |                    |                       |                             |

Table 71 (continued)

|        | Temp.<br>°C         | Pressure<br>MPa | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|--------|---------------------|-----------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| vapour |                     |                 | 0,181 4                      | 289,92                      | 303,23            | 1,676 5              | 0,570 8            | 0,644 7            | 122,46                | 87,66                       |
| liquid | -80                 | 0,005 43        | 1 396,1                      | 103,84                      | 103,84            | 0,586 2              | 0,761 2            | 1,124 6            | 922,1                 | -0,414 4                    |
| vapour |                     |                 | 0,388                        | 295,64                      | 309,65            | 1,651 7              | 0,596 1            | 0,671 1            | 125,23                | 74,65                       |
| liquid | -70                 | 0,011 1         | 1 370,8                      | 115,15                      | 115,16            | 0,643 3              | 0,773 2            | 1,139              | 874,4                 | -0,398 2                    |
| vapour |                     |                 | 0,758                        | 301,55                      | 316,23            | 1,633 1              | 0,621 1            | 0,697 6            | 127,78                | 63,9                        |
| liquid | -60                 | 0,021           | 1 345,1                      | 126,62                      | 126,64            | 0,698 4              | 0,786 5            | 1,155 7            | 827,3                 | -0,378 9                    |
| vapour |                     |                 | 1,375                        | 307,61                      | 322,92            | 1,619 3              | 0,645 9            | 0,724 7            | 130,06                | 55,05                       |
| liquid | -50                 | 0,037 2         | 1 318,9                      | 138,27                      | 138,29            | 0,751 8              | 0,800 7            | 1,174 5            | 780,8                 | -0,356 3                    |
| vapour |                     |                 | 2,341                        | 313,79                      | 329,7             | 1,609 5              | 0,670 9            | 0,752 7            | 132,04                | 47,77                       |
| liquid | -40                 | 0,062 2         | 1 292,1                      | 150,1                       | 150,15            | 0,803 7              | 0,815 4            | 1,195 3            | 734,9                 | -0,33                       |
| vapour |                     |                 | 3,781                        | 320,07                      | 336,52            | 1,603                | 0,696 1            | 0,782 1            | 133,66                | 41,81                       |
| liquid | -35                 | 0,078 9         | 1 278,5                      | 156,1                       | 156,16            | 0,829 2              | 0,823              | 1,206 4            | 712,1                 | -0,315 2                    |
| vapour |                     |                 | 4,725                        | 323,23                      | 339,93            | 1,600 8              | 0,708 8            | 0,797 5            | 134,31                | 39,25                       |
| liquid | -30                 | 0,098 9         | 1 264,7                      | 162,15                      | 162,23            | 0,854 3              | 0,830 6            | 1,218              | 689,5                 | -0,299 3                    |
| vapour |                     |                 | 5,843                        | 326,41                      | 343,34            | 1,599 2              | 0,721 6            | 0,813 3            | 134,86                | 36,93                       |
| liquid | -29,46 <sup>b</sup> | 0,101 3         | 1 263,1                      | 162,81                      | 162,89            | 0,857                | 0,831 5            | 1,219 3            | 687,1                 | -0,297 5                    |
| vapour |                     |                 | 5,976                        | 326,76                      | 343,71            | 1,599                | 0,723              | 0,815              | 134,91                | 36,7                        |
| liquid | -25                 | 0,122 8         | 1 250,6                      | 168,26                      | 168,36            | 0,879 2              | 0,838 4            | 1,230 1            | 667                   | -0,282                      |
| vapour |                     |                 | 7,16                         | 329,6                       | 346,75            | 1,598 1              | 0,734 5            | 0,829 6            | 135,28                | 34,85                       |
| liquid | -20                 | 0,150 9         | 1 236,3                      | 174,43                      | 174,55            | 0,903 8              | 0,846 2            | 1,242 7            | 644,7                 | -0,263 2                    |
| vapour |                     |                 | 8,698                        | 332,8                       | 350,14            | 1,597 4              | 0,747 5            | 0,846 6            | 135,59                | 32,96                       |
| liquid | -15                 | 0,183 7         | 1 221,7                      | 180,66                      | 180,81            | 0,928 2              | 0,854              | 1,255 9            | 622,4                 | -0,242 7                    |
| vapour |                     |                 | 10,485                       | 336                         | 353,52            | 1,597 2              | 0,760 7            | 0,864 1            | 135,76                | 31,27                       |
| liquid | -10                 | 0,221 8         | 1 206,8                      | 186,95                      | 187,13            | 0,952 3              | 0,862              | 1,269 8            | 600,2                 | -0,220 3                    |
| vapour |                     |                 | 12,548                       | 339,2                       | 356,87            | 1,597 3              | 0,773 9            | 0,882 5            | 135,79                | 29,74                       |
| liquid | -5                  | 0,265 7         | 1 191,7                      | 193,31                      | 193,53            | 0,976 2              | 0,87               | 1,284 3            | 578,2                 | -0,195 7                    |
| vapour |                     |                 | 14,92                        | 342,39                      | 360,19            | 1,597 8              | 0,787 2            | 0,901 6            | 135,68                | 28,36                       |
| liquid | 0                   | 0,315 9         | 1 176,1                      | 199,73                      | 200               | 1                    | 0,878              | 1,299 6            | 556,2                 | -0,168 6                    |
| vapour |                     |                 | 17,634                       | 345,57                      | 363,48            | 1,598 5              | 0,800 6            | 0,921 7            | 135,42                | 27,13                       |
| liquid | 5                   | 0,373           | 1 160,2                      | 206,23                      | 206,55            | 1,023 6              | 0,886 2            | 1,315 8            | 534,2                 | -0,138 5                    |
| vapour |                     |                 | 20,73                        | 348,74                      | 366,73            | 1,599 5              | 0,814 2            | 0,943              | 134,99                | 26,03                       |
| liquid | 10                  | 0,437 6         | 1 143,8                      | 212,8                       | 213,18            | 1,047                | 0,894 4            | 1,333 1            | 512,3                 | -0,104 9                    |
| vapour |                     |                 | 24,25                        | 351,88                      | 369,93            | 1,600 6              | 0,827 9            | 0,965 5            | 134,39                | 25,05                       |
| liquid | 15                  | 0,510 4         | 1 127                        | 219,45                      | 219,9             | 1,070 3              | 0,902 7            | 1,351 6            | 490,3                 | -0,067 2                    |
| vapour |                     |                 | 28,245                       | 355                         | 373,06            | 1,601 9              | 0,841 7            | 0,989 7            | 133,62                | 24,17                       |
| liquid | 20                  | 0,591 8         | 1 109,7                      | 226,18                      | 226,71            | 1,093 5              | 0,911 1            | 1,371 7            | 468,4                 | -0,024 5                    |
| vapour |                     |                 | 32,769                       | 358,07                      | 376,14            | 1,603 2              | 0,855 7            | 1,015 7            | 132,65                | 23,4                        |
| liquid | 25                  | 0,682 7         | 1 091,7                      | 233                         | 233,63            | 1,116 6              | 0,919 6            | 1,393 6            | 446,4                 | 0,024 2                     |
| vapour |                     |                 | 37,89                        | 361,11                      | 379,13            | 1,604 6              | 0,869 8            | 1,044              | 131,49                | 22,72                       |
| liquid | 30                  | 0,783 6         | 1 073,1                      | 239,92                      | 240,65            | 1,139 6              | 0,928 2            | 1,417 7            | 424,3                 | 0,080 3                     |
| vapour |                     |                 | 43,683                       | 364,09                      | 382,03            | 1,606                | 0,884 1            | 1,075 2            | 130,11                | 22,14                       |

<sup>a</sup> Triple point.<sup>b</sup> Normal boiling point.<sup>\*</sup> The values of  $C_v$ ,  $C_p$ , and  $w$  at the critical point are not included as part of this document.

Table 71 (continued)

|                                                                                                                                                                              | Temp.<br>°C | Pressure<br>MPa | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|-------------|-----------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| liquid                                                                                                                                                                       | 35          | 0,895 3         | 1 053,8                      | 246,93                      | 247,78            | 1,162 7              | 0,937              | 1,444 7            | 402                   | 0,145 5                     |
| vapour                                                                                                                                                                       |             |                 | 50,241                       | 367                         | 384,82            | 1,607 4              | 0,898 7            | 1,109 9            | 128,5                 | 21,64                       |
| liquid                                                                                                                                                                       | 40          | 1,018 5         | 1 033,6                      | 254,06                      | 255,05            | 1,185 7              | 0,946 1            | 1,475 1            | 379,6                 | 0,222 4                     |
| vapour                                                                                                                                                                       |             |                 | 57,674                       | 369,82                      | 387,48            | 1,608 6              | 0,913 5            | 1,149 3            | 126,65                | 21,22                       |
| liquid                                                                                                                                                                       | 45          | 1,153 9         | 1 012,3                      | 261,32                      | 262,46            | 1,208 7              | 0,955 3            | 1,510 1            | 356,9                 | 0,314                       |
| vapour                                                                                                                                                                       |             |                 | 66,121                       | 372,55                      | 390               | 1,609 6              | 0,928 7            | 1,194 8            | 124,55                | 20,89                       |
| liquid                                                                                                                                                                       | 50          | 1,302 3         | 989,9                        | 268,71                      | 270,02            | 1,231 8              | 0,964 9            | 1,551 1            | 333,9                 | 0,425 1                     |
| vapour                                                                                                                                                                       |             |                 | 75,754                       | 375,15                      | 392,34            | 1,610 4              | 0,944 3            | 1,248 5            | 122,16                | 20,63                       |
| liquid                                                                                                                                                                       | 55          | 1,464 7         | 966,1                        | 276,25                      | 277,77            | 1,255 1              | 0,974 8            | 1,600 1            | 310,5                 | 0,562 2                     |
| vapour                                                                                                                                                                       |             |                 | 86,799                       | 377,6                       | 394,48            | 1,610 8              | 0,960 4            | 1,313 5            | 119,48                | 20,45                       |
| liquid                                                                                                                                                                       | 60          | 1,641 8         | 940,6                        | 283,98                      | 285,73            | 1,278 6              | 0,985 3            | 1,660 3            | 286,6                 | 0,735 1                     |
| vapour                                                                                                                                                                       |             |                 | 99,553                       | 379,86                      | 396,35            | 1,610 7              | 0,977 1            | 1,394 7            | 116,46                | 20,36                       |
| liquid                                                                                                                                                                       | 65          | 1,834 7         | 912,9                        | 291,93                      | 293,94            | 1,302 5              | 0,996 4            | 1,737 2            | 262,1                 | 0,959 1                     |
| vapour                                                                                                                                                                       |             |                 | 114,432                      | 381,87                      | 397,9             | 1,609 9              | 0,994 6            | 1,500 5            | 113,1                 | 20,34                       |
| liquid                                                                                                                                                                       | 70          | 2,044 5         | 882,5                        | 300,14                      | 302,45            | 1,326 8              | 1,008 5            | 1,839 9            | 236,9                 | 1,259 7                     |
| vapour                                                                                                                                                                       |             |                 | 132,04                       | 383,56                      | 399,04            | 1,608 3              | 1,013 2            | 1,645 9            | 109,33                | 20,39                       |
| liquid                                                                                                                                                                       | 75          | 2,272 2         | 848,4                        | 308,68                      | 311,36            | 1,351 8              | 1,022              | 1,987 4            | 210,7                 | 1,682 4                     |
| vapour                                                                                                                                                                       |             |                 | 153,322                      | 384,81                      | 399,63            | 1,605 3              | 1,033 3            | 1,861 1            | 105,13                | 20,51                       |
| liquid                                                                                                                                                                       | 80          | 2,519 5         | 809,1                        | 317,69                      | 320,8             | 1,377 9              | 1,037 5            | 2,223 6            | 183,3                 | 2,317 8                     |
| vapour                                                                                                                                                                       |             |                 | 179,914                      | 385,43                      | 399,43            | 1,600 5              | 1,055 5            | 2,217 9            | 100,41                | 20,67                       |
| liquid                                                                                                                                                                       | 85          | 2,788 1         | 761,3                        | 327,42                      | 331,08            | 1,405 8              | 1,056 5            | 2,684 1            | 153,9                 | 3,379 5                     |
| vapour                                                                                                                                                                       |             |                 | 215,174                      | 385                         | 397,96            | 1,592 5              | 1,081 8            | 2,941              | 95,08                 | 20,78                       |
| liquid                                                                                                                                                                       | 90          | 3,080 8         | 695,9                        | 338,61                      | 343,04            | 1,437 8              | 1,084 4            | 4,113 1            | 121                   | 5,549 1                     |
| vapour                                                                                                                                                                       |             |                 | 268,811                      | 382,38                      | 393,84            | 1,577 7              | 1,120 6            | 5,287 7            | 88,89                 | 20,45                       |
| critical                                                                                                                                                                     | 94,70       | 3,384 4         | 476,7                        | 362,83                      | 369,93            | 1,509 9              | *                  | *                  | *                     | 0                           |
| <sup>a</sup> Triple point.<br><sup>b</sup> Normal boiling point.<br>* The values of $C_v$ , $C_p$ , and $w$ at the critical point are not included as part of this document. |             |                 |                              |                             |                   |                      |                    |                    |                       |                             |

## 5.21 R1233zd(E) — trans-1-chloro-3,3,3-trifluoropropene

### 5.21.1 Range of validity

$$T_{\min} = 195,15 \text{ K}, T_{\max} = 550 \text{ K}; p_{\max} = 100 \text{ MPa}; \rho_{\max} = 11,395 \text{ mol/l (1 487 kg/m}^3\text{)}$$

### 5.21.2 Coefficients and exponents of the ideal-gas part (Formulae 3 to 5)

Coefficients and exponents of the ideal-gas part are listed in [Table 72](#) and [Table 73](#). Coefficients and exponents of the real-gas part are listed in [Table 74](#) and [Table 75](#).

Table 72 — Coefficients and exponents for  $k = 0$ 

| $k$ | $c_k$ |
|-----|-------|
| 0   | 4,000 |

**Table 73 — Coefficients and exponents for  $k = 1$  up to 2**

| $k$ | $a_k$   | $b_k$ |
|-----|---------|-------|
| 1   | 7,097 4 | 2 870 |
| 2   | 13,7    | 761   |

**5.21.3 Coefficients and exponents of the real-gas part (Formula 2)**

Parameters not listed are zero.

**Table 74 — Coefficients and exponents for  $k = 1$  up to 5**

| $k$ | $N_k$        | $t_k$   | $d_k$ |
|-----|--------------|---------|-------|
| 1   | 0,043 942 57 | 1       | 4     |
| 2   | 1,062 919    | 0,182   | 1     |
| 3   | -1,287 914   | 0,865   | 1     |
| 4   | -0,808 861 9 | 1,092 4 | 2     |
| 5   | 0,237 242 7  | 0,49    | 3     |

**Table 75 — Coefficients and exponents for  $k = 6$  up to 18**

| $k$ | $N_k$         | $t_k$ | $d_k$ | $l_k$ | $\alpha_k$ | $m_k$    | $\beta_k$ | $\gamma_k$ | $\varepsilon_k$ |
|-----|---------------|-------|-------|-------|------------|----------|-----------|------------|-----------------|
| 6   | -1,940 3      | 1,958 | 1     | 2     | 1          | 1        | 0         | 1          | 0               |
| 7   | -2,831 967    | 2,05  | 3     | 2     | 1          | 1        | 0         | 1          | 0               |
| 8   | 0,373 421     | 0,658 | 2     | 1     | 1          | 1        | 0         | 1          | 0               |
| 9   | -1,515 798    | 2,051 | 2     | 2     | 1          | 1        | 0         | 1          | 0               |
| 10  | -0,027 556 27 | 0,862 | 7     | 1     | 1          | 1        | 0         | 1          | 0               |
| 11  | 4,240 23      | 1,852 | 1     | 2     | 2          | -1,532   | -0,291 2  | 1,717 1    | 0,883 4         |
| 12  | -0,031 526 71 | 1,92  | 2     | 2     | 2          | -0,635   | -0,624 5  | 0,63       | 1,386           |
| 13  | -1,366 494    | 1,936 | 3     | 2     | 2          | -1,405 6 | -0,669    | 0,785 2    | 0,519 6         |
| 14  | 2,647 143     | 1,515 | 1     | 2     | 2          | -1,451   | -0,579 8  | 2,251      | 1,133           |
| 15  | -2,325 463    | 2,668 | 1     | 2     | 2          | -1,395   | -0,464 3  | 1,821      | 0,978 8         |
| 16  | -0,254 152 1  | 1,755 | 1     | 2     | 2          | -2,259   | -2,449    | 2,074      | 1,166           |
| 17  | 0,133 083 443 | 0,526 | 1     | 2     | 2          | -24,3    | -1 061,4  | 1,079 7    | 0,924 4         |
| 18  | -0,156 921 74 | 2,98  | 1     | 2     | 2          | -23,6    | -917,8    | 1,084      | 0,937 2         |

**5.21.4 Reducing parameters, molar mass, and gas constant**

$$T^* = 438,86 \text{ K}, \rho^* = 3,704 \text{ mol/l}, M = 130,496 \text{ g/mol}, R = 8,314 462 618 \text{ J/(mol}\cdot\text{K)}$$

**5.21.5 Reference state parameters**

$$T_{\text{ref}} = 273,15 \text{ K}, p_{\text{ref}} = 1,0 \text{ kPa}, h_{\text{ref}} = 52 752,273 \text{ J/mol}, s_{\text{ref}} = 260,149 7 \text{ J/(mol}\cdot\text{K)}$$

Property values along the liquid-vapour saturation boundary are listed in [Table 76](#).

Table 76 — R1233zd(E) — Property values along the liquid-vapour saturation boundary

|        | Temp.<br>°C         | Pressure<br>MPa | Density<br>kg/m <sup>3</sup> | Internal<br>energy<br>kJ/kg | Enthalpy<br>kJ/kg | Entropy<br>kJ/(kg·K) | $C_v$<br>kJ/(kg·K) | $C_p$<br>kJ/(kg·K) | Sound<br>speed<br>m/s | J-T<br>coefficient<br>K/MPa |
|--------|---------------------|-----------------|------------------------------|-----------------------------|-------------------|----------------------|--------------------|--------------------|-----------------------|-----------------------------|
| liquid | -78,00 <sup>a</sup> | 0,000 286       | 1 487                        | 116,62                      | 116,62            | 0,641 9              | 0,695 7            | 1,006 3            | 1 111,7               | -0,490 3                    |
| vapour |                     |                 | 0,022 99                     | 341,96                      | 354,39            | 1,860 3              | 0,471 3            | 0,535 1            | 118,77                | 116,29                      |
| liquid | -70                 | 0,000 603       | 1 470,8                      | 124,72                      | 124,72            | 0,682 6              | 0,703 6            | 1,018 5            | 1 078,5               | -0,479 2                    |
| vapour |                     |                 | 0,046 66                     | 345,81                      | 358,74            | 1,834 6              | 0,494 7            | 0,558 7            | 120,8                 | 102,3                       |
| liquid | -60                 | 0,001 4         | 1 450,2                      | 134,98                      | 134,98            | 0,731 9              | 0,713 9            | 1,033 9            | 1 036,9               | -0,464 7                    |
| vapour |                     |                 | 0,103 2                      | 350,87                      | 364,43            | 1,808 4              | 0,523 1            | 0,587 3            | 123,28                | 87,68                       |
| liquid | -50                 | 0,002 97        | 1 429,5                      | 145,4                       | 145,4             | 0,779 7              | 0,724 9            | 1,049 6            | 995,1                 | -0,449 5                    |
| vapour |                     |                 | 0,209 3                      | 356,19                      | 370,37            | 1,787 8              | 0,550 5            | 0,615 1            | 125,68                | 75,65                       |
| liquid | -40                 | 0,005 83        | 1 408,5                      | 155,97                      | 155,98            | 0,826                | 0,736 5            | 1,065 8            | 953,4                 | -0,433 3                    |
| vapour |                     |                 | 0,394 1                      | 361,75                      | 376,53            | 1,772                | 0,576 8            | 0,642 1            | 127,96                | 65,73                       |
| liquid | -35                 | 0,007 96        | 1 397,9                      | 161,32                      | 161,33            | 0,848 7              | 0,742 6            | 1,074              | 932,6                 | -0,424 7                    |
| vapour |                     |                 | 0,527 8                      | 364,6                       | 379,68            | 1,765 6              | 0,589 6            | 0,655 2            | 129,05                | 61,44                       |
| liquid | -30                 | 0,010 7         | 1 387,3                      | 166,71                      | 166,72            | 0,871 1              | 0,748 8            | 1,082 4            | 911,9                 | -0,415 9                    |
| vapour |                     |                 | 0,697                        | 367,51                      | 382,88            | 1,760 1              | 0,602 1            | 0,668 3            | 130,1                 | 57,53                       |
| liquid | -25                 | 0,014 2         | 1 376,5                      | 172,15                      | 172,16            | 0,893 2              | 0,755 1            | 1,091              | 891,2                 | -0,406 6                    |
| vapour |                     |                 | 0,907                        | 370,47                      | 386,13            | 1,755 5              | 0,614 4            | 0,681 1            | 131,11                | 53,98                       |
| liquid | -20                 | 0,018 6         | 1 365,7                      | 177,62                      | 177,63            | 0,915 1              | 0,761 5            | 1,099 7            | 870,6                 | -0,397                      |
| vapour |                     |                 | 1,166                        | 373,47                      | 389,41            | 1,751 6              | 0,626 4            | 0,693 9            | 132,07                | 50,74                       |
| liquid | -15                 | 0,024           | 1 354,7                      | 183,14                      | 183,16            | 0,936 7              | 0,768 1            | 1,108 5            | 850,1                 | -0,386 9                    |
| vapour |                     |                 | 1,482                        | 376,51                      | 392,72            | 1,748 4              | 0,638 3            | 0,706 5            | 132,98                | 47,8                        |
| liquid | -10                 | 0,030 7         | 1 343,7                      | 188,7                       | 188,73            | 0,958                | 0,774 7            | 1,117 5            | 829,7                 | -0,376 4                    |
| vapour |                     |                 | 1,862                        | 379,59                      | 396,06            | 1,745 9              | 0,649 9            | 0,719              | 133,84                | 45,12                       |
| liquid | -5                  | 0,038 8         | 1 332,6                      | 194,31                      | 194,34            | 0,979 1              | 0,781 4            | 1,126 7            | 809,5                 | -0,365 3                    |
| vapour |                     |                 | 2,317                        | 382,7                       | 399,43            | 1,744                | 0,661 2            | 0,731 5            | 134,63                | 42,67                       |
| liquid | 0                   | 0,048 5         | 1 321,3                      | 199,96                      | 200               | 1                    | 0,788 1            | 1,136 1            | 789,3                 | -0,353 7                    |
| vapour |                     |                 | 2,857                        | 385,84                      | 402,82            | 1,742 5              | 0,672 4            | 0,743 9            | 135,36                | 40,44                       |
| liquid | 5                   | 0,060 1         | 1 309,9                      | 205,66                      | 205,71            | 1,020 7              | 0,794 8            | 1,145 7            | 769,3                 | -0,341 5                    |
| vapour |                     |                 | 3,491                        | 389,01                      | 406,23            | 1,741 6              | 0,683 5            | 0,756 4            | 136,02                | 38,41                       |
| liquid | 10                  | 0,073 8         | 1 298,4                      | 211,41                      | 211,47            | 1,041 2              | 0,801 6            | 1,155 4            | 749,3                 | -0,328 5                    |
| vapour |                     |                 | 4,232                        | 392,21                      | 409,65            | 1,741 1              | 0,694 3            | 0,768 8            | 136,61                | 36,56                       |
| liquid | 15                  | 0,089 9         | 1 286,7                      | 217,2                       | 217,27            | 1,061 4              | 0,808 3            | 1,165 4            | 729,5                 | -0,314 8                    |
| vapour |                     |                 | 5,091                        | 395,42                      | 413,08            | 1,741                | 0,705              | 0,781 3            | 137,12                | 34,87                       |
| liquid | 18,13 <sup>b</sup>  | 0,101 3         | 1 279,4                      | 220,86                      | 220,94            | 1,074 1              | 0,812 5            | 1,171 8            | 717,1                 | -0,305 7                    |
| vapour |                     |                 | 5,695                        | 397,44                      | 415,23            | 1,741 1              | 0,711 6            | 0,789 2            | 137,4                 | 33,89                       |
| liquid | 20                  | 0,108 7         | 1 274,9                      | 223,05                      | 223,13            | 1,081 6              | 0,815 1            | 1,175 6            | 709,8                 | -0,300 2                    |
| vapour |                     |                 | 6,082                        | 398,65                      | 416,52            | 1,741 2              | 0,715 5            | 0,793 9            | 137,55                | 33,33                       |
| liquid | 25                  | 0,130 3         | 1 262,9                      | 228,94                      | 229,05            | 1,101 5              | 0,821 8            | 1,186              | 690,1                 | -0,284 6                    |
| vapour |                     |                 | 7,219                        | 401,9                       | 419,95            | 1,741 8              | 0,725 9            | 0,806 6            | 137,89                | 31,92                       |
| liquid | 30                  | 0,155 3         | 1 250,8                      | 234,89                      | 235,01            | 1,121 3              | 0,828 5            | 1,196 8            | 670,6                 | -0,268                      |
| vapour |                     |                 | 8,517                        | 405,16                      | 423,39            | 1,742 7              | 0,736 2            | 0,819 5            | 138,14                | 30,64                       |
| liquid | 35                  | 0,183 7         | 1 238,4                      | 240,88                      | 241,03            | 1,140 9              | 0,835 2            | 1,207 8            | 651,1                 | -0,250 1                    |

<sup>a</sup> Triple point

<sup>b</sup> Normal boiling point

\* The values of  $C_v$ ,  $C_p$ , and  $w$  at the critical point are not included as part of this document.