BRITISH STANDARD

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Refrigerant properties

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British Standards

National foreword

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INTERNATIONAL STANDARD

ISO 17584

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Refrigerant properties

Propriétés des fluides frigorigènes

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Contents

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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The main task of technical committees is to prepare International Standards. Draft International Standards adopted by the technical committees are circulated to the member bodies for voting. Publication as an International Standard requires approval by at least 75 % of the member bodies casting a vote.

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ISO 17584 was prepared by Technical Committee ISO/TC 86, *Refrigeration and air-conditioning*, Subcommittee SC 8, *Refrigerants and refrigeration lubricants*.

Introduction

This document, prepared by ISO/TC 86/SC 8/WG 7, is a new International Standard. It is consistent with and is intended to complement ISO 817. The purpose of this International Standard 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 International Standard represent those for which sufficient high-quality data were available. While the working group recognizes the desirability of including additional fluids, such as the hydrocarbons, and including the transport properties of viscosity and thermal conductivity, the data and models for these were judged insufficient at this time to be worthy of designation as an International Standard. Therefore, the working group decided to prepare the present International Standard, incomplete though it might be, in a timely fashion rather than delay it awaiting additional data. The working group is continuing its efforts to add additional fluids and additional properties to this International Standard. It is anticipated that this International Standard will undergo regular reviews and revisions.

For applications such as performance rating of refrigeration equipment, having all parties adopt a consistent set of properties is more important than absolute accuracy. But consensus is easiest to achieve when high-quality property data are available.

With this in mind, the Working Group has taken as its starting point the results of Annex 18 Thermophysical Properties of the Environmentally Acceptable Refrigerants of the Heat Pump Programme of the International Energy Agency (McLinden and Watanabe[7]). Annex 18 reports the comprehensive evaluations of the available equations of state and recommended formulations for R123, R134a, R32, R125, and R143a. Wide participation was invited in this process, and anyone could submit an equation of state for evaluation. The formulations for R123, R134a, R32, and R143a adopted in this International Standard are the same as those recommend by Annex 18. (The recent equation of state for R125 adopted in this International Standard was shown to be more accurate than the older formulation recommended by Annex 18.)

A similar comparison of mixture models reported by Annex 18 facilitated the dissemination and adoption of a new mixture modelling approach. This model is based on Helmholtz energies for each of the mixture components, and it is the approach used in the NIST REFPROP refrigerant property database (Lemmon *et al.*[5]) and in the extensive tabulation of properties published by the Japan Society of Refrigerating and Air Conditioning Engineers (Tillner-Roth *et al.*[12]). The Lemmon and Jacobsen[2] model (implemented in the REFPROP database) is simpler than the Tillner-Roth *et al.*[12] model in that it avoids the ternary interactions terms required in the Tillner-Roth model, with practically the same representations of the experimental data. For these reasons, as well as the widespread use of REFPROP, the Lemmon and Jacobsen model was adopted as the basis for the mixture properties specified in this International Standard.

The one significant disadvantage of the formulations adopted here is their complexity. In recognition of this, this International Standard 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). This International Standard does not restrict the form of such alternative implementations, but it does impose requirements, in the form of allowable tolerances (deviations from the standard values), given in Annex A, which alternative implementations shall satisfy.

The question of allowable tolerances for alternative implementations generated the most controversy among the working group. In the working group discussions, some felt that the tolerances should be fairly large to encompass as many formulations in common use as possible. But others argued that this would defeat the very purpose of this International Standard, which was to harmonize the property values used across the industry. The concept of alternative implementations with their allowable tolerances was not intended to sanction the continued use of “incorrect” data but, rather, to provide for fast, application-specific equations that would be fitted to the properties specified in this International Standard. In the end, fairly strict tolerances were selected. The experiences and recommendations of the European Association of Compressor Manufacturers (ASERCOM) carried significant weight. They had experience with simplified property equations that were fitted to, and closely matched, several of the same equations of state recommended in this International Standard. They recommended strict tolerances.

These tolerances do not necessarily represent the uncertainty of the original experimental data or of the equation of state in fitting the data. The allowable tolerances specified in Annex A were selected to result in "reasonable" differences in quantities derived from these properties, for example, a cycle efficiency or compressor rating. For example, the tolerances specified in Annex A result in an overall variation of approximately 2,5 % in the efficiency of an ideal refrigeration cycle operating between an evaporator temperature of − 15 °C and a condenser temperature of 30 °C. By comparison, ISO 817 specifies that the primary energy balance for compressor tests agree with flow data within 4 %.

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. This scaling arose from a cycle analysis which revealed that a constant tolerance resulted in greatly differing sensitivities of the cycle efficiency depending on the enthalpy and entropy of vapourisation. 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 International Standard), 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 International Standard.

The values of the gas constant, R, vary from fluid to fluid. Similarly, the number of significant figures given for the molecular mass, M, vary. The values for R and M are those from the original equation of state source from the literature. These values are adopted to maintain consistency with the original sources. The various values of R differ by less than 5×10^{-6} (equal to parts per million, a deprecated unit) from the currently accepted value of 8,314 472 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 figures are given for consistency with the tables of "verification values" given in Annex D.

This International Standard anticipates regular reviews (see Clause 6) and will be reviewed every five years. Any interested party requesting the inclusion of additional refrigerant(s) to this International Standard or requesting the revision of one or more fluids specified in this International Standard should petition the ISO/TC 86 secretariat.

Refrigerant properties

1 Scope

This International Standard specifies thermophysical properties of several commonly used refrigerants and refrigerant blends.

This International Standard is applicable to the refrigerants R12, R22, R32, R123, R125, R134a, R143a, R152a, R717 (ammonia), and R744 (carbon dioxide) 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.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

ISO 817, *Refrigerants — Designation system*

3 Terms and definitions

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

3.1
algorithm
procedure for the computation of refrigerant properties

NOTE 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 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 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 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 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
all of the 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 International Standard specifies properties for the refrigerants listed in Clause 1. These properties are derived from experimental measurements. It is not practical, however, to directly reference the experimental data; they may not be available at all conditions of interest and some properties, such as entropy, cannot be measured directly. Furthermore, a simple tabulation, even for properties (such as vapour pressure) that are directly measurable, is not convenient for modern engineering use. Thus, some means to correlate the data is required to allow calculation of the properties at a desired thermodynamic state.

The properties enumerated in this International Standard are calculated from specified equations of state, although alternative algorithms are allowed. The properties themselves constitute this International Standard. The equations of state serve as a convenient means to represent and reproduce the properties. The properties enumerated in the tables in this International Standard thus represent only a subset of the properties specified by this International Standard; 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 and density. The equation is composed of separate terms arising from ideal-gas behaviour (subscript "id") and a "residual" or "real-fluid" (subscript "r") contribution as given in Equation (1):

$$\phi = \frac{A}{RT} = \phi_{\mathrm{id}} + \phi_{\mathrm{r}} \tag{1}$$

where R is the gas constant. Equations of this form may be written on either a molar basis or a mass basis. For a consistent representation in this International Standard, 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 Equation (2):

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

where

τ	is the dimensionless temperature variable T^*/T;
T^*	is the reducing parameter which is often equal to the critical parameter;
δ	is the dimensionless density variable ρ/ρ^*;
ρ^*	is the reducing parameter which is often equal to the critical parameter;
N_k	are numerical coefficients fitted to experimental data;
α_k, β_k, ε_k and γ_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 Equation (3):

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

where

h_{ref} is the arbitrary reference enthalpy for the ideal gas at the reference state specified by T_{ref};

s_{ref} is the arbitrary reference entropy for the ideal gas at the reference state specified by T_{ref} and p_{ref}.

In this International Standard, the h_{ref} and s_{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_{ref} and s_{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 Equation (4):

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

where

$$u_k = \frac{b_k}{T}; \tag{5}$$

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 Equation (6):

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

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, λ_k and t_k are either empirical or theoretical parameters.

Equation (6) is functionally equivalent to Equations (3) to (5), and an ideal-gas contribution in the form of Equation (6) may be converted to the heat capacity form as given by Equation (7):

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

where

$$u_k = \frac{\lambda_k T^*}{T} \tag{8}$$

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 Equation (9):

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

where

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

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

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

Equation (9) is added to the normal terms in Equation (1). The N_k, A_k, B_k, C_k, D_k, α_k and β_k are adjustable parameters fitted to data. Among the fluids in this International Standard, 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 Equation (13):

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

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 equation is combined with an expression for the ideal-gas heat capacity, such as Equation (4) or (5).

In this International Standard, pressure-explicit equations of state [such as Equation (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 Equation (14):

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

Thus, the Helmholtz energy can be evaluated from the pressure by an integration over volume, using Equation (15):

$$\frac{A_\text{r}(T, \rho)}{RT} = \phi_\text{r} = -\int_V^\infty \left(\frac{p}{RT} - \rho\right) \text{d}V \tag{15}$$

Equation (15) is then combined with an ideal-gas contribution given by Equations (3) to (5) to yield a complete description of the thermodynamic properties. Among the fluids in this International Standard, 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 Equations (1) through (15) encompass all those specified in this International Standard.

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 Equation (16):

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

The ideal gas part is given by Equation (17):

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

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 Equation (18):

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

The first summation in this equation 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 $\phi_{i,\text{r}}$ and $\phi_{ij,\text{excess}}$ functions in Equation (18) are not evaluated at the temperature, T_{mix}, and density, ρ_{mix}, of the mixture, but, rather, at a reduced temperature, τ, and density, δ. The mixing rules for the reducing parameters are given by Equations (19) and (20):

$$\tau = \frac{T^*}{T_{\text{mix}}} \tag{19}$$

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

$$\delta = \frac{\rho_{\text{mix}}}{\rho^*} \tag{20}$$

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

ζ_{ij} and ξ_{ij} are "interaction parameters";

T_i* and ρ_i* are the reducing parameters of the pure fluids.

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

$$\phi_{ij,\text{excess}} = F_{ij} \sum_{k} N_k \delta^{d_k} \tau^{t_k} \exp\left(-\delta^{l_k}\right) \tag{21}$$

The $\phi_{ij,\text{excess}}$ function will, in general, vary from mixture to mixture, and the coefficients and exponents are tabulated in Clause 5 for the refrigerant blends included in this International Standard. In all cases, the pure-component contributions are those defined in Clause 5 of this International Standard.

Methods for computing thermodynamic properties from a mixture equation of state are given in Annex C.

4.4 Implementation

An algorithm is conforming to this International Standard if it directly implements 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 demonstrated to reproduce, for the fluids implemented, the "verification values" given in Annex D.

4.5 Alternative implementation

An algorithm is conforming to this International Standard if, by any method, it reproduces the values of thermodynamic properties specified in this International Standard for the fluids implemented. An algorithm claiming compliance under this section can 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 must 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 International Standard and those of an alternative implementation vary from property to property and are defined in Annex A.

4.6 Certification of conformance

Any computer program or other implementation of this International Standard must satisfy the requirements specified in Annex A before it can claim compliance with this International Standard. These requirements shall be carried out by the developer of the particular implementation.

5 Specifications for individual refrigerants

5.1 General

The following sections specify the equations of state used to calculate the properties of each of the refrigerants covered by this International Standard 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 K, T_{max} = 1 100 K; p_{max} = 800 MPa; ρ_{max} = 37,24 mol/l (1 639 kg/m^3)

Table 1 — Coefficients and exponents of the ideal-gas part [Equations (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 [Equation (2)]

k	N_k	t_k	d_k	l_k	α_k	m_k	β_k	γ_k	ε_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 [Equations (9) to (12)]

k	N_k	a_k	b_k	β_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
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

$T^* = 304{,}128\ 2$ K, $\rho^* = 10{,}624\ 906\ 3$ mol/l, $M = 44{,}009\ 8$ g/mol, $R = 8{,}314\ 51$ J/(mol·K)

5.2.3 Reference state parameters

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

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

	Temp. °C	Pressure MPa	Density kg/m³	Internal energy kJ/kg	Enthalpy kJ/kg	Entropy kJ/(kg·K)	C_v kJ/(kg·K)	C_p kJ/(kg·K)	Sound speed m/s	J-T coefficient K/MPa
liquid	–56,56[a]	0,518 0	1178,5	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	1172,9	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	1154,6	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	1135,8	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	1116,4	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	1096,4	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	1075,7	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	1054,2	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	1031,7	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	1008,0	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
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	[b]	[b]	[b]	5,866 5

[a] Triple point.

[b] The values of C_v, C_p, and w at the critical point are not included as part of this International Standard.

5.3 R717 — Ammonia

5.3.1 Range of validity

The coefficients are valid within the following ranges:

T_{min} = 195,495 K, T_{max} = 700 K; p_{max} = 1 000 MPa; ρ_{max} = 52,915 mol/l (901 kg/m^3)

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

k	c_k	t_k
1	$1{,}887\,164\,1 \times 10^{1}$	– 0,333 333 333 333
2	$5{,}954\,993\,4 \times 10^{-4}$	1,5
3	$-\,7{,}498\,313\,1 \times 10^{-5}$	1,75

Table 6 — Coefficients and exponents of the real-gas part [Equation (2)]

k	N_k	t_k	d_k	l_k	α_k
1	– 1,858 814	1,5	1	0	0
2	0,0455 443 1	– 0,5	2	0	0
3	0,723 854 8	0,5	1	0	0
4	0,012 294 7	1	4	0	0
5	$2{,}141\,882 \times 10^{-11}$	3	15	0	0
6	– 0,014 300 2	0	3	1	1
7	0,344 132 4	3	3	1	1
8	– 0,287 357 1	4	1	1	1
9	0,000 023 525 89	4	8	1	1
10	– 0,034 971 11	5	2	1	1
11	0,0018 311 17	5	8	2	1
12	0,023 978 52	3	1	2	1
13	– 0,040 853 75	6	1	2	1
14	0,237 927 5	8	2	2	1
15	– 0,035 489 72	8	3	2	1
16	– 0,182 372 9	10	2	2	1
17	0,022 815 56	10	4	2	1
18	– 0,006 663 444	5	3	3	1
19	– 0,008 847 486	7,5	1	3	1
20	0,002 272 635	15	2	3	1
21	– 0,000 558 865 5	30	4	3	1

5.3.2 Reducing parameters, molar mass, and gas constant

T^* = 405,4 K, ρ^* = 13,211 777 15 mol/l, M = 17,030 26 g/mol, R = 8,314 471 J/(mol·K)

5.3.3 Reference state parameters

T_{ref} = 273,15 K, p_{ref} = 1,0 kPa, h_{ref} = 25 558,797 J/mol, s_{ref} = 147,991 0 J/(mol·K), f_1 = – 24,401, f_2 = 1 725,271 55

Table 7 — R717 property values along the liquid-vapour saturation boundary

	Temp. °C	Pressure MPa	Density kg/m³	Internal energy kJ/kg	Enthalpy kJ/kg	Entropy kJ/(kg·K)	C_v kJ/(kg·K)	C_p kJ/(kg·K)	Sound speed m/s	J-T coefficient K/MPa
liquid	−77,65[a]	0,00609	732,9	–143,15	–143,15	–0,4716	2,9343	4,2022	2124,2	–0,2336
vapour			0,0641	1246,20	1341,23	7,1213	1,5566	2,0628	354,12	171,13
liquid	−75,00	0,00751	730,1	–131,98	–131,97	–0,4148	2,9297	4,2167	2097,8	–0,2310
vapour			0,0780	1249,97	1346,24	7,0452	1,5613	2,0700	356,37	159,84
liquid	−70,00	0,0109	724,7	–110,83	–110,81	–0,3094	2,9206	4,2450	2051,3	–0,2260
vapour			0,111	1257,00	1355,55	6,9088	1,5715	2,0856	360,50	141,14
liquid	−65,00	0,0156	719,2	–89,53	–89,51	–0,2058	2,9113	4,2740	2008,0	–0,2208
vapour			0,155	1263,92	1364,73	6,7807	1,5836	2,1040	364,50	125,27
liquid	−60,00	0,0219	713,6	–68,09	–68,06	–0,1040	2,9019	4,3031	1967,1	–0,2155
vapour			0,213	1270,71	1373,73	6,6602	1,5975	2,1254	368,35	111,72
liquid	−55,00	0,0301	707,9	–46,51	–46,47	–0,0040	2,8928	4,3318	1927,9	–0,2101
vapour			0,287	1277,37	1382,56	6,5467	1,6133	2,1500	372,05	100,10
liquid	−50,00	0,0408	702,1	–24,79	–24,73	0,0945	2,8837	4,3599	1889,9	–0,2047
vapour			0,381	1283,88	1391,19	6,4396	1,6310	2,1778	375,60	90,06
liquid	–45,00	0,0545	696,2	–2,93	–2,85	0,1914	2,8749	4,3872	1852,7	–0,1992
vapour			0,498	1290,23	1399,59	6,3384	1,6507	2,2092	378,98	81,36
liquid	–40,00	0,0717	690,2	19,07	19,17	0,2867	2,8662	4,4137	1816,2	–0,1936
vapour			0,644	1296,41	1407,76	6,2425	1,6724	2,2441	382,19	73,77
liquid	–35,00	0,0931	684,0	41,18	41,32	0,3806	2,8577	4,4394	1780,2	–0,1878
vapour			0,822	1302,40	1415,68	6,1516	1,6961	2,2830	385,23	67,11
liquid	–33,33[b]	0,1013	682,0	48,62	48,76	0,4117	2,8548	4,4479	1768,2	–0,1858
vapour			0,890	1304,36	1418,26	6,1221	1,7045	2,2969	386,20	65,06
liquid	–30,00	0,1194	677,8	63,43	63,60	0,4730	2,8492	4,4645	1744,4	–0,1818
vapour			1,037	1308,19	1423,31	6,0651	1,7218	2,3259	388,08	61,24
liquid	–25,00	0,1515	671,5	85,79	86,01	0,5641	2,8408	4,4892	1708,8	–0,1756
vapour			1,296	1313,77	1430,65	5,9827	1,7495	2,3730	390,73	56,05
liquid	–20,00	0,1901	665,1	108,26	108,55	0,6538	2,8325	4,5138	1673,2	–0,1691
vapour			1,603	1319,12	1437,68	5,9041	1,7793	2,4245	393,18	51,43
liquid	–15,00	0,2362	658,6	130,86	131,22	0,7421	2,8243	4,5385	1637,7	–0,1623
vapour			1,966	1324,23	1444,37	5,8289	1,8110	2,4807	395,42	47,32
liquid	–10,00	0,2907	652,1	153,56	154,01	0,8293	2,8162	4,5636	1602,1	–0,1550
vapour			2,391	1329,10	1450,70	5,7569	1,8446	2,5419	397,45	43,63
liquid	–5,00	0,3548	645,4	176,39	176,94	0,9152	2,8082	4,5895	1566,4	–0,1472
vapour			2,885	1333,70	1456,67	5,6877	1,8802	2,6082	399,25	40,32
liquid	0,00	0,4294	638,6	199,33	200,00	1,0000	2,8003	4,6165	1530,5	–0,1388
vapour			3,457	1338,02	1462,24	5,6210	1,9176	2,6799	400,82	37,33
liquid	5,00	0,5157	631,7	222,39	223,21	1,0837	2,7926	4,6451	1494,4	–0,1297
vapour			4,115	1342,05	1467,39	5,5568	1,9569	2,7575	402,16	34,63
liquid	10,00	0,6150	624,6	245,58	246,57	1,1664	2,7851	4,6757	1458,1	–0,1198
vapour			4,868	1345,77	1472,11	5,4946	1,9979	2,8413	403,24	32,19
liquid	15,00	0,7285	617,5	268,91	270,09	1,2481	2,7780	4,7088	1421,5	–0,1090
vapour			5,727	1349,17	1476,38	5,4344	2,0406	2,9318	404,07	29,97
liquid	20,00	0,8575	610,2	292,38	293,78	1,3289	2,7711	4,7448	1384,5	–0,0971
vapour			6,703	1352,22	1480,16	5,3759	2,0849	3,0296	404,63	27,96
liquid	25,00	1,0032	602,8	316,00	317,67	1,4088	2,7647	4,7844	1347,1	–0,0840
vapour			7,807	1354,92	1483,43	5,3188	2,1308	3,1353	404,92	26,13
liquid	30,00	1,1672	595,2	339,80	341,76	1,4881	2,7587	4,8282	1309,3	–0,0695
vapour			9,053	1357,24	1486,17	5,2631	2,1782	3,2500	404,92	24,45

Table 7 (*continued*)

	Temp. °C	Pressure MPa	Density kg/m³	Internal energy kJ/kg	Enthalpy kJ/kg	Entropy kJ/(kg·K)	C_v kJ/(kg·K)	C_p kJ/(kg·K)	Sound speed m/s	J-T coefficient K/MPa
liquid vapour	35,00	1,3508	587,4 10,457	363,77 1359,16	366,07 1488,34	1,5666 5,2086	2,7532 2,2272	4,8771 3,3745	1271,0 404,63	–0,0534 22,92
liquid vapour	40,00	1,5554	579,4 12,034	387,95 1360,65	390,64 1489,91	1,6446 5,1549	2,7484 2,2776	4,9318 3,5104	1232,1 404,03	–0,0353 21,52
liquid vapour	45,00	1,7827	571,3 13,803	412,35 1361,68	415,48 1490,83	1,7220 5,1020	2,7443 2,3294	4,9935 3,6593	1192,7 403,12	–0,0152 20,24
liquid vapour	50,00	2,0340	562,9 15,785	437,01 1362,22	440,62 1491,07	1,7990 5,0497	2,7411 2,3828	5,0635 3,8233	1152,6 401,88	0,0076 19,06
liquid vapour	55,00	2,3111	554,2 18,006	461,93 1362,22	466,10 1490,57	1,8758 4,9977	2,7389 2,4377	5,1434 4,0051	1111,7 400,29	0,0333 17,98
liquid vapour	60,00	2,6156	545,2 20,493	487,17 1361,63	491,97 1489,27	1,9523 4,9458	2,7379 2,4942	5,2351 4,2084	1070,2 398,34	0,0626 16,98
liquid vapour	65,00	2,9491	536,0 23,280	512,76 1360,41	518,26 1487,09	2,0288 4,8939	2,7382 2,5525	5,3411 4,4376	1027,7 396,01	0,0960 16,05
liquid vapour	70,00	3,3135	526,3 26,407	538,75 1358,46	545,04 1483,94	2,1054 4,8415	2,7402 2,6126	5,4648 4,6990	984,4 393,29	0,1346 15,19
liquid vapour	75,00	3,7105	516,2 29,923	565,19 1355,73	572,37 1479,72	2,1823 4,7885	2,7441 2,6748	5,6103 5,0009	940,0 390,14	0,1793 14,39
liquid vapour	80,00	4,1420	505,7 33,888	592,15 1352,08	600,34 1474,31	2,2596 4,7344	2,7503 2,7393	5,7837 5,3546	894,7 386,54	0,2317 13,65
liquid vapour	85,00	4,6100	494,5 38,376	619,72 1347,40	629,04 1467,53	2,3377 4,6789	2,7594 2,8066	5,9930 5,7766	848,1 382,47	0,2935 12,94
liquid vapour	90,00	5,1167	482,8 43,484	648,01 1341,52	658,61 1459,19	2,4168 4,6213	2,7719 2,8770	6,2501 6,2907	800,4 377,88	0,3674 12,27
liquid vapour	95,00	5,6643	470,2 49,340	677,14 1334,20	689,19 1449,01	2,4973 4,5612	2,7886 2,9511	6,5731 6,9332	751,3 372,74	0,4569 11,63
liquid vapour	100,00	6,2553	456,6 56,117	707,30 1325,16	721,00 1436,63	2,5797 4,4975	2,8108 3,0297	6,9912 7,7622	700,7 366,99	0,5673 11,01
liquid vapour	105,00	6,8923	441,9 64,063	738,75 1313,98	754,35 1421,57	2,6647 4,4291	2,8400 3,1139	7,5551 8,8773	648,5 360,54	0,7063 10,40
liquid vapour	110,00	7,5783	425,6 73,550	771,88 1300,04	789,68 1403,08	2,7533 4,3542	2,8787 3,2049	8,3621 10,4630	594,4 353,29	0,8869 9,78
liquid vapour	115,00	8,3170	407,2 85,182	807,31 1282,36	827,74 1379,99	2,8474 4,2702	2,9307 3,3047	9,6278 12,9091	537,7 345,04	1,1313 9,15
liquid vapour	120,00	9,1125	385,5 100,068	846,28 1259,17	869,92 1350,23	2,9502 4,1719	3,0037 3,4163	11,9405 17,2119	477,4 335,41	1,4834 8,47
liquid vapour	125,00	9,9702	357,8 120,728	891,82 1226,54	919,68 1309,12	3,0702 4,0483	3,1159 3,5447	17,6583 26,9963	411,4 323,57	2,0455 7,69
liquid vapour	130,00	10,8977	312,3 156,766	957,12 1169,80	992,02 1239,32	3,2437 3,8571	3,3450 3,7014	54,2103 76,4902	333,6 306,58	3,1689 6,62
critical	132,25	11,3330	225,0	1068,82	1119,22	3,5542	[c]	[c]	[c]	5,0513

[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 International Standard.

5.4 R12 — Dichlorodifluoromethane

5.4.1 Range of validity

The coefficients are valid within the following ranges:

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

Table 8 — Coefficients and exponents of the ideal-gas part [Equations (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 9 — Coefficients and exponents of the real-gas part [Equation (2)]

k	N_k	t_k	d_k	l_k	α_k
1	0,207 534 340 2 × 10^{1}	0,5	1	0	0
2	– 0,296 252 599 6 × 10^{1}	1	1	0	0
3	0,100 158 961 6 × 10$^{–1}$	2	1	0	0
4	0,178 134 761 2 × 10$^{–1}$	2,5	2	0	0
5	0,255 692 915 7 × 10$^{–1}$	– 0,5	4	0	0
6	0,235 214 263 7 × 10$^{–2}$	0	6	0	0
7	– 0,849 555 331 4 × 10$^{–4}$	0	8	0	0
8	– 0,153 594 559 9 × 10$^{–1}$	– 0,5	1	1	1
9	– 0,210 881 677 6	1,5	1	1	1
10	– 0,165 422 880 6 × 10$^{–1}$	2,5	5	1	1
11	– 0,118 131 613 0 × 10$^{–1}$	– 0,5	7	1	1
12	– 0,416 029 583 0 × 10$^{–4}$	0	12	1	1
13	0,278 486 166 4 × 10$^{–4}$	0,5	12	1	1
14	0,161 868 643 3 × 10$^{–5}$	– 0,5	14	1	1
15	– 0,106 461 468 6	4	1	2	1
16	0,936 966 520 7 × 10$^{–3}$	4	9	2	1
17	0,259 009 544 7 × 10$^{–1}$	2	1	3	1
18	– 0,434 702 502 5 × 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 × 10$^{–2}$	0	5	3	1
22	0,378 919 000 8 × 10$^{–3}$	14	9	4	1

5.4.2 Reducing parameters, molar mass, and gas constant

T^* = 385,12 K, ρ^* = 4,672 781 mol/l, M = 120,913 g/mol, R = 8,314 471 J/(mol·K)

5.4.3 Reference state parameters

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

Table 10 — R12 property values along the liquid-vapour saturation boundary

	Temp. °C	Pressure MPa	Density kg/m³	Internal energy kJ/kg	Enthalpy kJ/kg	Entropy kJ/(kg·K)	C_v kJ/(kg·K)	C_p kJ/(kg·K)	Sound speed m/s	J-T coefficient K/MPa
liquid	–157,05[a]	$2,426\times10^{-7}$	1828,8	66,33	66,33	0,2780	0,5725	0,8561	1310,0	–0,5305
vapour			$3,038\times10^{-5}$	275,23	283,21	2,1461	0,2860	0,3548	99,51	532,60
liquid	–155,00	$3,883\times10^{-7}$	1823,4	68,08	68,08	0,2930	0,5674	0,8510	1299,6	–0,5333
vapour			$4,779\times10^{-5}$	275,82	283,94	2,1200	0,2894	0,3582	100,27	495,55
liquid	–150,00	$1,135\times10^{-6}$	1810,1	72,31	72,31	0,3280	0,5567	0,8404	1274,4	–0,5389
vapour			$1,340\times10^{-4}$	277,29	285,75	2,0612	0,2978	0,3665	102,10	418,14
liquid	–145,00	$3,019\times10^{-6}$	1796,9	76,49	76,49	0,3613	0,5482	0,8321	1249,5	–0,5430
vapour			$3,426\times10^{-4}$	278,80	287,61	2,0087	0,3062	0,3749	103,88	355,64
liquid	–140,00	$7,387\times10^{-6}$	1783,7	80,63	80,63	0,3930	0,5415	0,8257	1224,8	–0,5458
vapour			$8,068\times10^{-4}$	280,35	289,50	1,9617	0,3146	0,3833	105,63	304,78
liquid	–135,00	$1,680\times10^{-5}$	1770,6	84,75	84,75	0,4234	0,5363	0,8210	1200,3	–0,5473
vapour			$1,768\times10^{-3}$	281,94	291,44	1,9195	0,3229	0,3917	107,34	263,05
liquid	–130,00	$3,577\times10^{-5}$	1757,5	88,85	88,85	0,4525	0,5324	0,8177	1176,0	–0,5476
vapour			$3,635\times10^{-3}$	283,57	293,42	1,8816	0,3313	0,4001	109,02	228,57
liquid	–125,00	$7,189\times10^{-5}$	1744,5	92,93	92,93	0,4805	0,5296	0,8157	1152,0	–0,5469
vapour			$7,058\times10^{-3}$	285,25	295,44	1,8474	0,3396	0,4084	110,67	199,86
liquid	–120,00	0,000137	1731,4	97,01	97,01	0,5076	0,5277	0,8146	1128,1	–0,5453
vapour			0,01303	286,96	297,49	1,8167	0,3478	0,4166	112,29	175,81
liquid	–115,00	0,000250	1718,4	101,08	101,08	0,5338	0,5266	0,8145	1104,5	–0,5428
vapour			0,02297	288,72	299,59	1,7890	0,3559	0,4248	113,89	155,54
liquid	–110,00	0,000436	1705,3	105,15	105,15	0,5591	0,5263	0,8152	1081,1	–0,5395
vapour			0,03887	290,51	301,72	1,7640	0,3640	0,4330	115,45	138,34
liquid	–105,00	0,000732	1692,2	109,23	109,23	0,5838	0,5265	0,8166	1058,0	–0,5355
vapour			0,06339	292,34	303,89	1,7414	0,3719	0,4410	116,99	123,68
liquid	–100,00	0,00119	1679,1	113,32	113,32	0,6077	0,5272	0,8186	1035,0	–0,5308
vapour			0,1000	294,20	306,09	1,7210	0,3798	0,4491	118,49	111,11
liquid	–95,00	0,00187	1666,0	117,42	117,42	0,6310	0,5283	0,8211	1012,2	–0,5254
vapour			0,1529	296,10	308,32	1,7026	0,3876	0,4571	119,96	100,28
liquid	–90,00	0,00286	1652,8	121,53	121,53	0,6538	0,5298	0,8241	989,7	–0,5194
vapour			0,2275	298,03	310,59	1,6861	0,3953	0,4650	121,39	90,92
liquid	–85,00	0,00426	1639,6	125,66	125,66	0,6761	0,5316	0,8275	967,3	–0,5128
vapour			0,3302	299,98	312,87	1,6711	0,4030	0,4730	122,79	82,78
liquid	–80,00	0,00619	1626,3	129,80	129,81	0,6978	0,5337	0,8313	945,2	–0,5055
vapour			0,4683	301,97	315,19	1,6576	0,4105	0,4810	124,14	75,69
liquid	–75,00	0,00881	1612,9	133,97	133,98	0,7191	0,5361	0,8355	923,3	–0,4977
vapour			0,6503	303,98	317,52	1,6454	0,4181	0,4890	125,45	69,49
liquid	–70,00	0,0123	1599,5	138,16	138,17	0,7400	0,5386	0,8400	901,5	–0,4892
vapour			0,886	306,01	319,87	1,6344	0,4255	0,4971	126,71	64,05
liquid	–65,00	0,0168	1586,0	142,37	142,38	0,7604	0,5413	0,8448	879,9	–0,4801
vapour			1,186	308,07	322,24	1,6245	0,4330	0,5052	127,91	59,26

Table 10 (*continued*)

	Temp. °C	Pressure MPa	Density kg/m³	Internal energy kJ/kg	Enthalpy kJ/kg	Entropy kJ/(kg·K)	C_v kJ/(kg·K)	C_p kJ/(kg·K)	Sound speed m/s	J-T coefficient K/MPa
liquid vapour	–60,00	0,0226	1572,3 1,563	146,60 310,14	146,62 324,61	0,7806 1,6156	0,5442 0,4403	0,8499 0,5134	858,5 129,06	–0,4703 55,03
liquid vapour	–55,00	0,0300	1558,6 2,029	150,87 312,23	150,88 327,00	0,8003 1,6076	0,5472 0,4477	0,8553 0,5218	837,3 130,15	–0,4598 51,29
liquid vapour	–50,00	0,0391	1544,7 2,598	155,15 314,34	155,18 329,39	0,8197 1,6004	0,5503 0,4550	0,8609 0,5302	816,2 131,17	–0,4486 47,97
liquid vapour	–45,00	0,0504	1530,7 3,286	159,47 316,45	159,50 331,79	0,8389 1,5940	0,5535 0,4624	0,8668 0,5389	795,3 132,11	–0,4366 45,01
liquid vapour	–40,00	0,0641	1516,5 4,108	163,81 318,58	163,86 334,18	0,8577 1,5882	0,5568 0,4697	0,8730 0,5477	774,5 132,99	–0,4237 42,38
liquid vapour	–35,00	0,0806	1502,2 5,083	168,19 320,71	168,24 336,56	0,8763 1,5831	0,5602 0,4770	0,8795 0,5568	753,8 133,78	–0,4099 40,02
liquid vapour	–30,00	0,1003	1487,7 6,228	172,60 322,84	172,67 338,94	0,8946 1,5784	0,5636 0,4843	0,8863 0,5661	733,3 134,49	–0,3951 37,90
liquid vapour	–29,75[b]	0,1013	1487,0 6,289	172,82 322,95	172,89 339,06	0,8955 1,5782	0,5637 0,4847	0,8866 0,5666	732,3 134,52	–0,3943 37,81
liquid vapour	–25,00	0,1235	1473,0 7,563	177,04 324,98	177,12 341,30	0,9127 1,5743	0,5670 0,4917	0,8934 0,5757	712,9 135,10	–0,3792 36,00
liquid vapour	–20,00	0,1507	1458,1 9,109	181,51 327,11	181,62 343,65	0,9305 1,5706	0,5705 0,4990	0,9007 0,5857	692,5 135,63	–0,3620 34,29
liquid vapour	–15,00	0,1823	1443,0 10,889	186,02 329,24	186,15 345,98	0,9482 1,5673	0,5741 0,5064	0,9085 0,5960	672,3 136,05	–0,3434 32,75
liquid vapour	–10,00	0,2188	1427,6 12,925	190,57 331,36	190,72 348,29	0,9656 1,5644	0,5776 0,5139	0,9166 0,6068	652,1 136,38	–0,3233 31,35
liquid vapour	–5,00	0,2606	1412,0 15,244	195,15 333,47	195,34 350,56	0,9829 1,5618	0,5812 0,5213	0,9251 0,6180	632,0 136,59	–0,3015 30,09
liquid vapour	0,00	0,3081	1396,1 17,873	199,78 335,56	200,00 352,81	1,0000 1,5594	0,5849 0,5289	0,9341 0,6298	611,9 136,69	–0,2777 28,94
liquid vapour	5,00	0,3620	1379,8 20,842	204,45 337,64	204,71 355,01	1,0169 1,5573	0,5885 0,5365	0,9436 0,6423	591,9 136,68	–0,2516 27,91
liquid vapour	10,00	0,4227	1363,2 24,184	209,15 339,70	209,46 357,18	1,0337 1,5554	0,5922 0,5441	0,9537 0,6555	571,8 136,54	–0,2230 26,97
liquid vapour	15,00	0,4906	1346,3 27,935	213,91 341,73	214,27 359,30	1,0504 1,5537	0,5960 0,5519	0,9645 0,6696	551,8 136,28	–0,1915 26,11
liquid vapour	20,00	0,5664	1328,9 32,135	218,71 343,73	219,14 361,36	1,0669 1,5521	0,5997 0,5597	0,9761 0,6846	531,7 135,88	–0,1565 25,34
liquid vapour	25,00	0,6506	1311,0 36,828	223,56 345,70	224,06 363,37	1,0834 1,5506	0,6036 0,5676	0,9885 0,7008	511,5 135,34	–0,1176 24,65
liquid vapour	30,00	0,7437	1292,7 42,066	228,47 347,63	229,04 365,31	1,0997 1,5492	0,6075 0,5757	1,0021 0,7184	491,3 134,65	–0,0740 24,02
liquid vapour	35,00	0,8462	1273,8 47,906	233,43 349,51	234,10 367,18	1,1160 1,5478	0,6114 0,5838	1,0169 0,7377	471,0 133,82	–0,0248 23,46
liquid vapour	40,00	0,9588	1254,3 54,416	238,46 351,34	239,22 368,96	1,1322 1,5465	0,6155 0,5921	1,0332 0,7589	450,5 132,82	0,0311 22,96
liquid vapour	45,00	1,0821	1234,0 61,673	243,55 353,11	244,42 370,66	1,1484 1,5451	0,6197 0,6006	1,0514 0,7827	429,7 131,65	0,0950 22,52
liquid vapour	50,00	1,2166	1213,0 69,771	248,71 354,81	249,71 372,24	1,1645 1,5437	0,6242 0,6093	1,0719 0,8095	408,8 130,30	0,1688 22,14

Table 10 (*continued*)

	Temp. °C	**Pressure** MPa	**Density** kg/m³	**Internal energy** kJ/kg	**Enthalpy** kJ/kg	**Entropy** kJ/(kg·K)	C_v kJ/(kg·K)	C_p kJ/(kg·K)	**Sound speed** m/s	**J-T coefficient** K/MPa
liquid vapour	55,00	1,3630	1191,1 78,823	253,95 356,42	255,10 373,72	1,1807 1,5421	0,6288 0,6182	1,0953 0,8404	387,5 128,76	0,2549 21,81
liquid vapour	60,00	1,5219	1168,1 88,966	259,28 357,94	260,58 375,05	1,1969 1,5404	0,6338 0,6274	1,1225 0,8763	365,9 127,02	0,3565 21,54
liquid vapour	65,00	1,6941	1144,0 100,375	264,71 359,35	266,19 376,23	1,2131 1,5385	0,6391 0,6370	1,1545 0,9191	343,9 125,07	0,4783 21,31
liquid vapour	70,00	1,8802	1118,3 113,272	270,26 360,62	271,94 377,22	1,2295 1,5363	0,6450 0,6471	1,1931 0,9714	321,3 122,88	0,6264 21,14
liquid vapour	75,00	2,0811	1090,9 127,952	275,94 361,72	277,84 377,99	1,2461 1,5337	0,6517 0,6578	1,2410 1,0370	298,1 120,44	0,8103 21,01
liquid vapour	80,00	2,2975	1061,4 144,822	281,78 362,62	283,94 378,48	1,2629 1,5306	0,6594 0,6693	1,3024 1,1225	274,1 117,73	1,0439 20,92
liquid vapour	85,00	2,5304	1029,1 164,464	287,82 363,26	290,27 378,64	1,2801 1,5268	0,6684 0,6819	1,3844 1,2394	249,4 114,73	1,3495 20,85
liquid vapour	90,00	2,7808	993,2 187,766	294,11 363,54	296,91 378,35	1,2978 1,5220	0,6795 0,6961	1,5006 1,4101	223,6 111,41	1,7636 20,79
liquid vapour	95,00	3,0501	952,2 216,208	300,75 363,34	303,95 377,45	1,3163 1,5159	0,6936 0,7127	1,6794 1,6835	196,9 107,75	2,3518 20,68
liquid vapour	100,00	3,3399	903,8 252,577	307,89 362,38	311,58 375,60	1,3360 1,5076	0,7122 0,7332	1,9963 2,1924	169,0 103,73	3,2470 20,41
liquid vapour	105,00	3,6525	842,2 303,473	315,90 360,05	320,24 372,08	1,3581 1,4952	0,7387 0,7610	2,7539 3,4579	139,3 99,28	4,7872 19,71
liquid vapour	110,00	3,9924	742,7 396,337	326,44 353,88	331,82 363,95	1,3874 1,4712	0,7870 0,8089	7,8061 11,4400	105,3 93,96	8,2916 17,60
critical	111,97	4,1361	565,0	340,44	347,76	1,4283	[c]	[c]	[c]	13,3694

[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 International Standard.

5.5 R22 — Chlorodifluoromethane

5.5.1 Range of validity

The coefficients are valid within the following ranges:

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

Table 11 — Coefficients and exponents of the ideal-gas part [Equations (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 12 — Coefficients and exponents of the real-gas part [Equation (2)]

k	N_k	t_k	d_k	l_k	α_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

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

5.5.3 Reference state parameters

$T_{\text{ref}} = 273{,}15$ K, $p_{\text{ref}} = 1{,}0$ kPa, $h_{\text{ref}} = 35\ 874{,}594$ J/mol, $s_{\text{ref}} = 205{,}291\ 5$ J/(mol·K), $f_1 = 4{,}111\ 053\ 69$, $f_2 = 2\ 986{,}449\ 88$

Table 13 — R22 property values along the liquid-vapour saturation boundary

	Temp. °C	Pressure MPa	Density kg/m³	Internal energy kJ/kg	Enthalpy kJ/kg	Entropy kJ/(kg·K)	C_v kJ/(kg·K)	C_p kJ/(kg·K)	Sound speed m/s	J-T coefficient K/MPa
liquid	–157,42[a]	$3{,}795\times10^{-7}$	1721,3	29,60	29,60	0,0761	0,7161	1,0753	1410,9	–0,4446
vapour			$3{,}410\times10^{-5}$	321,58	332,71	2,6952	0,3292	0,4253	119,91	398,80
liquid	–155,00	$6{,}620\times10^{-7}$	1714,9	32,20	32,20	0,0983	0,7139	1,0735	1398,2	–0,4450
vapour			$5{,}827\times10^{-5}$	322,38	333,74	2,6505	0,3318	0,4280	121,05	380,74
liquid	–150,00	$1{,}934\times10^{-6}$	1701,8	37,56	37,56	0,1428	0,7086	1,0696	1371,9	–0,4456
vapour			$1{,}633\times10^{-4}$	324,05	335,90	2,5653	0,3375	0,4336	123,35	344,75
liquid	–145,00	$5{,}141\times10^{-6}$	1688,8	42,90	42,90	0,1853	0,7027	1,0663	1346,3	–0,4456
vapour			$4{,}172\times10^{-4}$	325,76	338,08	2,4887	0,3433	0,4394	125,60	311,19
liquid	–140,00	$1{,}258\times10^{-5}$	1675,8	48,22	48,22	0,2260	0,6972	1,0641	1321,4	–0,4449
vapour			$9{,}826\times10^{-4}$	327,49	340,29	2,4195	0,3492	0,4454	127,78	280,46
liquid	–135,00	$2{,}860\times10^{-5}$	1662,8	53,54	53,54	0,2652	0,6923	1,0628	1296,8	–0,4436
vapour			$2{,}153\times10^{-3}$	329,25	342,53	2,3571	0,3552	0,4514	129,92	252,63
liquid	–130,00	$6{,}091\times10^{-5}$	1649,8	58,85	58,85	0,3030	0,6882	1,0622	1272,4	–0,4417
vapour			$4{,}426\times10^{-3}$	331,04	344,80	2,3005	0,3614	0,4576	132,01	227,61
liquid	–125,00	0,000122	1636,8	64,16	64,16	0,3395	0,6847	1,0620	1248,0	–0,4396
vapour			0,00859	332,85	347,10	2,2492	0,3676	0,4639	134,05	205,23
liquid	–120,00	0,000233	1623,7	69,47	69,47	0,3747	0,6815	1,0619	1223,7	–0,4372
vapour			0,01585	334,70	349,42	2,2027	0,3739	0,4703	136,04	185,26
liquid	–115,00	0,000424	1610,7	74,78	74,78	0,4088	0,6786	1,0618	1199,5	–0,4346
vapour			0,02792	336,57	351,77	2,1603	0,3803	0,4768	137,99	167,49
liquid	–110,00	0,000740	1597,6	80,09	80,09	0,4419	0,6759	1,0616	1175,4	–0,4319
vapour			0,04719	338,48	354,15	2,1217	0,3868	0,4834	139,90	151,69
liquid	–105,00	0,00124	1584,5	85,40	85,40	0,4739	0,6732	1,0614	1151,4	–0,4289
vapour			0,0768	340,40	356,55	2,0865	0,3934	0,4902	141,76	137,65
liquid	–100,00	0,00201	1571,3	90,70	90,71	0,5050	0,6706	1,0612	1127,5	–0,4257
vapour			0,1210	342,35	358,97	2,0543	0,4000	0,4972	143,57	125,17
liquid	–95,00	0,00316	1558,1	96,01	96,01	0,5352	0,6680	1,0611	1103,7	–0,4221
vapour			0,1847	344,32	361,40	2,0249	0,4067	0,5044	145,34	114,07
liquid	–90,00	0,00481	1544,9	101,31	101,32	0,5646	0,6655	1,0612	1080,1	–0,4180
vapour			0,2744	346,31	363,85	1,9980	0,4136	0,5118	147,05	104,20
liquid	–85,00	0,00715	1531,6	106,62	106,63	0,5932	0,6632	1,0616	1056,6	–0,4134
vapour			0,3973	348,31	366,31	1,9734	0,4206	0,5195	148,70	95,41
liquid	–80,00	0,0104	1518,2	111,93	111,94	0,6210	0,6611	1,0624	1033,1	–0,4082
vapour			0,562	350,33	368,77	1,9508	0,4277	0,5276	150,29	87,58
liquid	–75,00	0,0147	1504,7	117,24	117,25	0,6482	0,6592	1,0637	1009,8	–0,4023
vapour			0,779	352,36	371,24	1,9300	0,4350	0,5359	151,82	80,60
liquid	–70,00	0,0205	1491,2	122,56	122,58	0,6747	0,6575	1,0655	986,4	–0,3956
vapour			1,060	354,39	373,70	1,9108	0,4425	0,5447	153,28	74,36
liquid	–65,00	0,0279	1477,5	127,90	127,91	0,7006	0,6562	1,0679	963,2	–0,3881
vapour			1,416	356,42	376,15	1,8932	0,4502	0,5539	154,66	68,78

Table 13 (*continued*)

	Temp. °C	Pressure MPa	Density kg/m³	Internal energy kJ/kg	Enthalpy kJ/kg	Entropy kJ/(kg·K)	C_v kJ/(kg·K)	C_p kJ/(kg·K)	Sound speed m/s	J-T coefficient K/MPa
liquid	–60,00	0,0375	1463,7	133,24	133,27	0,7260	0,6552	1,0710	939,9	–0,3796
vapour			1,863	358,46	378,59	1,8770	0,4581	0,5637	155,97	63,78
liquid	–55,00	0,0496	1449,7	138,60	138,63	0,7509	0,6546	1,0748	916,6	–0,3702
vapour			2,414	360,49	381,02	1,8619	0,4662	0,5739	157,18	59,29
liquid	–50,00	0,0645	1435,6	143,98	144,03	0,7752	0,6543	1,0793	893,4	–0,3597
vapour			3,088	362,52	383,42	1,8480	0,4745	0,5847	158,31	55,26
liquid	–45,00	0,0829	1421,3	149,38	149,44	0,7992	0,6544	1,0845	870,1	–0,3481
vapour			3,901	364,53	385,79	1,8351	0,4831	0,5962	159,33	51,63
liquid	–40,81[b]	0,1013	1409,2	153,93	154,00	0,8189	0,6548	1,0895	850,6	–0,3375
vapour			4,704	366,21	387,75	1,8250	0,4904	0,6063	160,11	48,85
liquid	–40,00	0,1052	1406,8	154,81	154,89	0,8227	0,6549	1,0905	846,9	–0,3353
vapour			4,873	366,53	388,13	1,8231	0,4919	0,6083	160,26	48,34
liquid	–30,00	0,1639	1377,2	165,76	165,88	0,8687	0,6570	1,1049	800,3	–0,3057
vapour			7,379	370,48	392,69	1,8015	0,5103	0,6349	161,78	42,68
liquid	–25,00	0,2014	1362,0	171,29	171,44	0,8912	0,6585	1,1134	777,0	–0,2887
vapour			8,958	372,42	394,90	1,7918	0,5199	0,6495	162,36	40,24
liquid	–20,00	0,2453	1346,5	176,86	177,04	0,9135	0,6604	1,1227	753,6	–0,2700
vapour			10,790	374,33	397,06	1,7826	0,5299	0,6650	162,82	38,01
liquid	–15,00	0,2962	1330,8	182,47	182,70	0,9354	0,6626	1,1328	730,2	–0,2495
vapour			12,901	376,20	399,16	1,7740	0,5400	0,6816	163,15	35,98
liquid	–10,00	0,3548	1314,7	188,13	188,40	0,9572	0,6651	1,1439	706,8	–0,2270
vapour			15,322	378,04	401,20	1,7658	0,5505	0,6994	163,35	34,13
liquid	–5,00	0,4218	1298,3	193,85	194,17	0,9787	0,6680	1,1561	683,4	–0,2023
vapour			18,086	379,84	403,16	1,7581	0,5613	0,7184	163,40	32,44
liquid	0,00	0,4980	1281,5	199,61	200,00	1,0000	0,6711	1,1692	659,9	–0,1750
vapour			21,229	381,59	405,05	1,7507	0,5723	0,7390	163,31	30,89
liquid	5,00	0,5841	1264,3	205,44	205,90	1,0212	0,6745	1,1836	636,3	–0,1448
vapour			24,792	383,29	406,85	1,7436	0,5836	0,7611	163,06	29,48
liquid	10,00	0,6809	1246,7	211,32	211,87	1,0422	0,6782	1,1993	612,7	–0,1112
vapour			28,820	384,93	408,56	1,7368	0,5953	0,7852	162,65	28,18
liquid	15,00	0,7893	1228,6	217,28	217,92	1,0630	0,6822	1,2166	588,9	–0,0737
vapour			33,362	386,51	410,16	1,7302	0,6072	0,8115	162,07	26,99
liquid	20,00	0,9100	1209,9	223,31	224,06	1,0838	0,6864	1,2356	565,1	–0,0316
vapour			38,477	388,01	411,66	1,7238	0,6195	0,8404	161,32	25,90
liquid	25,00	1,0439	1190,7	229,41	230,29	1,1045	0,6909	1,2568	541,1	0,0161
vapour			44,232	389,43	413,03	1,7174	0,6321	0,8724	160,38	24,90
liquid	30,00	1,1919	1170,7	235,61	236,62	1,1252	0,6956	1,2807	516,8	0,0704
vapour			50,705	390,76	414,26	1,7111	0,6450	0,9081	159,25	23,98
liquid	35,00	1,3548	1150,1	241,89	243,07	1,1458	0,7006	1,3077	492,4	0,1331
vapour			57,988	391,98	415,34	1,7048	0,6584	0,9485	157,91	23,14
liquid	40,00	1,5336	1128,5	248,29	249,65	1,1665	0,7059	1,3389	467,6	0,2060
vapour			66,193	393,08	416,25	1,6985	0,6722	0,9948	156,36	22,37
liquid	45,00	1,7292	1106,0	254,80	256,36	1,1872	0,7116	1,3755	442,5	0,2919
vapour			75,457	394,04	416,95	1,6919	0,6865	1,0487	154,58	21,66
liquid	50,00	1,9427	1082,3	261,45	263,25	1,2080	0,7176	1,4191	417,0	0,3945
vapour			85,952	394,83	417,44	1,6852	0,7014	1,1126	152,56	21,01
liquid	55,00	2,1751	1057,2	268,26	270,32	1,2291	0,7240	1,4724	390,9	0,5190
vapour			97,899	395,43	417,65	1,6781	0,7170	1,1902	150,28	20,41

Table 13 (*continued*)

	Temp. °C	**Pressure** MPa	**Density** kg/m³	**Internal energy** kJ/kg	**Enthalpy** kJ/kg	**Entropy** kJ/(kg·K)	C_v kJ/(kg·K)	C_p kJ/(kg·K)	**Sound speed** m/s	**J-T coefficient** K/MPa
liquid vapour	60,00	2,4275	1030,4 111,591	275,26 395,80	277,61 417,55	1,2504 1,6705	0,7308 0,7335	1,5392 1,2872	364,3 147,72	0,6730 19,85
liquid vapour	65,00	2,7012	1001,4 127,430	282,49 395,87	285,18 417,06	1,2722 1,6622	0,7384 0,7511	1,6259 1,4128	337,0 144,85	0,8674 19,32
liquid vapour	70,00	2,9974	969,7 145,991	290,01 395,56	293,10 416,09	1,2945 1,6529	0,7467 0,7702	1,7434 1,5837	308,8 141,66	1,1199 18,81
liquid vapour	75,00	3,3177	934,4 168,158	297,91 394,76	301,46 414,49	1,3177 1,6424	0,7563 0,7914	1,9127 1,8322	279,6 138,11	1,4598 18,28
liquid vapour	80,00	3,6638	893,7 195,404	306,34 393,26	310,44 412,01	1,3423 1,6299	0,7680 0,8157	2,1814 2,2308	248,8 134,15	1,9420 17,70
liquid vapour	85,00	4,0378	844,8 230,560	315,60 390,67	320,38 408,19	1,3690 1,6142	0,7840 0,8450	2,6821 2,9841	215,3 129,71	2,6843 16,98
liquid vapour	90,00	4,4423	780,1 280,625	326,39 386,04	332,09 401,87	1,4001 1,5922	0,8115 0,8843	3,9811 4,9749	177,0 124,64	4,0006 15,90
liquid vapour	95,00	4,8824	662,9 382,037	342,19 374,50	349,56 387,28	1,4462 1,5486	0,8918 0,9566	17,3120 25,2863	128,0 117,96	7,2855 13,40
critical	96,15	4,9900	523,8	357,37	366,90	1,4927	c	c	c	10,3661

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 International Standard.

5.6 R32 — Difluoromethane

5.6.1 Range of validity

The coefficients are valid within the following ranges:

T_{min} = 136,34 K, T_{max} = 435 K; p_{max} = 70 MPa; ρ_{max} = 27,473 4 mol/l (1 429 kg/m³)

Table 14 — Coefficients and exponents of the ideal-gas part [Equations (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 15 — Coefficients and exponents of the real-gas part [Equation (2)]

k	N_k	t_k	d_k	l_k	α_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

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

5.6.3 Reference state parameters

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

Table 16 — R32 property values along the liquid-vapour saturation boundary

	Temp. °C	Pressure MPa	Density kg/m³	Internal energy kJ/kg	Enthalpy kJ/kg	Entropy kJ/(kg·K)	C_v kJ/(kg·K)	C_p kJ/(kg·K)	Sound speed m/s	J-T coefficient K/MPa
liquid vapour	–136,81[a]	$4,800 \times 10^{-5}$	1429,3 $2,203 \times 10^{-3}$	–19,07 422,52	–19,07 444,31	–0,1050 3,2937	1,0658 0,4995	1,5925 0,6597	1414,4 169,60	–0,3376 881,12
liquid vapour	–135,00	$6,339 \times 10^{-5}$	1424,9 $2,872 \times 10^{-3}$	–16,19 423,42	–16,19 445,49	–0,0840 3,2579	1,0613 0,5007	1,5900 0,6609	1404,9 170,67	–0,3375 823,35
liquid vapour	–130,00	0,000131	1412,7 0,00574	–8,26 425,90	–8,26 448,77	–0,0276 3,1651	1,0494 0,5041	1,5835 0,6646	1378,4 173,59	–0,3369 686,24
liquid vapour	–125,00	0,000257	1400,6 0,01085	–0,36 428,39	–0,36 452,05	0,0267 3,0804	1,0380 0,5080	1,5777 0,6689	1352,1 176,44	–0,3359 576,21
liquid vapour	–120,00	0,000478	1388,4 0,01954	7,52 430,88	7,52 455,33	0,0790 3,0030	1,0274 0,5123	1,5726 0,6738	1325,8 179,21	–0,3345 487,31
liquid vapour	–115,00	0,000850	1376,1 0,03369	15,37 433,37	15,37 458,60	0,1294 2,9320	1,0173 0,5173	1,5682 0,6796	1299,5 181,91	–0,3327 415,01
liquid vapour	–110,00	0,00145	1363,8 0,0558	23,20 435,85	23,20 461,86	0,1782 2,8668	1,0079 0,5229	1,5647 0,6863	1273,4 184,52	–0,3304 355,78
liquid vapour	–105,00	0,00239	1351,5 0,0894	31,02 438,32	31,02 465,10	0,2254 2,8068	0,9991 0,5293	1,5619 0,6940	1247,3 187,05	–0,3277 306,92
liquid vapour	–100,00	0,00381	1339,0 0,1385	38,82 440,77	38,83 468,31	0,2711 2,7515	0,9910 0,5365	1,5600 0,7030	1221,2 189,50	–0,3244 266,28
liquid vapour	–95,00	0,00590	1326,5 0,2084	46,62 443,20	46,62 471,48	0,3155 2,7003	0,9834 0,5446	1,5588 0,7134	1195,3 191,84	–0,3205 232,23
liquid vapour	–90,00	0,00887	1313,9 0,3056	54,41 445,59	54,42 474,61	0,3586 2,6529	0,9764 0,5538	1,5586 0,7254	1169,3 194,09	–0,3160 203,45
liquid vapour	–85,00	0,0130	1301,2 0,438	62,20 447,96	62,21 477,70	0,4006 2,6089	0,9700 0,5641	1,5592 0,7390	1143,4 196,24	–0,3109 178,95
liquid vapour	–80,00	0,0187	1288,4 0,613	70,00 450,29	70,02 480,72	0,4415 2,5679	0,9641 0,5755	1,5606 0,7543	1117,5 198,26	–0,3051 157,95
liquid vapour	–75,00	0,0262	1275,4 0,842	77,81 452,57	77,83 483,68	0,4814 2,5296	0,9588 0,5880	1,5630 0,7714	1091,7 200,18	–0,2986 139,85
liquid vapour	–70,00	0,0361	1262,4 1,135	85,63 454,81	85,66 486,57	0,5204 2,4939	0,9540 0,6015	1,5663 0,7903	1065,8 201,96	–0,2913 124,19
liquid vapour	–65,00	0,0488	1249,1 1,507	93,46 456,99	93,50 489,38	0,5585 2,4604	0,9497 0,6160	1,5706 0,8110	1039,9 203,62	–0,2831 110,58
liquid vapour	–60,00	0,0650	1235,7 1,969	101,32 459,12	101,38 492,11	0,5958 2,4289	0,9460 0,6315	1,5758 0,8335	1014,1 205,14	–0,2740 98,73
liquid vapour	–55,00	0,0852	1222,1 2,538	109,21 461,19	109,28 494,74	0,6324 2,3993	0,9427 0,6477	1,5821 0,8576	988,2 206,52	–0,2640 88,40
liquid vapour	–50,00	0,1101	1208,4 3,232	117,13 463,19	117,22 497,27	0,6683 2,3714	0,9400 0,6646	1,5895 0,8835	962,2 207,75	–0,2528 79,39
liquid vapour	–51,65[b]	0,1013	1212,9 2,988	114,51 462,54	114,59 496,45	0,6565 2,3805	0,9408 0,6589	1,5869 0,8748	970,8 207,36	–0,2566 82,23
liquid vapour	–45,00	0,1406	1194,4 4,067	125,08 465,13	125,20 499,70	0,7035 2,3450	0,9377 0,6820	1,5980 0,9110	936,3 208,83	–0,2404 71,52
liquid vapour	–40,00	0,1774	1180,2 5,065	133,08 466,99	133,23 502,02	0,7382 2,3200	0,9359 0,6998	1,6077 0,9401	910,2 209,74	–0,2267 64,65
liquid vapour	–35,00	0,2214	1165,7 6,248	141,12 468,78	141,31 504,21	0,7723 2,2962	0,9346 0,7180	1,6187 0,9709	884,0 210,49	–0,2115 58,63
liquid vapour	–30,00	0,2734	1151,0 7,639	149,21 470,48	149,45 506,27	0,8060 2,2735	0,9338 0,7365	1,6311 1,0035	857,8 211,07	–0,1947 53,37

Table 16 (*continued*)

	Temp. °C	**Pressure** MPa	**Density** kg/m³	**Internal energy** kJ/kg	**Enthalpy** kJ/kg	**Entropy** kJ/(kg·K)	C_v kJ/(kg·K)	C_p kJ/(kg·K)	**Sound speed** m/s	**J-T coefficient** K/MPa
liquid vapour	–25,00	0,3346	1135,9 9,266	157,36 472,09	157,66 508,20	0,8392 2,2518	0,9334 0,7552	1,6451 1,0380	831,4 211,47	–0,1761 48,75
liquid vapour	–20,00	0,4058	1120,6 11,157	165,58 473,61	165,94 509,97	0,8720 2,2310	0,9335 0,7740	1,6607 1,0747	804,9 211,68	–0,1553 44,70
liquid vapour	–15,00	0,4881	1104,9 13,346	173,86 475,01	174,31 511,58	0,9044 2,2109	0,9341 0,7930	1,6783 1,1139	778,3 211,69	–0,1322 41,13
liquid vapour	–10,00	0,5826	1088,8 15,870	182,23 476,31	182,76 513,02	0,9365 2,1915	0,9351 0,8121	1,6980 1,1560	751,4 211,50	–0,1063 37,98
liquid vapour	–5,00	0,6906	1072,2 18,769	190,68 477,47	191,33 514,26	0,9684 2,1727	0,9366 0,8315	1,7201 1,2015	724,3 211,10	–0,0772 35,20
liquid vapour	0,00	0,8131	1055,3 22,091	199,23 478,49	200,00 515,30	1,0000 2,1543	0,9386 0,8510	1,7450 1,2511	696,9 210,48	–0,0444 32,72
liquid vapour	5,00	0,9514	1037,7 25,891	207,88 479,36	208,80 516,11	1,0314 2,1363	0,9412 0,8709	1,7733 1,3058	669,2 209,63	–0,0071 30,51
liquid vapour	10,00	1,1069	1019,7 30,232	216,66 480,05	217,74 516,66	1,0628 2,1185	0,9443 0,8911	1,8056 1,3667	641,2 208,54	0,0354 28,54
liquid vapour	15,00	1,2808	1000,9 35,190	225,56 480,54	226,84 516,93	1,0940 2,1008	0,9480 0,9118	1,8428 1,4353	612,7 207,20	0,0843 26,76
liquid vapour	20,00	1,4746	981,4 40,856	234,62 480,81	236,12 516,90	1,1253 2,0831	0,9524 0,9331	1,8859 1,5136	583,7 205,60	0,1410 25,16
liquid vapour	25,00	1,6896	961,0 47,339	243,84 480,82	245,60 516,51	1,1566 2,0652	0,9577 0,9550	1,9367 1,6045	554,2 203,72	0,2076 23,69
liquid vapour	30,00	1,9275	939,6 54,776	253,27 480,54	255,32 515,72	1,1881 2,0471	0,9638 0,9779	1,9973 1,7118	524,0 201,54	0,2865 22,36
liquid vapour	35,00	2,1898	917,0 63,343	262,92 479,91	265,30 514,48	1,2198 2,0285	0,9712 1,0019	2,0710 1,8412	493,0 199,04	0,3815 21,13
liquid vapour	40,00	2,4783	893,0 73,268	272,84 478,88	275,61 512,71	1,2520 2,0091	0,9800 1,0272	2,1629 2,0012	461,0 196,19	0,4976 19,98
liquid vapour	45,00	2,7948	867,3 84,859	283,09 477,36	286,31 510,29	1,2847 1,9888	0,9907 1,0542	2,2809 2,2056	428,0 192,96	0,6428 18,90
liquid vapour	50,00	3,1412	839,3 98,550	293,74 475,23	297,49 507,10	1,3183 1,9670	1,0039 1,0834	2,4385 2,4773	393,6 189,31	0,8288 17,86
liquid vapour	55,00	3,5199	808,3 114,989	304,93 472,32	309,29 502,93	1,3531 1,9432	1,0207 1,1156	2,6610 2,8594	357,6 185,16	1,0751 16,85
liquid vapour	60,00	3,9332	773,3 135,213	316,84 468,35	321,93 497,44	1,3898 1,9166	1,0428 1,1519	3,0007 3,4412	319,7 180,43	1,4157 15,83
liquid vapour	65,00	4,3843	732,3 161,092	329,81 462,84	335,80 490,05	1,4293 1,8855	1,0732 1,1947	3,5880 4,4462	279,4 174,95	1,9160 14,75
liquid vapour	70,00	4,8768	680,9 196,688	344,57 454,72	351,73 479,52	1,4740 1,8464	1,1194 1,2488	4,8653 6,6388	235,8 168,40	2,7233 13,49
liquid vapour	75,00	5,4168	605,9 255,587	363,45 440,53	372,39 461,72	1,5314 1,7880	1,2064 1,3310	10,1347 15,6016	186,1 159,64	4,3093 11,74
critical	78,11	5,7820	424,0	400,51	414,15	1,6486	[c]	[c]	[c]	8,0731

[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 International Standard.

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 K, T_{max} = 600 K; p_{max} = 40 MPa; ρ_{max} = 11,6 mol/l (1 774 kg/m^3)

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

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

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

k	N_k	t_k	d_k	l_k	α_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
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

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

5.7.3 Reference state parameters

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

Table 19 — R123 property values along the liquid-vapour saturation boundary

	Temp. °C	Pressure MPa	Density kg/m³	Internal energy kJ/kg	Enthalpy kJ/kg	Entropy kJ/(kg·K)	C_v kJ/(kg·K)	C_p kJ/(kg·K)	Sound speed m/s	J-T coefficient K/MPa
liquid	–107,15[a]	$4{,}202\times10^{-6}$	1771,0	98,81	98,81	0,5311	0,6295	0,9289	1243,8	–0,4755
vapour			$4{,}656\times10^{-4}$	313,47	322,50	1,8786	0,4194	0,4738	100,97	335,67
liquid	–105,00	$5{,}765\times10^{-6}$	1766,0	100,80	100,80	0,5430	0,6306	0,9280	1235,3	–0,4762
vapour			$6{,}306\times10^{-4}$	314,38	323,52	1,8675	0,4232	0,4776	101,57	319,10
liquid	–100,00	$,161\times10^{-5}$	1754,5	105,44	105,44	0,5702	0,6321	0,9261	1215,3	–0,4772
vapour			$1{,}233\times10^{-3}$	316,51	325,93	1,8436	0,4319	0,4863	102,95	284,41
liquid	–95,00	$2{,}233\times10^{-5}$	1743,2	110,07	110,07	0,5965	0,6328	0,9245	1195,0	–0,4775
vapour			$2{,}306\times10^{-3}$	318,69	328,38	1,8220	0,4405	0,4949	104,31	254,37
liquid	–90,00	$4{,}120\times10^{-5}$	1732,0	114,68	114,68	0,6221	0,6333	0,9235	1174,6	–0,4771
vapour			$4{,}138\times10^{-3}$	320,92	330,87	1,8025	0,4491	0,5035	105,65	228,26
liquid	–85,00	$7{,}317\times10^{-5}$	1720,8	119,30	119,30	0,6470	0,6338	0,9232	1153,9	–0,4759
vapour			$7{,}154\times10^{-3}$	323,18	333,41	1,7849	0,4575	0,5119	106,97	205,49
liquid	–80,00	0,000125	1709,6	123,92	123,92	0,6712	0,6346	0,9236	1133,1	–0,4740
vapour			0,01195	325,49	335,98	1,7691	0,4658	0,5202	108,27	185,55
liquid	–75,00	0,000208	1698,5	128,54	128,54	0,6948	0,6356	0,9247	1112,1	–0,4714
vapour			0,01935	327,83	338,60	1,7549	0,4740	0,5285	109,55	168,05
liquid	–70,00	0,000336	1687,4	133,17	133,17	0,7179	0,6371	0,9266	1091,1	–0,4681
vapour			0,03045	330,21	341,25	1,7422	0,4821	0,5367	110,81	152,63
liquid	–65,00	0,000528	1676,2	137,80	137,80	0,7404	0,6388	0,9290	1069,9	–0,4643
vapour			0,04666	332,63	343,94	1,7307	0,4902	0,5448	112,06	139,01
liquid	–60,00	0,000808	1665,1	142,46	142,46	0,7625	0,6410	0,9320	1048,7	–0,4599
vapour			0,06977	335,09	346,66	1,7206	0,4982	0,5529	113,27	126,94
liquid	–55,00	0,00121	1653,9	147,13	147,13	0,7842	0,6435	0,9354	1027,6	–0,4550
vapour			0,1020	337,58	349,42	1,7115	0,5061	0,5610	114,47	116,22
liquid	–50,00	0,00177	1642,6	151,81	151,81	0,8054	0,6462	0,9393	1006,4	–0,4496
vapour			0,1461	340,11	352,21	1,7034	0,5139	0,5690	115,64	106,68
liquid	–45,00	0,00254	1631,3	156,52	156,52	0,8263	0,6493	0,9435	985,3	–0,4437
vapour			0,2052	342,66	355,03	1,6964	0,5217	0,5770	116,78	98,17
liquid	–40,00	0,00358	1620,0	161,25	161,25	0,8468	0,6526	0,9480	964,3	–0,4375
vapour			0,2831	345,25	357,88	1,6901	0,5295	0,5850	117,90	90,55
liquid	–35,00	0,00495	1608,5	166,00	166,00	0,8669	0,6561	0,9528	943,4	–0,4309
vapour			0,3843	347,87	360,75	1,6847	0,5372	0,5931	118,98	83,73
liquid	–30,00	0,00675	1597,0	170,77	170,78	0,8868	0,6597	0,9578	922,6	–0,4239
vapour			0,5136	350,51	363,65	1,6800	0,5448	0,6011	120,03	77,60
liquid	–25,00	0,00906	1585,4	175,58	175,58	0,9063	0,6635	0,9629	901,9	–0,4166
vapour			0,6767	353,19	366,57	1,6760	0,5525	0,6092	121,04	72,09
liquid	–20,00	0,0120	1573,8	180,40	180,41	0,9256	0,6674	0,9682	881,3	–0,4088
vapour			0,880	355,88	369,52	1,6726	0,5601	0,6174	122,01	67,13
liquid	–15,00	0,0157	1562,0	185,26	185,27	0,9446	0,6714	0,9735	860,9	–0,4007
vapour			1,130	358,60	372,47	1,6698	0,5677	0,6256	122,94	62,65

Table 19 (*continued*)

	Temp. °C	Pressure MPa	Density kg/m³	Internal energy kJ/kg	Enthalpy kJ/kg	Entropy kJ/(kg·K)	C_v kJ/(kg·K)	C_p kJ/(kg·K)	Sound speed m/s	J-T coefficient K/MPa
liquid vapour	–10,00	0,0202	1550,1 1,435	190,14 361,34	190,15 375,45	0,9633 1,6675	0,6755 0,5753	0,9790 0,6339	840,7 123,82	–0,3923 58,60
liquid vapour	–5,00	0,0258	1538,2 1,802	195,04 364,10	195,06 378,44	0,9818 1,6656	0,6797 0,5828	0,9846 0,6423	820,6 124,66	–0,3834 54,93
liquid vapour	0,00	0,0326	1526,1 2,242	199,98 366,87	200,00 381,44	1,0000 1,6642	0,6839 0,5904	0,9902 0,6508	800,7 125,44	–0,3740 51,61
liquid vapour	5,00	0,0408	1513,9 2,762	204,94 369,67	204,97 384,44	1,0180 1,6633	0,6881 0,5979	0,9959 0,6594	780,9 126,17	–0,3643 48,60
liquid vapour	10,00	0,0506	1501,6 3,374	209,93 372,47	209,97 387,46	1,0358 1,6626	0,6924 0,6055	1,0017 0,6682	761,3 126,84	–0,3540 45,86
liquid vapour	15,00	0,0621	1489,2 4,088	214,95 375,29	214,99 390,48	1,0534 1,6624	0,6967 0,6130	1,0076 0,6771	741,9 127,45	–0,3431 43,37
liquid vapour	20,00	0,0756	1476,6 4,917	220,00 378,12	220,05 393,49	1,0707 1,6624	0,7011 0,6206	1,0135 0,6861	722,6 127,99	–0,3316 41,10
liquid vapour	25,00	0,0914	1463,9 5,872	225,08 380,95	225,14 396,51	1,0879 1,6627	0,7054 0,6281	1,0196 0,6953	703,4 128,47	–0,3195 39,03
liquid vapour	27,82[b]	0,1013	1456,6 6,471	227,96 382,56	228,03 398,22	1,0975 1,6630	0,7079 0,6324	1,0230 0,7006	692,7 128,71	–0,3123 37,95
liquid vapour	30,00	0,1096	1451,0 6,966	230,18 383,80	230,26 399,53	1,1049 1,6633	0,7097 0,6357	1,0257 0,7047	684,4 128,88	–0,3066 37,15
liquid vapour	35,00	0,1305	1438,0 8,213	235,32 386,64	235,41 402,54	1,1217 1,6641	0,7141 0,6432	1,0320 0,7144	665,5 129,21	–0,2929 35,43
liquid vapour	40,00	0,1545	1424,8 9,630	240,48 389,49	240,59 405,54	1,1383 1,6651	0,7185 0,6508	1,0385 0,7243	646,8 129,46	–0,2782 33,86
liquid vapour	45,00	0,1817	1411,4 11,230	245,68 392,35	245,81 408,53	1,1548 1,6662	0,7229 0,6583	1,0451 0,7344	628,2 129,64	–0,2625 32,42
liquid vapour	50,00	0,2125	1397,8 13,031	250,91 395,20	251,06 411,50	1,1711 1,6676	0,7273 0,6659	1,0519 0,7448	609,6 129,73	–0,2456 31,11
liquid vapour	55,00	0,2471	1384,0 15,051	256,17 398,04	256,34 414,46	1,1873 1,6691	0,7317 0,6735	1,0589 0,7556	591,2 129,73	–0,2274 29,91
liquid vapour	60,00	0,2859	1370,0 17,311	261,46 400,88	261,67 417,40	1,2033 1,6707	0,7362 0,6811	1,0663 0,7667	572,9 129,64	–0,2076 28,82
liquid vapour	65,00	0,3292	1355,7 19,830	266,78 403,72	267,03 420,31	1,2191 1,6725	0,7406 0,6887	1,0740 0,7783	554,6 129,46	–0,1861 27,82
liquid vapour	70,00	0,3772	1341,2 22,632	272,14 406,54	272,42 423,20	1,2349 1,6743	0,7451 0,6963	1,0820 0,7904	536,4 129,17	–0,1627 26,92
liquid vapour	75,00	0,4304	1326,4 25,743	277,54 409,34	277,86 426,06	1,2505 1,6762	0,7497 0,7040	1,0906 0,8030	518,2 128,79	–0,1370 26,09
liquid vapour	80,00	0,4891	1311,2 29,188	282,98 412,14	283,35 428,89	1,2660 1,6781	0,7542 0,7117	1,0996 0,8162	500,0 128,30	–0,1087 25,34
liquid vapour	85,00	0,5536	1295,7 33,000	288,45 414,91	288,88 431,68	1,2814 1,6801	0,7589 0,7194	1,1093 0,8302	481,9 127,69	–0,0773 24,66
liquid vapour	90,00	0,6242	1279,9 37,213	293,97 417,65	294,45 434,43	1,2967 1,6822	0,7636 0,7272	1,1197 0,8450	463,8 126,97	–0,0425 24,05
liquid vapour	95,00	0,7014	1263,6 41,863	299,53 420,37	300,08 437,13	1,3120 1,6842	0,7683 0,7350	1,1310 0,8609	445,6 126,12	–0,0036 23,51
liquid vapour	100,00	0,7855	1246,9 46,996	305,14 423,06	305,77 439,77	1,3271 1,6862	0,7731 0,7429	1,1433 0,8780	427,5 125,14	0,0402 23,03
liquid vapour	105,00	0,8769	1229,7 52,661	310,80 425,71	311,51 442,36	1,3422 1,6882	0,7781 0,7509	1,1568 0,8965	409,2 124,02	0,0896 22,61

Table 19 (*continued*)

	Temp. °C	Pressure MPa	Density kg/m³	Internal energy kJ/kg	Enthalpy kJ/kg	Entropy kJ/(kg·K)	C_v kJ/(kg·K)	C_p kJ/(kg·K)	Sound speed m/s	J-T coefficient K/MPa
liquid vapour	110,00	0,9760	1211,9 58,914	316,51 428,31	317,32 444,88	1,3572 1,6902	0,7831 0,7590	1,1717 0,9168	391,0 122,76	0,1460 22,24
liquid vapour	115,00	1,0832	1193,5 65,824	322,28 430,86	323,19 447,32	1,3723 1,6920	0,7883 0,7672	1,1884 0,9392	372,6 121,34	0,2106 21,94
liquid vapour	120,00	1,1990	1174,4 73,471	328,13 433,35	329,15 449,67	1,3872 1,6938	0,7936 0,7755	1,2072 0,9643	354,1 119,76	0,2854 21,69
liquid vapour	125,00	1,3237	1154,4 81,950	334,04 435,78	335,18 451,93	1,4022 1,6955	0,7991 0,7840	1,2287 0,9928	335,5 118,00	0,3728 21,51
liquid vapour	130,00	1,4578	1133,6 91,379	340,03 438,12	341,32 454,07	1,4173 1,6969	0,8048 0,7927	1,2536 1,0257	316,7 116,05	0,4759 21,38
liquid vapour	135,00	1,6018	1111,6 101,904	346,12 440,37	347,56 456,08	1,4323 1,6982	0,8107 0,8017	1,2828 1,0643	297,8 113,89	0,5992 21,32
liquid vapour	140,00	1,7563	1088,3 113,711	352,31 442,50	353,92 457,94	1,4475 1,6992	0,8170 0,8110	1,3178 1,1106	278,6 111,51	0,7487 21,32
liquid vapour	145,00	1,9217	1063,5 127,044	358,62 444,48	360,43 459,61	1,4628 1,7000	0,8236 0,8207	1,3606 1,1677	259,1 108,88	0,9334 21,39
liquid vapour	150,00	2,0987	1036,8 142,231	365,08 446,30	367,10 461,05	1,4782 1,7003	0,8307 0,8309	1,4146 1,2405	239,3 105,99	1,1664 21,53
liquid vapour	155,00	2,2879	1007,8 159,735	371,72 447,89	373,99 462,22	1,4940 1,7000	0,8384 0,8417	1,4855 1,3371	219,0 102,80	1,4686 21,75
liquid vapour	160,00	2,4901	975,7 180,242	378,58 449,20	381,13 463,01	1,5101 1,6991	0,8469 0,8534	1,5836 1,4728	198,2 99,29	1,8748 22,05
liquid vapour	165,00	2,7062	939,4 204,853	385,74 450,11	388,62 463,32	1,5267 1,6972	0,8565 0,8662	1,7303 1,6790	176,6 95,40	2,4478 22,41
liquid vapour	170,00	2,9372	896,9 235,543	393,33 450,42	396,61 462,89	1,5443 1,6939	0,8677 0,8806	1,9792 2,0332	154,0 91,07	3,3147 22,81
liquid vapour	175,00	3,1845	843,9 276,595	401,67 449,73	405,44 461,25	1,5635 1,6880	0,8817 0,8975	2,5102 2,7935	129,6 86,20	4,7779 23,12
liquid vapour	180,00	3,4506	765,9 341,950	411,72 446,73	416,22 456,82	1,5867 1,6763	0,9019 0,9194	4,5486 5,6613	102,3 80,62	7,8106 22,79
critical	183,68	3,6618	550,0	430,74	437,39	1,6325	[c]	[c]	[c]	16,5658

[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 International Standard.

5.8 R125 — Pentafluoroethane

5.8.1 Range of validity

The coefficients are valid within the following ranges:

T_{min} = 172,52 K, T_{max} = 500 K; p_{max} = 60 MPa; ρ_{max} = 14,09 mol/l (1 691 kg/m³)

Table 20 — Coefficients and exponents of the ideal-gas part [Equations (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 21 — Coefficients and exponents of the real-gas part [Equation (2)]

k	N_k	t_k	d_k	l_k	α_k	m_k	β_k	γ_k	ε_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

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

5.8.3 Reference state parameters

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

Table 22 — R125 property values along the liquid-vapour saturation boundary

	Temp. °C	Pressure MPa	Density kg/m³	Internal energy kJ/kg	Enthalpy kJ/kg	Entropy kJ/(kg·K)	C_v kJ/(kg·K)	C_p kJ/(kg·K)	Sound speed m/s	J-T coefficient K/MPa
liquid vapour	–100,63[a]	0,00291	1690,7 0,2446	87,13 265,48	87,13 277,39	0,4902 1,5931	0,6776 0,4984	1,0346 0,5689	932,6 116,43	–0,3837 90,26
liquid vapour	–100,00	0,00309	1688,7 0,2583	87,78 265,79	87,78 277,74	0,4940 1,5911	0,6781 0,4997	1,0351 0,5703	929,2 116,61	–0,3830 89,08
liquid vapour	–95,00	0,00481	1672,5 0,3918	92,97 268,25	92,97 280,54	0,5235 1,5764	0,6818 0,5099	1,0396 0,5810	903,2 118,03	–0,3766 80,43
liquid vapour	–90,00	0,00729	1656,2 0,5779	98,18 270,75	98,18 283,36	0,5524 1,5634	0,6860 0,5201	1,0450 0,5919	877,5 119,39	–0,3694 72,87
liquid vapour	–85,00	0,0107	1639,9 0,831	103,42 273,28	103,42 286,20	0,5806 1,5520	0,6906 0,5304	1,0512 0,6031	852,3 120,69	–0,3614 66,26
liquid vapour	–80,00	0,0155	1623,4 1,169	108,69 275,83	108,70 289,06	0,6082 1,5421	0,6955 0,5409	1,0581 0,6146	827,5 121,92	–0,3525 60,44
liquid vapour	–75,00	0,0218	1606,7 1,610	114,00 278,41	114,01 291,94	0,6354 1,5333	0,7006 0,5514	1,0656 0,6264	802,9 123,07	–0,3428 55,33
liquid vapour	–70,00	0,0301	1589,9 2,177	119,34 281,01	119,36 294,83	0,6620 1,5257	0,7060 0,5620	1,0736 0,6385	778,6 124,13	–0,3323 50,81
liquid vapour	–65,00	0,0408	1572,9 2,892	124,73 283,62	124,75 297,71	0,6882 1,5191	0,7115 0,5727	1,0822 0,6511	754,5 125,11	–0,3208 46,82
liquid vapour	–60,00	0,0543	1555,7 3,783	130,16 286,24	130,19 300,60	0,7140 1,5135	0,7171 0,5836	1,0912 0,6641	730,6 125,98	–0,3083 43,28
liquid vapour	–55,00	0,0713	1538,2 4,879	135,63 288,88	135,68 303,48	0,7394 1,5086	0,7229 0,5946	1,1007 0,6776	706,8 126,75	–0,2947 40,14
liquid vapour	–50,00	0,0922	1520,5 6,211	141,15 291,51	141,21 306,35	0,7644 1,5044	0,7288 0,6058	1,1107 0,6916	683,2 127,41	–0,2799 37,35
liquid vapour	–48,09[b]	0,1013	1513,6 6,790	143,27 292,52	143,34 307,44	0,7739 1,5030	0,7311 0,6101	1,1146 0,6971	674,2 127,63	–0,2738 36,36
liquid vapour	–45,00	0,1176	1502,4 7,814	146,72 294,15	146,80 309,20	0,7891 1,5009	0,7349 0,6171	1,1212 0,7063	659,6 127,94	–0,2636 34,86
liquid vapour	–40,00	0,1483	1484,0 9,725	152,34 296,79	152,44 312,03	0,8134 1,4980	0,7410 0,6286	1,1323 0,7216	636,1 128,35	–0,2458 32,65
liquid vapour	–35,00	0,1849	1465,3 11,985	158,01 299,41	158,14 314,84	0,8375 1,4955	0,7473 0,6402	1,1440 0,7376	612,6 128,61	–0,2262 30,67
liquid vapour	–30,00	0,2281	1446,1 14,639	163,74 302,03	163,90 317,61	0,8614 1,4935	0,7537 0,6520	1,1565 0,7545	589,1 128,73	–0,2044 28,91
liquid vapour	–25,00	0,2786	1426,5 17,736	169,53 304,63	169,73 320,34	0,8849 1,4919	0,7602 0,6640	1,1698 0,7724	565,7 128,70	–0,1803 27,33
liquid vapour	–20,00	0,3373	1406,4 21,331	175,38 307,22	175,62 323,03	0,9083 1,4906	0,7668 0,6761	1,1840 0,7912	542,2 128,50	–0,1532 25,91
liquid vapour	–15,00	0,4050	1385,8 25,486	181,30 309,78	181,59 325,67	0,9314 1,4895	0,7736 0,6882	1,1994 0,8112	518,7 128,11	–0,1228 24,66
liquid vapour	–10,00	0,4825	1364,5 30,271	187,29 312,30	187,64 328,24	0,9544 1,4887	0,7805 0,7003	1,2161 0,8324	495,2 127,54	–0,0883 23,55
liquid vapour	–5,00	0,5707	1342,6 35,768	193,35 314,79	193,77 330,74	0,9773 1,4881	0,7876 0,7122	1,2344 0,8550	471,6 126,77	–0,0489 22,61
liquid vapour	0,00	0,6705	1319,8 42,070	199,49 317,22	200,00 333,16	1,0000 1,4875	0,7948 0,7240	1,2547 0,8797	448,0 125,80	–0,0036 21,81
liquid vapour	5,00	0,7829	1296,2 49,291	205,72 319,59	206,33 335,47	1,0226 1,4869	0,8021 0,7359	1,2773 0,9073	424,3 124,60	0,0492 21,15

Table 22 (*continued*)

	Temp. °C	Pressure MPa	Density kg/m3	Internal energy kJ/kg	Enthalpy kJ/kg	Entropy kJ/(kg·K)	C_v kJ/(kg·K)	C_p kJ/(kg·K)	Sound speed m/s	J-T coefficient K/MPa
liquid vapour	10,00	0,9088	1271,5 57,564	212,05 321,87	212,76 337,66	1,0452 1,4863	0,8095 0,7483	1,3029 0,9392	400,4 123,17	0,1113 20,61
liquid vapour	15,00	1,0492	1245,6 67,054	218,48 324,06	219,32 339,71	1,0678 1,4856	0,8172 0,7617	1,3323 0,9770	376,3 121,49	0,1851 20,18
liquid vapour	20,00	1,2052	1218,3 77,966	225,03 326,12	226,02 341,58	1,0904 1,4846	0,8252 0,7764	1,3666 1,0230	352,0 119,55	0,2742 19,83
liquid vapour	25,00	1,3779	1189,4 90,557	231,71 328,05	232,87 343,26	1,1131 1,4834	0,8335 0,7928	1,4074 1,0798	327,4 117,32	0,3835 19,53
liquid vapour	30,00	1,5685	1158,4 105,170	238,55 329,80	239,91 344,71	1,1359 1,4817	0,8425 0,8111	1,4575 1,1517	302,4 114,78	0,5202 19,29
liquid vapour	35,00	1,7783	1125,0 122,270	245,57 331,33	247,16 345,88	1,1591 1,4794	0,8522 0,8315	1,5209 1,2452	276,9 111,88	0,6956 19,08
liquid vapour	40,00	2,0085	1088,4 142,522	252,82 332,60	254,67 346,69	1,1826 1,4764	0,8630 0,8542	1,6052 1,3716	250,8 108,58	0,9282 18,91
liquid vapour	45,00	2,2607	1047,7 166,954	260,36 333,50	262,52 347,05	1,2067 1,4724	0,8755 0,8796	1,7244 1,5535	223,8 104,82	1,2501 18,78
liquid vapour	50,00	2,5368	1001,1 197,293	268,29 333,89	270,83 346,75	1,2318 1,4667	0,8907 0,9083	1,9102 1,8425	195,6 100,51	1,7247 18,67
liquid vapour	55,00	2,8389	945,4 236,916	276,82 333,46	279,83 345,44	1,2585 1,4584	0,9106 0,9421	2,2517 2,3860	165,3 95,57	2,4948 18,51
liquid vapour	60,00	3,1703	872,1 294,367	286,46 331,44	290,10 342,21	1,2884 1,4448	0,9411 0,9856	3,1392 3,8329	131,5 89,84	3,9752 18,06
liquid vapour	65,00	3,5370	735,1 416,565	300,06 323,75	304,88 332,24	1,3311 1,4120	1,0139 1,0604	13,6692 20,0735	90,0 82,63	8,2955 15,85
critical	66,02	3,6177	573,6	311,75	318,06	1,3696	c	c	c	12,3608

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 International Standard.

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 K, T_{max} = 455 K; p_{max} = 70 MPa; ρ_{max} = 15,6 mol/l (1 592 kg/m^3)

Table 23 — Coefficients and exponents of the ideal-gas part [Equations (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 24 — Coefficients and exponents of the real-gas part [Equation (2)]

k	N_k	t_k	d_k	l_k	α_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

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

5.9.3 Reference state parameters

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

Table 25 — R134a property values along the liquid-vapour saturation boundary

	Temp. °C	Pressure MPa	Density kg/m³	Internal energy kJ/kg	Enthalpy kJ/kg	Entropy kJ/(kg·K)	C_v kJ/(kg·K)	C_p kJ/(kg·K)	Sound speed m/s	J-T coefficient K/MPa
liquid vapour	–103,30[a]	0,000390	1591,1 0,02817	71,45 321,11	71,46 334,94	0,4126 1,9639	0,7922 0,5030	1,1838 0,5853	1120,0 126,79	–0,3815 373,57
liquid vapour	–100,00	0,000559	1582,4 0,03969	75,36 322,76	75,36 336,85	0,4354 1,9456	0,7912 0,5107	1,1842 0,5932	1103,2 127,87	–0,3793 318,13
liquid vapour	–95,00	0,000939	1569,1 0,06479	81,29 325,29	81,29 339,78	0,4691 1,9201	0,7910 0,5224	1,1861 0,6052	1077,7 129,47	–0,3753 253,65
liquid vapour	–90,00	0,00152	1555,8 0,1024	87,22 327,87	87,23 342,76	0,5020 1,8972	0,7920 0,5341	1,1892 0,6173	1052,3 131,03	–0,3707 206,26
liquid vapour	–85,00	0,00240	1542,5 0,1570	93,18 330,49	93,18 345,77	0,5341 1,8766	0,7940 0,5457	1,1933 0,6294	1027,0 132,56	–0,3656 170,88
liquid vapour	–80,00	0,00367	1529,0 0,2343	99,16 333,15	99,16 348,83	0,5654 1,8580	0,7968 0,5573	1,1981 0,6417	1001,8 134,04	–0,3599 144,05
liquid vapour	–75,00	0,00548	1515,5 0,3412	105,16 335,85	105,17 351,91	0,5961 1,8414	0,8002 0,5689	1,2036 0,6540	976,8 135,47	–0,3536 123,38
liquid vapour	–70,00	0,00798	1501,9 0,4857	111,19 338,59	111,20 355,02	0,6262 1,8264	0,8040 0,5806	1,2096 0,6665	952,0 136,84	–0,3469 107,19
liquid vapour	–65,00	0,0114	1488,2 0,677	117,26 341,35	117,26 358,16	0,6557 1,8130	0,8082 0,5923	1,2161 0,6793	927,4 138,16	–0,3396 94,32
liquid vapour	–60,00	0,0159	1474,3 0,927	123,35 344,15	123,36 361,31	0,6846 1,8010	0,8127 0,6040	1,2230 0,6924	903,0 139,41	–0,3318 83,91
liquid vapour	–55,00	0,0218	1460,4 1,246	129,48 346,96	129,50 364,48	0,7131 1,7902	0,8175 0,6159	1,2304 0,7058	878,8 140,59	–0,3234 75,36
liquid vapour	–50,00	0,0295	1446,3 1,650	135,65 349,80	135,67 367,65	0,7410 1,7806	0,8224 0,6280	1,2381 0,7197	854,7 141,69	–0,3143 68,25
liquid vapour	–45,00	0,0391	1432,1 2,152	141,86 352,65	141,89 370,83	0,7685 1,7720	0,8276 0,6402	1,2462 0,7341	830,9 142,70	–0,3046 62,23
liquid vapour	–40,00	0,0512	1417,7 2,769	148,11 355,51	148,14 374,00	0,7956 1,7643	0,8328 0,6526	1,2546 0,7490	807,2 143,63	–0,2941 57,08
liquid vapour	–35,00	0,0661	1403,1 3,521	154,40 358,38	154,44 377,17	0,8223 1,7575	0,8382 0,6652	1,2635 0,7646	783,7 144,45	–0,2828 52,63
liquid vapour	–30,00	0,0844	1388,4 4,426	160,73 361,25	160,79 380,32	0,8486 1,7515	0,8438 0,6781	1,2729 0,7809	760,3 145,18	–0,2706 48,74
liquid vapour	–26,07[b]	0,1013	1376,7 5,258	165,74 363,51	165,81 382,78	0,8690 1,7472	0,8482 0,6884	1,2805 0,7942	742,0 145,67	–0,2602 46,01
liquid vapour	–25,00	0,1064	1373,4 5,506	167,11 364,12	167,19 383,45	0,8746 1,7461	0,8494 0,6912	1,2827 0,7979	737,0 145,79	–0,2573 45,31
liquid vapour	–20,00	0,1327	1358,3 6,784	173,54 366,99	173,64 386,55	0,9002 1,7413	0,8551 0,7046	1,2930 0,8158	713,8 146,28	–0,2428 42,26
liquid vapour	–15,00	0,1639	1342,8 8,287	180,02 369,85	180,14 389,63	0,9256 1,7371	0,8609 0,7183	1,3040 0,8346	690,7 146,65	–0,2270 39,54

Table 25 (*continued*)

	Temp. °C	Pressure MPa	Density kg/m³	Internal energy kJ/kg	Enthalpy kJ/kg	Entropy kJ/(kg·K)	C_v kJ/(kg·K)	C_p kJ/(kg·K)	Sound speed m/s	J-T coefficient K/MPa
liquid	–10,00	0,2006	1327,1	186,55	186,70	0,9506	0,8669	1,3156	667,6	–0,2096
vapour			10,041	372,69	392,66	1,7334	0,7322	0,8544	146,89	37,11
liquid	–5,00	0,2433	1311,1	193,13	193,32	0,9754	0,8729	1,3279	644,6	–0,1905
vapour			12,077	375,51	395,66	1,7300	0,7464	0,8752	146,99	34,92
liquid	0,00	0,2928	1294,8	199,77	200,00	1,0000	0,8791	1,3410	621,6	–0,1695
vapour			14,428	378,31	398,60	1,7271	0,7608	0,8972	146,94	32,95
liquid	5,00	0,3497	1278,1	206,48	206,75	1,0243	0,8854	1,3552	598,7	–0,1461
vapour			17,131	381,08	401,49	1,7245	0,7755	0,9206	146,74	31,17
liquid	10,00	0,4146	1261,0	213,25	213,58	1,0485	0,8918	1,3704	575,7	–0,1200
vapour			20,226	383,82	404,32	1,7221	0,7904	0,9455	146,38	29,57
liquid	15,00	0,4884	1243,4	220,09	220,48	1,0724	0,8983	1,3869	552,7	–0,0907
vapour			23,758	386,52	407,07	1,7200	0,8056	0,9721	145,85	28,12
liquid	20,00	0,5717	1225,3	227,00	227,47	1,0962	0,9050	1,4049	529,6	–0,0578
vapour			27,780	389,17	409,75	1,7180	0,8210	1,0007	145,15	26,81
liquid	25,00	0,6654	1206,7	233,99	234,55	1,1199	0,9119	1,4246	506,5	–0,0204
vapour			32,350	391,77	412,33	1,7162	0,8367	1,0316	144,26	25,64
liquid	30,00	0,7702	1187,5	241,07	241,72	1,1435	0,9189	1,4465	483,2	0,0223
vapour			37,535	394,30	414,82	1,7145	0,8527	1,0655	143,16	24,58
liquid	35,00	0,8870	1167,5	248,25	249,01	1,1670	0,9262	1,4709	459,9	0,0714
vapour			43,416	396,76	417,19	1,7128	0,8691	1,1028	141,86	23,63
liquid	40,00	1,0166	1146,7	255,52	256,41	1,1905	0,9336	1,4984	436,4	0,1285
vapour			50,085	399,13	419,43	1,7111	0,8858	1,1445	140,34	22,78
liquid	45,00	1,1599	1125,1	262,91	263,94	1,2139	0,9414	1,5298	412,8	0,1953
vapour			57,657	401,40	421,52	1,7092	0,9029	1,1917	138,57	22,02
liquid	50,00	1,3179	1102,3	270,43	271,62	1,2375	0,9494	1,5661	389,0	0,2746
vapour			66,272	403,55	423,44	1,7072	0,9205	1,2461	136,55	21,36
liquid	55,00	1,4915	1078,3	278,09	279,47	1,2611	0,9579	1,6089	364,9	0,3698
vapour			76,104	405,55	425,15	1,7050	0,9387	1,3099	134,25	20,77
liquid	60,00	1,6818	1052,9	285,91	287,50	1,2848	0,9668	1,6602	340,5	0,4861
vapour			87,379	407,38	426,63	1,7024	0,9577	1,3868	131,66	20,27
liquid	65,00	1,8898	1025,6	293,92	295,76	1,3088	0,9764	1,7234	315,7	0,6308
vapour			100,398	408,99	427,82	1,6993	0,9775	1,4822	128,74	19,83
liquid	70,00	2,1168	996,2	302,16	304,28	1,3332	0,9869	1,8039	290,3	0,8157
vapour			115,572	410,33	428,65	1,6956	0,9986	1,6051	125,46	19,46
liquid	75,00	2,3641	964,1	310,68	313,13	1,3580	0,9988	1,9115	264,1	1,0599
vapour			133,494	411,32	429,03	1,6909	1,0212	1,7714	121,80	19,14
liquid	80,00	2,6332	928,2	319,55	322,39	1,3836	1,0129	2,0648	236,6	1,3973
vapour			155,078	411,83	428,81	1,6850	1,0460	2,0122	117,69	18,86
liquid	85,00	2,9258	887,2	328,93	332,22	1,4104	1,0308	2,3064	207,4	1,8936
vapour			181,853	411,67	427,76	1,6771	1,0739	2,3971	113,09	18,57
liquid	90,00	3,2442	837,8	339,06	342,93	1,4390	1,0556	2,7559	175,9	2,6936
vapour			216,761	410,45	425,42	1,6662	1,1068	3,1207	107,90	18,20
liquid	95,00	3,5912	772,7	350,60	355,25	1,4715	1,0938	3,9385	141,2	4,1916
vapour			267,139	407,23	420,67	1,6492	1,1489	5,0195	101,91	17,51
liquid	100,00	3,9724	651,2	367,20	373,30	1,5188	1,1737	17,5915	101,0	8,1985
vapour			373,011	397,03	407,68	1,6109	1,2180	25,3503	93,95	15,30
critical	101,06	4,0593	511,9	381,71	389,64	1,5621	[c]	[c]	[c]	11,9312

[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 International Standard.

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 K, T_{max} = 650 K; p_{max} = 100 MPa; ρ_{max} = 15,85 mol/l (1 332 kg/m^3)

Table 26 — Coefficients and exponents of the ideal-gas part [Equations (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 27 — Coefficients and exponents of the real-gas part [Equation (2)]

k	N_k	t_k	d_k	l_k	α_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
17	0,004 908 049 2	19	5	3	1

5.10.2 Reducing parameters, molar mass, and gas constant

T^* = 345,857 K, ρ^* = 5,128 45 mol/L, M = 84,041 g/mol, R = 8,314 472 J/(mol·K)

5.10.3 Reference state parameters

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

Table 28 — R143a property values along the liquid-vapour saturation boundary

	Temp. °C	Pressure MPa	Density kg/m³	Internal energy kJ/kg	Enthalpy kJ/kg	Entropy kJ/(kg·K)	C_v kJ/(kg·K)	C_p kJ/(kg·K)	Sound speed m/s	J-T coefficient K/MPa
liquid	–111,81[a]	0,00107	1330,5	52,52	52,52	0,3142	0,8138	1,2112	1058,1	–0,4394
vapour			0,0675	303,67	319,59	1,9695	0,5283	0,6299	137,57	385,09
liquid	–110,00	0,00129	1326,2	54,71	54,71	0,3277	0,8128	1,2119	1049,4	–0,4375
vapour			0,0805	304,59	320,68	1,9579	0,5331	0,6350	138,22	354,60
liquid	–105,00	0,00211	1314,1	60,78	60,78	0,3643	0,8114	1,2151	1025,5	–0,4316
vapour			0,1274	307,17	323,73	1,9281	0,5467	0,6495	139,98	284,35
liquid	–100,00	0,00333	1301,9	66,87	66,87	0,4000	0,8115	1,2199	1001,7	–0,4247
vapour			0,1956	309,78	326,81	1,9012	0,5604	0,6642	141,68	230,56
liquid	–95,00	0,00510	1289,6	72,98	72,98	0,4348	0,8131	1,2260	977,9	–0,4171
vapour			0,2917	312,43	329,92	1,8770	0,5742	0,6792	143,32	189,21
liquid	–90,00	0,00761	1277,2	79,13	79,13	0,4688	0,8157	1,2333	954,2	–0,4086
vapour			0,4238	315,11	333,06	1,8553	0,5881	0,6944	144,89	157,26
liquid	–85,00	0,0111	1264,8	85,31	85,32	0,5021	0,8194	1,2415	930,4	–0,3994
vapour			0,601	317,83	336,22	1,8357	0,6021	0,7100	146,39	132,44
liquid	–80,00	0,0157	1252,2	91,54	91,55	0,5348	0,8238	1,2504	906,6	–0,3895
vapour			0,835	320,58	339,40	1,8180	0,6162	0,7258	147,81	113,01
liquid	–75,00	0,0219	1239,5	97,81	97,83	0,5669	0,8288	1,2601	882,8	–0,3789
vapour			1,138	323,36	342,60	1,8021	0,6304	0,7421	149,13	97,68
liquid	–70,00	0,0299	1226,7	104,14	104,16	0,5984	0,8344	1,2704	859,1	–0,3674
vapour			1,523	326,16	345,80	1,7879	0,6448	0,7589	150,37	85,45
liquid	–65,00	0,0402	1213,7	110,51	110,54	0,6294	0,8405	1,2813	835,3	–0,3551
vapour			2,005	328,98	349,01	1,7750	0,6593	0,7763	151,50	75,60
liquid	–60,00	0,0531	1200,6	116,94	116,99	0,6599	0,8470	1,2928	811,5	–0,3419
vapour			2,601	331,81	352,21	1,7635	0,6741	0,7944	152,51	67,57
liquid	–55,00	0,0691	1187,3	123,43	123,49	0,6900	0,8538	1,3049	787,7	–0,3277
vapour			3,329	334,66	355,41	1,7531	0,6892	0,8133	153,41	60,93
liquid	–50,00	0,0887	1173,9	129,97	130,05	0,7197	0,8608	1,3175	763,9	–0,3123
vapour			4,210	337,51	358,58	1,7438	0,7046	0,8331	154,19	55,38
liquid	–47,24[b]	0,1013	1166,4	133,61	133,70	0,7359	0,8648	1,3248	750,8	–0,3032
vapour			4,769	339,08	360,33	1,7391	0,7132	0,8444	154,55	52,70
liquid	–45,00	0,1125	1160,3	136,58	136,68	0,7490	0,8681	1,3309	740,1	–0,2956
vapour			5,264	340,36	361,74	1,7354	0,7203	0,8539	154,82	50,69
liquid	–40,00	0,1411	1146,4	143,26	143,38	0,7779	0,8756	1,3448	716,3	–0,2774
vapour			6,514	343,20	364,86	1,7279	0,7363	0,8758	155,31	46,68
liquid	–35,00	0,1750	1132,3	150,00	150,15	0,8065	0,8833	1,3596	692,5	–0,2576
vapour			7,988	346,04	367,95	1,7211	0,7526	0,8989	155,65	43,21
liquid	–30,00	0,2149	1117,9	156,81	157,00	0,8348	0,8911	1,3752	668,6	–0,2358
vapour			9,711	348,86	370,99	1,7149	0,7693	0,9233	155,84	40,20
liquid	–25,00	0,2614	1103,3	163,70	163,93	0,8629	0,8991	1,3918	644,7	–0,2118
vapour			11,716	351,67	373,98	1,7093	0,7863	0,9492	155,85	37,55
liquid	–20,00	0,3154	1088,3	170,66	170,95	0,8907	0,9072	1,4094	620,8	–0,1852
vapour			14,036	354,44	376,91	1,7043	0,8035	0,9767	155,68	35,22
liquid	–15,00	0,3774	1072,9	177,71	178,06	0,9183	0,9154	1,4283	596,8	–0,1555
vapour			16,709	357,18	379,76	1,6996	0,8211	1,0061	155,33	33,16

Table 28 (*continued*)

	Temp. °C	Pressure MPa	Density kg/m³	Internal energy kJ/kg	Enthalpy kJ/kg	Entropy kJ/(kg·K)	C_v kJ/(kg·K)	C_p kJ/(kg·K)	Sound speed m/s	J-T coefficient K/MPa
liquid vapour	–10,00	0,4482	1057,2 19,778	184,84 359,88	185,27 382,54	0,9457 1,6953	0,9237 0,8390	1,4487 1,0377	572,8 154,78	–0,1223 31,33
liquid vapour	–5,00	0,5287	1041,0 23,292	192,07 362,53	192,58 385,23	0,9729 1,6913	0,9322 0,8571	1,4709 1,0717	548,6 154,03	–0,0847 29,69
liquid vapour	0,00	0,6197	1024,3 27,306	199,40 365,11	200,00 387,81	1,0000 1,6876	0,9408 0,8756	1,4951 1,1087	524,3 153,06	–0,0420 28,24
liquid vapour	5,00	0,7219	1007,0 31,885	206,83 367,63	207,54 390,27	1,0270 1,6839	0,9495 0,8944	1,5219 1,1492	499,8 151,87	0,0069 26,94
liquid vapour	10,00	0,8363	989,1 37,107	214,37 370,06	215,22 392,60	1,0539 1,6804	0,9585 0,9135	1,5517 1,1942	475,1 150,43	0,0635 25,79
liquid vapour	15,00	0,9637	970,4 43,062	222,05 372,39	223,04 394,77	1,0809 1,6768	0,9678 0,9331	1,5854 1,2447	450,2 148,74	0,1295 24,76
liquid vapour	20,00	1,1052	950,8 49,864	229,86 374,60	231,02 396,76	1,1078 1,6732	0,9773 0,9531	1,6239 1,3024	425,0 146,77	0,2075 23,84
liquid vapour	25,00	1,2616	930,2 57,653	237,83 376,66	239,19 398,54	1,1349 1,6693	0,9873 0,9737	1,6687 1,3695	399,5 144,51	0,3007 23,04
liquid vapour	30,00	1,4340	908,4 66,605	245,98 378,54	247,56 400,07	1,1621 1,6652	0,9978 0,9951	1,7218 1,4494	373,5 141,93	0,4140 22,33
liquid vapour	35,00	1,6236	885,2 76,954	254,33 380,21	256,16 401,31	1,1895 1,6606	1,0091 1,0173	1,7863 1,5472	347,0 139,02	0,5543 21,71
liquid vapour	40,00	1,8314	860,3 89,018	262,91 381,61	265,04 402,19	1,2174 1,6553	1,0213 1,0408	1,8670 1,6715	319,8 135,73	0,7319 21,17
liquid vapour	45,00	2,0589	833,1 103,245	271,79 382,66	274,26 402,61	1,2457 1,6491	1,0350 1,0659	1,9725 1,8366	291,8 132,04	0,9636 20,69
liquid vapour	50,00	2,3073	803,0 120,307	281,02 383,25	283,90 402,43	1,2748 1,6416	1,0509 1,0932	2,1181 2,0700	262,7 127,89	1,2777 20,26
liquid vapour	55,00	2,5785	768,9 141,302	290,74 383,20	294,09 401,44	1,3051 1,6322	1,0702 1,1237	2,3369 2,4302	232,2 123,22	1,7273 19,84
liquid vapour	60,00	2,8744	728,9 168,236	301,15 382,16	305,09 399,24	1,3371 1,6197	1,0951 1,1595	2,7143 3,0685	199,5 117,93	2,4237 19,37
liquid vapour	65,00	3,1977	678,3 205,645	312,73 379,39	317,45 394,94	1,3726 1,6018	1,1312 1,2044	3,5635 4,5323	163,8 111,84	3,6529 18,67
liquid vapour	70,00	3,5527	600,8 270,096	327,28 372,27	333,19 385,42	1,4172 1,5694	1,1984 1,2720	7,7197 11,5008	122,4 104,25	6,4733 17,07
critical	72,71	3,7610	431,0	350,18	358,91	1,4906	[c]	[c]	[c]	12,3969

[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 International Standard.

5.11 R152a — 1,1–difluoroethane

5.11.1 Range of validity

The coefficients are valid within the following ranges:

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

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

k	c_k	t_k
0	3,354 952	–
1	1,098 649 × 10$^{–2}$	1
2	2,501 616 × 10$^{–5}$	2
3	– 2,787 445 × 10$^{–8}$	3

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

k	N_k	t_k	d_k	l_k	α_k
1	– 0,354 657 949 982 × 10^1	3	0	0	0
2	– 0,364 631 280 620	4	0	0	0
3	0,333 233 335 558 × 10$^{–1}$	5	0	0	0
4	– 0,680 968 435 117	0	1	0	0
5	0,735 212 646 801 × 10^1	0,5	1	0	0
6	– 0,112 473 063 838 × 10^2	1	1	0	0
7	0,549 916 715 657 × 10^1	2	1	0	0
8	– 0,240 186 327 322 × 10^1	3	1	0	0
9	– 0,709 036 447 042 × 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 × 10^1	3	2	0	0
13	– 0,860 546 479 693 × 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 × 10$^{–1}$	1	4	0	0
17	0,183 419 368 472 × 10$^{–1}$	2	5	0	0
18	– 0,338 550 204 252 × 10$^{–1}$	3	5	0	0
19	0,124 921 101 016 × 10$^{–1}$	2	6	0	0
20	– 0,221 056 706 423 × 10$^{–2}$	2	7	0	0

Table 30 (*continued*)

k	N_k	t_k	d_k	l_k	α_k
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

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

5.11.3 Reference state parameters

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

Table 31 — R152a property values along the liquid-vapour saturation boundary

	Temp. °C	Pressure MPa	Density kg/m³	Internal energy kJ/kg	Enthalpy kJ/kg	Entropy kJ/(kg·K)	C_v kJ/(kg·K)	C_p kJ/(kg·K)	Sound speed m/s	J-T coefficient K/MPa
liquid	–118,59[a]	$6{,}414\times10^{-5}$	1192,9	13,79	13,79	0,1119	0,9948	1,4774	1400,9	–0,4326
vapour			$3{,}297\times10^{-3}$	399,87	419,32	2,7357	0,5726	0,6987	154,04	336,54
liquid	–115,00	0,000103	1186,3	19,13	19,13	0,1460	1,0090	1,4921	1372,8	–0,4266
vapour			0,00516	401,93	421,84	2,6924	0,5803	0,7064	155,63	308,12
liquid	–110,00	0,000191	1177,1	26,62	26,62	0,1927	1,0210	1,5053	1337,3	–0,4203
vapour			0,00928	404,85	425,38	2,6368	0,5911	0,7173	157,80	273,32
liquid	–105,00	0,000339	1167,9	34,17	34,17	0,2383	1,0271	1,5131	1305,0	–0,4154
vapour			0,01600	407,81	428,96	2,5861	0,6020	0,7284	159,93	243,29
liquid	–100,00	0,000579	1158,7	41,75	41,75	0,2827	1,0297	1,5178	1274,9	–0,4112
vapour			0,02658	410,82	432,59	2,5399	0,6131	0,7398	162,01	217,25
liquid	–95,00	0,000956	1149,4	49,35	49,35	0,3259	1,0305	1,5210	1246,3	–0,4072
vapour			0,04268	413,87	436,26	2,4978	0,6244	0,7514	164,04	194,62
liquid	–90,00	0,00153	1140,1	56,96	56,96	0,3681	1,0304	1,5237	1218,9	–0,4030
vapour			0,0664	416,96	439,97	2,4593	0,6358	0,7634	166,02	174,86
liquid	–85,00	0,00237	1130,7	64,58	64,59	0,4091	1,0302	1,5265	1192,3	–0,3986
vapour			0,1005	420,10	443,71	2,4242	0,6475	0,7758	167,95	157,56
liquid	–80,00	0,00359	1121,3	72,22	72,23	0,4492	1,0302	1,5298	1166,3	–0,3937
vapour			0,1483	423,26	447,48	2,3920	0,6595	0,7886	169,81	142,37
liquid	–75,00	0,00530	1111,9	79,88	79,89	0,4884	1,0307	1,5339	1140,7	–0,3883
vapour			0,2136	426,46	451,27	2,3626	0,6718	0,8019	171,62	128,99
liquid	–70,00	0,00765	1102,4	87,56	87,57	0,5266	1,0317	1,5388	1115,5	–0,3824
vapour			0,3012	429,69	455,08	2,3357	0,6843	0,8157	173,36	117,18
liquid	–65,00	0,0108	1092,8	95,27	95,28	0,5641	1,0334	1,5446	1090,4	–0,3758
vapour			0,416	432,94	458,90	2,3111	0,6972	0,8301	175,03	106,73
liquid	–60,00	0,0150	1083,2	103,01	103,02	0,6009	1,0357	1,5513	1065,6	–0,3685
vapour			0,566	436,21	462,74	2,2885	0,7104	0,8452	176,62	97,46
liquid	–55,00	0,0204	1073,5	110,78	110,80	0,6369	1,0387	1,5589	1040,9	–0,3606
vapour			0,755	439,50	466,57	2,2677	0,7240	0,8609	178,12	89,21
liquid	–50,00	0,0274	1063,7	118,59	118,62	0,6723	1,0422	1,5674	1016,4	–0,3520
vapour			0,994	442,80	470,40	2,2487	0,7379	0,8774	179,54	81,87
liquid	–45,00	0,0362	1053,8	126,45	126,48	0,7071	1,0463	1,5768	991,8	–0,3427
vapour			1,289	446,10	474,21	2,2313	0,7522	0,8946	180,86	75,31
liquid	–40,00	0,0472	1043,8	134,35	134,40	0,7414	1,0509	1,5870	967,4	–0,3326
vapour			1,651	449,41	478,02	2,2152	0,7669	0,9127	182,08	69,45
liquid	–35,00	0,0607	1033,7	142,31	142,37	0,7752	1,0558	1,5979	943,0	–0,3216
vapour			2,089	452,72	481,79	2,2004	0,7820	0,9317	183,19	64,20
liquid	–30,00	0,0772	1023,5	150,32	150,39	0,8085	1,0612	1,6097	918,6	–0,3098
vapour			2,615	456,03	485,55	2,1868	0,7975	0,9516	184,18	59,49
liquid	–25,00	0,0970	1013,2	158,39	158,48	0,8413	1,0669	1,6222	894,2	–0,2970
vapour			3,241	459,33	489,26	2,1743	0,8133	0,9724	185,06	55,26
liquid	–24,02[b]	0,1013	1011,2	159,97	160,07	0,8477	1,0681	1,6247	889,5	–0,2944
vapour			3,376	459,97	489,98	2,1719	0,8164	0,9766	185,21	54,48
liquid	–20,00	0,1207	1002,7	166,52	166,64	0,8737	1,0730	1,6355	869,9	–0,2832
vapour			3,979	462,61	492,94	2,1627	0,8295	0,9943	185,80	51,45
liquid	–15,00	0,1487	992,1	174,71	174,86	0,9058	1,0793	1,6496	845,5	–0,2682
vapour			4,844	465,88	496,57	2,1520	0,8460	1,0172	186,41	48,02
liquid	–10,00	0,1815	981,3	182,98	183,16	0,9375	1,0859	1,6645	821,0	–0,2520
vapour			5,852	469,12	500,15	2,1421	0,8629	1,0414	186,88	44,93
liquid	–5,00	0,2198	970,3	191,31	191,54	0,9689	1,0927	1,6804	796,6	–0,2343
vapour			7,017	472,34	503,66	2,1329	0,8802	1,0667	187,20	42,13
liquid	0,00	0,2640	959,1	199,72	200,00	1,0000	1,0997	1,6972	772,0	–0,2149
vapour			8,359	475,53	507,11	2,1243	0,8978	1,0935	187,37	39,60

Table 31 (*continued*)

	Temp. °C	**Pressure** MPa	**Density** kg/m³	**Internal energy** kJ/kg	**Enthalpy** kJ/kg	**Entropy** kJ/(kg·K)	C_v kJ/(kg·K)	C_p kJ/(kg·K)	**Sound speed** m/s	**J-T coefficient** K/MPa
liquid	5,00	0,3148	947,7	208,22	208,55	1,0308	1,1069	1,7151	747,4	–0,1938
vapour			9,896	478,68	510,49	2,1164	0,9157	1,1218	187,37	37,31
liquid	10,00	0,3728	936,1	216,79	217,19	1,0614	1,1144	1,7342	722,7	–0,1706
vapour			11,651	481,79	513,78	2,1089	0,9339	1,1517	187,21	35,23
liquid	15,00	0,4386	924,2	225,45	225,93	1,0917	1,1220	1,7546	697,9	–0,1449
vapour			13,647	484,85	516,99	2,1018	0,9525	1,1834	186,87	33,35
liquid	20,00	0,5129	912,0	234,21	234,77	1,1219	1,1299	1,7765	673,0	–0,1165
vapour			15,910	487,85	520,09	2,0952	0,9714	1,2173	186,36	31,64
liquid	25,00	0,5964	899,5	243,07	243,73	1,1519	1,1379	1,8001	647,9	–0,0849
vapour			18,469	490,79	523,09	2,0888	0,9906	1,2536	185,65	30,09
liquid	30,00	0,6898	886,6	252,03	252,80	1,1817	1,1462	1,8258	622,7	–0,0495
vapour			21,357	493,66	525,96	2,0828	1,0101	1,2926	184,74	28,69
liquid	35,00	0,7939	873,4	261,10	262,01	1,2114	1,1548	1,8539	597,3	–0,0096
vapour			24,613	496,44	528,70	2,0769	1,0300	1,3349	183,63	27,41
liquid	40,00	0,9093	859,7	270,29	271,35	1,2411	1,1636	1,8847	571,7	0,0357
vapour			28,280	499,13	531,28	2,0711	1,0502	1,3811	182,30	26,25
liquid	45,00	1,0368	845,5	279,62	280,84	1,2707	1,1728	1,9190	545,9	0,0873
vapour			32,408	501,71	533,70	2,0655	1,0707	1,4320	180,74	25,20
liquid	50,00	1,1774	830,8	289,08	290,50	1,3003	1,1823	1,9574	519,9	0,1468
vapour			37,058	504,16	535,93	2,0598	1,0917	1,4887	178,94	24,24
liquid	55,00	1,3317	815,4	298,70	300,34	1,3299	1,1922	2,0009	493,5	0,2159
vapour			42,300	506,47	537,95	2,0540	1,1131	1,5526	176,89	23,38
liquid	60,00	1,5007	799,4	308,50	310,38	1,3596	1,2026	2,0510	466,9	0,2970
vapour			48,222	508,60	539,72	2,0480	1,1350	1,6257	174,57	22,60
liquid	65,00	1,6853	782,5	318,49	320,64	1,3895	1,2135	2,1094	440,0	0,3934
vapour			54,933	510,53	541,21	2,0418	1,1575	1,7109	171,96	21,90
liquid	70,00	1,8864	764,6	328,70	331,16	1,4196	1,2251	2,1789	412,6	0,5096
vapour			62,569	512,22	542,37	2,0351	1,1806	1,8122	169,04	21,27
liquid	75,00	2,1051	745,6	339,16	341,98	1,4501	1,2375	2,2637	384,8	0,6522
vapour			71,312	513,62	543,14	2,0279	1,2045	1,9360	165,79	20,71
liquid	80,00	2,3424	725,2	349,92	353,15	1,4810	1,2509	2,3703	356,4	0,8309
vapour			81,403	514,66	543,43	2,0198	1,2294	2,0924	162,17	20,20
liquid	85,00	2,5996	703,0	361,04	364,74	1,5126	1,2655	2,5099	327,4	1,0609
vapour			93,185	515,23	543,13	2,0107	1,2555	2,2985	158,15	19,74
liquid	90,00	2,8780	678,5	372,63	376,87	1,5451	1,2818	2,7034	297,4	1,3675
vapour			107,172	515,21	542,06	2,0000	1,2832	2,5863	153,69	19,32
liquid	95,00	3,1791	650,9	384,82	389,71	1,5790	1,3004	2,9947	266,3	1,7961
vapour			124,192	514,35	539,95	1,9871	1,3130	3,0228	148,70	18,90
liquid	100,00	3,5050	618,5	397,93	403,59	1,6151	1,3223	3,4951	233,5	2,4378
vapour			145,754	512,23	536,28	1,9707	1,3459	3,7759	143,11	18,43
liquid	105,00	3,8583	578,1	412,57	419,25	1,6552	1,3502	4,5947	198,0	3,5082
vapour			175,224	507,95	529,97	1,9479	1,3838	5,4245	136,73	17,78
liquid	110,00	4,2432	517,4	431,02	439,22	1,7058	1,3921	9,2614	157,9	5,7104
vapour			224,256	498,39	517,31	1,9096	1,4317	12,2150	129,14	16,42
critical	113,26	4,5168	368,0	465,28	477,55	1,8037	c	c	c	11,2920

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 International Standard.

5.12 R404A — R125/143a/134a (44/52/4)

5.12.1 Composition of R404A

Table 32 — Composition of R404A

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 g/mol			

5.12.2 Range of validity

The coefficients are valid within the following ranges:

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

5.12.3 Interaction parameters (Equations 19 and 20)

ξ_{12} = 5,551; ξ_{12} = – 0,000 445 2; ξ_{13} = – 0,432 6; ξ_{13} = – 0,000 345 3; ξ_{23} = 2 ,324; ξ_{23} = 0,000 618 2

5.12.4 Coefficients and exponents of the excess functions (Equation 21)

Table 33 — Coefficients and exponents of the excess functions,
i = 1; j = 2 (R125/143a binary pair)

R125/134a binary pair[a] and R143a/134a binary pair[b]				
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				

[a] i = 1; j = 3: F_{13} = 1,00; the $\phi_{ij,\text{excess}}$ function for the R125/134a pair is identical to that for the R125/143a pair.

[b] For i = 2; j = 3: F_{23} = 0,555 7; the $\phi_{ij,\text{excess}}$ 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

Table 34 — R404A property values of liquid on the bubble line and vapour on the dew line

	Pressure MPa	Temp. °C	Density kg/m³	Internal energy kJ/kg	Enthalpy kJ/kg	Entropy kJ/(kg·K)	C_v kJ/(kg·K)	C_p kJ/(kg·K)	Sound speed m/s	J-T coefficient K/MPa
bubble dew	0,0100	–84,93 –83,84	1421,3 0,626	91,82 300,87	91,83 316,83	0,5296 1,7229	0,7710 0,5719	1,2138 0,6635	932,6 135,39	–0,3545 113,71
bubble dew	0,0150	–79,30 –78,28	1404,8 0,916	98,65 303,83	98,66 320,21	0,5654 1,7064	0,7795 0,5860	1,2137 0,6793	895,9 136,88	–0,3495 96,75
bubble dew	0,0200	–75,05 –74,08	1392,4 1,199	103,80 306,10	103,81 322,78	0,5917 1,6953	0,7854 0,5968	1,2152 0,6915	870,1 137,93	–0,3444 86,40
bubble dew	0,0250	–71,61 –70,66	1382,3 1,477	107,99 307,94	108,01 324,87	0,6126 1,6870	0,7899 0,6055	1,2173 0,7016	850,1 138,74	–0,3396 79,22
bubble dew	0,0300	–68,68 –67,76	1373,7 1,752	111,56 309,52	111,58 326,65	0,6302 1,6805	0,7937 0,6130	1,2197 0,7104	833,7 139,39	–0,3349 73,86
bubble dew	0,0400	–63,85 –62,97	1359,4 2,293	117,45 312,13	117,48 329,58	0,6587 1,6707	0,7998 0,6255	1,2246 0,7252	807,5 140,40	–0,3262 66,23
bubble dew	0,0500	–59,92 –59,07	1347,7 2,825	122,28 314,28	122,31 331,97	0,6815 1,6635	0,8046 0,6359	1,2295 0,7377	786,8 141,14	–0,3181 60,94
bubble dew	0,0600	–56,57 –55,75	1337,7 3,351	126,40 316,10	126,44 334,00	0,7007 1,6578	0,8088 0,6447	1,2342 0,7487	769,6 141,72	–0,3106 56,99
bubble dew	0,0800	–51,03 –50,25	1321,0 4,390	133,25 319,13	133,31 337,36	0,7320 1,6494	0,8156 0,6596	1,2430 0,7675	741,6 142,57	–0,2967 51,36
bubble dew	0,1000	–46,50 –45,74	1307,1 5,415	138,89 321,62	138,97 340,08	0,7571 1,6434	0,8212 0,6720	1,2511 0,7836	719,2 143,16	–0,2839 47,44
bubble dew	0,1013[a]	–46,22 –45,47	1306,3 5,483	139,24 321,77	139,31 340,25	0,7586 1,6430	0,8215 0,6728	1,2516 0,7846	717,9 143,19	–0,2831 47,22
bubble dew	0,1200	–42,63 –41,90	1295,1 6,430	143,74 323,74	143,83 342,40	0,7783 1,6387	0,8260 0,6828	1,2587 0,7978	700,4 143,57	–0,2720 44,50
bubble dew	0,1400	–39,24 –38,53	1284,5 7,439	148,01 325,59	148,12 344,41	0,7967 1,6349	0,8303 0,6923	1,2658 0,8108	684,0 143,86	–0,2606 42,18
bubble dew	0,1600	–36,20 –35,51	1275,0 8,442	151,85 327,25	151,97 346,20	0,8130 1,6318	0,8341 0,7009	1,2726 0,8228	669,4 144,07	–0,2498 40,29
bubble dew	0,1800	–33,45 –32,78	1266,2 9,441	155,35 328,75	155,49 347,81	0,8277 1,6292	0,8377 0,7088	1,2790 0,8339	656,2 144,21	–0,2393 38,70
bubble dew	0,2000	–30,93 –30,27	1258,0 10,437	158,57 330,12	158,73 349,28	0,8411 1,6270	0,8409 0,7161	1,2852 0,8445	644,2 144,29	–0,2291 37,34
bubble dew	0,2500	–25,38 –24,75	1239,9 12,920	165,72 333,12	165,92 352,47	0,8703 1,6225	0,8482 0,7324	1,2998 0,8688	617,8 144,34	–0,2046 34,66
bubble dew	0,3000	–20,62 –20,02	1223,9 15,399	171,90 335,67	172,14 355,15	0,8950 1,6190	0,8546 0,7465	1,3134 0,8909	595,2 144,22	–0,1811 32,64
bubble dew	0,3500	–16,44 –15,86	1209,6 17,881	177,38 337,90	177,67 357,47	0,9166 1,6163	0,8604 0,7592	1,3264 0,9114	575,4 143,99	–0,1581 31,04
bubble dew	0,4000	–12,69 –12,12	1196,5 20,369	182,35 339,87	182,68 359,51	0,9358 1,6141	0,8656 0,7706	1,3388 0,9307	557,6 143,66	–0,1355 29,75
bubble dew	0,4500	–9,28 –8,73	1184,4 22,867	186,89 341,65	187,27 361,33	0,9531 1,6122	0,8704 0,7811	1,3509 0,9492	541,4 143,28	–0,1130 28,67
bubble dew	0,5000	–6,15 –5,61	1173,0 25,378	191,11 343,26	191,53 362,96	0,9690 1,6105	0,8750 0,7907	1,3627 0,9670	526,5 142,84	–0,0905 27,75
bubble dew	0,5500	–3,24 –2,72	1162,3 27,905	195,04 344,74	195,51 364,45	0,9837 1,6091	0,8792 0,7997	1,3744 0,9842	512,7 142,36	–0,0679 26,97
bubble dew	0,6000	–0,53 –0,02	1152,0 30,449	198,74 346,11	199,26 365,81	0,9973 1,6078	0,8832 0,8082	1,3859 1,0011	499,7 141,85	–0,0452 26,28

Table 34 (*continued*)

	Pressure MPa	Temp. °C	Density kg/m³	Internal energy kJ/kg	Enthalpy kJ/kg	Entropy kJ/(kg·K)	C_v kJ/(kg·K)	C_p kJ/(kg·K)	Sound speed m/s	J-T coefficient K/MPa
bubble dew	0,6500	2,02 2,52	1142,3 33,012	202,24 347,37	202,81 367,06	1,0101 1,6066	0,8871 0,8161	1,3973 1,0177	487,5 141,31	–0,0222 25,68
bubble dew	0,7000	4,42 4,91	1132,9 35,595	205,57 348,55	206,18 368,21	1,0222 1,6055	0,8908 0,8237	1,4087 1,0342	476,0 140,75	0,0011 25,16
bubble dew	0,7500	6,70 7,18	1123,8 38,201	208,74 349,65	209,41 369,28	1,0336 1,6044	0,8943 0,8309	1,4201 1,0506	465,0 140,17	0,0248 24,69
bubble dew	0,8000	8,87 9,34	1115,1 40,831	211,78 350,68	212,49 370,27	1,0444 1,6035	0,8977 0,8378	1,4316 1,0670	454,5 139,58	0,0489 24,27
bubble dew	0,8500	10,94 11,40	1106,5 43,485	214,70 351,64	215,46 371,19	1,0547 1,6025	0,9009 0,8445	1,4431 1,0835	444,5 138,96	0,0735 23,89
bubble dew	0,9000	12,92 13,37	1098,2 46,167	217,51 352,55	218,32 372,05	1,0646 1,6016	0,9041 0,8510	1,4547 1,1001	434,9 138,34	0,0986 23,55
bubble dew	0,9500	14,81 15,26	1090,2 48,876	220,22 353,41	221,09 372,85	1,0741 1,6007	0,9072 0,8573	1,4665 1,1169	425,6 137,70	0,1244 23,24
bubble dew	1,0000	16,64 17,08	1082,2 51,614	222,84 354,22	223,77 373,59	1,0832 1,5999	0,9102 0,8634	1,4784 1,1340	416,7 137,05	0,1507 22,95
bubble dew	1,2000	23,32 23,73	1052,0 62,884	232,60 357,03	233,75 376,12	1,1166 1,5965	0,9217 0,8869	1,5280 1,2058	383,5 134,36	0,2633 22,03
bubble dew	1,4000	29,22 29,60	1023,4 74,728	241,44 359,29	242,81 378,02	1,1462 1,5932	0,9325 0,9091	1,5821 1,2853	353,8 131,56	0,3901 21,35
bubble dew	1,6000	34,51 34,87	995,7 87,247	249,58 361,08	251,19 379,42	1,1730 1,5896	0,9431 0,9306	1,6427 1,3757	326,5 128,65	0,5351 20,82
bubble dew	1,8000	39,33 39,67	968,6 100,56	257,19 362,48	259,05 380,38	1,1977 1,5858	0,9535 0,9518	1,7122 1,4810	301,2 125,66	0,7033 20,41
bubble dew	2,0000	43,75 44,07	941,6 114,81	264,40 363,51	266,52 380,92	1,2208 1,5817	0,9643 0,9728	1,7941 1,6071	277,3 122,58	0,9015 20,07
bubble dew	2,2000	47,85 48,15	914,4 130,20	271,29 364,18	273,70 381,08	1,2427 1,5770	0,9755 0,9939	1,8935 1,7628	254,5 119,43	1,1392 19,79
bubble dew	2,4000	51,68 51,95	886,5 146,99	277,96 364,50	280,66 380,83	1,2635 1,5718	0,9875 1,0153	2,0185 1,9620	232,5 116,19	1,4301 19,55
bubble dew	2,6000	55,26 55,51	857,5 165,54	284,47 364,44	287,50 380,15	1,2837 1,5658	1,0009 1,0375	2,1832 2,2291	211,1 112,87	1,7950 19,31
bubble dew	2,8000	58,63 58,86	826,8 186,43	290,90 363,94	294,29 378,96	1,3036 1,5587	1,0161 1,0609	2,4136 2,6091	190,0 109,47	2,2671 19,06
bubble dew	3,0000	61,81 62,01	793,4 210,55	297,36 362,90	301,15 377,15	1,3234 1,5503	1,0343 1,0862	2,7653 3,1973	169,0 105,97	2,9028 18,74
bubble dew	3,2000	64,82 64,99	755,6 239,56	304,02 361,13	308,25 374,49	1,3438 1,5397	1,0570 1,1148	3,3812 4,2333	147,8 102,35	3,8068 18,29
critical	3,7289	72,05	486,5	336,26	343,92	1,4455	[b]	[b]	[b]	12,3347

[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 International Standard.

5.13 R407C — R32/125/134a (23/25/52)

Table 35 — Composition of R407A

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 K, T_{max} = 435 K; p_{max} = 60 MPa; ρ_{max} = 17,96 mol/l (1 548 kg/m^3)

5.13.2 Interaction parameters (Equations 19 and 20)

ξ_{12} = 28,95; ξ_{12} = – 0,006 008; ξ_{13} = 7,909; ξ_{13} = –0,002 039; ξ_{23} = – 0,432 6; ξ_{23} = – 0,000 345 3

Table 36 — Coefficients and exponents of the excess functions [Equation (21)]

R32/125 binary pair [a]				
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 [b]				
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 [c]				
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

[a] i = 1; j = 2; F_{12} = 1,00.

[b] i = 1; j = 3; F_{13} = 1,00.

[c] 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

Table 37 — R407C property values of liquid on the bubble line and vapour on the dew line

	Pressure MPa	Temp. °C	Density kg/m³	Internal energy kJ/kg	Enthalpy kJ/kg	Entropy kJ/(kg·K)	C_v kJ/(kg·K)	C_p kJ/(kg·K)	Sound speed m/s	J-T coefficient K/MPa
bubble	0,0100	–82,45	1495,5	90,48	90,48	0,5259	0,8200	1,2815	1008,4	–0,3299
dew		–74,81	0,527	347,81	366,78	1,9471	0,5654	0,6681	149,08	115,10
bubble	0,0150	–76,77	1479,1	97,75	97,76	0,5634	0,8219	1,2820	976,2	–0,3246
dew		–69,22	0,771	350,74	370,19	1,9253	0,5781	0,6826	150,70	100,56
bubble	0,0200	–72,50	1466,7	103,23	103,24	0,5910	0,8235	1,2835	952,7	–0,3198
dew		–65,02	1,010	352,95	372,75	1,9104	0,5879	0,6941	151,85	91,36
bubble	0,0250	–69,03	1456,6	107,68	107,70	0,6130	0,8250	1,2853	934,1	–0,3154
dew		–61,61	1,245	354,75	374,83	1,8991	0,5960	0,7038	152,74	84,79
bubble	0,0300	–66,09	1448,0	111,46	111,48	0,6314	0,8263	1,2872	918,5	–0,3113
dew		–58,72	1,477	356,27	376,59	1,8900	0,6031	0,7123	153,46	79,75
bubble	0,0400	–61,25	1433,7	117,70	117,72	0,6612	0,8287	1,2912	893,3	–0,3039
dew		–53,95	1,934	358,79	379,47	1,8761	0,6149	0,7269	154,58	72,38
bubble	0,0500	–57,31	1422,0	122,79	122,82	0,6850	0,8308	1,2950	873,1	–0,2972
dew		–50,08	2,384	360,83	381,80	1,8656	0,6248	0,7393	155,43	67,09
bubble	0,0600	–53,96	1412,0	127,13	127,17	0,7050	0,8327	1,2987	856,1	–0,2911
dew		–46,79	2,829	362,56	383,77	1,8573	0,6334	0,7502	156,10	63,04
bubble	0,0800	–48,42	1395,3	134,33	134,39	0,7374	0,8361	1,3056	828,3	–0,2799
dew		–41,34	3,707	365,41	386,99	1,8445	0,6479	0,7692	157,10	57,08
bubble	0,1000	–43,90	1381,5	140,24	140,31	0,7635	0,8391	1,3121	805,8	–0,2698
dew		–36,90	4,574	367,73	389,59	1,8349	0,6601	0,7855	157,81	52,81
bubble	0,1013[a]	–43,63	1380,7	140,60	140,67	0,7650	0,8393	1,3125	804,5	–0,2691
dew		–36,63	4,631	367,87	389,75	1,8343	0,6609	0,7865	157,85	52,57
bubble	0,1200	–40,05	1369,7	145,30	145,39	0,7854	0,8418	1,3181	786,8	–0,2604
dew		–33,11	5,432	369,69	391,78	1,8273	0,6707	0,8001	158,34	49,54
bubble	0,1400	–36,67	1359,1	149,75	149,86	0,8043	0,8443	1,3238	770,2	–0,2515
dew		–29,79	6,283	371,40	393,68	1,8210	0,6802	0,8133	158,74	46,91
bubble	0,1600	–33,65	1349,7	153,75	153,86	0,8211	0,8466	1,3292	755,4	–0,2431
dew		–26,83	7,130	372,92	395,36	1,8156	0,6887	0,8255	159,05	44,74
bubble	0,1800	–30,92	1341,0	157,38	157,51	0,8362	0,8488	1,3344	742,1	–0,2350
dew		–24,15	7,973	374,29	396,86	1,8110	0,6965	0,8369	159,29	42,90
bubble	0,2000	–28,41	1333,0	160,72	160,87	0,8499	0,8508	1,3394	729,9	–0,2272
dew		–21,69	8,813	375,53	398,22	1,8069	0,7038	0,8476	159,47	41,32
bubble	0,2500	–22,90	1315,1	168,11	168,30	0,8798	0,8555	1,3513	703,1	–0,2084
dew		–16,28	10,904	378,24	401,17	1,7984	0,7200	0,8722	159,74	38,14
bubble	0,3000	–18,19	1299,5	174,48	174,71	0,9050	0,8598	1,3624	680,1	–0,1906
dew		–11,66	12,989	380,52	403,62	1,7917	0,7340	0,8945	159,82	35,72
bubble	0,3500	–14,04	1285,5	180,12	180,39	0,9269	0,8637	1,3731	660,0	–0,1733
dew		–7,61	15,071	382,49	405,72	1,7861	0,7465	0,9151	159,79	33,80
bubble	0,4000	–10,33	1272,8	185,20	185,52	0,9465	0,8673	1,3834	641,9	–0,1564
dew		–3,97	17,154	384,24	407,55	1,7814	0,7578	0,9345	159,66	32,22
bubble	0,4500	–6,95	1261,1	189,86	190,21	0,9641	0,8707	1,3934	625,5	–0,1398
dew		–0,67	19,241	385,79	409,18	1,7772	0,7682	0,9528	159,46	30,89
bubble	0,5000	–3,85	1250,1	194,16	194,56	0,9801	0,8740	1,4032	610,4	–0,1233
dew		2,36	21,334	387,20	410,64	1,7735	0,7779	0,9704	159,20	29,76
bubble	0,5500	–0,98	1239,8	198,17	198,61	0,9950	0,8771	1,4129	596,3	–0,1069
dew		5,17	23,435	388,48	411,95	1,7702	0,7868	0,9875	158,91	28,77
bubble	0,6000	1,70	1230,0	201,93	202,42	1,0087	0,8801	1,4224	583,2	–0,0905
dew		7,79	25,545	389,66	413,15	1,7672	0,7953	1,0040	158,58	27,91

Table 37 (*continued*)

	Pressure MPa	Temp. °C	Density kg/m³	Internal energy kJ/kg	Enthalpy kJ/kg	Entropy kJ/(kg·K)	C_v kJ/(kg·K)	C_p kJ/(kg·K)	Sound speed m/s	J-T coefficient K/MPa
bubble dew	0,6500	4,22 10,24	1220,7 27,665	205,49 390,75	206,02 414,25	1,0216 1,7644	0,8830 0,8032	1,4319 1,0201	570,8 158,22	–0,0741 27,14
bubble dew	0,7000	6,60 12,56	1211,7 29,796	208,87 391,76	209,44 415,25	1,0338 1,7618	0,8857 0,8108	1,4413 1,0360	559,1 157,83	–0,0576 26,46
bubble dew	0,7500	8,85 14,76	1203,1 31,940	212,08 392,70	212,71 416,18	1,0452 1,7594	0,8884 0,8179	1,4507 1,0516	548,0 157,42	–0,0410 25,84
bubble dew	0,8000	11,00 16,85	1194,9 34,098	215,16 393,57	215,83 417,03	1,0561 1,7571	0,8911 0,8248	1,4600 1,0670	537,4 157,00	–0,0242 25,29
bubble dew	0,9000	15,00 20,74	1179,1 38,456	220,95 395,16	221,71 418,57	1,0764 1,7529	0,8961 0,8378	1,4789 1,0976	517,6 156,11	0,0098 24,32
bubble dew	1,0000	18,69 24,32	1164,1 42,877	226,33 396,57	227,19 419,89	1,0950 1,7491	0,9010 0,8499	1,4979 1,1282	499,2 155,16	0,0447 23,50
bubble dew	1,2000	25,30 30,73	1136,2 51,932	236,14 398,92	237,20 422,03	1,1283 1,7421	0,9102 0,8721	1,5370 1,1902	466,0 153,16	0,1180 22,18
bubble dew	1,4000	31,14 36,37	1110,2 61,306	244,98 400,79	246,24 423,63	1,1577 1,7358	0,9190 0,8926	1,5780 1,2549	436,4 151,05	0,1968 21,17
bubble dew	1,6000	36,39 41,43	1085,5 71,047	253,09 402,28	254,57 424,80	1,1843 1,7298	0,9274 0,9120	1,6219 1,3242	409,4 148,85	0,2826 20,36
bubble dew	1,8000	41,18 46,03	1061,7 81,203	260,64 403,44	262,33 425,61	1,2086 1,7241	0,9358 0,9305	1,6695 1,3996	384,5 146,57	0,3769 19,69
bubble dew	2,0000	45,59 50,25	1038,5 91,831	267,74 404,32	269,66 426,10	1,2311 1,7184	0,9441 0,9484	1,7218 1,4831	361,3 144,24	0,4815 19,13
bubble dew	2,2000	49,68 54,15	1015,7 103,00	274,47 404,93	276,64 426,29	1,2522 1,7126	0,9526 0,9660	1,7804 1,5770	339,3 141,84	0,5987 18,64
bubble dew	2,4000	53,51 57,79	993,1 114,78	280,92 405,29	283,34 426,20	1,2723 1,7068	0,9613 0,9834	1,8470 1,6845	318,4 139,40	0,7315 18,22
bubble dew	2,6000	57,11 61,19	970,5 127,27	287,14 405,42	289,82 425,85	1,2914 1,7007	0,9705 1,0008	1,9244 1,8096	298,2 136,90	0,8838 17,84
bubble dew	2,8000	60,51 64,38	947,5 140,60	293,17 405,30	296,12 425,21	1,3097 1,6944	0,9802 1,0183	2,0161 1,9582	278,6 134,35	1,0607 17,48
bubble dew	3,0000	63,73 67,40	924,1 154,93	299,07 404,93	302,31 424,29	1,3276 1,6877	0,9909 1,0360	2,1279 2,1390	259,4 131,75	1,2695 17,15
bubble dew	3,2000	66,80 70,25	899,9 170,45	304,88 404,28	308,43 423,06	1,3450 1,6805	1,0028 1,0543	2,2682 2,3648	240,4 129,09	1,5201 16,83
bubble dew	3,4000	69,73 72,94	874,6 187,47	310,65 403,33	314,54 421,46	1,3622 1,6726	1,0164 1,0734	2,4511 2,6567	221,6 126,38	1,8268 16,49
bubble dew	3,6000	72,53 75,50	847,6 206,40	316,46 402,01	320,71 419,45	1,3795 1,6639	1,0322 1,0937	2,7011 3,0504	202,7 123,59	2,2107 16,14
bubble dew	3,8000	75,22 77,92	818,1 227,89	322,38 400,24	327,02 416,91	1,3970 1,6540	1,0512 1,1156	3,0653 3,6132	183,8 120,73	2,7043 15,74
bubble dew	4,0000	77,82 80,21	785,1 253,04	328,54 397,85	333,64 413,66	1,4152 1,6424	1,0747 1,1401	3,6469 4,4863	164,8 117,75	3,3604 15,26
bubble dew	4,2000	80,32 82,37	746,0 284,01	335,20 394,55	340,83 409,34	1,4348 1,6281	1,1050 1,1687	4,7261 6,0289	145,6 114,58	4,2742 14,63
critical	4,6298	86,03	484,2	368,92	378,48	1,5384	[b]	[b]	[b]	10,3922

[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 International Standard.

5.14 R410A — R32/125 (50/50)

Table 38 — Composition of R410A

i	Component	Mass fraction	Mole fraction
1	R32	0,50	0,697 614 70
2	R125	0,50	0,302 385 30
M = 72,5855 g/mol			

5.14.1 Range of validity

The coefficients are valid within the following ranges:

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

5.14.2 Interaction parameters (Equations 9 and 20)

ξ_{12} = 28,95; ξ_{12} = – 0,006 008

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

R32/125 binary pair[a]				
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

a F_{12} = 1,00; i = 1; j = 2.

5.14.3 Reference state parameters

f_3 = 0,617 469 323, f_4 = – 0,596 795

Table 40 — R410A property values of liquid on the bubble line and vapour on the dew line

	Pressure MPa	Temp. °C	Density kg/m3	Internal energy kJ/kg	Enthalpy kJ/kg	Entropy kJ/(kg·K)	C_v kJ/(kg·K)	C_p kJ/(kg·K)	Sound speed m/s	J-T coefficient K/MPa
bubble dew	0,0100	–88,23 –88,14	1460,6 0,476	76,55 357,77	76,56 378,76	0,4588 2,0927	0,8662 0,5442	1,3441 0,6680	1004,0 159,71	–0,3215 156,70
bubble dew	0,0150	–82,84 –82,75	1444,9 0,697	83,79 360,37	83,80 381,90	0,4974 2,0635	0,8620 0,5569	1,3444 0,6836	977,6 161,51	–0,3156 137,58
bubble dew	0,0200	–78,79 –78,70	1432,9 0,912	89,24 362,31	89,26 384,25	0,5258 2,0432	0,8596 0,5670	1,3455 0,6964	957,8 162,79	–0,3105 125,06
bubble dew	0,0250	–75,50 –75,41	1423,1 1,124	93,67 363,88	93,69 386,13	0,5484 2,0276	0,8580 0,5757	1,3468 0,7074	941,8 163,78	–0,3060 115,92
bubble dew	0,0300	–72,71 –72,63	1414,8 1,333	97,42 365,21	97,44 387,71	0,5672 2,0151	0,8569 0,5833	1,3483 0,7172	928,2 164,59	–0,3018 108,80
bubble dew	0,0400	–68,12 –68,04	1401,1 1,745	103,61 367,37	103,64 390,29	0,5978 1,9956	0,8555 0,5964	1,3515 0,7344	905,8 165,84	–0,2944 98,17
bubble dew	0,0500	–64,39 –64,31	1389,7 2,151	108,66 369,11	108,70 392,36	0,6222 1,9807	0,8548 0,6075	1,3546 0,7492	887,6 166,78	–0,2878 90,44
bubble dew	0,0600	–61,22 –61,14	1380,0 2,551	112,96 370,58	113,00 394,10	0,6426 1,9687	0,8544 0,6172	1,3577 0,7624	872,1 167,53	–0,2818 84,44
bubble dew	0,0800	–55,98 –55,90	1363,9 3,342	120,08 372,99	120,14 396,92	0,6758 1,9500	0,8543 0,6338	1,3636 0,7855	846,5 168,66	–0,2708 75,56
bubble dew	0,1000	–51,70 –51,62	1350,5 4,123	125,92 374,92	125,99 399,17	0,7024 1,9358	0,8546 0,6477	1,3693 0,8054	825,6 169,47	–0,2609 69,16
bubble dew	0,1013[a]	–51,44 –51,36	1349,7 4,174	126,27 375,03	126,34 399,31	0,7040 1,9350	0,8547 0,6486	1,3697 0,8066	824,3 169,52	–0,2602 68,80
bubble dew	0,1200	–48,06 –47,98	1339,0 4,895	130,90 376,54	130,99 401,05	0,7247 1,9243	0,8552 0,6599	1,3747 0,8231	807,7 170,08	–0,2516 64,24
bubble dew	0,1400	–44,87 –44,79	1328,8 5,662	135,29 377,95	135,39 402,67	0,7441 1,9147	0,8559 0,6706	1,3799 0,8391	792,0 170,56	–0,2430 60,30
bubble dew	0,1600	–42,02 –41,94	1319,6 6,425	139,22 379,19	139,34 404,09	0,7612 1,9065	0,8567 0,6804	1,3850 0,8539	777,9 170,93	–0,2347 57,05
bubble dew	0,1800	–39,44 –39,36	1311,2 7,183	142,79 380,30	142,93 405,36	0,7766 1,8993	0,8576 0,6892	1,3899 0,8677	765,2 171,22	–0,2267 54,30
bubble dew	0,2000	–37,07 –36,99	1303,4 7,940	146,07 381,31	146,23 406,50	0,7905 1,8928	0,8585 0,6974	1,3946 0,8806	753,4 171,45	–0,2190 51,94
bubble dew	0,2500	–31,88 –31,79	1286,1 9,822	153,32 383,48	153,51 408,93	0,8209 1,8794	0,8608 0,7155	1,4061 0,9100	727,5 171,83	–0,2006 47,24
bubble dew	0,3000	–27,44 –27,35	1271,1 11,697	159,56 385,29	159,80 410,94	0,8466 1,8685	0,8631 0,7310	1,4172 0,9365	705,3 172,01	–0,1830 43,70
bubble dew	0,3500	–23,54 –23,45	1257,6 13,569	165,08 386,84	165,36 412,64	0,8689 1,8593	0,8655 0,7447	1,4279 0,9608	685,6 172,06	–0,1660 40,90
bubble dew	0,4000	–20,04 –19,95	1245,3 15,442	170,05 388,20	170,38 414,10	0,8887 1,8514	0,8678 0,7570	1,4384 0,9834	667,8 172,00	–0,1493 38,62
bubble dew	0,4500	–16,87 –16,78	1233,9 17,318	174,60 389,40	174,96 415,39	0,9065 1,8445	0,8702 0,7682	1,4487 1,0049	651,6 171,87	–0,1329 36,72
bubble dew	0,5000	–13,96 –13,86	1223,3 19,198	178,80 390,48	179,21 416,53	0,9228 1,8383	0,8725 0,7786	1,4589 1,0253	636,7 171,68	–0,1166 35,10
bubble dew	0,5500	–11,26 –11,16	1213,4 21,085	182,72 391,46	183,17 417,54	0,9379 1,8326	0,8747 0,7881	1,4690 1,0450	622,7 171,44	–0,1004 33,70
bubble dew	0,6000	–8,74 –8,64	1203,9 22,979	186,39 392,34	186,89 418,46	0,9518 1,8275	0,8770 0,7970	1,4791 1,0641	609,6 171,16	–0,0843 32,48

Table 40 (*continued*)

	Pressure MPa	Temp. °C	Density kg/m^3	Internal energy kJ/kg	Enthalpy kJ/kg	Entropy kJ/(kg·K)	C_v kJ/(kg·K)	C_p kJ/(kg·K)	Sound speed m/s	J-T coefficient K/MPa
bubble dew	0,6500	–6,38 –6,28	1194,9 24,882	189,86 393,16	190,40 419,28	0,9649 1,8227	0,8792 0,8054	1,4891 1,0827	597,3 170,85	–0,0681 31,40
bubble dew	0,7000	–4,15 –4,05	1186,3 26,795	193,15 393,90	193,74 420,03	0,9772 1,8183	0,8815 0,8133	1,4991 1,1008	585,6 170,52	–0,0519 30,44
bubble dew	0,7500	–2,04 –1,93	1178,1 28,718	196,28 394,59	196,92 420,71	0,9888 1,8141	0,8837 0,8207	1,5092 1,1186	574,5 170,16	–0,0355 29,58
bubble dew	0,8000	–0,03 0,08	1170,1 30,652	199,27 395,23	199,96 421,33	0,9998 1,8102	0,8859 0,8278	1,5193 1,1362	563,9 169,78	–0,0191 28,80
bubble dew	0,9000	3,72 3,83	1154,9 34,557	204,91 396,37	205,69 422,41	1,0204 1,8030	0,8902 0,8409	1,5396 1,1708	543,9 168,98	0,0142 27,45
bubble dew	1,0000	7,17 7,27	1140,5 38,515	210,15 397,35	211,02 423,31	1,0392 1,7964	0,8945 0,8529	1,5602 1,2051	525,4 168,13	0,0482 26,32
bubble dew	1,2000	13,34 13,46	1113,7 46,611	219,69 398,94	220,76 424,68	1,0730 1,7846	0,9030 0,8746	1,6025 1,2743	491,9 166,32	0,1190 24,52
bubble dew	1,4000	18,79 18,91	1088,8 54,978	228,27 400,12	229,56 425,59	1,1027 1,7741	0,9114 0,8943	1,6469 1,3466	462,0 164,40	0,1943 23,14
bubble dew	1,6000	23,68 23,80	1065,2 63,652	236,15 400,97	237,65 426,11	1,1296 1,7644	0,9199 0,9128	1,6941 1,4241	434,7 162,40	0,2751 22,03
bubble dew	1,8000	28,13 28,25	1042,6 72,672	243,46 401,54	245,19 426,31	1,1542 1,7552	0,9285 0,9308	1,7447 1,5090	409,5 160,33	0,3628 21,11
bubble dew	2,0000	32,22 32,34	1020,7 82,083	250,33 401,87	252,29 426,24	1,1769 1,7464	0,9374 0,9485	1,7998 1,6033	386,0 158,20	0,4586 20,33
bubble dew	2,2000	36,02 36,14	999,2 91,932	256,85 401,97	259,05 425,90	1,1983 1,7379	0,9465 0,9663	1,8608 1,7094	363,8 156,01	0,5643 19,64
bubble dew	2,4000	39,56 39,68	978,0 102,28	263,07 401,86	265,52 425,33	1,2185 1,7294	0,9560 0,9843	1,9295 1,8306	342,7 153,77	0,6821 19,03
bubble dew	2,6000	42,89 43,00	957,0 113,19	269,05 401,54	271,77 424,51	1,2377 1,7209	0,9660 1,0025	2,0082 1,9708	322,4 151,48	0,8150 18,47
bubble dew	2,8000	46,02 46,14	935,8 124,76	274,85 401,02	277,84 423,47	1,2561 1,7123	0,9767 1,0212	2,1005 2,1357	302,9 149,12	0,9665 17,96
bubble dew	3,0000	48,99 49,10	914,5 137,09	280,50 400,29	283,78 422,18	1,2740 1,7035	0,9881 1,0404	2,2112 2,3331	283,8 146,70	1,1416 17,47
bubble dew	3,2000	51,81 51,91	892,6 150,31	286,04 399,33	289,62 420,62	1,2913 1,6944	1,0005 1,0602	2,3479 2,5750	265,2 144,22	1,3469 17,01
bubble dew	3,4000	54,49 54,59	870,0 164,62	291,52 398,12	295,43 418,78	1,3085 1,6849	1,0141 1,0810	2,5218 2,8793	246,8 141,67	1,5913 16,55
bubble dew	3,6000	57,05 57,15	846,3 180,26	297,00 396,63	301,26 416,60	1,3254 1,6747	1,0295 1,1031	2,7517 3,2757	228,5 139,03	1,8874 16,09
bubble dew	3,8000	59,50 59,59	821,0 197,60	302,53 394,80	307,16 414,03	1,3425 1,6638	1,0472 1,1267	3,0704 3,8154	210,3 136,29	2,2534 15,61
bubble dew	4,0000	61,85 61,93	793,5 217,17	308,20 392,55	313,24 410,97	1,3600 1,6517	1,0684 1,1527	3,5413 4,5957	191,9 133,43	2,7169 15,10
bubble dew	4,2000	64,10 64,17	762,6 239,86	314,14 389,73	319,65 407,24	1,3783 1,6380	1,0950 1,1820	4,3058 5,8263	173,3 130,40	3,3224 14,53
critical	4,9026	71,36	459,5	357,88	368,55	1,5181	[b]	[b]	[b]	9,7477

[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 International Standard.

5.15 R507A — R125/143a (50/50)

Table 41 — Composition of R507A

i	Component	Mass fraction	Mole fraction
1	R125	0,50	0,411 839 71
2	R143a	0,50	0,588 160 29
M = 98,8594 g/mol			

5.15.1 Range of validity

The coefficients are valid within the following ranges:

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

T_{min} = 172,52 K, T_{max} = 500 K; p_{max} = 60 MPa; ρ_{max} = 14,96 mol/L (1 468 kg/m^3)

5.15.2 Interaction parameters [Equations (19) and (20)]

ξ_{12} = 5,551; ξ_{12} = – 0,000 445 2

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

R125/143a binary pair [a]				
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
[a] $i = 1$; $j = 2$; F_{12} = 1,169 7.				

5.15.3 Reference state parameters

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

Table 43 — R507A property values of liquid on the bubble line and vapour on the dew line

	Pressure MPa	Temp. °C	Density kg/m3	Internal energy kJ/kg	Enthalpy kJ/kg	Entropy kJ/(kg·K)	C_v kJ/(kg·K)	C_p kJ/(kg·K)	Sound speed m/s	J-T coefficient K/MPa
bubble dew	0,0100	–85,26 –85,24	1432,7 0,639	92,21 297,04	92,21 312,68	0,5310 1,7044	0,7633 0,5669	1,2026 0,6573	926,5 133,98	–0,3545 112,99
bubble dew	0,0150	–79,66 –79,65	1416,1 0,934	98,94 300,00	98,95 316,06	0,5663 1,6884	0,7720 0,5809	1,2028 0,6730	889,9 135,47	–0,3494 96,12
bubble dew	0,0200	–75,44 –75,43	1403,6 1,223	104,02 302,26	104,04 318,61	0,5923 1,6776	0,7780 0,5916	1,2044 0,6851	864,2 136,53	–0,3442 85,83
bubble dew	0,0250	–72,01 –72,00	1393,4 1,506	108,16 304,10	108,17 320,70	0,6130 1,6696	0,7826 0,6003	1,2067 0,6951	844,3 137,34	–0,3393 78,70
bubble dew	0,0300	–69,10 –69,09	1384,7 1,786	111,67 305,67	111,69 322,47	0,6304 1,6633	0,7865 0,6077	1,2091 0,7039	827,9 137,99	–0,3346 73,37
bubble dew	0,0400	–64,29 –64,29	1370,4 2,337	117,49 308,28	117,52 325,39	0,6586 1,6538	0,7926 0,6201	1,2141 0,7186	801,8 139,00	–0,3258 65,80
bubble dew	0,0500	–60,37 –60,37	1358,6 2,880	122,25 310,41	122,29 327,77	0,6812 1,6469	0,7976 0,6304	1,2191 0,7310	781,2 139,75	–0,3176 60,55
bubble dew	0,0600	–57,04 –57,04	1348,5 3,416	126,32 312,23	126,36 329,79	0,7001 1,6415	0,8017 0,6392	1,2238 0,7418	764,1 140,33	–0,3100 56,62
bubble dew	0,0800	–51,53 –51,53	1331,6 4,474	133,08 315,25	133,14 333,13	0,7310 1,6334	0,8085 0,6540	1,2326 0,7605	736,3 141,18	–0,2960 51,02
bubble dew	0,1000	–47,01 –47,01	1317,6 5,517	138,65 317,72	138,73 335,85	0,7559 1,6276	0,8141 0,6662	1,2408 0,7764	714,0 141,76	–0,2832 47,13
bubble dew	0,1013[a]	–46,74 –46,74	1316,8 5,586	138,99 317,87	139,07 336,01	0,7574 1,6273	0,8145 0,6670	1,2413 0,7774	712,7 141,79	–0,2824 46,91
bubble dew	0,1200	–43,16 –43,16	1305,6 6,551	143,44 319,83	143,53 338,15	0,7769 1,6231	0,8190 0,6769	1,2483 0,7905	695,2 142,17	–0,2712 44,21
bubble dew	0,1400	–39,79 –39,79	1294,9 7,578	147,65 321,68	147,76 340,15	0,7951 1,6195	0,8232 0,6863	1,2555 0,8033	678,9 142,47	–0,2598 41,91
bubble dew	0,1600	–36,77 –36,77	1285,2 8,599	151,44 323,33	151,57 341,93	0,8113 1,6166	0,8271 0,6948	1,2622 0,8152	664,3 142,67	–0,2488 40,03
bubble dew	0,1800	–34,03 –34,03	1276,4 9,616	154,90 324,82	155,04 343,54	0,8258 1,6141	0,8306 0,7026	1,2686 0,8262	651,2 142,82	–0,2383 38,45
bubble dew	0,2000	–31,52 –31,51	1268,2 10,631	158,08 326,19	158,24 345,00	0,8390 1,6119	0,8339 0,7098	1,2748 0,8367	639,2 142,90	–0,2280 37,11
bubble dew	0,2500	–25,99 –25,99	1249,8 13,159	165,14 329,18	165,34 348,18	0,8679 1,6077	0,8411 0,7259	1,2893 0,8607	612,9 142,96	–0,2034 34,44
bubble dew	0,3000	–21,26 –21,25	1233,7 15,682	171,24 331,72	171,48 350,85	0,8924 1,6044	0,8475 0,7399	1,3029 0,8825	590,5 142,84	–0,1797 32,43
bubble dew	0,3500	–17,10 –17,08	1219,3 18,208	176,66 333,93	176,95 353,15	0,9137 1,6019	0,8532 0,7524	1,3158 0,9028	570,7 142,60	–0,1565 30,85
bubble dew	0,4000	–13,36 –13,35	1206,1 20,741	181,56 335,90	181,89 355,18	0,9327 1,5998	0,8584 0,7637	1,3282 0,9219	553,0 142,28	–0,1337 29,57
bubble dew	0,4500	–9,97 –9,95	1193,8 23,284	186,05 337,67	186,43 356,99	0,9499 1,5980	0,8633 0,7741	1,3403 0,9401	536,9 141,89	–0,1111 28,49
bubble dew	0,5000	–6,85 –6,83	1182,3 25,841	190,21 339,28	190,63 358,63	0,9657 1,5965	0,8678 0,7836	1,3520 0,9577	522,0 141,45	–0,0884 27,59
bubble dew	0,5500	–3,96 –3,94	1171,5 28,413	194,10 340,75	194,57 360,11	0,9802 1,5951	0,8720 0,7924	1,3636 0,9747	508,3 140,98	–0,0657 26,81
bubble dew	0,6000	–1,26 –1,24	1161,2 31,003	197,75 342,11	198,27 361,47	0,9937 1,5939	0,8760 0,8007	1,3751 0,9913	495,3 140,47	–0,0427 26,14

Table 43 (*continued*)

	Pressure MPa	Temp. °C	Density kg/m3	Internal energy kJ/kg	Enthalpy kJ/kg	Entropy kJ/(kg·K)	C_v kJ/(kg·K)	C_p kJ/(kg·K)	Sound speed m/s	J-T coefficient K/MPa
bubble dew	0,6500	1,28 1,30	1151,3 33,612	201,21 343,37	201,77 362,71	1,0064 1,5928	0,8798 0,8086	1,3865 1,0077	483,2 139,93	–0,0195 25,55
bubble dew	0,7000	3,67 3,70	1141,8 36,243	204,49 344,55	205,11 363,86	1,0183 1,5918	0,8835 0,8160	1,3979 1,0240	471,7 139,37	0,0040 25,03
bubble dew	0,7500	5,94 5,97	1132,7 38,897	207,63 345,64	208,29 364,92	1,0296 1,5908	0,8870 0,8230	1,4093 1,0401	460,7 138,79	0,0279 24,57
bubble dew	0,8000	8,10 8,13	1123,8 41,575	210,63 346,67	211,34 365,91	1,0404 1,5899	0,8903 0,8298	1,4207 1,0563	450,3 138,19	0,0523 24,15
bubble dew	0,9000	12,13 12,16	1106,8 47,010	216,29 348,54	217,10 367,68	1,0604 1,5882	0,8968 0,8427	1,4438 1,0891	430,7 136,95	0,1025 23,45
bubble dew	1,0000	15,84 15,87	1090,6 52,559	221,56 350,20	222,48 369,22	1,0788 1,5865	0,9029 0,8550	1,4674 1,1227	412,5 135,67	0,1551 22,87
bubble dew	1,2000	22,49 22,53	1060,0 64,044	231,21 353,00	232,34 371,74	1,1119 1,5834	0,9143 0,8781	1,5170 1,1941	379,5 132,98	0,2691 21,98
bubble dew	1,4000	28,36 28,40	1031,0 76,121	239,93 355,25	241,29 373,64	1,1412 1,5802	0,9250 0,9001	1,5713 1,2736	349,9 130,18	0,3977 21,31
bubble dew	1,6000	33,63 33,67	1003,0 88,893	247,98 357,04	249,58 375,04	1,1678 1,5767	0,9355 0,9216	1,6321 1,3644	322,7 127,27	0,5449 20,81
bubble dew	1,8000	38,43 38,46	975,6 102,48	255,51 358,42	257,35 375,99	1,1923 1,5731	0,9460 0,9428	1,7020 1,4707	297,4 124,28	0,7161 20,41
bubble dew	2,0000	42,83 42,87	948,2 117,05	262,63 359,45	264,74 376,53	1,2152 1,5690	0,9567 0,9640	1,7846 1,5985	273,5 121,20	0,9183 20,08
bubble dew	2,2000	46,91 46,95	920,5 132,79	269,45 360,12	271,84 376,68	1,2368 1,5644	0,9679 0,9852	1,8854 1,7569	250,8 118,04	1,1615 19,81
bubble dew	2,4000	50,72 50,75	892,1 149,99	276,04 360,43	278,73 376,43	1,2576 1,5592	0,9800 1,0069	2,0128 1,9610	228,9 114,80	1,4600 19,58
bubble dew	2,6000	54,28 54,32	862,6 169,04	282,49 360,36	285,50 375,74	1,2777 1,5532	0,9934 1,0294	2,1818 2,2368	207,5 111,48	1,8360 19,35
bubble dew	2,8000	57,63 57,67	831,2 190,55	288,87 359,84	292,23 374,53	1,2974 1,5462	1,0088 1,0531	2,4206 2,6338	186,4 108,06	2,3252 19,09
bubble dew	3,0000	60,80 60,82	796,9 215,50	295,28 358,77	299,05 372,69	1,3172 1,5377	1,0271 1,0790	2,7910 3,2592	165,4 104,54	2,9890 18,77
bubble dew	3,2000	63,78 63,81	757,9 245,74	301,91 356,93	306,13 369,95	1,3375 1,5269	1,0504 1,1083	3,4581 4,3941	144,1 100,89	3,9440 18,30
bubble dew	3,4000	66,61 66,63	709,9 285,53	309,11 353,82	313,90 365,73	1,3596 1,5122	1,0828 1,1439	5,0548 7,0760	122,2 97,03	5,4432 17,52
bubble dew	3,6000	68,45 68,55	657,9 679,05	315,53 313,87	320,89 319,13	1,3796 1,3743	1,1237 1,1024	10,2657 6,5048	103,6 112,80	7,4847 6,40
critical	3,7050	70,62	490,8	332,90	340,45	1,4358	[b]	[b]	[b]	12,3835

[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 International Standard.

Annex A
(normative)

Requirements for implementations claiming conformance with this International Standard

Any computer program or other implementation of this International Standard shall satisfy the requirements specified in this annex before it can claim conformance to this International Standard. These requirements are to be carried out by the developer of the particular implementation.

A.1 Implementation of the specified equations of state

An algorithm conforms to this International Standard if it directly implements (for every refrigerant for which conformance is claimed) the equation of state specified in Clause 5 together with the methods of calculating the thermodynamic properties given in Annex B and is also demonstrated to reproduce the "verification values" for that(those) refrigerant(s) given in Annex D.

Since the properties enumerated in this International Standard have been computed using the equations of state specified in Clause 5, any other implementation of these equations should also yield the same values. The requirement for reproducing the "verification values" serves as a check on the implementation. These "verification values" span a wide range of temperature, pressure, and density and thus thoroughly test the implementation. The number of significant figures listed for these verification values far exceeds that warranted by the uncertainty of the experimental data and equation of state. The large number of significant figures serves to reveal any possible error in the implementation; if an implementation successfully reproduces the verification values (within ± 1 of the last digit listed), it is probably correct for all conditions.

A.2 Requirements of alternative implementations of the properties

An algorithm is conforming to this International Standard if, by any method, it reproduces the values of the thermodynamic properties specified in this International Standard for the fluids implemented. An algorithm claiming conformance under this section can 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 fluid(s) for which it is applicable and its applicable property(ies) and range(s). The allowable variations between the property values specified in this International Standard and those of an alternative implementation vary from property to property and are the following:

- vapour pressure: ± 0,2 %;
- density: ± 0,2 %;
- internal energy: ± a constant value equal to 0,2 % of the internal energy of vapourisation at the normal boiling point temperature; see Note;
- enthalpy: ± a constant value equal to 0,2 % of the enthalpy of vapourisation at the normal boiling point temperature; see Note;
- entropy: ± a constant value equal to 0,2 % of the entropy of vapourisation at the normal boiling point temperature; see Note;
- C_v, C_p, speed of sound: ± 1,0 %;
- Joule–Thomson coefficient: ± 1,0 %.

NOTE The triple point temperature is used to determine the tolerances for R744 (carbon dioxide). The allowable tolerances for internal energy, enthalpy, and entropy are given in Table A.1.

An alternative implementation shall demonstrate that it meets the above tolerances over the full range of conditions for which it claims conformance. Properties are to be compared at a temperature interval of not less than 5 °C.

Table A.1 — Allowable tolerances for internal energy, enthalpy, and entropy for the fluids in this International Standard

Fluid	Allowable tolerances		
	Internal Energy kJ/kg	**Enthalpy** kJ/kg	**Entropy** kJ/(kg·K)
R744	± 0,63	± 0,70	± 0,003 2
R717	± 2,51	± 2,74	± 0,011 4
R12	± 0,30	± 0,33	± 0,001 4
R22	± 0,42	± 0,47	± 0,002 0
R32	± 0,70	± 0,76	± 0,003 4
R123	± 0,31	± 0,34	± 0,001 1
R125	± 0,30	± 0,33	± 0,001 5
R134a	± 0,40	± 0,43	± 0,001 8
R143a	± 0,41	± 0,45	± 0,002 0
R152a	± 0,60	± 0,66	± 0,002 6
R404A	± 0,37	± 0,40	± 0,001 8
R407C	± 0,45	± 0,50	± 0,002 1
R410A	± 0,50	± 0,55	± 0,002 5
R507A	± 0,36	± 0,39	± 0,001 7

Annex B
(informative)

Calculation of pure-fluid thermodynamic properties from an equation of state

Starting with an equation of state explicit in reduced Helmholtz energy, e.g. Equations (1) to (5), the thermodynamic properties are given by the following:

$$p = RT\rho\left(1+\delta\frac{\partial\phi_\mathrm{r}}{\partial\delta}\right) \tag{B.1}$$

$$u = RT\left(\tau\frac{\partial\phi_\mathrm{id}}{\partial\tau}+\tau\frac{\partial\phi_\mathrm{r}}{\partial\tau}\right) \tag{B.2}$$

$$h = RT\left(1+\tau\frac{\partial\phi_\mathrm{id}}{\partial\tau}+\tau\frac{\partial\phi_\mathrm{r}}{\partial\tau}+\delta\frac{\partial\phi_\mathrm{r}}{\partial\delta}\right) \tag{B.3}$$

$$s = R\left[-\left(\phi_\mathrm{id}+\phi_\mathrm{r}\right)+\tau\frac{\partial\phi_\mathrm{id}}{\partial\tau}+\tau\frac{\partial\phi_\mathrm{r}}{\partial\tau}\right] \tag{B.4}$$

$$g = RT\left(1+\phi_\mathrm{id}+\phi_\mathrm{r}+\delta\frac{\partial\phi_\mathrm{r}}{\partial\delta}\right) \tag{B.5}$$

$$C_v = R\left(-\tau^2\frac{\partial^2\phi_\mathrm{id}}{\partial\tau^2}-\tau^2\frac{\partial^2\phi_\mathrm{r}}{\partial\tau^2}\right) \tag{B.6}$$

$$C_p = C_v + R\frac{\left(1+\delta\frac{\partial\phi_\mathrm{r}}{\partial\delta}-\delta\tau\frac{\partial^2\phi_\mathrm{r}}{\partial\delta\partial\tau}\right)^2}{1+2\delta\frac{\partial\phi_\mathrm{r}}{\partial\delta}+\delta^2\frac{\partial^2\phi_\mathrm{r}}{\partial\delta^2}} \tag{B.7}$$

$$w = \left\{\frac{RT}{M}\left[1+2\delta\frac{\partial\phi_\mathrm{r}}{\partial\delta}+\delta^2\frac{\partial^2\phi_\mathrm{r}}{\partial\delta^2}+\frac{\left(1+\delta\frac{\partial\phi_\mathrm{r}}{\partial\delta}-\delta\tau\frac{\partial^2\phi_\mathrm{r}}{\partial\delta\partial\tau}\right)^2}{\frac{C_v}{R}}\right]\right\}^{1/2} \tag{B.8}$$

where

w is the speed of sound;

M is the molar mass if the equation of state is on a molar basis, and M is 1 if the equation of state is on a mass basis.

The Joule-Thomson coefficient μ is given by

$$\mu = \frac{-1}{R\rho} \times \frac{\delta \frac{\partial \phi_{\mathrm{r}}}{\partial \delta} + \delta^2 \frac{\partial^2 \phi_{\mathrm{r}}}{\partial \delta^2} + \delta\tau \frac{\partial^2 \phi_{\mathrm{r}}}{\partial \delta \partial \tau}}{\left(1 + \delta \frac{\partial \phi_{\mathrm{r}}}{\partial \delta} - \delta\tau \frac{\partial^2 \phi_{\mathrm{r}}}{\partial \delta \partial \tau}\right)^2 + \left(-\tau^2 \frac{\partial^2 \phi_{\mathrm{id}}}{\partial \tau^2} - \tau^2 \frac{\partial^2 \phi_{\mathrm{r}}}{\partial \tau^2}\right)\left(1 + 2\delta \frac{\partial \phi_{\mathrm{r}}}{\partial \delta} + \delta^2 \frac{\partial^2 \phi_{\mathrm{r}}}{\partial \delta^2}\right)} \tag{B.9}$$

The calculation of saturation properties for a pure fluid at a given reduced temperature, τ, involves an iteration to find the reduced liquid and vapour densities at saturation, δ_{liq} and δ_{vap}, which satisfy the Maxwell criteria:

$$p\left(\tau, \delta_{\mathrm{liq}}\right) = p\left(\tau, \delta_{\mathrm{vap}}\right) \tag{B.10}$$

and

$$g\left(\tau, \delta_{\mathrm{liq}}\right) = g\left(\tau, \delta_{\mathrm{vap}}\right). \tag{B.11}$$

The pressure satisfying Equation (B.10) is the vapour pressure. The other thermodynamic properties are found using Equations (B.1) to (B.9) with inputs of τ, δ_{liq} and δ_{vap}.

The derivatives of the residual part of the reduced Helmholtz energy used in Equations (B.1) to (B.9) are given in terms of the coefficients and exponents of the equation of state by the following:

$$\phi_{\mathrm{r}} = \sum_k N_k \tau^{t_k} \delta^{d_k} \exp(\ )\left[-\alpha_k \left(\delta - \varepsilon_k\right)^{l_k}\right] \exp\left[-\beta_k \left(\tau - \gamma_k\right)^{m_k}\right] , \tag{B.12}$$

$$\delta \frac{\partial \phi_{\mathrm{r}}}{\partial \delta} = \sum_k N_k \tau^{t_k} \delta^{d_k} \exp\left[-\alpha_k \left(\delta - \varepsilon_k\right)^{l_k}\right] \exp\left[-\beta_k \left(\tau - \gamma_k\right)^{m_k}\right]\left[d_k - \delta \alpha_k l_k \left(\delta - \varepsilon_k\right)^{l_k - 1}\right] \tag{B.13}$$

$$\tau \frac{\partial \phi_{\mathrm{r}}}{\partial \tau} = \sum_k N_k \tau^{t_k} \delta^{d_k} \exp\left[-\alpha_k \left(\delta - \varepsilon_k\right)^{l_k}\right] \exp\left[-\beta_k \left(\tau - \gamma_k\right)^{m_k}\right]\left[t_k - \tau \beta_k m_k \left(\tau - \gamma_k\right)^{m_k - 1}\right] \tag{B.14}$$

$$\begin{aligned} \delta^2 \frac{\partial^2 \phi_{\mathrm{r}}}{\partial \delta^2} = {} & \sum_k N_k \tau^{t_k} \delta^{d_k} \exp\left[-\alpha_k \left(\delta - \varepsilon_k\right)^{l_k}\right] \exp\left[-\beta_k \left(\tau - \gamma_k\right)^{m_k}\right] \times \ldots \\ & \ldots \times \left\{\delta^2 \left(\delta - \varepsilon\right)^{l_k - 2}\left[\alpha_k{}^2 l_k{}^2 \left(\delta - \varepsilon\right)^{l_k} - \alpha_k l_k \left(l_k - 1\right)\right] - 2\delta d_k \alpha_k l_k \left(\delta - \varepsilon\right)^{l_k - 1} + d_k \left(d_k - 1\right)\right\} \end{aligned} \tag{B.15}$$

$$\begin{aligned} \tau^2 \frac{\partial^2 \phi_{\mathrm{r}}}{\partial \tau^2} = {} & \sum_k N_k \tau^{t_k} \delta^{d_k} \exp\left[-\alpha_k \left(\delta - \varepsilon_k\right)^{l_k}\right] \exp\left[-\beta_k \left(\tau - \gamma_k\right)^{m_k}\right] \times \ldots \\ & \ldots \times \left\{\tau^2 \left(\tau - \gamma_k\right)^{m_k - 2}\left[\beta_k{}^2 m_k{}^2 \left(\tau - \gamma_k\right)^{m_k} - \beta_k m_k \left(m_k - 1\right)\right] - 2\tau t_k \beta_k m_k \left(\tau - \gamma_k\right)^{m_k - 1} + t_k \left(t_k - 1\right)\right\} \end{aligned} \tag{B.16}$$

$$\begin{aligned} \tau\delta \frac{\partial^2 \phi_{\mathrm{r}}}{\partial \tau \partial \delta} = {} & \sum_k N_k \tau^{t_k} \delta^{d_k} \exp\left[-\alpha_k \left(\delta - \varepsilon_k\right)^{l_k}\right] \exp\left[-\beta_k \left(\tau - \gamma_k\right)^{m_k}\right] \times \ldots \\ & \ldots \times \left[d_k - \delta \alpha_k l_k \left(\delta - \varepsilon_k\right)^{l_k - 1}\right]\left[t_k - \tau \beta_k m_k \left(\tau - \gamma_k\right)^{m_k - 1}\right] \end{aligned} \tag{B.17}$$

For the derivatives of the critical region terms [Equations (9) to (12)], see Table 32 in Span and Wagner[9].

The ideal-gas part of the reduced Helmholtz energy and its derivatives used in Equations (B.1) to (B.9) are given in terms of the coefficients and exponents of the ideal gas function [Equations (4) and (5)] by the following:

$$\phi_{\text{id}} = f_1 + \frac{f_2}{T} + \ln\rho + (1 - c_0)\ln T - \sum_k c_k \left(\frac{1}{t_k + 1}\right)\left(\frac{1}{t_k}\right) T^{t_k} + \sum_k a_k \ln\left[1 - \exp\left(-\frac{b_k}{T}\right)\right] \quad \text{(B.18)}$$

$$\tau \frac{\partial\phi_{\text{id}}}{\partial\tau} = \frac{f_2}{T} - 1 + c_0 + \sum_k c_k T^{t_k} \left(\frac{1}{t_k + 1}\right) + \sum_k \frac{a_k b_k}{T}\left[\exp\left(\frac{b_k}{T}\right) - 1\right]^{-1} \quad \text{(B.19)}$$

$$\tau^2 \frac{\partial\phi^2{}_{\text{id}}}{\partial\tau^2} = 1 - c_0 - \sum_k c_k T^{t_k} - \sum_k a_k \left(\frac{b_k}{T}\right)^2 \exp\left(\frac{b_k}{T}\right)\left[\exp\left(\frac{b_k}{T}\right) - 1\right]^{-2} \quad \text{(B.20)}$$

Annex C
(informative)

Calculation of mixture thermodynamic properties from an equation of state

Starting with the mixture equation of state explicit in reduced Helmholtz energy, Equations (16) to (21), the thermodynamic properties of mixtures are given by the same expressions as for pure fluids [Equations (B.1) to (B.20)], except that the derivatives of the residual part are composed of contributions from the pure components and the excess function.

$$\phi_{\text{mix,r}} = \sum_{i=1}^{n} x_i \phi_{i,r} + \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} x_i x_j \phi_{ij,\text{excess}} \tag{C.1}$$

$$\delta \frac{\partial \phi_{\text{mix,r}}}{\partial \delta} = \sum_{i=1}^{n} x_i \delta \frac{\partial \phi_{i,\text{r}}}{\partial \delta} + \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} x_i x_j F_{ij} \sum_k N_k \tau^{t_k} \delta^{d_k} \exp\left(-\delta^{l_k}\right)\left(d_k - l_k \delta^{l_k}\right) \tag{C.2}$$

$$\tau \frac{\partial \phi_{\text{mix,r}}}{\partial \tau} = \sum_{i=1}^{n} x_i \tau \frac{\partial \phi_{i,\text{r}}}{\partial \tau} + \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} x_i x_j F_{ij} \sum_k N_k \tau^{t_k} \delta^{d_k} \exp\left(-\delta^{l_k}\right) t_k \tag{C.3}$$

$$\delta^2 \frac{\partial^2 \phi_{\text{mix,r}}}{\partial \delta^2} = \sum_{i=1}^{n} x_i \delta^2 \frac{\partial^2 \phi_i^r}{\partial \delta^2} + \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} x_i x_j F_{ij} \sum_k N_k \tau^{t_k} \delta^{d_k} \exp\left(-\delta^{l_k}\right) \times \ldots$$
$$\ldots \times \left\{\delta^{l_k}\left[l_k^2\left(\delta^{l_k} - 1\right) - l_k\left(2d_k - 1\right)\right] + d_k\left(d_k - 1\right)\right\} \tag{C.4}$$

$$\tau^2 \frac{\partial^2 \phi_{\text{mix,r}}}{\partial \tau^2} = \sum_{i=1}^{n} x_i \tau^2 \frac{\partial^2 \phi_i^r}{\partial \tau^2} + \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} x_i x_j F_{ij} \sum_k N_k \tau^{t_k} \delta^{d_k} \exp\left(-\delta^{l_k}\right) t_k\left(t_k - 1\right) \tag{C.5}$$

$$\tau\delta \frac{\partial^2 \phi_{\text{mix,r}}}{\partial \tau \partial \delta} = \sum_{i=1}^{n} x_i \tau\delta \frac{\partial^2 \phi_i^r}{\partial \tau \partial \delta} + \sum_{i=1}^{n-1} \sum_{j=i+1}^{n} x_i x_j F_{ij} \sum_k N_k \tau^{t_k} \delta^{d_k} \exp\left(-\delta^{l_k}\right)\left[t_k\left(d_k - l_k \delta^{l_k}\right)\right] \tag{C.6}$$

The derivatives of the ideal-gas part of the reduced Helmholtz energy in Equations (B.1) to (B.9) as applied to mixtures are simply summations of the pure component ideal-gas derivatives.

$$\phi_{\text{mix.id}} = \sum_{i=1}^{n}\left(x_i \phi_{i,\text{id}} + x_i \ln x_i\right) + f_3 + f_4 / T \tag{C.7}$$

$$\tau \frac{\partial \phi_{\text{mix,id}}}{\partial \tau} = \sum_{i=1}^{n}\left(x_i \tau \frac{\partial \phi_{i,\text{id}}}{\partial \tau}\right) + f_4 / T \tag{C.8}$$

$$\tau^2 \frac{\partial^2 \phi_{\text{mix,id}}}{\partial \tau^2} = \sum_{i=1}^{n} x_i \tau^2 \frac{\partial^2 \phi_{i,\text{id}}}{\partial \tau^2} \tag{C.9}$$

The calculation of properties at liquid-vapour equilibrium involves an iteration to find the reduced liquid and vapour densities δ_{liq} and δ_{vap}, and liquid and vapour compositions $x_{\text{liq},i}$ and $x_{\text{vap},i}$ which satisfy the following system of equations:

$$p\left(\tau,\delta_{\text{liq}}\right) = p\left(\tau,\delta_{\text{vap}}\right) \tag{C.10}$$

and

$$f_{\text{liq},i}\left(x_{\text{liq},i},\tau,\delta_{\text{liq}}\right) = f_{\text{vap},i}\left(x_{\text{vap},i},\tau,\delta_{\text{vap}}\right), \quad for\ i = 1\cdots n \tag{C.11}$$

The fugacity, f, for component i is given by

$$f_i = x_i \rho RT \exp\left[\frac{\partial\left(n\phi_{\text{mix,r}}\right)}{\partial n_i}\right]_{T,V,n_j} \tag{C.12}$$

where n_i is the number of molecules of component i in the blend, and the derivative is taken holding constant the temperature, total volume (not molar volume), and the number of molecules of the other components.

In solving Equations (C.10) and (C.11) either the liquid compositions or vapour compositions are known, corresponding to the bubble or dew point, respectively. The pressure satisfying Equation (C.10) is then the bubble point or dew point pressure. The other thermodynamic properties are found using Equations (B.1) to (B.9) with inputs of τ, $x_{\text{liq},i}$, $x_{\text{vap},i}$, δ_{liq} , and δ_{vap}.

Equations of state for mixtures of R–32, R–125, R–134a, R–143a, and R–152a are provided in Lemmon and Jacobsen[2].

Annex D
(informative)

Literature citations for equations of state and verification values

D.1 General

The equations of state specified in Clause 5 of this International Standard are drawn from the scientific literature. Literature citations for these equations are given here. Also given are "verification values" spanning a wide range of temperature, pressure, and density which may be used to test an implementation of any of these equations. The number of significant figures listed for these verification values far exceeds that warranted by the uncertainty of the experimental data and equation of state. The large number of significant figures serves to reveal any possible error in the implementation; if an implementation successfully reproduces the verification values (within ± 1 of the last digit listed), it will probably be correct for all conditions.

D.2 R744 — Carbon dioxide

Values for the equation of state given for R744 in Table D.1 are taken from Span and Wagner [9].

Table D.1 — R744 property values in the single-phase region to serve as verification values for the implementation of the equation of state

Temperature K	Density mol/l	Pressure MPa	Enthalpy J/mol	Entropy J/(mol·K)	C_v J/(mol·K)	C_p J/(mol·K)	Sound speed m/s
240,000 0	0,000 100 0	$0{,}199\ 544\ 2 \times 10^{-3}$	20 223,66	164,594 9	26,028 3	34,343 6	244,590 9
240,000 0	28,400 000 0	$0{,}931\ 599\ 9 \times 10^{2}$	6 984,40	23,429 4	44,030 8	74,474 3	1 243,448 2
304,128 2	1,000 000 0	$0{,}224\ 327\ 6 \times 10^{1}$	21 562,39	93,261 7	31,641 2	45,813 9	254,563 5
304,128 2	25,400 000 0	$0{,}980\ 899\ 4 \times 10^{2}$	11 733,78	40,308 2	41,459 9	71,077 9	1 039,393 7
500,000 0	0,000 100 0	$0{,}415\ 724\ 2 \times 10^{-3}$	30 611,70	187,354 3	36,317 7	44,632 4	340,716 6
500,000 0	17,400 000 0	$0{,}982\ 411\ 0 \times 10^{2}$	250 16,27	74,135 2	41,249 1	64,713 5	698,279 9

D.3 R717 — Ammonia

Values for the equation of state given for R717 in Table D.2 are taken from Tillner-Roth *et al*. [11].

Table D.2 — R717 property values in the single-phase region to serve as verification values for the implementation of the equation of state

Temperature K	Density mol/l	Pressure MPa	Enthalpy J/mol	Entropy J/(mol·K)	C_v J/(mol·K)	C_p J/(mol·K)	Sound speed m/s
220,000 0	0,000 100 0	$0{,}182\ 905\ 5 \times 10^{-3}$	23 716,39	154,617 7	26,007 3	34,326 3	376,489 4
220,000 0	43,400 000 0	$0{,}956\ 616\ 5 \times 10^{2}$	902,15	− 2,603 9	51,353 5	69,616 3	2 121,501 6
405,400 0	1,000 000 0	$0{,}301\ 572\ 0 \times 10^{1}$	29 117,16	93,477 5	34,570 9	48,925 6	471,553 5
405,400 0	32,600 000 0	$0{,}964\ 576\ 4 \times 10^{2}$	14 385,54	41,679 6	46,491 0	73,980 9	1 342,495 0
500,000 0	0,000 100 0	$0{,}415\ 720\ 9 \times 10^{-3}$	34 249,99	178,237 3	33,851 0	42,165 8	551,420 8
500,000 0	27,000 000 0	$0{,}991\ 883\ 4 \times 10^{2}$	21 471,86	57,182 1	45,985 3	75,616 5	1 077,241 8

D.4 R12 — Dichlorodifluoromethane

Values for the equation of state given for R12 in Table D.3 are taken from Marx *et al.* [6].

Table D.3 — R12 property values in the single-phase region to serve as verification values for the implementation of the equation of state

Temperature K	Density mol/l	Pressure MPa	Enthalpy J/mol	Entropy J/(mol·K)	C_v J/(mol·K)	C_p J/(mol·K)	Sound speed m/s
180,000 0	0,000 100 0	$0{,}149\ 638\ 2 \times 10^{-3}$	37 392,20	227,478 3	47,116 8	55,437 7	120,661 1
180,000 0	14,600 000 0	$0{,}895\ 352\ 6 \times 10^{2}$	19 212,75	69,146 9	67,463 7	96,414 2	1 252,438 9
385,120 0	1,000 000 0	$0{,}243\ 271\ 2 \times 10^{1}$	49 176,11	193,993 0	78,027 3	104,700 0	138,816 8
385,120 0	11,800 000 0	$0{,}977\ 220\ 6 \times 10^{2}$	40 641,90	145,718 7	81,564 6	108,273 8	832,271 1
500,000 0	0,000 100 0	$0{,}415\ 717\ 7 \times 10^{-3}$	61 666,26	293,496 3	81,414 0	89,729 1	194,660 1
500,000 0	10,400 000 0	$0{,}943\ 040\ 9 \times 10^{2}$	53 169,03	174,861 4	87,743 4	112,258 7	689,532 0

D.5 R22 — Chlorodifluoromethane

Values for the equation of state given for R22 in Table D.4 are taken from Kamei *et al.* [1].

Table D.4 — R22 property values in the single-phase region to serve as verification values for the implementation of the equation of state

Temperature K	Density mol/l	Pressure MPa	Enthalpy J/mol	Entropy J/(mol·K)	C_v J/(mol·K)	C_p J/(mol·K)	Sound speed m/s
180,000 0	0,000 100 0	$0{,}149\ 641\ 9 \times 10^{-3}$	31 345,16	200,950 5	35,259 6	43,580 0	146,243 1
180,000 0	18,600 000 0	$0{,}484\ 127\ 4 \times 10^{2}$	10 391,89	43,195 4	59,630 7	89,533 5	1 232,788 5
369,295 0	1,000 000 0	$0{,}246\ 504\ 9 \times 10^{1}$	39 359,61	153,643 1	60,038 8	82,135 7	173,670 3
369,295 0	14,000 000 0	$0{,}541\ 600\ 9 \times 10^{2}$	27 889,80	107,976 8	65,027 7	96,605v8	696,174 8
500,000 0	0,000 100 0	$0{,}415\ 721\ 5 \times 10^{-3}$	50 457,59	250,843 5	65,237 9	73,552 8	232,820 6
500,000 0	11,200 000 0	$0{,}574\ 566\ 1 \times 10^{2}$	40 884,41	137,468 9	72,690 5	100,321 9	519,184 8

D.6 R32 — Difluoromethane

Values for the equation of state given for R32 in Table D.5 are taken from Tillner-Roth and Yokozeki [13].

Table D.5 — R32 property values in the single-phase region to serve as verification values for the implementation of the equation of state

Temperature K	Density mol/l	Pressure MPa	Enthalpy J/mol	Entropy J/(mol·K)	C_v J/(mol·K)	C_p J/(mol·K)	Sound speed m/s
180,000 0	0,000 100 0	$0{,}149\ 637\ 2 \times 10^{-3}$	24 642,56	171,613 4	27,520 4	35,845 3	193,540 8
180,000 0	26,600 000 0	$0{,}678\ 660\ 9 \times 10^{2}$	4 407,98	12,952 9	52,025 2	78,243 0	1 411,750 0
351,255 0	1,000 000 0	$0{,}240\ 080\ 6 \times 10^{1}$	29 728,57	113,970 5	45,166 1	65,591 7	232,189 3
351,255 0	20,000 000 0	$0{,}657\ 835\ 9 \times 10^{2}$	17 751,81	65,274 6	52,263 8	81,082 4	824,899 9
420,000 0	0,000 100 0	$0{,}349\ 203\ 5 \times 10^{-3}$	35 093,81	200,438 5	44,711 9	53,026 9	282,144 4
420,000 0	17,600 000 0	$0{,}682\ 732\ 6 \times 10^{2}$	23 463,30	79,773 2	56,027 4	84,070 4	690,619 9

D.7 R123 — 2,2–dichloro–1,1,1–trifluoroethane

Values for the equation of state given for R123 in Table D.6 are taken from Younglove and McLinden [14]. This equation has been transformed from the MBWR form of the original reference to a Helmholtz energy form by the application of Equation (15).

Table D.6 — R123 property values in the single-phase region to serve as verification values for the implementation of the equation of state

Temperature K	Density mol/l	Pressure MPa	Enthalpy J/mol	Entropy J/(mol·K)	C_v J/(mol·K)	C_p J/(mol·K)	Sound speed m/s
200,000 0	0,000 100 0	$0{,}166\ 236\ 1 \times 10^{-3}$	51 932,59	271,015 4	72,941 1	81,272 2	110,034 5
200,000 0	11,200 000 0	$0{,}159\ 802\ 9 \times 10^{2}$	20 989,93	105,753 9	99,537 8	140,695 5	1 125,084 1
456,831 0	1,000 000 0	$0{,}260\ 763\ 8 \times 10^{1}$	74 932,17	268,877 9	128,403 8	172,820 8	118,162 1
456,831 0	8,200 000 0	$0{,}392\ 310\ 8 \times 10^{2}$	61 611,27	227,466 5	127,039 2	163,828 4	556,202 0
500,000 0	0,000 100 0	$0{,}415\ 713\ 8 \times 10^{-3}$	84 983,25	360,763 3	124,235 6	132,551 4	170,299 1
500,000 0	7,600 000 0	$0{,}370\ 207\ 1 \times 10^{2}$	68 699,97	242,875 3	130,455 4	167,894 8	484,679 8

D.8 R125 — Pentafluoroethane

Values for the equation of state given for R125 in Table D.7 are taken from Lemmon and Jacobsen [3].

Table D.7 — R125 property values in the single-phase region to serve as verification values for the implementation of the equation of state

Temperature K	Density mol/l	Pressure MPa	Enthalpy J/mol	Entropy J/(mol·K)	C_v J/(mol·K)	C_p J/(mol·K)	Sound speed m/s
200,000 0	0,000 100 0	$0{,}166\ 272\ 1 \times 10^{-3}$	35 264,67	225,586 9	65,917 0	74,236 2	124,901 3
200,000 0	14,000 000 0	$0{,}423\ 025\ 2 \times 10^{2}$	15 906,32	71,935 4	85,816 3	123,536 4	968,671 9
339,173 0	1,000 000 0	$0{,}213\ 324\ 3 \times 10^{1}$	45 066,59	187,464 2	101,757 7	131,702 5	127,877 5
339,173 0	11,400 000 0	$0{,}549\ 441\ 7 \times 10^{2}$	34 771,90	139,417 8	105,116 8	139,137 3	635,452 7
500,000 0	0,000 100 0	$0{,}415\ 719\ 7 \times 10^{-3}$	66 051,40	308,359 7	117,595 0	125,910 0	192,577 1
500,000 0	8,800 000 0	$0{,}576\ 070\ 8 \times 10^{2}$	58 381,94	195,593 0	124,570 9	152,147 8	460,407 1

D.9 R134a — 1,1,1,2–tetrafluoroethane

Values for the equation of state given for R134a in Table D.8 are taken from Tillner-Roth and Baehr [10].

Table D.8 — R134a property values in the single-phase region to serve as verification values for the implementation of the equation of state

Temperature K	Density mol/l	Pressure MPa	Enthalpy J/mol	Entropy J/(mol·K)	C_v J/(mol·K)	C_p J/(mol·K)	Sound speed m/s
200,000 0	0,000 100 0	$0{,}166\ 262\ 5 \times 10^{-3}$	36 070,67	217,719 5	57,594 2	65,918 6	136,555 3
200,000 0	15,500 000 0	$0{,}554\ 122\ 4 \times 10^{2}$	13 479,24	56,317 0	83,680 6	119,279 6	1 162,988 5
374,210 0	1,000 00 0	$0{,}234\ 989\ 9 \times 10^{1}$	47 594,85	183,166 9	98,683 0	129,206 5	146,495 0
374,210 0	12,200 000 0	$0{,}631\ 710\ 1 \times 10^{2}$	35 940,48	134,577 7	102,190 3	135,280 3	711,790 0
440,000 0	0,000 100 0	$0{,}365\ 830\ 3 \times 10^{-3}$	57 297,93	278,689 3	100,598 0	108,913 2	197,021 5
440,000 0	11,200 000 0	$0{,}685\ 725\ 9 \times 10^{2}$	45 217,73	156,266 6	110,055 3	141,253 6	634,823 3

D.10 R143a — 1,1,1–trifluoroethane

Values for the equation of state given for R143a in Table D.9 are taken from Lemmon and Jacobsen [4].

Table D.9 — R143a property values in the single-phase region to serve as verification values for the implementation of the equation of state

Temperature K	Density mol/l	Pressure MPa	Enthalpy J/mol	Entropy J/(mol·K)	C_v J/(mol·K)	C_p J/(mol·K)	Sound speed m/s
200,000 0	0,000 100 0	0,166 266 2 × 10^{-3}	29 045,32	193,149 5	51,532 1	59,855 6	151,579 2
200,000 0	15,800 000 0	0,648 278 0 × 10^{2}	11 245,14	41,576 0	71,010 3	101,123 0	1 142,182 1
345,857 0	1,000 000 0	0,215 875 6 × 10^{1}	37 147,53	148,319 0	85,392 2	114,327 8	156,365 6
345,857 0	13,400 000 0	0,901 458 6 × 10^{2}	28 271,15	98,620 6	90,157 5	116,496 8	879,874 8
500,000 0	0,000 100 0	0,415 719 3 × 10^{-3}	54 741,98	260,681 0	99,013 5	107,328 6	231,559 5
500,000 0	11,400 000 0	0,987 330 5 × 10^{2}	47 616,64	143,077 0	108,177 9	129,232 3	717,998 8

D.11 R152a — 1,1–difluoroethane

Values for the equation of state given for R152a in Table D.10 are taken from Outcalt and McLinden [8].

NOTE This equation has been transformed from the MBWR form of the original reference to a Helmholtz energy form.

Table D.10 — R152a property values in the single-phase region to serve as verification values for the implementation of the equation of state

Temperature K	Density mol/l	Pressure MPa	Enthalpy J/mol	Entropy J/(mol·K)	C_v J/(mol·K)	C_p J/(mol·K)	Sound speed m/s
180,000 0	0,000 100 0	0,149 627 0 × 10^{-3}	28 915,19	180,944 2	41,424 2	49,750 4	164,925 6
180,000 0	18,000 000 0	0,524 530 1 × 10^{2}	5 642,67	18,301 2	69,808 3	98,156 5	1 419,016 1
386,411 0	1,000 000 0	0,245 931 5 × 10^{1}	39 592,51	143,147 8	80,071 0	107,439 1	191,098 5
386,411 0	13,400 000 0	0,542 090 6 × 10^{2}	27 384,42	97,523 8	84,898 9	114,566 1	768,672 1
500,000 0	0,000 100 0	0,415 718 1 × 10^{-3}	52 482,90	243,606 9	88,282 7	96,597 9	262,423 5
500,000 0	11,200 000 0	0,578 693 2 × 10^{2}	41 011,44	127,717 0	95,800 3	123,574 6	602,256 5

D.12 R404A — R125/143a/134a (44/52/4)

Values for the equation of state given for R404A in Table D.11 are taken from Lemmon and Jacobsen [2].

Table D.11 — R404A property values in the single-phase region to serve as verification values for the implementation of the equation of state

Temperature K	Density mol/l	Pressure MPa	Enthalpy J/mol	Entropy J/(mol·K)	C_v J/(mol·K)	C_p J/(mol·K)	Sound speed m/s
200,000 0	0,000 100 0	0,166 267 3 × 10^{-3}	31 684,93	206,060 1	56,912 8	65,235 3	139,726 2
200,000 0	15,000 000 0	0,478 096 4 × 10^{2}	12 470,14	53,110 6	80,737 7	115,335 2	1 048,161 2
345,000 0	1,000 000 0	0,215 478 7 × 10^{1}	40 558,17	164,163 3	92,158 0	121,829 8	143,863 8
345,000 0	5,800 000 0	0,371 587 1 × 10^{1}	32 697,30	138,571 8	116,954 3	5 684,144 8	90,288 0
345,000 0	12,200 000 0	0,589 688 7 × 10^{2}	30 313,09	116,835 7	96,128 2	126,538 8	698,246 4
440,000 0	0,000 100 0	0,365 313 × 10^{-3}	52 653,79	266,237 5	98,412 5	106,727 6	201,612 4
440,000 0	10,400 000 0	0,570 197 1 × 10^{2}	42 711,70	148,976 5	107,399 7	135,438 2	546,926 9

D.13 R407C — R32/125/134a (23/25/52)

Values for the equation of state given for R407C in Table D.12 are taken from Lemmon and Jacobsen [2].

Table D.12 — R407C property values in the single-phase region to serve as verification values or the implementation of the equation of state

Temperature K	Density mol/l	Pressure MPa	Enthalpy J/mol	Entropy J/(mol·K)	C_v J/(mol·K)	C_p J/(mol·K)	Sound speed m/s
200,000 0	0,000 100 0	$0{,}166\,267\,5 \times 10^{-3}$	31 774,36	202,629 9	47,967 2	56,289 6	150,436 8
200,000 0	17,900 000 0	$0{,}553\,926\,9 \times 10^{2}$	10 927,61	45,265 7	73,513 9	107,094 6	1 152,133 7
355,000 0	1,000 000 0	$0{,}229\,640\,0 \times 10^{1}$	39 788,21	156,305 1	78,767 3	105,478 7	162,875 9
355,000 0	8,400 000 0	$0{,}435\,213\,7 \times 10^{1}$	29 746,16	124,669 9	96,528 3	468,523 2	137,917 1
355,000 0	14,000 000 0	$0{,}557\,344\,0 \times 10^{2}$	28 020,22	108,209 6	83,118 0	115,842 8	696,432 9
420,000 0	0,000 100 0	$0{,}349\,202\,3 \times 10^{-3}$	47 657,20	248,603 3	79,036 1	87,351 3	211,589 6
420,000 0	12,600 000 0	$0{,}594\,362\,1 \times 10^{2}$	35 796,97	127,595 2	89,326 4	120,705 6	598,869 6

D.14 R410A — R32/125 (50/50)

Values for the equation of state given for R410A in Table D.13 are taken from Lemmon and Jacobsen [2].

Table D.13 — R410A property values in the single-phase region to serve as verification values for the implementation of the equation of state

Temperature K	Density mol/l	Pressure MPa	Enthalpy J/mol	Entropy J/(mol·K)	C_v J/(mol·K)	C_p J/(mol·K)	Sound speed m/s
200,000 0	0,000 100 0	$0{,}166\,271\,3 \times 10^{-3}$	28 272,46	189,950 0	39,755 4	48,076 4	166,428 6
200,000 0	20,600 000 0	$0{,}560\,445\,5 \times 10^{2}$	8 824,58	35,989 8	63,515 5	93,716 8	1 137,248 4
340,000 0	1,000 000 0	$0{,}225\,047\,7 \times 10^{1}$	33 876,54	135,158 5	62,914 7	86,967 5	181,537 7
340,000 0	10,000 000 0	$0{,}450\,682\,3 \times 10^{1}$	23 770,26	101,635 1	81,639 8	397,059 8	156,705 1
340,000 0	16,200 000 0	$0{,}550\,240\,0 \times 10^{2}$	22 189,48	86,707 0	68,183 8	99,824 3	714,199 4
420,000 0	0,000 100 0	$0{,}349\,203\,3 \times 10^{-3}$	41 445,78	227,114 4	63,514 0	71,829 1	233,252 9
420,000 0	14,000 000 0	$0{,}592\,175\,4 \times 10^{2}$	30 450,19	107,776 3	74,125 2	104,685 5	584,444 2

D.15 R507A [R125/143a (50/50)]

Values for the equation of state given for R507A in Table D.14 are taken from Lemmon and Jacobsen [2].

Table D.14 — R507A property values in the single-phase region to serve as verification values for the implementation of the equation of state

Temperature K	Density mol/l	Pressure MPa	Enthalpy J/mol	Entropy J/(mol·K)	C_v J/(mol·K)	C_p J/(mol·K)	Sound speed m/s
200,000 0	0,000 100 0	$0{,}166\,267\,7 \times 10^{-3}$	31 767,48	206,895 2	57,458 0	65,780 3	138,752 2
200,000 0	14,900 000 0	$0{,}460\,896\,0 \times 10^{2}$	12 596,27	54,278 6	80,934 3	115,808 8	1035,313 1
340,000 0	1,000 000 0	$0{,}210\,473\,4 \times 10^{1}$	40 236,28	164,010 0	92,395 7	123,280 7	140,846 5
340,000 0	7,200 000 0	$0{,}343\,922\,5 \times 10^{1}$	31 045,65	134,438 7	106,760 9	474,594 0	124,120 2
340,000 0	12,200 000 0	$0{,}579\,585\,8 \times 10^{2}$	29 927,83	116,390 8	96,028 5	126,730 6	697,265 1
500,000 0	0,000 100 0	$0{,}415\,719\,4 \times 10^{-3}$	59 560,49	280,703 9	106,666 1	114,981 1	212,906 8
500,000 0	9,400 000 0	$0{,}577\,036\,1 \times 10^{2}$	51 358,49	167,937 2	114,301 5	140,078 1	493,140 6

Annex E
(informative)

Variation of mixture properties due to composition tolerance

ISO 817 specifies the compositions of refrigerant blends in the R400–series and R500–series but also specifies allowable deviations (tolerances) from the nominal compositions. Thermodynamic properties will generally change with a change in the mixture composition. Thus, any composition tolerance implies a variation in the thermodynamic properties. The extent a composition variation translates into a variation in a property depends on several factors, including the following:

a) type of system;

b) property of interest, because different thermodynamic properties depend differently on mixture composition;

c) location of the state point on the thermodynamic surface;

d) variables that are fixed during the composition change.

Information on how thermodynamic properties change due to changes in mixture composition is important to estimate the uncertainties in technical calculations. The analysis presented in this annex provides some estimate of this effect. It is informative only; the properties defined by this International Standard are those at the nominal compositions defined in ISO 817.

The properties of refrigerant blends defined in this International Standard are calculated using equations of state which are valid over the entire composition range, and this attribute allows a calculation of the effects of a composition tolerance. Given a composition tolerance specified in ISO 817, an allowable range of composition is defined. For R410A [R32/125 (50/50)], for example, the composition of R32 may range between 50,5 mass % and 48,5 mass % while that for R125 may range between 49,5 mass % and 51,5 mass %. Multiple property calculations can then be performed at a given state point at various compositions and the maximum variation of properties within the allowed composition range determined.

Table E.1 provides the maximum variation in several thermodynamic properties corresponding to the allowable composition tolerances specified in ISO 817 at three different state points, which have been chosen to be typical of conventional refrigeration calculations:

— maximum variations in p_{bubble}, ρ_{liq}, h_{liq}, and s_{liq} for saturated liquid at 25 °C;

— maximum variations in T_{bubble}, ρ_{liq}, h_{liq}, and s_{liq} for saturated liquid at a pressure of 0,1 MPa;

— maximum variations in ρ, h, and s for single–phase vapour at p = 2 MPa and T = 90 °C.

Table E.1 — Maximum variation of selected thermodynamic properties due to composition tolerances of refrigerant blends

	R404A	R407C	R410A	R507A
Mass %	R125: 44 $^{+2,0}_{-2,0}$	R32: 23 $^{+2,0}_{-2,0}$	R32: 50 $^{+0,5}_{-1,5}$	R125: 50 $^{+1,0}_{-1,0}$
Mass %	R143a: 52 $^{+1,0}_{-1,0}$	R125: 25 $^{+2,0}_{-2,0}$	R125: 50 $^{+0,5}_{-1,5}$	R143a: 50 $^{+1,0}_{-1,0}$
Mass %	R134a: 4 $^{+2,0}_{-2,0}$	R134a: 52 $^{+2,0}_{-2,0}$	—	—
Saturated liquid at 25 °C				
Δp_{bubble}	± 1,03 %	± 2,20 %	$^{+0,06}_{-0,17}$ %	± 0,07 %
$\Delta \rho_{\text{liq}}$	± 0,31 %	± 0,52 %	$^{+0,32}_{-0,11}$ %	± 0,25 %
Δh_{liq}	± 73 J/kg	± 250 J/kg	$^{+60}_{-180}$ J/kg	± 63 J/kg
Δs_{liq}	± 0,3 J/(kg·K)	± 0,9 J/(kg·K)	$^{+0,2}_{-0,6}$ J/(kg·K)	± 0,2 J/(kg·K)
Saturated liquid at 0,1 MPa				
ΔT_{bubble}	± 0,26 °C	± 0,56 °C	$^{+0,03}_{-0,01}$ °C	± 0,002 °C
$\Delta \rho_{\text{liq}}$	± 0,33 %	± 0,44 %	$^{+0,34}_{-0,11}$ %	± 0,26 %
Δh_{liq}	± 330 J/kg	± 1 060 J/kg	$^{+400}_{-130}$ J/kg	± 100 J/kg
Δs_{liq}	± 1,4 J/(kg·K)	± 4,5 J/(kg·K)	$^{+1,6}_{-0,5}$ J/(kg·K)	± 0,4 J/(kg·K)
Superheated vapour at 90 °C and 2 MPa				
$\Delta \rho_{\text{vap}}$	± 0,41 %	± 2,1 %	$^{+1,2}_{-0,41}$ %	± 0,33 %
Δh_{vap}	± 1 190 J/kg	± 3 760 J/kg	$^{+940}_{-2\,820}$ J/kg	± 640 J/kg
Δs_{vap}	± 3,4 J/(kg·K)	± 12 J/(kg·K)	$^{+3.1}_{-9,4}$ J/(kg·K)	± 2,0 J/(kg·K)

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