INTERNATIONAL STANDARD

ISO 17584

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Refrigerant properties

Propriétés des fluides frigorigènes

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Foreword

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

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.

Attention is drawn to the possibility that some of the elements of this document may be the subject of patent rights. ISO shall not be held responsible for identifying any or all such patent rights.

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.