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Transport properties of real moist air, dry air, steam, and water

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This paper presents the ASHRAE transport properties model for moist air as a "real-gas mixture" employing a modification of the mixing model of Vesovic and Wakeham. It uses the latest research from the International Association for the Properties of Water and Steam (IAPWS), the International Union of Pure and Applied Chemistry (IUPAC), and the National Institute of Standards and Technology (NIST). The modification represents an improvement and consists in an adjustment of the underlying Vesovic-Wakeham model to experimental data in accordance with the composition of the mixture moist air. The model allows the calculation of viscosity and thermal conductivity in the validity range with total pressures from 0.01 kPa to 10 MPa, temperatures from −70 to 300 °C, and humidity ratios from 0 to 10 kg_w/kg_a. The model has been used to generate transport property tables for moist air and for H_2O at saturation states for the Psychrometrics Chapter in the 2021 ASHRAE Handbook Fundamentals. This work summarizes the results of the ASHRAE Research Project 1767 (RP-1767).

Introduction

New experimental results and calculated values for the transport properties of dry air, water, and moist air became available from many different sources during the last years. This paper summarizes and unifies data and algorithms developed for calculating the moist air transport properties such as viscosity, thermal conductivity and the derived transport properties of kinematic viscosity, Prandtl number, and thermal diffusivity.

The algorithms are based on the model for viscosity and thermal conductivity for mixtures of Vesovic and Wakeham (1989, 1991). The modification of the Vesovic-Wakeham model for the description of moist air properties developed in this work takes into account measurements from the literature (Grüß and Schmick 1928; Kestin and Whitelaw 1964; Hochrainer and Munczak 1966). The used correlations for viscosity and thermal conductivity of dry air have been published by Lemmon and Jacobsen (2004). The correlation for viscosity of H_2O used in this model has been released as the IAPWS Formulation IAPWS R12-08 (2008) and based on Huber et al. (2009). The correlation for thermal conductivity of H_2O is based on the IAPWS Formulation IAPWS R15-11 (2011) of Huber et al. (2012).

The results of this paper are provided by the research project RP-1767 of the American Society of Heating, Refrigerating and Air-Conditioning Engineers, Inc., (ASHRAE RP-1767 2018), similar to the research project RP-1485 (ASHRAE RP-1485 2009; Herrmann et al. 2009) for the calculation of thermodynamic and psychrometric properties.

The presented algorithms are important for air conditioning-system psychrometrics and equipment design. They are especially significant at higher temperatures and pressures like those, encountered in the compression stage of gas turbines and in compressed air energy storage applications.

Fundamentals for the transport properties of dry air, steam, and water

Transport properties of dry air

The current correlations for the dynamic viscosity and the thermal conductivity of dry air are functions of temperature and density. Therefore, the density has to be calculated first for given values of temperature and pressure. This can be performed by means of the corresponding fundamental equation of Lemmon et al. (2000).

Description of the correlation for the viscosity

The formulation was developed using a large number of experimental data available in the literature and can be applied to

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