Properties of Humid Air for Power-Cycle Calculations

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To model compressed air energy storage power cycles and to design their components, accurate algorithms for thermodynamic properties of humid air are required. In the past, the evaluation of thermodynamic-property models and the verification of their accuracy were hampered due to the lack of experimental data for humid air at higher temperatures and pressures. New experimental data generated within the AA-CAES project of the European Commission Sixth Framework Programme [1] have become the basis for comparisons between different models described in this paper. Here, a model for calculating thermodynamic properties for humid air in power-cycle design and operation, developed out of these investigations, is recommended. This model consists of an ideal mixture of the real fluids dry air and steam, water, or ice [2]. Dry air is calculated from the fundamental equation provided by Lemmon *et al.* [3], steam and water from IAPWS-95, and ice from IAPWS-06. Saturation of humid air is calculated using a modified virial equation [4]. At high temperatures, dissociation is considered. The resulting model has been implemented in a property library which can be applied to modelling power cycles with the working fluid humid air. In addition, algorithms for transport properties are included. Properties can be calculated based on various sets of independent variables including (p,h), (p,s), and (h,s). Application of the software is possible up to temperatures of 2000 K and pressures of up to 100 MPa. Add-Ins have been prepared for using the property library in Excel®, MATLAB®, and Mathcad®.

[1] European Commission: Advanced Adiabatic Compressed Air Energy Storage, Contract-No. ENK6-CT-2002-00611, Project in the Sixth Framework Programme by the European Commission, www.cordis.lu.

[2] Herrmann, S.; Kretzschmar, H.-J.; Teske, V.; Vogel, E.; Ulbig, P.; Span, R.; Gatley, D.P.: Determination of Thermodynamic and Transport Properties for Humid Air for Power-Cycle Calculations. *PTB-Verlag*, Braunschweig (2008).

[3] Lemmon, E.W.; Jacobsen R.T.; Penoncello S.G.; Friend, D.G.: Thermodynamic Properties of Air and Mixtures of Nitrogen, Argon, and Oxygen from 60 to 2000 K at Pressures to 2000 MPa. *J. Phys. Chem. Ref. Data* **29**, 331-385 (2000).

[4] Herrmann, S.; Kretzschmar, H.-J.; Gatley, D.P.: Thermodynamic Properties of Real Moist Air, Dry Air, and H_2O. Final Report of the ASHRAE Research Project 1485, in preparation (2008).

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