



Contribution ID: 225

Type: **Invited Oral (30min)**

[Invited Oral] A deeper look into the thermodynamic perfection of the Debye equation of state for helium-3

Wednesday, 9 July 2014 16:00 (30 minutes)

A new form of a state equation for helium-3 in wide range of temperature and pressure, based on a conceptual extrapolation from the Debye equation for the specific heat of solid materials was previously developed. A deeper look into the performance of the state equation for helium-3 was recently considered necessary and valuable, due to some feedback from cryogenic applications, such as the observations of an unusual change in enthalpies during designing a J-T cooler with helium-3 as the working substance at pressure varying from 2 kPa to 200 kPa. A comprehensive evaluation of the state equation has been conducted with the Gruneisen parameter along isochores, cubic sound velocity –pressure linearity, C_v / T^3 –density relation, and virial coefficients as the benchmarks. The same analysis was applied to helium-4 for the sake of analogizing the common behavior in reduced forms for these isotopes in wide range of temperature and density, particularly in the critical region. The results were then checked with physics known for quantum fluids as well as general fluids, which confirms the good thermodynamic perfection of the Debye state equation for helium-3 in most areas on the phase diagram as declared before, except a narrow strip at low pressures. A revision of the equation is conducted to fix the located problem.

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Session Classification: Wed-Af-Orals Session 12

Track Classification: C-06: Heat transfer and thermo-physical properties of solids and fluids