Design of a New Cryogenic Densimeter for Measurements on Liquid Hydrogen

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Hydrogen-based technologies are a key factor for future energy systems. The availability of hydrogen in a high energy density form is essential for various applications, making liquid hydrogen increasingly important. Accurate property models are important to optimize processes such as the energy intensive hydrogen liquefaction. Regarding the reference equation of state for hydrogen by Leachman et al. [1], the uncertainty in density at low temperatures is claimed to be 0.1 % - deviations to published data are significantly larger. In comparison, the equations of state for nitrogen and methane have an uncertainty in density of only 0.02 % and 0.03 %, respectively [2, 3]. A significant factor for this circumstance is that for hydrogen only a few experimental density measurements at cryogenic temperatures are available [1]. Furthermore, these data sets were published prior to 1980 without using state-of-the-art technology. To the best of our knowledge, the database regarding cryogenic temperatures has remained essentially unchanged since the development of the equation of state by Leachman et al. [1].

To address this issue, a new densimeter is currently being designed for accurate density measurements of hydrogen in a temperature range from 14 K to 293 K at pressures up to 20 MPa. Here, a single-sinker measurement principle, developed by Brachthäuser et al. [4], in conjunction with a magnetic suspension balance will be employed. Temperature control is achieved via a two-stage vacuum-insulated thermostat enclosing the core apparatus. Liquid nitrogen will be used for the outer stage and liquid helium for the inner stage. Fine control will be realized by electric heating elements.

During the design process, various issues must be resolved, such as the selection of suitable materials. The avoidance of ferromagnetic properties is essential to reduce unwanted influence on the magnetic suspension coupling. Simultaneously, it is essential to ensure that all relevant components and connections are compatible with hydrogen. Another example of a design issue is the incorporation of a catalyst to accelerate, or at least control, the conversion of ortho- to para-hydrogen. The approaches to the various issues posed by the cryogenic measurement apparatus, as well as the current design of the new densimeter, will be presented.

References

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