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Improving accuracy of liquid hydrogen measurements by development of dedicated reference measurement standards

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Metrology is the science of measurement for which a global measurement infrastructure exists via the Bureau International des Poids et Mesures (BIPM). The BIPM members have signed the meter convention committing themselves to the usage of the SI-units of measurement (e.g., kilogram, second, meter etc.). National Metrology Institutes (NMIs) maintain the (reference) measurement standards that act as references to the SI-units of measurement. NMIs also maintain measurement standards for derived units such as flow units (kg/s, m3/h).

Liquid hydrogen poses challenges to the accurate measurement of measurands, i.e., the quantity to be measured, in any experimental setup or process. Temperature measurement standards maintained at NMIs typically do not range further down than 77 K (or −196 ℃), which limits the possibilities for accurate liquid hydrogen temperature determination at 20 K (or -253 ℃; at atmospheric pressure). The SI-units of measurement include the mole to express the amount of hydrogen molecules in any gas mixture, however accurate determination of the ortho- and para-spin isomer composition of liquid hydrogen are hampered by the lack of methods to determine their mole fractions at a particular cryogenic temperature. Flow meters can be used to determine the quantity of hydrogen transferred in a scientific experiment or, for instance, when delivered to an airplane. However, it is well-known that the accuracy of flow meters can be affected by the extreme low temperatures of liquid hydrogen; the extent to which is strictly unknown until a reference measurement standard which realizes the flow unit on liquid hydrogen conditions is used to compare it with. Thus, dedicated (reference) measurement standards, which directly link liquid hydrogen measurements to SI-units, are needed.

In 2025, the CryoMet project started as part of the European Partnership on Metrology. It sets out to deliver (reference) measurement standards for liquid hydrogen. These measurement standards will enable the determination of the accuracy of measuring equipment, such as a thermometer, in its process conditions (i.e., as installed in its experimental or industrial configuration). The measurement standards'direct link to the SI-units in combination with their usability in process conditions enables to identify unknown measurement errors of other sensors by their comparison with the reference measurement standards. The CryoMet project consortium will develop:
(1) Reference measurement standards for liquid hydrogen temperature determination suitable for industrial applications (target uncertainty up to 0.5 ℃ (k = 2)). This includes the development of highly accurate, cost-effective laboratory temperature sensor calibration capabilities at liquid hydrogen temperatures.
(2) Novel methods for SI-traceable measurements of the ortho- and para-spin isomer composition of liquid hydrogen. These methods are based on (I) Raman spectroscopy and (II) sound-speed measurements. Anticipated measurement uncertainty is at 1.0 % (k = 2).
(3) Validation of flow unit references through a bilateral intercomparison at industrial scale (up to 600 kg/h). Anticipated, validated measurement uncertainty is estimated at 0.5 % (k = 2).

Delivery of the metrological reference measurement standards by the CryoMet consortium will have an impact across the entire liquid hydrogen measurement chain. Thermodynamic equation-of-state modelling of liquid hydrogen will be improved by the reference measurement standards for temperature and ortho- and para-spin isomer composition. Safe transport of liquid hydrogen at industrial scales requires accurate temperature and ortho- and para-spin isomer composition determination. Cleary, progression of liquid hydrogen research and engineering towards the larger scale usage in a decarbonized energy system will be stimulated by the liquid hydrogen reference measurement standards.

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