Transfer standards for *on-line* speed of sound and density measurements in LNG

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Objectives

- Development of fully traceable sensors for speed of sound and density measurements at **ambient** and **cryogenic conditions**:
  - As transfer standards, the sensors are characterized in laboratory, but they are designed to be used for *on-line* measurements and/or for the calibration of *on-line* instruments by comparison;
  - Obtaining traceable speed of sound measurements;
  - Obtaining traceable density measurements of fluids **uninfluenced** by **composition** and **flow rates**.
- Development of a measurement apparatus suitable to work at cryogenic conditions with relative accuracies in the order of 0.1 %, with **fluid at rest**
- *On-line* test of sensors for validating performances when operating on **calibration facilities** (to be completed)

- **Speed of sound sensor** has been optimized to work with LNG with an expanded relative uncertainty of 0.2 % (k=2) and a repeatability of 0.05 %;
- **Density sensor** has been calibrated in the temperature range of 20 °C to 50 °C with the aim to be tested on flow calibration facility with water;
- We found that, in principle, **today available ultrasonic flow meters** should be ready to measure **density of LNG** independently from the fluid composition (*further studies are needed*).

Speed of sound measurements in methane

1. Speed of sound measurement **system** has been **optimized** to work at cryogenic temperature and for pressure up to 10 MPa.

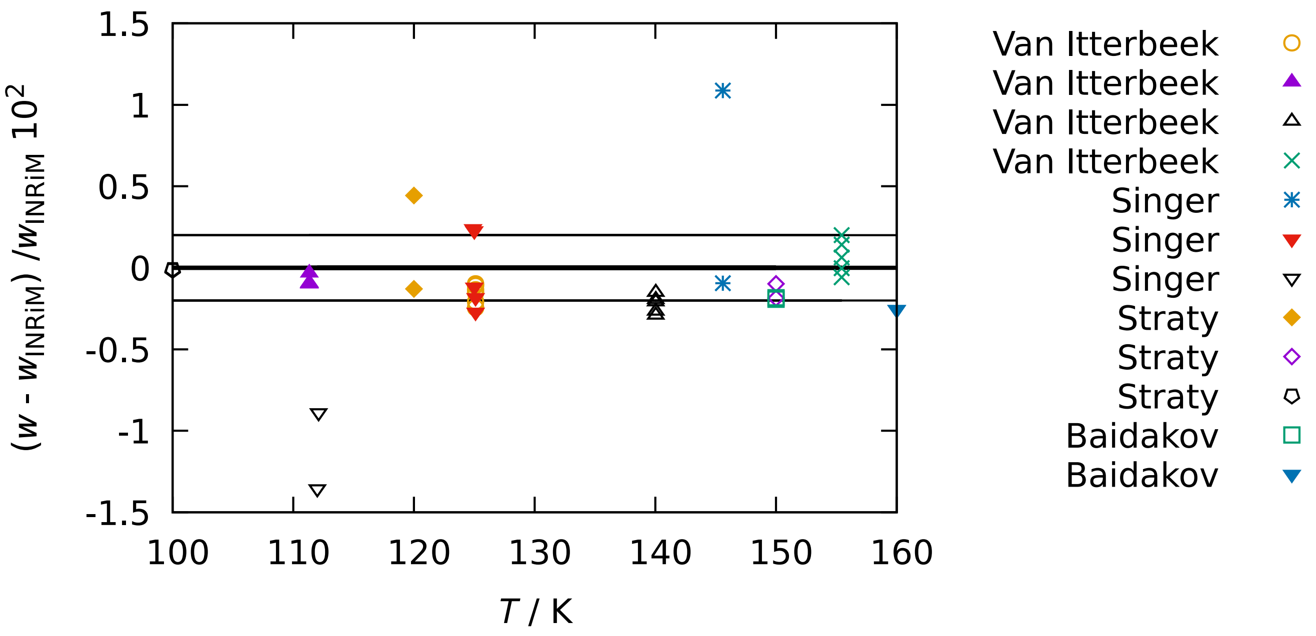
2. During measurements of mixtures, we found an **unexpected** mounting **problem** forcing us to **repeat** both methane and mixtures **measurements**

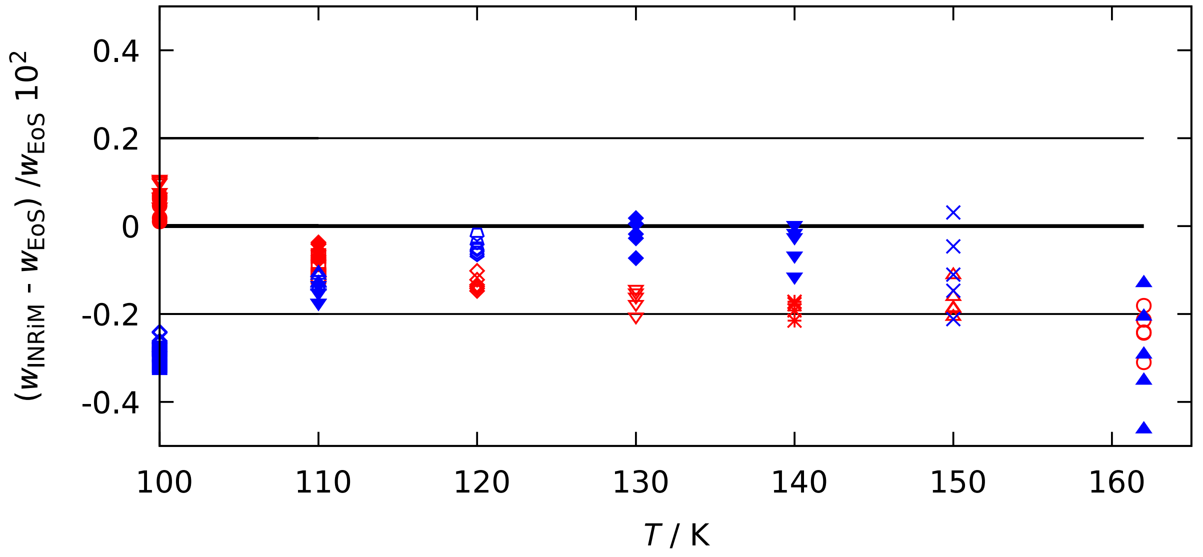
3. When problem has been solved, a **better agreement** with both literature measurements and equations of states has been found **for temperatures below 140 K**

4. **Repeatability and accuracy** of speed of sound measurements has been improved **by a factor of 2**. Now it is 0.2 % (*k*=2);

5. **Agreement** with Seitzmann and Wagner EoS, with a stated uncertainty of 0.3 %, and GERG 2008, with a stated uncertainty of 1.0 %, has been reported in the plot

6. Improved accuracy and traceability of the speed of sound **sensor** make it **suitable to verify ultrasonic flow meters calibration** and **improve** the accuracy of **equations of state**





Ultrasonic densimeter calibration in water

Ultrasonic densimeter is based on the measurement of the acoustic **impedance** of the **fluid** and that of a **buffer rod**.

By combining measured **speed of sound** of the fluid w_f and the **reflection coefficient** *R*, between the **fluid** and the **rod**, fluid density is determined by:

$$\rho_{\mathrm{f}} = \frac{1-R}{1+R}\frac{Z_{\mathrm{r}}(T,p)}{w_{\mathrm{f}}}$$

where Z_r is the **acoustic impedance** of the **buffer rod** that **does not depend on properties and flow rates** of the fluid. So that, it can be used to calibrate the sensor as a function of the temperature *T* and pressure *p*.

Obtained results:

1. Ultrasonic densimeter has been **calibrated** in the temperature range of 20 °C and 50 °C, with **fluid at rest**.
2. Calibration showed **residues** in the order of **0.1 %** but the **expected uncertainty** should be in the order of **0.2 %.**
3. A system for **mounting the ultrasonic densimeter on DN50** rigs has been realized an it will be used on the INRiM facility, with NEL support, at first.