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Development and preliminary investigation of a modular chamber for calibration of relative humidity instruments

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Abstract. In the scope of the project HUMEA – Expansion of European research capabilities in humidity measurement within the EURAMET EMPIR program, the modular chamber for calibration of relative humidity instruments was designed, manufactured and characterized. The modular chamber consists of arbitrary numbers of aluminum blocks each of which provides accommodation for the one relative humidity probe and also has the fittings for pressure and temperature probes as well as ports for gas sampling and/or supplying. The gas can be supplied from the dew/frost point generator or the larger climatic chamber. In the latter case, the airflow through the chamber can be enhanced by using an additional fan. The preliminary study was carried out to investigate the improvement in temperature uniformity using a new chamber in combination with two climatic chambers. The investigation results show significant improvement in temperature uniformity thus lowering the uncertainties of the calibration of relative humidity instruments.

1. Introduction

The measurement of relative humidity is complex and vitally important for many industrial, healthcare and meteorological applications. Therefore, the establishment of traceable humidity measurements while simultaneously assuring traceability and providing dissemination is an important activity of every national measurement institute (NMI). Ten European NMIs collaborate in the project HUMEA – Expansion of European research capabilities in humidity measurement financed in the scope of EURAMET EMPIR programme which kicked – off in 2016.

One of the project's objectives is to improve the calibration of relative humidity instruments by implementing the calibration chambers with a small working volume into the existing calibration setups. Reduction of the chamber working volume results in lower relative humidity gradients and shorter stabilization period, as already shown in similar systems [1-4]. Therefore, a new chamber concept was developed, comprising of modular blocks that can each accommodate one relative humidity probe (RHP). The number of blocks used as well as the carrier gas source can be adapted to the particular user needs. The gas can be supplied from the climatic chamber of larger working volume or the dew/frost point generator (DPG). In both cases, the modular chamber is placed inside the

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climatic chamber, which enables control of its temperature. If the modular chamber is supplied with the air from the climatic chamber, the airflow through it is achieved by a fan mounted at its exit. If required, the airflow can be controlled by fan rotation speed, using appropriate electronics. The higher airflow leads to lower temperature and humidity gradients due to more intensive air mixing inside the chamber. However, the negative side-effect lies in increased heat dissipation at the fan motor that should be then compensated by the climatic chamber. The small working volume of the modular chamber leads to a reduction in time required for the conditions inside the chamber working volume to stabilize after a change of temperature/dew-point temperature to a new value.

2. Chamber design

Figure 1 shows the modular chamber design consisting of three chamber blocks, two straight and one elbow with the 90° angle. By combining those two types of blocks, the user can assemble the modular chamber to accommodate the desired number of RHPs simultaneously. The chamber blocks are cube shaped with edges length of 80 mm. The air path cross-section is cylindrical with a diameter of 40 mm. The probes are positioned inside the chamber working volume using cylindrical adapters with an outer diameter of 60 mm. It can be seen that the chamber blocks accommodate only a portion of RHPs around the humidity sensor, allowing this way the reduction in the chamber working volume. Together with a bore for holding the RHPs, the adapters have four smaller bores with threads appropriate for mounting different fittings. Those fittings can be used for introducing additional instruments to the chamber working volume, for example, thermometers or pressure sensors, as well as for sampling or supplying the gas to the chamber. The block/adapter dimensions are appropriate for accommodating the cylindrical probes with a maximal diameter of 30 mm while larger probes would require larger chamber blocks and adapters. The bore for positioning of RHPs is drilled eccentrically to the adapter symmetry line. In this way, the RHPs can be positioned „left" and „right" from the central air streamline to avoid them being one behind the other in the airstream, by simple rotation of the adapter. The separate blocks are connected by using the cylindrical connectors with the glands for the O-ring seals. The RHP adapters use the same approach for the fitting and sealing, thus making the system relatively simple for assembly. The chamber blocks can be additionally tightened from the outside, using the thin metal plates.

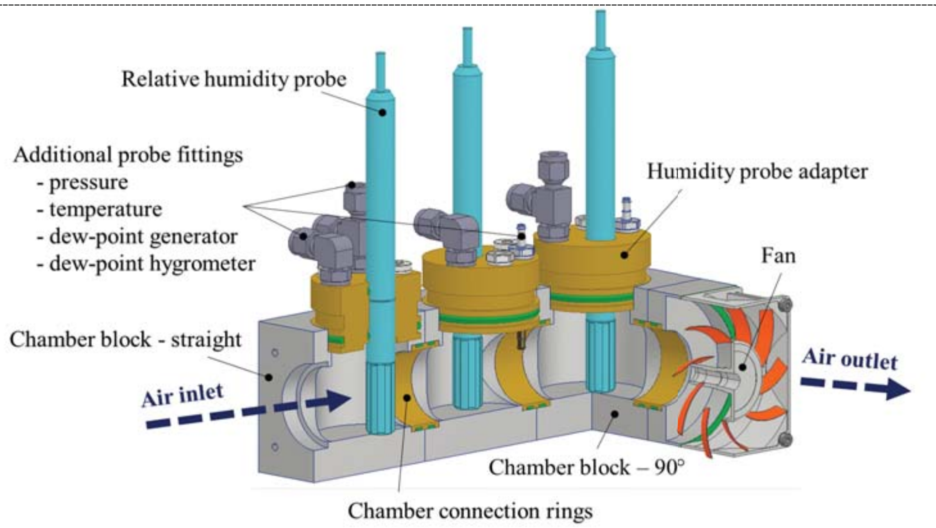

Figure 1. Modular chamber design.

While the assembly presented in Fig. 1 is appropriate for supplying with the air prepared in the climatic chamber, it can also be supplied from DPG. For this purpose, a fan should be removed, and custom-made tube fittings connected to the inlet and outlet of the chamber. Those fittings use the same type of sealing as for the blocks' connection. In order to account for concerns related to the self-heating of RHPs, when the chamber assembly is supplied from DPG having a low airflow, it is anticipated by this design to use a miniature chamber with small cross-section area between the probe and the chamber walls, as shown in Fig. 2. In this way the gas flow around the probe is increased significantly, lowering the self-heating effect.

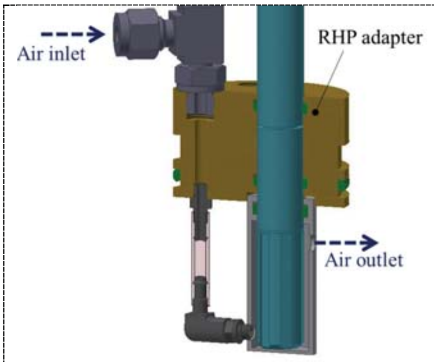

Figure 2. Additional miniature sub-chamber for reducing the RHPs self-heating effects when using the DPG as the gas supply. Air exits to the chamber volume and then flows out the chamber through one of the adapter bores.

During the development phase, several numerical simulations were performed to assess the influence of building material on temperature gradients inside the modular chamber. Based on the simulation results and experience with RH chambers, the aluminum was selected as optimal chamber material.

3. Preliminary performance investigation

Since the temperature uniformity (or inhomogeneity) corresponds, very often, to the highest uncertainty contribution in relative humidity (RH) calibration, a preliminary study was carried out by investigating its impact when the new chamber was used in combination with the climatic chambers.
The new chamber was assembled using three blocks and placed in the working volume of the larger climatic chamber, as shown in Fig. 3.

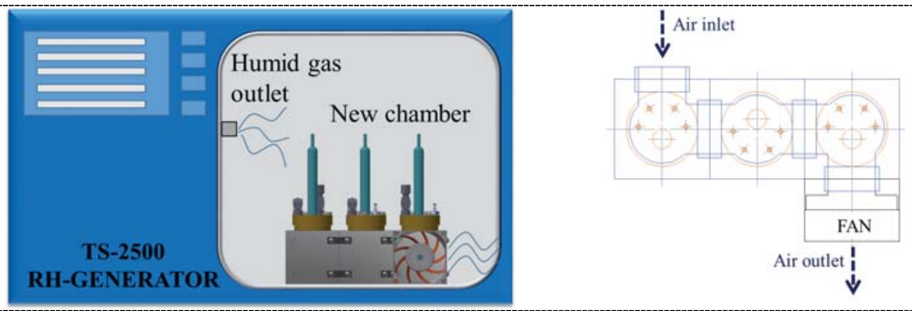

Figure 3. New chamber assembly and placement inside the large volume climatic chambers.

The surrounding air was feed to the new chamber by a suction fan placed downstream of the measuring channel, i.e., the new chamber working volume. In the absence of a real climatic chamber, this configuration was simulated using a TS2500 RH-generator with humid gas outlet open to generator test chamber. The measurements were performed at nominal temperatures of 1 °C, 35 °C and 70 °C, using a pair of 3-mm diameter Pt100 temperature sensors positioned inside each block and connected to a high-precision readout instruments (MBW T12 and Fluke 1586A). A pair of temperature sensors was placed in the air streamline, at the distance of few millimeters from the upper and the bottom chamber inner walls.

The results of the investigation are summarized in Fig. 4. The temperature uniformity was calculated as the greatest difference between any two sensors placed in the new chamber assembly. The related uncertainty ($u_{\mathrm{T\_unif}}$) was calculated assuming a uniform probability distribution function. The diagram on the left shows the investigation results obtained using new chamber (red points) in relation to the performance of the Thunder Scientific TS2500 RH generator. The similar investigation was also performed with new chamber placed inside larger thermostated test chamber Votsch VT7011. In the new setup, the air was supplied to the new chamber from the RH generator, and the fan was therefore removed. Nevertheless, the preliminary results obtained with the new setup were similar to those obtained with the TS-2500 RH generator. It can be observed that standard uncertainties achieved by using the new chamber are always much lower than the corresponding uncertainties due to temperature uniformity of the TS2500 and VT7011 test chambers considering for the latter the whole chamber volume and a reduced volume (a cube with a side of 20 cm).

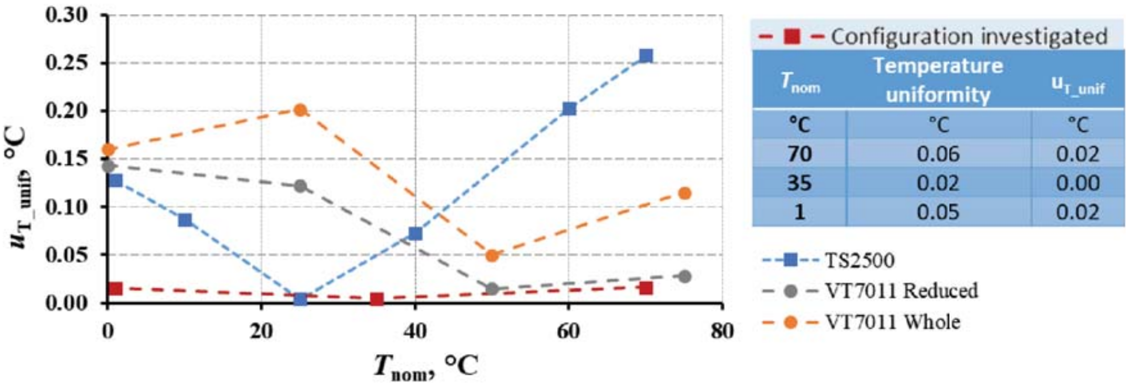

Figure 4. The plot of the experimental data compared with the performance.

When expressed as RH at the nominal temperatures, the uncertainty due to temperature uniformity always corresponds to a value lower or equal to 0.06 %rh at a nominal RH of 50 %rh.
The temporal stability of the air temperature monitored during 30 min was always lower than 5 mK.

4. Conclusion

This paper describes the design, manufacture and preliminary characterization of the modular chamber for calibration of RH instruments. A preliminary investigation was performed using three chamber blocks in combination with two different thermostated chambers and two different sources of humid air. As shown by the results, the use of a new chamber for RH calibration enabled improvement in calibration by increasing the temperature uniformity. Further performance investigations are planned, including intercomparison of RH realizations among several European NMIs, using this chamber design.

Acknowledgments
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5. References

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