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NEW PRIMARY LOW-RANGE DEW-POINT GENERATOR AT LPM

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Abstract − This paper describes the new primary low-range dew-point generator at LPM developed in cooperation with MIKES through EUROMET project no.912. The generator is designed for primary realisation of the dew-point temperature scale from -70 °C to +5 °C. The principle and the design of the generator are described in detail and schematically depicted. Results of the preliminary efficiency tests of it's saturator show that it is efficient enough for a primary realisation of the dew-point temperature scale. Standard uncertainties due to the non-ideal saturation efficiency are estimated to be 0.02 °C.

Keywords: humidity, saturator, dew-point generator

1. INTRODUCTION

The metrological system in Croatia is designed in such way that Croatian State Office for Metrology (DZM) presently has the role of the Croatian National Measurement Institute (HMI). The DZM-HMI has distributed architecture: while coordinating, supporting and internationally representing all national standards, the DZM itself maintains at present, directly only standards for mass and density. National standard laboratories for other physical quantities are located in various institutes and universities with traditionally related metrological activity and bound by contract to DZM-HMI.

In case of Laboratory for Process Measurement (LPM) at the Faculty of Mechanical Engineering and Naval Architecture - University of Zagreb these are national standards for temperature, pressure and humidity. The calibration ranges and uncertainty levels of these standards is adjusted to the available resources and to the calibration needs in Republic of Croatia.

To respond to the increasing demand for traceable calibration of hygrometers in Croatia, which was partly spurred by widespread certification of quality assurance systems, several hygrometer calibration facilities have been developed in the last ten years at LPM.

The first facility was completed in 1997 [1]. It was based on two temperature re-circulating humidity generator intended for operation in 5°C to 60°C dew point range. It featured a very large test chamber designed to accommodate not only dew-point hygrometers, but also relative humidity sensors and even chart recorders without remote sensors.

In 1997 a second humidity generator, based on one-pressure, two-temperature principle, was completed [2,3]. It had a wider (-15°C to 60°C) dew point range as well as wider (-15°C to 90°C) test chamber operating range, better stability and better response to stepwise temperature changes and lower overall uncertainty. It´s test chamber, which was submerged in liquid bath, could accommodate only relative humidity probes used remotely from monitoring instruments. The generator was mainly intended to operate in the re-circulating mode at nearly atmospheric pressure with possible use in the open circuit mode incorporated in the design.

It was this generator that LPM used to take part in EUROMET project no. 621, linking LPM dew point scale realisation to T-K6 reference values with uncertainties of about 100mK at dew-point temperature of -10°C and about 50mK at dew-point of 20°C (k=1).

In order to extend the lower end of the dew-point range and to improve the uncertainties of the humidity scale realisation at LPM, the new primary low-range dew-point generator was developed in cooperation with MIKES starting in year 2006 through EUROMET project no.912. The generator is designed for primary realisation of the dew-point temperature scale from -70 °C to +5 °C.

2. PRINCIPLE AND DESIGN

The system depicted in Fig. 1 was designed as the single pressure – single pass dew-point generator, i.e. sample gas passes through a saturator only once. The saturator was designed to be used with air as the sample gas but also other gases can be used.

MIKES designed and constructed the whole saturator to be implemented in a dew-point calibration system at LPM. The LPM took care of purchasing and adapting liquid bath, of implementing the temperature and pressure measurement equipment appropriate for use in the system, gas preparation and flow control system as well as the computer based system for automated data acquisition.

Due to difficulties in finding subcontractors for mechanical manufacturing, the saturator construction phase of the project was delayed and the Low Range Saturator was ready for the initial tests in autumn 2007. As a part of the project, the saturator was initially tested at MIKES before transporting to LPM.

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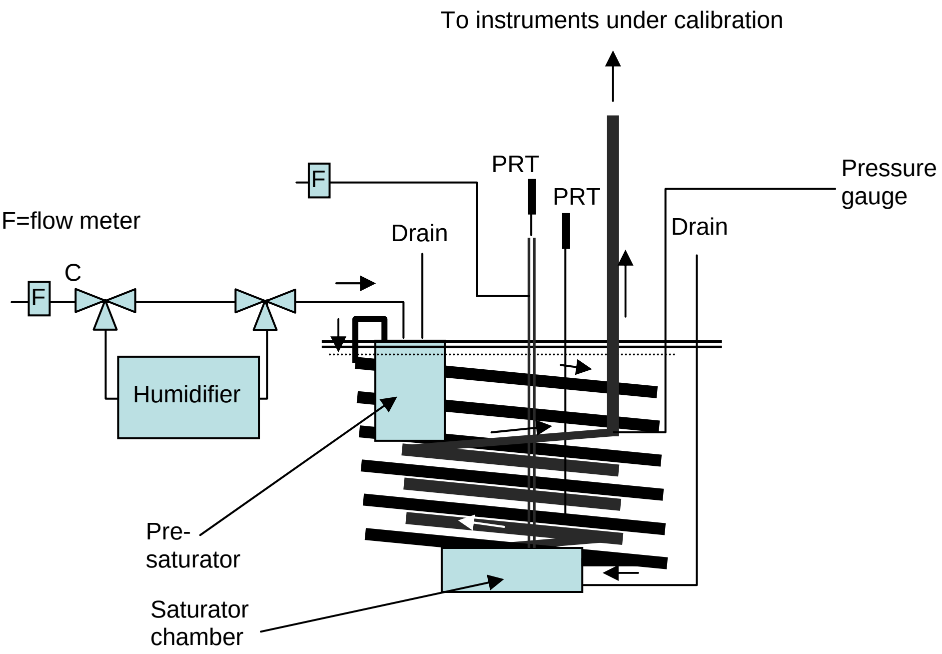

Fig. 1. Schematic diagram of the low-range saturator (LRS).

The schematic diagram and the principle of operation of the low-range saturator (LRS) is depicted in Fig.1. The dry filtered air enters humidifier where it is humidified to a dew-point temperature clearly above the saturator temperature. The humidifier consists of a by-pass tube and a water container with an ON/OFF valve. When humidification is needed (i.e. when saturator temperature is close to the upper limit of the range), the valve is opened and a part of the entering air flows through the container is the mixed with the by-passed part of the air.

Then, in the pre-saturator the air is dried (or humidified depending on the range) to a dew-point temperature slightly above the saturator temperature. The pre-saturator is a vertical vessel partly immersed in the bath liquid. Both inlet and outlet are in the cover of the vessel. Ice (or water) fills the pre-saturator only partly.

In the coiled-tube heat exchanger the air is forced to thermal equilibrium with the saturator bath. This causes a small amount of water vapour condensation in the coil. After passing the coil the dew-point temperature of air is about the same as the saturator.

Finally complete saturation is ensured by forcing the air in direct contact with water or ice surface in the saturator chamber. The saturation chamber is a horizontal vessel in which ice (or water) covers the bottom.

Air is then drawn off from the chamber through a short exchanger coil to prevent any condensation in the outlet tube in the region near bath liquid surface or above (during water freezing in the chamber). After the saturation chamber the dew-point temperature decreases only due to the air pressure drop.

The saturator temperature is measured with two platinum resistance thermometers (PRTs): One is outside the saturator immersed in the bath and the other is placed inside the saturator being in direct contact with water or ice. The latter one can be replaced by another PRT in the bath but then no information on the freezing of water in the saturator chamber is available. When working in the range -10 °C to 0 °C, this information would be very useful. If located inside, however, the PRT is inserted through a tube allowing easy calibration of the PRT. Air flow outwards through the tube minimizes the conductive heat flow along the PRT.

The outlet tube is slightly heated to avoid any condensation in it while rising the bath temperature.

The saturator chamber can be easily drained without opening any tubing. The pre-saturator can be easily filled through a separate access tube.

3. TESTING OF THE SATURATOR EFFICIENCY

The tests were performed at MIKES to investigate how close is the performance of the saturator to the performance of an ideal saturator. From the result of the tests uncertainty estimations for saturator efficiency and non-ideality were made.

The saturator efficiency was studied by monitoring the saturator output with a high quality chilled mirror hygrometer while varying the inlet air flow rate and dew-point temperature (the flow rate through the hygrometer was kept constant). Also the efficiency of the humidifiers and pre-saturators was studied. The non-ideality tests covered the following:

- temperature difference between the saturator bath and the air inside the saturator
- pressure drop in the outlet tube
- minimum flow rate
- comparison with the MIKES dew-point temperature standards through calibrated chilled mirror hygrometer

The precision chilled mirror dew-point meter used was the MBW 373LX. It was connected to the LRS outlet and dry air was supplied through the pre-saturator. The MBW was used for measuring the outlet dew-point temperature. Another outlet tube line was connected in parallel with the MBW hygrometer. The air flow rate through this tube was varied while the flow rate through the MBW was kept constant. Internally polished tubes were used for the connecting the MBW to the LRS.

For determination of the dew-point temperature a thermometer was inserted in the saturator for monitoring the water/ice temperature in the saturation chamber. Another thermometer was measuring the bath liquid temperature close the saturator. Also, the pre-saturator temperature was measured using another thermometer.

The tests were carried out at the saturator temperatures of -70 °C, -5 °C and +10 °C.

No flow dependence could be identified (see Fig. 2) except at the highest point (+10 °C). Slight flow dependence at this point was probably due to reduced humidifying efficiency in the pre-saturator.

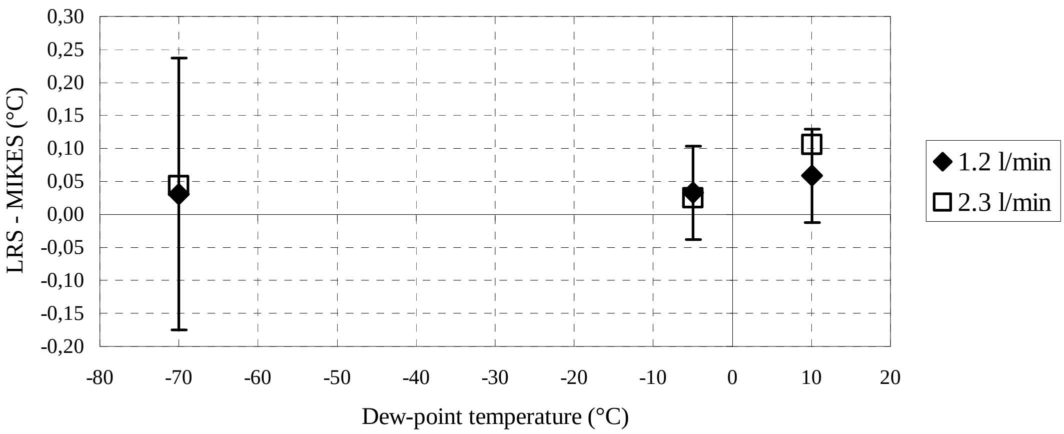

Fig. 2. Difference between the dew-point temperatures determined from the LRS saturator temperature & pressure and the MBW 373 LX indication (applying MIKES calibration results). Error bars show the expanded uncertainty (k=2) including uncertainty components related to the hygrometer and the uncertainty of temperature and pressure measurements.

Table 1. summarizes the determined difference between the LRS and the MIKES reference shown in Fig.1. The results cannot directly be used in the validation of the LRS set-up in Croatia because the different thermal conditions might affect the results.

Table 1. The results of the comparison of the dew-point temperature determination with the LRS and the MIKES reference hygrometer. (Difference = LRS – MIKES)

Dew-point temperature (°C)	Difference (°C)	Uncertainty (k=2)
-69.98	0.04	0.21
-4.95	0.03	0.07
10.07	0.08	0.07

To assess the phase transition period in the saturation chamber the temperature difference between the PRT in the saturation chamber and the PRT in the bath liquid was monitored. This temperature difference was also studied for investigating if the thermal equilibrium is achieved in the saturator (and thus thermal gradients in the saturator). A summary of this study is given graphically in Fig. 3. It shows that at each point the temperature difference was less than 0.02 °C once a stable bath temperature was achieved.

It was estimated that the pressure difference between the saturation chamber and the saturator outlet is less than 10 Pa at flow rates below 3 l/min.

The efficiency of the pre-saturator was also studied by measuring the dew-point temperature of air exiting the pre-saturator with different flow rates between 0.5 l/min to 2.5 l/min. First measurement set was carried out with no humidification before the pre-saturator. The methodology and the results obtained are beyond the scope of this paper and will be reported in different publication. However, they indicate that the humidification is needed when operating at bath temperatures above -15 °C.

It was concluded that the saturator efficiency of the LRS is sufficient when operating in the saturator temperature range -70 °C to +5 °C with flow rates (through the saturator) 1 l/min to 2.5 l/min. With a flow rate of 1 l/min, the efficiency is sufficient up to +10 °C.

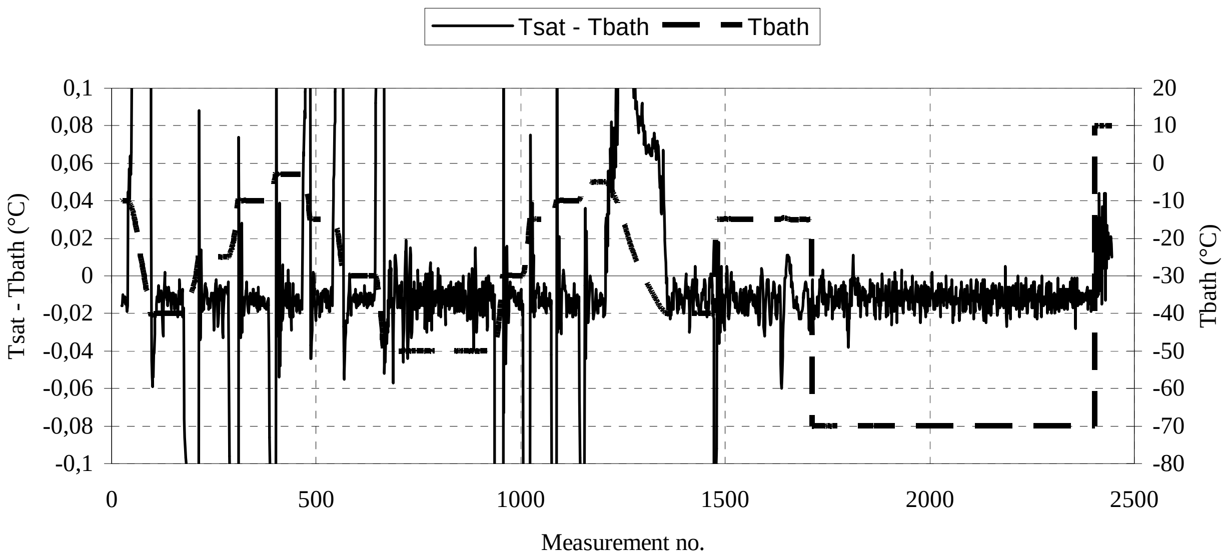

Fig. 3. Difference between the temperatures measured inside the LRS saturator and in the liquid bath close to the saturator, respectively. The corresponding bath temperature is shown with the dashed line. Its scale is shown on the secondary y-axis on the right.

The estimated standard uncertainty related to the saturator efficiency determination was estimated to be 0.022 °C.

The plans for future work include the experiments to quantify the possible effects of different thermal conditions in the set-up at LPM in terms of changes of the saturation efficiency at different flow-rates. Also the efficiency of the humidifiers and pre-saturators is planned to be re-evaluated in situ.

4. CONCLUSIONS

In order to extend the lower end of the dew-point range and to improve the uncertainties of the humidity scale realisation at LPM the new primary low-range dew-point generator was developed in cooperation with MIKES starting in year 2006 through EUROMET project no.912. It is based in the single pressure – single pass principle and designed for primary realisation of the dew-point temperature scale from -70 °C to +5 °C.

Results of the efficiency tests of its saturator show that it is efficient enough for a primary realisation of the dew-point temperature scale in the mentioned range. Standard uncertainties due to the non-ideal saturation efficiency are estimated to be 0.02 °C.

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