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THE INFLUENCE OF ASPIRATED PSYCHROMETER ON CALIBRATION PROCESS

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Abstract − In the proposed paper the influence of motor aspirated psychrometer on calibration process is investigated. Proper humidity measurement with psychrometer requires sample gas stream of sufficient velocity in order to achieve accurate measurements. For this reason modern psychrometer typically have integrated aspiration motor to assure such gas stream over the thermometer, which is enclosed by a wet wick (wet thermometer). The wick has to be maintained in a wet condition, which causes evaporation and consequently the unwanted humidification of the air being measured, especially in a closed humidity chamber or humidity generator. Different psychrometers were tested in a humidity test chamber in order to estimate the level of such humidification. The results are summarised in the paper. In addition, special considerations are addressed regarding the calibration of motor aspirated psychrometer in closed calibration environment.

Keywords: psychrometer, humidity, calibration

1. INTRODUCTION

Psychrometry is old and still popular method for measuring humidity, primarily due to its simplicity and inherent low cost. Generally speaking the measuring principle is fundamental, providing that it is properly operated during the measurement. In order to achieve accurate and reliable measurement, which in case of well-maintained psychrometer would mean uncertainty in order of 1-2 %r.h., some precautions have to be taken into account. Namely, both thermometers (dry and wet) which are part of the psychrometer have to be properly selected and calibrated. Avoiding so may lead to worst case scenario, when both errors combine into error in the temperature depression of psychrometer, consequently resulting in an appreciable total relative humidity ϕ error [1]. In the same manner pressure affect of the measured gas, thermal radiation and some other potential causes of errors have to be considered [2], [3].

As mentioned, psychrometer consists of two thermometers, one dry and the other enclosed by the wet wick. Constant flow of sample air needs to be drawn over the wet thermometer, causing its temperature to decrease and from the temperature diffe rence the relative humidity ϕ is calculated. In modern psychrometers constant air flow is controlled by in-built ventilator.

One of the errors of meas urement when calibrating the motor aspirated psychrometer in humidity chamber arises from the fact that sample gas stream which flows over the wet thermometer is humidified by the evaporation from this wet thermometer. Consequently, the measured air inside the chamber is humidified, causing the relative (and absolute) humidity ϕ to increase [4].

The purpose of this work is to find out the extent of this influence and to investigate the possibilities of calibration of psychrometers in (closed) humidity generators and humidity chambers. Experiments were performed in Laboratory of Metrology and Quality LMK, which is accredited for temperature and humidity calibrations according to ISO 17025 [5].

2. MEASURING SYSTEM

Measurements were performed in a humidity generator Thunder Scientific 2500ST-LT with test chamber dimensions of 381 mm × 381 mm × 305 mm (volume of approx. 45 l). The generator is so called two-pressure humidity generator. Temperature and humidity profile of the generator was evaluated accordi ng to laboratory procedure, which assures tracable results. The procedure and results are kept in laboratory archives.

Absolute humidity (dew-point temperature) of the inner air was measured with reference dew-point meter MBW 373H, which is tracable to international standards. Sampling tube is made of stainless-steel and it was put in the middle of the generator calibration space. It is assumed that differences in absolute hum idity over the inner space are insignificant, therefore the sampling tube can be placed anywhere inside the space. Th e uncertainty of measured dew-point was ± 0,22 °C. Corrections, obtained from the certificate were taken into account.

Temperature was measured with an Omega platinum-resistant thermometer PRT, which was calibrated in LMK temperature secondary laboratory. The uncertainty of the temperature sensor was is in the range from –75 °C to 200 °C ±0,01 °C. Corrections, obtained from the certificate were taken into account.

Psychrometers that were calibrated are commercially available measuring instruments of different types.

Psychrometer' sensor (two thermometers and ventilator) inside the generator was connected to the displaying device and ventilator switch that were placed outside the generator. The ventilator switch was used to determine the level of humidifiaction of the inner air. Measuring system is presented in Fig.1.

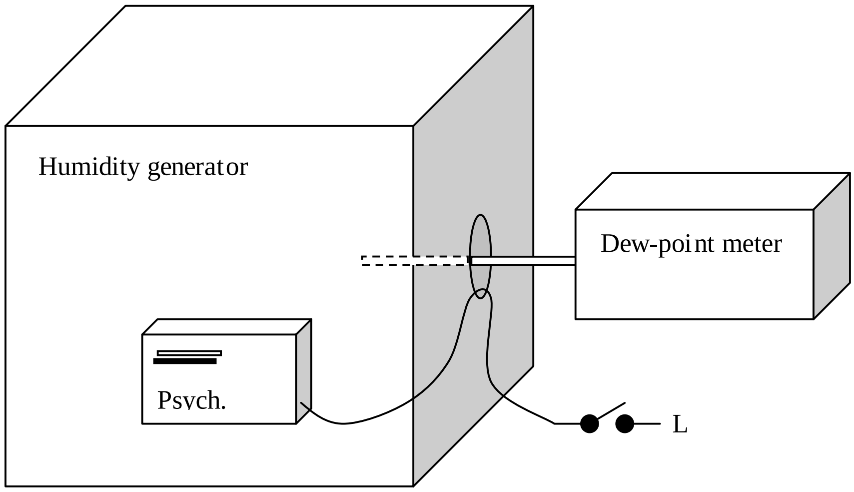

Fig.1. Measuring system: calibration of psychrometer; Humidity is measured with reference dew-point meter

3. MEASUREMENTS

Psychrometers were calibrated at different relative humidity of the air and at different air-flow of the generator. The temperature of the generated air was 24 °C. It was expected that with higher air-flow of the generator, the level of unwanted humidification (in terms of relative humidity) would decrease, since the humidified air-flow due to the psychrometer ventilator represent smaller portion in total air-flow.

At each relative humidity set, the psychrometer was first turned off in order to wait for relative humidity ϕ in generator to stabilise. After stabilising, the ventilation on the psychrometer was turned on, which lead the relative humidity of the generator to become stable at higher value. After this second stable state, the air-flow of the generator was decreased, which caused the ϕ to increase again.

The humidification was performed at 5 points of relative humidity ϕ between 10 %r.h. to 90 %r.h and at each ϕ generator air-flow was set between 5 l/min and 20 l/min. The example of measurement of change in ϕ can be seen in Fig.2.

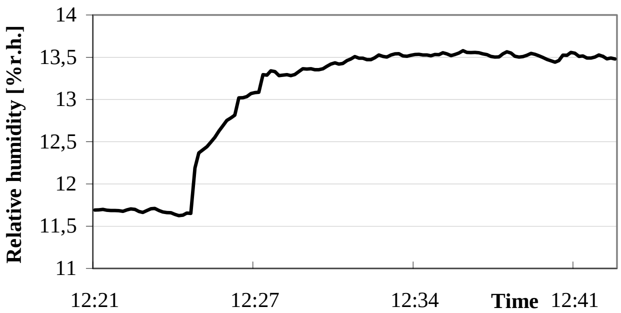

Fig.2. The change in ϕ when psychrometer's ventilation is turned on; generator set values: 10 %r.h., 24 °C, 20 l/min

It can be seen from Fig.2 that at generator temperature 24 °C and air-flow set at 20 l/min, approx. 2 %r.h. change in ϕ was detected after turning the ventilation of the psychrometer on. Change in ϕ was calculated from temperature of the air (see Fig.3) and dew/frost-point change ΔT_{dp}=+1,76 °C being measured by the reference dew-point meter (see Fig.4). Table I shows the change in dew-point measured over complete calibration range of relative humidity after turning the psychrometer's ventilation on.

TABLE I. Dew-point change ΔT_{dp} and rel. humidity change $\Delta\phi$ measured over complete calibration range of relative humidity after turning the ventilation on; the air-flow of the generator was set to 20 l/min and gen. temperature to 24 °C

ϕ [%r.h.]	**ΔT_{dp} [°C]**	**$\Delta\phi$ [%r.h.]**
10	+1,76	+1,8
30	+0,79	+1,7
50	+0,32	+1,1
70	+0,20	+0,7
90	+0,09	+0,03

As it can be seen from the Table I the difference in dew-point as well as the difference in relative humidity decreases as the relative humidity set in generator increases. Furthermore, it can be concluded, that there is consistency between ΔT_{dp} and $\Delta\phi$, which leads us to believe, that the psychrometer causes only absolute humidity to change, leaving temperature more or less the same. This also means, that self-heating of the ventilator's motor does not have significant negative impact on temperature of generated air. Temperature measured by reference thermometer for the same time period as in Fig.2 is shown in Fig.3.

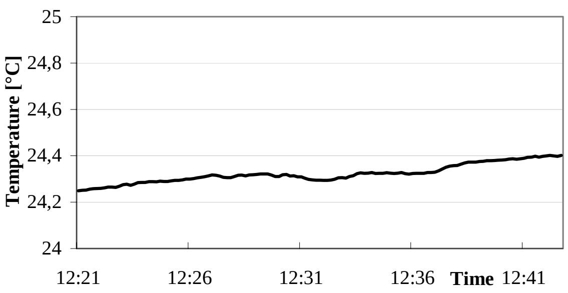

Fig.3. Temperature measured by reference thermometer for the same time period as in Fig.2

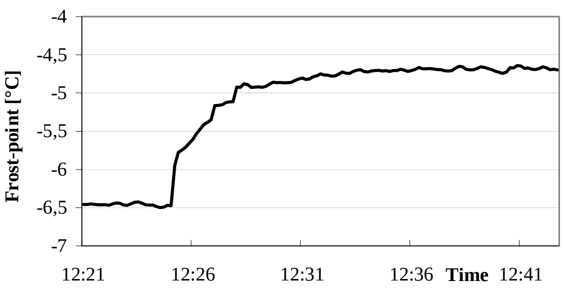

Fig.4. Frost-point measured by reference dew-point meter for the same time period as in Fig.2

Standard deviation of temperature in the time period of 7 hours was 0,13 °C.

As it was expected, the change in generator air-flow did have an influence on the relative humidity. Results did also confirm, that decrease in air-flow caused significant increase in relative humidity. In Fig.5. $\Delta\phi$ is plotted when the air-flow decreases from 20 l/min to 5 l/min at 30 %r.h, ventilation on. Maximum changes of relative humidity due to decrease of generator air-flow are summarised in Table II.

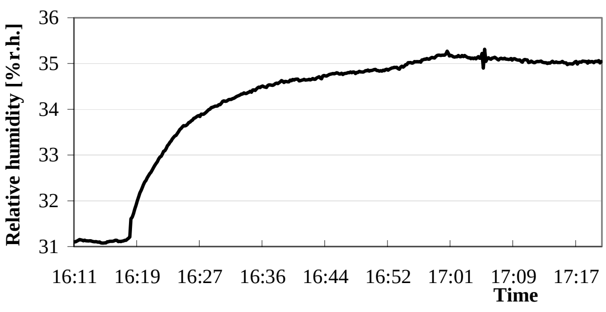

Fig.5. Relative humidity change due to decrease of air-flow of the generator from 20 l/min to 5 l/min

It can be concluded from Table II, that actual ϕ, set by generator, is highly dependent on the level of air-flow of the generator. However, the readouts of psychrometers followed the actual set ϕ, which means, that the procedure for calibration of aspirated psychrometers could be adequate. Furthermore, it can be seen from the calibration certificate that for the best psychrometer the difference in ϕ between that psychrometer and reference dew-point meter in a complete range of ϕ (from 10 %r.h. to 90 %r.h.) did not exceed 0,6 %r.h.. In addition to that the expanded uncertainty due to non-linearity was 0,2 %r.h.

TABLE II. Rel. humidity change $\Delta\phi$ measured over complete calibration range of relative humidity after decreasing gen.air-flow from 20 l/min to 5 l/min; gen. temperature was set to 24 °C

ϕ [%r.h.]	ΔT_{dp} [°C]	$\Delta\phi$ [%r.h.]
10	+3,50	+4,5
30	+1,77	+4,1
50	+0,88	+2,8
70	+0,20	+0,7
90	-0,09	-0,6

5. CONCLUSIONS

Motor aspirated psychrometers can be relatively complex instruments and can be used as fundamental measuring principle. As such, their back influence on the environment is not negligible, especially if they are placed in smaller area such as calibration test chambers. It has been shown that the aspiration of psychrometer affects only the absolute humidity of the test air, leaving its temperature deviations small and insignificant. Nevertheless, the differences between readout of the psychrometer and reference dew-point meter for all relative humidities and different air-flows are small and consistent. Expanded uncertainty due to non-linearity was relatively small, as it was expected for a fundamental measurement principle.

It has to be stressed out, that all relative humidity changes that were presented in this article apply only for calibration environments, where relative humidity control is implemented indirectly – ϕ is measured indirectly by measuring some other quantity, e.g. pressure like in mentioned two-pressure humidity generator.

The proposed measurement system could be used as a proper calibration system for calibrating aspirated psychrometers in closed humidity environment.

REFERENCES

[1] P.R. Wiederhold, "Water vapour measurement: methods and instrumentation", *Marcel Dekker, Inc.*, New York, USA, 1997.

[2] G.J.W.Visscher, K.Schurer, "The psychrometer coefficient: calculation versus calibration", *Proceedings The 3rd International Symposium on Humidity and Moisture*, NPL, UK, 1998

[3] M.Megharfi, E.Devin, D.Jouin "Calibration and Using Methods of Mechanical Psychrometers and Associated Uncertainties", *Proceedings The 4th International Symposium on Humidity and Moisture*, Taipei, Taiwan, R.O.C. 2002

[4] "A Guide to the Measurement of Humidity", *The Institute of Measurement and Control*, London, UK, 1996

[5] J.Bojkovski, I.Pušnik, J.Drnovšek, "Quality Manual, Laboratory of Metrology and Quality", Procedure for evaluation of climatic chambers, *University of Ljubljana*, Ljubljana, 1999

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