Measurement 133 (2019) 162–167

Contents lists available at ScienceDirect

Measurement

journal homepage: www.elsevier.com/locate/measurement

Improved method for pressure measurement in saturation chamber of primary dew/frost point generators

Danijel Sestan, Lovorka Grgec-Bermanec, Davor Zvizdic

Croatian Metrology Institute/Faculty of Mechanical Engineering and Naval Architecture, Laboratory for Process Measurement (HMI/FSB-LPM), Ivana Lucica 5, 10000 Zagreb, Croatia

ARTICLE INFO

Article history:
Received 7 May 2018
Received in revised form 16 September 2018
Accepted 17 September 2018
Available online 27 September 2018

Keywords:
Humidity generators
Saturation pressure
Primary dew/frost-point realization

ABSTRACT

This paper describes two methods for measurement of air pressure inside the saturation chambers of two primary dew/frost point generators, used as national humidity standards at Laboratory for process measurement (HMI/FSB-LPM) in Croatia. Together, the generators cover the dew/frost point temperature range from −70 °C to + 65 °C. Low range generator operates at air temperatures between −70 °C and 5 °C, while high range covers the range between 1 °C and 65 °C. The saturation pressures considered are in the range between atmospheric and 1060 hPa, at the air flow rates between 1.0 L min^{-1} and 2.5 L min^{-1}.

The dew/frost point of the saturated air depends strongly on the saturation pressure, making improvement in this kind of measurements of great importance for humidity realizations.

In the old method, the precise digital barometer is used for determination of saturated air pressure inside the saturation chamber. The barometer is traceable to the pressure balance, which is used as a national standard for pressure in Croatia. In the new method, the pressure was maintained directly by the primary pressure balance, achieving this way the significant improvement of related measurement uncertainties for both, pressure measurement and the dew/frost point realization. The paper will give a detailed description of both measurement setups as well as corresponding measurement uncertainty analyses. During the experiments it was also observed that in the second setup, balance stabilized the pressure oscillations as well as oscillations of the dew-point temperature measured by the chilled mirror hygrometer under calibration, making indirect improvement of related measurement uncertainties.

1. Introduction

The metrological system in Croatia consists of Croatian Measurement Institute (HMI) that has distributed architecture, coordinating, supporting, and representing all national standards on an international level. The national standards for temperature, pressure and humidity are located at the Laboratory for Process Measurement (LPM) which is part of the Faculty of Mechanical Engineering and Naval Architecture (FSB) at the University of Zagreb.

In 2009, HMI/FSB-LPM in cooperation with national metrology institute of Finland (MIKES) designed the primary low- and high-range dew-point saturators in order to extend the existing dew-point range and to improve the uncertainties of the humidity scale realization in Croatia. The low-range saturator is used in the dew/frost-point temperature range between 70 °C and 5 °C, while the high-range saturator covers the range from 1 °C to 60 °C. While primary generators among national institutes use several basic operating principles [1–7], HMI/FSB-LPM adopted design of a single-pressure, single-pass dew-point generation for both the saturators. In such a system, sample gas passes through a saturator only once, and its dew-point temperature is controlled only by controlling the temperature of the liquid bath which accommodates the saturator. Although the saturators were initially designed for air as the sample gas, in this work the nitrogen supplied from the cylinder was also used.

To put the saturators in operation, the HMI/FSB-LPM implemented the temperature, and pressure measurement equipment to the system developed the gas preparation and flow control and made the computer-based automated data acquisition software.

The measurement of pressure is performed inside the saturation chamber and at the sensor of the instrument being calibrated. Since the saturated air flows through the tubes connecting the saturator and the instrument under calibration, a certain pressure drop occurs. The difference in pressures inside the saturation chamber and at the calibrated instrument reflects on the difference in corresponding dew/frost point temperatures, requiring a correc-

E-mail address: lovorka.grgec@fsb.hr (L. Grgec-Bermanec)

https://doi.org/10.1016/j.measurement.2018.09.051
0263-2241/

tion to be made. Initially, the pressure measurements were performed using the digital barometer. In this work, the high accuracy pressure balance was added to the measurement system, improving the pressure stability inside the saturator and at the calibrated hygrometer. In this way, uncertainties of pressure related dew/frost point corrections are decreased.

2. Measurement setup and procedure

The measurement system consists of low-range saturator immersed in a thermostated ethanol bath, pressure measurement equipment, saturation temperature measurement equipment, inlet gas preparation system (controlling the flow-rate, frost-point, pressure, filtering) and hygrometer under calibration, as shown in Fig. 1.

The details containing operating principle, design and performance of the saturator are given in [8,9].

During all the measurements, the pressures inside the saturation chamber and at the hygrometer sensor were monitored using a precise digital barometer, traceable to the Croatian pressure standard. The barometer was connected to the personal computer using RS232 interface, enabling continuous recording of its readings at 2 s interval.

The first set of measurements was performed with a pressure balance connected to the saturation chamber. For those measurements, 5 N purity nitrogen was used as a sample gas. Measurements were performed with gas flow-rates of 1 L/min and 2.5 L/min through the saturation chamber. Low pressure below the pressure balance bell was maintained at the level less than 0.0012 hPa, using a combination of membrane and turbo molecular vacuum pumps. Precise vacuum meter was used for this measurement. During the measurements with pressure balance connected to the system, the piston was moving vertically with the changes of pressure at the system inlet. Therefore, several careful manual adjustments of the precise pressure regulators were required within the measurement period of one hour. The piston was allowed to move in the range from – 2 mm to 2 mm in relation to its central position.

In the second set of measurements, pressure balance was disconnected from the system leaving all other components remained in the same configuration. Measurements were repeated immediately with the same gas flow-rates through the saturation chamber. Comparison of the results obtained this way enables indication of the improvements achieved by using the pressure balance in the system.

The third set of measurements was performed with saturator being supplied with compressed air, as it is the case during the everyday use of the generator. During these measurements, the pressure balance remained disconnected from the system.

Together with pressure, following quantities were monitored and recorded during all the experiments:

1. Saturation temperature,
2. Dew/frost point temperature of the gas, measured by the hygrometer under test,
3. Temperature of the piston-cylinder assembly,
4. Gas flow-rates through the saturation chamber, bypass, and hygrometer under test.

The saturation temperature was monitored in order to verify that pressure measurements were conducted under the same conditions, during all the experiments. Two 25.5 Ohm standard platinum resistance thermometers (SPRTs) were used for that purpose. SPRTs were immersed into the calibration bath liquid, placed very close to the saturation chamber. The SPRTs were connected to the precise resistance bridge through the ten channels scanner. In combination with 100 Ohm Wilkins type standard resistor, the bridge has a resolution of 1 ppm, corresponding to temperature equivalent of 1 mK. Temperature readings were recorded using a personal computer with the 60 s interval. During all the measurements the saturation temperature was maintained in the range between 5.10 °C and 5.33 °C.

Precise chilled mirror hygrometer was used for the measurement of dew/frost point temperature of the gas exiting the generator, together with the corresponding flow rate. Those measurements were performed in order to determine if the stabilities of the flow-rate and dew/frost point temperature were improved with the pressure balance connected to the system. To achieve the dew-point temperature measurements of highest precision, the 100 Ohm platinum resistance thermometer, embedded into the hygrometer mirror, was connected to the resistance bridge described above. For the measurements with the gas flow-rate of 1 L/min through the saturation chamber, flow-rate through the hygrometer was kept at 0.5 L/min. For the measurements with 2.5 L/min through the chamber, hygrometer flow-rate was set to 1 L/min. Different flow rates through the saturation chamber and hygrometer under test were achieved by using bypass line, whose flow-rate was adjusted and monitored by rotameter.

In everyday operation, saturator is supplied with room air which is compressed using an oil-free compressor. To decrease pressure oscillations due to charging and discharging the proprietary air tank of the compressor assembly, an additional, the much larger tank is installed downstream from the compressor. Sample

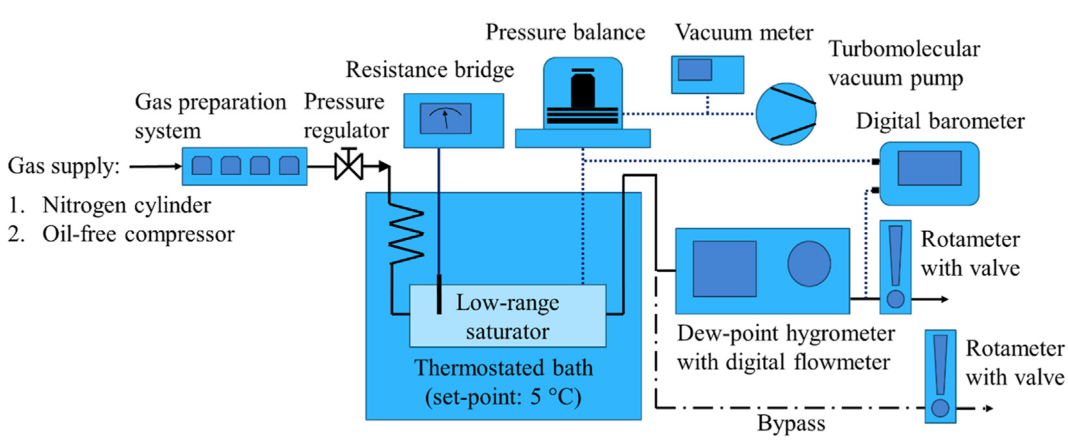

Fig. 1. Measurement setup.