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Testing the reliability of humidity generator through measurements traceable to calibration standards

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ABSTRACT

This paper describes the metrological performance of NIS two-pressure humidity generator for testing the generator reliability after working for 13 years. In this work, humidity & temperature are observed and the measuring system is prepared for the calibration of humidity & temperature measurements. In the generator test chamber, relative humidity measurements are performed between 10% and 95% at fixed temperature of 25 °C and temperature measurements are performed between 10 °C and 65 °C at fixed humidity of 50% relative humidity.

Results showed that the uniformity value is between ± 0.13 °C and ± 0.25 °C for temperature and between ± 0.46% and ± 0.62% for relative humidity. The value of stability is between 0.005 °C and 0.04 °C for temperature and 0.03% to 0.08% for relative humidity. Homogeneity value is in range between 0.09 °C and 0.12 °C for temperature, and between 0.43% and 0.52% for relative humidity, these satisfactory results showed the good performance of the generator. The expanded uncertainty of a coverage factor $k = 2$ was found to be from ± 0.2 °C to ± 0.32 °C for temperature and ± 0.8% to ± 0.96% for relative humidity. The obtained results give us the confidence that NIS two-pressure humidity generator can be used as a high accurate humid air generator and reference instrument, for calibrating all types of dew-point meters and humidity sensors with high accuracy.

1. Introduction

There are several techniques available to generate humidity references by using stream of saturated gas with well-known water vapor content. Two-pressure humidity generator is the most commonly used for realization of relative humidity scale at National Institute for standards (NIS) and for disseminating traceability. The generator is based on the two-pressure principle [1]. This generator has been shown to be highly reproducible when properly used. The present work describes the evaluation of two-pressure humidity generator performance through uniformity, homogeneity and stability measurements [2]. The main objective of these measurements was to test the reliability of two-pressure humidity generator in order to utilize it as a reference instrument for calibrations. The values of stability and homogeneity of the humidity generator are used to estimate total uncertainty budget.

2. Method and equipment

In this work, Thunder scientific two-pressure humidity generator model 2500, Test space inside humidity generator dimensions is 38 cm width, 30 cm depth and 38 cm heights. The operation of a two-pressure humidity generator requires a high pressure air supply, which should be clean, dry and oil free. This pressurized air is driven to the main saturator placed inside of a controlled temperature bath. Temperature and pressure (T_s, P_s) are measured at the saturator output, then the saturated air pressure is reduced to about the ambient pressure via an isothermal expansion valve and then conducted to the test chamber where the temperature and pressure (T_c, P_c) are measured again [6]. Eq. (1) shows how to calculate relative humidity using two-pressure generator [1].

$$\%RH = \frac{ew(Ts)}{ew(Tc)} \times \frac{Pc}{Ps} \times 100 \tag{1}$$

where, $ew(T_s)$ the saturation vapor pressure at the saturation temperature, Ts, $ew(T_c)$ the saturation vapor pressure at the chamber temperature, Tc, P_c the absolute pressure in the chamber, and P_s the absolute pressure in the saturator.

Nine platinum resistance thermometers of equivalent type and calibrated MBW dew-point meter model DP30 were used, then the thermometers were placed at various locations within the test chamber of

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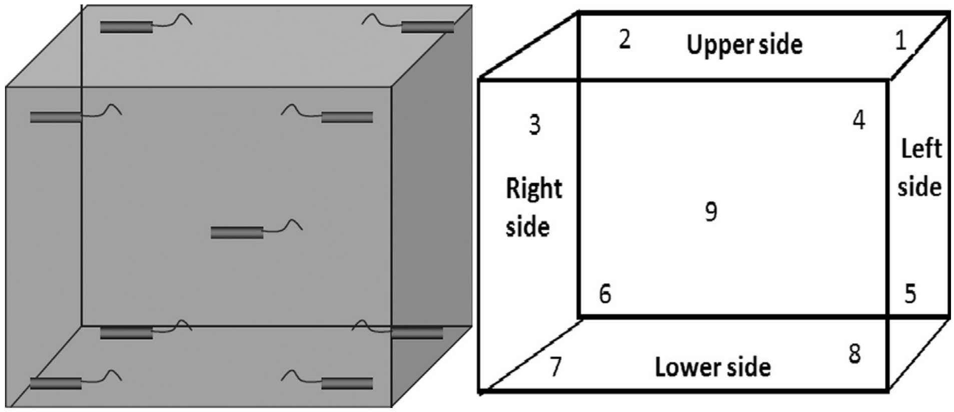

Fig. 1. Nine determined points in NIS two-pressure humidity generator.

Table 1
Temperature uniformity analysis of two-pressure humidity generator.

Probe	Location	@ 10 °C	@ 25 °C	@40 °C	@65 °C
1	Upper left rear	10.81	25.59	40.42	64.95
2	Upper right rear	10.84	25.56	40.40	65.00
3	Upper right front	11.0	25.53	40.25	65.02
4	Upper left front	11.04	25.57	40.42	65.05
5	Lower left rear	10.79	25.52	40.17	64.87
6	Lower right rear	10.86	25.78	40.00	64.95
7	Lower right front	10.88	25.49	40.4	65.03
8	Lower left front	10.80	25.61	40.33	65.02
9	Center	10.86	25.65	40.14	64.54
Max deviation (Max Dev)		± 0.12	± 0.14	± 0.21	± 0.25
Uniformity		± 0.13	± 0.14	± 0.21	± 0.25

Table 2
Humidity uniformity analysis of two-pressure humidity generator.

Probe	Location	@ 10%	@ 50%	@ 95%
1	Upper left rear	10.62	49.15	94.77
2	Upper right rear	10.66	49.41	94.93
3	Upper right front	10.79	49.50	95.97
4	Upper left front	9.87	48.57	94.74
5	Lower left rear	10.70	49.53	94.84
6	Lower right rear	10.54	48.77	94.76
7	Lower right front	10.72	49.64	95.34
8	Lower left front	10.65	49.27	94.78
9	Center	10.76	49.59	94.92
Max deviation (Max Dev)		± 0.46	± 0.53	± 0.62
Uniformity		± 0.46	± 0.54	± 0.62

the humidity generator, approximately 1–2 in. from each corner (8 probes total), and the center (1 probes total). The measuring locations are from the corner points and the spatial center of the cuboid, which span the useful volume. Fig. 1 shows the determined 9 points in the test chamber of the two-pressure humidity generator.

For relative humidity, the dew point was determined in the center of the useful volume by dew-point meter then calculate the spatial distribution of the relative humidity based on the distribution measured of the air temperature [2].

Calibration of the platinum resistance thermometers is carried out by comparison with Fluke Calibrated Platinum Resistance Thermometer (PRT) and calibrated AΣA Resistance Bridge. Calibrated temperature bath with high stability for the range of 10 °C to 65 °C used as a medium [3]. Calibration is carried out between 10 °C and 65 °C .The uncertainty of the thermometers u (t) after calibration is estimated to be ± 0.03 °C.

Each platinum resistance thermometer is fixed respectively in the test chamber of humidity generator as shown in Fig. 1.

3. Results and discussion

3.1. Measurements

Measurements are performed under the following conditions:

Relative humidity measurements are performed between 10% and 95% at fixed temperature of 25 °C and temperature measurements are performed between 10 °C and 65 °C at fixed humidity of 50% relative humidity. Ambient conditions of the laboratory were 23 °C ± 2 °C temperature and 40% to 60% relative humidity to ensure good performance. The flow rate of dew-point meter was kept at 20 L/h. Measuring system started by setting humidity generator at flow rate of 20 L/h which will stabilize after 30 min. Dew-point meter was turned on for 15 min at least to warm up, and then connected the dew-point meter with humidity generator using Teflon tube. Humid air was transfer from humidity generator to dew-point meter by dew-point meter pump. This pump is built in dew-point meter. It is required that for the dew-point meter to measure dew-point temperatures above ambient temperature, the meter measuring head and the sample gas line must be heated. The temperature of the unheated connections between the sampling point (inlet of heated hose) and the measuring head (outlet of heated hose) must be above the required dew-point temperature. This is to avoid any undesired condensation.

When the dew-point temperature & the temperature measured by PRTs inside the two-pressure humidity generator were stable, the data was taken for approximately 4 h for each point.

The two-pressure humidity generator is adjusted at value of relative humidity 50% for temperatures 10 °C, 25 °C, 40 °C and 65 °C respectively. The data was taken at 10 °C for the adjusted humidity set point for 4 h then repeated for the other temperatures. After that, the temperature was set at 25 °C for 10%, 50%, 95% relative humidity respectively for 4 h for each relative humidity set point.

3.2. Determination of uniformity

The temperature uniformity is determined as square root of the sum of the squares of the maximum deviation and the estimated thermometer uncertainty [4].

The maximum measurement deviation will be determined by noting the maximum and minimum readings from the set of all thermometers at the same point in the same time, then taking half the difference of these values

$$\text{Max Deviation} = \pm 0.5\ (\text{Max Reading-Min Reading}) \tag{2}$$

$$\text{uniformity}^2 = \text{MaxDev}^2 + u^2\ (\text{T}) \tag{3}$$

where u (t) is the uncertainty of PRTs inside the generator.

Table 1 shows data gathered during the temperature uniformity analysis. The generator was run at a fixed relative humidity 50%. The