METROLOGY AND MEASUREMENT SYSTEMS
Index 330930, ISSN 0860-8229
www.metrology.pg.gda.pl

REALIZATION OF HUMIDITY STANDARD FACILITY USING TWO-PRESSURE HUMIDITY GENERATOR AND HUMIDITY CHAMBER

Essam El-Din, Mostafa Mahmoud Mekawy, Khaled Mohamed Ali

National Institute for Standards, Thermometry & Humidity Measurements Lab, Tersa St. P. O. Box: 136 Giza,12211, El-Haram, Egypt
(✉ essam70@yahoo.com, +2 0122867003, m_mekawy@yahoo.com, khalidali@nis.sci.eg)

Abstract

The realization of a dew/frost-point temperature scale is important for the calibration of hygrometers and dew/frost-point meters. Also, it was found that it is prime important for the National Institute for Standards-Egypt (NIS) to develop measurements of humidity field.
Experimental work used for realization of the dew/frost-point temperature scale, to calculate humidity measurements with high accuracy and to calculate the measurement uncertainty value of the dew-frost point. The dew-point temperature scale was realized using a two-pressure generator, humidity chamber, chilled mirror hygrometer and testo hygrometer. This work shows that the dew/frost-point temperature scale cover the range from -20 °C up to +70 °C with an uncertainty range from ± 0.52 °C to ± 1.7°C and covered the calibration requests from Egyptian industries.
We are looking forward to increase this range and decrease measurement the uncertainty value.

Keywords: dew/frost-point, humidity generator, humidity chamber, hygrometers, realization.

1. INTRODUCTION

One of fundamental tasks of thermometry laboratory at National Institute for Standards is the realization of dew point temperature scale and to develop techniques for calibration of hygrometers with highest possible accuracy. Dew/Frost-point measurements are very important to calculate relative humidity correctly in most of the research, calibration, medicine, industries and many other fields. Dew point is the temperature to which a given parcel of air must be cooled at constant pressure and constant water-vapor content so that saturation is occurred. When this temperature is below 0 °C, it is called the frost point [1].

The dew/frost point temperature scale was realized for the first time in NIS-Egypt. In Egypt, the traceability of humidity measurements will base on the realization of the dew point temperature scale. For this purpose, the dew-point temperature scale was realized. A humidity two-pressure generator and chilled mirror were used to realize the range from -20 °C up to +50 °C, a humidity chamber and hygrometer testo 650 were used to realize the range from +50 °C up to +70 °C. The generator has been investigated by analyzing the operation of the system [2].

MBW and testo 650 were calibrated by the dew-point generator which is traceable to ITS-90.

The method of dew point meter calibration using the humidity generator and NIS-dew-point meter is capable of high degree of precision.

2. EXPERIMENTAL WORK

2.1 Generation

2.1.1 Humidity Generator

Operation of the humidity generator is based on the two-pressure method of producing known atmospheres of relative humidity and assumes that the water vapor pressure remains a fraction of the total pressure, known as Dalton's Law of Partial Pressure [3]. Dalton's Law states that the pressure exerted by a mixture of gases in a given volume at some temperature is equal to the sum of the pressures which would be exerted by each individual gas if it alone occupied the volume at the same temperature. Equation (1) shows how to calculate relative humidity using a two-pressure generator [1].

$$\%RH = \frac{ew(Ts)}{ew(Tc)} x \frac{Pc}{Ps} x100 , \qquad (1)$$

where:

ew(Ts) - the saturation vapor pressure at the saturation temperature, *Ts*,
ew(Tc) - the saturation vapor pressure at the chamber temperature, *Tc*,
Pc - the absolute pressure in the chamber, and
Ps - the absolute pressure in the saturator.

The two-pressure method (shown in elemental schematic form in Fig. 1 involves saturating air, or some other gas such as nitrogen, with water vapor at a given pressure and temperature. The saturated gas then flows through an expansion valve where it is isothermally reduced to chamber pressure. If the temperature of the gas is held constant during pressure reduction, the humidity, at chamber pressure, may then be approximated as the ratio of two absolute pressures.

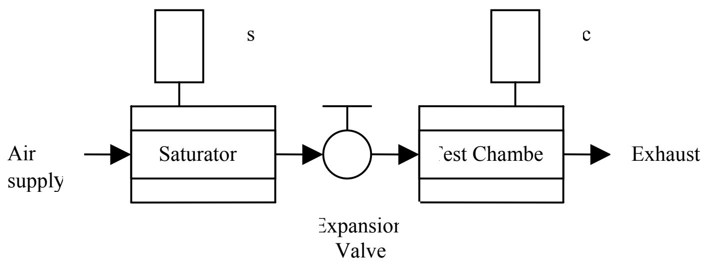

Fig. 1. Prototype of two-pressure humidity generator.

2.1.2 Humidity Chamber

The operation of the humidity chamber is based on an air stream that is temperature conditioned and/or air conditioned precisely to the entered set values and continuously flows through the test space and ensures an optimum spatial distribution of air and temperature. The circulating air duct installed at the rear wall of the test chamber contains the modules required for conditioning the air. Generously dimensioned axial fans with an external drive motor draw the air out of the test chambers. The test chambers with a test space volume of 180 (?) have two circulating air fans each. This circulating air then flows through a fin-type heat exchanger in which it is cooled if required. Special circuits prevent any undesired formation of condensate during the air-conditioning operation and ensure the best possible constancies of temperature and humidity. An electrical heater installed behind the heat exchanger heats the circulating air. The stream of air then passes over a water bath; integrated heating elements ensure quick and precise heating of the water. The patented air-conditioning system also enables to achieve a high relative humidity even with a heat load. The humidity of the test space air is measured psychrometrically. Dry and wet thermometers are positioned one next to the other in the stream of circulating air. Depending on the climate the humidity sensor thermometer is wetted automatically and cleaned in the process. This considerably increases the service life.

2.2 Measuring of dew/frost temperature

2.2.1 Chilled Mirror Hygrometer

The MBW chilled mirror hygrometer is for industrial and laboratory use, for continuous or spot measurement of the dew point of air, gas and gas mixture. Its extended measuring range and its ability to make measurements at high pressures and temperatures enable it to cover a wide range of applications from -60 °C to +60 °C. The measurement is based on the chilled mirror principle, which guarantees direct and accurate measurement of the actual humidity with no errors due to inertia and hysteresis. Because the MBW hygrometer is covering the range from 60 °C to +60 °C only, hygrometer testo 650 was used in this work to cover the range from +50 °C up to +70 °C.

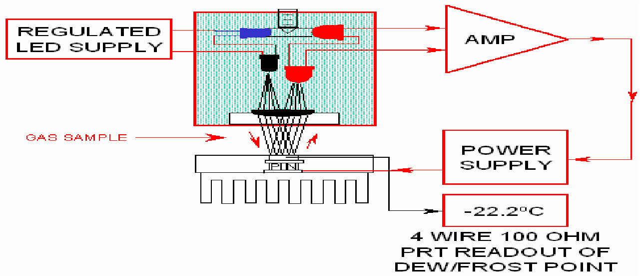

Fig. 2. Prototype of chilled mirror hygrometer.

2.2.2 Capacitive RH Sensors

Capacitive RH sensors have proven themselves to be a practical sensor technology in a wide variety of industrial applications. In its simplest form, a capacitor is formed when two conductive plates are separated by an insulator (dielectric).

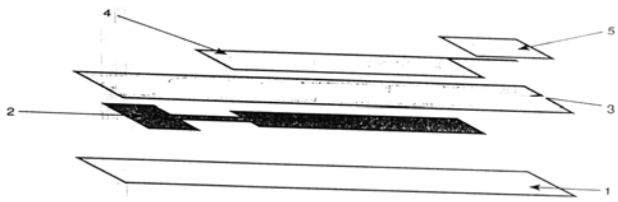

Fig. 3. Schematic of Capacitive Polymer Sensor.

1. A substrate base, typically glass. Its main function is to support the other layers of the sensor.
2. One of the electrodes made of conductive and corrosion-resistant material.
3. A thin polymer layer; this is the heart of the sensor. The amount of absorbed water in the film varies as a function of the surrounding relative humidity. The thickness of this film is typically 1 to 10 μm.

4. The upper electrode, which also plays a role in determining the performance and characteristics of the sensor. For fast response it must have good permeability for water. It must also be electrically conductive and have strong corrosion resistance.
5. A contact pad for the upper electrode. Since there are many constraints on the design of the upper electrode, a separate metallization for making reliable contacts is often required [1].

Fig. 1 Capacitor Structure: the electrical capacitance is defined by the area of the plates, the distance between them and the dielectric coefficient of the medium separating the plates. In a Capacitive RH Sensor, the dielectric material is allowed to diffuse and absorb water vapor so that it equilibrates with the external environment. The "dry" dielectric coefficient is significantly lower than that of water, and thus the electrical capacitance increases as the dielectric absorbs water reflecting the Relative Humidity of the surroundings. From an electrical standpoint, however, these Sensors exhibit a relatively small change in capacitance over their measurement range [4].

3. RESULTS AND DISCUSSION

Table 1 shows dew point measurements which were obtained using the chilled mirror up to point number 15 and the testo hygrometer from point number 15 to point number 18. The measurements cover the range from -20 °C up to +70 °C. All measurements are suitable for calibration of a dew-point meter which requires calibration. The stability of measurements is in the range between ±0.03 °C and ±0.16 °C for more than 4 hours; this period is enough for calibration.

Table 1. Measurements of Dew-Point Using a Two-Pressure Generator.

Serial	**Dew-Point** °C	**Stability of dew point** °C
1	-20.00	±0.05
2	-14.47	±0.15
3	-9.72	±0.13
4	-4.79	±0.15
5	0.14	±0.10
6	4.87	±0.09
7	10.19	±0.10
8	15.19	±0.10
9	20.02	±0.10
10	25.64	±0.03
11	30.55	±0.11
12	35.62	±0.03
13	40.73	±0.16
14	45.89	±0.03
15	50.72	±0.06
16	58.9	±0.3
17	64.2	±0.4
18	70.0	±0.5

Fig. 2 shows the covered dew point temperature range at NIS which started from – 20 °C up + 70 °C.

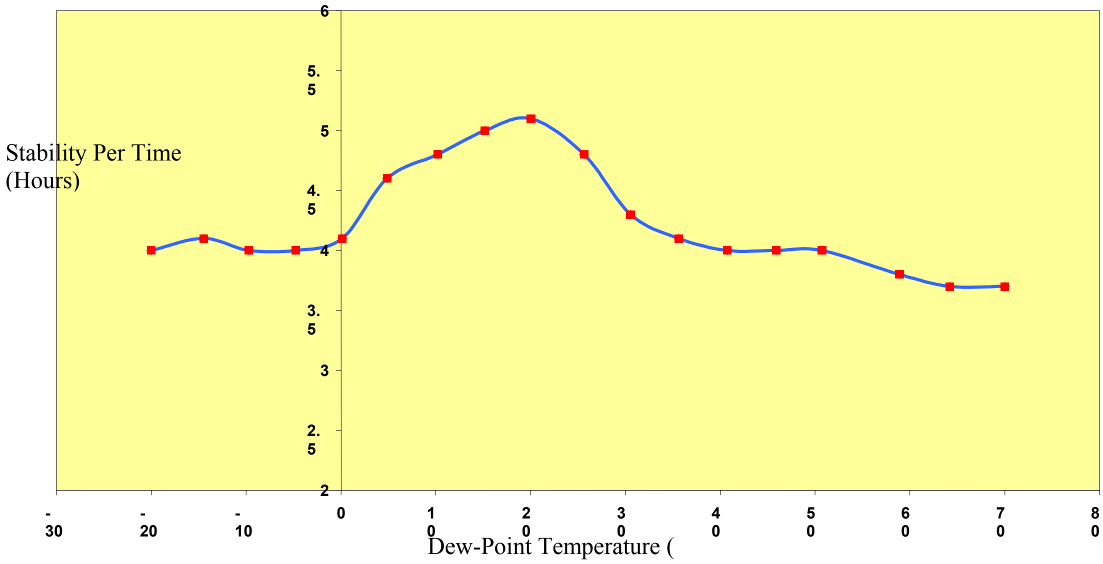

Fig. 4. Range of Dew-Point Temperature.

The uncertainty evaluated at confidence limit 95% is shown in Table 2.

Table 2. Uncertainty Values.

Range of dew point °C	Uncertainty Value
-20 °C up +20 °C	±0.52 °C
+20 °C up +50°C	±0.75 °C
+50 °C up +70°C	±1.7 °C

4. CONCLUSION

A dew/frost point temperature scale starting from -20 °C up to +70 °C was realized. The stability of dew points is from ± 0.03 up ±0.16 °C and this stability is suitable for accurate calibration for the first time in Egypt. The dew/frost point temperature scale can be used for the calibration of different sensors with an accuracy which is sufficient for calibration of research and industrial sensors. The uncertainty was estimated to be between ±0.52 °C and ±1.7 °C as a guide to the expression of uncertainty in measurement.

All measurements give us trust to calibrate all kinds of hygrometer and dew-point meters at NIS.

REFERENCES

[1] P.Wiederhold, P: *Water Vapor Measurement*. 1997.

[2] E. E. Mahmoud: "Metrological performance of NIS humidity generator". *5th International Symposium on Humidity and Moisture – ISHM 2006 Brazil May 02-05*, 2006.

[3] R. Pragnell, R. Benyon: "A Prototype Two-Pressure Humidity Generator for the Spanish National Humidity Standard Facility". *Third International Symposium on Humidity & Moisture*, 1998.

[4] B. Kevin: "Methods of Accurately Measuring Capacitive RH Sensors". *5th International Symposium on Humidity and Moisture – ISHM 2006 Brazil May 02-05*, 2006.