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HUMIDITY GENERATOR FOR COMPARISON CALIBRATION PURPOSE

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Abstract – This paper presents a facility for humid air generation – the humidity generator. The generator was developed for calibration of hygrometers. The principle of operation is based on the two-temperature method for humid air generation and the open circuit flow mode is applied. Saturation of the air is achieved by the water atomization in air flow. The generator is designed to operate in the test chamber temperature range from 5 °C to 85 °C and in dew point temperature range from 2 °C to 35 °C. The paper makes a point to the possibility the system works in nonsaturation mode and the comparison method is applied for calibration purpose. The excellent dynamic characteristics are obtained by the fast changes of the quantity of water dispersed in air flow. Maintenance the intensity of the atomization and stationary temperature at the same time enables stationary air humidity circumstances in the test chamber. Dynamic and stationary characteristics of generator, as well as uniformity working area inside the test chamber is numerically and graphically presented. Analysis of the uncertainty using comparison calibration method is also reported. The software developed in LabVIEW environment supervises the system operation.

Keywords: humidity generator, calibration, atomization.

1. INTRODUCTION

The humidity generator was developed for calibration purpose of different types of industrial hygrometers. The generator is designed to operate in 2 °C to 35 °C dew point range and in temperature range inside the test chamber from 5 °C to 85 °C. The principle of operation of the generator bases on the two-temperature method at constant pressure. Humidifying of the air inside the saturator is achieved by the water atomization with special designed nozzle system [1], [2]. The generator is also able to operate in the nonsaturated mode. That means that the humidifying in the saturator is fully controlled at any desired level. Fast change of the water quantity dispersed in the air flow is followed by the change of the humidity in the test chamber in a very short time. The nonsaturated mode of operation and open circuit flow mode enable an excellent dynamic behaviour of the humidity generator.

2. CONSTRUCTION OF THE HUMIDITY GENERATOR AND THE AIR FLOW THROUGH THE SISTEM

The humidity generator is schematically presented in the fig. 1. The open circuit air flow is applied. The incoming air flowing trough the filters and condensation air dryer. Relative humidity of the air at the input of the generator is between 5% and 10 %. The control unit -1 determines the flow rate of the incoming air. Maximum flow rate of the humidity generator is 2500 l/h. The air stream flows through the pipe heat exchanger -8 immersed in the first thermostatic bath to be preheated or precooled to the temperature of the first thermostatic bath before introducing in the saturator. The saturator -2 is cylindrical and is partially immersed in

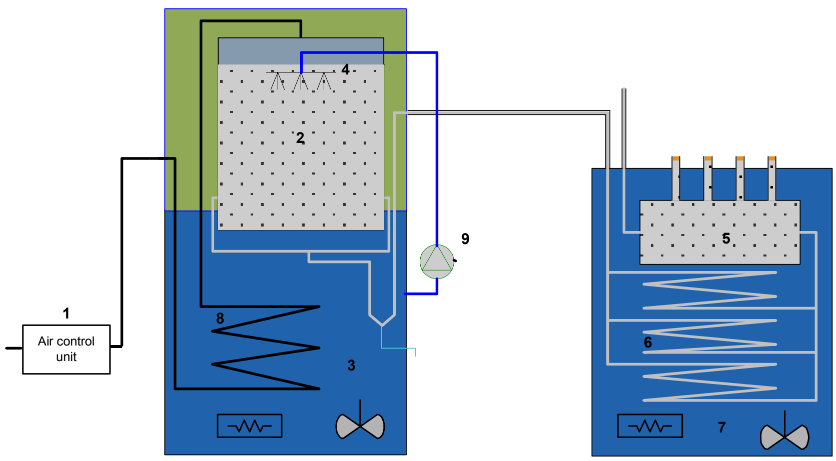

Fig. 1. Schematic diagram of the humidity generator: 1-control unit, 2-saturator, 3;7-thermostatic baths, 4- nozzles system, 5-test chamber, 6;8-pipe heat exchanger, 9 pump.

the first water thermostatic bath -3.

The air is forced to flow through the saturator from its top towards the bottom. Saturation of the air is achieved by the water atomization in air flow. The pressure of the water in the special designed nozzles -4 mounted on the top of the saturator controls the intensity of the atomization. The temperature of the first thermostatic bath from which the water for atomization is applied conditions the temperature of the saturated air flow.

The temperature of the saturated air is measured at the outlet of the saturation part of the system and is assumed to be the dew point temperature. The air flow arrives in the test chamber of the system -5 through three parallel pipe heat exchanger -6. Both of them are total immersed in the second thermostatic bath -7. The temperature of the second bath determines the temperature circumstances in the test chamber. The test chamber is intended for calibration of hygrometers. The temperature and the relative humidity of the air passing through the test chamber are measured by the reference hygrometer and thermometer. At the outlet of the test chamber the air flow vent to the atmosphere.

3. PRINCIPLE OF OPERATION

The design of the humidity generator is based on the two-temperature method at a constant pressure. It is able to operate in the standard fully saturated or the nonsaturated mode.

3.1. Standard fully saturated mode

To operate in fully saturated mode two conditions should be accomplished:

- air should be saturated at known temperature and pressure,
- saturated air is then heated to the higher temperature at the constant absolute humidity and the constant pressure.

If the following parameters are known:

- temperature of the air at the outlet of the saturator T_{sat},
- temperature of the air in the test chamber T_{ch},
- pressure at the outlet of the satorator $p_{sat,}$
- pressure in the test chamber p_{ch},

the relative humidity in the test chamber can be evaluated using the equation:

$$\varphi = \frac{f(p_{sat}, T_{sat})\ \ e_w(T_{sat})\ \ p_{ch}}{f(p_{ch}, T_{ch})\ \ e_w(T_{ch})\ \ p_{sat}} \cdot 100 \ , \qquad (1)$$

where $e_w(T_{sat})$ and $e_w(T_{ch})$ are saturation vapour pressure [3] at corresponding temperature, $f(p,T)$ is the water vapour enhancement factor due to the presence of additional gases as the function of the total pressure and the temperature.

3.2. Nonsaturated mode

In the nonsaturated operation mode the air coming out of the saturator is not saturated. The relative humidity in the test chamber cannot be evaluated using equation (1) but should be measured by another reference hygrometer. The function of thermostatic baths is to maintain the stationary temperature condition in the system. Only the comparison calibration method can be applied.

A rather sophisticated humidifying system makes possible the saturation of the air passing through the saturator. Controlling the intensity of humidifying can generate the air flow at different stages of humidity. The intensity of humidifying is controlled by a system that enables very fast changes of the intensity and maintains it at constant level during a longer period. In this way different stationary levels of relative humidity in the test chamber can be generated very quickly as shown in the fig. 2.and 3.

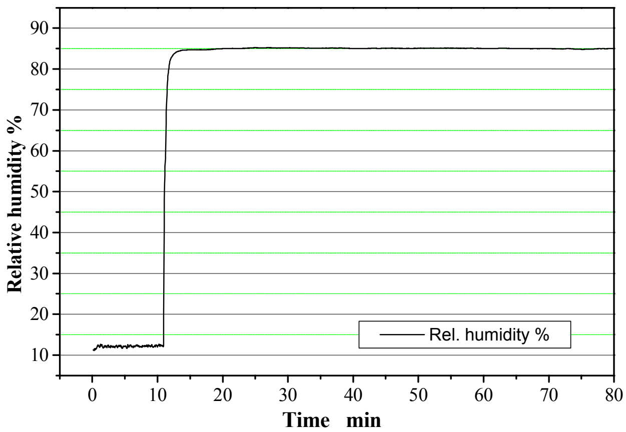

Fig.2. Response characteristic of the humidity generator measured in the test chamber at 23 °C and flow rate 1500 l/h applying fast change of intensity of humidifying from minimum to maximum level.

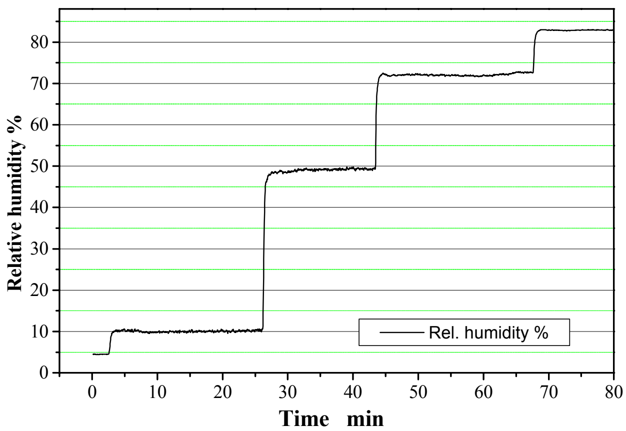

Fig. 3. Response characteristic of the humidity generator measured in the test chamber at 23 °C and flow rate 1500 l/h applying different stage of intensity of humidifying.

Applying comparison calibration method the generator can be also used operating in fully saturated mode. Setting the temperature in thermostatic baths a stationary level of relative humidity in the test chamber can be generated in the range from 5 % and 99 %. Dynamic characteristic of the system is conditioned by the dynamic characteristic of the thermostatic water bath (Fig. 4.).

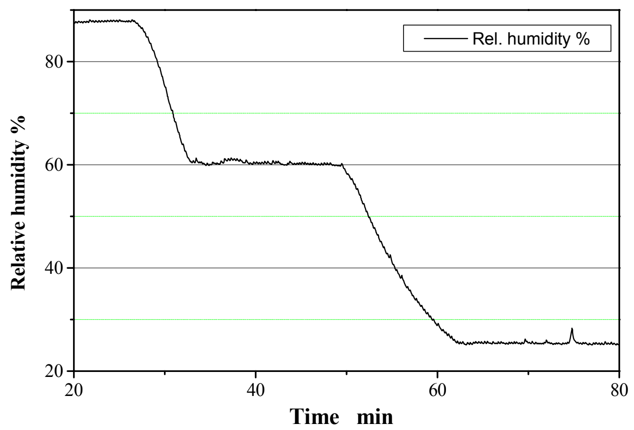

Fig. 4. Response characteristic of the humidity generator, measured in the test chamber at 23 °C and flow rate 1500 l/h applying fully saturated mode.

In the process of calibration of hygrometers the fluctuations of certain condition in test chamber directly influence to the measurement uncertainty. Maintaining the constant intensity of humidifying and stationary temperature conditions in thermostatic baths in the limit of ±0,05 °C caused the fluctuation of relative humidity in the test chamber that does not exceed ±0,3 % (Fig. 5).

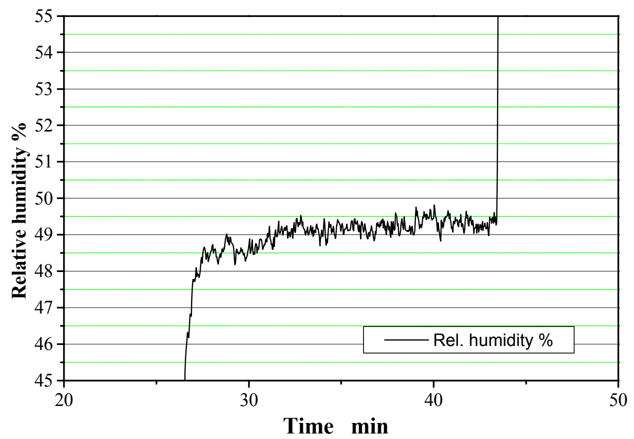

Fig. 5. Fluctuation of relative humidity measured in the test chamber at 23 °C and flow rate 1500 l/h applying different stage of intensity of humidifying (from the graph figure 3.)

Operating in fully saturated mode the fluctuation of the relative humidity in the test chamber is even smaller (±0,15 %). In this case the condition in the test chamber is not influenced by the unstability of the humidifying (Fig. 6.).

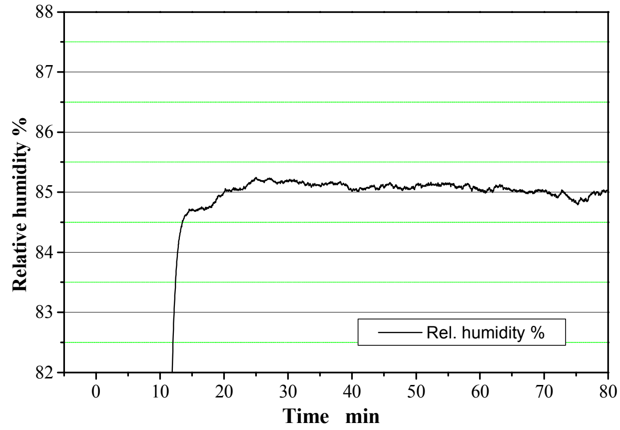

Fig. 6. Fluctuation of relative humidity measured in the test chamber at 23 °C and flow rate 1500 l/h applying fully saturated mode. (from the graph fig. 2.)

4. SUPERVISION AND CONTROL OF THE SYSTEM

The software developed in LabVIEW environment supervises the system. Special graphic interface was developed for numerical and graphical representation of the measured parameters in real time. It also enables setting and controlling the system parameters of the humidity generator.

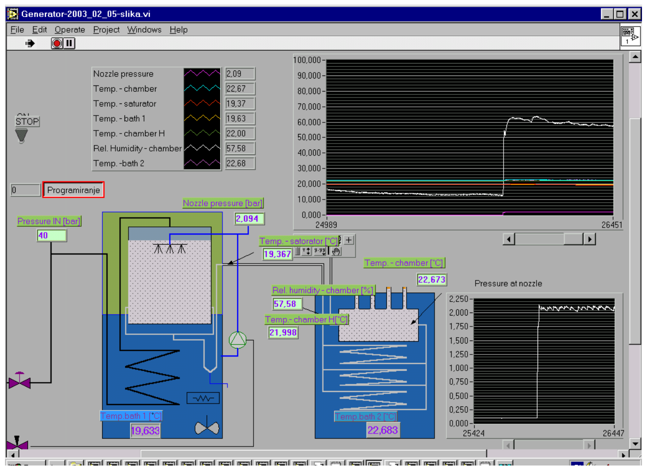

Fig. 7. Virtual graphical user interface developed in LabView environment.

5. HUMIDITY DISTRIBUTION IN THE TEST CHAMBER

The test chamber has a cylindrical form of 80 mm diameter and 200 mm of length. For better homogeneity of the air flow through the chamber, the air is coming into the chamber through the perforate plat. The chamber is totally immersed in the thermostatic water bath for better homogeneity of temperature distribution inside the chamber.

For inserting the measured devices there are three pipes coming into the chamber at the upper side. The angle between the pipe axes is approximately 15 degrees to achieve the same flow rate to all devices immersed into the chamber (Fig. 8.).

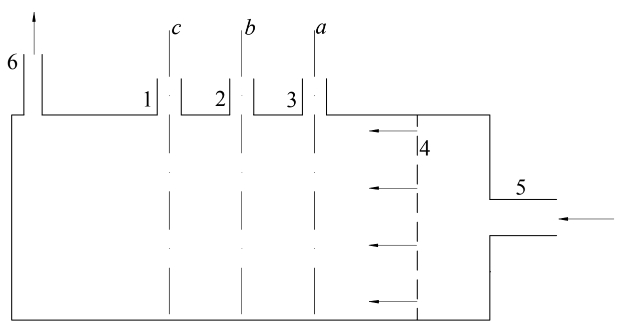

Fig. 8. Construction of the test chamber: 1,2,3-pipe, 4- perforate plate, 5-input for air flow, 6-outlet, a,b,c-pipe axis.

The temperature distribution across the working area of the test chamber was measured with two Pt100 sensors. For better dynamic characteristic of measuring system a sensors of small size are used (1,5 x 3 mm). To avoid the influence of the heat flow along the conductive wires from the sensors toward the ambient or inversely the conductive wires of 0,5 mm in diameter are applied. The temperature distribution was observed along the axis of pipes (axes a,b,c figure 8.). At the first step both sensors were immersed to the bottom of the test chamber. In the next step one of them was moved upwards step-by-step of 10 mm. Using two sensors the influence of fluctuation of temperature is avoided. The similar principle for detecting temperature distribution along the horizontal axis was applied. Measured temperature distributions in the test chamber are in the vertical axes less then ±0,01 °C and the disturbance across all the working area is less then ±0,02 °C. The results are obtained applying all the dew point operation range of humidity generator at 1500 l/h air flow rate through the system and at temperature in the test chamber about 23 °C. With regards to detected temperature distribution we calculate [4] the distribution of relative humidity in the test chamber, which is ±0,06 % and ±0,12 % respectively.

6. CALIBRATION MEASUREMENT UNCERTAINTY

Measurement uncertainty applying comparison calibration method is influenced by the uncertainty assigned to the reference hygrometer, humidity distribution error caused by temperature gradient in the test chamber and by measurement at a fluctuating condition. Standard uncertainty of the reference hygrometer u_1 is estimated as ±0,9 %, the standard uncertainty of distribution of relative humidity along the vertical axis u_2 is estimated as ±0,04 % and across the working area in the test chamber ±0,08 %, the standard uncertainty associated with measurement of a fluctuating condition u_3 is estimated as ±0,09 % or ±0,17 % depending of the operating mode of the humidity generator.

The standard uncertainty of the calibration u is calculated with following equation [4]:

$$u = \sqrt{{u_1}^2 + {u_2}^2 + {u_3}^2} = \sqrt{0{,}08^2 + 0{,}17^2 + 0{,}9^2} = 0{,}92\,\% \tag{2}$$

The total uncertainty U (k=2) is:

$$U = k \cdot u = 2 \cdot 0{,}92 = 1{,}84\,\% \tag{3}$$

7. CONCLUSIONS

The humidity generator was developed for calibration purpose based on the two-temperature method. Applying the water atomization in the saturator is a very effective way for humidifying the air flow. The generator can also operate in the nonsaturated mode controlling the intensity of humidifying with the unique nozzle system enabling very fast changes of intensity. In spite of excellent dynamic characteristics of the humidity generator the extended uncertainty, applying comparison calibration method, can be less than 2 % in terms of relative humidity. The estimated uncertainty of calibration is mostly caused by the uncertainty of the reference hygrometer. By improving the uncertainty of the reference hygrometer the total uncertainty ca be significantly reduced bellow 1 %.

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