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CALIBRATION OF HUMIDITY SENSORS USING THE TWO TEMPERATURE METHOD

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Annotation

Currently, in the production of various materials and their primary processing is considered an important part of the production cycle. But as we know in material processing, moisture control is considered one of the important processes. The exact measurement of humidity depends on the type of primary transducer and its measurement accuracy. The accuracy of the measurement depends on the setup and accurate calibration of the signal converter. A more efficient method for calibrating humidity sensors is being considered.

Keywords: pressure, water vapor, isobaric, temperature, saturation, heating, measurement results, importance, working chamber, evaporation, condensate, heat exchanger, refrigerating chamber, operating temperature.

1. Introduction

The two-temperature method is based on gas humidification to a state of saturation at a certain temperature, followed by heating to operating temperature.

If a moist gas is heated isobarically, its relative humidity will change due to the corresponding saturation partial pressure at the new temperature and the constant value of the partial pressure of water vapor. To create a wet gas with a given relative humidity, the gas is brought to a state of saturation at a certain temperature, and then heated to operating temperature. Then, the relative humidity in the working chamber at temperature T_2 is equal to:

$$\varphi = \frac{P_{n1}(T_1)}{P_{n2}(T_2)}, \tag{1}$$

where P_{n1} is the partial pressure of saturated water vapor at temperature T] in the saturator; P_{n2} - partial pressure of saturated water vapor at temperature T2 in the working chamber.

2. Material and methods

The dynamic humid air generator PSG-120 is designed for calibration and verification of hygrometers used to measure humidity at high temperatures [1].

The main components of the PSG-120 are a humidifier, a condensation unit, an air heater and a working chamber. Air humidification in PSG-120 is carried out by bubbling it through a column of heated water, followed by mixing with water vapor in a free volume above the surface of the evaporating water. From the humidifier, the steam-air mixture enters the condensation unit. The temperature of the surfaces of the condenser and saturator is set at (3÷4) °C below the dew point of the steam-air mixture leaving the humidifier. A decrease in the temperature of the steam-air mixture in the condensation unit causes the condensation of excess moisture and the transition of the steam-air mixture to a saturated state. The presence in the condensation unit of surfaces cooled below the dew point of the passing steam-air mixture eliminates the phenomenon of oversaturation and, thereby, guarantees a high density of the created dew point temperature. The unevenness of the temperature field in the saturator does not exceed ± (0.03÷0.04) ° C.

Next, the steam-air mixture passes through an air heater, where it is preheated to a temperature close to the operating temperature, then enters the useful volume of the working chamber and takes on the specified operating temperature. The design of the working chamber ensures high uniformity of the temperature field.

Main technical characteristics of the PSG-120 generator: the absolute error limit for setting the humidity is ±1%; range of specified relative humidity values - (10÷98)%; operating temperature range - (40÷200) ° C; time to establish humidity is no more than 60 minutes; flow rate of the created steam-air mixture is up to 50 l/min; useful volume of the working chamber is 18 dm^3.

The Polyus-2 generator, unlike the PSG-120 generator, is intended for certification and verification of devices operating in the range of low relative humidity and temperatures [2].

The operation of the generator is based on the method of phase equilibrium in the processes of condensation and crystallization of water vapor over a cooled surface [3]. Advantages of the method and generator: wide range of temperature and humidity of the resulting vapor-gas mixtures, high flow rate of wet gas and a wide range of its measurement, the ability to obtain not only air, but also almost any gases with a given humidity, the ability to separate impurities from the gas (oil vapor and carbon dioxide) , which condense at a given temperature.

The design of the Polyus-2 generator is the following device. A heat and mass transfer apparatus is located in the working nitrogen-cooling chamber. Liquid nitrogen from the thermos is evaporated by the heater and enters the working chamber through a metering solenoid valve. The operation of the valve is controlled by a command thermostat, which automatically maintains the set temperature in the working chamber. The heat and mass transfer apparatus consists of preliminary and main heat exchangers, which are flat panel structures with short intermittent fins. The preliminary heat exchanger is designed to reduce the temperature difference between the wet gas and the cooled surface. When warm, moist gas is directly supplied to a cooled surface (temperature difference of more than 30 °C), saturation exceeding critical is possible, which causes the appearance of fog and the production of supersaturated gas at the output of the heat and mass transfer apparatus. From the preliminary heat exchanger, the cooled gas enters the main heat exchanger and then exits the heat and mass transfer apparatus.

Technical characteristics of the Polyus-2 generator: range of set values of humidity, frost point temperature - (-100÷20) ° C; the main absolute error of the frost point temperature is ±0.2 ÷ ° C; gas flow through the generator - 50 l/min; time to enter the mode when first turned on - (40÷60) min., when switching from one mode to another - (10÷15) min.

3. Results Obtained

Based on the generator, an installation was developed for checking and calibrating hygrometers at subzero temperatures [4]. The installation allows you to create specified values of relative humidity, which significantly expands the scope of the generator.

The main components of the installation are: a model dynamic generator “Polyus” and a thermostated test volume in which the instruments to be verified and calibrated are installed. Relative humidity is determined based on the known dew point temperature at the generator outlet and the temperature in the working chamber using formula (1). There are three options for thermostatting the working chamber; using the Feitron 3001 climate chamber; using a nitrogen refrigeration chamber; using a special low-temperature chamber from NPO VNIIM. From the point of view of technical characteristics, the last option is the most optimal.

Technical characteristics of the installation: range of specified humidity values, dew point temperature (-604÷20) °C, (14÷100) % at temperature (-60÷0) °C; temperature stability - ±0.1 °C; error in reproducing the dew point - ±0.2 °C; time to enter the mode - 60 minutes.

The Dipole generator implements a method for preparing wet gas, which is a combination of the two-pressure and two-temperature method [5]. The essence of the method is as follows. If a certain volume of air is brought to a state of saturation at temperature t_n and pressure P_n, and then changes its temperature and pressure to P and t , then the relative humidity of the air in this volume will be equal to:

$$\varphi = \frac{P_n(t_H) \cdot P}{P_n(t) \cdot P_H} \cdot 100\%, \qquad (2)$$

where $P_n(t_n)$ is the partial saturation pressure of water vapor at temperature t_H; $P_n(t)$ - partial saturation pressure of water vapor at temperature t .

The use of the “Dipole” generator in the metrological support system for means of measuring humidity during radio sounding made it possible to simulate atmospheric conditions up to the maximum altitude.

The main difference of the generator is the ability to create abrupt changes in humidity in the working chamber, necessary for studying the dynamic characteristics of the sensors. Such abrupt changes in humidity are carried out using a switching system that allows for variable supply of flows from different saturation chambers.

Technical characteristics of the “Dipole” generator: temperature range in the working chamber (-70÷+30) °C; pressure range - (10÷1100) GPa; range of set humidity values - (14-95)% at positive temperatures, (5÷95)% at negative temperatures; limit of permissible absolute error in determining relative humidity ±1% - (0÷30) °C, ±3% - (-20÷0) °C, ±5% - (-70÷20 °C) [6].

The Cloud generator also uses a combined method of setting humidity, which consists of varying the temperature and pressure of pre-saturated air. The generator allows you to simulate the operating conditions of radiosondes and many ground-based meteorological instruments [7]. The generator has the following technical characteristics: operating temperature range - (-50÷+30) ° C, temperature instability - ±0.1 °C, uneven temperature field - ±0.1 °C, operating pressure - (10÷110) kPa with an error - ±0.25 kPa, range of set humidity values - (1÷95)% with an error ±1% - (0÷30) °C , ±3% - (-20÷0) °C, ±5% (-50÷-20) °C, air flow speed in the working volume of the generator - (0.2÷1.0) m/s.

The main sources of method error:

- temperature measurement in the saturator and working chamber;
- instability of temperatures in the saturator and working chamber;
- temperature unevenness;
- completeness and reliability of reference data on saturated vapor pressure at various temperatures [9].

Conclusions

In the method of two pressures, two temperatures and combined, from the point of view of analyzing the error in obtaining gas of a given humidity. It can be concluded that the error of the two-temperature method can be achieved by reducing the error in the analytical representation of the dependence of the partial pressure of saturated water vapor on temperature and increasing the accuracy of temperature measurement. Increasing the accuracy of the combined method should lead, first of all, to a decrease in the increasing coefficients of difference between the gas and the ideal one, and then to an increase in the accuracy of measuring pressure and temperature. And also, when calculating the absolute error in measuring humidity of all three methods, the two-pressure method has the minimum error at the temperature range (-70÷+70) ^{0}C, and the advantage increases as humidity increases and temperature decreases. When relative humidity is less than 25% in the region of negative temperatures, the two-temperature method and the combined method are approximately equivalent and their error is lower than in the two-pressure method.

A significant advantage of the method is accuracy. However, the method makes it possible to reproduce discrete values of humidity at a certain temperature and, due to the rather significant thermal inertia, the method is of little use for dynamic studies.

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