A humidity calibrator for measurements at pressures up to 15 MPa is designed. The effect of pressure on the characteristics of capacitive humidity sensors is demonstrated. A method of taking this effect into account is proposed. A procedure for calibrating humidity transducers with capacitive sensors at high pressure is described.

Key words: capacitive humidity sensor, pressure, moist-gas calibrator.

One of the main problems in hygrometry is to measure humidity at a pressure considerably exceeding atmospheric pressure. The importance of this problem is due to the need for such measurements in the extraction and transfer of natural gas. The main quantity that is measured is the dew point temperature, and the most accurate devices are based on the direct measurement of this quantity. However, such instruments are clumsy and expensive. The possibility arises of using fairly cheap microprocessor measuring instruments, in which capacitive sensors of relative humidity are used as the primary transducers. These sensors calculate and also provide values of the dew-point temperature in the form of a current signal and/or readings of an indicator, based on the values of the humidity and temperature which they measure. However, the effect of pressure on the sensors employed in such instruments is unknown and requires separate investigations. Moreover, in view of the high demands imposed on the instruments intended for such purposes, it is important to check (calibrate) them at working pressures up to 15 MPa.

The purpose of this research was to check the effect of pressure on capacitive sensors and to determine a method for correcting their characteristics. Note that the sensors were not investigated as individual independent devices, but as part of the ROSA-10 humidity and temperature measuring transducer. Hence, we determined the sensor characteristic from the output current signal of the transducer or the readings of its indicator. The advantage of this method is its operating convenience, clarity, and also the fact that the temperature correction of the sensor parameters is introduced into the transducer a priori.

Experimental Equipment. Moist gas generators, which use two-pressure methods [1] or a mixture of dry and moist gases are the most widely used of the available metrological equipment. However, these methods of reproducing humidity not only do not enable one to make measurements at pressures above 0.3 MPa, but also do not take into account any of its variations. We therefore designed a humidity calibrator based on the two-temperature method [1], a sketch of which is shown in Fig. 1. The gas from a gas cylinder 1 at a pressure of up to 17 MPa arrives through a reduction valve 2, which reduces the pressure to a value \( p \) in the saturation device at a temperature \( T_K \) where its humidity approximates to 100%. Condensation of the excess moisture and saturation of the vapor in the gas to 100\% then occurs in the chamber of the generator 5, which is in a thermostat 6 at a temperature \( T_1 < T_K \). In the measuring chamber 8 of the thermostat 7 at a temperature \( T_2 \) the relative humidity of the gas amounted to

\[
\varphi_0 = \frac{E(T_1)Z(p, T_1)}{E(T_2)Z(p, T_2)} \times 100.
\]
Here $E(T)$ is the saturation vapor pressure at a temperature $T$ and an atmospheric pressure of the order of 100 kPa [2], and $Z(T, p)$ is the correction for the fact that the gas is nonideal [3], which depends both on the temperature and on the overall gas pressure $p$. The gas was released into the atmosphere through the reduction valve 9 and the capillary 11, which ensured a constant specified flow rate. In fact, this calibrator was a dew-point-hoarfrost temperature calibrator $T_D = T_1$. A change in the relative humidity (and the dew point-hoarfrost point) was produced by changing the temperature $T_1$. The pressure transducers 4 and 10 measure the pressure at the input and output of the calibrator.

The thermostat 6, the cooling and heating in which was controlled using Peltier elements, enabled a value of the dew point to be obtained from –45°C to 50°C with an error of not greater than 0.1°C. This value included the errors in reproducing the temperature in the thermostat and transmitting it to the gas being analyzed. The thermostat 7 was a liquid thermostat, the temperature in which could be varied from room temperature to 100°C. Four humidity transducers could be placed in the measuring chamber simultaneously.

The values of the temperature were measured by TPU-0304 transducers with an error of not more than 0.05°C, while the values of the pressure were measured with AIR-20 transducers of class 0.1. The error in reproducing the relative humidity was determined by the above-mentioned errors and did not exceed 0.1–1% for a change in humidity from 0.5% to 100%. All the measurements, including the output signal of the humidity transducers investigated, and also the processing of the results were automated and were carried out using an IRT-5103 8-channel measuring-regulator instrument and a special computer program.

All the measuring instruments were produced at the Elemer enterprise.

**Results.** We investigated four E+E Elektronik NS1000 sensors and three Honeywell HIH3602 sensors, which are the sensitive elements of the ROSA-10 humidity transducers. The transducers were first calibrated using a Rodnik-4 moist gas generator.

For four values of the relative humidity of 5, 22, 52, and 85%, we took readings of the ROSA-10 as a function of the gas pressure. Graphs of the change in the readings $\varphi - \varphi'$ for one of the transducers (ROSA-10 No. 167) with the NS1000 sensor are shown in Fig. 2. Here $\varphi$ and $\varphi'$ are the readings of the instrument at atmospheric pressure and at a pressure $p$, respectively. When drawing the graphs and processing the data further, we introduced corrections for the change in the generated (standard) value of the humidity, which occurred due to the change in both the pressure (via the dependence of $Z(p, T_1)Z(p, T_2)$ on the pressure) and the temperatures $T_1$ and $T_2$.

It follows from Fig. 2 that the graphs are nonlinear and differ for different values of the reproduced humidity. Moreover, these graphs are individual for each of the sensors investigated. This fact and the fact that the sensors are affected by the pressure raise doubts about the advisability of using them at pressures that are ten or more times greater than atmospheric pressure. However, careful analysis and correct processing of the experimental data enable these drawbacks to be compensated to a considerable extent.