

The Application of Selected Saturated Standard Solutions to Examine the Uncertainty of Integrated Humidity Sensors Testing

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Abstract- Results of experiments concerning humidity measurements have been presented in the paper. Integrated humidity sensors were used for the experiments, which transformed the value measured into a corresponding capacity. The structure of a measuring system was described, and the requirements concerning particular elements of the measuring track were defined. Using the regression method, an analytical equation was modelled, combining the output capacity value of the sensor with the examined humidity changes. With the use of the experimental results as well as the least square method, the values for the above equation's parameters were determined.

I. Introduction

Beside temperature and pressure, humidity forms a set of parameters which have a very relevant influence on many physical phenomena and technological processes. Hence the need to determine humidity. Humidity changes have an influence on operational reliability and restrictions of elements and devices. Therefore, humidity measurement is an exceptionally important issue. Several main principles of humidity measurement may be distinguished. They have different applications and give information on different quantities expressing humidity.

The most important principles are as follows [1]:

- removal of humidity from the air and the measuring of the quantity of water acquired in this way;
- balancing of water vapour contained in the air with the second phase, and the measurement of this state's parameters;
- observation of temperature decrease, caused by water evaporation from a moistened substance into the outside air;
- changes in mechanical or electrical parameters of solid, influenced by relative humidity of the outside air.

II. Humidity sensor

Now a large number of humidity sensors are produced, which vary in working rule, resistance to outer conditions, measurement range, or errors. It was the relative FE09/2 type of humidity sensor that went under examination in the present experiments. The structure of measuring circuit was described, the transformation characteristics of these sensors were determined and the results of model description of transformation equation of the sensor were presented.

FE 09/2 sensors consist of a system of electrodes covered with a semiconductor protecting layer, located on ceramic base. Their working is based on the rule of output capacity C change in the function of relative humidity RH . The basic parameters of these sensors are the following: measuring range between 0 and 100% of relative humidity, working temperature – between $-60^{\circ}C$ and $200^{\circ}C$, basic capacity - (135 ± 10) pF, response time – 10 s, linearity $< \pm 1.5\%$ of relative humidity [2].

III. Experimental research

The transformation characteristics of this sensor was determined on the measuring system shown in Fig.1.

A calibrated sensor was put into a hermetically closed vessel in the environment of vapours of saturated standard solution. The vapours of this solution transpired into the field where the examined sensor was located through semi-permeable membrane. Depending on the kind of solution used for the experiment, appropriate value of relative humidity was acquired. Chlorides and bromide of different elements were used as standard solutions. For each solution relative humidity is defined in the function of temperature [3].

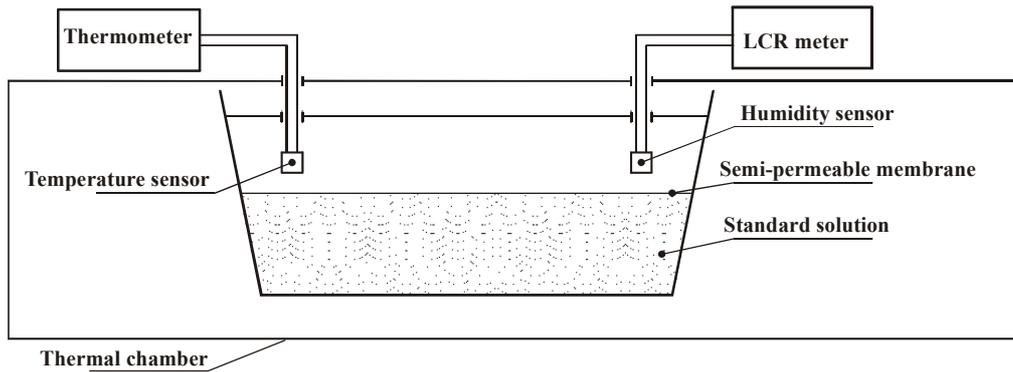


Figure 1. Scheme of a measuring system designed to determine the transformation characteristics of FE09/2 humidity sensor

The measurement of sensor capacity C , dependent on humidity value RH , was performed with 4263B LCR digital meter. The temperature inside the vessel was measured with DTM 1010 digital thermometer. As sensor co-operating with the thermometer, a nickel-chromium thermo-element was used. A special thread connection between humidity and temperature sensors inside the vessel and the thermometer and the LCR meter prevents the exchange of temperature and humidity with the outside environment.

Statement of measuring results of capacity C in the function of relative humidity changes RH , for three sensors, performed in the system shown in Fig.1, was presented in Table 1.

Table 1. Statement of measuring results concerning the determination of transformation characteristics of FE 09/2 humidity sensors

standard solution	relative humidity	sensor 1	sensor 2	sensor 3
		capacity	capacity	capacity
	%	pF	pF	pF
Lithium Chloride	12	137.0	138.0	138.0
Magnesium Chloride	33	142.0	143.0	142.0
Sodium Bromide	59	151.0	152.0	151.0
Sodium Chloride	75	155.0	156.0	155.0
Potassium Chloride	85	159.0	160.0	160.0

All the measurements were conducted at a temperature of $T = 25^{\circ}C$.

There are many possibilities of presenting the experimental data of Table 1 by means of an equation illustrating relations of the values of measurement-based variables. When selecting the shape of empirical equation that presents the experimental data, one should keep in mind two postulates. First – the equation should in the best possible way present the dependence among variables values that result from the measurement. Second – it should contain the least possible number of constants [4].

Analysing the measurement results in Table 1, one can assume that it is possible to use linear regression to describe the dependence of the influence of relative humidity changes RH on changes in output capacity C .

The regression equation is formulated in order to enable the prediction of the values of dependent variable C , based on the values of independent variable RH . This prediction is more or less accurate, according to lower or higher degree of dependence of both variables. The measure of the dependence between these variables is correlation coefficient. If it reaches values close to the boundary values ± 1 , one can infer that the dependence between the variables is strong, and that it is linear.

Based on the results of the experiment shown in Table 1, the estimators of the correlation coefficient $r_{RH,C}$ of the examined indicators were determined. After the calculations, the result obtained was equal to $r_{RH,C} = 0.996$. Hence, a linear regression equation was accepted to describe the dependence between the variables RH and C :

$$C = \alpha + \beta \cdot RH \quad (1)$$

Estimators a and b of parameters α and β were determined from trial. Number values of these parameters were determined using the least squares method. According to the method, the parameter values were selected so in order to minimize the sum square of differences between observed values \dot{C} and the estimate expected value $C = a + b \cdot RH$. Parameters values a and b were determined using the computer program, hence the empirical regression equation was assumed:

$$C = 132.84 + 0.30 \cdot RH \quad (2)$$

Fig. 2 presents the experimental characteristic $\dot{C} = f(RH)$ for sensor 1, in the form of measuring points, and transformation characteristic of the same sensor in the form of regression line with the use of equation (2).

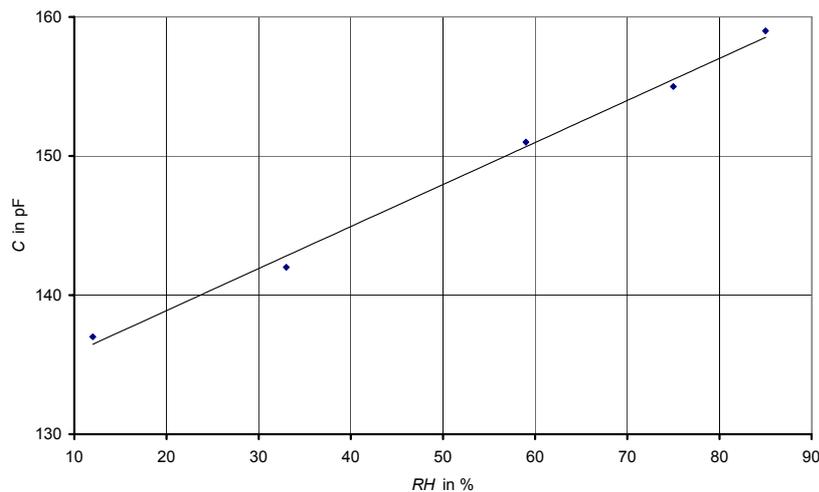


Figure 2. Transformation characteristics $\dot{C} = f(RH)$ in the form of measuring points together with the determined regression line for sensor 1

IV Uncertainty budget

The expanded uncertainty of this integrated humidity sensor was evaluated according to an international document [5].

There are four uncertainty sources, according to the measuring system presented in Fig. 1:

- measurement of capacity value C of calibrated sensor performed with LCR digital meter - u_1 ,
- temperature reading inside the vessel, measured with digital thermometer - u_2 ,
- nonlinearity of transformation equation of humidity sensor - u_3 ,
- uncertainty of evaluation of relative humidity standard solutions - u_4 .

All uncertainty values were determined. Based on the results of the experiment, a combined standard uncertainty u_C , when variables are independent, was determined according to dependence:

$$u_C = \sqrt{\sum_{i=1}^4 u_i^2} \quad (3)$$

In this situation all uncertainties are uncertainties of type B, because for each standard solution the capacity of humidity sensor was measured once.

Therefore, four standard uncertainties of type B are analyzed, which reflects a standard deviation of rectangular distribution.

The expanded uncertainty U is determined as:

$$U = k(\alpha) \cdot u_C \quad (4)$$

where, coverage factor $k(\alpha)$ acquires values of standardized variable of distributions being convolution of four rectangular distributions.

The calculations were executed for one selected probability value $\alpha = 0.95$. The Matlab program was used for the calculations.

The results of evaluating the uncertainty of humidity sensor testing by means of selected saturated standard solutions are presented in Table 2.

Table 2. Values of the expanded uncertainty U of humidity sensor

standard solution	capacity	combined uncertainty u_C	coverage factor	expanded uncertainty U
	pF	pF	-	pF
Lithium Chloride	137.0	0.6325	1.9121	1.3
Magnesium Chloride	142.0	0.7904	1.9366	1.6
Sodium Bromide	151.0	0.5708	1.8748	1.1
Sodium Chloride	155.0	0.5661	1.8703	1.1
Potassium Chloride	159.0	0.6883	1.9273	1.4

V Conclusions

The static transformation characteristics of humidity sensors FE09/2 were determined on a designed and performed measuring system presented in Fig. 1.

The evaluation of the expanded uncertainty U of the integrated humidity sensors tested by means of a selected saturated standard solution was presented in this paper.

The maximum value of expanded uncertainty U , presented in Table 2., for the analyzed probability α does not exceed 1.6 pF.

References

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