Correction of Static and Dynamic Errors of Thermometers

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Abctract - **Examining question of static and dynamic errors correction of temperature measurements taken by resistance thermometers and thermocouples .**

Keywords - **sensor, thermometer, static and dynamic errors, transfer characteristic, thermometer 's parameters, the correction of static and dynamic errors**.

I. Introduction

Primarily the performance of modern electronic data processors, is determined by the sensor's inertion. The receiving of data and its processing by electronic devices lies in the range of microseconds. At the same time, sensor's inertion lies in the range of seconds or minutes. In particular, temperature sensors in the form of resistance thermometers and thermocouples have the large inertia. Temperature measurement is important in scientific research, production processes, emergency warning systems, transport, etc. The large inertia of thermometers and related errors are often nadmissible in practice. It is not possible to reduce the inertia of thermometers because it is determined by processes of heat transfer from the environment to a massive sensor enclousure by componet's heat resistance and heat capacity as well as structure of a sensitive element.

II. Instruction for Authors

Fig. 1a shows a block diagram of the direct measurement of temperature T by resistance thermometer Tr. Measuring circuit Ws converts the resistance, which is temperature dependent, into an analog voltage Ua which is coverted into a digital code by analog-digital converter ACP, and displays data a on indicator In. Accuracy and inertiaof measuring and analog-digital circuits can be ignore..

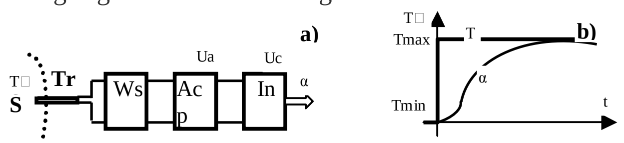

Fig. 1. Block diagram of the direct measurement of temperature (a), a typical transfer characteristic of a jump-like change in temperature T (b).

Fig. 1b shows a typical relation of displayed data a of the measuring device in case of jump-like temperature's changes (with immersion of the thermometer into hot environment). Note that the dynamics of displayed data depends not only on sensor's heat-electrical parameters, but also on the type of environment (air, water, metal) and its state (calm, agitaed, turbulent).

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A common method of compensation of dynamic errors in measuring temperature is correction of data using known parameters of the transient response of a measuring device.

The essence of the correction is in measuring experimentally the transient response of the measuring device in a given environment and conditions. Transient response can be represented as a relation in form of simple differential equation of a given order.

$$\frac{d^n a}{dt^n}+a_{n-1}\frac{d^{n-1}a}{dt^{n-1}}+\dots+a_1\cdot\frac{da}{dt}+a_0\cdot a=b_n\cdot\frac{d^n T}{dt^n}+b_{n-1}\cdot\frac{d^{n-1}T}{dt^{n-1}}+\dots+b_1\cdot\frac{dT}{dt}+b_0\cdot T \quad (1)$$

The order n and coefficients a, b of the relation (1) can be determined using a known transient response fig.1b. Now the inverse problem can be solved– using data a and by integrating equation using numerical method, the corrected temperature of researched can be determined:

$$b_n\cdot\frac{d^n T}{dt^n}+b_{n-1}\cdot\frac{d^{n-1}T}{dt^{n-1}}+\dots+b_1\cdot\frac{dT}{dt}+b_0\cdot T=\frac{d^n a}{dt^n}+a_{n-1}\frac{d^{n-1}a}{dt^{n-1}}+\dots+a_1\cdot\frac{da}{dt}+a_0\cdot a \quad (2)$$

The diagram of the measuring device is shown in Fig. 2a. In the measuring diagram data from the sensor a,b are entered in the memory of the processor $\Pr$, which adjusts data of measuring circuit using progamming method. The uncorrected index a and corrected index ak are displayed on the display In.

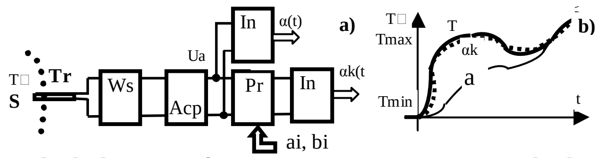

Fig. 2. Block diagram of temperature measurement with the correction of dynamic errors of the transient response of the device (a), temperature change T, and the indicator shows a and corrected shows ak (b).

Disadvantage of data correction of measuring system by parameters of the transient response is the system's adaptability to measuring only with a given sensor in a given environment and its conditions.

In measuring system is more appropriate to adjust separately the parameters of the sensor, which is reversible thermoelectric converter and can be described by mathematical model in operator form.

$$\begin{vmatrix} Q1(p) \\ T1(p) \end{vmatrix} = \begin{vmatrix} A11(p) & A12(p) \\ A21(p) & A22(p) \end{vmatrix} \cdot \begin{vmatrix} Q2(p) \\ U2(p) \end{vmatrix} \quad (3)$$

and separately by the thermal parameter of the enviroment Rsk, which is the thermal (heat) resistance of transmissin between the environment and sensor enclousure :

$$Q1 = Rsk \cdot Ts \quad (4)$$

here: $T1$, $Q1$ - temperature and heat flow from the enviroment S to the thermometer; $U2$, $Q2$ - data from the sensor and the heat flow that is put to the resistance thermometer by the measuring circuit. The overheating of the thermometer's element caused by current in the element is ignored. Having the parameters of the sensor Aij and of the enviroment Rsk, we can make the correction of data from measuring device's data.

$$a_k(A_{ij}, R_{SK,}\, t) \qquad (5)$$

In addition, we have more convenient method of dynamic error's correction. That's why, with this type of sensor, we determine its own A-parameters that are not dependent of the environment and its conditions. Therefore, when changing the environment or its conditions, only one parameter Rsk needs to be changed when measuring temperature in specific environment and its conditions, enviroment parameter Rsk. In measurement device it is now expected that the sensor's parameters A will input into processor's memory t Pr and parameter Rsk when measuring temperature in specific environment and its conditions.

Fig. 3a shows a method of identifying resistance thermometer parameters , the influence of environment (water, metal). Jump-like temperature's change in is formed by inserting sensor into heated or cooled environment. Simultaneously, using low-inertia thermometers Tk and To, as a thermocouple or thermoresistance, we measure temperature of thermometers enclouser T by thermometer Tk and enviroment temperature by thermometer To.

Thermometer's connectors are connected to measuring circuits W_S, output data from which is transfered to computer through the analog-digital converters ACP, where the data is processed by software and then entered into measuring device. In studying sensor's own parameters they are identified by its influence on elemet Fig. 3 b. Current of overheating I_2 is sent to the thermometer's resistance (which allows to calculate the heat flow submitted to element) and temperature change on the sensor encloser Tk and output voltage $U2$ is registred . As a resalt of both experiments all sensors parameters are identified. These data are changed only in the case sensor replacement. The accuracy of identification is checked in the same experiments by chaoticly changing of ambient temperature, by adding hot or cold substance to the dish. Then , the test of matching of corrected data of researched thermometer T and low-inertia thermometer To is conducted.

Thus in the laboratory conditions we can identify native parameters of a sensor as a reversible thermoelectric converter that will not change in the future, and in the process, shall be entered only the measurement of the environment's parameter that is defined by a simple method of measuring device by inserting a sensor in the studied enviroment and change of the parameter Rsk allows to reach the best correction of the temperature jump.

Figure 4 shows the results of temperature measurements of the thermometer TSP V4T3 in the case jump-like and chaotic change in water temperature without the correction and with correction of measured data

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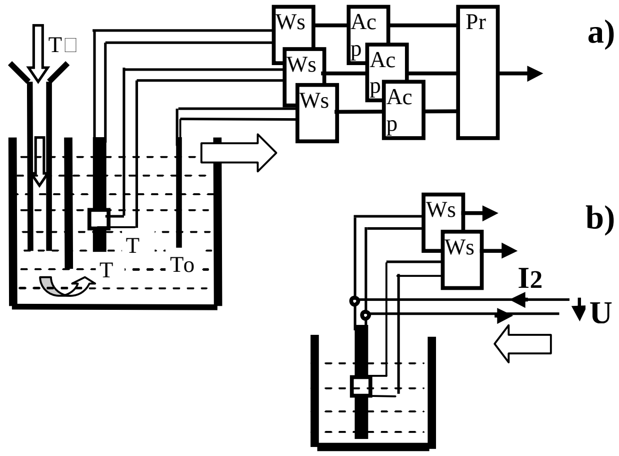

Fig. 3. Measurements using resistancen thermometers, according to to influence on enclosure(a) and on the sensor element (b).

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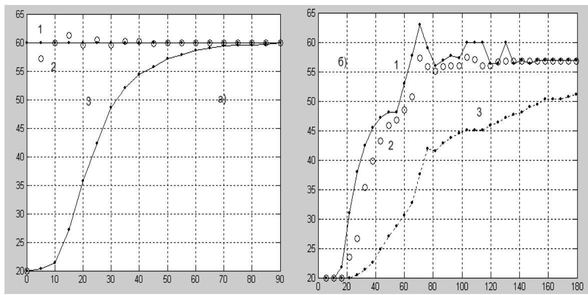

Fig. 4 The results of the research thermometer V4T3 on the temperature jump from 20 to 60 º C (a) and some change of temperature (b).

III. Conclusion

Studies have shown that the method of correction of errors of thermometers with separated parameters of sensors and environment which is more universal than correction with parameters of the transient response. This method opens an opportunity to make correction of static and dynamic errors of the thermometer due to sensor aging, impact of line resistance, non linear parameters of the sensor elements e.t.c. This technique enables to ask questions about building intelligent measuring system with possibility of measurements in different conditions.

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