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STRUCTURAL-ALGORITHMIC METHODS FOR AUTOCALIBRATION OF THERMOELECTRIC MEASURING CHANNEL TEMPERATURE UNDER THEIR USE

The method of autocalibration (complete calibration) of measuring channels thermoelectric (TEC) temperature in the conditions of use. According metodu formed successively calibrated additive and multiplicative electrothermal effects directly on the working end of the primary converter (PP) TEC. Logged additional observations Output enable DEC to determine the formula temperature controlled facility as close to the actual value due to its auto-progressive errors of both PP and secondary conversion units TEC and find an amendment that is automatically entered in the results of current measurements of temperature.

Keywords: thermoelectric converter temperature drift calibration performance, structural and temporal redundancy measurement conversions, auto- additive and multiplicative errors , the accuracy of the method of auto-calibration .

Introduction

In many industrial sectors such as Ukraine thermal and nuclear power , machine , instrument , medicine , food, agriculture , etc. to control the temperature settings of various thermal processes (TP) are widely used as analog and digital channels measuring the thermoelectric (TEC) that are part of multi-functional automated systems for managing these processes. The high efficiency and Energy-saving modern technology associated with maintenance of optimal regimes of strong heat-power equipment, thermal processing of various substances and materials , etc. fully and directly dependent on the metrological reliability of measuring temperature , and in particular the TEC , which refers to capacity measuring device to store the normalized precision not only in inter-verification interval , but for a longer time of operation. According to statistics [1,2,3,4] error TEC under various destabilizing factors (aggressiveness controlled environment , high temperature , etc.) for inter-verification interval can greatly exceed the permissible value. The main sources of measurement errors are relatively fast temperature calibration drift characteristics (GC) primary thermoelectric converter (TEC), change the conversion factor and zero drift TEC secondary links , as well as the effect on them of various destabilizing influential variables. At the same time of the next periodic verification TEC is quite complicated and inefficient procedure that provides for mandatory dismantling of TEP installation location for technological equipment to replace or perehraduyuvannya in the laboratory. A need for metrological studies of secondary transducers TEC requires a lot of time and usually results in many cases is not desirable to stop the continuous thermal processes. The disadvantage of this method of calibration TEC element is also significant uncertainty in mathematical models of the resulting measurement error , due to the lack of experimental data on the systematic errors that arise as a result of DEC various external destabilizing factors.

In view of the above difficulties of unit testing procedures TEC and the resulting uncertainty for its error in article discusses an alternative method of auto-calibration or calibration complete TEC directly in terms of their operation. The high efficiency of the method , the possibility of progressive auto- TEC errors in real time enables increased metrological reliability TEC while the thermal efficiency of modern AFL and high quality of products.

The method of auto-calibration of thermoelectric temperature measurement channels

The method of auto-calibration by using built- in TMC structure means forming additive and multiplicative calibrated electro influences on your end TEP directly in operation. Consistent implementation of these influences over time smaller than the thermal inertia of the controlled object , in accordance with the proposed algorithm of the TEC , makes it possible on the basis of the results obtained additional observations of output signals TEC determined from the formula mentioned temperature controlled facility as close as possible to its actual value . This is achieved by algorithmic not only progressive auto- TEP error caused by relatively rapid drift and non-linearity of its GC, zero drift and change the conversion factor of the secondary measurement units TEC , but also as a result of additional error in the TEC in operation of various destabilizing influential variables.

Block diagram of the microprocessor TEC auto-calibration is presented in Figure 1, a block diagram of the algorithm of its operation is shown in Figure 2. The method of auto-calibration TEC is as follows. Working late TIC TEC is in a controlled environment, temperature is in the range ($T_{xmin} \div T_{xmax}$) should be measured . Three loose ends TEP placed in box 4 of constant temperature maintenance . Switch 5 enables perekomutatsiyu free ends and thus form two versions of TEP with one common electrode , ie, 1.1-1.2 and 1.1-1.3 . During the commissioning process objects to carry out initial calibration of the TEC at a certain temperature TC of choice from the equation :

$$T_K = \sqrt{T_{x\max} \cdot T_{x\min}} \qquad (1)$$

Transform using ATSP7 thermoelectric power (rubbed) on the output TEP (electrodes 1.1-1.2) into digital code

$$N_1^{'} = S(\varepsilon_{n1} T_K - \varepsilon_{01} T_0), \qquad (2)$$

where S - slope characteristics ATSP7 ; $\varepsilon_{п1}$, the initial value of the thermoelectric coefficient of the working end of primary TEP (1.1-1.2) at a temperature Tc calibration ; ε_{01} - free thermoelectric coefficient over the temperature TEP So who is actually for a long time of operation is determined by the DEC and GC TIC .

Digital code rubbed the free ends of TEA (1.1-1.2) is determined by the ratio

$$N_{01} = S\varepsilon_{01} T_0 = S\varepsilon_{n1} T_K - N_1^{'} \ . \qquad (3)$$

From equation (3) we obtain an expression for the initial value of the thermoelectric coefficient of the working end of the TEP (1.1-1.2)

$$\varepsilon_{П1} = \frac{N_{01} + N_1^{'}}{ST_K} \ . \qquad (4)$$

Digital codes $N_1^{'}$ та N_{01} record and remember . Then change the sensitivity of TEP by connecting it to the working end , instead of the main electrode 1.2, the consistency of him 1.3 electrode , which is made so that the thermoelectric coefficient him "hot" end K1 = 0,9-0,95 times less working of thermoelectric coefficient end of the electrode is 1.2. This performance electrode 1.3 is achieved , for example, artificial aging of its " hot" end. Changing the sensitivity of TEP results in reduction rubbed his output digital code which will make a difference :

$$N_2^{'} = S(\varepsilon_{n2} T_K - \varepsilon_{01} T_0) = S\left[\varepsilon_{n1}(1 - \frac{\Delta\varepsilon^{'}}{\varepsilon_{n1}})T_K - \varepsilon_{01} T_0\right] = S(\varepsilon_{n1} K_1 T_K - \varepsilon_{01} T_0)\,, \qquad (5)$$

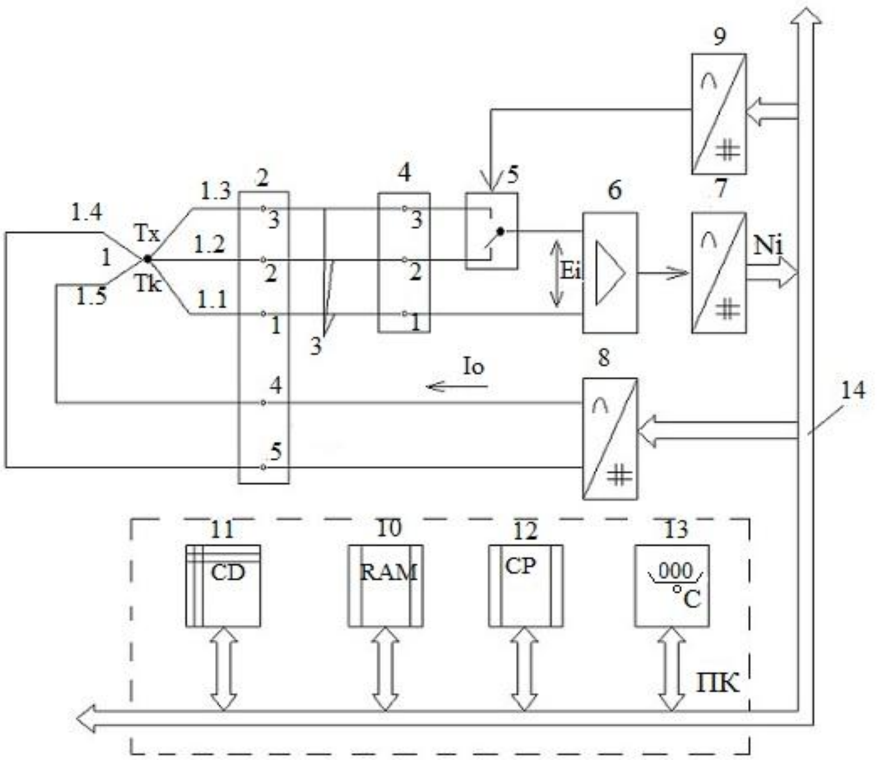

Figure 1. Block diagram of the microprocessor thermoelectric temperature measurement channel with auto-calibration :

T_x - temperature-controlled facility ; T_k - known temperature value of TEP working late in the primary calibration of the TEC , 1 - double TEP with measuring electrode and an additional electrode 1.1,1.2 1.3 , 1.4 and 1.5 - electrodes that are used for electro additive effect on the working end of the TEP 2 - TEP terminal block , 3 - wire extension compensation , 4 - box stabilize or compensate for changes in temperature of the free ends of TEA , 5 - managed switch , 6 - normalizing signal amplifier TEP ; 7 - analog-to- digital converter (ADC) 8.9 - digital to Analog Converters DC (DAC) 10 - block RAM , 11 - control unit 12 - computing device 13 - digital display of temperature controlled Tx; 14 - Common Bus PC computer.

where ε_{n2} - sensitivity coefficient working end formed TEP (electrodes 1.1-1.3); $\Delta\varepsilon^{'} = (\varepsilon_{n1} - \varepsilon_{n2})$.

The resulting code $N_2^{'}$ is recorded and stored. Go to the measuring circuit is connected instead of an additional electrode (1.3), the main electrode (1.2). This initial calibration procedure TEC before any long-term operation is completed.

In the implementation of auto-calibration procedure TEC during its operation initially receive a digital code TEP , which corresponds to a controlled temperature T_x :

$$N_1^{''} = S\left[(\varepsilon_{n1} + \Delta\varepsilon_{x1})T_x + \Delta e_1 - \Delta\varepsilon_{01}T_0\right], \quad (6)$$

where $\Delta\varepsilon_{x1}$ - uncontrolled change of the thermoelectric coefficient TEP working end because of his progressive physical degradation and due to differences in temperature T_x initial temperature calibration TEC ; Δe_1 -additive component of the informative signal is due, firstly, because of the emergence of parasitic rubbed structural heterogeneity electrodes TEP on their length and the imposition on them of gradient temperature field and , secondly , - zero drift amplifier 6.

Digital code $N_1^{''}$ record and memorize the PC . In view of (3) digital code (6) can be written as :

$$N_1^{''} = S\varepsilon_{n1}T_x + S\Delta\varepsilon_{x1}T_x + S\Delta e_1 - S\varepsilon_{01}T_0 = S\varepsilon_{n1}T_x + \Delta N_1 + \Delta N_2 - N_{01}, \quad (7)$$

where $\Delta N_1 = S\Delta\varepsilon_{x1}T_x$–multiplicative measurement error in the digital code to change the sensitivity of the working end of the TEP ; $\Delta N_2 = S\Delta e_1$–additive measurement error in digital code, due to the development of heterogeneity electrodes TEP and zero drift amplifier 6.

From the expression (7) implies that the actual value of the temperature controlled can be determined as follows :

$$T_x = \frac{N_1^{"} + N_{01} - \Delta N_1 - \Delta N_2}{S\varepsilon_{n1}}. \quad (8)$$

Measurement error and ΔN_1 та ΔN_2 nevidomi and their influence on the outcome determine the temperature can be reduced by entering offsetting adjustments that have the opposite sign to the signs of error. To find the corrections measured rubbed TEA (1.1-1.3) formed with an optional third electrode (1.3) by perekomutatsiyi free ends of TEP . Digital code at the free end of TEP (1.1-1.3) will make a difference :

$$N_2^{"} = S\left[(\varepsilon_{n1} + \Delta\varepsilon_{x2})T_x + \Delta e_2 - \varepsilon_{01}T_0\right] = S\left[(\varepsilon_{n1} + \Delta\varepsilon_{x1})T_x K_2 + \Delta e_2 - \varepsilon_{01}T_0\right], \quad (9)$$

where $K_2 = \left(1 - \frac{\Delta\varepsilon^{"}}{\varepsilon_{n1} + \Delta\varepsilon_{x1}}\right)$; $\Delta\varepsilon^{"} = (\varepsilon_{n1} + \Delta\varepsilon_{x1}) - (\varepsilon_{n2} + \Delta\varepsilon_{x2})$, $\Delta\varepsilon_{x2}$ changing thermoelectric coefficient of the working end TEP (1.1-1.3).

In this case, given that the conditions of physical degradation of the working parts of TEP (1.1-1.3) and (1.1-1.2) are almost identical, one could argue that $\Delta\varepsilon_{x1} = \Delta\varepsilon_{x2}$. Digital code $N_2^{"}$ record and remember in PK. So in accordance with TEC calibration algorithm additionally heated working end TEP using a thermoelectric Peltier effect [5]. To this end through working TEP (1.1-1.3) using the second pair of electrodes 1.4 and 1.5 TEP double pass within a certain time t optimal DC I_0 some direction . The temperature of the working end of the TEP increased by an amount $\Delta T = 4 - 5^o C$. The digital code values rubbed on the free ends of TEA (1.1-1.3) will value:

$$N_3^{"} = S\left[(\varepsilon_{n1} + \Delta\varepsilon_{x1})(T_x + \Delta T)K_2 + \Delta e_2 - \varepsilon_{01}T_0\right], \quad (10)$$

where $\Delta T = \frac{\Pi I_0}{cm} n\tau$ - overheating of the working end TEP relatively temperature -controlled facility , P - Peltier coefficient of the working end of the TEP ; c and m averaged mass and specific heat of the working end of the TEP ; $t = n\tau -$ heating time working end TEP ; $\tau -$ heat was the working end TEP ; n=(0,1÷ 0,2). Digital code $N_3^{"}$ record and memorize the PC .

After registering and storing digital code $N_3^{"}$ immediately under unites to the working end of the TEP, instead of an additional electrode 1.3 1.2 main electrode , thus restoring the initial value sensitivity TEP $(\varepsilon_{n1} + \Delta\varepsilon_{x1})$, to afford the corresponding value of the digital code rubbed on the free ends of the TEP .

$$N_4^{"} = S\left[(\varepsilon_{n1} + \Delta\varepsilon_{x1})(T_x + \Delta T) + \Delta e_1 - \varepsilon_{01}T_0\right]. \quad (11)$$

Digital code $N_4^{"}$ also register and zapamyatovuyut . Given that the additive measurement error for the two TEC variations (1.1-1.2) and (1.1-1.3) is the same , one can calculate the fair equality $\Delta e_1 = \Delta e_2 = \Delta e$, which allows using the results of additional observations to determine the corrections additive and multiplicative in error by the formulas:

$$\Delta N_1 = \frac{\left(N_1'' - N_2''\right)\left(N_1 + N_{01}\right)}{\left(N_1' - N_2'\right)} - \frac{T_x}{T_K}\left(N_1' + N_{01}\right); \qquad (12)$$

$$\Delta N_2 = N_1'' + N_{01} - \frac{\left(N_1'' - N_2''\right)\left(N_4'' - N_1''\right)}{\left(N_4'' - N_3''\right) - \left(N_1'' - N_2''\right)}. \qquad (13)$$

Taking into account the obtained values amendments ΔN_1 and ΔN_2 determined the actual value of temperature controlled in accordance with the expression (8) by the formula:

$$T_x = \left[\frac{N_1'' + N_{01}}{N_1' + N_{01}} + \frac{1}{2}\left(\frac{N_1'' - N_2''}{N_1' - N_2'} - M\right)\right] T_K, \qquad (14)$$

where $M = \frac{\left(N_1'' - N_2''\right)\left(N_4'' - N_2''\right)}{\left[\left(N_4'' - N_3''\right) - \left(N_1'' - N_2''\right)\right]\left(N_1' + N_{01}\right)}$ – algorithmic factor.

Block diagram of the algorithm operation TEC temperature with auto-calibration has presented on figure 2.

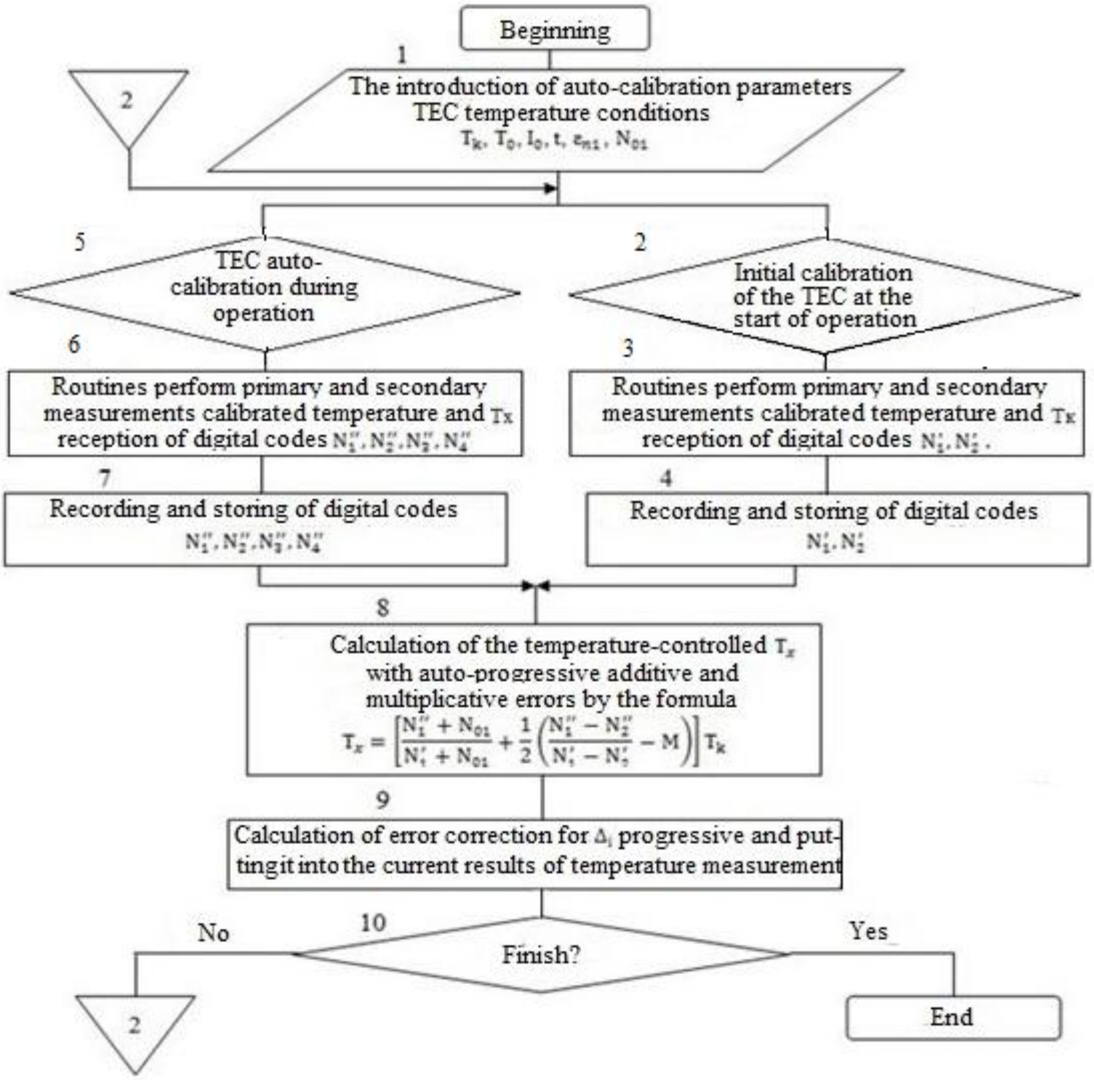

Figure 2 . Block diagram of the algorithm operation TEC temperature with auto-calibration

Conclusions

Consequently, the auto-calibration TEC value obtained by the controlled temperature of the object as close to the real value of which is independent of the nonlinearity and progressive drift GC TEP, zero drift and change coefficient converting amplifier informative signal effect on TEC various destabilizing factors and determined only digital codes results rivnotochnyh measuring change. Accuracy of the method of auto-calibration TEC is mainly determined by the error of forming calibrated electro effects on TEP and is located at $\pm 1{,}0\%$ in a given operating range of measured temperatures . Value adjustments to the current results of temperature measurement is calculated by the formula:

$$\Delta i = T_x - T_{xi} , \tag{15}$$

where T_x - temperature, obtained by the expression (14) during the regular calibration of the TEC; T_{xi} - current result of direct measurement of the temperature until the calibration TEC.

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