10th IMEKO TC7 International Symposium
June 30–July 2, 2004, Saint-Petersburg, Russia

INCREASING OF ACCURACY OF TEMPERATURE MEASUREMENT BY METHOD OF COMPARISON PRIMARY CONVERTERS WITH AMBIGUOUS MEASURE OF RESISTANCE

B.D. Kolpack, V. V. Parakuda, B. M. Lisij, O. S. Sulima

State research institute „Systema", Lvov, Ukraine

Abstract – Methods of raising accuracy of temperature measurement channels of the measurement systems (MS) and computer-aided process control systems (CAPCS) are considered, as well as measurements resistance of thermometers with unified output signal which are the component parts of measurements of temperature for graduations, checks and metrological certifications for resistance of thermometers of MS and CAPCS.

Keywords: significant measure of electric resistance (SMER), regulator of temperature (RT), measuring channel (MC)

BACKGROUND

Increase of exactness of metrology descriptions (MD) of measuring channels (MC) of temperature of the measuring-informative systems (MIS) and automated systems of technological process (ASC TP) control, and also measuring thermometers of resistance with a compatible initial signal, which are component parts of the MC temperature is the actual task of the present. For the increase of exactness of measuring of temperature the exact measuring of electric resistance of termo-transducers with a compatible initial signal is needed.

Due to mushroom growth of the automated checking systems of different technological processes, machines and mechanisms, to introduction of the flexible automated productions there was the necessity of providing of such systems by sensor of different physical sizes, especially by the transformers of temperature. At present in Ukraine, Russia, and also in other countries the is a lot of different types of transformers of temperature are let out (PMV-T- C, T-S, T-V; TSPR-0196-0196; TSM 011, TSMOU 011). In these transformers termo-sensitive elements matter resistance, that do not respond to request GOST 6651-94 [1], and are greater from the values of resistance of present standard thermometers in a few times (500-1000 Ω) with limit of basic absolute error from ± 0,1 ^{O}C to ± 0,5 ^{O}C. Traditional calibration of transformers of resistance foresees the by turn measuring of resistance of explored and standard thermometers by means the ohmmeter. It does not allow with sufficient exactness to define resistance of working thermometer, because measuring are parted in time, that causes changes MD as a result of change of influential sizes between the intervals of measuring. Except for it, using the methods of measuring [2] for example, where the value of resistance of standard measure is multiple a 10 Ω, that brings in in the result of measuring the double error of class of potentiometer from inequality of resistances. It is offered in [3] the method of measuring of resistance of sensible elements by substitution of their resistances by the significant standard measure of resistance, allows to remove these failing, to optimize the process of measuring, and also measure resistance of termo-transducers on which spreads and the state metrology supervision with necessary (even higher) exactness does not spread.

Thus it is necessary once again to mark that on this method find the actual value of resistance of the explored sensible elements and a temperature in the swept volume (to the chamber) by means the control of actual value of resistance of standard thermometer is specified simultaneously. The electric chart of experimental researches is resulted on ris.1. Thus, standard R_{tN} and two working thermometers of resistance R_{tx1} and R_{tx2} chamber with the regulator of temperature (RT), by which 5-6 values of temperature from the range of measuring is standing in turn. Measuring on a chart is carried out by the reserved cycle, that is at every proposed temperature comparator of tension (for example R3003) is counterbalanced at first on R_{tN}, and then with the help of significant measure of electric resistance (SMER) „to a 1" class of exactness 0,02 (for example R4831) counterbalance the shows U_{MO} (inheritance of tension on SMER R4831) and come back on R_{tN} again, controlling the same the stability of currents in the circle of thermometers and measure of resistances. From the results of these measuring the actual value of resistance of sensible element of standard thermometer is found after the known formula (1)

[2-4], in which unlike the classic potentsion method of value of standard measure not multiple 10, and even to the value of resistance of the explored thermometer:

$$R_{tN_1} = R_{MO}\frac{U_{tN}}{U_{MO}}, \qquad (1)$$

where R_{MO} is value of resistance on ten-day switches SMER „1", taken in the moment of balancing by him U_{MO}. or, passing to granitsi of relative error:

$$\delta_{R_{tN}} = \pm(\delta_{R_{Mi}} + \delta_{M3} + \delta_0), \qquad (2)$$

where $\delta_{R_{Mi}}$ = 0,02% for SMER to the type R4831; $\delta_{M3} = \pm 2K\left|\frac{U_{t_{N1}} - U_{Mм}}{U_{Mм}}\right|$ is error of method of substitution; K=0,0005 is class of exactness of comparator of tension; $\delta_0 = \pm\frac{0{,}5\Delta U_K}{U_{Mм}}\cdot 100\%$ is error of counting R3003 out; ΔU_K- a price is the degrees of junior ten-day period R3003.

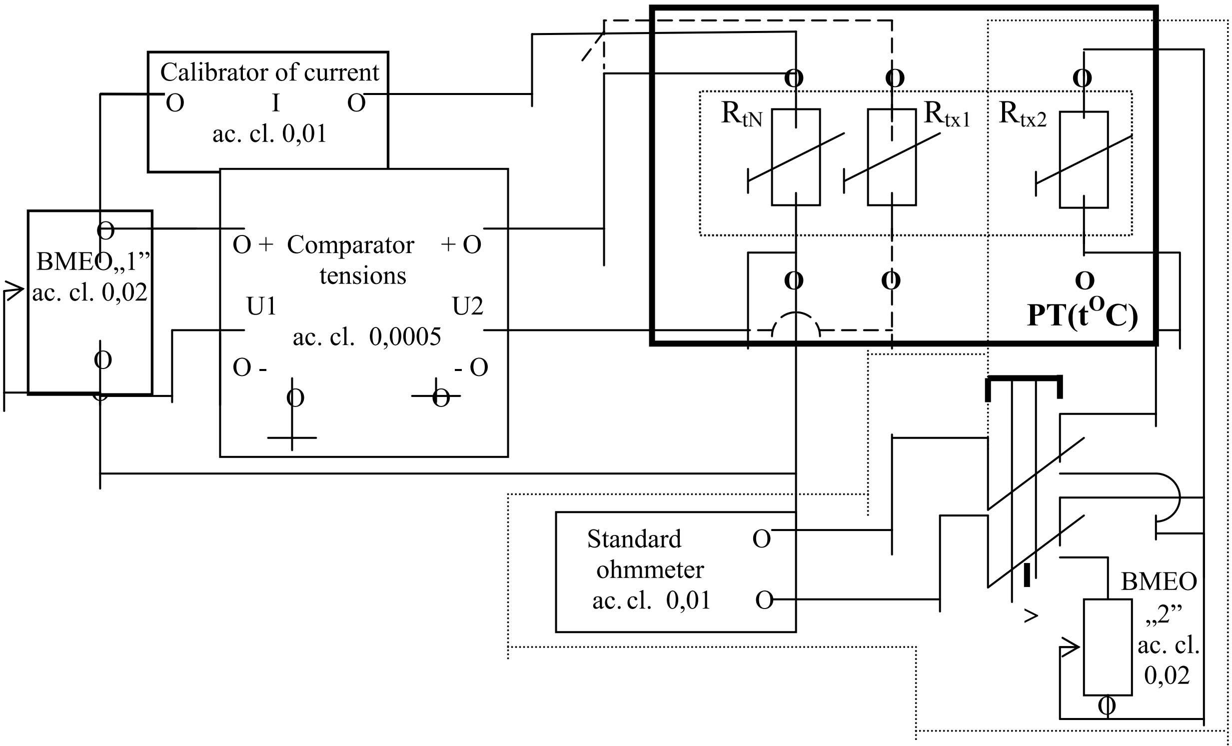


Fig.1

We will estimate component errors $\delta_{R_{tN}}$, taking into account, that limit of measuring of comparator of tensions U_K = 1,11 V, $\Delta U_K = 1\cdot 10^{-7}$ V. We will accept that the regulator of temperature RT sets a temperature with a permissible error ± 1 °S, then R_{MO} will differ from R_{tN} pursuant to table A1 [1] in worst case on a 0,79 Ω, therefore component $\left|\frac{U_{t_{Ni}} - U_{M_1}}{U_{M_1}}\right| \approx 0{,}008$. Consequently, $\delta_{M3} = \pm 0{,}001\cdot 0{,}008 = \pm 8\cdot 10^{-6}$ %, a $2\delta_0 = \pm 1\cdot 10^{-5}$ %, that is this scorning small sizes is comparative with δ_{RM} = ± 0,02%. Thus, it is possible to consider that $R_{tN} = R_{M1}(1 \pm 0{,}0002)$ Ω.

On the basis of found from (1) the values R_{tNi} specify on tabl. A2 [1] actual value of temperature RT in the controlled point.

Then in place of to the shop of resistance connect to comparator of tensions R_{tx1} (on ris.1 it is shown the dotted line), by the whereupon reserved cycle the inheritances of tension U_{tN} and U_{tx1} are measured, what the actual value R_{tx} is determined on the basis of in the controlled points of temperature after a formula

$$R_{tx_1} = R_{tN_1}\frac{U_{tx_1}}{U_{tN_1}}, \qquad (3)$$

where R_{tN1} is meaning resistance of standard thermometer, certain from a formula (1).

On the basis of the values R_{txi}, expected from a formula (3), on tabl. A2 [1] the value of temperature of txi is found, in a chamber, measured by a working thermometer R_{tx1}. Find the absolute error of working thermometer in the controlled points RT as

$$\Delta t_{x_i} = t_{x_i} - t_{N_i}. \qquad (4)$$

In case when, the values of resistance of termo-sensitive elements do not respond to request [1], in [3] two methods were offered, this - "determination of the expected value of resistance of explored termo-transducer" and " appropriations of values of resistance of standard measure of explored termo-transducers" which some differ from considered higher just from their standard, that is from the vidsoutnosti tabbed values of nominal static description (NSD) of transformation. In first case propose by means ten-day switches SMER „1" the value of resistance of explored termo-transducers is expected, then connect to the entrance the "U_1" inheritance of tension on R_{th1} and change of positions of ten-day periods by the "X_1" method of the nine counterbalance comparator of tensions, fixing their show U_{tx1}. Watching for U_{tx1} = const, by the change of positions of ten-day switches SMER „1" counterbalance comparator of tensions in relation to his entrance "U_2," that is the show U_{M1} is got , proportional U_{tx1} = const. The value R_{tx2} is found from a formula similar (1), namely:

$$R_{tx1} = R_M \frac{U_{tx1}}{U_{M1}}. \quad (5)$$

Possibly, that $R_{tx1} \approx 1000\ \Omega$, $U_{tx1} \approx 10$ V, then measuring R_{tx1} and RM is carried out in a range U_k=11,1V comparator of tensions. In such case ΔU_k =1·10-6 and $2\delta_0 = \pm\frac{1\cdot10^{-6}}{10}\cdot100\% = \pm1\cdot10^{-5}\%$, by what it is possible to scorn it is comparative with δ_{Rm} =0,02% (so as $\delta_{RMZ} << 2\delta_0$). Consequently, and for explored $\delta_{Rtx1} \approx \delta_{Rm}$. Like determine R_{tx1} and in other controlled points CP. Mattering pursuant to (5), build for explored R_{tx1} as $R_{tx2} = f(ti)$, that is at first calibrate R_{tx1}. After it limit of absolute error Δ_{t22} transformer R_{tx1} in the controlled points of t_{TKi} find like (4).

Features of method of determination of actual value of resistance of sensible element for the working thermometers of resistance with a compatible initial signal, in which the value of resistance of sensible element is in a few one time greater from resistance of standard thermometer (see the part of lines led around by a stroke line. 1) is following. After determination of temperature in a chamber by a standard thermometer R_{tN}, it is needed to connect to the standard ohmmeter a working thermometer R_{tx2} and measure his value of resistance. Then to disconnect R_{tx2} from a standard ohmmeter by means the switch „R_{tx2}" and to connect the measure of resistance SMER to him „2" and to set by means its ten-day periods the identical shows of standard ohmmeter. Value of resistance SMER „2" accept even to the value of resistance of sensible element of working thermometer. Then it is necessary to define limit (lower, overhead) of absolute error of calibrating of sensible element $\Delta_{CHE(N)\ In}$, to take into account her at determination of total error of the indicated thermometers, that consist of two components - sensible element and electronic part.

For determination of total basic absolute error of explored termo-transducers, which a sensible element and electronic transformer of resistance (ETR) in compatible signals enter in the complement of, it is necessary to disconnect a sensible element from the transformer of resistance and connect SMER in place of him „2", and to the output ETR to connect a standard ohmmeter.

The mean arithmetic values of resistance are certain for every temperature to propose by means the measure of resistances SMER „2" and to conduct measuring of values of analog or code signal (Volt, NART- protokol) by means standard ommeter or PEOM for NART - protokol. The value of initial signal is fixed. The indicated measuring repeat 20 time and determine the values of temperature, measured by means electronic part of transformer, and then find limit of permissible error of initial signal of electronic part $\Delta_{EL.(N)In}$ explored the ETR accordant existent methods. Then the total value of basic absolute error of explored termo-transducers is found in the controlled points after a formula:

$$\Delta t_{Xi} = \pm\ |\Delta_{ЧЕ(Н)В}| + |\Delta_{ЕЛ.(Н)В}|. \quad (6)$$

Calibration of the MC temperature, and also primary sensor without dismantling from the object of control it is possible to conduct by means connecting of significant measure of resistance BMEO at the three by a leading chart in obedience to lines. 2. to the terminals 8-14-15; 9-14-15; 10-14-15; 11-14-15; 12-14-15; 13-14-15 shoe trees H12 TMS - pay a lot of point thermometer of resistance of R_t 100 sensor MRT6, adhering to here the following sequence of implementation of operations of calibration:

- by means phone combination to know about the value of temperature of t_{Xc} presently to time at certain set even petroleums, that is lighted up on the display of the PEOM system TRL/2 and to write down him;
- by means the software to define the amount of submerged individual sensors of suspension points sensor of temperature;
- to disconnect from the X12 TMC-pays by turns on one sensible element, and connect in place of them the significant measure of electric resistance and by means its ten-day switches set the same value of t_{Xc} temperature by turns, that was lighted on a display PEOM, and to write down each time the value of resistance of proposed on SMER;
- after the calculation of mean value of resistance which was set in place of each of the

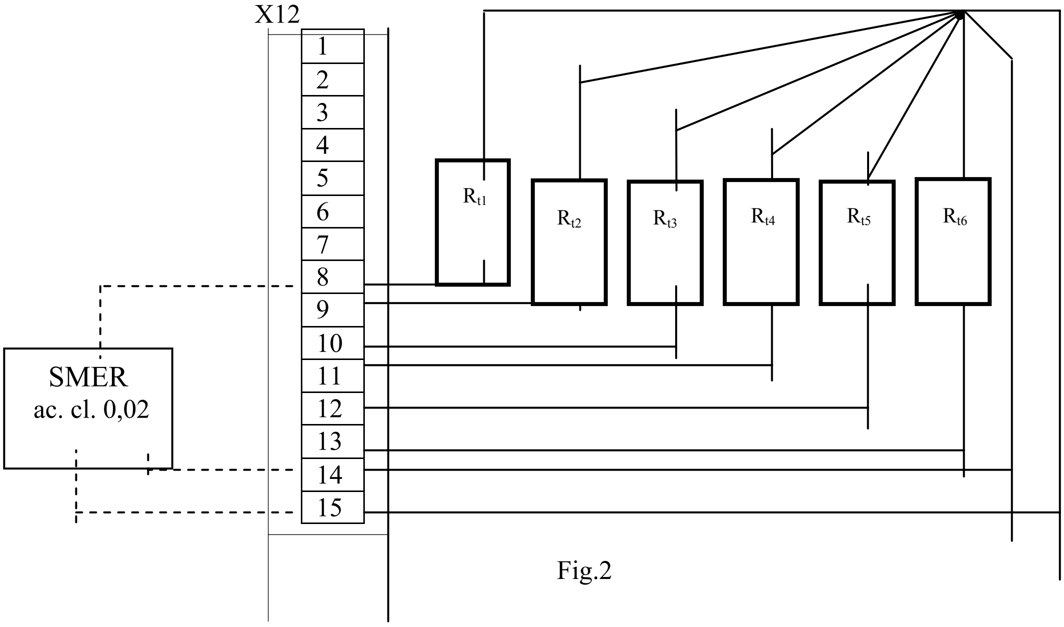


Fig.2

involved sensible elements, to specify the actual value of temperature of t_{Xd} pursuant to table A2 [1]. On the basis of the specified values of t_{Xd} and measured values of t_{Xc} we find the absolute error of the MC temperature.

Like to carry out measuring for all suspension points sensor of temperature (at the fully filled reservoir). In the offered chart of connecting of transformers the repeated sad of individual explorers of combination, which are not taken into account by the developers of the systems and devices, is absent.

Errors Δ_{co} real measuring channels of temperature (object) without mounting transformers it is possible to define applying co-operation of object and standard measures of resistance [2] at the proper co-operation of components in the measuring system. As creating a standard channel object ASC TP is impossible, for conducting of metrology experiments it is created and "standard" mathematical-physical models are applied and test the signals, new calculation-experimental methods [5], by means which the certain controlled points from the range of measuring to the parameter are transformed, are developed. In all these case there are the problems of determination MD MC ASC TP during their metrology attestation (MA) or calibration. Thus in the basis of measuring of these parameters there is determination of the defined value of electric resistance directly, or with subsequent transformation of him in a certain physical size. For determination MD MC it is possible to apply parallel combination resistors taking into account co-operation of object (MIS or ASC TP) and standard significant measure (in this case resistance).

In relation to the theoretical aspects of the given problem it is necessary to mark the following. Taking on an unknown value of the explored resistance, as R_x, and also using the known standard values of degrees of the defined value of resistance R_{et}, accepting, that $R_x = R_{et} + \delta x$. For the case $R_x \approx R_{et}$ and applying parallel combination resistors swims out, that

$$R_{\Sigma} = \frac{R_{ET} \bullet (R_{ET} + \delta_x)}{2 \bullet R_{ET} + \delta_x}\ . \quad (7)$$

And in the case of $R_x \approx nR_{et}$

$$R_{\Sigma} = \frac{n \bullet R_{ET} \bullet (R_{ET} + \delta_x)}{(n+1) \bullet R_{ET} + n \bullet \delta_x}. \quad (8)$$

From here it is possible to find the value δ_x explored degree of electric resistance. In all examples of application of the given method of measuring of correlation of limit of permissible errors of standard measures of degrees δ_{et} and permissible error of the explored degrees of electric resistance δ_{xd} satisfy inequalities must $\delta_{et} \le \delta_{hd} \cdot 1/4$ or $\delta_{et} \le \delta_{hd} \cdot 1/5$, depending on the prevailing constituents of error (systematic or casual).

We will consider possibility of application of the given approach for example for calibration of the MC temperature, in which termo-sensitive elements matter resistance, which respond to request [1]. As chance offers it is necessary to notice that the lane technical decision can be applied for determination of the MD MC temperature, in which termo-sensitive elements matter resistance, that do not respond to request [1]. Taking this approach the actual value of resistance of the explored sensible elements of transformers of temperature is determined, and also by means parallel combination to the sensible element of standard degrees of significant measure of electric resistance of cl. t. 0.02, (for example R4831), other controlled points from the range of measuring of temperature are transformed. The electric chart of experimental researches is resulted on rice. 3.

For determination of the MD MC temperature on be to which with object, after combination in obedience to the chart of ris.3, it is necessary to know about the value of temperature of t_x, presently time, that is lighted up on the display of WA and to write down him. By means SMER the half value of temperature of t_{x2}, which was reflected, is set. After establishment of this value, which is shined on the monitor of operator of WA, the show SMER is written down. On the basis of the proposed values SMER specify on table A2 [1] actual value of temperature of t_x.

On the basis of the specified values of t_{yt} table A2 [5] the absolute error of the VC temperature is found in a point t_{x1}

$$\Delta t_{BKx1} = t_{xi} - t_{yt} \ . \quad (9)$$

Like propose by means SMER tertiary, quarter-litre and etc value of temperature of t_{xi} and find the absolute error of the MC temperature in transformer us controlled Δ_{tBKxi} points which are lighted on the board of AW.

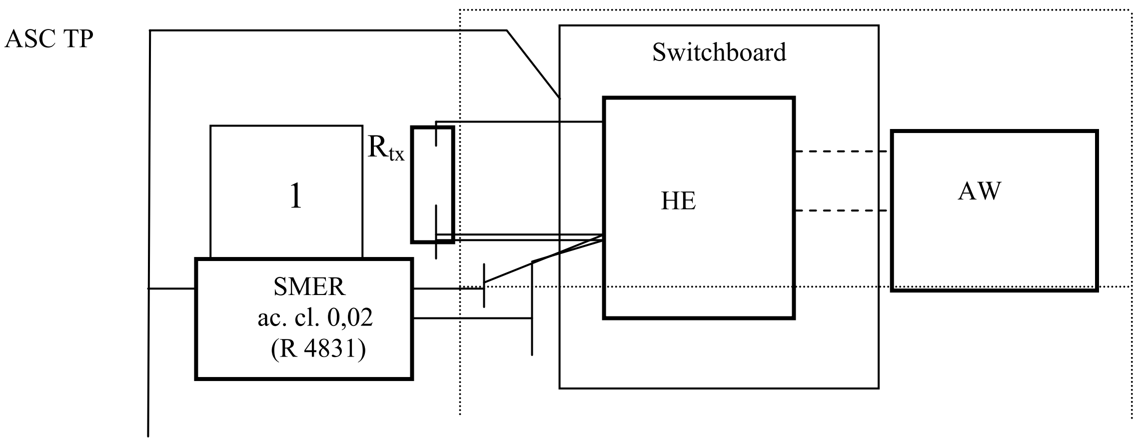
Result Δt_{MCxi} to limit of permissible absolute error Δ_{tBK} in obedience to the certificate about MA or calibration of the MC temperature ASC TP.

This method passed measuring experimental approbation on object to ASC TP of 1-i turn of marine oil transfer complex (MNPC) in the district of Odessa (MNT "South") during DMA VC this system, where one of points of state metrology attestation was conducting of approbation of instruction from calibration of the MC temperature. On the basis of results of experimental approbation limit of absolute error of the MC temperature was found in limit of permissible absolute error in obedience to the requirements of norms of technical document on the system.

CONCLUSION

1. Methods of measuring of resistance of sensible elements by substitution of their resistances by the significant standard measure of resistance allow:

- to promote exactness of measuring of temperature, measuring the value of resistance of sensible elements here, and also to define the actual value of temperature of set in a volume;
- to optimize the process of measuring, and also conduct calibration of termo-transducers on which spreads and the metrology supervision with necessary exactness does not spread;



1-object control of temperature;
R_{tx} –explore thermometer of resistance;
SMER- significant measure of electric resistance, class of exactness 0,02;
HE –highway electrical;
AW – automated workplace.

Fig. 3

- to define limit of absolute error of calibrating of sensible element of explored termo-transducers, also separately to define granitsi of absolute error of the second transformer (electronic part).
- the given methods of measuring allow to define nominal static description of transformation of all types of transformers, to conduct their povircou and metrology attestation.

In the methods described higher, the increase of exactness is achieved for help:

- application of method of substitution of resistances of sensible elements of all types by the termo-transducers significant standard measure of resistance, that enables exactly to measure the value of resistance of sensible elements with the removal of double error of class of exactness of potentiometer.

2. The described methods of measuring allow to conduct calibration of MC MIS and ASC TP temperature in working terms and without dismantling of primary transformers from the object of control.

3. As a result of application of co-operation of object and standard measures of resistance the controlled points transformed with the known exactness turn out from the range of measuring of temperature of measuring channel of MIS or ASC TP., that it is necessary for determination of metrology descriptions of many types MC.

REFERENCES

[1] GOST 6651-94.Termo-transducer of resistance. General technical requirements and methods of tests.

[2] GOST 8.461-82 Termopreobrazovateli soprotivleniya. Metodi I sredstva poverki.

[3] Lisij B., Kolpak B. Increase exactness of measuring of electric resistance of different types of termo-transducer of resistance // Measuring technique and metrologiya. – N 59. – 2002. – P. 37-41.

[4] Electric measuring of sizes electric and unelectric/ After red. E. S. Polishouca// Kiev, “High school," 1978. – 335 pp.

[5] B.D. Kolpak, B.M. Lisij, V.V. Parakuda. Influence of co-operation of objecta and standard measures of resistance on determination of metrological descriptions of the automated checking systems and management. In Technique measuring and calculable in technological processes. – Khmelnitskij, №3, 2001.- P. 190-192.