A Method For Testing the Quality of Cable Thermocouple Junction

A.V. Karzhavin, A.V. Belevtsev, A.A. Ulanowsky

Industrial company "TESEY", Obninsk, Russia

Abstract. A method for revealing technological defects in the hot junction of a cable thermocouple is proposed. Disadvantages of existing (traditional) methods are considered. The method proposed is based on Peltier effect inside a thermocouple junction. The method is implemented for outlet quality control during cable thermocouples production.

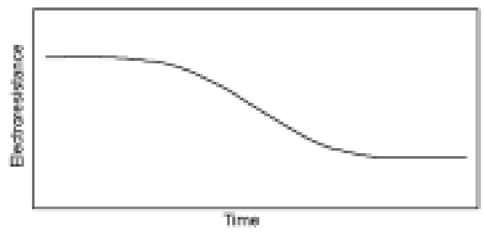
INTRODUCTION

Hot junction defects of a thermocouple are micro cracks, pores, fistulas, wire thinning and non-welded areas. Enumerated defects results to earlier destruction of a thermocouple junction, especially by the influence of heatstroke and thermocouple exploitation in thermal cycling conditions.

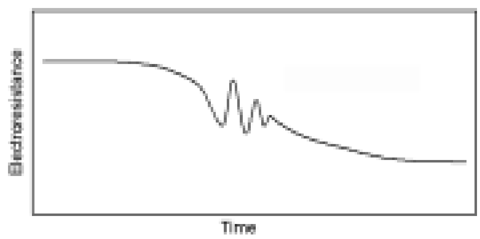
A few traditional methods for the hot junction defects revealing are known. They are outward inspection, inspection with the help of optical instruments; Roentgen radioscopy; testing by means of heat strokes. However, none of them will show you total imagination about the presence and quantity of the defects. The outward inspection including inspection with optical instruments allows finding out only surface defects of the junction.

Roentgen radioscopy reveals micro cracks inside the junction and the depth of wires melting. However, complete imagination of the junction structure and wire structure near the junction can be got by means of X-rays examination only at 5 to 10-fold magnification in condition of the fact that the pictures were exposed in 3 – 4 directions. X – rays examination demands a lot of time, special equipment and rooms to test thermocouples serially produced.

Junction defects revealing by means of heat strokes consists in thermocouple junction heating and exposing at the temperature of 400°C during 5 min followed by sharp cooling in water. Sensual device records the electric resistance changing of the thermocouple wires. Resistance value changing is not monotonous if the defects are present. The peaks appear on the curve that is shown in Fig. 1.



Good junction



Defective junction

FIGURE 1. Electric Resistance Changing in Time under Sharp Cooling of a Thermocouple.

The peaks arising can be explained by the sharp changing of junction electric resistance because of micro cracks appearing or widening. As a rule, 2-3 heat strokes are needed to confirm the defects presence. Total time to exam a thermocouple with heat strokes can reach 30-40 min. Except for much time spending, heat strokes influence may results to changing of thermocouple calibration. The change value depends on thermocouple cooling rate and the number of heat strokes fulfilled.

Complexity and long duration of the methods considered result to the situation when junction quality testing under thermocouples production, in practice, is limited only by visual and optical controls.

DESCRIPTION OF THE METHOD

The offering method for technological defects detection inside a thermocouple junction [2] bases on using Peltier's effect. This effect consists in heat release or heat absorption in the junction consisted of various metals or semiconductors when constant electric current passes through the junction.

Different types of hot junction defects are presented in Fig. 2. They are:
- non-welded wires;
- welded junction thinning;
- microcracks and pores in welded zone of a junction.

All of them result to increasing of the junction electric resistance.

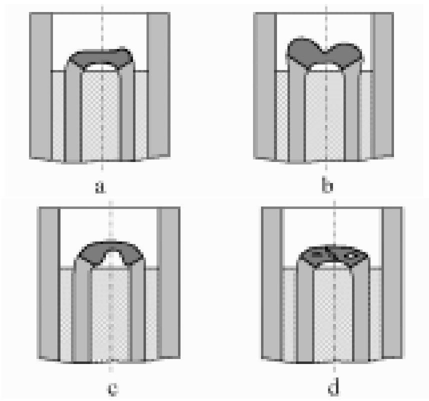


FIGURE 2. Possible Defects in Hot Junction Zone: a – without defects; b –non-welded wires; c – welded junction thinning; d – micro cracks and pores in welded zone of a junction.

Three heat transfer processes take place simultaneously in the hot junction while reverse polarity current passing through the thermocouple (positive current source lead is connected with negative thermoelement):
- heat absorption due to Peltier's effect;
- heat release due to resistance heating of the junction;
- heat transfer to or out of the hot junction zone through thermoelements.

Heat amount, absorbed in hot junction:

$$Q_P = IP\tau \ , \quad \text{where:}$$

Q_P is Peltier's heat value, Joules;
I is electric current value in a chain, Amperes;
P is Peltier coefficient for the couple of conductors;
τ is the time of current passing, seconds.

The current passing through the thermocouple wires results to resistance heating of the junction. The heat value released in the junction is determined by the formula:

$$Q_J = I^2\tau R \ , \quad \text{where:}$$

Q_J is Joule heat, Joules;
R is resistance value of junction zone itself, Ohm.

The heat input (or rejected heat) through the thermoelements depends on direction and value of temperature gradient along the thermoelements within the zone nearest to junction:

$$Q_\lambda = (\lambda / \delta)\Delta TS \ , \quad \text{where:}$$

Q_λ is the heat amount transferred to or out of the junction by means of thermal conductivity, Joules;
λ is thermal conductivity coefficient for material of thermoelements, Wt/mK;
δ is the distance between the source of heat release and the junction, m;
ΔT is temperature difference within the junction zone, K;
S is the cross section of thermoelements, m^2.

The total heat release in junction zone is determined with the sum of three components Q_P, Q_J, Q_λ and the sum may be more or less zero (Fig. 3).

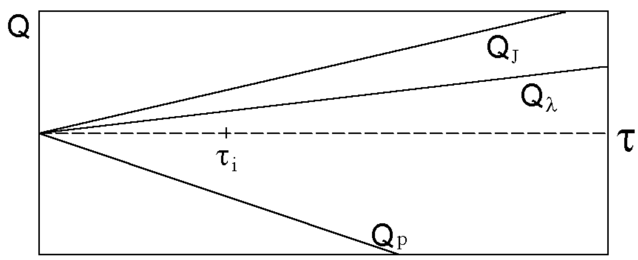


FIGURE 3. Three Components of Heat Transfer Process in a Thermocouple Hot Junction.

For a certainly good cable thermocouple that have been checked with all accessible methods it is possible to select the nominal current value “I_n” and the current pulse longitude τ_i, so that the total heat release in the junction would be equal zero at the moment of time τ_2 – moment of current switching off. In table 1 some I_n and τ_2 values are given for cable thermocouples of K-type in dependence of outer diameter value.

TABLE 1. Nominal Values of Testing Current Pulse for K-type Cable Thermocouples.

Cable Diameter, mm	Thermo-Elements Diameter, mm	Nominal Values of Current Pulse	
		Amlitude, A	Longitude, s
3,0	0,65	1,4	0,4
4,0	0,85	2,0	0,4
5,0	0,90	2,5	0,4

The method is realized by the following manner. The thermocouple tested is connected through a switchboard to measuring device – oscillograph. Thermal EMF signal of the thermocouple E_1 is detected. At the moment of time τ_1 (see Fig.4a) the thermocouple is switched to the power supply of constant electric current. During the time $\tau_i=\tau_2-\tau_1$ electric current passes through the thermocouple at a nominal value I_n. At the moment of time τ_2 the thermocouple is switched again to the oscillograph and the EMF value registered again (E_2).

If the thermocouple junction has not any defects EMF value E_2 at the moment of current switching off would not differ from E_1 value. Oscillogram of the process with nominal current value and pulse longitude is shown in Fig.4a for good junction.

As it has been indicated before, the presence of a technological defect in a junction results to increasing of the junction resistance. Therefore, after the nominal current pulse passing (with I_n and τ_i values) through a defective junction Joule’s heat will be increased in the junction. The total heat release in the junction Q_J and Q_λ will exceed the amount of Peltier heat absorbed in the junction. So, if we have defective thermocouple junction the EMF value E_2 registered after the current pulse switching off will be greater than E_1 value registered before current passing. If the (E_2-E_1) difference exceeds the uncertainty of EMF measuring we can confirm the presence of junction defects. Oscillogram of the process with the nominal current pulse is shown in Fig. 4b for defective junction.

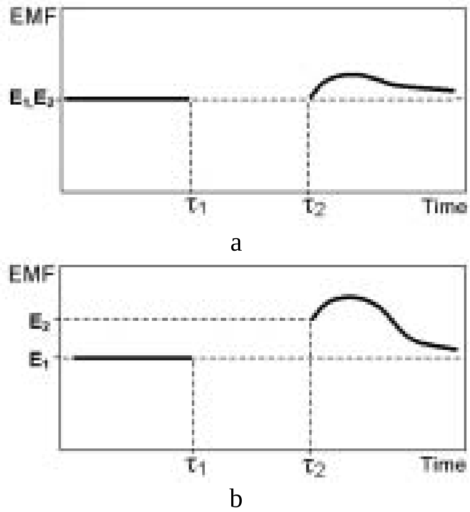


FIGURE 4. The Diagram of Transient Process of Thermal EMF for Good (a) and Defective (b) Hot Junctions. τ_1 and τ_2 are the moments of time for current switching on and off. $\tau_i = \tau_2 - \tau_1$ is a longitude of current pulse.

CONCLUSIONS

Thus, it is possible to select the nominal characteristics of current pulse (longitude value and amplitude) for any thermoelement diameters of a cable thermocouple so that the total heat released and absorbed in a good junction while the pulse passing would be equal zero. That can be confirmed by the absence of temperature increasing in the thermocouple hot junction. Any technological defect of the junction increases the junction resistance and violates the heat balance through the growth of Joule’s heat while nominal current pulse passing. This fact will result to the temperature increase in the junction at the moment of time when current pulse has been switched off.

During five years the method described is implemented under the output control of cable thermocouples production at Industrial Company “TESEY”, Ltd. Russian Federation patent (No.2093926) protects the method, the patent priority is April 16, 1996.

REFERENCES

1. Reference book, *The temperature measurings,* edited by V.I.Geraschenko, Kiev: Naukova dumka, 1984.

2. Karzhavin A.V., and Kasatkin A.A., *Russia Patent No.2093926*, Moscow: Inventions bulletin, No.18, 2001