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INFLUENCE OF A MEASUREMENT UNCERTAINTY OF A COLD JUNCTION IN TESTING OF HEATING

Gaber Begeš, Valentin Batagelj, Igor Pušnik

University of Ljubljana, Faculty of Electrical Engineering, Laboratory of Metrology and Quality, Tržaška 25, Ljubljana, Slovenia

Abstract – Testing of safety of electrical appliances is very important for assuring of safety of users. One of the safety tests is testing of heating of appliances and their surrounding. The test is performed in a measurement system so called "black test corner", which is partially standardised. Measurement of heating is performed with thermocouples. This paper describes the analysis of the influence of the measurement uncertainty of a cold junction of a thermocouple in testing of heating. Heating of appliances is measured as a difference between the temperature of the appliance and the temperature of the surrounding. If the cold junction of a thermocouple is exposed to temperature of the surrounding the thermocouples measure the heating and not the absolute temperature. The measurement uncertainty and the temperature value of the cold junction must be known for proper measurement and uncertainty evaluation.

Keywords: testing, cold junction, heating.

1. INTRODUCTION

In the field of testing of safety of household appliances standard SIST EN 60335-1 (adopted European standard EN 60335-1), with all amendments is considered. The European standard EN 60335-1, [1] was accepted by the European committee for standardisation in the field of electrotechnics CENELEC. The standard acknowledges the international level of a danger protection and includes fundamental safety requirements of the following directives: Low voltage directive 73/23/EEC [2], Machinery directive 89/392/EEC, Construction product directive 89/106/EEC. One of safety tests described in the standard is testing of heating of household appliances. The test is performed in a measurement system so called "black test corner". Standard defines only basic requirements for the measurement system. In our laboratory we developed a measurement system with automatic measurement of heating of the whole surface of the black test corner. The short introduction of the measurement system and potential problems with cold junctions are described in the paper. Also calibration data and importance of the measurement uncertainty of cold junctions are presented.

2. THE MEASUREMENT SYSTEM

The main guidance in the development of a measurement set-up for measuring of heating of electrical appliances (Figure 1) was that the set-up shall be compatible for all appliances and its maintenance as well as traceability shall be assured.

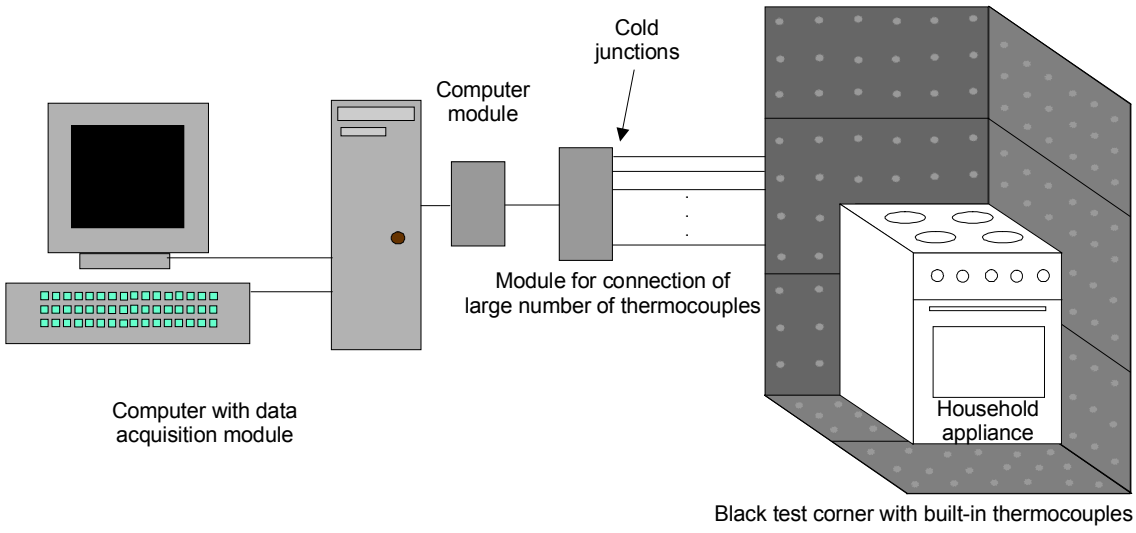

Fig.1. Developed measuring system for measuring of heating of household electrical appliances

In the assessment of a testing laboratory, according to SIST EN ISO/IEC 17025, [2], traceability of all equipment is required. Figure 1 shows the suggested measurement set-up, which analysed and calibrated. The black test corner is partitioned to more units – measuring plates, which can be combined. Each plate contains 60 thermocouples. Border thermocouples are built-in at a half distance from the end of the measurement plate as it is between the thermocouples. Thermocouples are made of Fe-CuNi wire (type J) with 0,2 mm diameter. A thermocouple is soldered to a cooper disk. A diameter of the disk is 15 mm and a thickness is 1 mm. For fixation of thermocouples high temperature resistant silicon mastic was used. Thermocouples are connected to the "module for connection of large number of thermocouples". This new module enables data acquisition of 720 inputs in a very short time and the developed software demonstrate the results of the measurement in numerical, graphical or colour-scaled way. At the point where thermocouples are connected to the module are cold junctions of thermocouples, which are essential element of this paper.

3. CALIBRATION OF THE MEASUREMENT SYSTEM

The system in Figure 1 was calibrated in an accredited laboratory. Calibration was made at 30 °C, 60 °C, 100 °C, and 150 °C. This range of calibration was determined according to range, at which the measurement system is used. According to the standard are typically measured heatings between 60 K and 150 K. It depends on type of testing (normal or abnormal use) and type of the appliance.

Calibration was made in a temperature chamber of 1 m^3 volume, [3]. Eight measurement plates (see Figure 1) are placed in the chamber in two lines, during every calibration on the same place (see Figure 2). To measure the temperature in the chamber 10 PRT (Platinum Resistance Thermometer) were used. They were placed in each corner of the chamber, 10 cm away from the walls and two thermometers in the centre of the chamber. PRT-s were connected to the "Keithley/HP measurement system" which includes Keithley scanner for scanning of 10 thermometers per card and HP measurement instrument, which is connected by GPIB connection to PC, for the resistance measurement (which is calculated to temperature).

Thermocouples built-in the measurement plate are connected to the developed switching module (Figure 3), which enables measurement of one measurement plate at the time. These signals are then connected to the computer data acquisition system.

Cold junctions of the thermocouples were measured with additional 16 PRT-s, one on each connector of thermocouples.

Calibration of the black test corner was made in two different ways but at the same temperature chamber conditions. First calibration was made without consideration of temperature of cold junctions of each thermocouple. In calibration the average ambient temperature was used for the temperature of cold junctions of thermocouples. Second calibration was performed with compensation of measured values of thermocouples with temperature of cold junctions of thermocouples measured by PRT.

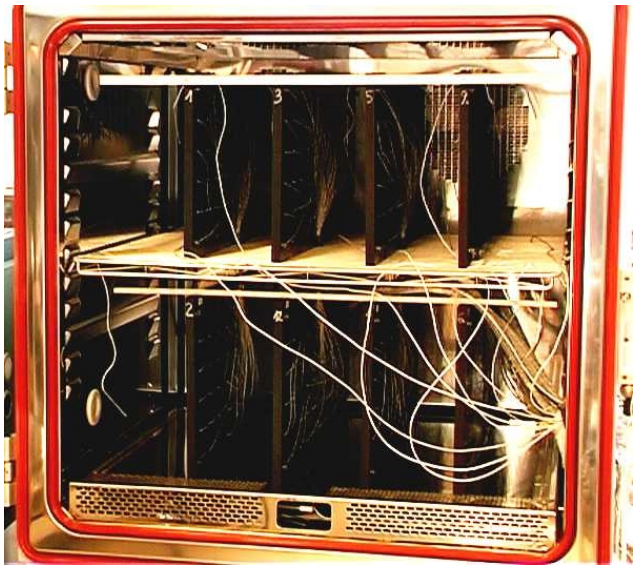

Fig. 2. Calibration in temperature chamber

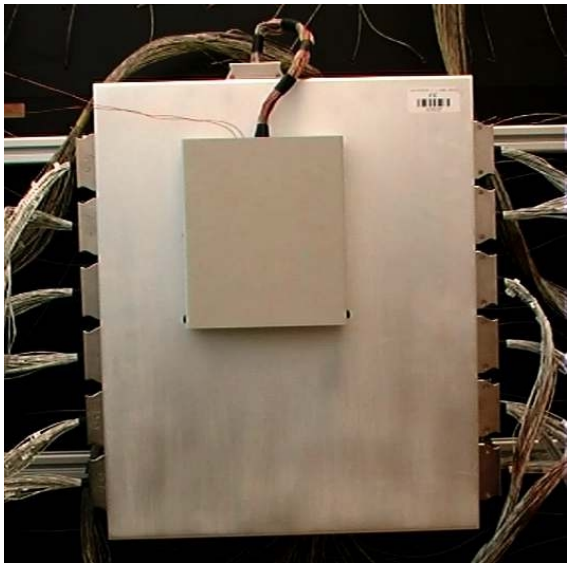

Fig. 3. Developed switching module

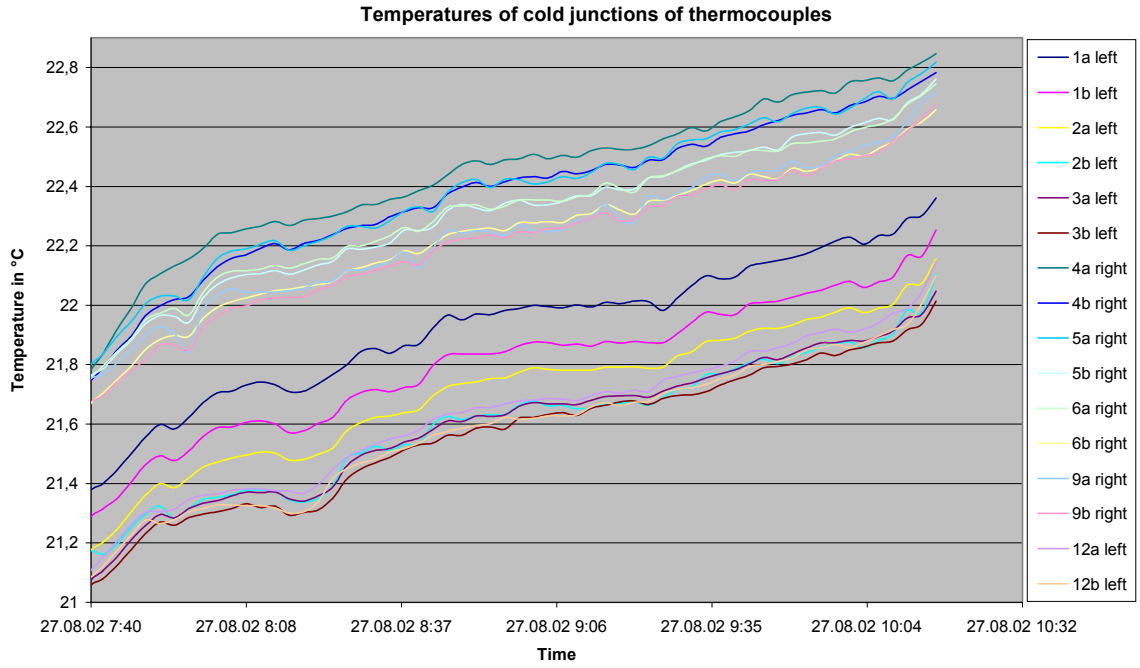

Fig. 4. Temperatures of cold junctions of thermocouples

4. ANALYSE OF THE MESUREMENT UNCERTAINTY OF COLD JUNCTIONS

According to Figure 4 the aim of the paper is to analyse all calibration data in order to establish the right conclusion about using average ambient temperature or temperature of each cold junction of thermocouples, as a compensation of measurement. As presented in Figure 4 there is a temperature difference between left and right connectors of thermocouples on the switching module (see Figure 3). This shows the importance of analyse of the influence of this fact on the measurement of heating with thermocouples.

Two zones of measurement results in Figure 4 can be clearly indicated. The top zone are results of the temperature of cold junctions of the right side of the switching module and the bottom zone are results of the temperature of the cold junctions on the left side of the switching module. This clearly indicates that the temperature around the measurement system is not the same. Reasons for that can be different: position of the measurement system in the laboratory, impact of the climatic system of the laboratory, influence of other laboratory equipment, or simply influence of tested appliance. The important thing is, that temperature of cold junctions did not exceeded the allowed value, which is defined with the temperature of surrounding.

Figure 5 shows results of repeatability of thermocouples, together with cold junctions. Horizontal axis presents each thermocouple (1-480) and vertical axis presents measurement uncertainty contribution in °C. Broken line shows results where average temperature of cold junction was used for compensation and continuous line shows results, where calibration was performed with compensation of measured values of thermocouples with temperature of cold junctions of thermocouples. In Figure 5 are also clearly indicated all thermocouples on each measuring plate. From the graph can be seen that results of measuring plate three and five deviate from the other results. Temperature of cold junctions on these two plates was not the same as it was on the other six measuring plates. Each measuring plate has two connectors for connecting thermocouples to the switching module. In case of measuring plate three and five it can be clearly seen that the temperature of connectors is not the same. Conclusion of this analyse of the results is that it is important to take into consideration the temperature of cold junctions of thermocouples in order to measure temperature heatings correctly and not with too large measurement uncertainty.

After the detailed analyse of the measurement uncertainty contributions of the measurement system in Figure 1, major contributions can be exposed:

- measurement uncertainty because of the resolution of the data acquisition card (U=0.261 °C),
- contribution of calibration measurement instruments (U=0.06 °C)
- homogeneity of the temperature chamber (0.72 °C),
- repeatability of the thermocouples together with cold junctions (0.5 °C)

Total measurement uncertainty of the measurement system calculated as an extended standard uncertainty (k=2) is then U=0.92 °C ≈ 1 °C. If the temperature of cold junctions is not taken into consideration or just an average value is used for compensation, the measurement uncertainty of the system is enlarged. To avoid all problems in the measurement and to get competent results it is important to consider the temperature of each cold junction.

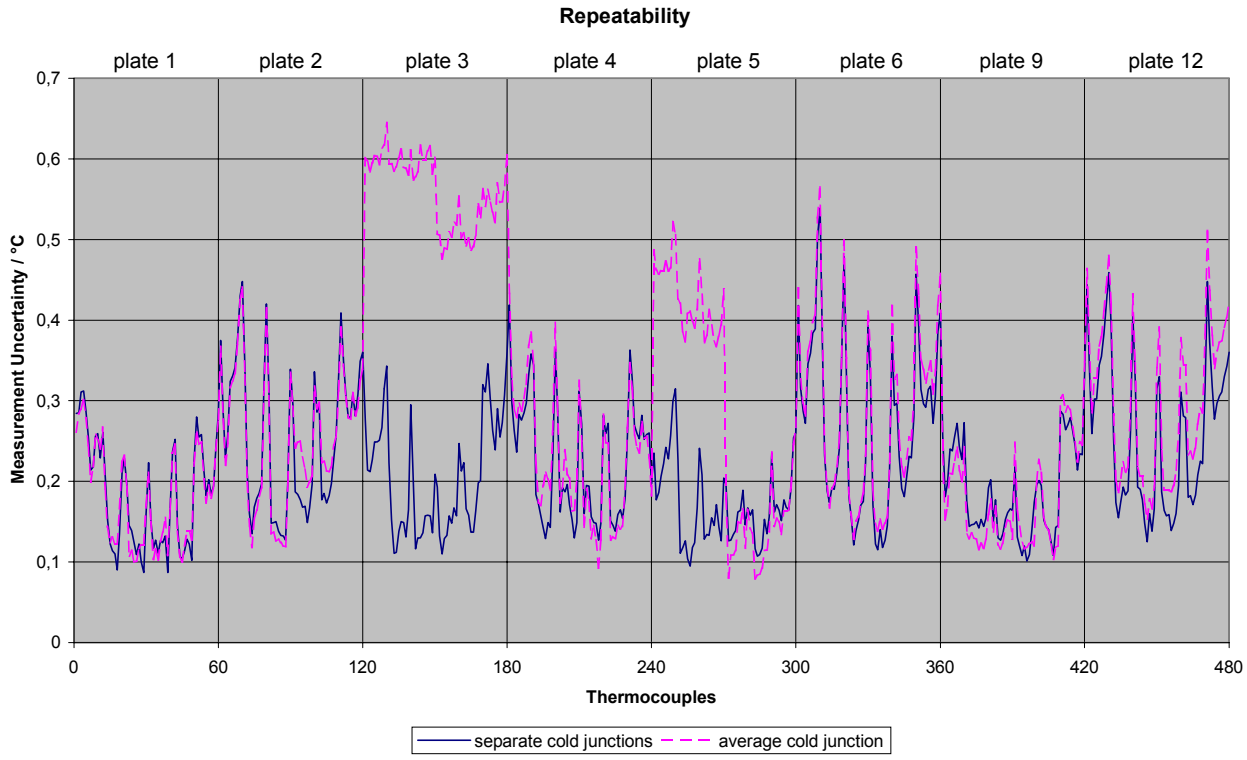

Fig. 5. Contribution of thermocouples together with cold junctions to the measurement uncertainty

5. CONCLUSIONS

The paper describes the measurement system for measuring of heating. During calibration of the system appeared some problems about cold junctions of thermocouples. Paper describes two different calibrations and possible solutions of the problem. In the paper are presented all measurement uncertainty contributions in made calibrations, [4], such as: resolution of the data acquisition card, contribution of calibration measurement instruments, homogeneity of temperature chamber, contribution of thermocouples together with cold junctions (repeatability of measurement). At the end of the paper is discussed if there is a need to take in to consideration the temperature of cold junctions of thermocouples, or simply determine higher measurement uncertainty of the measurement system in order to be the measurement system as simple as possible. The Figure 5 shows that consideration of temperature of cold junctions is necessary. The total measurement uncertainty of measurement system is quite large (≈1 °C). If the temperature of cold junctions is not considered the measurement uncertainty is even larger and the measurement is not reliable.

REFERENCES

[1] SIST EN 60335-1
[2] SIST EN ISO/IEC 17025
[3] I. Pušnik, J. Bojkovski, J. Drnovšek, Quality Manual; Procedure for evaluation of climatic chambers, LMK, Ljubljana, 1996
[4] European Accreditation, Publication reference EAL-R2 “Expression of the uncertainty of measurement in calibration”, Edition 1, April 1997

AUTHOR(S): **Gaber Begeš**, University of Ljubljana, Faculty of Electrical Engineering, Laboratory of Metrology and Quality, Tržaška 25, 1000 Ljubljana, Slovenija, Tel.: +386 1 4768 224, Fax.: +386 1 4264 633, e-mail: gaber.beges@fe.uni-lj.si,

Valentin Batagelj, University of Ljubljana, Faculty of Electrical Engineering, Laboratory of Metrology and Quality, Tržaška 25, 1000 Ljubljana, Slovenija, Tel.: +386 1 4768 224, Fax.: +386 1 4264 633, e-mail: valentin.batagelj@fe.uni-lj.si,

Igor Pušnik, University of Ljubljana, Faculty of Electrical Engineering, Laboratory of Metrology and Quality, Tržaška 25, 1000 Ljubljana, Slovenija, Tel.: +386 1 4768 224, Fax.: +386 1 4264 633, e-mail: igor.pusnik@fe.uni-lj.si