TESTING OF HEATING IN A BLACK TEST CORNER

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Abstract: The article describes implementing of a personal computer and the LabVIEW program in measurement of temperature rising in a black corner in testing laboratories. A testing device can be considered as a complete measurement system, which can be regularly calibrated and thus providing traceable measurements. Besides the automation of the measuring process traceability is the most important category that must be considered in accredited laboratories. The whole project with its extension could change the Heating part of the standard or more likely cause an edition of a new standard describing the Testing in the Black Corner. Important standards that should be taken into consideration are SIST EN 45001 and SIST EN 45002 (identical to EN 45001 and EN 45002). They include criteria for testing laboratories. The standard SIST EN 45001 describe general criteria for testing laboratories, while the SIST EN 45002 describe general criteria for assessment of testing laboratories. As an example the measurement of heating of a kitchen-range was made in the measurement system.

Keywords: testing, safety, black test corner.

1 INTRODUCTION

A subject of the article is the safety of electrical household appliances. Slovenian standard SIST EN 60335-1 (resumed EN 60335-1) includes general requirements for safety of household and similar electrical appliances. 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. The article deals with the item 11 (Heating) in the standard EN 60335-1. Appliances and their surroundings shall not attain excessive temperatures in a normal use. Compliance is checked by determining the temperature rise under specified conditions.

2 GENERAL REQUIREMENTS FOR TESTING IN A BLACK TEST CORNER

Dull black-painted plywood, approximately 20 mm thick, is used for the test corner, the supports and for the installation of build-in appliances. Build-in appliances are installed according to the manufacturer's instructions. Other appliances are placed in a test corner as follows:

- Appliances normally placed on a floor or a table in use, are placed on the floor as near to the walls as possible;
- Appliances normally fixed to a wall are fixed on one of the walls, as near to the other wall and to the floor or ceiling as it is likely to occur in normal use, unless the manufacturer has given other instructions concerning their installation;
- Appliances normally fixed to a ceiling are fixed to the ceiling as near to the walls as it is likely to occur in normal use, unless the manufacturer has given other instructions concerning their installation.

Other motor-operated appliances are positioned as follows:

- Appliances normally placed on a floor or a table in use are placed on a horizontal support;
- Appliances normally fixed to a wall are fixed on a vertical support;
- Appliances normally fixed to a ceiling are fixed underneath a horizontal support.

Temperature rises other than those of windings are determined by means of fine-wire thermocouples positioned so that they have minimum effect on the temperature of the part under test. Thermocouple having wires with a diameter not more than 0,3 mm are considered to be fine-wire thermocouples.

Thermocouples used for determining the temperature rise of a surface of walls, ceiling and floor are attached to the back of small-blackened disks of cooper or brass, 15 mm in diameter and 1 mm thick. The front of the disk is flush with a surface of the board. Tested appliances are positioned so that thermocouples detect the highest temperatures. An ambient temperature should be 20 °C ± 5 °C. If the temperature rise is close to the highest level, the ambient temperature should be 23 °C ± 2 °C.

These are very general requirements for testing of heating. Standard does not state anything about measurement set-up and its maintenance, traceability assurance and the way of measuring. For testing laboratories should be important that they measure in the same way. That is the main purpose of the suggested and the described solution.

3 MEASUREMENT SET-UP

The main guidance in the development of a measurement set-up for measuring of heating of electrical appliances was that the set-up shall be compatible for all appliances and its maintenance as well as traceability shall be assured. In the assessment of a testing laboratory traceability of all equipment is required.

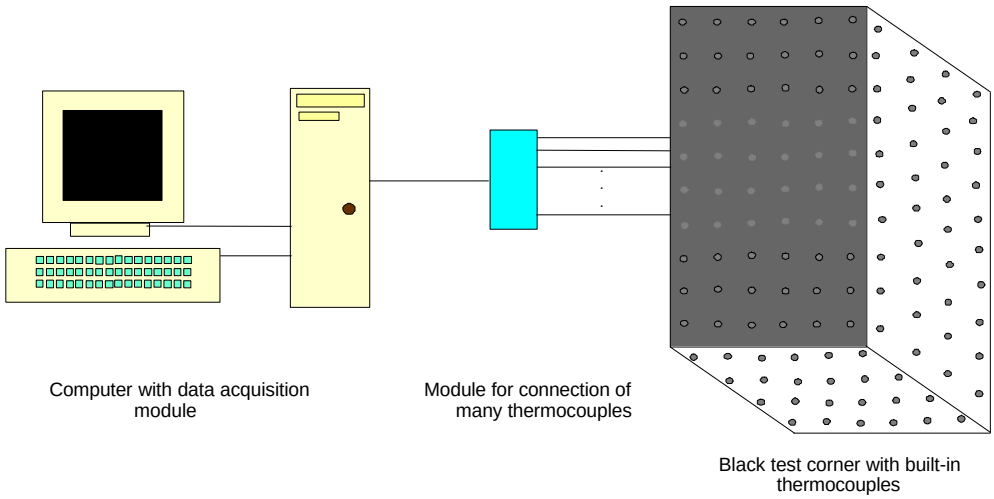

Figure 1. The suggested measurement set-up

Figure 1 shows the suggested measurement set-up. The black test corner is partitioned to more units, which can be combined. One part of the test corner is a measurement plate. This plate contains 60 thermocouples. Figure 2 shows dimensions of built-in thermocouples. Border thermocouples are built-in at a half distance from the end of the measurement plate as it is between the thermocouples.

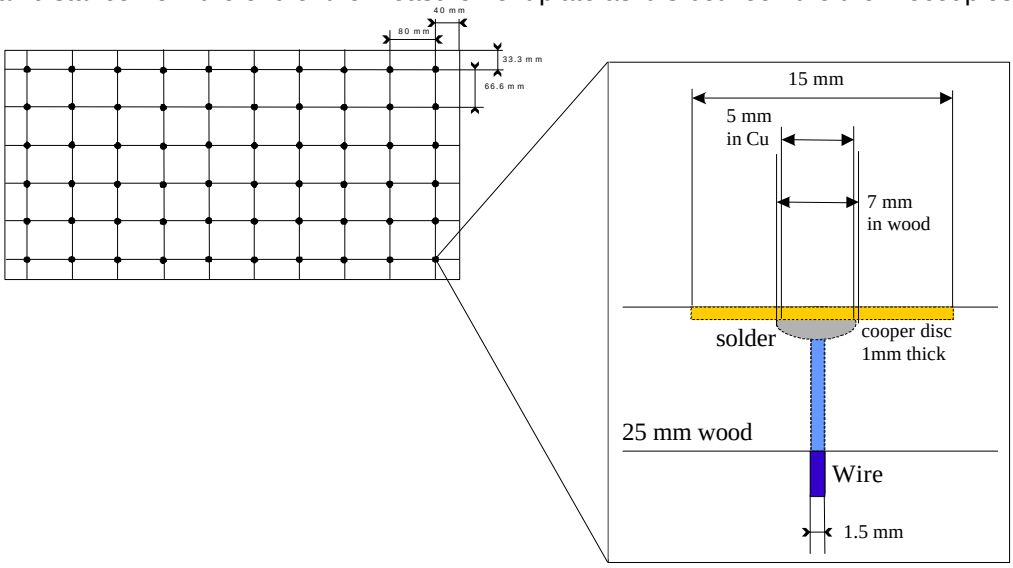

Figure 2. The measurement plate with built-in thermocouples

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 a high temperature resistant silicon mastic was used. Before the thermocouples were built-in, they were calibrated in our accredited laboratory. The calibration was made at 20 °C, 40 °C, 60 °C, 80 °C, 100 °C, 150 °C and 180 °C. During calibration the thermocouples were connected to the personal computer so the calibration was performed for the complete measurement system. All plates of the test corner are inserted in the aluminium guidance that is easy to compose. The terminal block for thermocouples is made by the National Instruments type SCB-100. This block is connected to the computer module AT-MIO-64E also made by the National Instruments. This module enables 64 single-ended or 32 differential terminals, has a temperature sensor for cold-junction compensation and is built in a personal computer. A program package used is the LabVIEW. The main program offers saving and printing of measured data in a graphic or a numeric shape. Two sub-programs perform scooping of temperature and measuring the temperature of one measuring plate.

A measurement uncertainty of the system has three main contributions, the uncertainty due to the computer module resolution (0,4 °C), the uncertainties of auxiliary measuring instruments, temperature calibration baths and a standard thermometer used in the calibration (0,04 °C), and the uncertainty of a thermocouple with the worse deviation (1,2 °C). The recommendation of the EA (European Accreditation) was taken into consideration and the respective value was divided by $\sqrt{3}$, [3].

$$u_s = \sqrt{u_{cm}^2 + u_{ci}^2 + u_{th}^2} = \sqrt{\left(\frac{0.4\,°C}{\sqrt{3}}\right)^2 + (0.04\,°C)^2 + \left(\frac{1.2\,°C}{\sqrt{3}}\right)^2} = 0.75\,°C \quad (1)$$

The measurement uncertainty of the system u_s is calculated as: the measurement uncertainty of the computer module squared (u_{cm}), measurement uncertainty of the calibrating instruments (u_{ci}) and the measurement uncertainty of the worse thermocouple (u_{th}).

The resolution of the module is divided by $\sqrt{3}$ because of the rectangle distribution. If the measurement uncertainty of thermocouples is considered, the whole system has the uncertainty of 0,8 °C. This is the worse uncertainty, concerning to the worse thermocouple, which exhibited the maximum deviation of 1,2 °C.

If a normal distribution instead of a rectangular distribution is taken into account in calibration of thermocouples, the measurement uncertainty of the system could be 0,6 °C.

4 MEASUREMENT OF HEATING OF KITCHEN-RANGE

The maximum normal temperature rise in a black test corner should not exceed the specified temperature rise of 65 K in a normal use and 150 K in the specified abnormal use.

In the normal use an appliance is placed as near as possible to the sidewalls in the test corner. The appliance is operated in accordance with conditions of adequate heat discharge, with all heating elements that can be switched on at the same time under normal conditions of use in circuit. The supply voltage is such that the total input of the appliance is 1,15 times rated input. If the appliance is provided with means to limit the total input, the test is made with whichever heating unit, or combination of heating units, as may be selected by this means. Such testing imposes the most severe conditions. Hob elements are operated in accordance with conditions of adequate heat discharge with their control devices adjusted to the highest setting until the water boils, and then the control devices are adjusted so as to maintain of the gently boiling water. Ovens provided with a thermostat are operated so that the mean temperature over a cycle of the thermostat, in the centre of the useful oven space is maintained at 240 °C ± 4 °C, unless this condition cannot be obtained, in which case the control is adjusted to the highest setting. Appliance is operated for 60 minutes, unless steady conditions are obtained before that.

In the abnormal use an appliance is placed as near as possible to the sidewalls in the test corner. The appliance is tested separately with switched oven and separately with only that heating unit operating, which imposes the severe conditions. Its control device is adjusted to the highest setting. The supply voltage is such that the total input of the appliance is 0,85 times rated input, 1,24 times rated input and 1,15 times rated input with the associated oven thermostat short-circuited. Appliance is tested until steady conditions are established.

Graphical results of heating of a sample appliance in the abnormal use are shown in Figure 3. Numeric results are not presented as clearly as graphic results. Figure 3 shows the heating of a sidewall in colour a scale, a back wall and a floor of the appliance. The colour scale presents temperature rises from 0 K to 150 K. Every coloured square in Figure 3 presents the temperature rise of one thermocouple. The system enables determining the highest temperature and the place of its appearance.

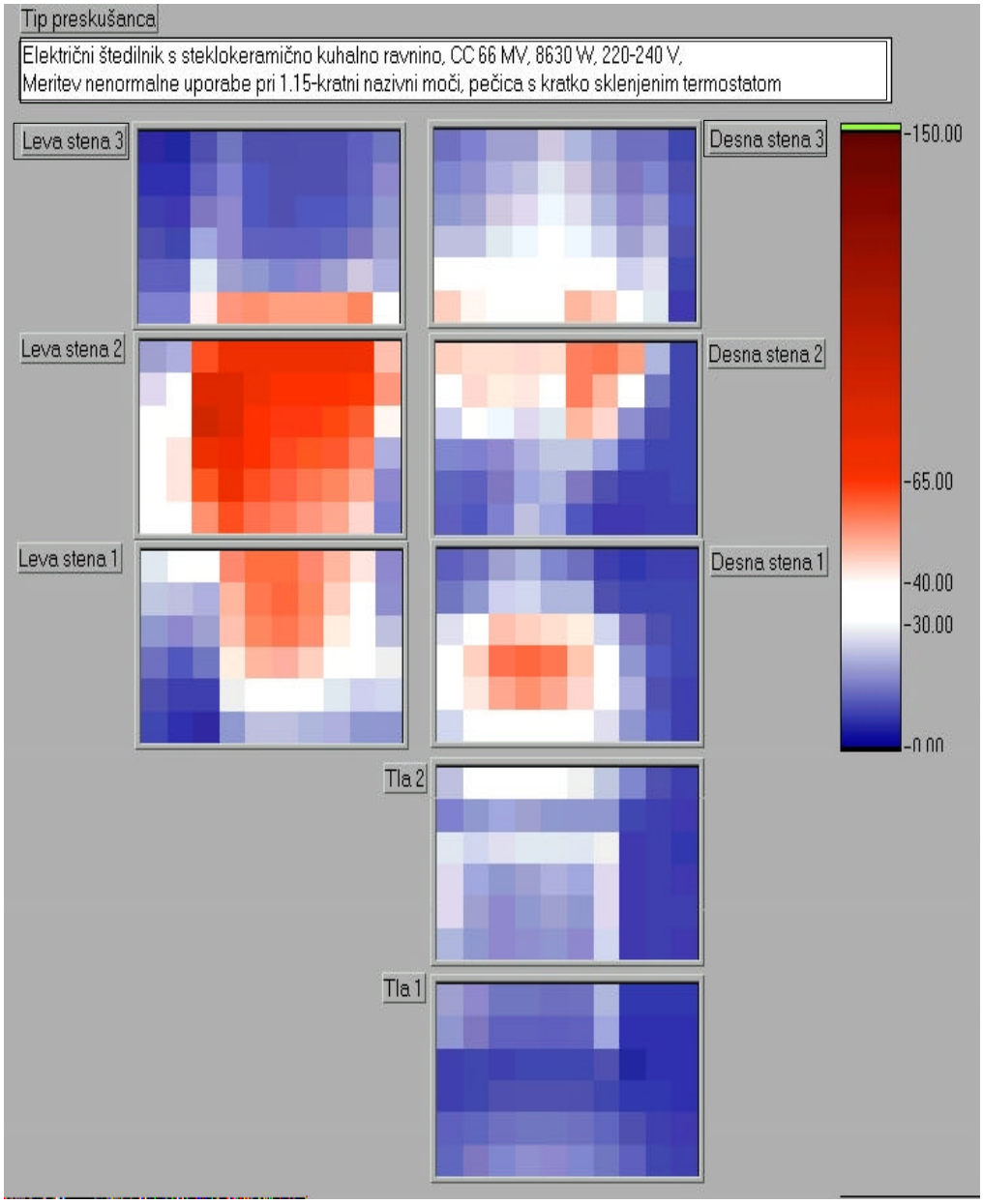

Figure 3. Test results of heating of a kitchen-range

Table 3 presents numerical values for the temperature rise of each thermocouple at the end of the measurement. From the table 3 it is possible to read the place and the value of the temperature rise of the black test corner. Of course the graphical presentation is more evident as the numerical. If a value from the table 3 is compared with the dimensions of the measuring plate (Figure 2), it is easy to determine the position of a particular thermocouple and it's temperature rise.

Table 1. Temperature rise of the kitchen-range (numerical values)

Measurement data, abnormal use of the kitchen-range									
TEMPERATURE RISE in K									
Place (X , Y), temperature rise									
Left wall									
5.1	5	9.5	14.1	10.3	9.3	9.9	9.9	11	14.5
6.1	5.8	12.1	15.6	10.5	9.9	9.9	10.1	11.6	16.9
7.5	6.9	15.1	16.5	10.9	10.1	10.4	10.8	12.4	18.1
9.3	8.8	20	16.9	11.8	11.2	11.3	12.2	14.8	19.6
11.9	11.3	27.8	19.6	18.1	16.1	16.6	19.1	24.3	21.1
15.4	15.2	41.5	52.9	53.1	51.6	51.3	52.3	55.4	40.1
19.4	20.9	61.7	74.1	70.3	70.3	70.8	70.9	67.7	48
26.3	30.2	83.4	76.7	68.1	65.7	66.1	66.2	64.6	53
32.1	39	85.1	78.2	67.2	64.3	63.8	63.1	59.9	40.7
35.4	43.3	73.5	76.1	65.5	62.4	61	60.3	55.8	20.8
36	43.1	61.1	69.2	61.5	59	56.7	55.1	50.5	16.5
32.8	38.6	53.5	61.8	57.8	55.6	52.7	50.2	45.1	15.3
27.9	30.3	35	54.8	58.3	58.1	54.7	49.4	43.2	16.3
23.5	22.7	21.4	49.2	56.5	58.9	54.9	45.6	38.6	17
18.5	16.3	19.1	47.2	55.2	57.1	53.8	41.9	34	23.4
13.4	10.4	14.3	41.8	49.3	49.8	45.5	36.8	30.3	28.3
10	7.8	7.4	28.7	33.1	33.1	30.7	27.9	24.7	25.6
8.2	6.2	5.1	18.4	22.3	22.5	21.8	21.2	18.5	17.7
Right wall									
13.8	15.2	19	19.8	24.2	22	17.7	13.3	13.5	9.1
16	16.9	21.4	23.2	27.4	24.3	19.5	14.6	16.2	10.2
18.4	18.9	24	26.3	29.9	26.9	22.1	16.4	18.8	10.6
22.5	23.1	28.1	29.8	33.4	29.7	25.5	19.7	22.3	10.2
30.6	31.9	34.8	32.6	36.3	35.3	31.3	24.9	26.4	8.7
46.4	40.6	38.4	36	39.5	48.6	45.9	38.1	28.1	7
45.5	43.9	44.1	44.4	43.7	55.5	56.9	51.8	22.2	8.8
36.7	44.3	42.3	42.5	40.3	55.7	49.4	34.8	14.5	8.6
25.2	34.5	29.8	25.9	27.6	48.4	45	17.3	9.9	8.4
15.8	15.4	16.9	20.7	24	23.6	20.1	10.9	8.5	8.4
12.6	11.5	14.8	20.4	22	14.6	9.5	7.8	7.9	8.2
11.2	10.9	15.4	22.3	20.4	10.8	7.2	6.9	7.5	7.9
11.4	13.5	18.8	22.1	16.1	13.1	7.9	6.7	7.5	7.9
14.3	18.4	25	25.6	21.8	22.1	10.3	8.3	8	8.2
26.8	37.7	47.4	46.3	43.8	41.9	25.5	14.6	9.2	8.2
33	46	57.8	58.7	57.1	47	36.4	17.6	10.5	8.4
31.6	42.4	51.1	53.1	50.6	45.1	35	20.5	9.9	7.7
25.3	33.9	40	40.6	38.3	33.2	26.4	17.5	10.4	7.7
Ceiling									
NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
NM	NM	NM	NM	NM	NM	NM	NM	NM	NM
Floor									
22.3	31.7	36.3	35.7	33.2	29.1	23.4	16.1	10.2	7.8
15.6	18.3	20.3	19.6	18.2	17.7	17.7	8.4	7.7	7
27.1	25.2	26.7	27.7	27.8	27	29.3	7.4	7.7	6.5
26.2	20.3	18.5	19.7	21.1	20.2	26.1	7.1	7.5	7.1
26.1	18.8	16.8	18.4	19	18.4	25.9	7.1	7.6	7.6
21.7	18.4	16.3	17.4	17.7	16.8	25.7	7.3	7.9	7.3
18.9	16.9	14.4	14.5	13.1	13.5	21.8	6.3	6.8	6.4
18	15	11.8	11.8	11.5	11.8	20.1	5.7	6.2	6.1
7.6	8.6	8	8.1	8.2	8.2	10.1	5	5.6	5.6
7.6	8.9	9.5	9.8	9.8	9.5	9	6.8	6.2	6.2
11	12.6	13.6	14.1	14	13.5	12.3	9.5	7.6	6.9
12.6	14.8	16.3	17.1	16.7	16.1	14.4	11.2	9	7.6

5 POSSIBLE IMPROVEMENTS

Improvements are possible in the field of a new approach to the calibration and the total automation of the measurement. The calibration could be performed after thermocouples are built-in, so that we avoid damaging thermocouples during the calibration. Therefore the calibration shall be performed in a temperature chamber with appropriate calibration space. Improved automation would require only one data acquisition module and a switch module for scanning measurements on many measuring plates.

6 CONCLUSION

The importance of testing in a black test corner is due to the fact that low voltage appliances, which do not have to be electrically tested, could also cause fire. The article describes implementation of a personal computer and the LabVIEW program in measurement of temperature rising in a black test corner. The temperature is measured with calibrated thermocouples connected to the computer. Because of permanently built-in thermocouples into a black test corner the re-calibration of the whole system is problematic.

The article deals with a systematic approach to the testing. At the moment laboratories use different methods of testing which are applicable only to the particular tested appliances. For a good independent laboratory it is important that it is capable of performing measurements independently on the size of a tested appliance. A testing device, so called Black Test Corner, can be considered as a complete measurement system, which can be regularly calibrated and thus providing traceable measurements. The whole project with its extension could change the Heating part of the standard or more likely cause an addition to a new standard describing the Testing in the Black Test Corner.

REFERENCES

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