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GUIDELINES FOR ASSESSMENT OF TEMPERATURE UNIFORMITY AND INVESTIGATION OF THE MEASUREMENTS UNCERTAINTY WITHIN LABORATORY OVEN

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Abstract - Laboratory ovens as drying and heat-treatment ovens require to be calibrated in order to meet the measurement traceablitiy according to the ISO Guide 17025 requirements, special in accredited laboratories. Industrial and medical laboratories also need to evaluate and assessment of the temperature uniformity within their ovens, to get the optimum working conditions.

This paper describes the methodology for assessment the temperature uniformity within the working space of the oven and the measurements uncertainty budget. The method covers the temperature range from ambient up to 1000°C.

The paper is presented also the method for assessment of some oven parameters as temperature gradient, stability, temperature fluctuation and temperature drift within the oven.

Keywords oven, temperature uniformity.

1. INTRODUCTION

The laboratory ovens and heat-treatment furnaces are today the most widely –used in labs and industry. Most accredited or certified places require calibrating this type of ovens. At present there are no standards or guidelines for this calibration procedure, resulting in constant discussion among the accredited laboratories on how to formulate the result reports belonging to the issued certificates. This paper presents the guidelines for test the uniformity, stability and fluctuation of ovens.

The calibration and survey equipment system was described in complete diagram showing the thermocouple distribution within the ovens. The survey procedure can used also to calibrate the thermometer of the oven indicator and temperature-control probe, which will be helpful for calibration of thermocouples *in situ*.

2. INSTRUMINTATION USED FOR THE OVEN CHARACTRIZATION SYSTEM

Flexible thermocouples is needed with sufficient long of types T, N or K at least 12 thermocouples per each type. Our reference thermocouples are calibrated according to ITS-90, by the thermometry department of NIS which can realize the temperature scale up to 962 °C.

Thermocouple data logger (computable with the previous types) provided with multi-channel thermocouples [1]. The number of channels will depend on the extent of the survey. This equipment can be interface able to portable computer using automated program developed in Lab View soft wear.

The use of analogical equipment requires a very well trained people to obtain the final determination of the oven conditions.

3. METHODOLOGY

3.1 Arrangement of the sensors

The oven under test should be cold and empty but with usual accessories. The flexible thermocouples are positioned at the corners of the working space of the oven plus one standard thermocouple (or reference PRT) to determine the reference temperature in the geometric center. The working space of the oven needs to be well specified, usually the space at least 5cm from any wall (including the roof) is a good guide. Mounting of the survey thermocouples can be facilitated by using a rigid wire frame to hold the thermocouples close to their sites. Wires can shift with heating if they are not secured [1]. Two more thermocouples for the recording and control probes with one to monitor the ambient temperature makes 12 as the minimum number of survey probes (as shown in figure (1)). At least 3 temperature set points should be selected generally at 5%, 50% and 95% of temperature operation [2].

3.2 Preliminary Test and Conditions

Before starting a survey, ensure that the oven controller is working properly. Poor control will result in poor spatial and temporal temperature of the test and any recording thermometer should read within 1°C of the setting. For a test, the controller should be set to temperature and not subsequently adjusted to obtain the 'right' temperature. Tuning of the controller may be needed. Ensure that both the controller and recorder instrumentation are functioning correctly and are they calibrated.

Measurements shall not commence until at least one hour after the oven has been switched on.

The thermocouples shall be calibrated and the hot junction shall then be cleaned and thinly.

The oven door-joint and all other possible sources of leakage shall be effectively sealed. The leads may be brought out through a split rubber stopper inserted in the thermometer aperture.

3.2 Temperature uniformity

The most important advantage of this guideline procedure is the determination of the temperature uniformity within the ovens. Temperature uniformity reflects the quality of oven design regarding isolation, location of heaters and air circulation patterns [2]. We can evaluate the temperature uniformity by surveying the temperature within the oven in steps of rising-temperature (figure (1)). Record the temperature rise and its settling to a stable condition for each step. Often a uniformity specification may require that the overshoot should not be excessive and that the oven comes to an equilibrium condition over a few control cycles [1].

We can use the standard deviation of all this recorded measurements to evaluate the temperature uniformity.

During the measurements, a digital multi-meter is checking the line voltage to the oven. This value shall vary by not more than 5% during the 20 minuets period. The portable computer thought the GPIB communication makes this determination.

With the data obtained from the set up shown in the figure (1), and by means of the computer software, the following parameters can easily be determined:

3.2.1 Temperature Gradient; expressed as the difference between the highest and lowest average temperature value of the temperature sensors on different locations within the working space, after achieving stability.

3.2.2 Temperature Fluctuation; it is a measure of the variation of temperature on location inside of the oven chamber in a period of time after achieving stability.

Records of the difference between the maximum and minimum temperature of the five successive readings for each of the nine thermocouples shall be obtained.

From the nine differences are selected the two greatest and the average of these, and the result is the temperature fluctuation value.

3.2.3 Temperature Drift; The difference between the highest and the lowest oven temperature recorded during a long period of time (48 hour or more) of continuous operation without alternation to the thermostat setting shall not exceed 1^oC at 100^oC setting point.

For this purpose, the oven temperature shall be measured at least thrice daily at intervals of at least three hours.

3.2.4 Reproducibility of Oven Temperature; The initial oven temperature shall be regained to within 1^oC after the oven has been switched off, allowed to cool for at least six hours and switched on again for at least two hours, without any alteration to the thermostat setting.

4. EVALUATION OF THE MEASUREMENT UNCERTAINTY

The measurement uncertainty of temperature uniformity assessment of the laboratory oven is obtained from the combination of the individual components uncertainty is given by;

$$U = 2\sqrt{u_{st}^2 + u_{dt}^2 + u_{vt}^2 + u_{res}^2 + u_{sw}^2 + u_{rep}^2} \quad (1)$$

Where;

u_{st}; calibration of the standard thermocouples with cold junction at 0^oC.

u_{dt}; drift of the standard thermocouples since their last calibration.

u_{vt}; resolution of the voltmeter.

$u_{res;}$ calibration of the voltmeter

$u_{sw;}$ contact effect of the switching device.

$u_{rep;}$ reproducibility of oven temperature.

The assessment uncertainties should be expressed in the final report or certificate.

5. SAMPLE OF EXPRIMENTAL RESULTS

Tests on the four laboratory ovens included the evaluation of temperature uniformity, temperature gradient, temperature fluctuation, temperature drift and the reproducibility. The sample of results in table (1) was made at $150\ ^oC$.

TABLE I. The results sample at $150\ ^oC$

Oven parameters in ^oC	Code			
	M1	M2	M3	M4
Nominal temp.	150	150	150	150
Reference temp.	150.11	150.09	150.26	150.21
Temp. uniformity	0.1	0.1	0.1	0.1
Temp. gradient	0.6	0.5	0.6	0.4
Temp. fluctuation*	0.2	0.2	0.2	-0.1
Temp. drift**	0.6	0.7	0.9	0.8
Reproducibility	0.2	0.2	0.2	0.2

*Over a period of 30 minutes.

**Recorded during 48 hours.

6. REPORTING

Because the interoperation of the uniformity can become complex if both time and space variations are taken into account, clear and detailed reporting of the results is often called for. To say an oven had a uniformity of $\pm 3^oC$ at 120^oC may not be adequate for a test that requires an object to be heated at 120 ± 3^oC for 50 minutes. The uniformity may apply to the oven only after it has on for 2 hours.

Depending on the oven survey specifications, there are many variations on the uniformity requirements and the reporting should address these directly.

If required, a calibration certificate may be issued for the recorder and perhaps the controller. A calibration certificate may not be required for the survey thermocouples or the oven because of the short-term nature at the calibration. While a certificate may be issued for the oven, it generally will be for the oven complying with a specification.

In principle, a final report or certificate for the oven should contain the set up diagram for the thermocouples distribution within the oven.

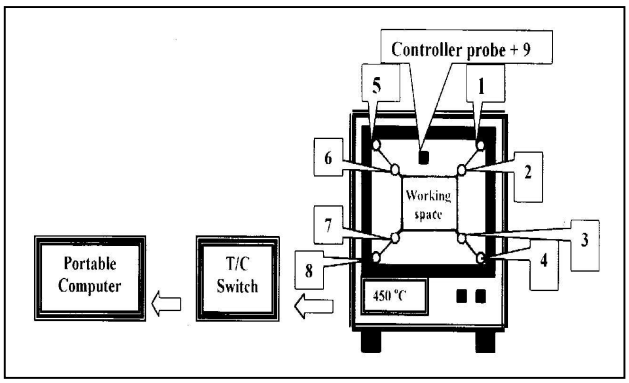

Fig. 1. Set up diagram of equipment to assessment the temperature uniformity- the numbered boxes indicate to the thermocouple locations- within the oven.

6. CONCLUSIONS

The laboratory ovens and furnaces are usually used in labs, industry for heat treatment & drying, and another using. The methodology for assessment of working space temperature parameters is present in this paper.

The proposed methodology includes; temperature gradient, stability, temperature fluctuation and temperature drift. The paper also includes the measurement uncertainty budget.

It can be conclude that the assessment of temperature uniformity is simple but require a trained people and standard method include the previous parameters assessment.

Assessment procedure and uncertainties are still open for discussion.

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