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# MEASUREMENT UNCERTAINTY IN DYNAMIC CALIBRATION OF TEMPERATURE SENSORS

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**Abstract:** This paper presents a preliminary methodology for the calculation of measurement uncertainty of temperature sensors in dynamic regime. The experimental results show that the proposed methodology is suitable for the determination of the measurement uncertainty in the transient state of the calibration process.

**Keywords:** dynamic calibration, temperature sensors, thermo pair, temperature calibration.

## 1. INTRODUCTION

This work is part of an effort set forth to set up a national reference laboratory. The developed devices and its metrological characteristics are presented.

Although the dynamic calibration is almost a new field in metrology, many studies of pressure have been done in important research centers. These studies allowed the development of dynamic calibration devices of temperature sensors like the “Shock Tube” and the “Quick-opening Device”.

Meanwhile, regarding the dynamic calibration of temperature sensors, slow advances are happening and many metrological questions are still opened.

The main trouble to achieve the dynamic calibration of temperature sensors is due to the sensors linking to the calibration resource, and also the trouble in establishing its intrinsical characteristics, the trouble to generate an exterior degree with metrological quality and the inexistence of specific norms related to this subject.

In the case of generating a temperature degree to the calibration in liquid resources, some advances are happening through the metrological characterization of a rotative cube, showed in Fig. 1. Actually, this cube works as an infinite length channel, with the possibility to vary the Reynolds number and the unmasking speed, to assure that the time of the degree’s formation do not interfere on the response time of the sensor. With these technical resources it was able to make a rigorous metrological characterization of the rotative cube, establishing the operational procedures that assure the assays repetition and qualify the rotative cube as an instrument of metrological trust. With these available resources it is possible to propose and test a consistent methodology to the calculation of the measurement uncertainty.

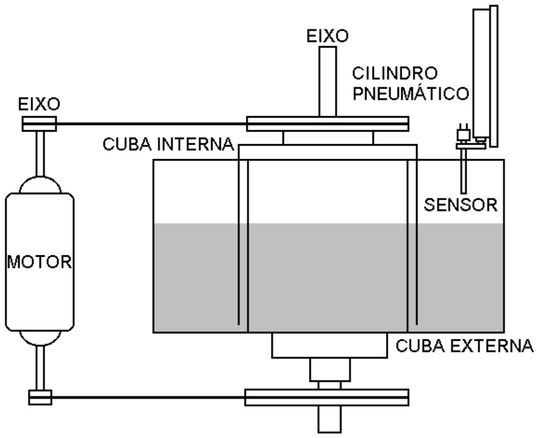


**Fig. 1. Draw of the cube system.**

## 2. PURPOSE

The purpose of this work is to present the development of a method to calculate the measurement uncertainty in dynamic calibration of temperature sensors using a thermo pair with the sensitive element exposed and submitted to one degree. The study is done based on time and using as reference the international norms accepted for static calibration.

## 3. METHODS

The dynamic calibration of a temperature sensor is done experimentally by a curve based on a system of first order, obtained through a linear differential equation with constant coefficients that relate the entrance signals with the exit ones. Knowing the static sensibility?, this curve allows to determine the time constant ? and the dynamic response of the sensor, when it is submitted to a degree *R*, according to the Eq. 1.

$$\frac{S?t?}{? ?R} ? ?1 ? e^{?t/?} ? \qquad (1)$$

The response curve of the sensor is made starting with a set of points obtained according to its capture rate that is done by a system of data acquisition. In this work, it is proposed to consider each point acquired as a point of static calibration. Thus, this adaptation consists in considering the dynamic response of the sensor as the set of static measurement points, and applying the procedures of uncertainty calculation for each one of these points during the time.

This method results in two problems to be resolved, related to the dynamic character of the measurement. The first problem is related to the characterization of the zero base-time of the dynamic response that is used as a base to uniform, during the time, the points of all dynamic responses. This characterization is done by the derivates calculation.

The other problem is that there is no sensor which the dynamic response is used as reference for sensors of the same kind, making impossible the calibration by comparison with a standard reference. In this case, the theoric response of the sensor is considered as reference.

The acquisition of data for analysis is based firstly in the intention to improve the calculation of measurement uncertainty and in the correlation analysis between the enormousness of measurement influence. This analysis requires a simultaneous collection of data relating to each enormousness, creating independent pair of repeated observations.

Observing the model function of the dynamic measurement of temperature in rotative cube, it was determined in a practical way which the entrance enormousness could be measure simultaneously in a sequence of experiments.

## 4. RESULTS

The methodology developed consists in applying the norms and recommendations of the static models in each time from the dynamic process sample. As the zero of the dynamic process in each set of 10 accomplishments is adjusted like the proposed method of the second derivate, in each moment, it is generated 10 static samples of the thermo pair tension which is related to the other enormousness that influence in the measurement system. With one point sample it was done every calculation referred to the time of 0.55430 seconds, whom it is associated not only the measurement enormousness but the tension value estimated by the mathematical model function of the temperature measurement.

The frequency used on the signal dynamic analyzer was 2.5 kHz, using the maximum graphic resolution. This value is equal to an acquisition time of 0.8 seconds. The estimated value of tension is 1.86886 mV ? 0.02896 mV, using an embracing factor of 2 and a level of trust of 95%, considering a normal distribution.

A set of all points in a space of 0.8 seconds, generate a dynamic response of the thermo pairs with its respectively enormousness. In Fig. 2 it is presents the curves from the dynamic response of the sensor and the uncertainty of measurement represented by the trusting spaces. It can be observed that as the curve also change its forming effects of the heat transferring process stops to interfere.

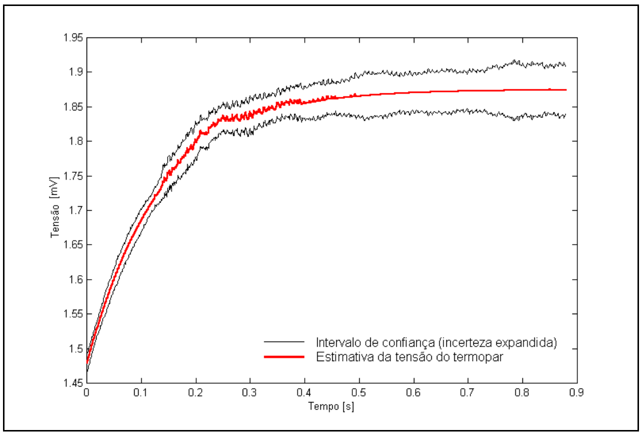


**Fig. 2. Medium dynamic response of the thermo pair, with the trusting spaces determined by the expanded uncertainness, for a k =2.**

## 5. CONCLUSIONS

The development of this work and the upcoming analysis of the results show that the methodology proposed is metrologically consistent and valid universally because it incorporates all the directives recommendations of the international norms accepted for the static calibration.

Although the calculation process requires a complex theoric degree and keeps inside peculiarities about the sensors that respond as a first degree order system, the method of calculation can be understood for the sensors of superior orders, with the adaptations to its constructive peculiarities.

At last, the fact of considering the reference sensor as the theoric model, with the same time constant of the sensor to be calibrated, it is a good strategy to the models of first order once it overcomes the difficulties for the accuracy determination of the intrinsic properties of the sensitive element.

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