PAPER REF: 4673

# MANAGEMENT SYSTEM FOR MONITORING AND MEASURING EQUIPMENT

**José Barradas[1(*)]**

[1]CATIM – technological center for metal industry, Porto, Portugal
[(*)]*Email:* jose.barradas@catim.pt

## ABSTRACT

The management of the monitoring and measuring equipments is one of the requirements of the process of certification according to ISO 9001 standard or other quality management system.
For some companies, it becomes difficult to implement a management system of measurement that suits your needs.
The purpose of a management system is to manage the risk measurement equipment and measurement process that can lead to incorrect results affecting the conformity of products.
The purpose of this work is to explain in practical and summarized way one methodology for implementing and maintaining a management system of measurement in accordance with requirement 7.6 of ISO 9001 standard, which covers the control of Monitoring and Measurement Equipment.

***Keywords:*** management system, monitoring and measuring equipment.

## INTRODUCTION

The control of equipments of monitoring and measurement (subclause 7.6) is one of the essential requirements of ISO 9001 standard. To fulfill this requirement it is critical to establish a management system of measurement as a way to minimize the risks associated with errors of measurement of product characteristics and process parameters, not always appropriately viewed as a strategic issue for organizations and usually relegated into the background by the top management.

Certified organizations generally perform measurements of characteristics of product or process, but rarely is there a measurement management system implemented. The lack of an effective system of this nature increases the risks involved in erroneous measurements, ie, the risk of unduly approving or disapproving a product, a given characteristic or parameter.
Measurements and calibration procedures are essential elements inside a quality system to monitor the quality of the process parameters in various states of production and final testing of products. The measurements in intermediate states and final production provide a means to evaluate the success of the quality system. Such measurements should reflect the means by which the consumer will perceive the quality of the product purchased. This means that the quality and uncertainty of the equipment must be guaranteed by the respective metrological confirmation, ie, have a good management system of measurement.

For ISO 10012 standard, a measurement management system is a *"set of interrelated or interacting elements necessary to achieve metrological confirmation and continual control of*

*measurement processes"*. Metrological confirmation is, in turn, a *"set of operations required to ensure that measuring equipment conforms to the requirements for its intended use"*, operations that involve calibration, verification, adjustment, repair, identification and documentation appropriate to use the equipment of measurement.

## IMPLEMENTATION OF A MANAGEMENT SYSTEM OF MEASUREMENT

The implementation of a management system of measurement (MSM) comprises five fundamental phases (Barradas and Pereira, 2012). In this chapter we will describe in summary form and relate the different phases. The following figure shows the sequence of implementing the management system of measurement.


Fig.1 Phases in the implementation of a management system for monitoring and measuring equipment (Barradas and Pereira, 2012).

## DEFINITION OF RESPONSIBILITIES AND AUTHORITIES.

The implementation of a management system measurement begins with the definition of responsibilities and authorities, which involves the creation of procedures that describe these responsibilities and authorities, including those related to the definition of the quantities to be measured, the selection of measurement equipment, methods of metrological confirmation and adjustments when necessary, the methods of determining intervals of metrological confirmation, actions resulting from non-metrological confirmation, etc.. You should also pay special attention to the qualification of personnel performing these tasks, especially those that perform calibrations and checks or make decisions relating to the results of measurements.

You may want to consider these activities as a process of quality management system, and assign performance indicators and targets for this process. Examples of these indicators may be complaints of stakeholders linked to failures in the process of measurement and metrological confirmation, improvements in this process realization, failures in the process of realization of the product/service due to errors in measurement/calibration etc. If you treat the measurement processes and metrological confirmation process as the company's management system, it is guaranteed that they will be liable to audits and reviews, which will make them more likely to better. You should implement corrective and preventive actions on non-conformities or potential.

## SELECTION OF MEASURING EQUIPMENT

Determine which measurement equipment best suits each of the quantities to be measured is the second phase of a MSM. This is a decision that involves a compromise between cost (equipment, process measurement and metrological confirmation) and benefit (the accuracy or uncertainty of measurement obtained). When it comes to the acquisition of means of measurement it is necessary to define the adequacy of the measurement equipment based on characteristics such as scale, resolution, class or measurement uncertainty.

According to Duarte Jr. and Nasario (2008), a good practice that can be used is the rule of "4 to 10 times" that relates the resolution of the equipment with the tolerance of the measurand, where the resolution should preferably be $\frac{1}{10}$ of tolerance and a maximum of $\frac{1}{4}$ of the same. In all cases you must determine the maximum permissible error - MPE (VIM - 4.26) for measuring equipment, which will serve as a reference for their metrological confirmation or not. It is recommended that the maximum permissible error is based on the process that will be used, usually no more than $\frac{1}{3}$ and preferably $\frac{1}{10}$ of tolerance, or as defined in any laws or standards applicable to the measuring system. When necessary, some additional conditions must be specified (environment, qualification of the observer, measuring method, etc.), which aim to minimize the errors reading from of the equipment.

The measurement methods and in particular the calibration should be based on validated standards or procedures, and should also bring information about the correct use, storage and transportation of the measuring equipment. The methods of calibration / verification must define the standards used, the frequency of metrological confirmation and how it is adjusted according to previous results, the limits of permissible error, environmental conditions, calibration, training of technical requirements, number of points by scale , number of measurement cycles (hysteresis, repeatability), the measurement sequence and method of adjustment or compensation (if possible).

All measuring and monitoring equipment, subject to metrological confirmation or not, must have a form of equipment which shall include at least the following items:

- Identification number;
- Description of the equipment;
- Serial number;
- Model;
- Range of use;
- Resolution;

- Manufacturer;
- Location of use;
- Date of the last calibration;
- Periodicity of calibration;
- Date of the next calibration;
- Acceptance criteria;
- Calibration certificate number;
- Observations.

## CALIBRATION AND VERIFICATION/CALIBRATION PROGRAM

Any equipment that performs a measurement can be calibrated. According to Bunday *et al.* (2007), when we are measuring, the error and the uncertainty are always present and can never be totally eliminated, thus the importance of metrology.

In a world more competitive for all organizations, any factor of differentiation from your competitors could mean staying in first or second in possible business and the metrology might be assumed as a competitive advantage in these situations (Rios and Brandon, 2010).

The calibration of measuring equipment is an important function for quality in the manufacturing process and should be considered normal activity of production, which provides a number of advantages, such as:

- Ensures traceability of measurements;
- Allows confidence in measurement results;
- Reduces the variation of the technical specifications of products;
- Prevents defects.

One of the most popular tools used by quality organizations are the control charts. These charts use data/values from measurement equipment. If these devices are not properly calibrated, the analysis of control chart loses its meaning and added value, because nothing guarantees the accuracy of the values.

After identified the measuring and monitoring equipments, subject to metrological confirmation, the department responsible for controlling these devices (usually the quality department) should plan and program the calibrations or verification, as shown in Table 1.

Table 1 – Example of a program of calibration or verification.

| Identification number | Periodicity of calibration | Year: 2013 | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Months | | | | | | | | | | | |
| | | Jan | Feb | Mar | Apr | May | Jun | Jul | Aug | Sep | Oct | Nov | Dec |
| PQ.01 | Annual | | P | | | | | | | | | | |
| PQ.02 | Annual | D | | | | | | | | | | | |
| MC.01 | Annual | | | | P | | | | | | | | |
| CD.01 | 6 months | | | | P | | | | | | | | |
| VOLT.01 | Annual | | | | | P | | | | | | | |

Legend: P - Planned D - Done.

You should distribute the first calibration of each device along the deadline for full implementation of the measurement system. It is suggested that for similar equipment or the same family the planned calibrations are marked in different months, preventing that during the calibration period the organization do not stay without any substitute equipment of that group.

After the first calibration, the next will be made according to the periodicity of calibration defined and can not be delayed.

## METROLOGICAL CONFIRMATION

All equipment used to perform the measurement of a characteristic of the product during the manufacturing process, which may in any way affects the quality of the final product should be checked and calibrated periodically to ensure the reliability of measurements. So it should be done to verify the fitness for use of equipment, called metrological confirmation, which is the third phase of implementation of the MSM.

The metrological confirmation covers various actions, which are highlighted as follows:

- Calibration;
- Metrological Verification (compliments of acceptance criteria)
- Adjust if necessary and consequent calibration;
- Repair, if necessary, and consequent calibration;
- Review of the confirmation interval (frequency), if necessary;
- Marking of metrological confirmation;
- Registration of metrological confirmation.

Usually, the process of the metrological confirmation of an measuring equipment is described by means of a flowchart. Figure 2 shows the flowchart model given in ISO 10012 standard and which may be implemented in its entirety or adapted to the specific needs for any organization.

The metrological confirmation must be designed and implemented to ensure that the measurement characteristics of the measuring equipment fulfill the metrological requirements of the measurement process.

All the relevant information about the state of metrological confirmation of the measuring equipment must be accessible to the operator including any limitation on use or particular requirements.

One aspect that should be taken into consideration is the metrological characteristics of the measuring equipment, which must be suitable for the intended use. For example if the tolerance process measurement is ± 2% of the value, the technical specification of the equipment should be less than 2%.

The methods used to determine or modify the intervals confirmation shall be described in documented procedures. These intervals should be reviewed and adjusted as necessary to ensure continued compliance with the metrological requirements specified.

When the equipment is repaired, adjusted or modified, the respective interval for metrological confirmation should be revised.

The records of the metrological confirmation process must be dated and approved by an authorized person to ensure the correctness of the results. These records should be maintained and available.

**Acceptance criteria**

The objectives of the existence of acceptance criteria is to define, in particular the maximum or minimum acceptable value, given by the measurement tolerances of the process and allow to analyze the results of calibrations / verifications performed and make decisions about its use.

Whenever exists some applicable law or normative document the acceptance criteria should be defined as the respective document. Without other specification we can use the following criterion for acceptance of the calibration:

- The sum of the module of the measurement error with module of uncertainty must be less or equal to the maximum acceptable value (MAV) for the equipment, ie,
  $| \text{error} | + | \text{uncertainty} | \leq \text{MAV}$.

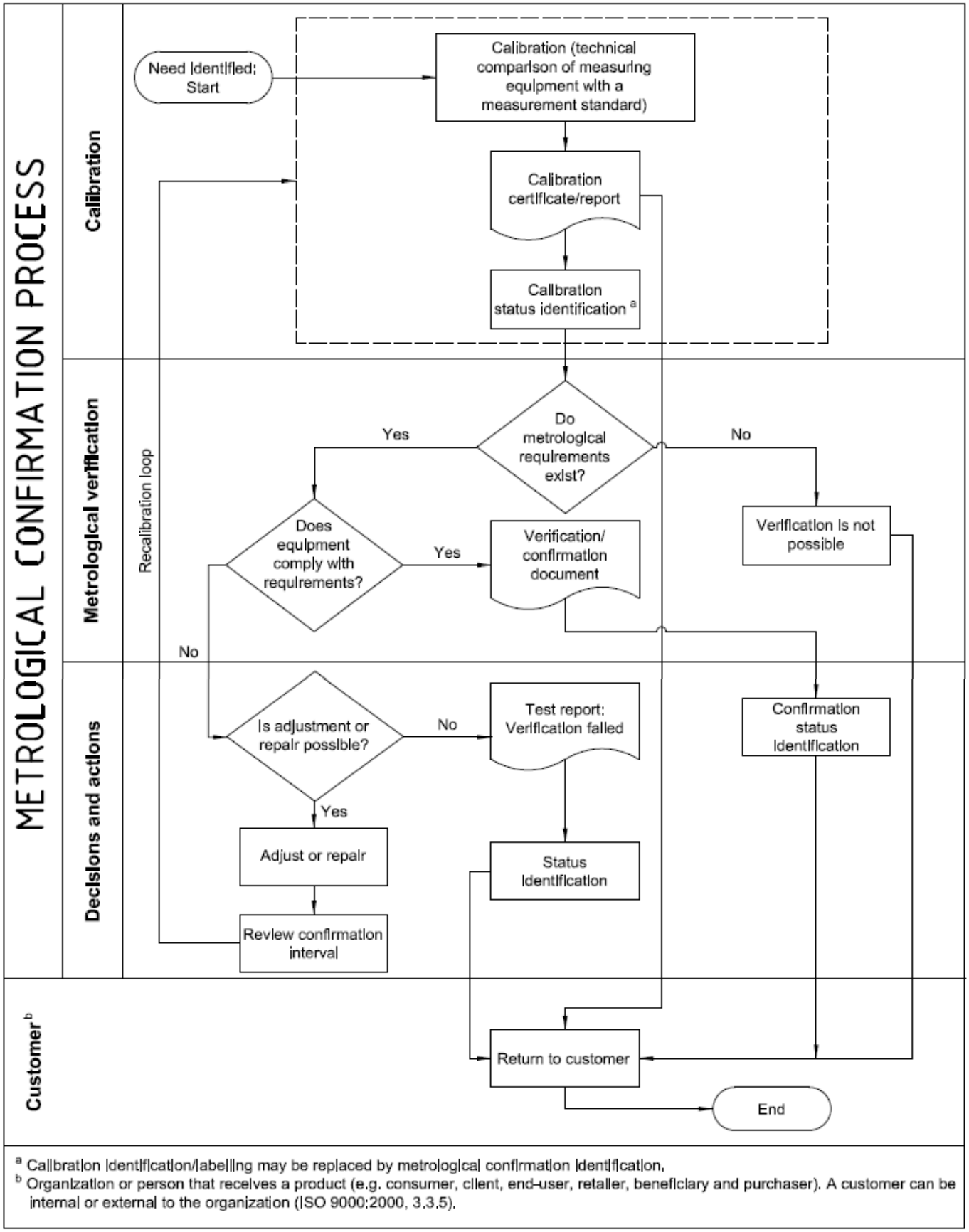


Fig. 2 – Metrological confirmation process for measuring equipment (ISO 10012: 2003)

**Definition of maximum acceptable value (MAV)**

As indicated above, where there is a legal document or applicable law the maximum acceptable value should be set as the respective document, in the absence of such value we may use other forms to define it.

Resort to the technical characteristics of the equipment or technical specifications, according to manufacturers, is one of the ways to set the MAV. In this case the maximum acceptable value should be equal to the technical specifications defined by the manufacturer for the measuring equipment. The fulfillment of this specification ensures, according to its manufacturer, that the measuring equipment is measuring correctly and meets the characteristics with which it was manufactured.

If your measuring equipment is being used in a process that has a tolerance defined by the user, the MAV should comply with such tolerance and be able to define the maximum acceptable value such as $\frac{1}{3}$ of the tolerance or if we want to be more restrictive adopt $\frac{1}{4}$ or $\frac{1}{10}$ of tolerance. We will use the following example to better illustrate this definition.

Example:
Abbreviations and definitions:
T - tolerance of the product or process
IT - tolerance interval
k - factor of safety (always greater than 1 and user defined)

The tolerance on the temperature measurement process in an oven is of ± 2 ° C.
How can I set the MAV to accept the thermometer that controls this process?

$T = \pm 2\ ^{\circ}C$
$IT = T \times 2 = 2 \times 2 = 4\ ^{\circ}C$
$MAV = \frac{IT}{k} = \frac{4}{3} = 1{,}3\ ^{\circ}C$

In this case, the acceptance criterion is: | Error | + | Uncertainty | ≤ 1.3 º C
You should perform this analysis for all values reflected in the calibration certificate.

**Calibration intervals**

The calibration and respective metrological confirmation of measuring equipment must be performed before the initial use and at intervals established. These intervals are called calibration intervals or frequency calibration.

The initial frequency of metrological confirmation, according to the guide ILAC-G24 / OIML D 10, should take into consideration the following:

- Equipment manufacturer's recommendation;
- Intensity and frequency of use;
- Environmental conditions at the place of use;
- Required measurement uncertainty;
- Maximum permissible errors (for example, by the legal metrology);

- The influence of the measured quantity (eg, high temperature effect on thermocouples);
- Experience with similar equipment.

**Calibration intervals**

If the equipment always complied with the acceptance criteria defined previously and after a history of at least three calibrations, you can make a revision to the calibration interval, otherwise this review should be performed just after the failure of the acceptance criteria . The review method must minimize costs and ensure the reliability of the measurement system.

Methods for redefinition of calibration intervals according to the guide ILAC-G24 / OIML D10, include automatic adjustment or "staircase", control chart, history, “in-use” time and in service checking or “black-box” testing. Additionally, ISO/IEC 17025 standard requires the validation of the measurement process in terms of production, involving methods such as evaluate the trend, linearity, stability, repeatability and reproducibility (MSA – Measurement System Analysis).

## MEASUREMENT PROCESS

The realization of the measurement process, including records of the measurements should occur as the methods set in point “Selection of measuring equipment”. Any doubts related to the measurement equipment (for example, due to incidents, falls or overload during use of it) should cause it to be removed from service and return to metrological confirmation. The resulting data should be analyzed periodically to assess trends in product/process, but also for corrections on the measurement processes and metrological confirmation. Products/processes measured with unproven equipment metrologically should be considered products/processes suspected of non-compliance, and adequately controlled, along with related equipment.

## CONCLUSIONS

A management system of measurement has great influence on decisions about product quality and process control but does not always receive that amount being relegated to the status of essentially technical issue. Five basic phases are involved in establishing a management system of measurement: definition of responsibilities and authorities, selection of measuring equipment, calibration or verification program, metrological confirmation and measurement process. The correct execution of these phases allows a decision on measurements on more solid foundations, minimizing the risk of pass/fail inappropriate of products or processes.

## REFERENCES

Barradas J, Pereira A. Management system of measurement: a guide for development. Proceedings of 12th International Symposium on Quality. Solin, Croatia, 2012 p. 103-110.

Bunday, D., Allgair, A., Caldwell, M., Solecky, P., Archie, N., Rice, J., Singh, B., Cain, P., Emami, I. Value-Added Metrology. IEEE Transactions on Semiconductor Manufacturing, 2007, Volume 20, Nº 3, p 266-277.

Duarte Jr., Nasario F. Sistema de Gestão de Medição: importante, mas nem sempre reconhecido. Metrologia & Instrumentação, 2008, nº 56, ano 7.

ILAC-G24 / OIML D 10:2007. Guidelines for the determination of calibration intervals of measuring instruments. International Laboratory Accreditation Cooperation: Silverwater, Autralia, International Organization of Legal Metrology: Paris, França.

NP EN ISO 9001:2008. Sistemas de gestão da qualidade - Requisitos. Instituto Português da Qualidade, Lisboa, Portugal.

NP EN ISO 10012:2005. Sistemas de gestão da medição. Requisitos para processos de medição e equipamento de medição. Instituto Português da Qualidade, Lisboa, Portugal.

NP EN ISO/IEC 17025:2005. Requisitos gerais de competência para laboratórios de ensaio e calibração. Instituto Português da Qualidade, Lisboa, Portugal.

Rios, R., Brandon, J. Metrology for a Competitive Advantage. Cal Lab - The International Journal of Metrology, 2010, Volume 17, Nº 2, p 35-37.

VIM (2008). Vocabulário Internacional de Metrologia. Instituto Português da Qualidade, Lisboa, Portugal.