Tecaliman
Center of expertise for a sustainable feed business

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Checking temperature probes

1. Industrial context

Control of a heat treatment process involves having to control the main parameters that guarantee treatment efficacy, i.e. temperature. Generally speaking, this means making sure that the temperatures recorded during a batch treatment are conform with the initial set temperature and, therefore, that the temperature measurement chain is providing reliable data.
Use of this method forms part of the mandatory quality assurance process for plants certified to ISO 9002
This means of guaranteeing product quality is both faster and more cost-effective than the analytical control.
In the animal feed industry, several heat treatment techniques are affected by this topic; this includes processes designed to:

- Reduce microflora and eliminate salmonella
- Eliminate anti-nutritional factors (e.g. the antitrypsin factor in soybeans)
- Prepare meal prior to pressing, to facilitate the transfer of water and the steam's heat content in the meal.

2. Temperature

2.1. Basic principles

2.1.1. Checking Pt 100 probes and the Calibration chain

The control consists in comparing the temperature readings taken by the process's measurement chain (Pt 100 probe, transmitter, line, display) against those read on a calibrated reference thermometer, which is connected to a calibration chain.
All the information required to carry out this check is described in the guide "Métrologie dans l'entreprise" (*Metrology in Business and Industry* - AFNOR 1996) and the French standards handbook referred to as the "GUM" (*Guide to the expression of uncertainty in measurement*) (AFNOR 1997)

2.1.2. Calibration or verification

There are two options: calibration or verification

- Calibration consists in all the operations, carried out under a set of specified conditions, used to establish the relationship between the orders of magnitude indicated by a measuring instrument or system and the corresponding orders of magnitude read on the standards.
- **Verification** consists in confirming by means of an investigation and collection of evidence that the specified requirements have been complied with.

Verification is the preferred method as this method provides for:

- using a single measurement point close to the sensor's usual measuring point.
- asserting whether the measurement meets the pre-requirements (i.e. permissible error limits)

2.1.3. Orders of magnitude that are characteristic of the verification

The verification consists in establishing three orders of magnitude:

- **Maximum permissible error:** this is the value defined by the user according to their objective.
- **Variance *(noted E)*:** this is the difference between the value read with a sensor and that measured by a standard, or an observed value minus its reference value.
- **Measurement uncertainty:** in terms of measurement readings, this parameter characterises the spread of plot points for this measurement (similar concept to standard deviation).

Generally speaking, the measurement uncertainty includes several components or standard uncertainties (U_n). In this case, it is referred to as a ***combined standard uncertainty*, U_C**, which is equal to:

$$U_c = \sqrt{U_1^2 + U_2^2 + U_3^2 + ... U_n^2}$$

Health or safety applications require an uncertainty measurement that defines, around a given measurement reading, an interval within which it should

hopefully be possible to plot most of the value spread.
The new uncertainty measurement that meets this requirement is referred to as the ***expanded uncertainty (U_{EL})***. This is obtained by multiplying the combined standard uncertainty U_C, by an *expansion factor k.*

$$U_{EL} = U_c \times k$$

2.2. When should the temperature measurement chain be checked?

2.2.1. When installing a new piece of equipment

This control is designed to check the operation of a new equipment or apparatus (sensor linked to a measurement chain) and to record all the data that could impact on this temperature measurement.

2.2.2. During the measurement chain operating period

The purpose of this control is to check that the equipment is in proper working order and to take readings in order to correct any malfunctions. A checking frequency for sensors and the measurement chain should be established.
Between these controls, the probe should be stored in a clean place and its position checked.
Any modifications made to the probe and measurement chain should be notified, recorded and, where necessary, verified.

2.3. Who can perform the verification?

2.3.1. External control

Companies with ISO 9002 certification are advised to seek a provider that is either connected to the BNM or COFRAC certified.
Probe verifications can be carried out on-site or at a laboratory. In the latter case, the probe will have to be dismantled.

2.3.2. Internal control

Internal verification of the measurement chain is economically justified whenever the business has a large sensor base.

2.4. How?

2.4.1. The verification procedure

First, it has to be checked whether the location of the Pt 100 probe enables a representative measurement to be taken of product temperature during the treatment process.
In the first instance, it is advisable to check the whole measurement chain, and then check each of its component parts in the event of a malfunction.

2.4.2. Verification principles, example of Pt 100 probe

2.4.2.1 Uncertainties and temperature measurements

Concerning temperature, the verification's combined standard uncertainty (Ut_C) for a Pt 100 probe breaks down into two main parts:

- The uncertainty for the temperature read by the sensor to be verified;
- The uncertainty for the actual temperature read by the standard sensor;

Each component is itself composed of various uncertainties.
A careful and comprehensive analysis of the calibration process used, the technical means employed, the calibration instrument used and the instrument to be verified makes it possible to draw up a report on all the identified uncertainties.

2.4.2.2 Equipment and apparatus

All the equipment and apparatus is described below:

- **A room** (laboratory or workshop) in which to carry out the verification
- **A local thermometer** used to read the ambient temperature.
- **The Pt 100 probe that needs to be verified.**
- **The standard sensor:** The standard should be used in most operations that use comparative testing. It is not needed when the verification is made using a fixed-point temperature controlled room. In this case, the chamber provides the standard.
- **The link cable:** This is a disruptive element that is required in most cases. It is more or less mandatory for on-site verifications. It should be made of flexible copper wire, with a cross-section of 2 mm^2 .
- **Temperature controlled room:** This is a room with a steady temperature.
  Where verifications are concerned, this involves a basin or oven with an equalization unit that maintains a satisfactory insulating capacity.
- **Precision measuring instruments :** A tester-standard with a direct readout in °C, with a known temperature uncertainty.

2.4.2.3 Methods

To check a Pt 100 probe, it will be necessary to identify:

- the **variance E_C** between the temperature measured by the probe (t_i) and the temperature measured by the standard (t_r)

$$E_C = t_i - t_r$$

- **combined standard uncertainty (Ut_C)** of the verification of the probe to be calibrated relating to determination of the actual temperature (t_r)

$$Ut_C = \sqrt{(Ut_r^2 + Ut_i^2)}$$

The following have to be identified for each measurement point:

t_i : temperature of the probe to be verified.

t_r : temperature measured by the standard

Ut_i : uncertainty for the probe to be verified

Ut_r : uncertainty for the standard

- **expanded uncertainty (U_{EL})** on the verification of the probe to be calibrated relating to determination of the actual temperature (t_r)

2.4.2.4 Data records and document management

The data collected during the verifications are recorded on log sheets, after which a verification report should be drafted.
It is essential to record in these documents the references for the verification equipment and the verified probe, the operator's name, the date of the operation, etc.
These documents should be archived to enable the calculations to be verified at a later date and to ensure metrological traceability of the sensors.

2.5. Exploitation of the results

To be able to use a verified sensor, the "raw" temperature reading indicated by this sensor must lie within a specified interval that has been approved by the user. This interval or tolerance zone or permissible error range is equal to:

$2e$:

where

e is the maximum error tolerance for the user's temperature measurement.

Generally speaking, once the sensor has been checked, the industrial should:

- Identify the sensor's tolerance zone
- Demarcate the sensor's zones of conformity and/or nonconformity, taking account of the expanded measurement uncertainty (U) and the variance (Ec) between the temperature on the sensor to be calibrated and that of the standard (Table 1).
- Take their decision, i.e.:
  - approve the probe
  - replace the probe
  - calibrate the probe

In this last case, the calibration cost would probably be greater than the probe's replacement cost.

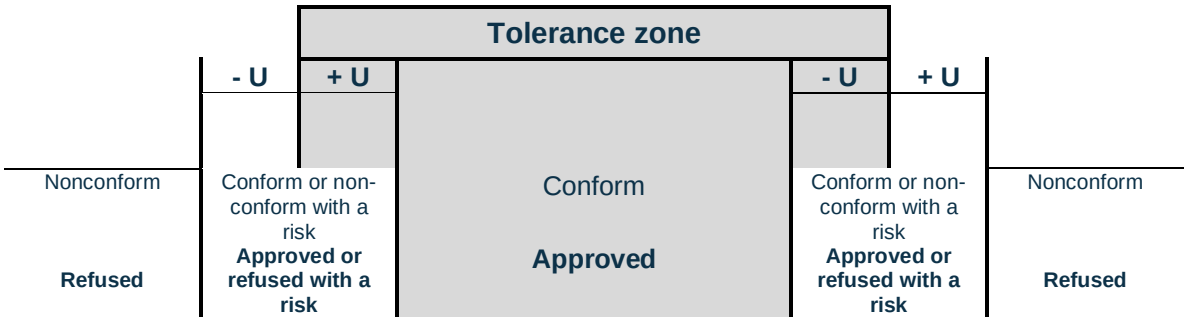

Table 1

2.6. Checks on verification means

All the apparatus used to make the verification must be calibrated on a regular basis, i.e. standard probe, temperature controlled chamber, and calibrator. These calibrations should be carried out by a metrology dept. connected to the national network.

3. Bibliography

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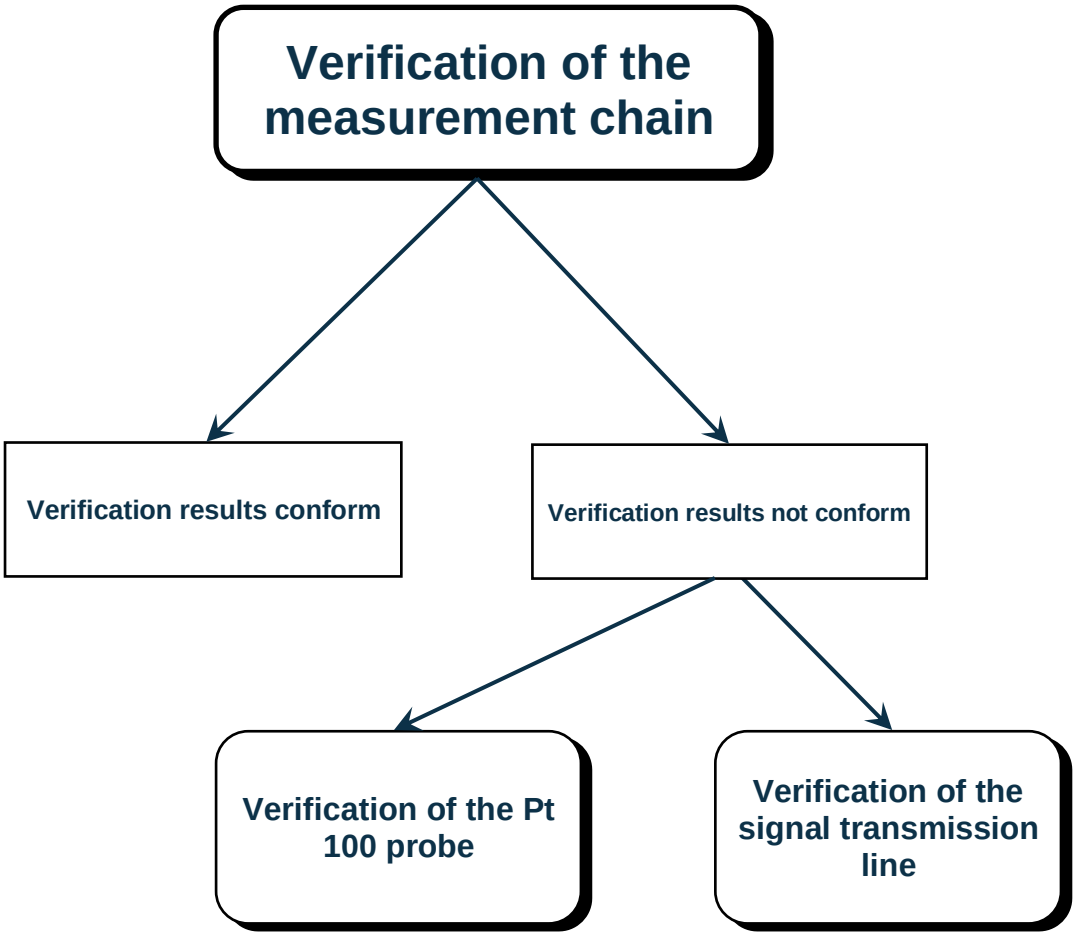

Figure 1: Verification procedure for a plant temperature measurement chain