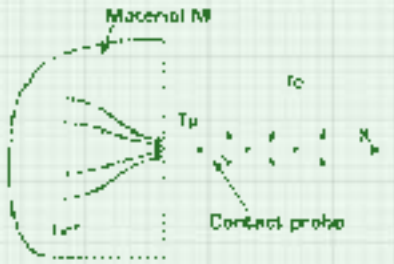
Calibration and use of surface temperature sensors

To improve the accuracy of surface temperature measurements, a workgroup run by Pyro-Contrôle, bringing together members from industry and the Laboratoire National d'Essais (French National Test Laboratory) has instituted a project called Gemini-Cats. It is going to produce, in a pre-standard context, a Guide to using surface temperature sensors and a Guide to calibrating them. The project is based on the temperature reference surface principle developed by the LNE, industrialised and marketed by Pyro-Contrôle under the Surfacal name, which enables measurements to be related to national measurement standards. The progress status of Gemini-Cats and the Surfacal equipment, reference surface are given.

Some theoretical aspects of surface temperature measurement and calibration

The most widely held ideas among users of contact temperature measurements is that the temperature measured is the actual temperature. In the case of surface temperatures, this supposition is all the more false because there is a "mandatory" difference linked to the measurement itself, which is made at the interface between two mediums at different temperatures.
It is worth recalling here some basic theory*. Surface temperature is determined by the application of a sensor at the material/environment interface.



At the material/sensor interface, there is a temperature difference that has several kinds of origin:

> macroconstriction, a phenomenon related to the material itself;
> the resistance of the contact related to the surfaces in contact between the material and the sensitive component and lastly,
> the fin effect, related to the construction of the sensor.

Findings

Numerous industrial applications use contact-type surface temperature sensors. However, at the present time there is no reliable industrial method enabling correct calibration and use of this type of sensor. Research has nevertheless repeatedly shown that incorrect use of these contact-type surface temperature sensors can be at the root of very significant measurement errors - from several degrees to several dozen degrees.

The project

Aim of project
It is two-fold:

> firstly to establish a method of calibrating contact-type surface temperature sensors and confirming the method on the basis of calibrating a set of sensors representative of existing technologies;

> secondly, establishing and confirming a method of using contact-type surface temperature sensors based on concrete instances of applications in an industrial environment.

Benefit of the project

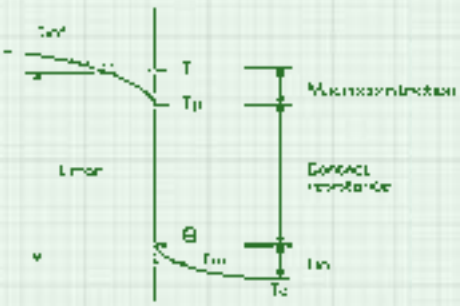
Economic aspect
Better assessment of temperatures actually measured, resulting in improvements in running and monitoring processes.

Quality assurance
Possibility in the near future of checking measurements made by contact-type surface temperature sensors, by COFRAC (or equivalent) calibrations.

Standard aspect
Guides for calibrating and using contact-type surface temperature sensors will be able to form the basis of work on standardisation in the field. … and it concerns many sectors of business, such as aeronautics, iron and steel, and the food and agriculture industries.

Participants in the project

The project group which is coordinated by Pyro-Controle, is made up of equipment manufacturers and calibration laboratories: AOIP, Berruet Monnet and users directly concerned by the issue: EDF, Airbus, Apave and the LNE's National Bureau of Metrology.



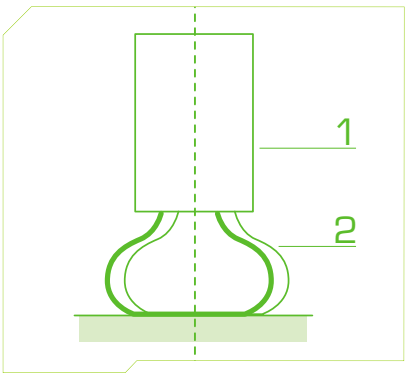
This causes the following known difficulties:

> two different sensors applied to the same surface will give two different measurements (fin effect and contact resistance);
> a sensor applied to two different surfaces of the same temperature, will give two different temperatures (macroconstriction of the material and contact resistance);
> and in all cases, the accuracy of measurements thus made cannot be narrowed by calibrating the sensor by the traditional method (by immersion).

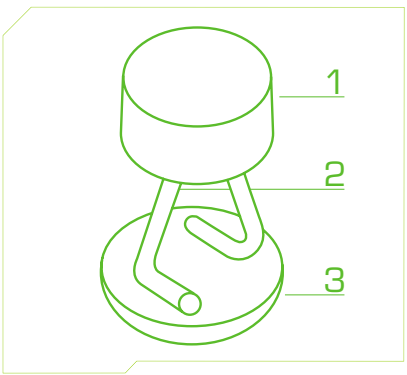
The present state of the art

What is the current practice, first of all as regards using the sensors themselves, then calibrating them?

Measuring surface temperatures
Users have a huge variety of surface sensors for manual entries (hand-held sensors). Most applications concern checking or monitoring industrial processes. The measurements thus made do not come within the ambit of process regulation. They are external to the process itself. In practice, only a few models are suitable from the metrology point of view, i.e. with "acceptable" accuracy. This is the case with the sensor below**:



At the end of the sensor's body (1), the thermocouple fins (2) are soldered and guarantee proper application of the hot point to the surface. Some models marketed with the "surface sensors" description give errors that can be more than 20 °C at high temperature (300 °C). Below is an example of a contact-type surface temperature sensor that is not suitable for measurement purposes**:



The end of the sensor's body (1), the thermocouple fins (2) are brazed onto a tip (3).

The substantial errors in accuracy that these measurements are subject to make contact-type surface temperature sensors instruments currently used for a limited number of applications. The sensors used, most often developed to a specific specification, meet the user's requirements as regards process measurement but very few of them for a precise measurement of temperature.

Temperature sensors are at the heart of monitoring industrial processes

Calibrating surface temperature sensors

There is currently no means available for calibrating surface sensors in accordance with a method that is related to national measurement standards. An initial method consists of calibrating by immersion in a bath or insulated container (traditional method for contact-type temperature sensors), which is not necessarily compatible with the integrity of the sensor to be calibrated. This process is not at all representative of subsequent use in application. Even though the calibration is properly done, the value given by the sensor when used is very different from the actual value for the surface to be measured. The difference can sometimes reach about twenty degrees. One method of calibration dedicated to detachable surface sensors has recently been developed by the BNM-LNE. It consists of generating a reference surface temperature, materialised by a heated skin used for applying sensors to be calibrated. The surface temperature is determined by the method termed "extrapolation"**.

The new benches also allow the connection of industrial furnaces dedicated to calibrating surface sensors.

Responses

The Surfacal innovation, Surfacal temperature reference surface

is a furnace generating a known surface temperature, that can be related to national measurement standards. All proportions of accuracy kept, the principle is that of an in-cell calibration: the temperature read by the sensor to be calibrated is compared to the actual temperature of the standard surface given by the instrument. The instrument is used to calibrate sensors by means of metal skins of different kinds, aluminium (metal material that is a good conductor of heat) or stainless steel (metal material that is a poor conductor of heat), in order to cover the broad requirements of measurement. The scale of use is from +35 °C to +300 °C.

Surface sensors can lastly be calibrated under conditions identical to their use.

Producing a Guide to using surface temperature sensors

Tests conducted on-site have demonstrated what the rules for choosing and using these sensors should be.

The guide, which at the present time is still being prepared, will enable users to make a technological choice of sensor, then to put it into use in application.

Several developments are to be expected from the application of the Guide on use:

> first of all with manufacturers: an upgrade of their offer of surface temperature sensors. Some models will be developed for measurement applications, others that cannot be calibrated will be of limited use;

> with users, a better specification of requirements and more relevant use of measurements.

Producing a Guide to calibrating surface temperature sensors

A guide intended for laboratory staff engaged in metrology, enabling them to calibrate such sensors correctly. The errors found and inaccuracies encountered for example in the case of a sensor with fins are given in the table below:

Case of an aluminium skin

Temperature sensor (°C)	Difference (°C)	Uncertainty (°C)
100°C	-1°C	0,5°C
180°C	-2°C	1°C
300°C	-3°C	2°C

Case of a stainless steel skin

Temperature sensor (°C)	Difference (°C)	Uncertainty (°C)
100°C	-2°C	1°C
180°C	-4°C	2°C
300°C	-6°C	3°C

The method of calibration developed has been confirmed by several campaigns of comparisons between laboratories.

A one-day training course is necessary for temperature metrology laboratory personnel to adapt to the special features of these calibrations.

Several developments can be expected from the application of this calibration Guide:

> first of all with calibration laboratories: an upgrade of their offer of surface temperature sensor calibration so as to provide a calibration service related to national measurement standards. Some laboratories will incorporate these procedures into their COFRAC approval;

> with users, better metrological supervision of their surface temperature measuring instruments.

These guides, currently being produced, will be finished some time in mid-2004.

References

** JP. Bardon, B. Cassagne, Température de surface, Mesure par contact, Techniques de l'Ingénieur, 1998, vol. R2730.*

*** R. Morice, E. Devin, "La mesure par contact des températures de surface, étalonnage et traçabilité des capteurs", dans Conférences du congrès française de thermique, SFT2000, Lyon, 15-17 mai 2000.*

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