EMPIR Call 2017 – Industry, Fundamental, Normative and Research Potential

Selected Research Topic number: **SRT-i28**
Version: 1.0

Title: Enhancing process efficiency through improved temperature measurement 2

Abstract

Almost every modern industrial process relies on accurate knowledge of the temperature. However, modern high value manufacturing has several unsolved temperature measurement problems which currently impede effective and efficient production. These include sensor drift and inaccurate surface temperature measurement caused by process control issues with welding, coating, forming and forging processes. Further to this, combustion processes often have unacceptably large uncertainties and there is currently a lack of traceability to national standards. Therefore, the development of industry focused temperature measurement solutions are needed in order to retain traceability to the SI unit the kelvin and to enhanced process efficiency.

Keywords

Temperature control, Combustion, Surface temperature, Materials processing

Background to the Metrological Challenges

Inaccurate surface temperature measurement causes process control problems with welding, coating, forming and forging processes. In addition, the control and improvement of combustion processes often have unacceptably large uncertainties and no traceability to national standards. For example traceability to national standards is completely new for combustion, or does not exist for fibre optic thermometry.

Reliable measurement of the temperature of surfaces is very challenging for industry. For example shipbuilding relies on steel being held at a tightly defined temperature during welding, and forming and forging in aerospace applications requires accurate surface temperature measurement. Phosphor thermometry has shown great promise in improving surface temperature measurement however it is currently limited to relatively small areas and temperatures <500 °C. In addition, quantitative thermography can capture a wide field of view but its usefulness is severely hampered by the unknown emissivity of the surface. However, the combination of these two techniques could extend the temperature range of phosphor thermometry, and overcome a wide range of process control problems.

The development of high temperature, low cost, low drift thermocouples currently represents a huge step forwards for industry. For example for drift testing, there is a need for an in-situ reference thermocouple (i.e. self-validating) within the furnace in order to ensure traceability. Current contact thermometry measurements up to 1300 °C are mineral insulated, metal sheathed Type K and N (base metal) thermocouples. These have recently been extended in terms of the temperature at which they can be reliably operated, and their stability, with the advent of the double-walled Type K and N thermocouples. However, this has also introduced new problems such as the standardisation and traceability of newer types of thermocouples including optimised and more stable Pt-Rh thermocouples (i.e. Pt-6 %Rh vs. Pt-40 %Rh).

Gas turbines and internal combustion engines are very conservative in design due to the high uncertainty in combustion temperatures. The temperature of combustion processes are generally determined by complicated, elaborate laser diagnostic arrangements yet despite the sophistication of these optical methods the temperatures typically have uncertainties of 5-10 %. Therefore use of portable standard reference flames in a wide range of industrial environments needs to be demonstrated in order address this uncertainty issue and to show how the efficiency of combustion processes can directly fed into improved energy use and products.

In harsh environments, as the sensor materials degrade in-process, the sensor drifts out of calibration. In some cases e.g. silicon processing and high temperature ionising radiation environments (such as nuclear fuel/waste processing and decommissioning), thermocouples are not viable and fibre-optic based techniques are needed. A number of fibre-optic thermometry techniques are currently available however such methods need validating; as few, if any, of such devices permit traceable measurements.

Objectives

Proposers should address the objectives stated below, which are based on the PRT submissions. Proposers may identify amendments to the objectives or choose to address a subset of them in order to maximise the overall impact, or address budgetary or scientific / technical constraints, but the reasons for this should be clearly stated in the protocol.

The JRP shall focus on the development of metrological capacity for enhanced process efficiency through improved temperature measurement.

The specific objectives are

1. To develop accurate methods for phosphor thermometry for temperatures up to 1000 °C. Such methods should also be combined with quantitative thermography in order to determine emissivity measurements for temperature measurements over wide fields of view. The in-process target uncertainty for these techniques is less than 3 °C at 1000 °C.
2. To develop and implement improved and traceable low-drift temperature sensors for enhanced process efficiency and improved temperature control. The low-drift temperature sensors should address the following:
    - the traceability of optimised Pt-Rh thermocouples
    - a reduction in the uncertainty of new in-process temperature sensors (i.e. by solving double-walled mineral insulated and metal sheathed thermocouples resistance breakdown) to less than 3 °C at temperatures up to 1500 °C.
3. To develop a validated in-situ combustion reference standard (i.e. flame reference standard) of known temperature with an in-process target uncertainty of less than 0.5 %. In addition to use the flame reference standard to evaluate the linkage between portable standard reference flames, improved process temperature control, and an enhancement in process efficiency (target temperature uncertainty below 0.5 %).
4. To develop reliable, accurate and validated methods for demonstrating the traceability of at least two different types of fibre-optic thermometry in hostile environments. In addition, to develop novel methods for fibre-optic thermometry, validated in at least one harsh environment with a target uncertainty of better than 5 °C up to 500 °C.
5. To facilitate the take up of the technology and measurement infrastructure developed in the project by the measurement supply chain, standards developing organisations (e.g. those associated with the Energy Efficiency Directive 2012/27/EU) and end users (petrochemical industry, nuclear power industry, cement manufacture, iron and steel manufacture, gas turbines and automotive industries, consumer electronics industry, metals industries, food and beverages industry, and healthcare).

Proposers shall give priority to work that meets documented industrial needs and include measures to support transfer into industry by cooperation and by standardisation. An active involvement of industrial stakeholders is expected in order to align the project with their needs – both through project steering boards and participation in the research activities.

Proposers should establish the current state of the art, and explain how their proposed project goes beyond this. In particular, proposers should outline the achievements of the EMPIR project 14IND04 and how their proposal will build on those.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 1.5 M€, and has defined an upper limit of 1.8 M€ for this project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 30 % of the total EU Contribution to the project.

Any industrial partners that will receive significant benefit from the results of the proposed project are expected to be unfunded partners.

Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the “end user” community, describing how the project partners will engage with relevant communities during the project to facilitate knowledge transfer and accelerate the uptake of project outputs. Evidence of support from the “end user” community (e.g. letters of support) is also encouraged.

You should detail how your JRP results are going to:

- Address the SRT objectives and deliver solutions to the documented needs,
- Feed into the development of urgent documentary standards through appropriate standards bodies,
- Transfer knowledge to the Industrial sector.

You should detail other impacts of your proposed JRP as specified in the document “Guide 4: Writing Joint Research Projects (JRPs)”

You should also detail how your approach to realising the objectives will further the aim of EMPIR to develop a coherent approach at the European level in the field of metrology and include the best available contributions from across the metrology community. Specifically the opportunities for:

- improvement of the efficiency of use of available resources to better meet metrological needs and to assure the traceability of national standards
- the metrology capacity of EURAMET Member States whose metrology programmes are at an early stage of development to be increased
- organisations other than NMIs and DIs to be involved in the work

Time-scale

The project should be of up to 3 years duration.