# Title: High temperature metrology for industrial applications (>1000 ºC)

## Abstract

The measurement of temperatures above 1000 ºC is both difficult and yet vital for the success of a wide range of industrial processes. Growing environmental concerns, and worldwide competition, require better temperature control in order to improve efficiency of processes. The proposed JRP should address improved traceability and accuracy of both contact and non-contact temperature measurements above 1000 °C; and include improved reliability and accuracy of sensors, which will facilitate stability testing and lifetime assessment of sensors.

## Conformity with the Work Programme

This Call for JRPs conforms to the EMRP 2008, section on "*Grand Challenges"* related to *Industry & Environment:*

p12 "*Temperature measurement devices*. Priorities had been identified for applications in safety, security, healthcare environment, high technologies and sustainable resources: rapid and low-cost sensor calibration, new types of temperature sensors, self validating sensors..."

p35 "*New types of temperature sensors.* For special applications new types of highly specialised thermometers will be developed like… thermometers with improved temporal and spatial resolution, stable high temperature thermocouples…"

## Keywords

Thermometry, radiation thermometry, industry, high temperature, novel sensors, self-validation, calibration, thermocouple, eutectic, ITS-90

## Background to the Metrological Challenges

The measurement of temperatures above 1000 ºC is both difficult and yet vital for the success of a wide range of industrial processes e.g. aerospace/space (~1300 - 3000 ºC), nuclear fuel production (~1800 ºC), refractory metals production (2500+ ºC), silicon carbide, carbon/carbon composites (to >2800 ºC) and steel and glass manufacture (1100 to 2000 ºC). Many of these industries require improved process efficiency/control, because of growing environmental concerns and competition from beyond Europe.

Current temperature sensing technology generally resides with sensor manufacturers, with some bespoke solutions developed by particular industrial sectors. All thermocouples are known to drift, often unpredictably. The current state of the art industrial practice is:

- below 1250 ºC type N thermocouples:
- 1250 - 1700 ºC: Type R, S or B thermocouples: Pt/Pd thermocouples are superior to current R, S or B types, but currently not robust enough for industrial application and need further development.
- above 1700 ºC refractory (W/Re) thermocouples: W/Re are the sensor of last resort as they drift quickly, embrittle in place so cannot be removed for re-calibration, and even new W/Re thermocouples can have an uncertainties of order 20 ºC, which means processes are often "overcooked" leading to higher emissions and poor energy use.



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- All temperatures: Non-contact thermometry. Non-contact thermometers often have to view through a window, requiring knowledge of the window's optical parameters. In addition the window is often progressively contaminating, leading to a requirement for scheduled process shutdown and window decontamination. Unknown and varying surface emissivity is a significant source of uncertainty for the technique and the need for traceable methods for emissivity compensation is urgent.

The project will address all aspects of the traceability chain and will develop the methods for improving of the uncertainty level for both short and long-term stability of all device types

## Scientific and Technological 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 JRP protocol.

The overall aim of the JRP is to develop new and more accurate methods and instrumentation for the determination of the high temperatures above 1500 °C for different industrial applications and more accurate methods and instrumentation for the determination of the high temperatures in the range (1000 – 1500) °C. The JRP should provide validated and reliable measurements/methods with traceability wherever it is practicable to do so.

The specific objectives are:

1. Develop traceable and accurate measurement techniques for in-situ and surface high temperature measurements in range above 1000 ºC
2. Develop the techniques to enable lifetime testing, and stability evaluation of temperature sensors above 1000 ºC
3. Develop self-validating contact thermometry sensors for use above 2000 ºC
4. Develop self-validating methods for non-contact thermometry suitable for use between 2500 ºC and 2800 ºC including novel correction techniques.
5. Develop traceable temperature measurements for exotic thermal processing methods such as by plasmas, laser welding and hardening etc.
6. Develop and validate 'reference functions' for non-standard thermocouple types used in specialist industries.

Proposers shall give priority to work that meets documented industrial needs and that which supports transfer into industry e.g. by cooperation and/or by standardisation.

Proposers should establish the current state of the art, and explain how their proposed project goes beyond this. Proposers must ensure that they are familiar with the existing EURAMET funded Joint Research Projects (link below); you must explain how the project is different from the previously funded work, and describe the scientific and technological steps beyond the state of the art.

- ENG06 POWERPLANTS http://www.euramet.org/index.php?id=a169jrps

## Potential Impact

Proposals must demonstrate adequate and appropriate participation/links to the "end user" community. This may be through the inclusion of unfunded JRP partners or collaborators, or by including links to industrial/policy advisory committees, standards committees or other bodies. Evidence of support from the "end user" community (eg letters of support) is encouraged.

Where a European Directive is referenced in the proposal, the relevant paragraphs of the Directive identifying the need for the project should be quoted and referenced. It is not sufficient to quote the entire Directive per se as the rationale for the metrology need. Proposals must also clearly link the identified need in the Directive with the expected outputs from the project.

You should also detail other Impacts of your proposed JRP as detailed in the document "Guidance for writing a JRP"

You should detail how your JRP results are going to:

- feed into the development of urgent standards through appropriate standards bodies
- transfer knowledge to the at least three industrial sectors
- link to and build on the existing EMRP funded project ENG06 POWERPLANTS, and the related EMRP researcher grants.

You should also detail how your approach to realising the objectives will further the aim of the EMRP to develop a coherent approach at the European level in the field of metrology. 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 Member States and countries associated with the Seventh Framework Programme whose metrology programmes are at an early stage of development to be increased
- outside researchers & research organisations other than NMIs and DIs to be involved in the work

## Time-scale

The project should be of 3 years duration.