European Metrology
Research Programme
Delivering Impact

Improving nuclear reactor safety

Few instruments and sensors will survive inside a 2000 °C furnace. Yet such high temperatures must be measured accurately, if we are to keep improving the materials which are manufactured at or submitted to such temperatures - materials which are key to industries like aerospace and energy. New methods are needed to provide reliable measurement of the extremely high temperatures which underpin vital industrial processes.

Europe's National Measurement Institutes working together

The European Metrology Research Programme (EMRP) brings together National Measurement Institutes in 23 countries to address key measurement challenges at a European level. It supports collaborative research to ensure that measurement science meets the future needs of industry and wider society.

Challenge

Many industrial processes, such as steelmaking, glass and ceramics manufacture, and materials research are done in industrial furnaces operating at very high temperatures. Reaching the required temperature is important for producing the right material properties and reliable temperature measurement is key to demonstrating such temperatures have been attained.

Accurately measuring these high temperatures is challenging and is frequently carried out using non-contact thermometers performing measurements through protective windows. These thermometers suffer from measurement inaccuracies caused by the harsh environments produced by the industrial processes. Reliability is further reduced as the windows become covered with a contaminant film of vaporised material from the furnace, depressing the measured temperature by an unknown amount.

Overcoming these measurement problems requires new measurement approaches which can provide traceable, *in-situ* calibration of optical thermometers, without being compromised by the harsh, hot environments.

Solution

The EMRP project *High temperature metrology for industrial applications (>1000 °C)* (HiTeMS) developed and tested new calibration standards for the high temperatures within industrial furnaces.

Small high-temperature fixed-point blackbody cells were developed containing a combination of metal carbon eutectic alloys – cobalt-carbon, ruthenium-carbon and rhenium-carbon - which melt at precise temperatures. Such high temperature fixed points, with very reliable melting temperatures above 1100 °C, have only become available for industrial use through the work of the HiTeMS project. Rigorous laboratory testing was undertaken to ensure they would withstand hostile industrial environments, including very rapid temperature excursions likely to be encountered in industry.

These cells are placed directly in the industrial furnace. For *in-situ* calibration the control non-contact thermometer views the fixed point blackbody. The fixed point melts at a known temperature, against which the thermometers can be calibrated. This *in-situ* calibration against traceable temperature standards creates more accurate and reliable measurements, automatically compensating for the changing window transmission and so allowing industrial processes to be run at optimal temperatures.

Impact

The Alternative Energies and Atomic Energy Commission (CEA), a key player in nuclear power and safety research, is the first user of the temperature cells developed by the project.

The CEA is investigating the properties of materials formed at the very high temperatures in the event of a nuclear reactor accident. Reliable property data for these materials is essential for reliable nuclear power plant safety modelling. Such reliable data can only be obtained if precise material temperatures are known, this demands accurate temperature measurement. However, up to now it has not been possible to perform *in-situ* non-contact thermometer calibrations, leading to potentially significant errors in the furnace operating temperature. The CEA is now using the project's temperature cells to regularly recalibrate their non-contact temperature sensors.

The CEA has greatly increased precision of high temperature measurement using the in-situ standards developed by this project, reducing measurement uncertainties and in particular improving assurance of the furnace operating temperature. The CEA now has increased confidence that materials have been formed at the specified temperatures and reliable test results will improve models used for severe nuclear accident prevention and management. They are also promoting the use of the project's temperature cells to other members of the EURATOM FP7 Framework project SAFEST, which is researching the control of accidents in nuclear power plants.

Projects such as these should ensure that, in the extreme event of an accident in a nuclear power plant, damage is contained and the consequences minimised.

High-temperature metrology for industry

The EMRP project *High temperature metrology for industrial applications (>1000 °C)* developed and extended accurate temperature measurements at high temperatures to support a wide range of manufacturing processes. It addressed specific problems associated with both contact and non-contact thermometry techniques and calibration methods in hostile high-temperature environments with a focus on practical *in-situ* measurement techniques. By enabling effective control of temperature-dependent processes the research supports improved safety, product quality, reduced waste and reduced energy use.

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