

Title: Improving thermal conductivity measurements of super insulating materials (SIMs)

Abstract

Europe's ambitious policy about CO₂ emissions reduction in the building sector depends on efficient insulating materials with reliable thermal performance values. Super insulating materials (SIMs) like Vacuum Insulation Panel (VIP) and Advanced Porous Material (APM) are up to a magnitude lower in thermal conductivity than conventional insulating materials. In this context the accurate measurement of thickness and temperature of the specimens, heat flux and electrical power of the measurement apparatus is crucial for reducing measurement uncertainty. Therefore, boundary conditions and measurement procedures in CEN and ISO standards for traditional insulating materials have to be re-defined for SIMs, in order to guarantee reliable thermal performance values to the market and support European Regulation.

Keywords

Super Insulating Material (SIM); Vacuum Insulation Panel (VIP); Advanced Porous Material (APM); Guarded Hot Plate (GHP); Heat Flow Meter (HFM); Thermal conductivity measurement; Thermal Resistance; Measurement Uncertainty; Boundary conditions.

Background to the Metrological Challenges

During the last years a new group of insulating materials has reached market readiness. These materials make use of suppressed thermal conductance of the gas in the pores – either by size of these pores (Knudsen-effect) or by evacuating the material - to reduce overall thermal transport. These so called Super Insulating Materials (SIMs) are mainly vacuum insulation panels (VIPs) and advanced porous materials (APMs). Aerogels and Nano-Porous powders (such as fumed silica) are sub-groups of APMs.

EN 12667:2001 "Determination of thermal resistance by means of guarded hot plate and heat flow meter methods" is the reference standard for the thermal characterisation of insulating materials. It adopts the criteria of ISO 8301:1991 and ISO 8302:1991. The Guarded Hot Plate (GHP) and Heat Flow Meter (HFM) methods together with the standardised procedures and boundary conditions for the measurement of thermal properties of insulating materials were originally developed for conventional insulation products, such as e.g. polystyrene boards and mineral wool boards. The thermal conductivity for these products ranges from 0.020 W/(m*K) for freshly produced PU foam to 0.070 W/(m*K) for wood wool boards or Calcium silicate boards. This is the intended range that the apparatuses have been designed for. CEN standards EN 12667, EN 12664, EN 12939, EN 1946-2 and EN 1946-3 describe apparatuses and procedures leading to a measurement uncertainty for these materials equal or less than 2 % for GHP and 3 % for HFM. SIMs however are up to a magnitude below that in their thermal conductivity, showing 0.002 W/(m*K) or even less for freshly evacuated VIPs with fibre glass cores.

In order to reduce the uncertainty for SIMs, the accurate measurement of thickness and temperature of the specimen and heat flux and electrical power in the apparatus is crucial. It has been shown that the main portions of the total measurement uncertainty budget are due to the thickness measurement and temperature measurement, as well as resulting from the calibration tests of the machines. Further uncertainty portions come from the very low heat flux through the specimen, the temperature imbalance errors between the central metering and guard sections and non-uniform thermal contact resulting from uneven surfaces / shrinkage / swelling / flaps of the VIP / compression of loose fill etc., as well as for VIPs in a two-plate apparatus from somewhat different thermal conductivities for both specimens.

Therefore it is necessary to reduce the thermal conductivity measurement uncertainty of these materials and increase the level of confidence among customers and potential users for the new materials. More accurate simulations and calculations of thermal performance - based on accurate measurements - will allow a better

evaluation of SIM behaviour in steady state heat transfer and dynamic hygrothermal processes. This includes the possibility to exploit advantages of these new materials at higher temperatures, e.g. when dealing with thermal comfort of buildings in summer. Especially for products that show ageing, it is essential to being able to distinguish between uncertainty (repeatability and uncertainty from method and apparatus) and impact of ageing (deterioration) of the product. This will allow a better understanding of the performance of these materials over time and therefore raise confidence on the market.

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 metrology research necessary to support standardisation in thermal conductivity measurements of Super Insulating Materials (SIMs).

The specific objectives are

1. To assess and enhance the design principles, measurement procedures and boundary conditions for the thermal characterisation of Super Insulating Materials (SIMs) by means of standardised test procedures (Guarded Heat Flux Meter (HFM) and Guarded Hot Plate (GHP) methods) in order to increase the reliability of thermal performance of SIMs.
2. To reduce the measurement uncertainty of the thermal conductivity of Super Insulating Materials (SIMs) toward 3 % as is available for conventional insulating materials in order to realise more accurate simulations of the thermal performance of constructions containing SIMs, thus resulting in higher efficiency due to smaller security add-ons and less construction damages.
3. To develop and demonstrate validated methods that will enable the possibility to determine small changes of the thermal performance over time of Super Insulating Materials (SIMs) associated with physical or chemical deterioration thus leading to reduction in the measurement uncertainty for thermal conductivity and therefore a higher level of confidence among customers and potential users for the new materials.
4. To provide a substantial contribution to standardisation within CEN and ISO by developing guidelines on the measurement of thermal properties of Super Insulating Materials SIMs, product standards for Vacuum Insulation Panel (VIPs), and supplement measurement standards for thermal conductivity to be suitable for SIMs.
5. To collaborate with the technical committees CEN TC 88 WG11, CEN TC 89 and ISO TC 163 SC3, and SC1 and the users of the standards they develop to ensure that the outputs of the project are aligned with their needs, including the provision of a report on the measurement of the thermal properties of super insulating materials and recommendations for incorporation of this information into future standards at the earliest opportunity.

The proposed research shall be justified by clear reference to the measurement needs within strategic documents published by the relevant Regulatory body or Standards Developing Organisation or by a letter signed by the convenor of the respective TC/WG. EURAMET encourages proposals that include representatives from industry, regulators and standardisation bodies actively participating in the projects. The proposal must name a “Chief Stakeholder”, not a member of the consortium, but a representative of the user community that will benefit from the proposed work. The “Chief Stakeholder” should write a letter of support explaining how their organisation will make use of the outcomes from the research, be consulted regularly by the consortium during the project to ensure that the planned outcomes are still relevant, and be prepared to report to EURAMET on the benefits they have gained from the project.

Proposers should establish the current state of the art, and explain how their proposed research goes beyond this.

EURAMET expects the average EU Contribution for the selected JRPs in this TP to be 0.6 M€, and has defined an upper limit of 0.8 M€ for this project.

EURAMET also expects the EU Contribution to the external funded partners to not exceed 30 % of the total EU Contribution across all selected projects in this TP.

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 insulation manufacturers and the construction industry.

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.

Additional information

CEN/CENELEC identified this topic as one of their priorities. Details are available at:
https://msu.euramet.org/current_calls/pre_norm_2018/documents/cen_priority_005.pdf