2009 BFRL Project Description

Project Title: Development of New Standard Reference Materials for Testing of Thermal Insulation

September 4, 2008

Principal Investigator: Robert Zarr

Co-Investigator(s): William Healy, Luis Luyo

BFRL Program: Healthy and Sustainable Buildings

Objective: To reduce uncertainties in measurements of the thermal resistance of insulating materials by developing high temperature measurement capabilities, a high-temperature reference material (i.e., SRM® and/or Calibration), and a replacement for SRM 1450c, Fibrous-Glass Board, using BFRL guarded-hot-plate facilities. **Problem:**

What is the problem? National studies, such as those done by the Partnership for Advancing Technology in Housing, have identified insulation levels as a cost-effective method to reduce energy consumption in buildings. Achieving these expected energy savings requires accurate measurements of the thermal performance of building insulation. A critical component, identified by the Bureau International des Poids et Mesures (BIPM) for accurate measurements, is thermophysical property standards. At present, SRM 1450c, Fibrous Glass Board, is becoming depleted and a replacement is needed. A major complication is that the insulation material is no longer available and, as a result, research is needed to evaluate the suitability of alternative candidate materials. Additional issues arise at elevated temperatures, as inter-comparison studies have revealed an unacceptable scatter of ±15 % for measurements of thermal resistance[1]. Statutory regulations at the federal[2] and state[3] levels require the use of reference materials when testing thermal insulation and have designated NIST as the mandatory purveyor of them for the U.S building industry. The introduction of new/replacement reference materials requires measurements of thermophysical properties on candidate materials and development of the science to minimize measurement uncertainty, especially at high temperatures.

Comment [WG1]: Is this the fibrous-glass board?

Why is it hard to solve? A thermal insulation SRM must be made of a uniform and stable material that can be accurately measured for certification purposes. Establishing a high-quality thermal insulation SRM requires instruments that establish and accurately measure one-dimensional heat flow through the specimen as well as accurately measure the meter area, specimen thickness, and temperature difference. At high temperatures, additional complications

[1] Albers on Thermal Conductivity Testing, ASTM STP 1426, pp. 116-127 (2002).
[2] Federal Trade Commission "Labeling and Advertising of Home Insulation" (16 CFR, Part 460).
[3] Department of Consumer Affairs, Bureau of Home Furnishings and Thermal Insulation, "Standard for Insulating Materials" (California Code of Regulation, Title 24, Part 12.).

arise because the materials must be stable when subjected to elevated temperatures. Elevated temperatures cause difficulties with the thermal testing as well because potential excess heat losses from the apparatus to the environment are exacerbated, thereby disturbing the one-dimensional specimen heat flow. Furthermore, the apparatus itself must be built from materials that can tolerate elevated temperatures (in this case up to 900 K).

How is it solved today, and by whom? At room temperatures, NIST issues SRM 1450c Fibrous Glass Board which, at current rate of issue. No replacement for 1450c is currently available. Other countries do possess capabilities to make measurements at room temperature, and several national metrology institutes are evaluating their guarded-hot-plate measurements by conducting an inter-comparison study under the auspices of the BIPM. Participating laboratories include those from France, China, the United Kingdom, Germany, Russia, Mexico, and the U.S. (NIST). At elevated temperatures, there are no high temperature thermal insulation reference materials; the only national metrology institute with a high-temperature guarded hot plate capability is the National Physical Lab in the United Kingdom.

Why NIST? The proposed work will enhance the competitiveness of the U.S. building industry by providing the measurement science to ensure that thermal resistance measurements of building insulation are accurate. The work fits in with the goals of BFRL's Measurement Science for Net Zero Energy, High Performance Buildings Strategic Priority area in that heating and cooling load reduction through increased insulation in building envelopes is viewed as a critical aspect of achieving minimal energy use in buildings. Federal and state governments have designated the usage of NIST thermal insulation reference materials as mandatory for U.S building industries. BFRL has two unique, but complementary, guarded-hot-plate facilities to provide the measurement science needed for the development of reference materials.

Approach:

What is the new technical idea? NIST will carry out the research needed to develop two new thermal insulation SRMs. One SRM, to be developed jointly in both BFRL guarded-hot-plate facilities, is a replacement for SRM 1450c, Fibrous Glass Board. The initial development of this replacement SRM requires characterization of the physical and thermal properties of materials that are obtained from new sources. To ensure that guarded-hot-plate measurements at room temperature are consistent with those from other national metrology institutes, NIST will continue to partner with members of the Thermophysical Properties Working Group of BIPM in a pilot study on thermal conductivity. The other SRM is to be developed for high-temperature applications in conjunction with input from an ASTM task group on thermal insulation. NIST will measure the pertinent thermophysical properties of several materials to ensure that the candidate material is suitable for high-temperature applications. The thermal characterization of the candidate material will be conducted using the recently-constructed high-temperature guarded hot plate apparatus. Although, this apparatus has been designed to provide measurement uncertainties of 1 % at room temperature and up to 3% at 900 K, the research plan will require verification of uncertainty levels at elevated temperatures. Additionally, to effectively provide a measurement service to the public, NIST will complete development of a control scheme for the 0.5 m hot plate that will bring the apparatus to the proper operating temperature quickly without undue oscillations. Complementing this effort is a general plan to

continue updating the quality system for the new apparatus in accordance with policies under the NIST Quality System.

Why can we succeed now? Several interested parties have now partnered with NIST with the mutual goal of developing the next generation of reference materials. In particular, one thermal conductivity instrument maker that uses SRM 1450c has agreed to work directly with NIST on the replacement. ASTM Committee C16 has identified the need for this work and established a task group to assist NIST with technical guidance and materials acquisition. Perhaps, most importantly, BFRL has extended measurement capabilities with the new NIST 500 mm guarded-hot-plate apparatus. BFRL has also maintained and cultivated a proficient managerial and technical staff with experience in the development of multiple thermal insulation SRMs.

What is the research plan? The research plan covers the development of NIST thermal insulation reference materials (i.e., SRMs® or Calibrations), as well as the pilot study under the auspices of the Thermophysical Properties Working Group of the Bureau International des Poids et Mesures. The development of a replacement for SRM 1450c, Fibrous-glass board, and the development of a new high-temperature SRM are outlined as follows:

- Pre-production: 1) Assessment of customer needs (with input from ASTM C16); 2) location of material sources; 3) selection of a NIST statistician and, 4) evaluation of material and thermal properties using several techniques including guarded-hot-plate apparatus, heat-flow-meter apparatus, thermogravimetry, furnace testing, among others.
- Production: 1) Location and purchase of candidate lot of material; 2) Development of experimental design in consultation with NIST Statistician; 3) Batch-certified measurements of thermal resistance using both NIST guarded-hot-plate apparatus following the experimental design; 4) Draft certificate and, 5) Delivery to Standard Reference Material Program including draft Reports of Analysis.
- Post-production: 1) Documentation of certification effort including NIST SP 260 Series publication; and, 2) Administrative duties handled by Measurement Services Division.

The SRM development and production process is a multiyear effort culminating in two thermal insulation SRMs, one of which would be designated SRM 1450d, Fibrous Glass Board and the other a new high-temperature SRM (number to be assigned by Standard Reference Material Program). In FY09, the focus is on pre-production for both candidate materials. To achieve this work, a careful assessment of the control scheme and measurement uncertainty associated with the 500-mm guarded-hot-plate apparatus will be carried out. As part of the SRM development, the Building Environment Division Quality Manual will be updated as needed.

Comment [WG2]: unfamiliar term

The analysis of the test results for the pilot study on thermal conductivity are expected to be completed in June 2008. In FY09, the participants will review the test results and determine if the NMIs are prepared for a key comparison. If deemed successful by the participants, a multiyear effort key comparison could be initiated which will establish a key-comparison reference value, associated uncertainty, and degrees of equivalence among the participating NMIs.

Recent Results:

- Completion of new 500 mm Guarded-Hot-Plate Apparatus

- *Outcome*: Established NIST Measurement Service Measurements for Thermal Resistance using NIST 1016 mm Guarded-Hot-Plate Facility
- *Outcome*: Lead revision of standards – ASTM C 1044-07 and ASTM C 1558-03 (2007)
- *Output: R. R. Zarr, "Status of NIST Thermal Insul*ation Re*ference* Materials," *Thermal Conductivity 29/Thermal Expansion 17* (2008).

Standards and Codes:

- ASTM C 518 currently requires that all calibration specimens for certification purposes be metrologically traceable to a national metrology institute.
- Department of Consumer Affairs, Bureau of Home Furnishings and Thermal Insulation, "Standard for Insulating Materials" requires all reference materials be traceable to NIST (California Code of Regulation, Title 24, Part 12.)
- ASTM Standard Test Method C177 does not address measurements of thermal insulation at elevated temperatures. Research findings from this work will contribute to extensions of this standard to elevated temperatures.