APPENDIX

Reference Materials of Low Thermal Conductivity

During recent years, Subcommittee C16.30 on Thermal Conductance of ASTM Committee C-16 on Thermal and Cryogenic Insulating Materials has spent a considerable amount of time and effort revising and upgrading its standards relative to the measurement of heat transmission in thermal insulations and systems.

In particular, the ASTM Test for Thermal Conductivity of Materials by Means of the Guarded Hot Plate (C 177-63) has been revised in scope so that it now covers the temperature range of 4 to 1300 K. In addition, the ASTM Test for Thermal Conductivity of Materials by Means of the Heat Flow Meter (C 518-70) has been accepted as a standard for certification purposes over a limited temperature range at or near room temperature, and further activities have been directed toward the promulgation of international specifications based on these methods.

The members of the task groups responsible for the revisions are quite aware of the fact that there are numerous deficiencies and a number of improvements still necessary in the standards. Furthermore, different organizations have continually obtained wide variations in values on similar materials, even over a limited temperature range, when using modified forms of the basic apparatus. These diversities are magnified as the temperatures and conditions become more extreme and consequent heat loss problems increase.

A task group has been established to resolve these problems and to examine the question of the availability of reference materials of low thermal conductivity covering the widest temperature range possible. If reference materials are available then a cooperative measurements investigation should be carried out. In this way all measurements will be improved and unreliable apparatus and techniques corrected. Ultimately, testing laboratories will have to be certified to carry out ASTM tests. In the area of heat transmission it is important to provide reference materials which can be used to evaluate the performance of a test apparatus.

Unlike materials of higher thermal conductivity where heat transport is predominantly by solid conduction mechanisms, heat transfer in thermal insulation is by a combination of modes including solid, gaseous, convection, and radiation. Because the properties are affected by environment and temperature conditions, the ideal reference materials must be readily available and unaffected by heat treatment or at least be in a stabilized condition after heat treatment. In order to obtain a true concept of their properties and stabilities, such materials must be made available and numerous measurements must be made on them by as many organizations as possible using different types of hot plate and heat meter apparatus under controlled temperature and environmental conditions.

The task group has concluded that disregarding the difficulties of effects of environment and temperature there are many candidate materials now available. Many materials have been examined including a number in the range of thermal conductivity ($\sim 10^{-2}$ to 1 $W \cdot m^{-1} K^{-1}$) covering various ranges of temperature, and at least one under high vacuum and at cryogenic temperatures ($\sim 10^{-4}$ $W \cdot m^{-1} K^{-1}$).

The following materials have been proposed as worthy of study.

1. Min K 2000 for the range 300 to 1000 K.
2. A fiberglass material for the range 100 to 500 K. Also a candidate for measurements in high vacuum at cryogenic temperatures.
3. Hypalon and a silicone rubber for the range 100 to 500 K.
4. A foamed glass for the range 100 to 600 K.
5. A foamed silica for the range 100 to 1100 K.
6. A silica fiber for the range 300 to 1200 K in different environments.

The accompanying questionnaire was sent to all those known to have apparatus for evaluation of thermal insulations. So far, approximately 70 worldwide organizations have responded positively, stating they are willing to participate in all or part of an evaluation program. Participation by others is welcome.

Thermal Conductivity Reference Materials Project

Questionnaire

1. Do you have
   (*a*) guarded hot plate apparatus?
   (*b*) heat meter apparatus?
   (*c*) other for thermal insulations? Please identify.
2. What are the temperature limits?
   (*a*) hot face
   (*b*) cold face
   (*c*) differential across sample
3. Can you control sample environment?
   (*a*) vacuum below 10^{-3} torr
   (*b*) gas pressures above 1 atm
4. What is orientation of plates?
5. Can you change heat flow direction?
6. What is sample configuration and maximum thickness?
7. Can you control contact pressure on sample?
8. Please give brief details of
   (*a*) temperature measurement techniques
   (*b*) power measurement techniques
   (*c*) thickness measurement and control
   (*d*) procedures for calibration
9. Please give details of known or estimated
   (*a*) accuracy
   (*b*) precision
10. Are you willing to participate in measurement of some or all of the candidate reference materials?
11. Will you buy sets of samples once they can be made available?
12. Can you suggest other possible materials for consideration as reference materials of low thermal conductivity?

Please supply the requested information and return to R. P. Tye, Dynatech R/D Company, 99 Erie Street, Cambridge, Mass. 02139.