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Taking test
Instruments
Into the
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THEORY OF THE METHOD

The general principle of the FOX heat flow meter instruments is based on one-dimensional Fourier-Biot law:

$$q = - \lambda \, (dT/dx) \qquad (1)$$

where q is heat flux (W/m^2) flowing through the sample, λ is its thermal conductivity (W m^{-1} K^{-1}), dT/dx is temperature gradient (K m^{-1}) on the isothermal flat surface.

If a flat sample is placed between two flat isothermal plates maintained at two different temperatures, and a uniform one-dimensional temperature field has been stabilized, the temperature field in the sample should be uniform within all the sample's volume (size of the plates is supposed to be much larger than thickness of the sample). The temperature gradient can be determined by measurements of the difference between temperatures of the hot and cold plates ($\Delta T = T_{hot} – T_{cold}$) and thickness of the sample Δx, because in this case average temperature gradient dT/dx is equal to $-\Delta T/\Delta x$.

Before starting tests (i.e. measurements of thermal conductivity) of a sample with unknown thermal conductivity, the heat flow meter instrument must be calibrated using some certified sample (standard) having reliable known values of thermal conductivity $\lambda_{cal}\,(T)$.

Electric signal from the transducer Q (μV) is proportional to the heat flux q:

$$q = \lambda_{cal}\,(T_{cal})\, \Delta T_{cal} / \Delta x_{cal} = S_{cal}\,(T_{cal})\, Q \qquad (2)$$

Because physical properties of the transducer change with temperature, temperature calibration of the instrument using the calibration standard is always necessary to get the temperature dependent calibration factor $S_{cal}\,(T)$. Dimension of the calibration factor is $W\ m^{-2}\ \mu V^{-1}$ or $W\ m^{-2}\ mV^{-1}$. A reciprocal value (sensitivity of the heat flow meter) is used in some laboratories. Each of the two transducers has its own temperature, so the calibration factors should be referred to the transducers' actual temperatures. Two separate sets of the calibration factors are measured during the calibration run.

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The calibration factors $S_{cal}(T)$ are the instrument's characteristics. They are used for thermal conductivity calculation during the test run:

$$\lambda_{test} = S_{cal}(T_{test})\, Q\, \Delta x_{test} / \Delta T_{test} \quad (3)$$

Similarly, because each plate has its own temperature the calibration factors should be calculated for plate's actual temperature. Average of two thermal conductivity values is a final result of thermal conductivity test.

Typical value of thermal diffusivity $a=\lambda/(C_p\rho)$ of thermal insulation materials is about (4-7) 10^{-7} m^2s^{-1} ($C_p\rho$ is volumetric specific heat, C_p is specific heat at constant pressure, ρ is density). Fourier number (dimensionless thermal similarity parameter used in studying heat flow problems) $Fo = at/(\Delta x/2)^2$ is about 9-16 per hour for 1" (25.4 mm) thick sample. So, it takes a fairly long time (not less than 0.5 hour for 1"-thick sample) to reach full temperature equilibrium to have $Fo \gg 1$. And 4"-thick sample needs about 16 times more time (about 8 hours) to reach the same temperature equilibrium. Experimental check showed that *average* value of two heat flow meters signals reaches equilibrium several times faster than their *individual* values. So, practically the duration of tests is shorter, because thermal conductivity value is calculated using the *average* value of the signals (see Chapter "Thermal Equilibrium Criteria").

If you have questions – feel free to call, fax or e-mail to LaserComp:
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