KD2 Pro Transforms Theory into Solid, Real-world Technology for Measuring Thermal Conduct

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It's a tiny little thing, especially when compared to the large bench-top instruments most researchers use to measure thermal conductivity. And, at a fraction of the price, it's hard not to wonder whether this pocket-sized instrument can really do what it says it can do-measure thermal conductivity in less than two minutes using just one needle-like sensor.

Student Plants the Seed

Dr. Gaylon Campbell had his doubts when he first heard the method proposed back in the 1970's. His lab was doing lots of thermal properties research, and this method seemed flawed. "A student came over from Ag Engineering. He wanted to put a heater and a temperature sensor inside a probe and measure thermal conductivity that way. He had run across the method in some old literature. The idea had been around, but from my experience with other methods, I told him, 'There's no way you can get thermal conductivity out of that without knowing the other thermal properties of the soil.' I couldn't see how you could use a transient method without involving heat storage."

Insight from a Computer Model

Using computer models he was running for other research, Dr. Campbell set out to show the student why the method wouldn't work and discovered an interesting quirk. "Because the probe is inserted in the sample, the heat flow is limited so much by the material that's right around the [heat] source that the heat storage value drops out of the equation and you're left with the heat transfer values."

Complex Problem Made Simple

Decagon's KD2 series evolved from early sensors built to take advantage of this discovery. The sensor itself looks like a hypodermic needle. The needle contains a heater and a temperature sensor. The sensor is connected to a little controller which sends a heat pulse-just a few tenths of a degree C-to the sample and then monitors the result. It doesn't sound too complicated...but the devil is in the details. "It's a simple looking thing," says Dr. Campbell, "But it involves the deepest and most complicated math that I'm capable of doing." Luckily for the rest of us, all we have to do is push the button.

Multipurpose Instrument Excels with Liquids

The KD2 is capable of measuring a wide variety of things-styrofoam, soil, insulation, food, organic materials, carpet fiber-but it has one of its most interesting applications in liquids.

Monitoring Drilling Fluid Life-span

One of these liquids is actually called mud. It's the high-tech substance used to flush the borehole when oil wells are drilled. As oil wells are drilled deeper, the borehole must be drilled through more difficult geological architecture. Complex formulations of drilling fluid make this possible-balancing the pressure of the oil or gas, stabilizing the walls of the borehole, removing the rock cuttings without clogging the drilling system, and, critically, cooling the drill bit and cutting surface as the hole is drilled. Drilling fluid is pumped through the system, cleaned, and recirculated, but as you would expect from a component with so many functions, the fluid has a limited life-span. Researchers are using the KD2 to monitor this life-span, measuring fluid breakdown as a reduction in thermal conductivity.

Thermal Conductivity Measurement Revolution

Other researchers are using the KD2 for a wide variety of tasks-everything from designing pasteurization equipment for minimizing off-flavors and colors in syrups and sauces, to engineering car engines, to transferring heat more effectively. It's used to measure the thermal conductivity of oil, toothpaste, shampoo, and chocolate sauce. And it's so simple, and so inexpensive, that most researchers experience it as a revolution.

What's the Catch?

How can it be so much less expensive than the other available instruments? It seems a little too good to be true. Does it possibly have some serious limitations? “Well,” admits Bryan Wacker, head of Decagon's Research Instruments division, “you can't stick a needle into a rock.” Because the KD2 probe must be inserted into the sample, certain samples can't be read at all. And other samples are subject to “contact resistance errors,” meaning that what the probe can't adequately touch and heat, it can't measure. These errors can be reduced or even eliminated by using thermal grease on the probe (see the application note available online at www.decagon.com/appnotes/contactresistance.pdf).

Conduction vs. Convection

In liquids, the KD2 may have some limitations, too. Measuring thermal conductivity in liquids can be tricky, because they're...well...fluid. Conduction-the transfer of heat by molecular agitation-must be distinguished from convection-the transfer of heat by mass motion of the fluid itself-in order to get an accurate reading. Convective heat transfer can come from something as inadvertent as jiggling the sample. It can be the result of any shaking or mixing of the liquid, and because heat transfer by convection can be significantly higher than heat transfer by conduction, its effects can cause significant inaccuracies. Convection can also result from something hotter or cooler being stuck into the object-something like the sensor itself.

Reducing Convection Errors

“Fortunately, the KD2 heats the sensor just a few tenths of a degree,” says Decagon Research Scientist Doug Cobos. “That's much less than the heating normally associated with the single-needle heat pulse technique, and that really minimizes error from free convection.” Errors from free convection can also come from the viscosity of the sample and the orientation of the probe during measurement.

How Does Fluid Viscosity Affect Measurements?

Measurements on more viscous samples, such as castor oil, are not affected by free convection. Less viscous fluids, like water, can be significantly affected. Low viscosity fluids may be stabilized to give better readings-in fact, thermal properties probes are commonly calibrated in water, but only after the water has been stabilized with a thickener. And for anything less viscous than water? “Throw it out the window,” advises Dr. Cobos.

Proper Orientation May Improve Accuracy

Additionally, the way you put the sensor in the fluid matters. That’s because of the way the heat pulse from the probe creates free convection. If the probe is oriented horizontally, the heated molecules tend to move upward away from the probe and through the sample in a non-uniform direction. If the probe is oriented vertically, fluid molecules tend to stay close to the probe, and the heat is transferred uniformly on all sides of the probe. So, orienting the probe vertically may mean more accurate measurements.

Optimum Measurement Range Includes Most Samples of Interest

The KD2 has a limited range-0.02 to 2 watts per meter °C. “You won’t be measuring the thermal conductivity of molten metal with this instrument,” observes Bryan Wacker. But for most samples of interest to researchers-soils, foods, fluid formulations-the KD2 is a perfect blend of speed, accuracy, and portability.

Solid Proven Technology

“I actually like to take the KD2 [customer support] calls,” admits Dr. Cobos, “because users like this instrument so much. They say ‘This saves me so much time and energy, I can’t believe we were using this other stuff before.’ It’s small, it’s simple, it’s inexpensive-it’s such a solid instrument.”

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