METER
ENVIRONMENT

THERMAL RESISTIVITY FREQUENTLY ASKED QUESTIONS

WHAT IS THE DIFFERENCE BETWEEN A "FIELD" PROBE AND A "LAB" PROBE?

In some standards, field probes were conceived and designed to measure thermal resistivity of a large representative sample of soil. Field probes are large needles (~ 1 meter long) that put out a lot of heat. Unfortunately, their temperature resolution is rather poor. Thus, the measurement takes a lot of power and time to create enough temperature change to get accurate results. "Lab"-type needles have amazing temperature resolution (0.0001 °C) and with a couple of 5-minute measurements can accurately characterize the thermal resistivity of most soils. Small needles also require a lot less power (4 AA batteries) than a field probe. Keep in mind that field measurements only give you the thermal resistivity of soil at its current moisture content. Lab testing is needed to get a complete picture of a soil's thermal resistivity.

HOW CAN I ACCESS THE SOIL OF INTEREST IN THE FIELD?

The two primary ways to access soil for testing are pulling drill core samples or digging a test pit. Core samples pulled from the depth of interest can be tested on site or sent to a lab. A test pit allows for testing in the field or pulling samples to send in for lab testing. Also, it is a good idea to observe the soil of interest to look for strata layers and inconsistencies in the soil. Remember that field testing does not give the complete picture of a soil's thermal resistivity like lab testing can.

CAN I TAKE FIELD MEASUREMENTS WITH A SMALL (E.G., 100 MM LONG) NEEDLE?

Small "lab" probes can be used in the field as long as the soil of interest is accessible. Consider it the same as removing a soil sample and taking it to the lab. Multiple measurements are suggested to check for variability across the sample of interest.

HOW LONG SHOULD I WAIT AFTER NEEDLE INSERTION TO START THE READING?

2 to 5 minutes. However, this answer is very much dependent on the size of the needle and the temperature difference between the soil/material of interest and the needle. Needles are typically stainless steel and thus have a high thermal conductivity and can come to temperature equilibrium with the surroundings very quickly. But temperature drift (other than needle heating) during a reading can cause errors. It is best to be safe and wait the 5 minutes to ensure the needle and sample are at equilibrium.

HOW LONG DO I NEED TO WAIT BETWEEN READINGS?

Treat each reading like a new test. Wait 2 to 5 minutes before taking a reading. If taking multiple readings, some users have found it advantageous to use a couple of needles (spaced appropriately), moving the controller from sensor to sensor.

WHAT IS THE LARGEST GRAIN SIZE I CAN TEST WITH A SMALL HEATED NEEDLE?

A small (~100 mm length, ~2.5 mm diameter) heated needle can test soil grains up to about 2 mm. At that point, the air gaps start to provide more thermal resistance than the soil itself. Thermal grease and longer read times can help overcome the error caused by air gaps. However, do not ignore air gaps in soil as the line-heat source method, which the heated needle design is based on, mimics the heat dissipation of an underground power cable. If there are air gaps in the soil, it will impact the heat flow from the power cable.

CAN I TEST FROZEN SOIL WITH THE HEATED NEEDLE TECHNIQUE?

Frozen soil can be tested with a heated needle as long as the temperature is within the specifications of the instrument. Do not attempt to measure soil thermal resistivity right around freezing as the phase change invalidates the measurement.

ARE THE CALCULATIONS FOR COMPUTING THERMAL RESISTIVITY DIFFICULT TO DO?

The mathematical computations for computing soil thermal resistivity are not overly complex, but doing any computation by hand can lead to errors. Most commercially available heated needle instruments do all the calculations and give you the resistivity number. The same can be said for soil water content measurements.

DOES METER'S TEMPOS MEET THE REQUIREMENTS IN THE IEEE STANDARD?

The TEMPOS is classified as a "lab" probe in the eyes of the IEEE 442 standard. However, much has changed since the IEEE standard was written in 1981. The IEEE standard is being revised, and the smaller "lab" needles are being considered for fieldwork. As long as the soil of interest can be accessed and the user follows the instruments precautions for field measurements, a "lab" probe can actually be more accurate than a large field probe.

The ASTM standard does not require specific needle lengths for specific applications.

ARE THE SMALL "LAB" NEEDLES FRAGILE?

All heated needle probes have an internal heater and temperature sensor that is filled with a thermal epoxy, but the strength of the needle is in the stainless steel "tube." Forcing the needle could cause it to bend, which may damage the circuitry in the sensor. If faced with a hard soil, it is possible to use a pilot pin or a drill to create a small pilot hole. If doing so, make sure the needle fit is snug. If not, create a new hole or use some thermal grease to fill air gaps.

WHY ARE MY THERMAL RESISTIVITY NUMBERS SO HIGH?

Soil particles have a wide range of resistivities (~15 to 700 °C-cm/W), whereas, water (172 °C-cm/W) and air (~4000 °C-cm/W) have more finite values. The soil particle, water, and air mixture that makes up a soil's characteristic have a large impact on thermal resistivity. Increasing soil moisture typically decreases soil thermal resistivity. On the other hand, the more air in the soil-air-water mixture, the higher the resistivity. Air in soil pores is part of the natural soil makeup, so it should not be

eliminated from consideration. If thermal resistivity readings of the natural soil are high due to air, you may want to consider engineered backfill.

WHAT "NUMBERS" SHOULD I REPORT?

When reporting thermal resistivity, it should always be reported with a moisture content. If the means are available, the density/compaction of the soil should also be reported. For more on reporting see "Thermal resistivity: real rho values for the professional power engineer".

HAVE MORE QUESTIONS?

METER scientists have over 100 years combined experience measuring thermal properties. Contact us if you need application-specific expertise. And, if you don't have time to make your own measurements, METER also offers Thermal Properties Testing Services.