TP02

NON-STEADY-STATE PROBE FOR THERMAL CONDUCTIVITY MEASUREMENT

TP02 is a probe that offers the possibility to perform a practical and fast measurement of the thermal conductivity (or thermal resistivity) of the medium in which it is inserted at the highest accuracy level. It works in compliance with the ASTM D 5334-00, D 5930-97 and IEEE 442-1981 standards. The standard TP02 probe has proven suitability in soils, thermal backfill materials, sediments, foodstuff, powders, sludges, paints, glues and various other materials. The Non-Steady-State Probe (NSSP) measurement method (also known as transient line source, thermal needle, hot needle, heat pulse- and hot wire technique) has the fundamental advantages that it is fast and absolute while the sample size is not critical. Hukseflux is specialised in NSSP design. Special models have been developed for in-situ field experiments. For permanent installation in soils, a dedicated model, TP01, is available. TP02 has been designed and tested in collaboration with the Applied Physics Group of Wageningen University.

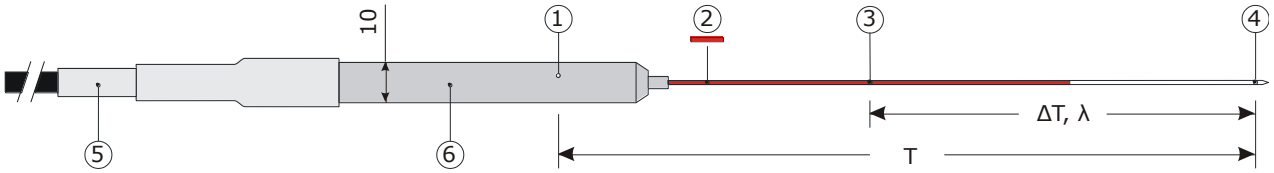

Figure 1: TP02 Non-Steady-State Probe consists of a needle with 2 thermocouple junctions; the hot joint (3), and the cold joint (4) (the cold joint at the tip remains at a stable temperature) and a heating wire, (2). It is inserted into the medium that is investigated. In the base, (6), a reference temperature sensor (pt1000), (1), is mounted. Advantages of this design: an optimal accuracy independent of the medium temperature, a minimal sensitivity to thermal gradients, a high sensor stability and the possibility to use normal cables and connectors. Needle length 150 mm. All dimensions are in mm.

INTRODUCTION

The standards of the American Society for Testing and Materials (ASTM) and Institute of Electrical and Electronics Engineers (IEEE) describe proven methods for determining the thermal conductivity of materials.
ASTM D 5334-00 and D 5930-97 and IEEE Std 442-1981 " Standard Test Methods" specify the use of Non-Steady-State Probes (NSSP) in various applications. In general a NSSP consists of a heating wire, representing a perfect line source, and a temperature sensor capable of measuring the temperature at this source. The probe is inserted in the medium that is investigated. The NSSP principle relies on a unique property of a line source: after a short transient period the temperature rise, ΔT, only depends on heater power, Q, and medium thermal conductivity, λ:

$$\Delta T = (Q / 4 \pi \lambda) (\ln t + B)$$

With ΔT in K, Q in W/m, λ in W/mK, t the time in s and B a constant. By measuring the heater power, and tracing the temperature in time (for TP02 typically heating for 100s), λ can be calculated. The sample size is not critical, as long as a 20 mm radius around the needle is covered.

The measurements of Q, t and ΔT are all direct measurements of power, time, and temperature respectively. These are done without need of reference materials. The measurement with TP02 is absolute.

TP02 can be obtained as a separate probe for incorporation in the user's measurement and control system. It is suitable for operation with the Campbell Scientific CR10X and CR1000.

TP02 DESIGN

The Hukseflux TP02 is designed to be able to cover a wide range of applications. Design considerations are as follows:
Optimal Accuracy: TP02 incorporates 2 thermocouple junctions in the needle producing a voltage output, U, that is proportional to ΔT. The one in the tip is not heated. The main signal is the differential signal between this hot joint at 1/3 of the length and the cold joint at the tip. In this configuration the voltage before starting the measurement is always small, independent of the medium temperature. In designs with only one sensor in the needle, the signal U will appear on top of a larger signal.
The two junction design has a superior accuracy when measuring at high and low temperatures.

TP02 DESIGN (CONTINUED)

In addition, by having both the cold- and the hot junction in the needle, the sensitivity to temperature changes of the medium is minimised.

Temperature sensor in the base: The reference temperature sensor in the base (Pt1000) serves as a "cold junction" measurement for establishing the absolute medium temperature T. (As required by ASTM). This is used for temperature correction of the thermocouple sensitivity, again offering superior accuracy across the temperature range.

Temperature and moisture resistance: All the materials in TP02 are highly temperature resistant. It has a full stainless steel needle and base. TP02 is completely sealed. It has a welded tip. This no-compromise sealing guarantees the long term stability of the sensor. Designs with glued sealing or epoxy housings are less reliable in this respect, particularly when working in moist environments.

Standard cables and connectors: Putting the Pt1000 temperature sensor in the base allows the use of normal copper core cables and connectors for cable extension of TP02.

Data processing: the data obtained with TP02 can be processed in any normal spreadsheet program.

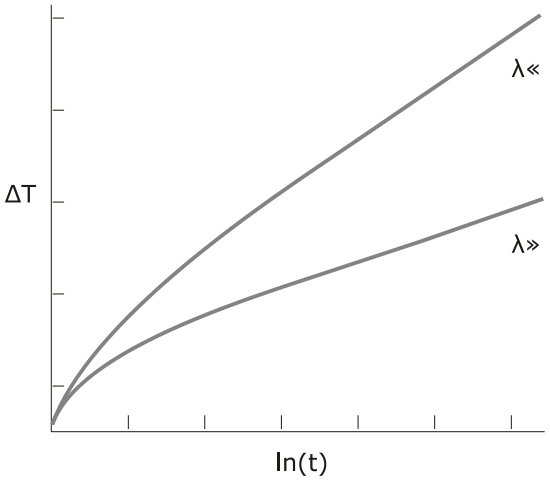

Figure 2 *The signal of TP02 as a function of the natural logarithm of time (ln(t)). After a transient period the graphs show linear behaviour. In this phase the slope of the graph is inversely proportional to the thermal conductivity λ.*

CALIBRATION / ISO 9000

Verification of the stability of the total probe can be done by repeated (yearly) testing in Calibration Reference Cylinders (CRC) traceable to NPL. These can be purchased at Hukseflux. TP02 is suitable for use by ISO certified labs.

SUGGESTED USE

- Studies of soils and soft rock
- Studies of foodstuff, plastics and powders

MORE INFORMATION / OPTIONS

Standards: ASTM standards can be obtained from ASTM at http://www.astm.org.

Alternative designs: Hukseflux is specialised in NSSP design. Alternative models, for instance smaller, more robust or temperature resistant have been manufactured on request.

Permanent installation in soils: The dedicated model TP01 is specifically designed for long term monitoring. A separate brochure is available.

Solutions for measurement and control: See the TP02 manual or inquire at Hukseflux. Programs for Campbell Scientific CR10X and CR1000 are available. Turn key systems are offered for sale: see TPSYS. Manuals: The TP02 manual is available free of charge as a PDF file via e-mail.

NEW!

For high accuracy calibration CRC Calibration Reference Cylinders are available.

For insertion into hard soils GT Series Guiding tubes can be applied.

TP02 SPECIFICATIONS

Test method:	ASTM D 5334-00 and D 5930-97 IEEE Std 442-1981
Needle length:	150 mm
Traceability:	NPL
Range (λ):	0.1 to 6 W/m.K
Sensitivity (ΔT):	Thermocouple K, ANSI MC96.1-1982
Temperature range (total sensor including cable):	-55 to +180 °C
Accuracy (@ 20 °C):	+/- (3% + 0.02) W/mK
Temperature dependence of the accuracy:	+/- 0.02 %/K (additional)
Heating cycle duration:	100 s (typical)
Power requirements (switched) :	3 V, 1 Watt (max)
Medium / sample requirements:	Granular materials, powders, slurries, gels, pastes. Some samples require pre-drilling. Sample size: Min 20 mm radius. Smaller samples: consult Hukseflux. Caution: please consult the product manual for more details.
Protection needle and base:	IP 68
Protection total sensor:	IP 67