

Soil thermal conductivity selection guide

Choose the right measuring system or sensor for your application

Hukseflux is a leading manufacturer of thermal conductivity / thermal resistivity measuring systems and sensors for use in soils. This brochure offers general guidelines for choosing the right system or sensor for your soil thermal conductivity measurement application.



Figure 1 Soil thermal route survey with FTN02 including CRU02 control and readout unit



Figure 2 Guiding tubes for hard soils and dryout experiments

The right instrument for your application

Hukseflux offers a wide range of products for material characterisation and measurement of soil thermal conductivity, or its inverse value thermal resistivity.

Hukseflux sells a range of measuring systems which include "thermal needles". All systems comply with ASTM D 5334-00, D 5930-97 and IEEE 442-1981 standards. Thermal needles are suitable for repeated insertion into various specimens or into undisturbed soil.

These sensors and systems can be divided in:

- high-accuracy measuring systems, using models TP02 and TP08 thermal needles, and measuring system TPSYS02
- systems more focused at robustness during field use, compromising on accuracy (FTN02 / MTN02 and TNS02 systems) with thermal needles TP09 and TP07
- a special model for long term monitoring, foil type sensor model TP01

Soil thermal conductivity measurement

Measurand	thermal conductivity thermal resistivity
Products	single sensors measuring systems
Material types	soils, concrete, thermal backfill material
Standardisation	ASTM, IEEE
Commercial options	-purchase -rent -outsource to our material characterisation laboratory -expert training

Measuring systems using thermal needles: what we offer

Hukseflux offers the following measuring systems:

- FTN02: a 100 % field instrument
- MTN02: for mixed field / laboratory use
- TPSYS02: a scientific measuring system typically for the laboratory, but also useful in case you are only working with soft sediments and dryout experiments

For thermal needle types TP07 (used in MTN02) and TP08 and TP02 Hukseflux offers stainless steel "guiding tubes". Using these tubes it is possible to measure in hard materials such as cements and thermal backfill (heavy clay) and dried-out soil by casting them into specimens.

For all models there are Calibration Reference Cylinders available, providing a traceable reference material. Hukseflux is also capable of supplying custom designed models (heavy duty, pressure resistant) for field or offshore applications.

High-accuracy measuring systems

TP02 and TP08 are primarily intended for use in the lab providing the highest possible measurement accuracy.

Although intended for indoor measurement, TP02 and TP08 may be taken outdoors for on-site testing, provided that care is taken during operation. Operation in soft soils, such as sediments is easy. In harder soil holes must be pre-drilled, or guiding tubes may be used. TP02 and the smaller TP08 may be purchased as a single needle or as part of a complete turnkey system TPSYS02. Models TP02 or TP08 can be operated using "standard" electronics, found in most measurement laboratories.

The user should carefully consider which probe to use. The standard model is TP02. This offers the highest accuracy, the lowest sensitivity to external influences and the best performance at higher or lower temperatures.

In case the specimen size for TP02 (typically 150×10^{-3} m height) is not available, use of TP08 should be considered. TP08 is shorter than TP02, but its general operation is identical to that of TP02. A special sample container (TP08-CO) is available for use with TP08. TP08 is also often used in analyses of sediment cores in offshore experiments. Many times insertion of TP08 from the side of the core is possible.

Robust measuring systems for field use

For field experiments, Hukseflux offers measuring systems FTN02, MTN02 and the combined TNS02. These "heavy duty" systems are equipped with robust thermal needles suitable for penetrating soft as well as harder soils. The FTN02 system is designed for field use, in particular surveys for high voltage electric cables (not during operation) typically measuring at a depth of 1.5 metres below the soil surface. FTN02 includes a 1.4 metre long lance (model LN02) at the tip of which a very robust (6.3×10^{-3} m diameter) needle (model TP09) is mounted. Using a lance rather than digging trenches saves time. The MTN02 system is suitable for laboratory experiments as well as field experiments. The 3.5×10^{-3} m diameter needle (model TP07) is mounted on a small insertion tool (IT03).

Models TP07 and TP09 are more robust than TP02 or TP08; however, the attainable measurement accuracy is considerably lower.



Figure 3 Accurate thermal needle TP08



Figure 4 The complete and robust FTN02 measuring system including the 1.4 m long lance LN02

Table 1 Comparison of systems that employ thermal needles

MEASURING SYSTEMS INCLUDING THERMAL NEEDLES				
Model	TPSYS02	TPSYS02	FTN02	MTN02
Comment	TPSY02 may be used with TP02 as well as with TP08 needles		FTN02 and MTN02 have the same type of handheld control and readout unit CRU02. A combined system can be purchased as TNS02	
Needle type	TP02 with connector^[1]	TP08 with connector^[1]	TP09	TP07
Main users	Researchers Commercial soil test labs for soil dryout testing	Researchers Commercial soil test labs for soft sediment core testing	Commercial soil test labs for field testing	Commercial soil test labs for mixed lab / field testing
Main application	High accuracy laboratory experiments on soils	Experiments on small specimens	Soils: outdoor route surveys at 1.5 m depth	Soils: laboratory analysis
Measurement range ^[2]	0.1 to 6 W/(m·K)	0.1 to 6 W/(m·K)	0.1 to 6 W/(m·K)	0.1 to 6 W/(m·K)
Minimum insertion length	150 x 10 ⁻³ m	35 x 10 ⁻³ m	170 x 10 ⁻³ m	100 x 10 ⁻³ m
Power	External 12 VDC See options	External 12 VDC See options	Battery pack	Battery pack
Readout	External PC See options	External PC See options	LCD included	LCD included
Robustness for field surveys	+	+	++++	+++
Field surveys at 1.5 m	+	+	++++	+
	From trench only	From trench only	Using ground drill	From trench only
Accuracy	++++	+++	++	++
Small specimen size	++	++++	+	++
Fast measurement	++++	++++	+	++
Low dependence on specimen thermal equilibrium	++++	+	++	++
Low temperature rise during heating	++++	+++	+	+
Wide temperature range ^[3]	++++	++++	+	+
Other less common applications	Soil dryout experiments, Frozen soils			Soil dryout experiments
Guiding tubes ^[4]	GT02	GT01	N/A	GT03
Calibration reference cylinders ⁵	CRC01	CRC01	CRC05	CRC04
Options	Field version: TPSYS02F Battery pack Keyboard Display	Field version: TPSYS02F Battery pack Keyboard Display Specimen container: TP08-CO		

1. TP02 and TP08 are also available as separate probes for use with the user's own electronics, for instance Campbell Scientific CR1000

2. systems may be used outside their rated measurement range, but will then offer a lower accuracy than specified

3. temperature ranges may be extended upon request

4. guiding tubes are supplied in sets of 5 pieces. They essentially create a needle with a larger diameter. The heating time when using needles with guiding tubes is 50 % longer than without. Guiding tubes are often used in cements and soil dryout experiments. Guiding tubes can also be used cast in inside plastics, glues, etc. This may be easier than specimen preparation for THASYS, which often is too costly or impossible

5. a low-cost approach to calibration is to use glycerol with plastic fibres as calibration reference material. However, Calibration Reference Cylinders offer a formal traceability to international standards which glycerol does not offer

Specials: TP01 for long-term monitoring

A special category is model TP01, which is a foil type sensor (so not a needle type). It is generally part of a larger meteorological system, used for long term use at one location. Contrary to needle type sensors it is fully waterproof. TP01 is not a good choice for repeated insertion into various specimens. Advantages of TP01 are pricing, its easy (steady state) signal analysis and the fact that it makes a crude measurement of thermal diffusivity, which is proportional to soil water content. A disadvantage might be that the measurement range is smaller than that of thermal needles; in practice this only leads to errors in very dry sand and organic soils.

Table 2 Example of thermal needles (TP01 is a modification of the thermal needle in a flat foil) developed at the request of our customers

EXAMPLES OF CUSTOM-MADE THERMAL SENSORS		
Model	TP01	TP03
Application	Long-term monitoring of soil thermal conductivity; typically incorporated in a meteorological system	Ocean sediment temperature and thermal conductivity measurement; To be incorporated into user's own mounting structure
Advantages	Fully water-proof; Simplified signal processing; IP67 protection class; Low price	Water pressures up to 300 bar Rated tip force up to 300×10^3 g
Comment	Foil type sensor. Geometry adapted to the requirements of long-term monitoring	Very short thermal needle. Dedicated calibration by the customer required to compensate for sub-optimal length-diameter ratio
Less common applications	Estimate of soil thermal diffusivity heat capacity and thermal effusivity Use as surface mounted sensor Monitoring trends in soil moisture	

Equipment rental

In case you only need a system like FTN02, MTN02 or TRSYS02 for one project, consider renting a system. Rental costs for one month are in the order of 20 % of purchasing costs of a system. Please ask for our rental agreements.

Expert training for system operators

Although in general the systems can be operated by following manuals and standards, we can provide you with expert training. Training vastly improves the level of service to the third party, the efficiency of working with the equipment and reduces the uncertainty of the end result.



Figure 5 Foil type sensor model TP01, for long term monitoring, IT03 insertion tool with needle type TP07 (both part of MTN02) and CRC Calibration Reference Cylinder, offering a traceable reference material



Figure 6 *Laboratory measurements with thermal needle model TP02 and CRC Calibration Reference Cylinders*

See also

Besides the possibility to purchase and rent thermal conductivity instruments, Hukseflux offers custom-made products, via our engineering and consultancy services. We also offer material characterisation services using our laboratory.

About Hukseflux

Hukseflux Thermal Sensors offers measurement solutions for the most challenging applications. We design and supply sensors as well as test & measuring systems, and offer related services such as engineering and consultancy. With our laboratory facilities, we provide testing services including material characterisation and calibration. Our main area of expertise is measurement of heat transfer and thermal quantities such as solar radiation, heat flux and thermal conductivity. Hukseflux is ISO 9001:2008 certified. Hukseflux sensors, systems and services are offered worldwide via our office in Delft, the Netherlands and local distributors.

Need for support in your selection process?
E-mail us at: info@huksefluxusa.com