Hukseflux
Thermal Sensors

FHF04SC

Self-calibrating foil heat flux sensor with thermal spreaders and heater

A next-level sensor from the world market leader in heat flux measurement, FHF04SC is a combination of our standard model FHF04 heat flux sensor and a heater. The heater allows the user to perform self-tests, verifying sensor functionality and stability during use, without having to remove the sensor. FHF04SC is ideal for high-accuracy and long-term heat flux measurement, construction of calorimeters, (zero heat flux) core temperature measurement and thermal conductivity test equipment.

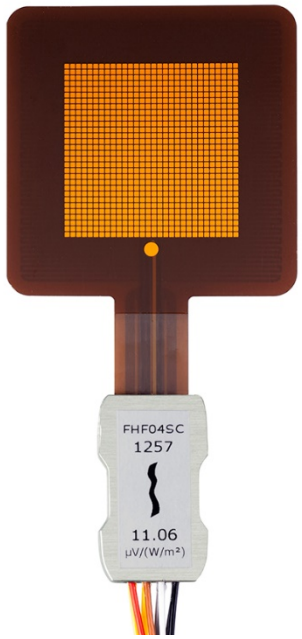

Figure 1 *FHF04SC self-calibrating heat flux sensor with heater: thin, flexible and versatile*

Figure 2 *FHF04SC being installed to measure heat flux on a curved surface*

Introduction

FHF04SC is a sensor for general-purpose heat flux measurement, combined with a heater. It is used when the highest level of quality assurance is required and for long-term heat flux measurement. It is thin, flexible and versatile. FHF04SC measures heat flux through the object in which it is incorporated or on which it is mounted, in W/m^2. The sensor in FHF04SC is a thermopile. This thermopile measures the temperature difference across FHF04SC's flexible body. A type T thermocouple is integrated as well. The thermopile and thermocouple are passive sensors; they do not require power.

Multiple small thermal spreaders, which form a conductive layer covering the sensor, help reduce the thermal conductivity dependence of the measurement. With its incorporated spreaders, the sensitivity of FHF04SC is independent of its environment. Many competing sensors do not have thermal spreaders. The passive guard area around the sensor reduces edge effects and is also used for mounting.

Unique features and benefits

- heater for self-test
- flexible (bending radius ≥ 15 x 10^{-3} m)
- low thermal resistance
- wide temperature range
- fast response time
- integrated type T thermocouple
- robustness, including metal connection block, may be used as strain relief
- IP protection class: IP67 (essential for outdoor application)
- integrated thermal spreaders for low thermal conductivity dependence

Using FHF04SC is easy. It can be connected directly to commonly used data logging systems. The heat

flux in W/m^2 is calculated by dividing the FHF04SC output, a small voltage, by the sensitivity.
The sensitivity is provided with FHF04SC on its product certificate. When used under conditions that differ from the calibration reference conditions, the FHF04SC sensitivity to heat flux may be different than stated on its certificate. See the user manual for suggested solutions.

Self-testing

Measuring heat flux, users may wish to regularly check their sensor performance. During use, the film heater is activated to perform a self-test. The heat flux sensor response to the self-test results in a verification of sensor performance. Implicitly also cable connection, data acquisition, thermal connection of sensor to its environment and data processing are tested. Heat flux sensors are often kept installed for as long as possible. Using self-testing, the user no longer needs to take sensors to the laboratory to verify their stable performance. In a laboratory environment, using a metal heat sink, you may even perform a formal calibration. The heater has a well characterised and traceable surface area and electrical resistance.

Suggested use

- high-accuracy scientific measurement of heat flux, with a high level of data quality assurance
- study of convective heat transfer mechanisms
- calorimeter prototyping
- (zero heat flux) non-invasive core temperature measurement
- thermal conductivity test equipment

Measurement and control

Requirements for data acquisition and control:

- for heat flux: one millivolt measurement
- for heater voltage: one voltage measurement
- optional, for heater current: one current measurement or voltage measurement over a resistor
- for switching the heater current on and off: one relay with 12 VDC nominal output

Calibration

FHF04SC calibration is traceable to international standards. The factory calibration method follows the recommended practice of ASTM C1130 - 17. In a typical calibration setup as shown in figure 3, the FHF04SC is positioned between an insulating material and a heatsink with the FHF04SC heater on the side of the insulating material. In such a setup, the heat losses through the insulation may be ignored.

FHF04SC specifications

Measurand	heat flux
Measurand	temperature
Temperature sensor	type T thermocouple*
Thermal spreaders	included
On-line functionality testing	self-test including self-calibration
Rated bending radius	≥ 15 x 10^{-3} m
Rated load cable	≤ 1.6 kg
Outer dimensions foil with guard	(50 x 50) x 10^{-3} m
Sensing area	9 x 10^{-4} m^2
Sensor thermal resistance	30 x 10^{-4} K/(W/m^2)
Sensor resistance range	160 to 240 Ω
Sensor thickness	0.7 x 10^{-3} m
Uncertainty of calibration	± 5 % (k = 2)
Measurement range	(-10 to +10) x 10^3 W/m^2
Sensitivity (nominal)	11 x 10^{-6} V/(W/m^2)
Rated temperature range - continuous use	-40 to +120 °C**
IP protection class	IP67***
Standard wire length	2 m
Heater resistance	100 Ω (nominal)
Heater power supply	12 VDC
Options	with 5 m wire length BLK-5050 black sticker GLD-5050 gold sticker

* temperature measurement uncertainty: 2 % of value in C. For details, refer to user manual.
** rated operating conditions: 120 °C continuous use, 150 °C short intervals; use to -80 °C is possible.
*** sensor is not suitable for continuous exposure to water.

Measuring the heater power (voltage U_{heater} square divided by resistance Rh_{eater}), and dividing by the surface area A_{heater}, gives the applied heat flux. The heat flux sensor sensitivity S is the voltage output U_{sensor} divided by the applied heat flux.

$$S = (U_{sensor} \cdot R_{heater} \cdot A_{heater})/U_{heater}^2$$

The reproducibility of this test is much improved by using contact material (such as glycerol or a thermal paste) between sensor and heat sink.

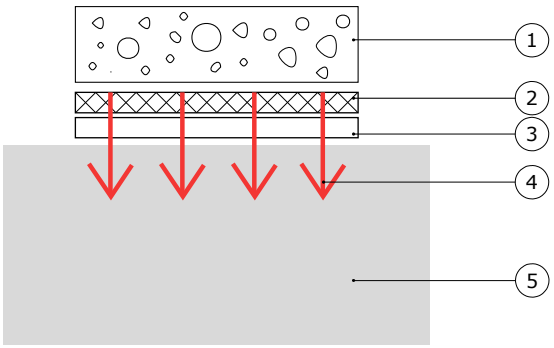

Figure 3 *Calibration of FHF04SC; a typical stack used for calibration consists of a block of metal (mass > 1 kg), for example aluminium (5), the heat flux sensor (3), with heater (2) and an insulation foam (1). Under these conditions, heat losses through the insulation are negligible. Heat flux (4) flows from hot to cold.*

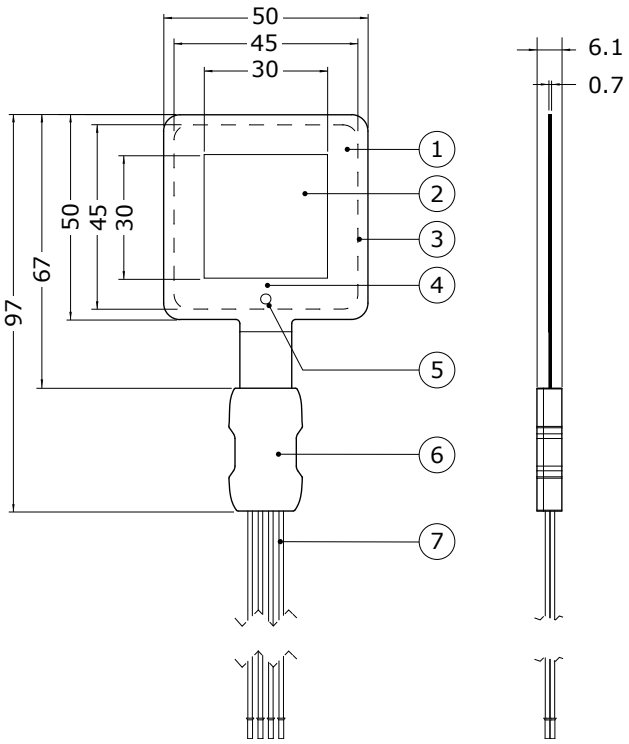

Figure 4 *FHF04SC heat flux sensor: (1) sensing area with thermal spreaders, (2) passive guard, (3) contour of the heater area for self-test, (4) type T thermocouple, (5) dot indicating front side, (6) metal connection block showing serial number and sensitivity, (7) wires, standard length is 2 m. Dimensions in x 10^{-3} m.*

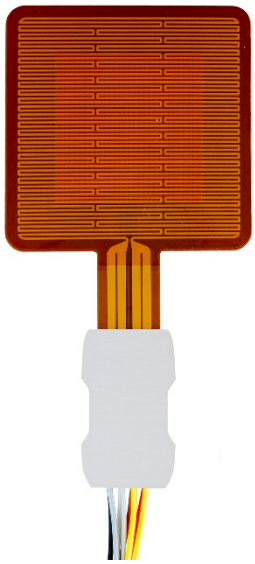

Figure 5 *FHF04SC heat flux sensor's heater side*

Robust and stable

Equipped with a metal connection block, which may serve as strain relief, and with potted protective covers on both sides so that moisture does not penetrate, FHF04 has proven to be very robust and stable.

Application example

The FHF04SC heater can be used to check for stable performance of the FHF04SC at regular intervals without the need to uninstall the sensor or to interrupt operation. A typical stability check is based on the step response of the measured heat flux and sensor temperature to a applied heater. Upon installing the sensor, a reference measurement should be made. A time trace of the heater voltage, the measured heat flux and the measured sensor temperature should be stored as reference measurement. Stable operation of the sensor can then be confirmed at any time by comparing to the reference measurement. The test protocol is as follows:

1. Make sure that the absolute temperature is similar to that during the reference measurement
2. Check the heater resistance stability; this can accurately be done because the connection is 4-wire. Subtract wire-to-wire resistance from the wire-sensor-wire resistance.
3. Store the same parameters, normalise with the heater power. Normally (if the heater is stable) this process scales with V^2.
4. Compare patterns of heat flux and temperature rise and fall during and after heating. In both cases relative to the values just before heating.

• When signal patterns match but the amplitude differs (after correction for heater power), this points towards sensor instability.
• Non-matching patterns point towards changes in sensor environment e.g. loss of contact between sensor and sample.

GLD and BLK sticker series

Would you like to to study energy transport / heat flux in detail? Hukseflux helps taking your measurement to the next level: order FHF04 with radiation-absorbing black and radiation-reflecting gold stickers. You can then measure convective + radiative flux with one, and convective flux only with the other. Subtract the 2 measurements and you have radiative flux. BLK – GLD stickers can be applied by the user to the sensor. Optionally, they can be ordered pre-applied. See the BLK – GLD sticker series user manual and installation video for instructions.

Options

- with 5 metres wire length
- LI19 hand-held read-out unit / datalogger
  NOTE: LI19 measures heat flux only, not temperature

BLK-5050 black sticker (to measure radiative as well as convective heat flux)
- GLD-5050 gold sticker (to measure convective heat flux only)
- BLK - GLD sticker series can also be ordered pre-applied at the factory

Figure 6 *FHF04SC heat flux sensor: with BLK-5050 and GLD-5050 stickers*

See also

- model FHF04, our standard model for general-purpose heat flux measurement
- model FHF03, our most economical foil heat flux sensor
- model HFP01 for increased sensitivity (also consider putting two or more FHF04s in series)
- BLK - GLD sticker series to separate radiative and convective heat fluxes
- Hukseflux offers a complete range of heat flux sensors with the highest quality for any budget

About Hukseflux

Hukseflux Thermal Sensors makes sensors and measuring systems. Our aim is to let our customers work with the best possible data. Many of our products are used in support of energy transition and efficient use of energy. We also provide services: calibration and material characterisation. 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 certified. Hukseflux products and services are offered worldwide via our office in Delft, the Netherlands and local distributors.

Interested in this product?
E-mail us at: info@hukseflux.com