Hukseflux
Thermal Sensors

FHF05SC series

Two self-calibrating foil heat flux sensors with thermal spreaders and heater

Next-level sensors from the world market leader in heat flux measurement, FHF05SC series is a combination of our standard models FHF05 heat flux sensor and a heater. The heater allows you to perform self-tests, verifying sensor functionality and stability during use, without having to remove the sensor. FHF05SC series 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. Available in two models: standard model size 50X50 mm and a larger size of 85X85 mm.

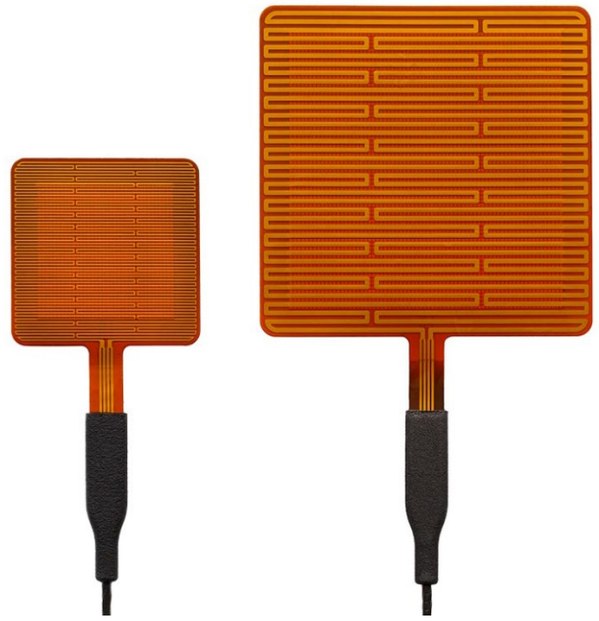

Figure 1 *Model FHF05SC-50X50 and FHF05SC-85X85 self-calibrating heat flux sensor with heater: thin, flexible and versatile.*

Figure 2 *FHF05SC-50X50 being installed to measure heat flux on a curved surface.*

Introduction

FHF05SC series are sensors 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 measurements. It is thin, flexible and versatile. FHF05SC series measures heat flux through the object in which it is incorporated or on which it is mounted, in W/m^2. The sensor within is a thermopile. This thermopile measures the temperature difference across FHF05SC's flexible body. A type T thermocouple is integrated as well to provide a temperature measurement. 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 FHF05SC series 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.
Looking only for heat flux and temperature measurement without the heater: see our FHF05 series heat flux sensors.

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 potted 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 FHF05SC series is easy. For heat flux measurements, it can be connected directly to commonly used data logging systems. The heat flux in W/m^2 is calculated by dividing the sensor output, a small voltage, by the sensitivity.
The sensitivity is provided with FHF05SC series on its product certificate. When used under conditions that differ from the calibration reference conditions, the FHF05SC series sensitivity to heat flux may be different than stated on its certificate. See the user manual for suggested solutions.
Make sure your data acquisition accepts type T thermocouples before doing temperature measurements.

Figure 3 *Working with FHF05SC-85X85 on a metal wall.*

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 installed for long periods of time. 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.

FHF05SC series specifications

Measurand	heat flux
Measurand	temperature
Temperature sensor	type T thermocouple, IEC 60584-1:2013 class 2*
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 (85 x 85) x 10^{-3} m
Sensor thermal resistance	24 x 10^{-4} K/(W/m^2)
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) per model	
50X50	13 x 10^{-6} V/(W/m^2)
85X85	50 x 10^{-6} V/(W/m^2)
Rated temperature range	
continuous use:	-40 to +120 °C**
short intervals:	-160 to +150 °C*
IP protection class	IP67***
Standard wire length	2 m
Heater resistance per model	
50X50	120 Ω (nominal)
85X85	40 Ω (nominal)
Heater power supply	12 VDC
Options	5 or 10 m cable length separate cable BLK black sticker GLD gold sticker

* temperature measurement uncertainty: 5 % 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.

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

FHF05SC series calibration is traceable to international standards. The factory calibration method follows the recommended practice of ASTM C1130 - 21.
In a typical calibration setup as shown in figure 3, the FHF05SC series is positioned between an insulating material and a heatsink with the FHF05SC series heater on the side of the insulating
material. In such a setup, the heat losses through the insulation may be ignored.

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.

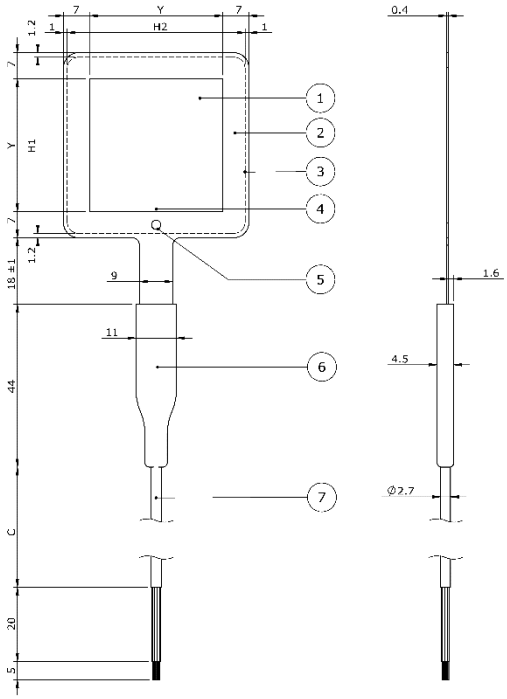

Figure 4 *FHF05SC series models 50X50 and 85X85 heat flux sensor; Y = 36 or 70, H1 = 47.6 or 82.6 and H2 = 48 or 83.Dimensions in x 10^{-3} m. (1) sensing area with thermal spreaders, (2) passive guard, (3) contour of the heater area for self-test, (4) type T thermocouple, (5) dot indicating front side, (6) connection block for strain relief, (7) cable, standard length is C = 2 m.*

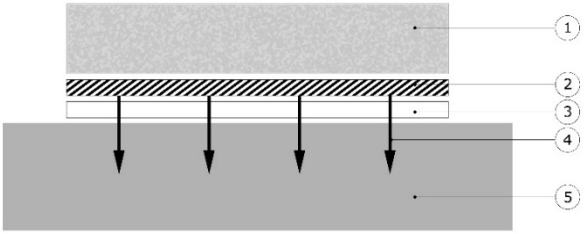

Figure 5 *Calibration of FHF05SC series; a typical stack used for calibration consists of a block of metal (mass > 1 kg), for example aluminium (5), the heat flux sensor (3), with heater (2) and an insulation foam (1). Under these conditions, heat losses through the insulation are negligible. Heat flux (4) flows from hot to cold.*

Robust and stable

Equipped with a connection block, which may serve as strain relief, and with potted protective covers on both sides so that moisture does not penetrate, FHF05SC series has proven to be very robust and stable.

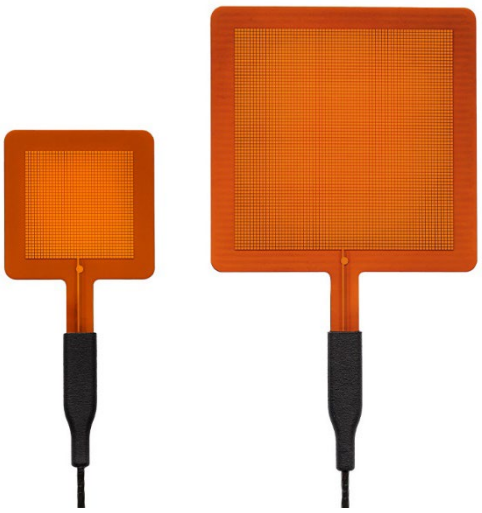

Figure 6 *Model FHF05S0C-50X50 and FHF05SC-85X85 heat flux sensors' front side.*

Application example

The FHF05SC series heater can be used to check for stable performance of the sensor 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 an 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.

Hukseflux
Thermal Sensors

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 study energy transport / heat flux in detail? Hukseflux helps taking your measurement to the next level: order FHF05SC series 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. There are stickers for every sensor dimension. Optionally, they can be ordered pre-applied. See the BLK – GLD sticker series user manual and installation video for instructions.

Options

- with 5 or 10 metres cable length
- separate cable in 2, 5 or 10 metres length
- LI19 hand-held read-out unit / datalogger
  NOTE: LI19 measures heat flux only, not temperature, does not support the self-test functionality
- BLK black sticker (to measure radiative as well as convective heat flux)
- GLD gold sticker (to measure convective heat flux only)
- BLK - GLD sticker series can also be ordered pre-applied at the factory

Figure 7 *FHF05SC series heat flux sensor with BLK-5050 and GLD-5050 stickers.*

See also

- FHF05 series, our standard model for general-purpose heat flux measurement
- model HFP01 for increased sensitivity (also consider putting two or more FHF05s in series)
- model HTR02, a loose heater for calibration and verification of performance of FHF type sensors
- 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 is the leading expert in measurement of energy transfer. We design and manufacture sensors and measuring systems that support the energy transition. We are market leaders in solar radiation- and heat flux measurement.
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