

# FHF02SC

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

A next-level sensor from the world market leader in heat flux measurement, FHF02SC is a combination of our model FHF02 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. FHF02SC 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** FHF02SC heat flux sensor with heater



**Figure 2** example of an FHF02SC installation

### Introduction

FHF02SC 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 special experiments. The FHF02SC thermophile sensor measures heat flux ( $W/m^2$ ) through the object in which it is incorporated or on which it is mounted.

Additionally the integrated type T thermocouple allows for temperature measurements. Both the thermopile and thermocouple are passive sensors; they do not require power. The combination of a heat flux sensor with a heater allows the user not only to measure a heat flux, but also to apply a heat flux.

Using FHF02SC's heat flux sensor is easy. It can be connected directly to commonly used data logging systems. The heat flux sensor output is a voltage signal that is proportional to the heat flux through the sensor: 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 FHF02SC on its product certificate.

### Unique features and benefits

- heater for self-test
- low thermal resistance
- wide temperature range
- fast response time
- large guard area
- integrated type T thermocouple
- robustness, including wiring with strain relief block
- IP protection class: IP67 (essential for outdoor application)
- thermal spreader included, low thermal conductivity dependence

### 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.

A thermal spreader, which is a conductive layer covering the sensor, helps reduce the thermal conductivity dependence of the measurement. With its incorporated spreaders, the sensitivity of FHF02SC 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 used for mounting.

### 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

FHF02SC 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 FHF02SC is positioned between an insulating material and a heatsink with the FHF02SC heater on the side of the insulating material. In such a setup, the heat losses through the insulation may be ignored.

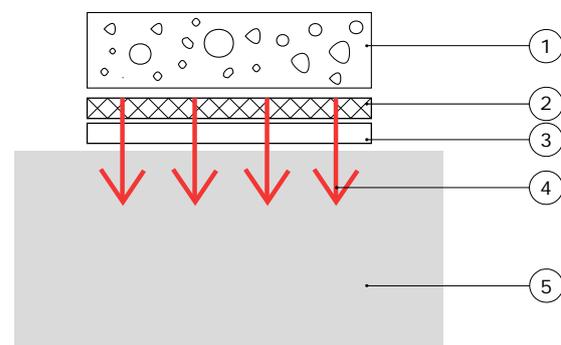
### FHF02SC specifications

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	infinite, bending is not recommended
Sensing area	$9 \times 10^{-4} \text{ m}^2$
Sensor thermal resistance	$37 \times 10^{-4} \text{ K}/(\text{W}/\text{m}^2)$
Sensor resistance range	50 to 100 $\Omega$
Sensor thickness	$0.9 \times 10^{-3} \text{ m}$
Uncertainty of calibration	$\pm 5 \%$ ( $k = 2$ )
Measurement range	$(-10 \text{ to } +10) \times 10^3 \text{ W}/\text{m}^2$
Sensitivity (nominal)	$5.5 \times 10^{-6} \text{ V}/(\text{W}/\text{m}^2)$
Operating temperature range	$-40 \text{ to } +150 \text{ }^\circ\text{C}$
IP protection class	IP67
Standard wire length	2 m
Heater resistance	100 $\Omega$ (nominal)
Heater power supply	12 VDC
Options	longer wire length upon request

Measuring the heater power (voltage  $V$  square divided by resistance  $R$ ), and dividing by the surface area  $A$ , gives the applied heat flux. The heat flux sensor sensitivity  $E$  is the voltage output  $U$  divided by the applied heat flux.

$$E = U R A / V^2$$

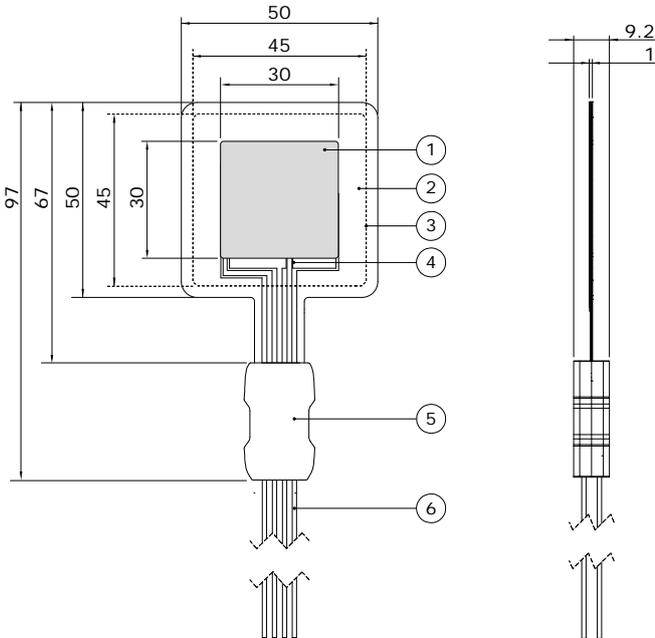
The reproducibility of this test is much improved by using contact material (such as glycerol or a thermal paste) between heater, sensor and heat sink.



**Figure 3** Calibration of FHF02SC; 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.

### Working with heat flux sensors

When used under conditions that differ from the calibration reference conditions, the FHF02SC sensitivity to heat flux may be different than stated on its certificate. See the user manual for suggested solutions.



**Figure 4** FHF02SC heat flux sensor: (1) sensing area with thermal spreader, (2) passive guard, (3) contour of the heater for self-test, (4) type T thermocouple, (5) strain relief block, (6) wires, standard length is 2 m. Dimensions in  $\times 10^{-3}$  m.



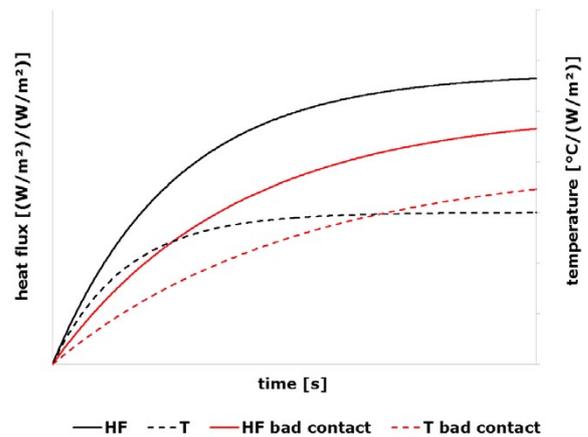
**Figure 5** FHF02SC heat flux sensor's heater side

### Application example: in situ stability check

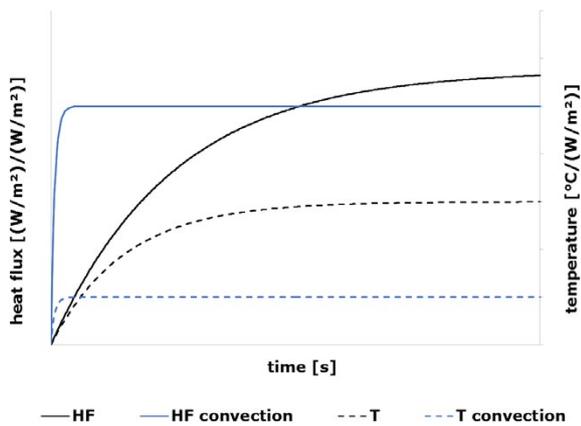
The FHF02SC heater can be used to check for stable performance of the FHF02SC at regular intervals without the need to uninstall the sensor or to interrupt operation. A typical stability check is based on the step response of the measured heat flux and sensor temperature to a heat flux

applied by the 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, amplitude differences, after correction for heater power, point towards sensor instability
  - Non-matching patterns point towards changes in sensor environment e.g. loss of contact between sensor and sample.



**Figure 6** in situ sensor stability check. Comparison of responses to stepwise heating relative to reference curves. Normalised to heater power ( $P$ ) and relative to the heat flux and the temperature just before heating. Solid graphs show heat flux, dotted graphs show temperature. The black HF and T signals are the reference curves at good thermal contact. The sensor loses thermal contact, which results in the red responses: slower response times, lower heat flux and higher temperature rise.



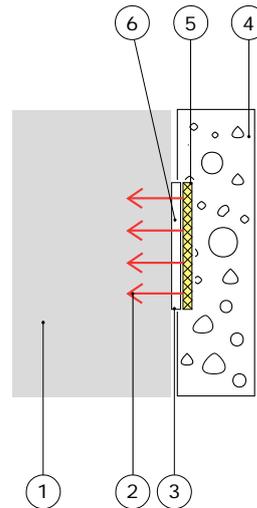
**Figure 7** in situ sensor stability check. Comparison of responses to stepwise heating relative to reference curves. Normalised to heater power ( $P$ ) and relative to the heat flux and the temperature just before heating. Solid graphs show heat flux, dotted graphs show temperature. The black HF and T signals are the reference curves at zero wind speed. The sensor is exposed to convection, which results in the blue responses: faster response times at lower heat flux and lower temperature rise.

### Application example: non-invasive core temperature measurement

FHF02SC may be used for non-invasively measuring the core temperature of objects, for example of human beings. The measurement is usually done with a sandwich of object – heat flux & temperature sensor-heater- insulation material. To determine the core temperature, the heater power should be adjusted such that the heat flux equals zero. This can for example be done by means of a PID controller. When zero heat flux is attained, the measured temperature equals the core temperature. See Figure 8.

#### See also

- model **FHF02** without heater
- model **FHF01** for increased flexibility
- model **HFPO1** for increased sensitivity (also consider putting two or more FHF02's in series)
- view our complete [range of heat flux sensors](#)



**Figure 8** FHF02SC in a non-invasive core-temperature measurement. For measurement of the core temperature (1), the heater (5) is controlled to a setpoint of zero heat flux (2) measured by the heat flux sensor (3). At zero heat flux, the temperature of the core (1) and the temperature sensor (6) are equal. Insulation material (4) is attached to work at stable boundary conditions.

#### FHF02SC options

- longer wire length

#### 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 certified. Hukseflux sensors, systems 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](mailto:info@hukseflux.com)

# FHF02SC outperforms competing models: how?

FHF02SC is Hukseflux' next-level heat flux sensor with integrated heater. FHF02 offers a high level of quality assurance and is a unique building block for testing.

