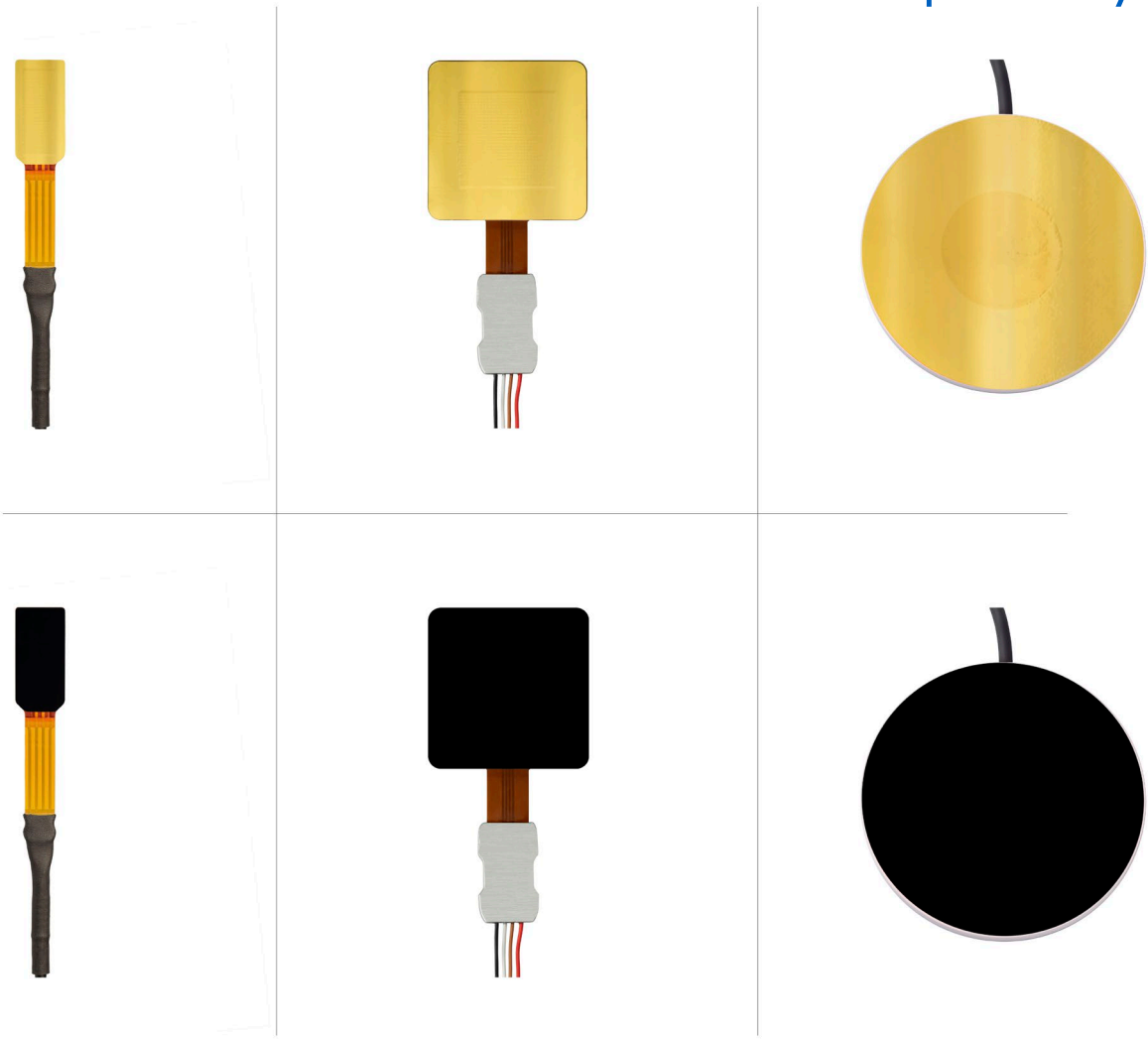
Hukseflux
Thermal Sensors

USER MANUAL **BLK-GLD STICKER SERIES**

Black and gold stickers for measuring convective and radiative heat flux separately



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Cautionary statements

Cautionary statements are subdivided into four categories: danger, warning, caution and notice according to the severity of the risk.

DANGER

Failure to comply with a danger statement will lead to death or serious physical injuries.

WARNING

Failure to comply with a warning statement may lead to risk of death or serious physical injuries.

CAUTION

Failure to comply with a caution statement may lead to risk of minor or moderate physical injuries.

NOTICE

Failure to comply with a notice may lead to damage to equipment or may compromise reliable operation of the instrument.

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List of symbols

Quantities	Symbol	Unit
Heat flux	Φ	W/m²
Voltage	U	V
Sensitivity	S	V/(W/m²)
Temperature	T	°C
Thermal resistance per unit area	$R_{thermal,A}$	K/(W/m²)
Area	A	m²
Reflection factor	r	-
Absorbance	α	-
Emissivity	ε	-
Stefan-Boltzmann constant	σ	W/m²·K⁴

Subscripts

Property of sensor	sensor
Net radiative heat flux	radiation
Convective heat flux	convection
Black sticker	BLK
Gold sticker	GLD

Abbreviations

Ultraviolet	UV
Visible light	VIS
Near-infrared	NIR
Far-infrared	FIR

Introduction

Heat flux measurement is a powerful tool to gain insights into processes involving thermal energy. Heat flux consists of conductive, convective and radiative flux. Measuring heat flux, users may wish to measure only radiative or only convective heat flux. This is now possible with the BLK – GLD sticker series, designed to be used with a wide range of our market-leading heat flux sensors. The BLK black absorbing stickers will absorb all radiation and are sensitive to both radiative and convective heat flux, while the GLD gold reflective stickers reflect all radiation and are sensitive to convective heat flux only. Combining BLK and GLD, applied to two separate heat flux sensors, will allow for measuring radiative heat flux:

$$\Phi_{\text{radiation + convection}} = \Phi_{\text{BLK}}$$

$$\Phi_{\text{convection}} = \Phi_{\text{GLD}}$$

$$\Phi_{\text{radiation}} = \Phi_{\text{BLK}} - \Phi_{\text{GLD}}$$

BLK – GLD stickers have unique features and benefits:

- makes it possible to perform convective and radiative heat flux measurements
- available as accessory for FHF04, FHF04SC, FHF03 and HFP01 heat flux sensors
- designed to be applied by the user

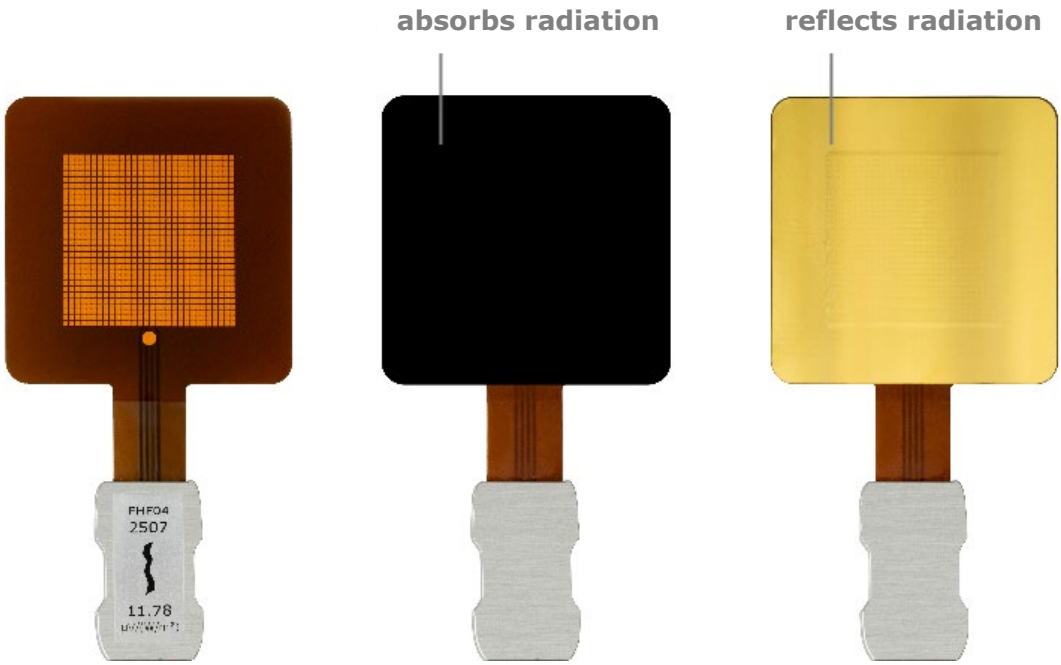


Figure 0.1 *From left to right: FHF04 heat flux sensor, FHF04 with BLK-5050 sticker, and FHF04 with GLD-5050 sticker. BLK – GLD stickers are also available for FHF04SC, FHF03 and HFP01 heat flux sensors. The BLK black absorbing stickers will absorb all radiation and are sensitive to both radiative and convective heat flux, while the GLD gold reflective stickers reflect all radiation and are sensitive to convective heat flux only.*

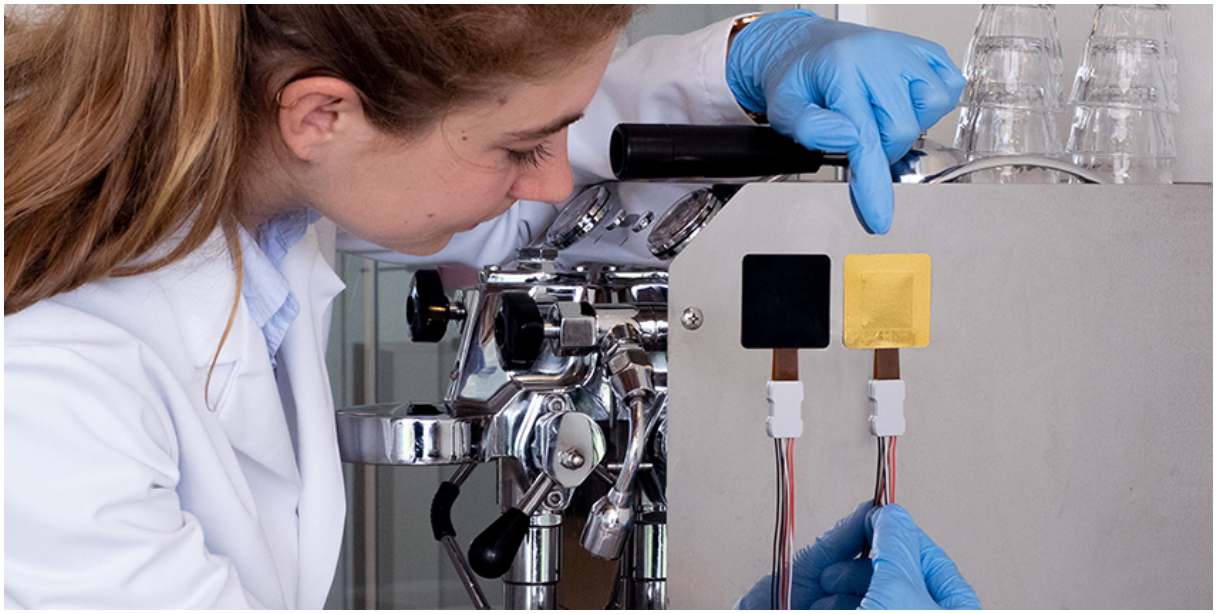


Figure 0.2 *Working with BLK - GLD stickers: measuring the radiative and convective heat fluxes around an espresso machine.*

BLK – GLD stickers are easy to use:

They are designed to be applied by the user, but can optionally also be pre-applied at the factory. Applying a sticker to a heat flux sensor does not change the sensitivity of the sensor, so no additional calibration is required. Using the reliable measurement technology behind our heat flux sensors, separating convective and radiative heat flux has never been easier.

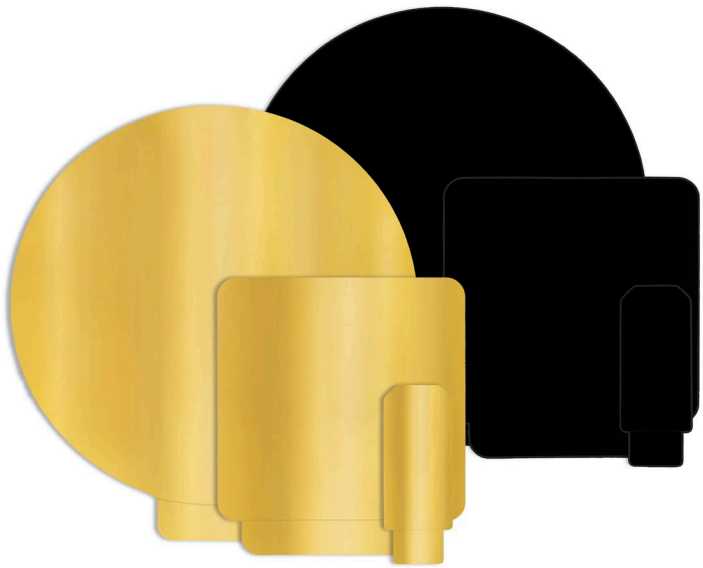


Figure 0.3 *BLK – GLD sticker series is a range of accessories for use with Hukseflux heat flux sensors FHF04, FHF04SC, FHF03 and HFP01. The stickers have matching sizes and are designed to be applied by the user to the sensor.*

See also:

- BLK – GLD sticker application instruction video on our YouTube channel
- model FHF04 general-purpose heat flux sensor
- model FHF04SC self-calibrating heat flux sensor with integrated heater
- model FHF03 economical heat flux sensor
- model HFP01 for increased sensitivity
- view our complete range of heat flux sensors

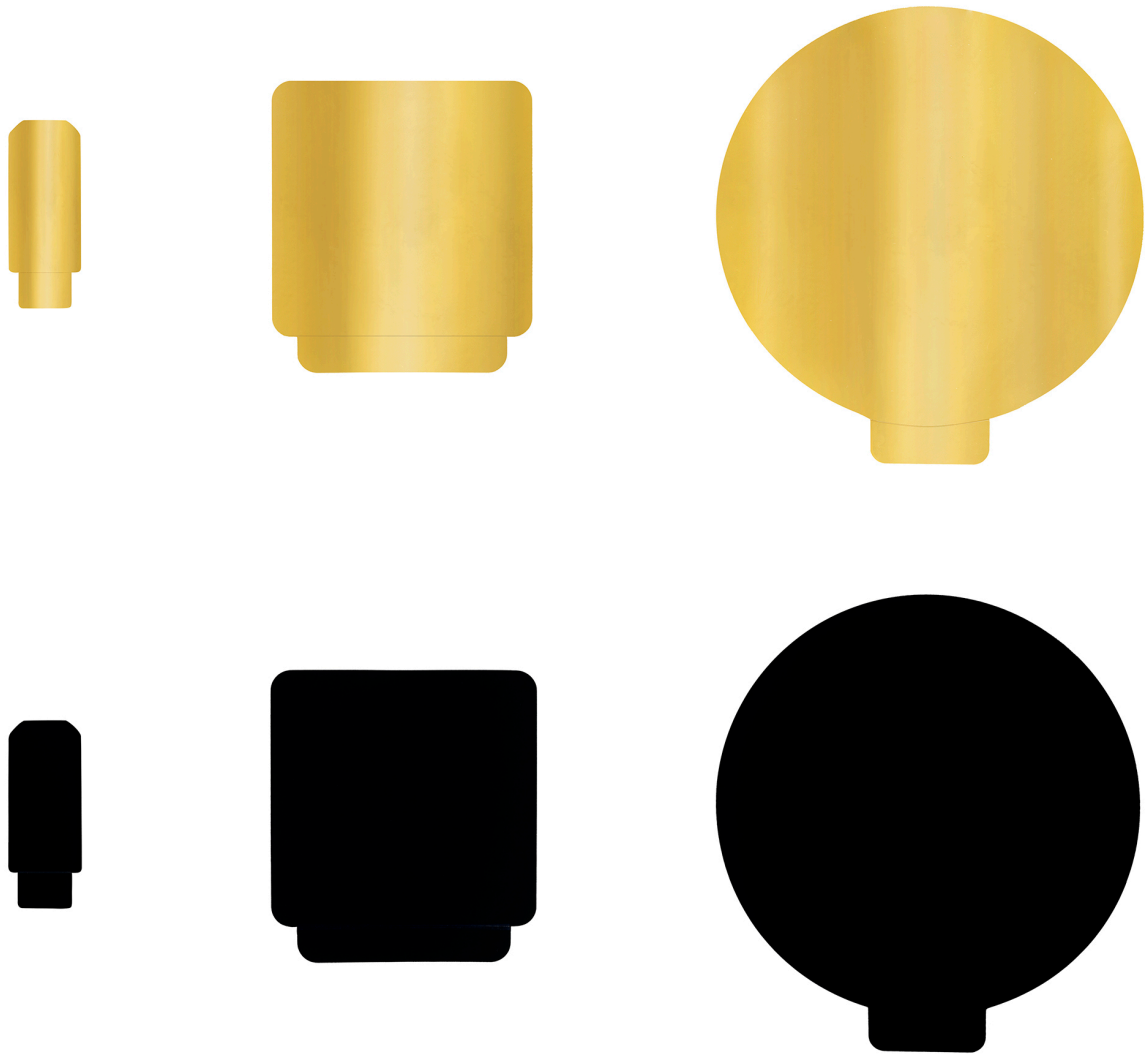


Figure 0.4 *Overview of BLK-GLD stickers series: black absorbing stickers and gold reflective stickers matching FHF04, FHF04SC, FHF03 and HFP01 heat flux sensors. They are designed to be applied by the user, but can optionally also be pre-applied at the factory. The figure shows, from left to right, the stickers GLD-3015 and BLK-3015 for FHF03, GLD-5050 and BLK-5050 for FHF04(SC) and GLD-80 and BLK-80 for HFP01. The peeling tabs are still visible on these unapplied stickers.*

1 Ordering and checking at delivery

1.1 Ordering BLK – GLD stickers

The BLK – GLD sticker series is a range of accessories for use with Hukseflux heat flux sensors FHF04, FHF04SC, FHF03 and HFP01.

The ordering codes of the different versions in the series are BLK-5050, BLK-3015, BLK-80, GLD-5050, GLD-3015 and GLD-80.

Table 1.1.1 *Overview of versions in the BLK – GLD sticker series*

BLK versions	
BLK-5050	Black absorbing sticker to measure convective + radiative heat flux, to be used with FHF04 and FHF04SC heat flux sensors
BLK-3015	Black absorbing sticker to measure convective + radiative heat flux, to be used with FHF03 heat flux sensor
BLK-80	Black absorbing sticker to measure convective + radiative heat flux, to be used with HFP01 heat flux sensor
GLD versions	
GLD-5050	Gold reflective sticker to measure convective heat flux only, to be used with FHF04 and FHF04SC heat flux sensors
GLD-3015	Gold reflective sticker to measure convective heat flux only, to be used with FHF03 heat flux sensor
GLD-80	Gold reflective sticker to measure convective heat flux only, to be used with HFP01 heat flux sensor

A common option is:

- pre-application of the sticker to the sensor(s) of your choice at the factory

When opting for pre-application at the factory, please use the following ordering code: product code sensor with cable/wire length indicated + product code sticker

example: HFP01-05-GLD-80

for an HFP01 with 5 metres of cable and a pre-applied gold sticker

1.2 Included items

Arriving at the customer, the delivery should include:

- BLK – GLD sticker version(s) as ordered
- application procedure instruction sheet
- presaturated IPA (Isopropyl Alcohol) wipe

See the instruction sheet included with your delivery, the instruction movie on our YouTube channel or Section 4.1 of this manual for instructions how to apply the BLK – GLD stickers to your sensor.

When opting for pre-applied BLK – GLD stickers, the delivery should include:

- heat flux sensor with sticker applied, with wires / cable of the length as ordered
- product certificate matching the instrument serial number

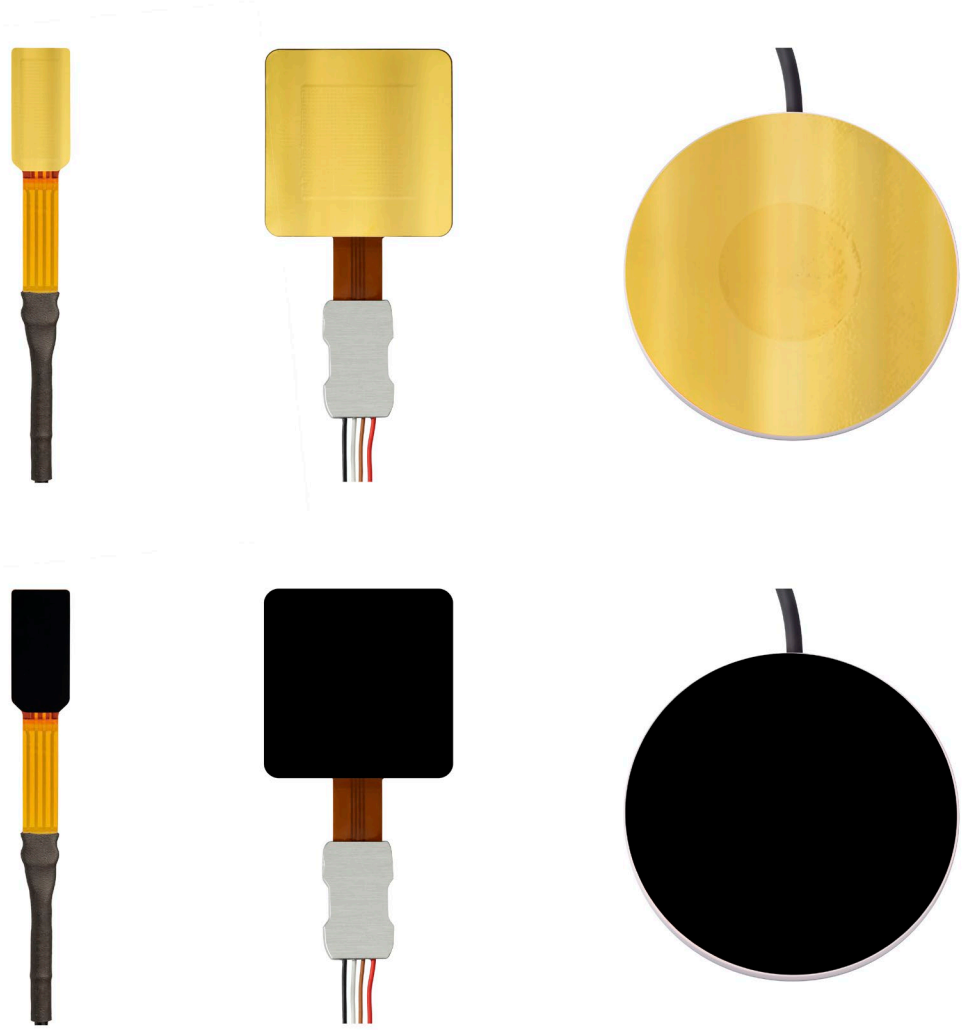


Figure 1.2.1 *GLD and BLK stickers pre-applied to their matching sensors at the factory*

2 Instrument principle and theory

BLK and GLD stickers series are accessories to FHF04, FHF04SC, FHF03 and HFP01 heat flux sensors. These stickers allow the heat flux sensors to be used to measure radiative and convective heat flux sources.

BLK black stickers absorb all radiation, as Figure 2.1 shows.

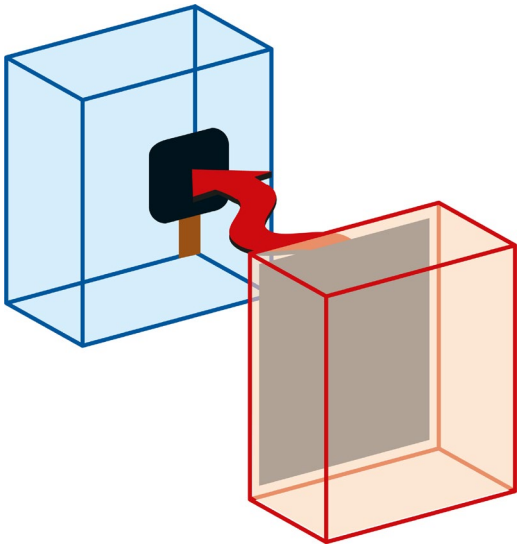


Figure 2.1 *BLK black stickers absorb all radiation*

In contrast to BLK black stickers, GLD gold stickers reflect all radiation.

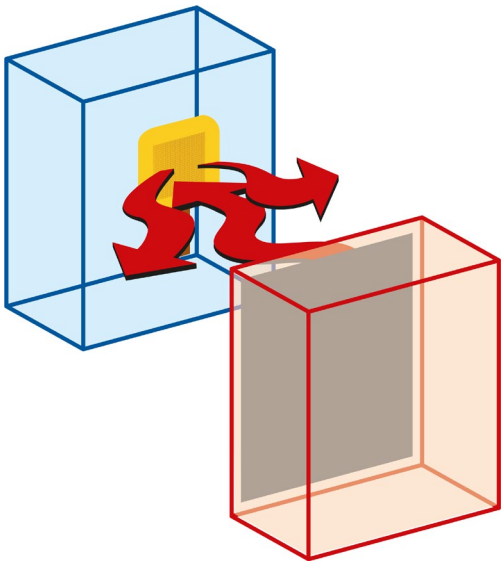


Figure 2.2 *GLD gold stickers reflect all radiation*

BLK black stickers are sensitive both to radiative and convective heat flux, whereas GLD gold stickers, reflecting all radiation, are sensitive to convective heat flux only. See Figure 2.3.

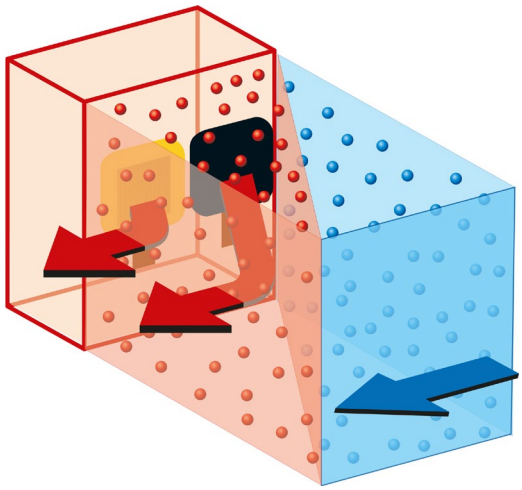


Figure 2.3 *Both BLK and GLD stickers are sensitive to convective heat flux.*

Radiative and convective heat flux are absorbed by the black sticker. The absorbed heat flows through the heat flux sensor, creating a temperature difference across the thermopile detector inside the heat flux sensor. This thermopile generates a small voltage proportional to the sum of the radiative and convective heat flux.

Radiative heat flux is reflected by the gold sticker, convective heat flux is absorbed. The absorbed heat flows through the heat flux sensor, creating a temperature difference across the thermopile detector inside the heat flux sensor. This thermopile generates a small voltage proportional to the convective heat flux.

The proportionality factor, the ratio of heat flux sensor voltage to heat flux, is called the sensitivity S in V/(W/m²). This is determined individually for the heat flux sensor by calibration and reported on its product certificate.

Applying a sticker to a heat flux sensor does not change the sensitivity of the heat flux sensor.

Heat flux sensors with stickers can still be used to measure conductive heat flux.

2.1 Basic operation

Applying a sticker does not alter the working principle of the heat flux sensor. The original sensitivity S_{sensor} still applies.

The heat flux Φ in W/m² as measured by the heat flux sensor is

$$\Phi = U_{sensor}/S_{sensor} \quad \text{(Formula 2.1.1)}$$

where U_{sensor} is the heat flux sensor voltage output.

For more details, see the user manual of the heat flux sensor.

To measure radiative and convective heat flux, place two heat flux sensors side by side. Apply the BLK black sticker on the first heat flux sensor, apply the GLD gold sticker on the second heat flux sensor.

Measure both heat fluxes

$$\Phi_{radiation\ +\ convection} = \Phi_{BLK} = U_{sensor,BLK}/S_{sensor,BLK} \quad \text{(Formula 2.1.2)}$$

$$\Phi_{convection} = \Phi_{GLD} = U_{sensor,GLD}/S_{sensor,GLD} \quad \text{(Formula 2.1.3)}$$

To find radiative heat flux, subtract the two measurements

$$\Phi_{radiation} = \Phi_{radiation\ +\ convection} - \Phi_{convection} = \Phi_{BLK} - \Phi_{GLD} \quad \text{(Formula 2.1.4)}$$

2.2 Radiation measurement

Heat flux sensors measure heat flux in both directions. A heat flux sensor mounted on a surface measures the net radiation and convection: the difference between the incoming and outgoing radiation and convection.

To measure incoming radiation, mount the heat flux sensors on a heatsink and account for the heat flux sensor surface temperature of the heat flux sensor with the black sticker.

Examples of heatsinks are well-conducting metal blocks, sometimes air- or water-cooled.

The stickers have a small thermal resistance. The temperature of the heat flux sensors is a good estimate of the heat flux sensor surface temperature.

For radiation measurements with one heat flux sensor with a black sticker, the incoming total heat flux is

$$\Phi_{radiation + convection,incoming} = \Phi_{radiation + convection} + \sigma \cdot (T + 273.15)^4 \quad \text{(Formula 2.2.1)}$$

with σ the Stefan-Boltzmann constant, T the temperature of the heat flux sensor in °C.

When a second heat flux sensor with a gold sticker is available, the incoming radiative heat flux is

$$\Phi_{radiation,incoming} = \Phi_{radiation + convection} - \Phi_{convection} + \sigma \cdot (T_{sensor,\ BLK} + 273.15)^4 \quad \text{(Formula 2.2.2)}$$

2.3 Spectral properties of the stickers: reflection

In an ideal scenario, a black sticker reflects no radiation across all wavelengths and a gold sticker reflects all radiation across all wavelengths. In reality, both stickers deviate from the perfect case. This is caused by the spectral properties of the stickers.

The reflection of both stickers depends on the wavelength of the incoming radiation.

The BLK black sticker has an average reflection of 3 % (r_{BLK} = 0.03) in the UV, visible, near-infrared and far-infrared spectrum.

The GLD gold sticker has a reflection of about 35 % (r_{GLD} = 0.35) in the UV spectrum, which increases through the visible spectrum to an average reflection value of 98 % (r_{BLK} = 0.98) in the near-infrared and the far-infrared.

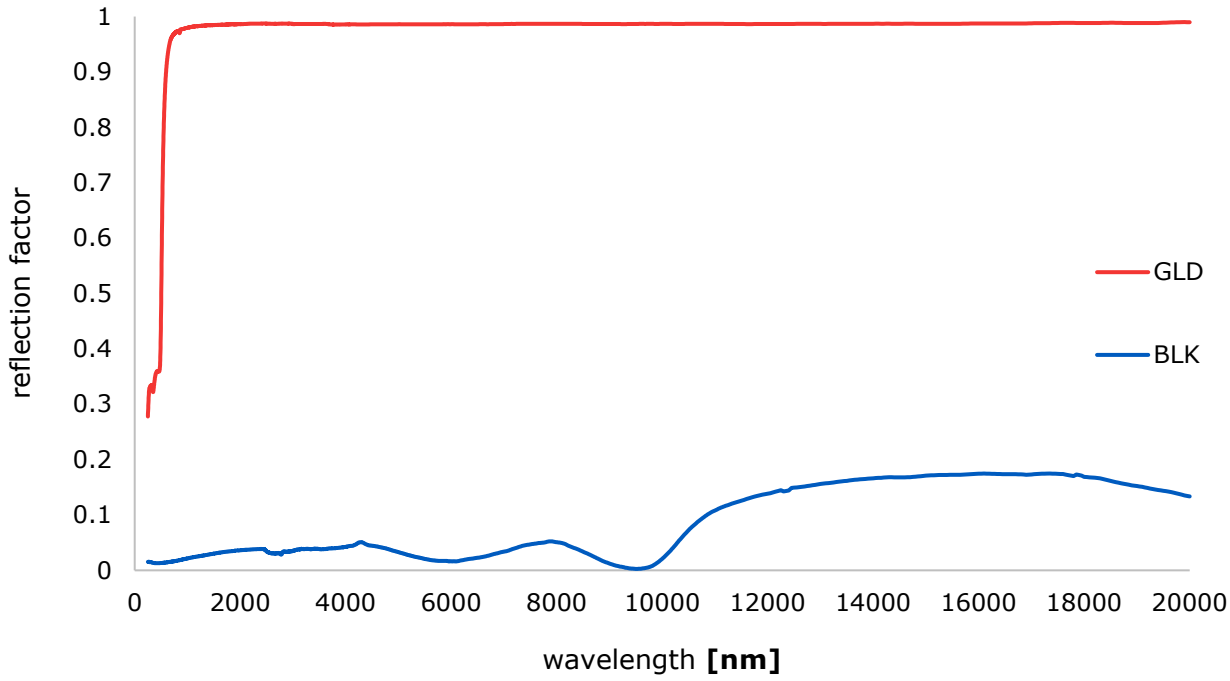


Figure 2.3.1 *BLK and GLD reflection factors as a function of wavelength*

To account for this non-perfect spectral response, use

$$\Phi_{radiation} = (\Phi_{BLK} - \Phi_{GLD})/(r_{GLD} - r_{BLK}) \quad \text{(Formula 2.3.1)}$$

$$\Phi_{convection} = ((r_{GLD} - 1)\cdot\Phi_{BLK} + (1 - r_{BLK})\cdot\Phi_{GLD})/(r_{GLD} - r_{BLK}) \quad \text{(Formula 2.3.2)}$$

$$\Phi_{radiation\ +\ convection} = (r_{GLD}\cdot\Phi_{BLK} - r_{BLK}\cdot\Phi_{GLD})/(r_{GLD} - r_{BLK}) \quad \text{(Formula 2.3.3)}$$

where

$$\Phi_{BLK} = U_{sensor,\ BLK}/S_{sensor,\ BLK} \quad \text{(Formula 2.3.4)}$$

$$\Phi_{GLD} = U_{sensor,\ GLD}/S_{sensor,\ GLD} \quad \text{(Formula 2.3.5)}$$

Typical values of the average reflection factors for common radiation sources are given in Table 2.3.1.

Table 2.3.1 *Typical reflection factor for common radiation sources*

RADIATION SOURCE	r_{BLK}	r_{GLD}
UV radiation	0.02	0.35
Solar radiation, Xenon lamps (colour temperature 6000 K)	0.02	0.80
Halogen and infrared lamps, industrial heaters (colour temperature < 4000 K)	0.03	0.97
Low temperature infrared sources such as radiant heaters, stoves, most objects in the human environment (colour temperature < 1000 K)	0.09	0.99

For more details on spectral properties of the stickers, refer to Appendix 6.1.

2.4 Spectral properties of the stickers: absorption and emissivity

In certain applications, absorption and emissivity are the relevant spectral properties instead of reflection.

Absorption α is the amount of energy absorbed by an object.

$\alpha_{BLK} = 1 - r_{BLK}$
$\alpha_{GLD} = 1 - r_{GLD}$

Emittance is the amount of thermal energy emitted by an object. Numerically, emissivity is the same as absorption.

$\varepsilon_{BLK} = \alpha_{BLK}$
$\varepsilon_{GLD} = \alpha_{GLD}$

Table 2.4.1 *Typical absorption factors for common radiation sources*

RADIATION SOURCE	α_{BLK}	α_{GLD}
UV radiation	0.98	0.65
Solar radiation, Xenon lamps (colour temperature 6000 K)	0.98	0.20
Halogen and infrared lamps, industrial heaters (colour temperature < 4000 K)	0.97	0.03
Low temperature infrared sources such as radiant heaters, stoves, most objects in the human environment (colour temperature < 1000 K)	0.91	0.01

Table 2.4.2 *Typical emissivity factors for common situations*

EMITTING OBJECT	ε_{BLK}	ε_{GLD}
Far-infrared emission at sensor temperatures < 250 °C	0.90	0.01

Every object emits energy, but only very hot objects are easily visible to the eye. Heat flux sensors with stickers emit energy too. When performing measurements of emitted radiation from a surface, use a heat flux sensor with a sticker that matches the emissivity of the surface.

For example, use a heat flux sensor with a GLD sticker to measure emitted radiation from a reflective surface.

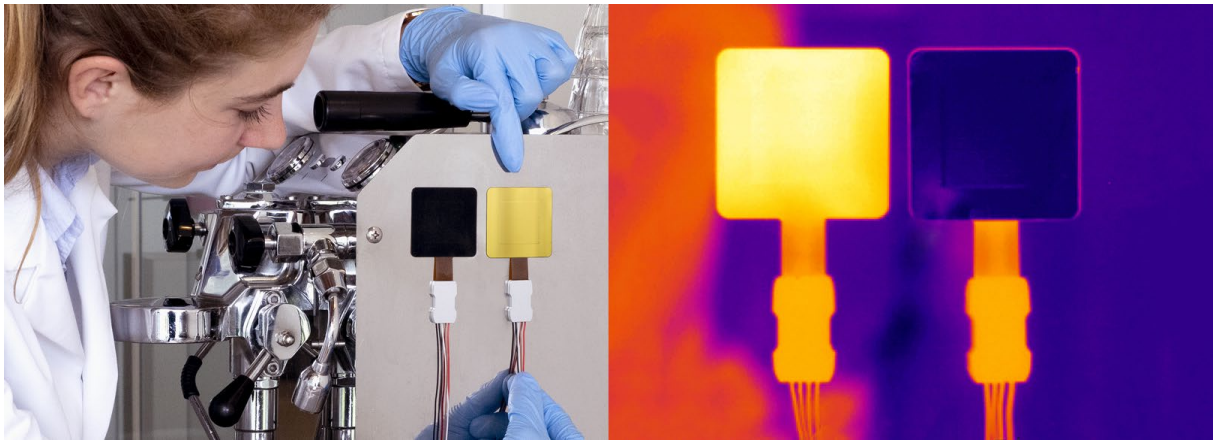


Figure 2.4.1 *Measuring with BLK – GLD stickers; application of a BLK black sticker and a GLD gold sticker on FHF04 sensors for measuring radiative and convective heat flux on an espresso machine. The machine has a polished metal surface of 46 °C. The IR image on the right shows that the black sticker on the left, as well as the sensor wires and connector blocks, emit radiation and appears as bright on the image. The gold sticker and the metal surface have lower emission, and appear in the IR picture as "black". The BLK and GLD stickers have the same temperature. The measurement with the sensor with the GLD sticker is most representative of the heat flux at the metal surface, while the sensor with the BLK sticker overestimates the heat flux. The bright orange on the left is the IR reflection of the human operator on the polished metal surface.*

3 Specifications of BLK – GLD sticker series

3.1 Specifications of BLK – GLD stickers

BLK – GLD sticker series can be applied to a Hukseflux heat flux sensor. BLK stickers provide the sensor with a black absorbing surface which allows for measurement of convective and radiative heat flux, expressed in W/m². GLD stickers provide the sensor with a gold reflecting surface which allows for measurement of only convective heat flux. Combining BLK and GLD stickers, applied to two separate heat flux sensors, will allow for measuring radiative heat flux.

Table 3.1.1 *Specifications of BLK – GLD sticker series (continued on next page)*

BLK SPECIFICATIONS	
Product type	sticker
Measurand	convective + radiative heat flux
Measurand in SI units	heat flux density in W/m²
Measurement range	(-2 to 2) x 10³ W/m² (HFP01) (-10 to 10) x 10³ W/m² (FHF03, FHF04 and FHF04SC)
Measurement function / required programming	$\Phi_{convective+radiative}$ = U/S
Rated temperature range - continuous use	-40 to +260 °C
Rated temperature range - short intervals	-40 to +150 °C
Spectral range (UV-VIS-NIR-FIR)	250 to > 10000 × 10^{-9} m
Absorption over range	> 95 % see appendix for more information
Carrier material	Kapton®
Coating material	fully inorganic metal based
Adhesive	3M™ VHB™ F9460PC acrylic transfer tape
Sticker thickness	0.14 x 10^{-3} m
Sticker thermal resistance	10 x 10^{-4} K/(W/m²)
Sticker thermal conductivity	1.38 x 10^{-1} W/(m·K)
GLD SPECIFICATIONS	
Product type	sticker
Measurand	convective heat flux
Measurand in SI units	heat flux density in W/m²
Measurement range	(-2 to 2) x 10³ W/m² (HFP01) (-10 to 10) x 10³ W/m² (FHF03, FHF04 and FHF04SC)
Measurement function / required programming	$\Phi_{convective}$ = U/S
Temperature range (short term)	-185 to +260 °C
Temperature range (long term)	-185 to +150 °C
Spectral range (NIR-FIR)	700 to > 10000 × 10^{-9} m
Reflection over range	> 95 % see appendix for more information
Spectral range (VIS)	400 to 700 × 10^{-9} m
Reflection over range	> 80 % see appendix for more information
Solar absorption	< 20 %
Carrier material	Kapton®
Coating material	gold

Table 3.1.1 *Specifications of BLK – GLD sticker series (started on previous page)*

Adhesive	ARcare® 8026 silicone transfer tape
Sticker thickness	0.05×10^{-3} m
Sticker thermal resistance	3.5×10^{-4} K/(W/m^2)
Sticker thermal conductivity	1.45×10^{-1} W/(m·K)
GENERAL SPECIFICATIONS	
Effect on sensor sensitivity	negligible
Effect on type T sensor (FHF sensors only)	negliglible
Additional response time (95 %)	3 s (nominal)
Rated temperature range when applied to sensor	see sensor specifications
Sticker dimensions	
BLK-5050 / GLD-5050	$(50 \times 50) \times 10^{-3}$ m
BLK-3015 / GLD-3015	$(30 \times 15) \times 10^{-3}$ m
BLK-80 / GLD-80	Ø 80×10^{-3} m
Bending radius	see sensor specifications for limiting bending radius
Protection foil	remove before measurement
INSTALLATION AND USE	
Typical conditions of use	in experiments, in measurements in laboratory and industrial environments. Exposed to heat fluxes for periods of several minutes to several years. Sensor connected to user-supplied data acquisition equipment. Regular inspection of the sensor and sticker surface. Continuous monitoring of sensor temperature. No special requirements for immunity, emission, chemical resistance.
Recommended number of sensors	2 per measurement location placed side by side
Recommended number of stickers	one per sensor per measurement location,
Application	see chapter on application procedure, see instruction sheet included with delivery see our instruction video on YouTube, or order sensors with stickers pre-applied at the factory
Installation	see recommendations in this user manual
MEASUREMENT ACCURACY	
Uncertainty of the sensor	see user manual of the sensor for more information about calibration method and uncertainties
Uncertainty of the measurement	statements about the overall measurement uncertainty can only be made on an individual basis
VERSIONS AND ORDER CODES	
BLK-5050 / GLD-5050	to be used with FHF04 and FHF04SC heat flux sensors
BLK-3015 / GLD-3015	to be used with FHF03 heat flux sensor
BLK-80 / GLD-80	to be used with HFP01 heat flux sensor
OPTIONS	
Pre-applied to the sensor	When opting for pre-application of the sticker to the sensor at the factory, please use the following ordering code: product code sensor with wire / cable length indicated + product code sticker example: HFP01-05-GLD-80 for an HFP01 with 5 metres of cable and a pre-applied gold sticker

3.2 Dimensions of BLK – GLD stickers

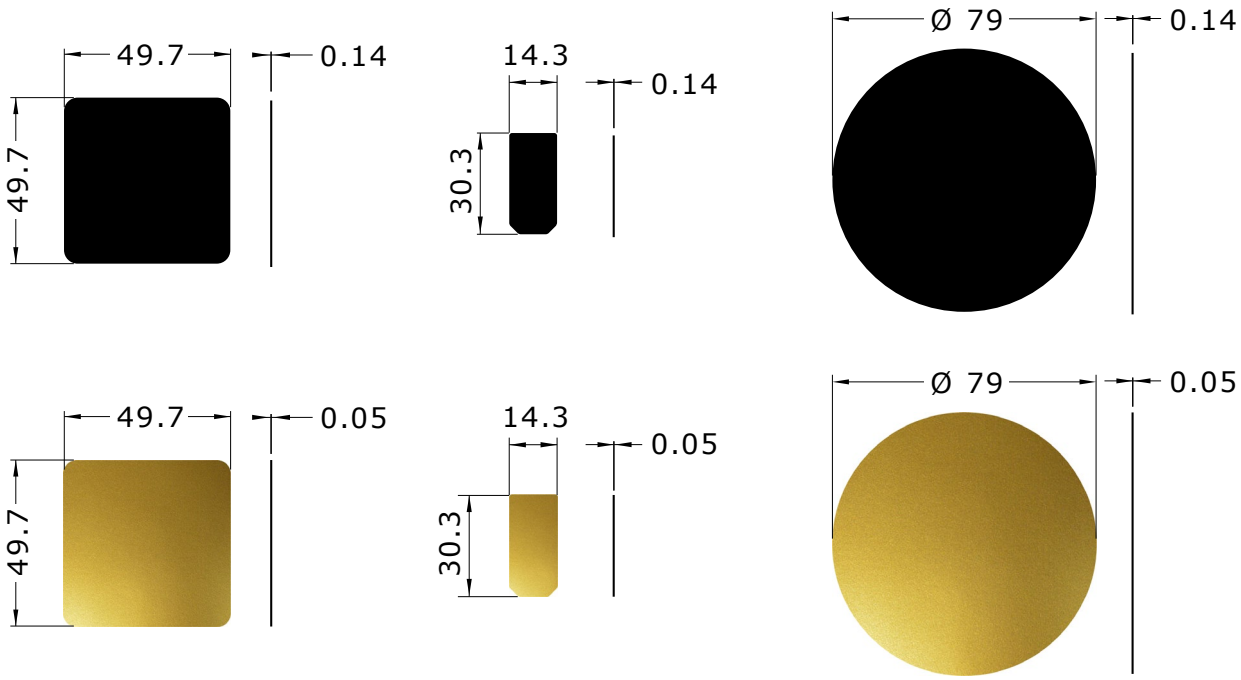


Figure 3.2.1 *Dimensions of BLK – GLD sticker series; all dimensions in x 10^{-3} m*
Top row from left to right: BLK-5050, BLK-3015 and BLK-80
Bottom row from left to right: GLD-5050, GLD-3015 and GLD-80

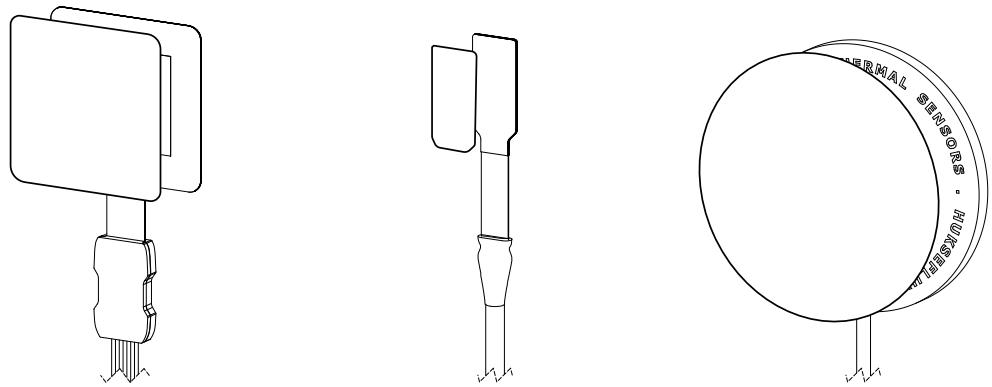


Figure 3.2.2 *The dimensions of the BLK – GLD stickers match the dimensions of the corresponding heat flux sensors FHF04(SC), FHF03 and HFP01*

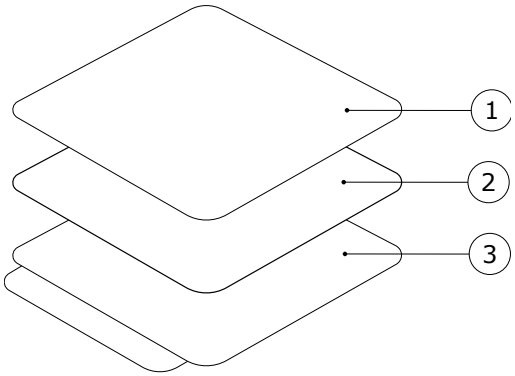


Figure 3.2.3 *Layer build-up for the BLK - GLD sticker series. Depicted is BLK/GLD-5050*

(1) protective foil
(2) BLK / GLD sticker
(3) release liner with peeling tab

4 Installation of BLK – GLD sticker series

4.1 Application procedure

For the best possible measurement of heat flux sensors with BLK - GLD stickers applied, it is important that the application is done correctly. The stickers have to be aligned with the sensor, without leaving scratches, (finger) grease, or inclusion of air pockets.

It is advised to do a quick instrument check of the sensor, before applying the sticker. See the user manual of the sensor for further instructions.

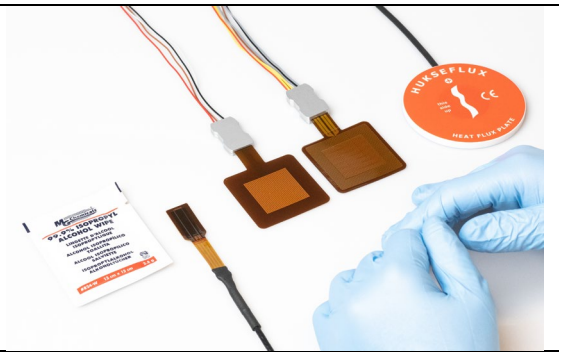
NOTICE
Wear powderless gloves during application.

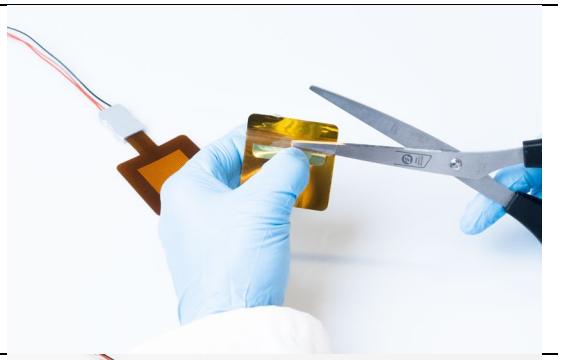
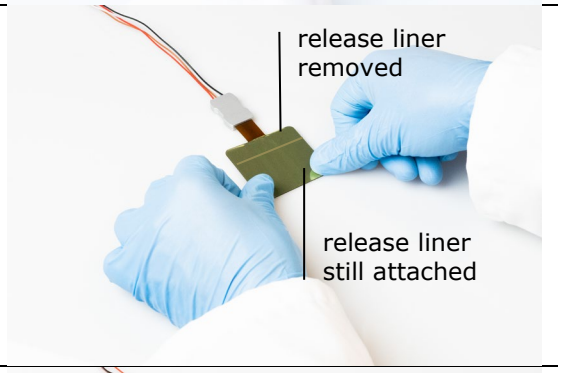
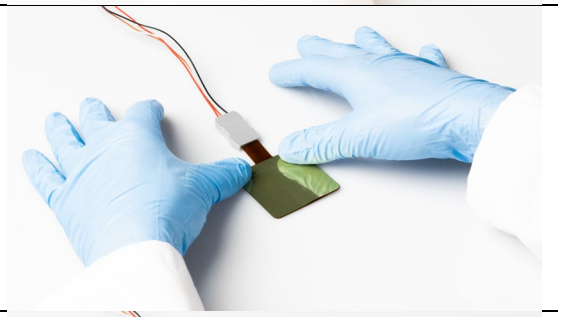
NOTICE
BLK – GLD stickers are designed for single use. Removing them after application will render them unsuitable for reapplication.

NOTICE
Do a quick instrument check before application of the sticker.

- When applying a black or gold sticker to FHF04(SC), please note it should be applied to the side of the heat flux sensor where the dot on the foil is NOT visible.
- When applying a black or gold sticker to FHF03, please note it should be applied to the side of the heat flux sensor where the label with FHF03s sensitivity is NOT visible.
- When applying a black or gold sticker to HFP01, please note it should be applied to the side of the heat flux sensor which is coloured red.

Table 4.1.1 *Application procedure for BLK – GLD stickers (continued on next page)*

1	Place the sensor on a stable surface as shown on the right. Pay attention to the orientation. Clean the sensor surface using the provided alcohol wipe.	

2	Partially peel and cut the release liner (approximately 1 cm). Do not remove the release liner completely.	
3	Position the sticker on the sensor surface.	
4	Fixate the top part of the sticker onto the sensor. If the sticker does not align properly, remove the sticker and go back to step 3.	
5	Slowly peel back the remaining release liner while simultaneously applying the rest of the sticker to avoid air pockets.	
6	Remove the protective foil before measuring. Handle with care once the protective foil is removed.	

4.2 Site selection and sensor installation

Table 4.2.1 *Recommendations for installation of sensors with BLK – GLD stickers applied*

Location	choose a location that is representative of the process that is analysed avoid direct exposure to the sun
Positioning	when using multiple sensors with BLK and GLD stickers, place them side by side
Surface cleaning and levelling	create a clean and smooth surface before mounting the sensor
Mounting: orientation	when mounting a sensor with a BLK or GLD sticker, keep the directional sensitivity in mind orient the sensor surface with sticker away from the object on which it is mounted
Mounting: avoiding strain on sensor cable or wires	during installation as well as operation, the user should provide proper strain relief of the sensor cable/wires so that they are not exposed to significant force first install the cable/wires including strain relief and after that install the sensor
Mounting: curved surfaces	when mounting sensors on curved surfaces, apply BLK – GLD stickers before mounting the sensor. See the user manual of the sensor for its rated bending radius
Short term installation	avoid any air gaps between sensor and surface. Air thermal conductivity is in the 0.02 W/(m·K) range, while a common glue has a thermal conductivity around 0.2 W/(m·K). An air gap of 0.1×10^{-3} m increases the effective thermal resistance of the sensor by 200 % to avoid air gaps, we recommend thermal paste or glycerol for short term installation. When mounting on curved surfaces, glycerol is not recommended as it will leak out use tape to fixate the sensor on the surface. Tape only over the passive guard area (the area without thermopile traces) use tape to fixate the strain relief of the sensor usually the cables are provided with an additional strain relief, for example using a cable tie mount as in Figure 4.2.1
Permanent installation	for long-term installation, fill up the space between sensor and object with silicone construction sealant, silicone glue or silicone adhesive that can be bought in construction depots the use of thermal paste for permanent installation is discouraged because it will dry out over time. Silicone glue is more stable and reliable
Electrical connection	when measuring incoming radiation, connect the sensor as indicated in the user manual of the sensor. Incoming radiation will then give a positive sensor signal for measurements of outgoing radiation, switch the [+] and [-] wires of the sensor to change its polarity. Outgoing radiation will then give a positive sensor signal

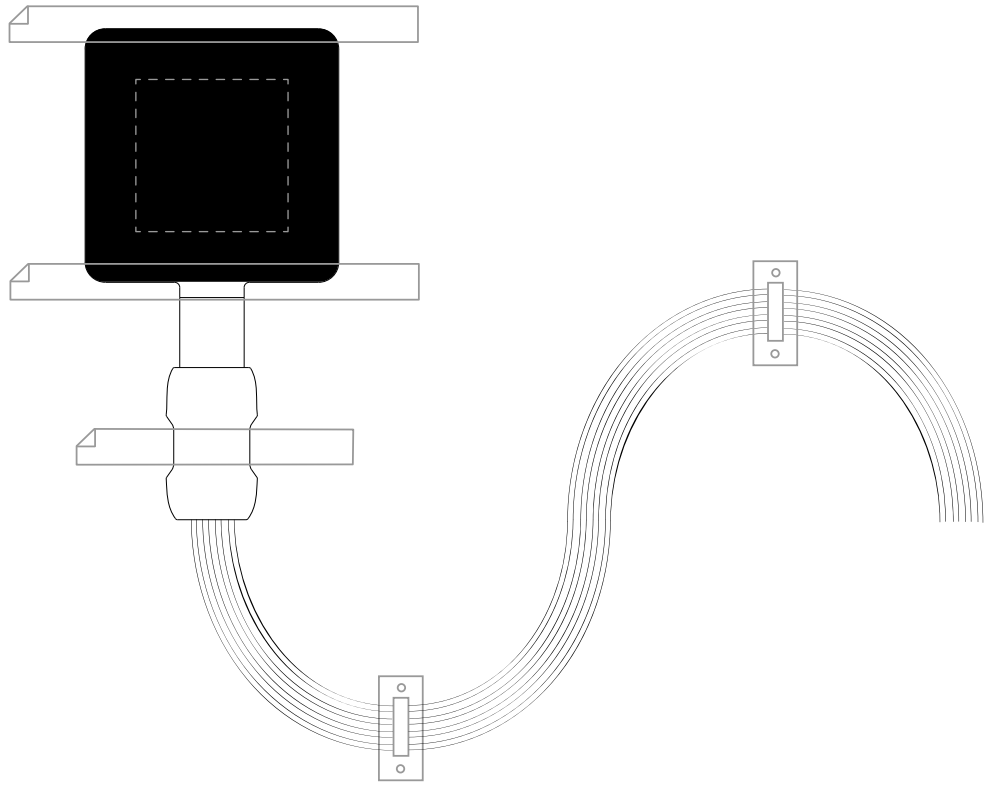


Figure 4.2.1 *Installation of an FHF04 with BLK sticker using tape to fixate the sensor and FHF04's metal connection block serving as strain relief. Extra strain relief on the wires is provided using cable tie mounts equipped with double-sided tape as adhesive. As also indicated in Table 4.1.1, tapes fixating the sensor should only be taped over the passive guard area and not over the sensing area (the latter indicated by a dashed line in Figure 4.2.1).*

5 Maintenance and trouble shooting

5.1 Recommended maintenance and quality assurance

Hukseflux heat flux sensors with sticker perform reliably at a low level of maintenance. Unreliable sensor output can be detected by scientific judgement, for example by looking for unreasonably large or small measured values. The preferred way to ensure a reliable sensor output, is a regular critical review of the measured data.

Table 5.1.1 *Recommended maintenance of heat flux sensors with BLK – GLD stickers. If possible, the data analysis is done on a daily basis*

MINIMUM RECOMMENDED HEAT FLUX SENSOR MAINTENANCE			
	INTERVAL	SUBJECT	ACTION
1	1 week	data analysis	compare measured data to the maximum possible or maximum expected heater power, to other measurements from other redundant instruments and to data previously measured under identical circumstances. Look for any patterns and events that deviate from what is normal or expected. Compare to acceptance intervals.
2	6 months	inspection	inspect wire quality, inspect mounting, inspect location of installation look for seasonal patterns in measurement data
3	2 years	recalibration	recalibration by comparison to a calibration standard instrument in the field, see following paragraphs. recalibration by the sensor manufacturer
4	2 years	lifetime assessment	judge if the instrument will be reliable for another 2 years, or if it should be replaced

5.2 Trouble shooting

Table 5.2.1 *Trouble shooting for heat flux sensors with BLK – GLD stickers*

General	Inspect the quality of application / installation. Inspect the sticker surface for any damage or stains like grease or dirt. Inspect if there are any air pockets between the sticker and sensor. Check if the sensor wires are properly attached to the data logger. Check the condition of the wires.
Grease or dirt on BLK surface	Gently clean with a soft cloth, like an anti-static or microfiber cloth, and demiwater. Avoid IPA or aceton as it will remove the black coating. Wear powderless gloves during cleaning.
Grease or dirt on GLD surface	Gently clean with a soft cloth, like an anti-static or microfiber cloth, and IPA or aceton. Avoid touching the sticker surface with anything other than a soft cloth as it highly prone to scratching. Wear powderless gloves during cleaning.
Issues with sensor signal	See sensor manuals for help on trouble shooting with the sensor signal

5.3 Calibration and checks in the field

The recommended calibration interval of heat flux sensors is 2 years.
Recalibration of field heat flux sensors with stickers is ideally done by the sensor manufacturer.

On-site field calibration is possible by comparison to a calibration reference sensor. Usually mounted side by side, alternatively mounted on top of the field sensor.

Hukseflux main recommendations for field calibrations are:

1) to compare to a calibration reference of the same brand and type as the field sensor
2) to connect both to the same electronics, so that electronics errors (also offsets) are eliminated
3) to mount all sensors on the same platform, so that they have the same body temperature
4) typical duration of test: > 24 h
5) typical heat fluxes used for comparison: > 600 W/m^2
6) to correct deviations of more than ± 20 %. Lower deviations should be interpreted as acceptable and should not lead to a revised sensitivity

Users may also design their own calibration experiment, for example using a well characterised foil heater.

6 Appendices

6.1 Reflection for different wavelengths

Figure 6.1.1 and 6.1.2 show the reflection of the BLK and GLD stickers as a function of wavelength of the incoming radiation. Upon request, the data from these graphs are also available in CSV format.

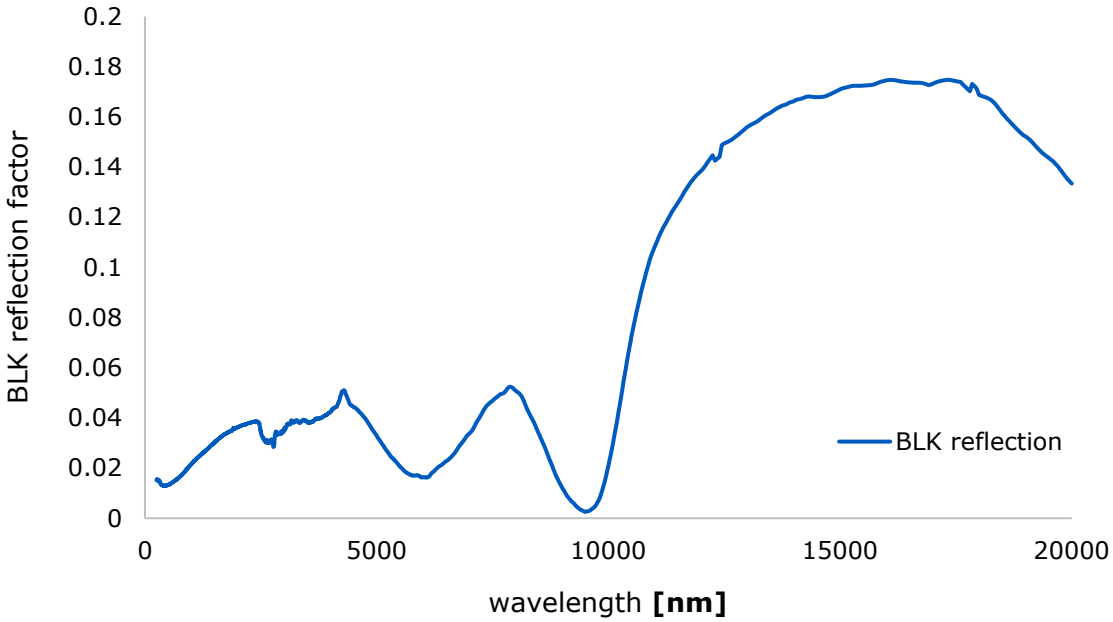


Figure 6.1.1 *reflection factor of BLK sticker as a function of wavelength of the incoming radiation*

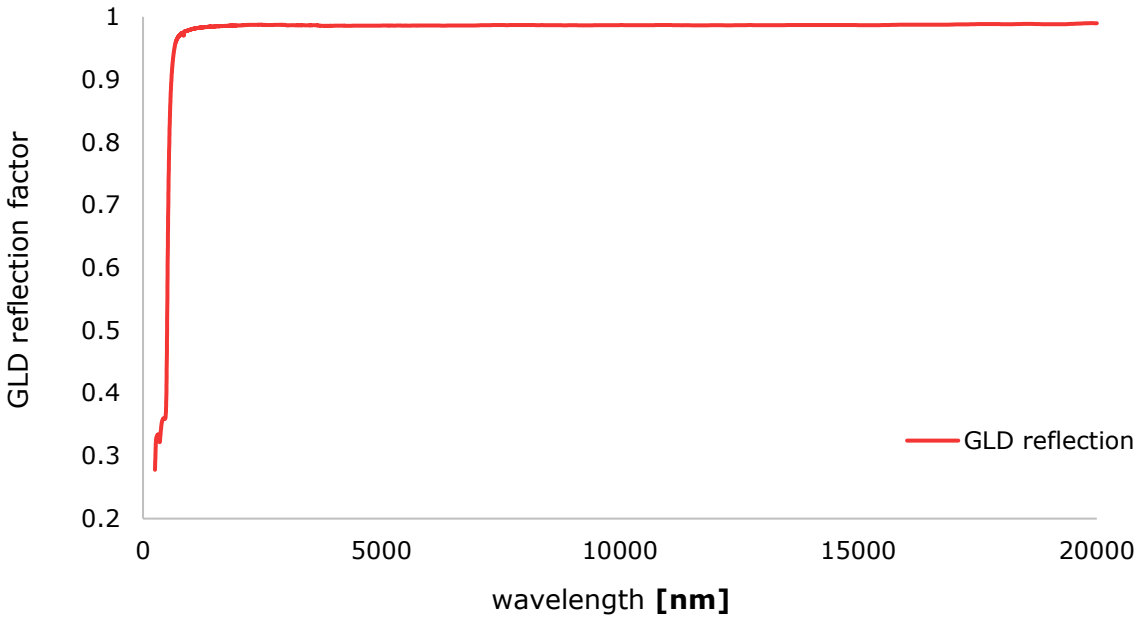


Figure 6.1.2 *reflection factor of GLD sticker as a function of wavelength of the incoming radiation*

Usually, the spectral composition of the source is not known exactly. If the source can be reasonably described as a blackbody source of a certain temperature T, an average reflectance factor can be calculated by integrating the reflectance of the sticker with the blackbody spectrum. This way, the formulas in Section 2.3 can be used.

Figure 6.1.3 and 6.1.4 show the average reflection factor for the BLK and GLD sticker for blackbody sources of different temperatures.

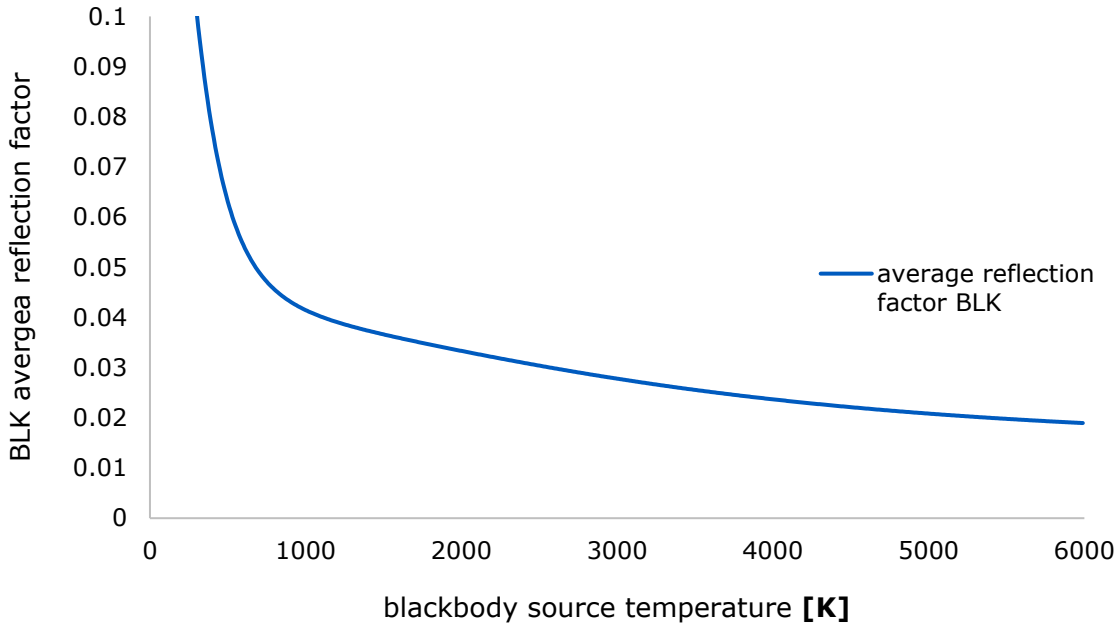


Figure 6.1.3 *average reflection factor of BLK sticker when measuring radiation from blackbody sources of different temperatures.*

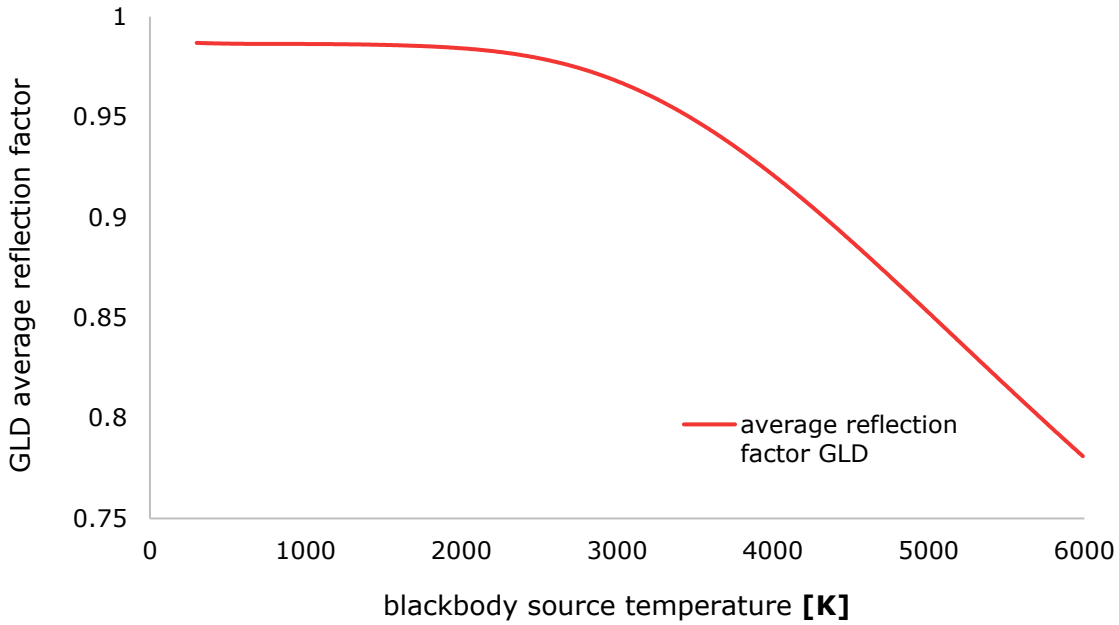


Figure 6.1.4 *average reflection factor of GLD sticker when measuring radiation from blackbody sources of different temperatures. .*

6.2 EU declaration of conformity

CE

We, Hukseflux Thermal Sensors B.V.
Delftechpark 31
2628 XJ Delft
The Netherlands

in accordance with the requirements of the following directives:

2011/65/EU, (EU) 2015/863 The Restriction of Hazardous Substances Directive

hereby declare under our sole responsibility that:

Product model: BLK GLD sticker series
Product type: sticker

has been designed to comply and is in conformity with the relevant sections and applicable requirements in the directive under typical conditions of use as defined in product specifications.

Eric HOEKSEMA
Director
Delft
June 29, 2021