

# USER MANUAL HF02

Flare radiation monitor / heat flux sensor  
equipment models LEX35 A/B/C



## Warning statements



Follow the installation instructions of this manual. It contains safety notes, rated operating conditions, recommendations on installation and shielding and requirements for maintenance.



HF02 must be used under its ATEX rated operating conditions only. The user is responsible for assessment of local conditions as well as for proper certification of any connecting equipment.



We recommend use of HF02 in a decision-supporting role only, and not to use measurements of HF02 as the sole or main source of information supporting decision making or judgements on safety.



The sensor-to-cable transition is vulnerable. The user should provide proper strain relief of the cable so that transition is not exposed to significant force. First install the cable including strain relief, then install the sensor.



Under no condition more than  $U_{\max}$  5V should be put across the HF02 output wiring,  $I_{\max}$  equals  $5 \times 10^{-3}$  A.

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## List of symbols

### Quantities

	<b>Symbol</b>	<b>Unit</b>
Heat flux	$\Phi$	W/m <sup>2</sup>
Voltage output	U	V
Sensitivity	S	V/(W/m <sup>2</sup> )
Temperature	T	°C
Resistance	R	$\Omega$

### Subscripts

N/A

## Introduction

HF02 is a sensor that measures radiant heat flux or thermal radiation in the outdoor environment. A common application is monitoring the radiation emitted by flares. HF02 is certified for use in potentially explosive atmospheres, and is rated for radiation levels up to  $15 \times 10^3 \text{ W/m}^2$ . We recommend use of HF02 in a decision-supporting role only, and not to use measurements of HF02 as the main or sole source of information for judging safety.

The formal equipment model names of the HF02 are LEX35 with extension A, B or C, depending on the connection of the sensor shield.

HF02 is used in alarm systems, using the heat flux measurement to issue a warning in case of high thermal radiation exposure of equipment or personnel. It is typically installed close to a flare. A common assumption is that the heat flux level in a safe environment for personnel must not exceed  $5 \times 10^3 \text{ W/m}^2$  (or  $1.5 \times 10^3 \text{ BTU}/(\text{hr}\cdot\text{ft}^2)$ ). Above that heat flux level, or when the temperature of the sensor body exceeds  $70 \text{ }^\circ\text{C}$ , an alarm is activated.

A typical alarm system will include multiple HF02 sensors, all aimed at the main source of radiation, as well as other decision-supporting devices such as camera systems and temperature sensors.

The sensor in HF02 measures the heat flux to its black (absorbing) surface, in the plane of the sensor, from a source in the field of view angle. It offers measurement of the effective exposure for personnel and equipment from a source in the direction it is aimed at the location of the sensor.

Using HF02 is easy. It can be connected directly to commonly used data logging systems. The heat flux in  $\text{W/m}^2$  is calculated by dividing the HF02 output, a small voltage, by the sensitivity. The sensitivity is provided with HF02 on its calibration certificate.

The measurement function of HF02 is:

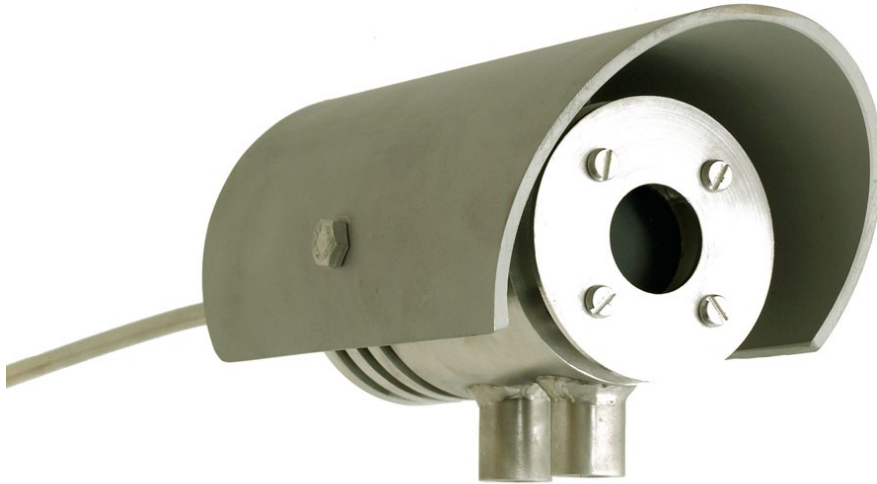
$$\Phi = U/S \quad (\text{Formula 0.1})$$

The sensor body temperature is monitored as a redundant safety precaution. In case the sensor has a temperature above a specified level, typically  $70 \text{ }^\circ\text{C}$ , we recommend to consider this a sign that there are strong local heat sources and to activate the alarm.

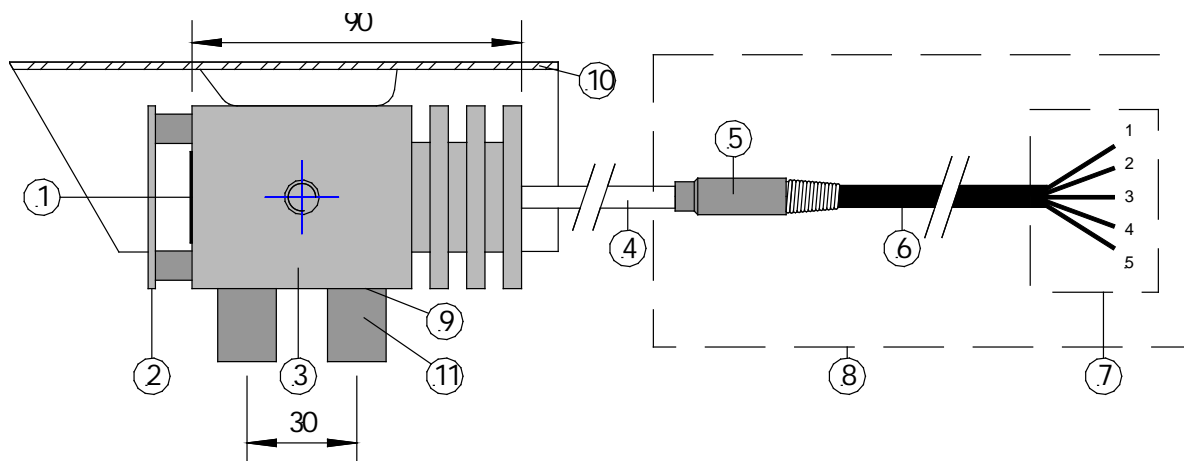
HF02 is rated for use in (potentially explosive) environments. It is supplied with a product certificate specifying the ATEX rating as II 2 G EEx d IIC T6.

Hukseflux provides a traceable calibration. Hukseflux is ISO 9001: 2008 certified, but not an accredited measurement laboratory according to ISO 17025.

HF02 should be regularly inspected. The sensor performance can be verified by comparison to a portable heat flux sensor such as model HF03.



**Figure 0.1** HF02. Standard cable length is 3 m high temperature metal sheathed cable plus 3 m low temperature extension cable.



**Figure 0.2** HF02 consists of a heat flux sensor (1) providing both a heat flux and a sensor body temperature measurement, a sensor body (3), a radiation shield (2) and rain screen (10) to protect the sensor against the environment, a high-temperature metal sheathed cable (4), a cable transition piece (5), a low temperature extension cable (6), mounting holes (3/8 UNC) (9) and spacers (11). The transition piece (5) to the cable end (at 7) in area 8 must be between  $-20$  and  $+70$  °C, and the cable end (at 7) must be provided by the user with an enclosure certified for use in the area of installation. Installation is the responsibility of the user. Dimensions in  $\times 10^{-3}$  m.

# 1 Ordering and checking at delivery

## 1.1 Ordering HF02

The standard configuration of HF02 is with 3 m high temperature metal sheathed cable and 3 m low temperature extension cable.

Common options are:

- longer cable (specify total cable length for both cable types in m)

Specify the shielding option: the standard version LEX35B has the sensor body and the high temperature cable connected to the shield/drain wire of the low temperature plastic cable. A shield disconnected from the high temperature metal cable and sensor body is offered as an option.

- LEX35A: shield not connected to high temperature cable and sensor body
- LEX35B : shield connected to high temperature cable and sensor body (standard version)
- LEX35C: no low temperature extension cable, high temperature metal sheath material and the sensor body may act as shield

## 1.2 Included items

Arriving at the customer, the delivery should include:

- heat flux sensor HF02
- cables of the lengths as ordered
- product certificate matching the instrument serial number
- EC type examination certificate (ATEX) II 2 G EEx d IIC T6

### 1.3 Quick instrument functionality check

A quick test of the instrument can be done by connecting it to a multimeter.

1. Check the electrical resistance of the heat flux sensor between the black [-] and red [+] wires and the thermocouple between the green [+] and white [-] wires. Use a multimeter at the 100  $\Omega$  range. Measure the sensor resistance first with one polarity, then reverse the polarity. Take the average value. Typical resistance should be the nominal sensor resistance of 4 to 14  $\Omega$  for the thermopile sensor at standard cable lengths, plus for additional low temperature extension cable 0.1  $\Omega$ /m (resistance per meter cable ) for the total resistance of two wires (back and forth added), for high temperature cable 1  $\Omega$ /m. For the thermocouple work with 5 to 15  $\Omega$  at standard cable lengths, plus additional low temperature extension cable 0.7  $\Omega$ /m resistance per meter cable ), for high temperature cable 2  $\Omega$ /m. Infinite resistance indicates a broken circuit; zero or a lower than 1  $\Omega$  resistance indicates a short circuit.
2. Check if the heat flux sensor reacts to heat: put the multimeter at its most sensitive range of DC voltage measurement, typically the 100 x 10<sup>-3</sup> VDC range or lower. Expose the sensor heat, for instance touching it with your hand. The signal should read > 2 x 10<sup>-3</sup> V now. Touching or exposing the black surface should generate a positive signal. Also look at the reaction of the thermocouple to heat.
3. Check the shield connection. Measure the drain-wire to housing connection. The options are: LEX35A: shield not connected to high temperature cable and sensor body and LEX35B: shield connected to high temperature cable and sensor body. Measure with a multimeter with one connection at the drain wire the other in the sensor body.
4. Inspect the instrument for any damage.
5. Check the sensor serial number engraved on the transition piece between high temperature cable and low temperature extension cable, against the certificate provided with the sensor.



## 2 Instrument principle and theory

HF02 is a sensor that measures heat flux. It is mainly used to measure heat flux from flares. HF02 measures heat flux in the range of  $(0 \text{ to } 15) \times 10^3 \text{ W/m}^2$ . Equipped with a black absorber, heat flux sensors of this type are designed for measurement in an environment in which heat flux is dominated by radiation.

HF02's thermopile sensor generates an output voltage proportional to the incoming irradiance.

To convert the measured voltage,  $U$ , to a heat flux  $\Phi$ , the voltage must be divided by the sensitivity  $S$ , a constant that is supplied with each individual sensor.

The measurement function of HF02 is:

$$\Phi = U/S \quad \text{(Formula 0.1)}$$

The sensitivity is provided with HF02 on its calibration certificate.

As the detector is essentially open (it has no protective windows) the measurement is influenced by wind in the same way as any exposed surface such as clothing worn by personnel or the surface of equipment; increased wind speed leads to a reduction of the measured heat flux. Rain on the detector can also lead to cooling and a reduction of the measured heat flux.

To perform a heat flux measurement representative of human exposure or equipment exposure, the sensor temperature should be as close as possible to the ambient air temperature. This is the purpose of the rain- and radiation screens of HF02 (in combination with cooling fins). They reduce radiative heating of the sensor by the sun. The screens also reduce the effect of wind and rain, reducing the risk of a false indication of a safe situation.

The temperature sensor inside HF01 is a type K thermocouple. It measures the sensor body temperature.

For readout the user only needs an accurate voltage measurement in the millivolt range, and a type K thermocouple measurement.

The total exposure of personnel or equipment is determined by the total heat flux, both from the flare that the HF02 is aimed at and from the sun. The maximum solar radiation level is about  $1.3 \times 10^3 \text{ W/m}^2$ , which means it is a potentially significant contribution. If the sun is in HF02's field of view, solar radiation might lead to an offset of the flare irradiance. The solar radiation may also have its maximum contribution from a direction that is not within HF02's field of view. Users typically accept that solar radiation is part of the measurement in case the sun is within HF02's field of view, and ignore the solar contribution if the sun is not within the sensor's field of view.

Measuring with heat flux sensors, errors may be caused by differences between calibration reference conditions and the conditions during use. The user should analyse his own experiment and make his own uncertainty evaluation.

### 3 Specifications of HF02

HF02 measures heat flux density from 90 ° field of view angle, through the surface of the HF02 sensor. This quantity, expressed in  $W/m^2$ , is called heat flux. It also measures its body temperature. HF02 is rated for use in environments in which the heat flux is dominated by radiation at heat flux levels up to  $15 \times 10^3 W/m^2$ . It measures the combined radiative and convective heat flux. HF02 is passive, using thermopile and thermocouple sensors. The thermopile generates a small output voltage proportional to the heat flux. HF02 can only be used in combination with a suitable measurement system. It is rated for use in potentially explosive environments. The sensor should be used in accordance with the recommended practices this manual.

**Table 3.1** Specifications of HF02 (continued on next page)

<b>HF02 SPECIFICATIONS</b>	
Sensor type	flare radiation monitor/ heat flux sensor
Heat flux sensor	thermopile
Measurand	heat flux
Measurand in SI units	heat flux density in $W/m^2$
Full field of view angle	90° (with radiation screen)
Rated measurement range	0 to $15 \times 10^3 W/m^2$
Limiting measurement range	150 % of rated measurement range
Temperature sensor	thermocouple type KX
Temperature sensor specification	ANSI MC96.1-1982 / EN 60584
Measurand	temperature
Measurand in SI units	temperature in °C
Measurement range	-30 to 100 °C
Limiting temperature range	500 °C (short term exposure of sensor and high temperature cable)
Measurement function / required programming	$\Phi = U/S$
Recommended number of sensors	2 per measurement location
Sensitivity (nominal)	$0.3 \times 10^{-6} V/(W/m^2)$
Response time (95 %)	180 s
Expected voltage output	multiply the sensitivity by the maximum expected heat flux typically $4.5 \times 10^{-3} V$
Required readout	heat flux sensor: 1 x differential voltage channel or 1 x single ended voltage channel temperature sensor: 1 x Type K differential thermocouple channel or 1 x Type K single ended thermocouple channel both with input resistance $> 10^6 \Omega$
IP protection class	
Sensor and high temperature cable	IP68
Low temperature extension cable	IP67
Rated operating relative humidity range	0 to 100 %
Required sensor power	zero (passive sensors)
Sensor diameter	$25 \times 10^{-3} m$
Standard cable lengths	
High temperature cable	3 m (see options)
Low temperature extension cable	3 m (see options)

**Table 3.1** Specifications of HF02 (started on previous page, continued on the next pages)

High temperature cable type	metal sheathed mineral insulated signal cable
Low temperature extension cable type	PVC signal cable with shield and drain wire
Heat flux sensor resistance range	4 to 14 $\Omega$ (standard cable length)
Low temperature extension cable: heat flux sensor cable resistance	0.1 $\Omega$ /m (nominal)
High temperature cable: heat flux sensor cable resistance	1 $\Omega$ /m (nominal)
Temperature sensor resistance range	5 to 15 $\Omega$ (standard cable length)
Low temperature extension cable: temperature sensor cable resistance	0.7 $\Omega$ /m (nominal)
High temperature cable: temperature sensor cable resistance	2 $\Omega$ /m (nominal)
Black coating emissivity	0.92 (nominal)
High temperature cable diameter	$6 \times 10^{-3}$ m
Low temperature extension cable diameter	$7.5 \times 10^{-3}$ m
Connection diameter	transition piece between high temperature and low temperature cable: $17 \times 10^{-3}$ m (including spring), $14 \times 10^{-3}$ m (metal only)
Marking	1 x engraving on the transition piece, showing serial number 1 x sticker at low temperature extension cable end, showing serial number.
Use of materials	stainless steel, duplex steel and PVC
Net weight	3 kg (with 3 m high temperature cable and 3 m low temperature extension cable)

#### ATEX SPECIFICATIONS AND INSTRUCTIONS

Equipment status according to directive 2014/34 EU	HF02 is a passive sensor which does not have its own source of ignition. It becomes equipment in the sense of Article 2 of the directive only when operating in combination with other equipment.
ATEX rated operating conditions	II 2 G EEx d IIC T6
Rated use	stationary use only
Model names according to EU type examination	LEX35A, LEX35B. LEX35C
Electrical data	$U_{\max}$ 5 V, $I_{\max}$ $5 \times 10^{-3}$ A
Rated process temperature range (sensor and high temperature cable)	-50 to +300 $^{\circ}$ C
Rated operating temperature range low temperature extension wire and cable end	-30 to +70 $^{\circ}$ C
EC type examination certificate	included in delivery
Safety notes	see warning statements and the chapter on recommended practices for use
Maintenance requirements	regular inspection of the sensor surface and field of view as well as regular performance verification. See the chapter on maintenance.

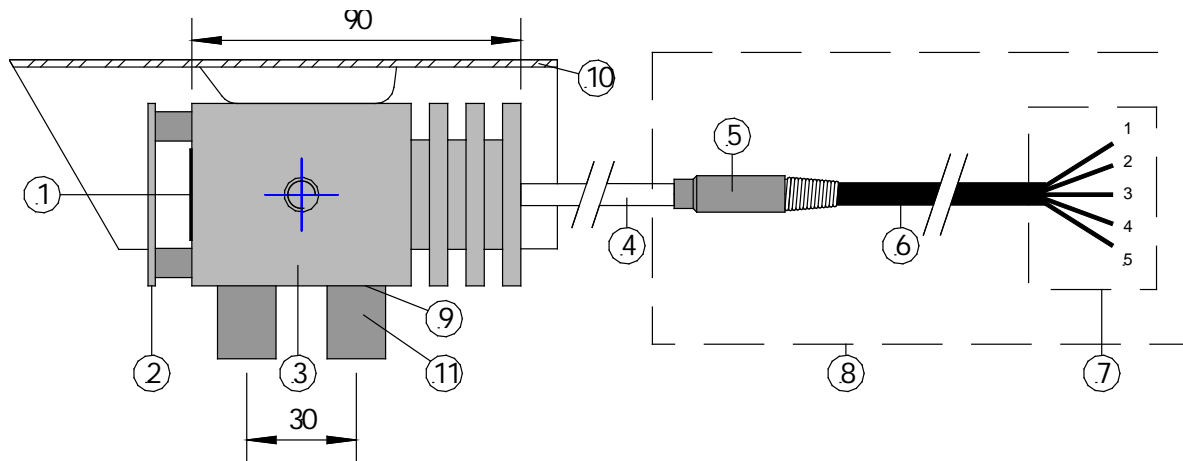
**Table 3.1** Specifications of HF02 (started on previous 2 pages, continued on the next page)

<b>GENERAL INSTALLATION AND USE</b>	
Location	HF02 is usually located at the point where safety must be assessed, pointed at the main source of radiation. Take into account the 90° full field of view angle.
Installation	see recommendations in this user manual. avoid mechanical force on the sensor-to-cable transition.
Mounting	2 x mounting bolt 3/8 UNC at $30 \times 10^{-3}$ m hart-to-hart distance
Cable extension	extension or replacement of cables is not covered by the product EU type examination. Cables may be extended under user responsibility employing a connection box certified for use in its operating environment
Recoating	the black sensor surface may be recoated with high temperature black paint, see the appendix on this subject
<b>CALIBRATION</b>	
Calibration traceability	to ITS90
Product certificate	Included (showing calibration result and traceability)
Calibration method	SBGC secondary calibration according to ISO 14934-3
Calibration hierarchy	from SI through international standards and through an internal mathematical procedure
Calibration uncertainty	< 20 % (k = 2)
Calibration laboratory accreditation	not accredited
Calibration laboratory management system certification	ISO 9001
Recommended recalibration interval	2 years
Calibration reference conditions	30 °C, heat flux of $10 \times 10^3$ W/m <sup>2</sup>
Validity of calibration	based on experience the instrument sensitivity will not change during storage. During use the instrument "non-stability" specification is applicable.
Field calibration	is possible by comparison to a calibration reference sensor. Usually mounted side by side under exposure to a radiation source > $10 \times 10^3$ W/m <sup>2</sup> . Heat flux sensor model HF03 may be used as a calibration reference.
Temperature sensor tolerance class	IEC Tolerance class EN60584-2: Type KX, class 2
Temperature sensor error limits	ASTM E230-ANSI MC96.1: Type KX, standard limits
<b>MEASUREMENT ACCURACY</b>	
Uncertainty of the measurement	statements about the overall measurement uncertainty can only be made on an individual basis.

**Table 3.1** Specifications of HF02 (started on previous 3 pages)

VERSIONS / OPTIONS	
	LEX35A: shield not connected to high temperature cable and sensor body LEX35B : shield connected to high temperature cable and sensor body LEX35C: no low temperature cable, high temperature metal sheath and sensor body may act as shield
Order code	HF02 / model LEX35A, LEX35B or LEX35C/ high temperature cable length in m / low temperature extension cable length in m
SPARE PARTS	
Spare part	radiation screen with 4 spacers and 4 bolts
Spare part	rain screen with 2 bolts

### 3.2 Dimensions of HF02



**Figure 3.2.1** HF02 flare radiation monitor / heat flux sensor. Dimensions in  $\times 10^{-3}$  m.

## 4 Installation of HF02

### 4.1 Electrical connection

A heat flux sensor should be connected to a measurement system, typically a so-called datalogger. HF02 is a passive sensor that does not need any power, neither for the heat flux sensor, nor for the temperature sensor. Cables may act as a source of distortion, by picking up capacitive noise. We recommend keeping the distance between a datalogger or amplifier and the sensor as short as possible.

**Table 4.1.1** *The electrical connection of HF02*

WIRE	SIGNAL
Red	heat flux signal [+]
Black	heat flux signal [-]
Green	thermocouple type K [+]
White	thermocouple type K [-]
Blank	shield

Options for grounding and shield connection are:

- LEX35A: shield not connected to high temperature cable and sensor body
- LEX35B : shield connected to high temperature cable and sensor body
- LEX35C: no low temperature extension cable, high temperature metal sheath and sensor body may act as shield

## 4.2 Site selection and installation

**Table 4.2.1** *Recommendations for installation of HF02 heat flux sensors*

Location	<p>HF02 measures the heat flux through the plane of the black sensor. Make sure the orientation of the HF02 matches the orientation of the plane of interest.</p> <p>For studies of exposure of personnel and equipment, the maximum or worst-case heat flux is usually found by measuring at the relevant location and by pointing the HF02 at the strongest local radiation source. Take into account that HF02 has a 90° full field of view angle.</p>
Safety	<p>The free cable end must be connected to a junction box that is certified for use in the local environment.</p> <p>For limitations to the environment: see the HF02 ATEX specifications.</p> <p>Use proper terminals to connect the sensor wires Use the ground wire if provided to connect to the safety ground</p> <p>Use a suitable cable gland on the junction box to maintain the IP67 protection classification</p> <p>Install sensor and cable in such a way that it they are protected against mechanical force</p>
Performing a representative measurement	<p>we recommend using &gt; 2 sensors per measurement location. This redundancy also improves the assessment of the measurement accuracy</p>
Mechanical mounting	<p>the sensor-to-cable transition is vulnerable.</p> <p>Users should not exert significant mechanical force on the sensor or on the sensor to cable transition.</p> <p>during installation as well as operation, the user should provide proper strain relief of the cable so that transition is not exposed to significant force.</p> <p>mounting: first install the cable including strain relief and after that install the sensor. use the two 3/8 UNC bolts at a hart-to-hart distance of <math>30 \times 10^{-3}</math> m.</p>
Signal amplification	<p>ask the manufacturer for recommendations for signal amplification / conversion</p>



## 5 Recommended practices for use

### 5.1 Short user guide

**Table 5.1** *Recommended practices for use*

<b>HF02 RECOMMENDED PRACTICES FOR USE</b>		
1	Read the full manual	
2	Check EEx rating	compare HF02's ATEX rated operating conditions to actual site conditions
3	Determine options	choose cable lengths and shielding options
4	Design mounting and amplification	see the chapter on electrical connection and installation
5	Ordering	
6	Unpack HF02	check shipment contents (see paragraph on included items)
7	Check sensor functionality	see the paragraph on the functionality test
8	Install	see the directions on installation
9	Check performance	verify by comparing measured heat flux to a reference measurement for example with heat flux sensor HF03
10	Check inspection / maintenance / verification procedures	check if the maintenance schedule contains a recalibration or performance check at an interval of 0.6 years or less. See the chapter about maintenance

## 6 Maintenance and trouble shooting

### 6.1 Recommended maintenance and quality assurance

HF02 measures reliably at a low level of maintenance, but does require frequent inspection. Unreliable measurement results are detected by scientific judgement, for example by looking for unreasonably large or small measured values. The preferred way to obtain a reliable measurement is a regular critical review of the measured data, preferably checking against other measurements.

**Table 6.1.1** *Recommended maintenance of HF02. If possible the data analysis is done on a daily basis.*

MINIMUM RECOMMENDED HEAT FLUX SENSOR MAINTENANCE			
	INTERVAL	SUBJECT	ACTION
1	after every incident in which HF02 was exposed to flames or high fluxes	inspection	inspect black sensor surface, inspect cable quality, inspect mounting, inspect location of installation. The black sensor surface should be smooth.
2	1 week	data analysis and inspection	<p>compare measured data to the maximum possible or maximum expected heat flux and to other measurements for example from nearby or redundant instruments. Historical records can be used as a source for expected values. Look for any patterns and events that deviate from what is normal or expected. Compare to acceptance intervals.</p> <p>verify the cleanliness quality of the black paint on the sensor surface. The surface should be black and without scratches. A dirty surface may be cleaned with water. If necessary the radiation screen may be removed.</p> <p>verify that the field of view of the black sensor surface is unobstructed.</p>
3	6 months	inspection	inspect black sensor surface, inspect cable quality, inspect mounting, inspect location of installation
4	2 years	recalibration	<p>recalibration by comparison to a calibration standard instrument in the field, see following paragraphs.</p> <p>alternatively: recalibration by the sensor manufacturer</p>
5		lifetime assessment	judge if the instrument will be reliable for another 2 years, or if it should be replaced



**Figure 6.1.1** *Picture of HF02's sensor surface. The sensor surface should be inspected on a weekly basis. The picture shows that the sensor field of view is unobstructed, and that the sensor surface is not scratched and that it is clean.*

## 6.2 Trouble shooting

**Table 6.2.1** *Trouble shooting for HF02*

General	<p>Inspect the sensor for any damage. Inspect the quality of mounting / installation. Verify that the sensor has a free field of view.          Inspect if the wires are properly attached to the data logger.          Check the condition of the cable.          Inspect the connection of the shield (typically connected at the datalogger side).          Check the datalogger program in particular if the right sensitivity is entered.          HF02's sensor serial number is engraved on the transition piece between high temperature cable and low temperature extension cable. The sensitivity can be found on the calibration certificate.</p>
	<p>Check the electrical resistance of the heat flux sensor between the black [-] and red [+] wires and the thermocouple between the green [+] and white [-] wires. Use a multimeter at the 100 <math>\Omega</math> range. Measure the sensor resistance first with one polarity, then reverse the polarity. Take the average value. Typical resistance should be the nominal sensor resistance of 4 to 14 <math>\Omega</math> for the thermopile sensor at standard cable lengths, plus for additional low temperature extension cable 0.1 <math>\Omega</math>/m (resistance per meter cable ) for the total resistance of two wires (back and forth added), for high temperature cable 1 <math>\Omega</math>/m. For the thermocouple work with 5 to 15 <math>\Omega</math> at standard cable lengths, plus additional low temperature extension cable 0.7 <math>\Omega</math>/m resistance per meter cable ), for high temperature cable 2 <math>\Omega</math>/m. Infinite resistance indicates a broken circuit; zero or a lower than 1 <math>\Omega</math> resistance indicates a short circuit.</p>
The sensor does not give any signal	<p>Check if the heat flux sensor reacts to heat: put the multimeter at its most sensitive range of DC voltage measurement, typically the 100 x 10<sup>-3</sup> VDC range or lower. Expose the sensor heat, for instance touching it with your hand. The signal should read &gt; 2 x 10<sup>-3</sup> V now.</p> <p>Check the reaction of the thermocouple sensor to heat.          Check the data acquisition by replacing the sensor with a spare unit.</p>
The sensor signal is unrealistically high or low	<p>Check the cable condition looking for cable breaks.          Check the shield connection. Measure the drain-wire to housing connection. The options are: LEX35A: shield not connected to high temperature cable and sensor body and LEX35B: shield connected to high temperature cable and sensor body. Measure with a multimeter with one connection at the drain wire the other in the sensor body.          Check the data acquisition by applying a 1 x 10<sup>-6</sup> V source to it in the 1 x 10<sup>-6</sup> V range. Look at the measurement result. Check if it is as expected.          Check the data acquisition by short circuiting the data acquisition input with a 10 <math>\Omega</math> resistor. Look at the output. Check if the output is close to 0 W/m<sup>2</sup>.</p>
The sensor signal shows unexpected variations	<p>Check the presence of strong sources of electromagnetic radiation (radar, radio).          Check the condition and connection of the shield.          Check the condition of the sensor cable.          Check if the cable is not moving during the measurement.</p>

### 6.3 HF02 diagnostics

The following tables are used for checking and trouble shooting HF02.

**Table 6.3.1** Resistance checks for diagnostics of HF02

WIRE	WIRE	RESISTANCE ACCEPTANCE INTERVAL
Red	Black	4 to 14 $\Omega$ for standard version (* <sup>1</sup> )
Red	Green	infinite ( $> 10^6 \Omega$ )
Red	Body	infinite ( $> 10^6 \Omega$ )
Green	White	5 to 15 $\Omega$ for standard version (* <sup>2</sup> )
Green	Body	infinite ( $> 10^6 \Omega$ )
Blank shield / drain wire	Body	LEX35 A: infinite ( $> 10^6 \Omega$ ) LEX35 B: $< 10 \Omega$

\*<sup>1</sup>) optionally plus 0.1  $\Omega$ /m low temperature cable plus 1  $\Omega$ /m high temperature cable (approx.)

\*<sup>2</sup>) optionally plus 0.7  $\Omega$ /m low temperature cable plus 2  $\Omega$ /m high temperature cable (approx.)

### 6.4 Calibration and checks in the field

The recommended calibration interval of heat flux sensors is 2 years.

Recalibration of field heat flux sensors is ideally done by the sensor manufacturer.

On-site field calibration is possible by comparison to a calibration reference sensor, temporarily mounted side by side.

Hukseflux main recommendations for field calibrations are:

- 1) to compare to a calibration reference for example model HF03
- 2) typical heat fluxes used for comparison:  $> 3000 \text{ W/m}^2$
- 3) to correct deviations of more than  $\pm 20 \%$ . Lower deviations should be interpreted as acceptable and should not lead to a revised sensitivity.
- 4) you may use a flare but also an artificial source such as a lamp or electrical heater

## 6.5 Recoating/ repainting of sensor surfaces

Hukseflux recommendations for repainting are:

Remove the radiation screen.

Verify sensor functionality. This can also be done with a non-coated sensor (see the chapter of the quick sensor test).

Purchase a matt (not glossy) black paint which is temperature resistant up to 600 °C. Silicone based black paints are a good choice. Typically aerosol spray cans are most easy to use, but such paints can also be used purchased in cans. In case a solvent is needed: typically acetone is a good solvent for these paints.

Surface preparation: In case the existing sensor surface coating has small scratches but is otherwise in good condition, apply new paint directly to the existing paint. In case of heavy damage to sensor surface coatings: remove the existing coating, clean with acetone or ethanol. Lightly sand the metal surface.

Paint application: Spray some paint in a small cup, use a pipette to apply the paint. In case a pipette is not available, use a small paint brush.

Recalibration: newly coated sensors should be recalibrated. We do not expect significant (> 5 %) changes relative to the original sensitivity.



## 7 Appendices

### 7.1 Appendix on calibration hierarchy

HF02 factory calibration is traceable from SI through international standards and through an internal mathematical procedure. The formal traceability of the generated heat flux is through a secondary standard calibration reference to the international temperature standard ITS90.

The Hukseflux SBGC method follows the recommended practice of ISO 14934-3, however we calibrate at one heat flux level only. Calibration relies on a comparison to a secondary standard heat flux sensor under a radiant heat source.

HF02 is calibrated at a heat flux level of  $10 \times 10^3 \text{ W/m}^2$ .

### 7.2 Typical heat flux ranges

**Table 7.2.1** *Typical allowable heat flux levels in industrial environments as found in literature. NOTE: these data should not be used as a reference.*

		Btu/Hr Ft <sup>2</sup>	x 10 <sup>3</sup> W/m <sup>2</sup>
1	Equipment	3000	9.5
2	Human: Run	2000	6.3
3	Human: Walk	1500	4.7
4	Human: Work (static)	500	1.6

**Table 7.2.2** *typical ranges of heat flux levels, from ISO 14934-4*

	x 10 <sup>3</sup> W/m <sup>2</sup>	Comment
1	300	maximum level in a fully developed fire
2	200 to 100	incident heat flux on the wall in a developed fire enclosure
3	about 100	radiation from burning house
4	about 30	causing ignition of tree
5	20 to 10	causing ignition of timber
6	about 7 or 8	lowest level for causing ignition of a timber wall under a pilot flame
7	about 4	lowest level for causing a burn
8	about 2,5	highest level for people to endure
9	1,5	solar constant, maximum level of solar irradiance



### 7.3 EU declaration of conformity



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

in accordance with the requirements of the following directives:

2014/30/EU The Electromagnetic Compatibility Directive  
2014/34/EU Equipment and Protective Systems for Use in Potentially Explosive Atmospheres (ATEX)

hereby declare under our sole responsibility that:

Product model: HF02 with equipment model name LEX35A, LEX35B and LEX35C  
Product type: Flare radiation sensor / heat flux sensor

has been designed to comply and is in conformity with the relevant sections and applicable requirements of the following standards:

Emission: EN 61326-1: 2013  
Immunity: EN 61326-1: 2013  
Health & Safety: EU IEC 60079-1:2007  
EU IEC 60079-0-2012

and that produced products are accompanied by a separate declaration of conformity and EC type examination certificate according to the requirements of Directive 2014/34/EU, which together with this certificate forms a dossier as allowed by note 24.

A handwritten signature in blue ink, appearing to be 'Eric HOEKSEMA', written over a faint grid background.

Eric HOEKSEMA  
Director  
Delft  
March 01, 2016



