Hukseflux – heat flux measurement at the next level

Hukseflux is the global market leader in heat flux measurement. This white paper briefly explains the fundamentals of measuring with heat flux sensors. It also offers general directions what to watch out for and some, perhaps surprising, applications of heat flux sensors. Would you like to get more information? Please contact Hukseflux.

Heat flux sensors measure energy flux onto or through a surface in [W/m^2]. The heat may be transported by conduction, radiation or convection. All heat transfer is driven by temperature differences, flowing from a hot source to a cold sink. Convective and conductive heat flux is measured by letting this heat flow through the sensor. Radiative flux is measured using heat flux sensors with black absorbers; the absorber converts radiative to conductive energy. Hukseflux started in 1993 designing sensors for measurement of heat flux in soils and through walls. In the course of the years, we have added specialised sensors and systems for many other applications.

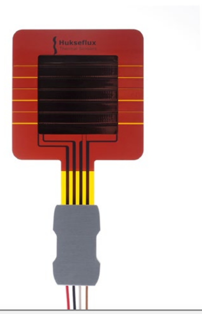
Heat flux sensors manufactured by Hukseflux are optimised for the demands of different applications. The most important variables are:

- rated temperature range
- rated heat flux range
- sensitivity
- response time
- chemical resistance, safety requirements
- size, shape and spectral properties

Hukseflux heat flux sensors typically employ thermopiles. Thermopiles generate a signal, as a result of the temperature difference between the hot and cold side of the thermopile. The signal is proportional to the heat flux. Thermopiles are passive sensors; they do not require power. The output usually is a small millivolt signal. Pictures show models SBG01 water-cooled heat flux sensor, IHF01 industrial heat flux sensor and FHF02 foil heat flux sensor.

Water-cooled heat flux sensor for radiative flux

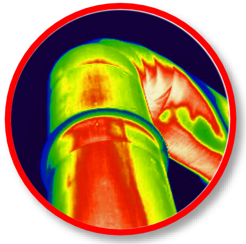
High-temperature all-metal heat flux sensor (industrial)



Plastic flexible heat flux sensor (general purpose)

Measurement with a heat flux sensor; what matters most?

On this page, the fundamentals of heat flux measurement are briefly explained. These are general considerations for measuring heat flux.

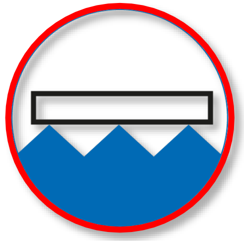


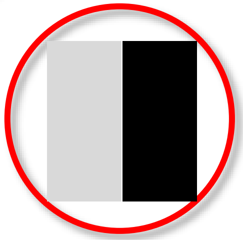
Representativeness in time and space; average!

A heat flux sensor measures at a certain location. Is this location representative of what you need to measure? If possible, use a relatively large sensor, rather than a small one, and consider use of multiple sensors. Thermal processes often have large time constants; instantaneous measurements may be misleading. Average to get the full picture.

Thermal contact sensor to heat sink

A small layer of air often forms a major contribution to the thermal resistance. Make sure that there is good thermal contact between sensor and environment or heat sink. Avoid air-gaps. Use double-sided tapes, welded connections, graphite sheets. Use Power strips to fill up gaps.
Read our note How to install a heat flux sensor with tips & tricks.



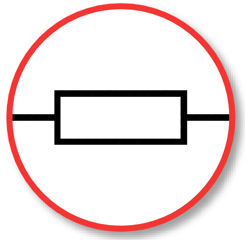


Optical properties

When heat flux sensors also measure radiation, pay attention to the surface colour. If needed paint the sensor surface. Please mind that shiny metallic surfaces reflect both infra-red and visible radiation. Paints may have different colours in the visible range, but are usually "black" absorbers and at the same time black emitters in the far-infra-red.

Sensor thermal resistance

A heat flux sensor distorts the local heat flux. In order to minimise this effect, use the sensor with the lowest possible thermal resistance.

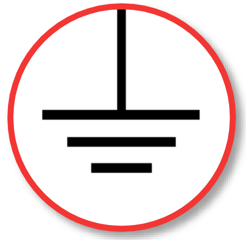


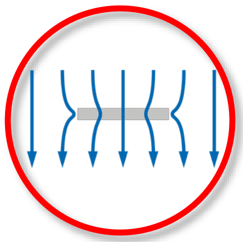
Absolute temperature

Sensors are calibrated at room temperature T CAL. Typical temperature dependence is in the order of 0.15 % / K. When working at high or low temperatures T, ask for the temperature dependence. Typically, this is a linear correction with (T – T CAL). Self-calibrating sensors may compensate for temperature dependence.

Noise? Pay attention to signal ground

Signals from thermopiles are small DC voltages in the microvolt range. These are easily distorted. To guarantee immunity to external sources pay attention to grounding and shielding. A good starting point is to make sure that signal wires are well insulated from the environment (no possibility for ground loops) and are well protected against humidity ingress (possibly creating electrical contact)



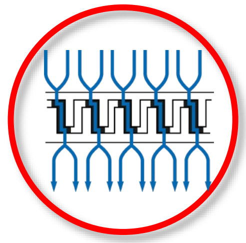


Edge effects

A heat flux sensor locally distorts the heat flow pattern, in particular around the edges of the sensor; the heat may have a preference to travel through the sensor rather than through the surrounding material. A passive guard, i.e. a non-sensitive part around the sensor is essential to avoid errors due to edge effects. On a smaller scale, this effect may again play a role: see the text block on micro effects.

Micro effects – thermal conductivity dependence

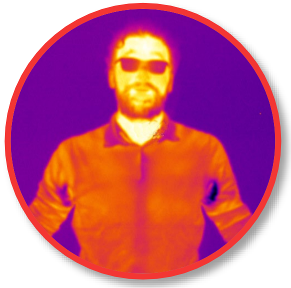
In case the thermopile sensor has direct exposure to the environment, there is a risk of so-called micro effects; on a micro scale (scale of the thermopile grid), the local heat flux gets distorted, and shows a preference to travel though the thermopile. The result is that sensor sensitivity changes as a function of the thermal conductivity of the environment. The calibration is no longer valid. A thermal spreader, for example using a metal cover, is a proven counter-measure. The heat flux then first meets a metal plate and the thermopile always has the same thermal environment.



Heat flux sensors in insulation testing

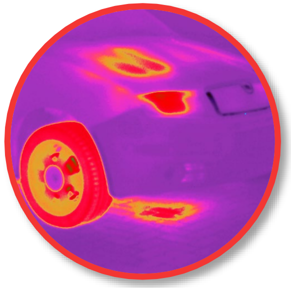
Hukseflux Thermal Sensors is the global market leader in heat flux measurement. Here are some examples of heat flux sensor application:

In situ study of LNG tanker insulation
with HFP03 special design



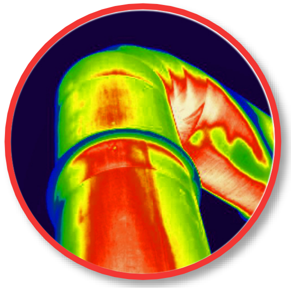
Clothing thermal performance
Analysed with FHF02

Heat loss and insulation of industrial installations heat flux
With IHF01 and IHF02

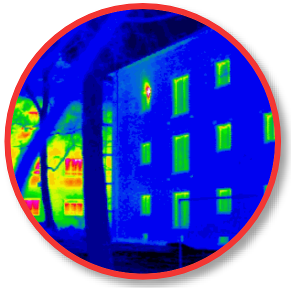


Insulation of car parts
Analysed with FHF02

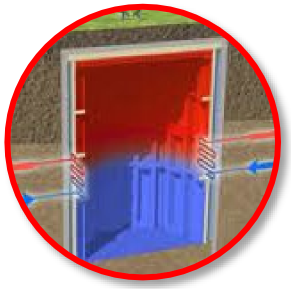
In situ verification of airplane insulation
With HFP03



Industrial insulation performance
Analysed with FHF and IHF sensors



Building envelope thermal resistance
Measure it with HFP01 and TRSYS



Solar hot water storage
Analysis of system performance and heat loss with HFP01 and HFP03

Heat flux / insulation of home appliances
With HFP01 and FHF02

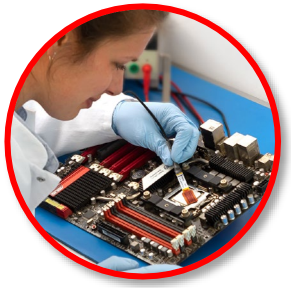
Heat flux sensors characterising the thermal environment

Hukseflux Thermal Sensors is the global market leader in heat flux measurement. Here are some examples of heat flux sensor application:

Indoor climate studies
With HFP01 and TCOMSYS

Human thermal comfort measurement, thermal mannequin
Special equipment made with

Server park thermal management
Analysis of electronics cooling efficiency by airflow with TCOMSYS and FHF03



Electronics components heat flux measurement
Analysed with FHF03

Ground surface energy balance Eddy covariance / Bowen ratio
Soil heat flux measurement in meteorology with HFP01SC

Bread oven thermal / heat flux profiling
With FHF02

Industrial (aluminium reduction cell) heat flux and temperature survey
With IHF01 / IHF02 and ALUSYS, input for modelling reduction process and cell behaviour

Microclimate in cars
Thermal climate and human thermal comfort with TCOMSYS

Heat flux sensors in fire / flammability / high heat flux

Hukseflux Thermal Sensors is the global market leader in heat flux measurement. Here are some examples of heat flux sensor application:

Fire academy / education
Get a better feeling for heat flux levels
With HF02 + LI19

Battery thermal runaway / fire
Study the runaway process and flammability
with FHF03 and SBG01

Cone calorimeter calibration
Calibrate and adjust the heat flux
level with water-cooled SBG01

Welding torch heat flux measurement
Study heat transfer by flames
with HFS1 and GG01

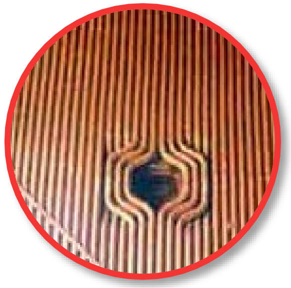
Forest fire research
Study heat forest fires

Determining human and equipment exposure to heat sources
With HF03 portable heat flux
sensor

Full scale fire testing
Study of flame spread with
SBG01 on "full scale wooden
school building fire test"

Heat flux sensors in process monitoring & control

Hukseflux Thermal Sensors is the global market leader in heat flux measurement. Here are some examples of heat flux sensor application:

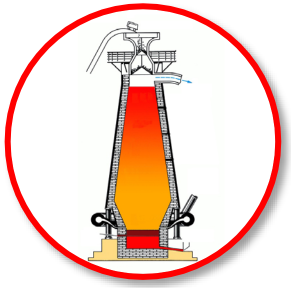


Boiler water wall fouling

Heat flux sensors may be included on the steam tube surface of boiler tubes! From the trend in heat flux, users can analyse flame position and fouling of the surface. This is done with an adapted IHF01. Data are used for sootblower control / cleaning scheduling

Blast furnace refractory performance

Analysed with NF01 in the shell; improved emergency response in case of process overheating or cooling water malfunction



Flare monitoring

Improving safety for equipment and personnel. Issue warnings with HF02

Catalytic cracker fouling measurement

Analysed with HF05 and a meteorological station. Input data are used to schedule servicing. Fouling translates in lower heat flux

Pharmaceutical vial freezing / freeze-drying

Control of freeze drying / verify if sufficient heat is transferred via a surface heat flux measurement

Solar concentrator boiler heat flux

Verify the heat flux level, prevent overheating, with a special IHF01 on the boiler pipe

Ice rink thermal control

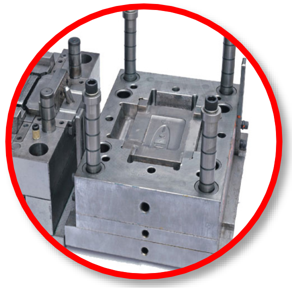
Improved with HFP01; heat flux sensors react faster and have a higher resolution than temperature sensors

Solar radiation heat flux for PV system performance assessment

With pyranometer model SR30

Plastics and composite process- and flow front monitoring

Process monitoring of the flow front and of the curing process in the mould with the sensitive NF02



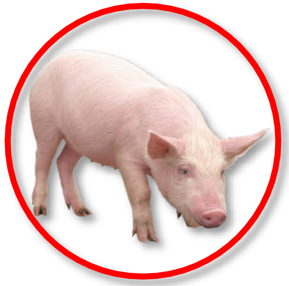
Heat flux sensors in specialised measurement applications

Hukseflux Thermal Sensors is the global market leader in heat flux measurement. Here are some examples of heat flux sensor application:

Solar concentrator heat flux
Water-cooled SBG01 to measure heat flux of a solar concentrator

Thermal mannequin
Equipped with FHF02

Engine overheating studies
Overheating studies in racecars



Human and animal metabolism studies
with HFP01 and FHF02

Physics education
Experiments in calorimetry, Stefan-Boltzmann's law of radiation, heat transfer

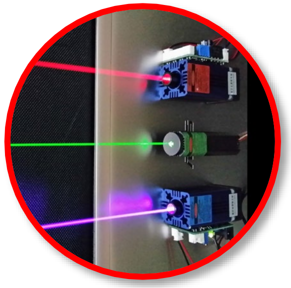
Performance evaluation of IR heaters and radiant panels
Using FHF02 and TCOMYS

Geothermal heat flux / permafrost melting
Measure at ultra-low heat flux levels with HFP03 or multiple HFP01's

Solar simulator / climate testing of cars
Using pyranometer SR30 and heat flux sensor FHF02

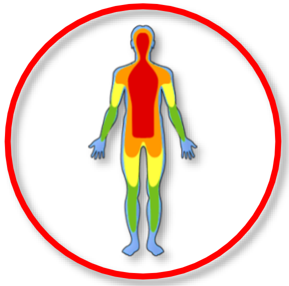
Heat flux sensors various applications / as OEM component

Hukseflux Thermal Sensors is the global market leader in heat flux measurement. Here are some examples of heat flux sensor application as a component in measuring equipment made by other manufacturers than Hukseflux.

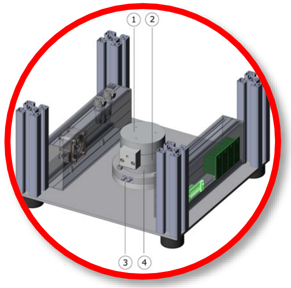


laser power measurement
With adapted FHF02

Monitoring and control of freeze drying
With FHF02



body core temperature measurement (zero heat flux temperature measurement)
With FHF02 and FHF02SC



LED thermal power calorimeter
Designed for the Zhagi consortium; TPL01

heat flow meter apparatus
Thermal conductivity measurement of insulation materials with an adapted FHF02 at its core

heat flow reaction calorimeter
With adapted FHF01