Hukseflux – heat flux measurement at the next level

Hukseflux is the world 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/m²]. The source of the heat flux may be conduction, radiation or convection. Convective and conductive heat transfer are associated with a temperature difference. Heat always flows from a source to a sink, from a hot to a cold environment. 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 absorbers converts radiative to conductive energy. Hukseflux started in 1993 with sensors for measurement of heat flux in soils and on 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:

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

Hukseflux heat flux sensor 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.
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.

**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 in the far-infra-red.

**Absolute temperature**
Sensors are calibrated at room temperature \( T_{\text{CAL}} \). 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 \((T - T_{\text{CAL}})\). Self-calibrating sensors compensate for temperature dependence.

**Edge effects**
A heat flux sensor locally distorts the heat flow pattern, in particular around the edges of the sensor. A passive guard, i.e. a non-sensitive part around the sensor is essential to avoid errors due to edge effects.

**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.

**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.

**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).

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

- **Blast furnace refractory performance**
  Analysed with NF01 in the shell

- **Clothing thermal performance**
  Analysed with FHF02

- **Catalytic cracker fouling measurement**
  Analysed with HF05 and a meteorological station

- **Cone calorimeter calibration**
  With water-cooled SBG01

- **Building envelope thermal resistance**
  Measure it with HFP01 and TRSYS

- **Building block: thermal comfort measurement, thermal mannequin**
  Special equipment made with FHF02

- **Building block: heat flow reaction calorimeter**
  With adapted FHF01

- **Building block: LED thermal power calorimeter**
  Designed for the Zhagi consortium; TPL01

- **Building block: industrial insulation performance**
  Analysed with FHF and IHF sensors

- **Flare monitoring**
  With HF02

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- **Ice rink thermal control**
  Improved with HFP01

- **Industrial insulation performance**
  Analysed with FHF and IHF sensors

- **Boiler waterwall 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; With adapted IHF01

- **Solar concentrator boiler heat flux**
  With a special IHF01

- **Boiler waterwall fouling**
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Heat flux sensors applications

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- **Human and animal metabolism studies** with HFP01 and FHF02
- **Aerospace engineering:** thermal test in vacuum. Water-cooled SBG01 to measure heat flux of a solar simulator.
- **Firefighter exposure measurement** with HF02 + LI19
- **In situ study of airplane insulation** with HFP03
- **Eddy covariance / Bowen ratio** Soil heat flux with HFP01SC
- **Monitoring and control of freeze dryers** With FHF02
- **Battery exothermic reaction calorimeters** Using FHF02
- **Insulation of car parts** Analysed with FHF02
- **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
- **Body core temperature measurement** (zero heat flux temperature measurement) With FHF02 and FHF02SC
- **Determining human and equipment exposure to heat sources** With HF03 portable heat flux
- **Geothermal heat flux** With HFP03 or multiple HFP01’s
- **Industrial (aluminium reduction cell) heat flux and temperature survey** With HF01 and ALUSYS