Hukseflux
Thermal Sensors

HUKSEFLUX THERMAL SENSORS 30 YEARS OF INNOVATION

Omega HFS-5 heat flux sensors

compared to Hukseflux FHF05 series: test results

For accurate heat flux measurement, sensor buyer may reasonably assume that

- *sensitivity does not change over time; stability*
- *sensitivity as specified on the calibration certificate can be relied upon; that it does not depend on the environment of the sensor*

Testing at Hukseflux reveals that Omega heat flux sensors of model HFS-5 are less stable than those manufactured by Hukseflux, and that their sensitivity depends on the environment. In applications that require traceable measurements, users must account for both in their uncertainty evaluation. This leads to a much larger measurement uncertainty than the 5 % stated on the HFS-5 calibration certificate.

Omega manufacturing technology

Omega manufacturing technology is based on the use of metal filled electrically conducting inks. See also US patent 10393598.
Hukseflux carried out testing* of model HFS-5.

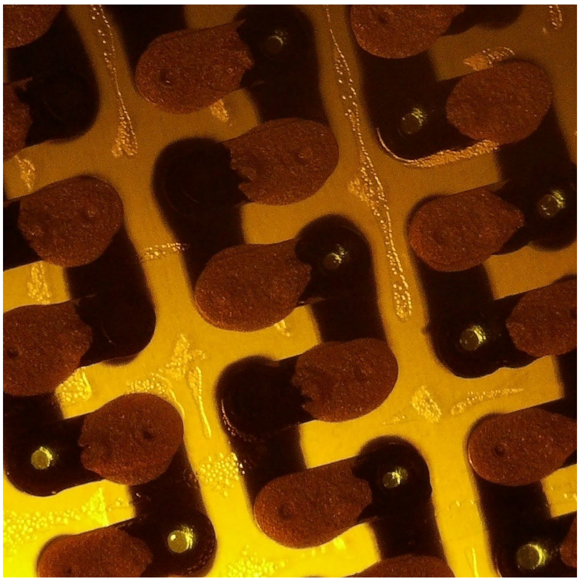

Figure 1 *Close-up of an Omega HFS-5 heat flux sensor. The thermopile is made using printing technology. Two different metal-filled electrically conducting inks are printed into through-holes.*

* Experiments were carried out on Hukseflux FHF series models, as well as HFS-5 sensors purchased from Omega. The test results may not be applicable to sensors produced by other manufacturers or when improving manufacturing technology.

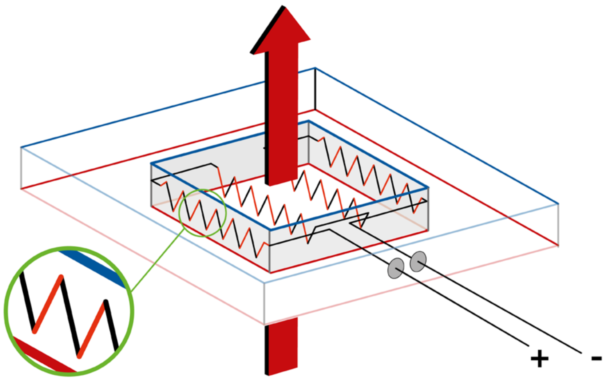

Figure 2 *General heat flux sensor principle: the sensor contains a thermopile consisting of an alternating pattern of two metal alloys.*

Test results: stability

The sensitivities of the sensors were tested for

- stability under bending
- stability at high temperatures

Sensors of Omega and Hukseflux are all rated for long-term use up to 120 °C, and sold as "flexible". Omega Data sheet "UHF-HFS-Series _spec" accessed on website FEB 10, 2023: "*the heat flux sensor is flexible enough to be easily attached to round surfaces*". Changes are all relative to those at the start of the test, positive values indicating a higher value after testing.

Testing was performed at 20 °C after 1-time bending around a pipe of 25 x 10^{-3} m radius, and after 24 hours of exposure to high temperatures. Sensors were exposed to 120 °C. The changes of sensitivity were all relative to an initial measurement by Hukseflux at 20 °C and were all performed on a flat surface. When determining the sensitivity, the capability to measure changes has a reproducibility in the order of 1 %, asserting that changes of 3 % can meaningfully be detected. In this experiment the absolute accuracy is not a factor.

sensor technology	test	permanent change of sensitivity	permanent change of resistance
	[name]	[(V/(W/m²))/(V/(W/m²))]	[Ω / Ω]
Hukseflux printed	bending radius 25 x 10^{-3} m	not detectable (< 3 %)	< 2 %
Omega printed	bending radius 25 x 10^{-3} m	-7 %	+11 %
Hukseflux etched	120 °C	not detectable (< 3 %)	< 2 %
Omega printed	120 °C	+ 10 to -12 %	+ 77 to 223 %

Table 1 *Stability testing: tests were performed before and after 24-hour exposure to high temperature.*

Bending test on YouTube

Interested to see the kind of experiment we perform? See a movie on the bending test on YouTube. At 2 min into the video "*improved technology for heat flux sensors*" you can witness testing.

Sensitivity as a function of environment

A heat flux sensor is supposed to keep its sensitivity whatever the environment.
The sensitivity of Omega HFS-5 sensors however depends on the material on which it is mounted.
The sensitivity of Hukseflux sensors remains the same in all environments.
Thermal conductivity dependence is an intrinsic property of a heat flux sensor that its sensitivity depends on the thermal conductivity of the surrounding material. This is expressed as % change of sensitivity, either absolute or per [W/(m·K)] change of thermal conductivity.

Thermal conductivity dependence is reported relative to the sensitivity at the calibration reference condition, mounted on a metal heat sink. There are no standardised experiments to perform tests. The results presented are therefore "comparative" only.

Test results

The sensitivities of the sensors were tested under different conditions. The reference condition is mounted on aluminium, the other conditions surrounded by Pyrex (glass) and silicone (plastic) create an environment with different thermal conductivities.

Conclusions

- the risk that the sensitivity of an HFS-5 sensor instantly and significantly changes is very high, especially when bending the sensor (at installation) or when using it a high temperatures. Very mild short term exposure testing - all within rated conditions of use advertised by Omega – already leads to changes of sensitivity in the order of 7 %. (see Table 1). Hukseflux sensors are perfectly stable under the same conditions.
- the Omega company accepts this instability. Comment by email to Hukseflux on JUL 30, 2023 is "*For customers with extreme applications (i.e., running at max temperature) they may see initial sensitivity drift but Omega is more than happy to recalibrate these sensors after initial break-in.*"
- the HFS sensitivity depends on the sensor environment; this dependence is in the ± 10 % range, and is significantly larger than the calibration uncertainty of 5 %**. Hukseflux sensors show deviations in the order of only ± 2 % under the same conditions.
- users must take the risk of instability and the thermal conductivity dependence into account in their uncertainty evaluations. Hukseflux sensors do not suffer from similar instability or thermal conductivity dependence. Measurements with Omega HFS sensors therefore tend to be less accurate than those with Hukseflux sensors under the same conditions.

* source: text and brochures on Omega website 04 FEB 2023, "*temperature range -50 to 120 °C,*
**source: HFS-5 calibration certificate 15304, supplied in 2020

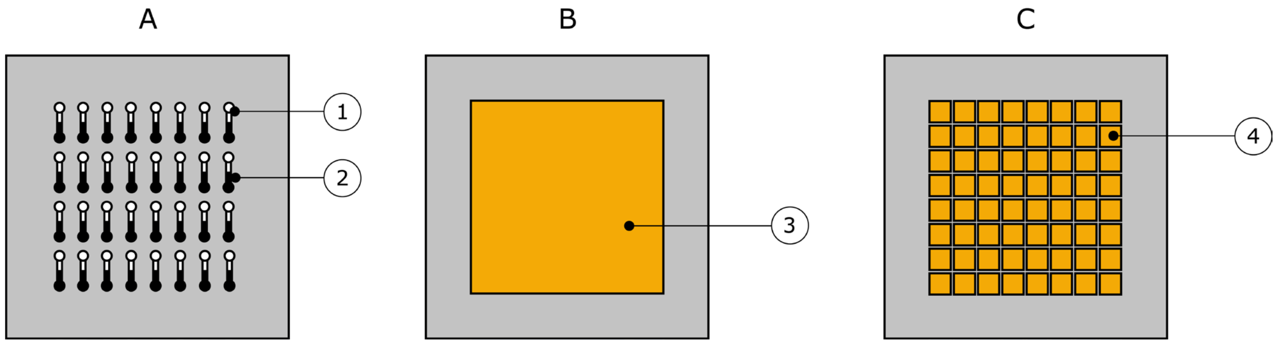

Figure 3 *A: sensor without a spreader such as Omega model HFS-5. One thermopile alloy (1), other thermopile alloy (2) In B and C, the thermopile is covered by spreaders. B: sensor with a single large spreader (3) C: sensor with multiple small spreaders (4) such as the FHF05 series sensors made by Hukseflux.*

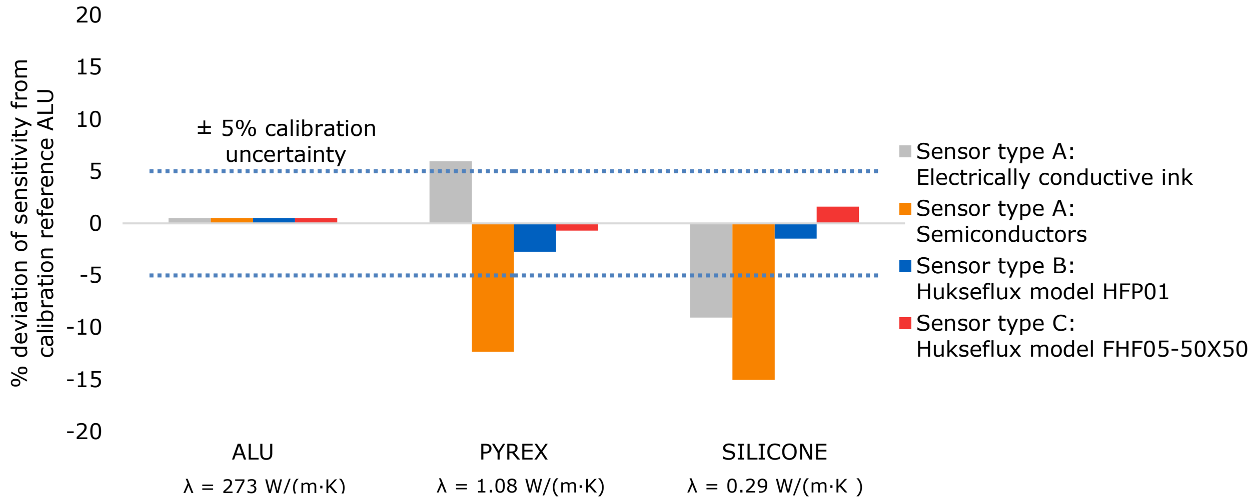

Figure 4 *Thermal conductivity dependence of three sensor types. Two "type A" sensors were tested: one Omega with a thermopile made of electrically conductive inks and the other made of semiconductors. The calibration uncertainty is 5 %. The Omega HFS-5 makes up to 10 % error when the thermal conductivity of the environment changes. Errors made with type B and C – Hukseflux FHF05 series - sensors are negligible.*

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Other Omega models

Omega model HFS-6 is a sensor sandwiched between two metal foils. Why is this done? Text from the Omega website JAN 31, 2023:
"Metal encapsulation increases the robustness of the sensor itself for repeated applications of the sensor to measurement surfaces."

This may be beneficial to stability when bending. Metal foils may make it impossible to bend the sensor at all. The foil may also absorb part of the force and also reduce the influence of the environment on sensitivity (thermal conductivity dependence). However, the stability at higher temperatures will not improve.

Older and discontinued Omega heat flux sensor models such as Omega HFS-3 have a fundamentally different manufacturing process. Hukseflux did not test model HFS-3, but expect a much better stability.

More details about the tests

Hukseflux has published two detailed notes about the experiments. In these notes the Omega brand and model HFS-5 model name are not specifically mentioned:

- heat flux sensor technology: why use sensors with spreaders
- heat flux sensor technology: printed thermopile conductors vs. etched-and-plated

Figure 5 *Example of Hukseflux model FHF05-50X50 heat flux sensor. This model is stable under bending and high temperature exposure.*

About Hukseflux

Hukseflux is the leading expert in measurement of energy transfer. We design and manufacture sensors and measuring systems that support the energy transition. We are market leaders in solar radiation- and heat flux measurement.
Customers are served through the main office in the Netherlands, and locally owned representations in the USA, Brazil, India, China, Southeast Asia and Japan.

Would you like more information?
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