Innovative Sensor Technology
physical. chemical. biological.

Application Note
OOL Module
Thermal mass flow

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1. About the OOL

The Innovative Sensor Technology IST AG thin-film mass flow sensor solutions were developed to offer solutions for a wide variety of flow applications with considerable advantages. The Out-of-Liquid-Technology is developed for flow measurement of liquids. IST AG offers a factory calibrated «ready-to-use» module which already contains the evaluation electronics. This flow meter convinces by its corrosion resistance and robustness, which is given by design, as the measuring element is separated from the flow medium by a stainless steel wall (1.4301).

The sensitive element of the OOL module is based on our established platinum thin-film technology. The optimized design allows easy interpretation and evaluation of the measurement signal. The sensor can be used for various non-corrosive but also corrosive fluids. Furthermore, the OOL has a fast response time and a high sensitivity. The OOL module is calibrated for a common range of water flow and temperature conditions. This solution opens a wide range of applications.

2. Applications & Design

2.1 Characteristics & Benefits

- Calibrated «ready-to-use» sensor module, communication via I^2C
- Calibrated for DI-water flow ranging from 0.1 to 20 kg/h
- Temperature compensated between 5 and 50 °C
- High robustness and corrosion resistance
- Very good repeatibility
- Suitable for other liquids (overtemperature of the heating element can be varied)

2.2 Application Areas

- Industrial temperature control systems, incl. cooling circuits
- Lubrication systems, incl. gear oil
- Various dosing systems, incl. food, life science, agriculture, white goods and mining
- Leakage, incl. water drip detection

2.3 Measuring Principle

The OOL module is operated with the anemometric measuring principle (more precisely constant temperature anemometry CTA). This measuring principle is based on a heated body, which is cooled by convection caused by the flow (see figure 1). The OOL sensor has a heating element, which is controlled such that the temperature difference between the fluid and the heater remains constant. The fluid temperature is monitored by an additional temperature sensor. For water, the temperature difference is typically about 8 K. In order to keep the temperature difference constant, a certain power must be provided by the electronics. The power signal is primarily dependent on the flow velocity and describes a monotonically increasing function. When the medium is at rest, no heat is transported away from the heater and the power is reduced to zero. With increasing flow velocity and thus higher heat removal, more power must be brought into the system so that the temperature difference remains constant.

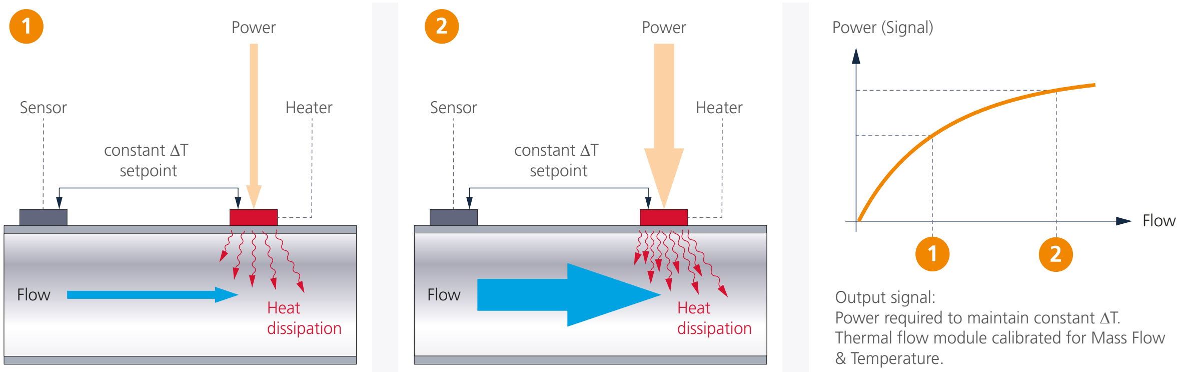

Fig. 1: Anemometric measuring principle

2.4 Sensor Design & Features

The sensitive platinum elements are applied onto a stainless steel tube (see figure 3). This results in an optimal and reproducible heat transfer, so that a short response time and a very good sensitivity of the OOL sensor are ensured. The material in contact with the medium is stainless steel 1.4301, which is highly resistant to corrosion. This includes water (tap water), lubricants, oils, alcohols and slightly acidic liquids. Ultrapure water and seawater are excluded. It is recommended that the corrosion resistance in contact with a particular fluid is tested under the exact operating conditions (temperature, pressure, time period) of the intended application.

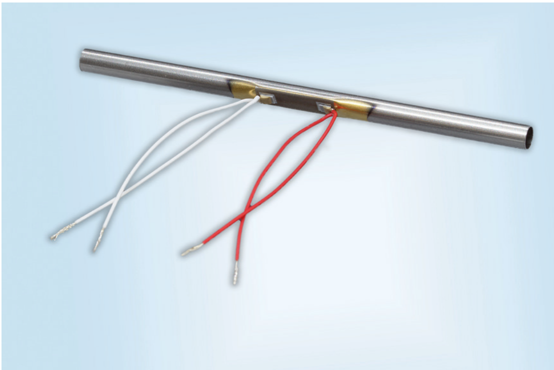

Fig. 3: OOL sensor

The OOL sensor is extended with electronics and a housing, calibrated and assembled as a ready-to-use module. IST AG offers such a module (see figure 6). The digital CTA electronics controls the OOL sensors (see point 2.3 Measuring principle). Furthermore the OOL module has an integrated temperature compensation. Each module is measured and calibrated.

Fig. 4: Calibrated «ready-to-use» *OOL-module*

2.5 Characteristics & Performance

The output signals of the OOL module are linearized and temperature compensated mass flow, heater power (raw signal), temperature of the liquid and in the electronics. The module internal electronics measures the raw signal and uses it to calculate the linearized mass flow signal. The module is calibrated for water as the measurement medium. Figure 5 shows the heater power as a function of the mass flow for three temperatures. The dependence of the heater power on the medium temperature is clearly visible and can be attributed to the temperature dependencies of the physical parameters of the medium (such as density, thermal conductivity, thermal capacity, viscosity). By suitable calibration these effects can be corrected and a nearly temperature independent signal is obtained. The OOL module therefore gives the user access to temperature-compensated flow measurement over a large parameter space.

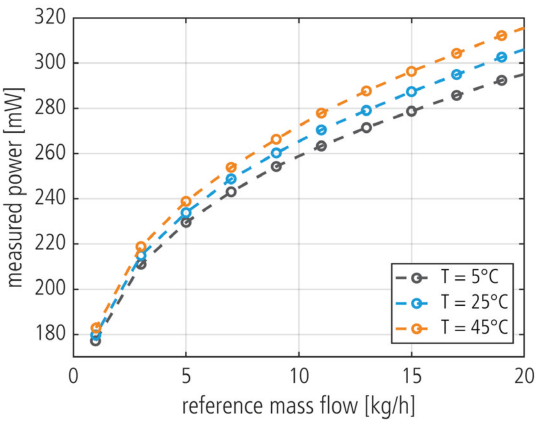

Fig. 5: Heating power as a function of the mass flow for three temperatures

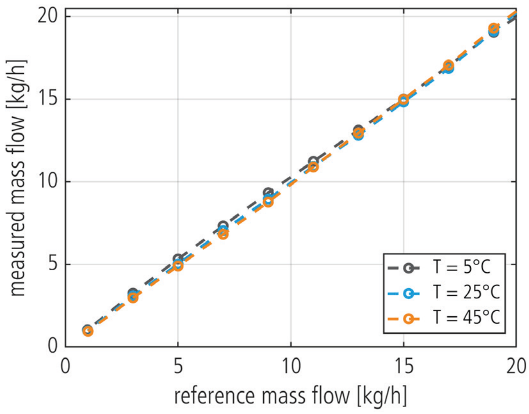

Fig. 6: Linearized and temperature compensated signal of OOL module as a function of the mass flow of reference

2.6 Calibration & Linearization

Calibration

If conditions different to the calibration conditions prevail, the raw signal can be taken as the output signal and an external handling of the data can be made. For flow measurements the calibration can be based on King's law. The characteristic curve can be described as follows:

$$P = A + B\dot{m}^c$$

The output signal given by the heater power P is shown as a function of the mass flow $\dot{m}$. The parameters A, B and C are calibration parameters and are determined by a calibration measurement and by fitting this characteristic curve with the shown equation.

It is recommended that the measurement range of the calibration covers the application range as best as possible and that the calibration is carried out under application conditions. In order to fit the characteristic curve, at least 3 measuring points are required However, since this can lead to very large inaccuracies, we recommend a minimum number of 5 measuring points, and that the range of the measuring points covers the minimal and maximal flow velocity. Depending on the application and sensor installation, however, these values can deviate greatly from this.

Linearization

With the parameters A, B and C determined, the calibration is completed. The inverse function gives the mass flow for a measured output signal and enables linearization.

$$\dot{m} = \left(\frac{P - A}{B}\right)^{\frac{1}{c}}$$

2.7 Influences

The performance can be influenced by conditions listed below. These influences are strongly dependent on the application. If questions arise for a specific application and the possible influences, do not hesitate to contact us so that the best possible solution can be found for your application.

Flow medium:	The flow medium can affect the performance of the sensor, as the thermal parameters (thermal conductivity, heat capacity, density, viscosity and others) can be different and affect the sensor signal.
Contamination:	Dirt/ Particles and contamination can also affect the signal or even damage the sensor.
Mounting:	Geometry of the measurement setup and integration of the sensor in the flow channel can affect performance. Inlet length can change thermal and hydrostatic flow profiles. The location of the sensor can also change the flow profile.
Temperature:	The OOL module has a temperature dependence, since the parameters of the flow medium have a temperature dependence.

2.8 Mounting

Basically, there are different ways to mount the OOL sensor:

1. Cover by a plastic tube and fasten it by means of a 1-ear bride.
2. The selected stainless steel is easily weldable (e.g. by laser welding) and you can weld the sensor to the desired counterpart. Attention must be paid to the wall thickness of the sensor.
3. Adhesive bonding is also an option.

The flow profile influences the signal, i.e. the inlet conditions should be comparable during the calibration to the application.

The OOL module is calibrated at the factory with a straight inlet pipe of 30 cm and a diameter of 4 mm. To achieve the specified accuracy, a comparable inlet is recommended, whereby the angle between sensor channel and inlet channel should be < 2°.

3. Associated Products

- EvaKit OOL Module V1.2.1 (153332)
- OOL Module V1.2.1 (153331)
- Out of Liquid Demo Module (104021)

4. Supplementary Documents

- Datasheet OOL Module
- Datasheet OOL sensor element
- Datasheet FlowDemo Board

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