EFFICIENT GAS FLOW MEASUREMENTS IN BYPASS

Measuring gas flow in applications requiring high precision and cost-efficiency is a challenge. Experience in recent years has shown that microthermal flow sensors are superior to other technologies. Industries with exacting demands, such as automotive and medical technology, have recognized that microthermal gas flow sensors give their products decisive advantages. These manifest themselves in high long-term stability and precision even when flow rates are minimal, and the sensors' suitability for cost-efficient and reliable mass production.

Where in the gas flow should a sensor be positioned? And how should the flow guide be designed to achieve the best-possible results while keeping the production processes simple? Experience with many of our customers' applications and endurance tests for product certification give a clear answer: In most cases a bypass configuration is preferable to placing the sensor in the direct flow.

Methods of gas flow measurement

There are many different methods of measuring gas flow: mechanical volumetric, float-type, differential pressure, ultrasonic, coriolis, magnetic inductive and thermal flow metering to name but a few. Metering techniques without contact between gas and sensor require relatively expensive technology and are thus out of the question for many applications. Whereas in the classic differential pressure method, hysteresis effects and membrane fatigue can lead to drift problems and a lack of zero-point accuracy, because here the mechanical deflection of a sensor membrane over an orifice is used to gauge the pressure drop.

Consequently, measuring techniques based on thermal principles are widespread. In the simplest of these – the hot-wire anemometer – gas flow is determined via the rate of cooling of an electrically heated wire with a temperature-dependent resistance. Advanced methods use a heating element and at least two temperature sensors, which measure the transport of heat through the gas (see Fig. 1). We refer to the term "microthermal flow sensors" when the sensor components are integrated into a millimeter-scale silicone microchip.

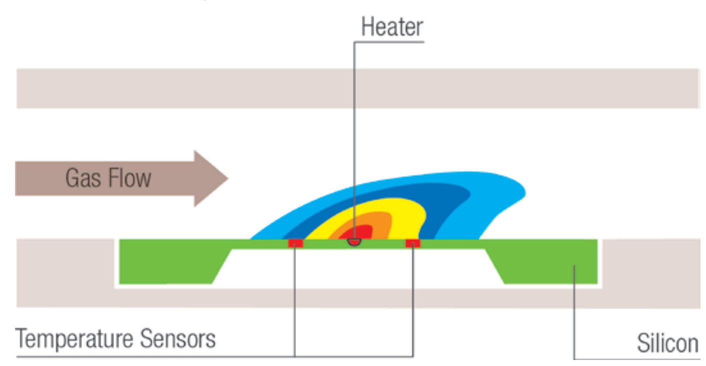

Figure 1: microthermal measuring principle

Microthermal flow sensors

For many applications, microthermal sensors bring decisive advantages. The small size of the sensors and the use of standardized semiconductor manufacturing processes enable mass production with a consistently high quality. And thanks to the economies of scale, unit costs remain moderate. Modern sensor elements deliver superior precision compared to classic hot-wire anemometers, while a glass coating of the sensor element provides corrosion-resistance. All these advantages are enormously useful in various branches of industry. Over the past decade, leading industries have moved towards microthermal sensor technology for gas flow measurement, which is now the predominant sensor type used for demanding automotive, medical and HVAC applications.

But direct contact with the gas can pose challenges of its own. Flow speed measurement is only selective, which means that extrapolation to the overall flow depends on the velocity distribution in the pipe and thus inlet conditions become crucial. A bend in the tube immediately before the sensor, different types of surface structure inside the tube, or corners and edges in the flow passage will alter the measurement. Moreover, heavily polluted gas flowing past the sensor element can lead to soiling issues.

A good way to tackle such challenges is to place the sensor chip in a bypass. An orifice, a Venturi or another flow restrictor generates a pressure drop, which guides a small proportion of the gas through a bypass channel (see Fig. 2). While the microthermal flow sensor guarantees high accuracy, reproducibility, and stability, particularly in the case of very low flow rates, a well designed pressure drop element ensures that the resulting differential pressure is less susceptible to changes to the inlet conditions. Also important is the arrangement of the bypass inlet. By using inertia effects and minimizing the bypass flow, an intelligent tap design will ensure a clean gas flow to the sensor chip.

Using a bypass configuration helps to simplify the manufacturing process too. It allows for the flow element to be molded and assembled independently of the sensor. Under the premise of tight production tolerances and by positioning the pre-calibrated sensor at the end, it is often possible to forgo final calibration of the entire system.

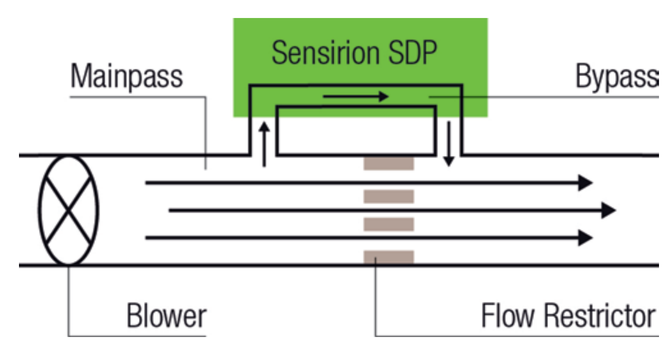

Figure 2: Bypass Configuration

Good design for a bypass solution

How should a bypass configuration be engineered to achieve the desired results?

Flow restrictor

The flow restrictor's job is to slightly increase the resistance in the gas flow and, as a result, generate a differential pressure. Physically speaking, this happens in two ways. First, friction between the gas and the flow restrictor's surface areas (surfaces parallel to the flow) leads to a pressure drop that increases linearly with the flow. Secondly, end faces and their edges create turbulence and thus a drop in pressure which increases quadratically with the flow. In practice, flow restrictors are always a mix of the two types and thus their pressure/flow characteristics are always a combination of linear and quadratic components (see Fig. 3).

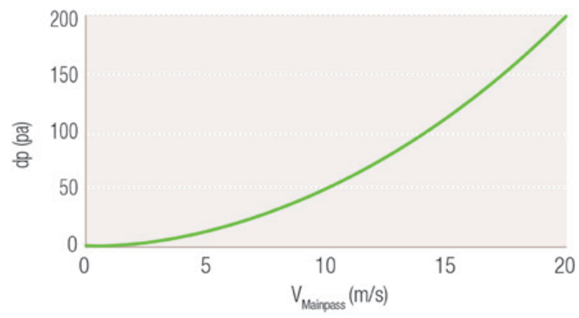

Figure 3: Pressure/flow characteristics

Which of the two characteristics prevails is determined by the design of the flow restrictor. Usually a linear characteristic is preferable because it increases sensitivity at small flows, stabilizes the zero point, and decreases the pressure drop at high flow rates. Therefore, as a general rule of thumb, a pressure drop element should have as much surface exposure parallel to flow as possible and a smallest possible cross section area. Classic circular orifices are not particularly well suited to the job; honeycomb structures are ideal, but expensive. An arrangement of blades, as shown in Fig. 4, has proved to be a simple yet suitable design. It can be easily produced using injection molding and its flow/differential pressure characteristic tends to be close to linear.

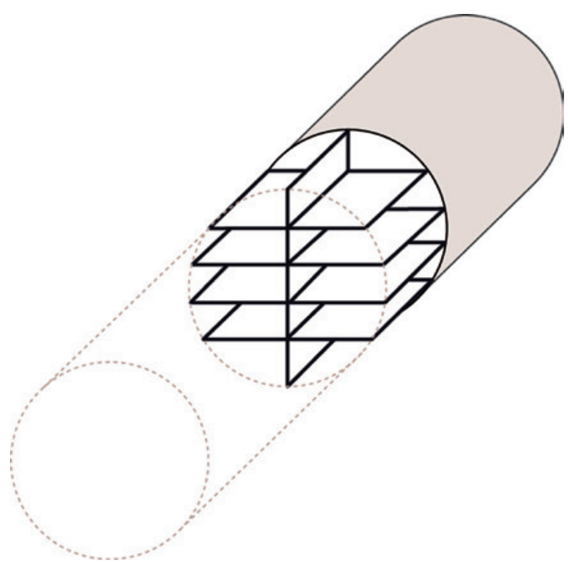

Figure 4: Sketch of orifice

Bypass inlet

Thanks to inertia, most dust particles stay in the main channel. This desired effect can even be significantly improved with a good tap design. The inlet channel of the bypass should face backwards so that the gas needs to reverse to reach the sensor. It has also been noted that flow guides next to the tabs keep the flow stable and laminar and thus reduce sensor signal noise. And, eventually, the tap should be small, ideally with a diameter of 0.6 mm (see Fig. 5).

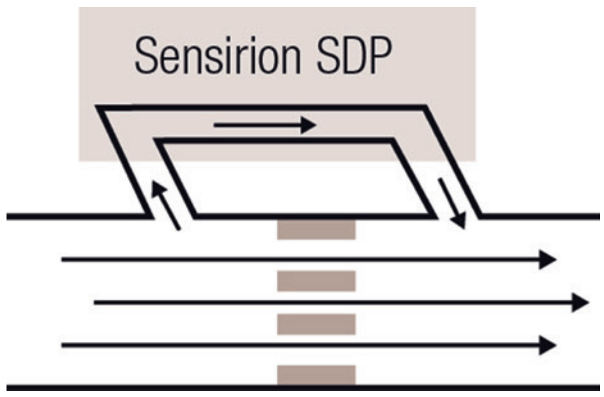

Figure 5: Bypass Inlet

Inlet conditions

Even though flow measurement using a bypass configuration is less sensitive to changes in the inlet conditions, it is still important to design the inlet path with care. Ideally, there should be no sharp bends or edges in the pipe directly upstream of the flow element, and no abrupt changes in the pipe diameter. Apart from that, some form of resistance to the flow (such as a sieve), just upstream of the main flow restrictor and evenly distributed across the entire diameter of the pipe, can help to stabilize turbulence and other undesired influences.

Choice of sensor

With the right sensor, flow measurement in bypass is the most reliable and economical method. Microthermal differential pressure sensors, such as those made by sensor manufacturer Sensirion, are ideally suited to fulfill the requirements for several reasons.

- The components are small, which helps to keep the size of the bypass small and thus reduces the space required for flow measurement.
- Flow-based thermal differential pressure sensors have a high level of sensitivity and are very stable at around zero. It is thus possible to achieve a very wide measurement range (high dynamic range or high turn-down ratio).
- Despite the thermal flow measurement method, the sensors are calibrated to measure the applied differential pressure The sensors can thus be replaced and exchanged without recalibration.
- Sensirion offers a specific temperature compensation geared towards flow measurement in bypass (see further information at the end of this article).

The latter two points offer a further advantage. In many cases, provided that the main channel has a good design and meets specified production tolerances, there is no need for final calibration of the entire system. The fact that sensors are supplied calibrated and temperature-compensated, and that tolerances in modern injection molding are small, means that in many cases random testing of the pressure drop element will suffice.

Conclusion

To measure gas flow with a high degree of accuracy and repeatability, while at the same time keeping costs low, a bypass or differential pressure solution is generally most favorable. Compared with direct flow measuring techniques, the effects of external conditions can be reduced, and the cleanliness of the gas around the sensor element significantly increased. Additionally, if we select a thermal differential pressure sensor, which offers high-level precision even when flow rates are minimal, measurements around the zero point are extremely precise. In many cases, having the sensor calibrated for differential pressure combined with a suitable temperature compensation will eliminate the need for additional calibration over the entire measurement range.

Further Information

Differential pressure sensor with mass flow temperature compensation

The so-called mass flow temperature compensation of differential pressure sensors simplifies gas flow measurement using the bypass configuration. The integrated calibration is implemented so that the flow can be correctly measured over the entire temperature range. Consequently, no further temperature compensation is required for the conversion of the differential pressure output signal to mass or volume flow. The user is spared the complicated process of characterizing the bypass system using several flow/temperature measurement points.

SDP3x differential pressure sensor

The unbelievably small size of Sensirion's new differential pressure sensor is its standout feature. The sensor measures a mere 5 x 8 x 5 mm and thus opens up countless new applications.

Like all Sensirion differential pressure sensors, the SDP3x comes with outstanding precision and long-term stability, together with no zero-point drift. Aside from this, it can be reflow soldered, offers new functions such as multiple I2C addresses or interrupt functions, and has a very fast response time of 2 kHz at 16-bit resolution. All these factors make Sensirion's new differential pressure sensor the perfect choice for high-volume but cost-sensitive applications.

SENSIRION
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About Sensirion

Sensirion is the leading manufacturer of high-quality sensors and sensor solutions for the measurement and control of humidity, and of gas and liquid flows. Founded in 1998, the company is based in Staefa near Zurich, Switzerland, and employs people in countries such as the USA, South Korea, Japan, China, Taiwan, and Germany. The headquarters in Switzerland is responsible for research, development, and production.
Millions of Sensirion's sensor components and solutions are used all over the world, including in the automotive industry, medical technology and building technology. Sensirion's success is based on the innovative CMOSens® Technology, which combines the sensor and analysis electronics in a single semiconductor chip. This means large unit numbers can be produced at high quality and low cost.

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