Gas Flow Sensing Technology in Medical Ventilation Devices

Sensors are used to measure gas flows for various purposes in modern medical ventilation technology. A variety of measuring principles are used, depending on the manufacturer and the intended use. Many different sensor products are now available on the market. Medical ventilation technology has made rapid progress since the invention of the "iron lung" about 80 years ago – the first device used for patient ventilation. Along with pressure sensors, flow sensing technology and gas flow sensors play a significant role today. The original iron lung used negative pressure to achieve patient ventilation, but modern devices use positive pressure in the patient's lungs for this purpose. Along with air, other gases – primarily oxygen – are also used for ventilation. The quantity and mixture of the various gases are precisely controlled and monitored using sensor systems. The requirements on sensor systems vary greatly, depending on where and how the ventilation device is used.

Diverse application areas

Medical ventilation devices can basically be divided into three application areas: devices for emergency treatment, devices for intensive care, and devices for home use. Naturally, each area and each individual device has its own specific features. The key considerations with emergency treatment devices are size and weight, since it must be possible to bring them to patients quickly and easily. They usually operate from battery power to make them independent of the AC power line. Ventilation devices for intensive care are used in hospitals and operated by medical staff. They have a significantly greater functional scope than devices for emergency treatment. The main consideration with these devices is their performance capability. Finally, ventilation devices for home use must ensure proper breathing for patients who are not able to breathe adequately on their own.

Manifold requirements for flow sensing technology

The previously mentioned three application areas for ventilation technology lead to diverse requirements for flow sensors. In emergency treatment devices, the pressure drop due to the flow resistance of the sensor in the gas stream should be as small as possible. This is because a high pressure drop means more work for the turbine that generates the positive pressure for the patient. A low pressure drop therefore translates into longer battery service life or a smaller battery, which has a beneficial effect on size or weight.

In intensive care, the desire to be able to use the device in the greatest possible variety of setting imposes additional requirements on flow sensing technology. For instance, it should be possible to use the same device for all patients, regardless of whether they are infants or adults. The greatest possible dynamic range and high sensor resolution ensure that the device can be used for patients of different sizes. For example, modern flow sensors should ideally be able to measure flow volumes up to 250 liters per minute, while still being able to detect volumes less than 1 liter with high precision. Along with this wide dynamic measuring range, measurement accuracy with low gas flows in particular is a crucial aspect. A short sensor response time is also necessary, since various ventilation modes are used in intensive care. A common aspect of all areas is that the sensors must be robust and have the best possible long-term stability, in order to minimize recalibration and maintenance effort.

Other requirements for sensor technology result from the various functions that are used to control or monitor the sensors. A distinction is made between inspiration sensors, expiration sensors and patient-side sensors (spirometry). Sensors on the inspiration side (breathing in) are installed in the device. They are distant from the patient, and the gas always flows from the sensor to the patient (never the other direction). The gas is clean and dry. By contrast, sensors on the expiration side measure the air that is breathed out. This air is moist and comes from the patient. The third area – patient-side sensors – has the most severe requirements. Patient-side sensors must either be suitable for reconditioning, which means cleaning and autoclaving, or disposable. In addition, patient-side sensors must be able to measure both inspiration and expiration, which makes bidirectional calibration essential. This is a major challenge for some types of sensors, in particular hot-wire anemometers. If patient ventilation extends over a relatively long time, weaning creates special challenges for the sensor system if the patient's breathing must be assisted. The onset of breathing must be detected by the device without any time delay.
Various measuring principles

A variety of measuring principles are used for flow measurement in ventilation technology. Due to accuracy requirements and the progressive integration of electronic control systems, the floating-body flow gauges previously used on a wide scale are now only found in older devices.

Differential pressure sensors are used for flow measurement in many devices. This allows the differential pressure sensor to be located relatively far away from the patient and still determine the flow close to the patient. The accuracy of this measuring method does not depend directly on the sensor, but instead on the combination of the differential pressure sensor and the component used to obtain the pressure drop, which is usually an orifice or a linear flow element. The hose between the flow element and the sensor is also a significant factor. The hose basically has an attenuating effect, so kinks in the hose should be avoided.

There are also sensors available that use ultrasonic signals to make "time of flight" measurements. The actual sensor measures through a plastic wall. Easy reconditioning is one of the advantages of this method. However, it entails much higher manufacturing costs.

There are also thermal measuring principles. With the thermal methods, we can distinguish between conventional hot-wire anemometers and hot-film anemometers. A drawback of hot-wire anemometers is that only the magnitude of the gas flow is measured. It is not possible to indicate the direction. This drawback can be eliminated by using hot-film anemometers with several zones.

Sensirion's CMOSens® Technology

Sensirion's CMOSens® mass flow sensors represent a refinement of the thermal measurement method. In the mass flow sensor, the temperature sensors are arranged symmetrically around a heating element. This allows the flow direction to be determined and enables precise bidirectional measurement. Integration of the sensor and the analog and digital signal processing circuitry on a microchip enables precise calibration and temperature compensation of flow measurement. The sensor element and processing with calibration data allow the measurement signal to be processed quickly. Other information about the gas flow can also be obtained, depending on the gas or gas mixture. If the gas consists of a mixture of two pure gases with different thermal properties, the mixing ratio can be determined in addition to the flow. This signal is used in ventilation technology for purposes such as measuring nitrous oxide / air mixtures or helium/oxygen mixtures. However, it can also be used as a redundant signal if the mixture is regulated by other flow sensors.

In addition to pure flow sensors, mass flow controllers are available. Mass flow controllers have a built-in valve, and they are an especially attractive option for smaller manufacturers because the cost of developing the same capability in-house can be considerable. A ready-made solution also reduces time to market for the product. However, mass flow controllers for ventilation technology must be significantly faster than those for industrial applications, since they have to be able to follow the patient's breathing.
Additional information

About Sensirion

Sensirion is a leading manufacturer of high-quality sensors and sensor solutions for measuring and controlling humidity, gas flow and liquid flow. Founded in 1998 as a spin-off from ETH Zurich, the company now has over 500 employees worldwide at branches in the USA, South Korea, Japan China and Taiwan. Research, development and production take place at the company's headquarters in Switzerland. Sensor components and solutions from Sensirion are used in the millions worldwide in areas such as medical technology, the automotive industry, building services, industrial processes and consumer goods. Sensirion's success is based on innovative CMOSens® Technology, which combines the sensor and the signal processing circuitry on a single semiconductor chip. This allows large quantities to be produced in high quality at low cost, making Sensirion a preferred supplier of microsensors and sensor solutions.

SFM3000: the mass flow meter for medical technology

The SFM3000 mass flow meter is a digital gas flow sensor specifically suitable for high-volume use in medical ventilation and anesthesia equipment. Thanks to an optimized flow channel design, the SFM3000 has a very low pressure drop of less than 1.5 mbar. The mass flow sensor measures flow rates of air and other non-aggressive gases bidirectionally at up to 200 slm with high accuracy and very short response time. It outputs a digital, internally linearized and temperature compensated 14-bit signal at a 2 kHz rate. The mass flow sensor operates with a 5 VDC supply voltage, which makes direct connection to a microprocessor quick and easy. The outstanding performance of the SFM3000 mass flow meter is based on Sensirion's unique, patented CMOSens® Technology, which integrates the sensor element, signal processing and digital calibration in a single microchip.

Website SFM3000:

Website Mass flow Meters:

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