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Selection of Suitable Flow Meter Technology for Bioprocess Applications

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Abstract

The ability to accurately measure flow is an essential part of being able to control critical aspects of bioprocesses. Flow meters can be used to provide feedback in order to control a process or simply be inline as a passive monitoring device ensuring that the flowrate does not exceed defined process limits. In either case, the flow meter must be able to reliably read flow. In order to achieve accurate flow measurements, the proper flow meter technology must be selected for each step of the process. This poster discusses the fundamentals of each flow measuring technology and which meter is best suited for different types of applications.

Available Technologies

This section will provide a brief overview of how each type of sensor technology works and their pros and cons.

Ultrasonic

Ultrasonic flow meters use sound waves to determine the velocity of a fluid flowing in a pipe. Under flowing conditions, the frequency of the reflected wave is different due to the Doppler effect. When the fluid moves faster, the frequency shift increases linearly. The transmitter processes signals from the transmitted wave and its reflections to determine the flow rate.

This technology can be very accurate and has high turndown (can read low as a percentage of the full scale or top reading), handles high pressures, is repeatable (consistent), handles extreme temperatures, is low maintenance, highly reliable and self – diagnosing. Disadvantages can include high cost and sensitivity to stray process vibrations.

Coriolis

Coriolis mass flow meters measure the force resulting from the acceleration caused by mass moving toward (or away from) a center of rotation. With flow meters, water is flowing toward and away from the center of rotation, opposite forces are generated and cause the hose to twist. The amount of twist is proportional to the mass flow rate of fluid passing through the tube(s). Sensors and a Coriolis mass flow meter transmitter are used to measure the twist and generate a linear flow signal.

This technology has high accuracy, and is ideal for situations when the characteristics of a fluid will be changing. High cost is a primary disadvantage.

Magnetic Flow Meter

An electromagnetic flow meter, commonly referred to as a mag flow meter, is a volumetric flow meter with no moving parts and ideal for applications where low-pressure drop and low maintenance are required. These meters measure fluid velocity using electromagnetic induction. A fluid passes through the metering tube where a magnetic field is applied. This results in a potential difference proportional to the flow velocity which the meter then converts to a linear flow measurement.

Mag flow meters provide reliable accuracy and minimal maintenance as there are no moving parts, however they do not work on non-conductive streams.

Thermal Flow Measurement

Thermal mass flow meters are ideal for measuring very low fluid flow rates. They operate by introducing a known amount of heat into a flowing stream and measuring the associated temperature change. Thermal mass flow meters are unaffected by changes in viscosity, density, temperature, or pressure. However, thermal flow meters are subject to blockage by foreign particles.

Rotary (Impeller) Flow meter

The flow sensor works by measuring the rotations of the rotor that is in the flow path. The rotor blades reflect an infrared light beam and each rotation measured is converted to an electrical pulse that is received by the flow monitor which has a “pulse accumulator” that counts the pulses. This is low cost technology but accuracy suffers at low flows and with streams other than water.

Product / Technology	Description	Flow Range / Typical Accuracy	Single Use?	Application
 **Coriolis Flow meter**	**PendoTECH Coriolis Flow meter:** Coriolis flow meters require no calibration. This flow measurement technology is needed if a change in viscosity/density is expected, or if particles in the fluid are present	Available in different sizes, from 12- 1,500 mL/min, to 750-24,000 mL/min Accuracy: 1% of reading + Z.O.S. (Z.O.S. varies by model)	No	Applications where viscosity of liquid is changing. Often used on retentate line of TFF processes.
 **Rotary**	**Single Use Rotary Flow meters:** Cost effective and single use. Calibration of pulse constant may be required. Cannot handle change in viscosity/density, comparatively poor accuracy, particles and debris in fluid will diminish performance. Small turbine located in line of the fluid path.	Available in different sizes, 0.1-2 L/min and 0.3- 20L/min Accuracy: ± 5%	Yes	Processes with constant flow regime and density/viscosity of solution. Works best with filtered materials. Processes where costs must be kept low. Often used on TFF permeate lines.
 **Non-Single Use Ultrasonic**	**Non-Single Use Ultrasonic** Must be calibrated per liquid used. Preferred option for very low flow rates. Non-invasive	Flow rate: 2-200 mL/min Accuracy: ± 2% of the reading for flow rates over 100 mL/min, ± 2% ± 0.2 mL/min for flow rates under 100 mL/min	No	High accuracy ultrasonic flowmeter for low flow applications. Ideal for small normal flow filtration applications or on TFF permeate lines.
 **Single Use Ultrasonic**	**Leviflow Single Use Flow meters** Accurate ultrasonic flowmeter from Levitronix. Must be calibrated to specific liquid being processed. Designed for single use applications.	FM-LFS-03SU = 0-0.8 L/min FM-LFS-06SU = 0-8 L/min FM-LFS-10SU = 0-20 L/min FM-LFS-20SU = 0-80 L/min Accuracy ~3% of reading. Depends on model	Yes	High accuracy ultrasonic flowmeter for low flow applications. Various models for any flow requirements. Ideal for normal flow filtration applications or on TFF permeate lines.
 **Electro-magnetic**	**Endress+Hausser PROMAG** No pressure loss. No obstructions in fluid path. Very accurate, wide flow rate range. Non-invasive. Liquid MUST have some conductivity to read	Flow rate: 2-98 L/min (smallest size) Accuracy: ±0.2 %	No	Applications where viscosity of liquid is changing. Often used on retentate line of TFF processes.
 **Heat Capacitance**	**Sensirion LD20 Liquid Flow Sensor** Small inline device for extremely low flow experiments. Designed for single-use but can be cleaned and reused.	Flow Rate: 0.5 to 16.6 ml/min Accuracy: • +/- 0.042 ml/min up to 0.83 ml/min • +/- 5% of reading above 0.83 ml/min	Yes	Low flow experiments. • TFF • NFF •,Chromatography • Bioreactor Feeds

Technology Highlight

PendoTECH is now offering the Sensirion LD20 Liquid Flow sensor. As mentioned above, this flow meter is specifically designed for extremely low flow measurements, ideal for early stage development studies. In order to be qualified for single-use these sensors must be capable of withstanding sterilization treatment in order to be more easily integrated into a single-use tubing set or manifold. In order to establish performance after EtO sterilization PendoTECH tested a range of sensors before and after sterilization. The testing of the sensors following EtO treatment is presented below. Sensor flow rates were compared to a flow rate determined from a calculation based on the changing weight of the collection scale.

Average Values across sensors after EtO

Sensor Flow Rate	Scale Flow Rate	% Error
0.37	0.36	3.47%
0.54	0.54	2.88%
1.08	1.06	2.13%
4.18	4.17	1.06%
6.70	6.78	1.95%
10.21	10.24	1.24%

Conclusions:

- The Sensirion LD20 Liquid Flow sensor continued to perform exceptionally well in low flow conditions after EtO sterilization. This enables integration of sensor into pre-assembled, single-use, tubing sets or manifolds.
- Sensors cannot be treated with Gamma Irradiation

Overall Conclusions

- The accuracy required for a specific application plays a large role in determining what type of sensor is required. Highly precise measurements require more expensive sensors such as a Coriolis or ultrasonic flow meters. Sensors used for general trending or information collection only can use more basic technology like the rotary flow meter mentioned above.
- To obtain the most robust measurements the proper flow meter must be chosen based on specific process characteristics. These characteristics include, but are not limited to, the following: viscosity, density, particulates, range of flow, and temperature.
- Mass flow meters provide the most accurate/reliable measurements and remain effective even when the fluid properties are constantly changing. However, other limitations impact widespread applicability
- Single-use options are available and can be integrated into pre-sterilized tubing sets or manifolds.
- Any technology would need to be qualified for its specific use with respect to process conditions.
- Periodic monitor verification can be performed.