T400-Series Technical Note

Keys to Accurate Tubing Flow Measurements with Transit-Time Ultrasound

Acoustic principles govern the design, tubing-specific manufacture and proper use of Transonic® Clamp-on Tubing Flowsensors. Because acoustic properties of specific tubing affect Clamp-on Flowsensor accuracy, Transonic® requests a sample of tubing for Flowsensor calibration.

"Squaring Off"

Tubing can attenuate, reflect, focus or delay ultrasound timing dependent upon tubing material, density, wall thickness and temperature. Since the most accurate transit time measurements are achieved under uniform acoustic conditions, the challenge in Flowsensor design is to ensure conditions where the tubing affects ultrasound transmission in a uniform predictable way. Thus, Transonic® sterile tubing Flowsensors "square off" the tubing circumference to minimize focusing of the ultrasound and variable path lengths of the acoustic beam. The ultrasound transmit level and received signal timing window, and calibration factor are determined and set specifically for the tubing to be used. Even so, there are conditions of acoustic mismatch which affect accuracy. If anticipated, these can be minimized.

Temperature

The most significant changes in uniformity of the acoustic beam occur at the Sensor/tubing border and the tubing/liquid border. Fluctuations in temperature can affect the acoustic properties of these interfaces. To minimize these effects, we recommend that the Sensor be allowed to equilibrate on the tube before measurement. Zero stability can be improved for measurement of circulating cold liquids by cooling the Flowsensor as well. This can be as simple as insulating around the Sensor and tube with foam or maintaining the tubing circuit and Flowsensor in a controlled environmental chamber.

Vaseline Seal

We recommend a thin smear of Vaseline to acoustically couple sterile tubing Sensors with tubing. Water-based gels will dry out and can build up on the Sensor to contribute their own layer of offset and error.

Calibration

A discussion of accuracy in tubing flow measurement would not be complete without consideration of the acoustic properties of the liquid to be measured. Transonic® will custom calibrate the Sensor for the specific liquid if a sample is provided. Changing the liquid (or temperature) will affect the calibration. Transonic® TS410 Flow Modules allow the user to adjust the calibration gain on site; users of the T106/T206 should apply a correction factor to collected data. Adjustments to flow data should be made only after a comparison of Flowmeter reading with timed collection.

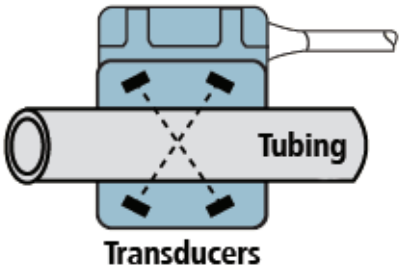

Fig. 1: Sterile Tubing Flowsensor

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Flow Profiles

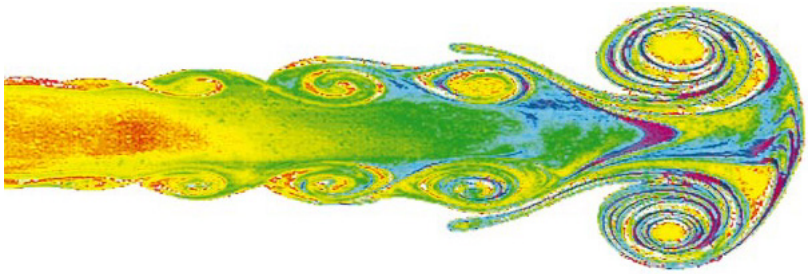
While it is technically possible for the Flowsensor to be used on fluid with turbulent or undeveloped flow, there is an increased chance for inaccuracies, making it inadvisable. Since the ultrasonic field of the Flowsensor is not 100% uniform, one portion of the flow may be sensed in an area that is more sensitive and another portion in an area that is less sensitive. With laminar flow, these areas are appropriately integrated across the entire Flowsensor. However with turbulent flow there is no control over which areas of high, low, average or reverse flow fall within the sensitivity window of the ultrasonic field, this could lead to widely varying flow rates or highly inaccurate values.

To ensure the flow profile will be uniform and developed before entering the Flowsensor have a straight segment of tubing 10 x ID of the tubing before the Flowsensor and just about the same after. Even tubing connectors can cause turbulence.

Note: Laminar flow can develop over a shorter distance than 10 x tubing ID depending on flow conditions and fluid properties.

FLOW STRAIGHTENERS

When it is not reasonable to have the necessary length of straight tubing for fully developed flow (10xID), flow straighteners may be used to reduce turbulence. Flow straighteners often resemble a sieve or a bundle of small tubes and act as a physical interruption to turbulent effects such as swirl and allow for faster development of laminar flow profiles by reducing the Reynolds number. The Reynold's number is directly proportional to the diameter of a tube. Reducing the tube diameter by turning one big tube into many small tubes reduces the Reynold's number which corresponds with more laminar flow behavior which is perpetuated when the flow is recombined into a single stream. The diameter and length of the small tubes needed to create laminar flow depends on the fluid viscosity, flow rate and amount of turbulence to be corrected.



Vortex rings can form from jets in the fluid flow (when fluid passes at high speeds though a reduced opening). It is possible for the Flowsensor to read a value close to zero by adding the combined forward (positive) and backward (negative) motion of the vortex.

Additive Errors

When using multiple Flowsensors on a single flow system (such as input/output measurements) it is important to remember that the absolute accuracy of the Clamp-on Tubing Flowsensors is ±10% and that error is additive. In a worst case scenario, two Sensors with error in the opposite direction could give a total system error of 20%. However, it is possible to mitigate the total system error by calibrating the Sensors together against a known flow, determining a correction factor for each and adjusting the gains of the Flowsensor through the program in the TS410 Flow Module This will give you the tightest overall accuracy for the whole system.

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Sensor Sizes Correlate to Outer Tubing Diameters

Transonic® Clamp-on Sensors are sized to the outer diameter (OD) of the tube so that the tubing fits properly in the tubing slot of the Flowsensor. Sensor sizes vary in 1/16" increments (see Tables). The number within a Flowsensor name refers to this OD size in 1/16" steps. For instance a ME5PXL is designed to accept 5/16" OD tubing. Sensors for metric OD sizes (4 mm to 25 mm) are available on special order.

Sensors Can Be Custom Matched

Some tubing types do not conform to the standard OD dimensions that are listed on the Transonic® Clamp-on Sensor specifications list (see RL-28-fly), but may be suitable for use with Transonic® Sensors. A sample of the tubing may be sent to Transonic® for evaluation and Transonic® will match the tube outer diameter to the nearest standard Sensor size to see if it gives acceptable signal.

SENSOR	TUBING (inches) ID x WALL
2 PXL	3/32 x 1/32
3 PXL	1/8 x 1/32
4 PXL	1/8 x 1/16
5 PXL	3/8 x 1/16
6 PXL	1/4 x 1/16
7 PXL	1/4 x 3/32
8 PXL	3/8 x 1/16 5/16 x 3/32

SENSOR	TUBING (inches) ID x WALL
9 PXL	3/8 x 3/32
10 PXL	1/2 x 1/16
11 PXL	1/2 x 3/32
12 PXL	1/2 x 1/8
14 PXL	5/8 x 1/8 11/16 x 3/32
16 PXL	3/4 x 1/8
20 PXL	1 x 1/8

Clamp-on Flowsensor sizes and the respective tubing sizes for which they are used.

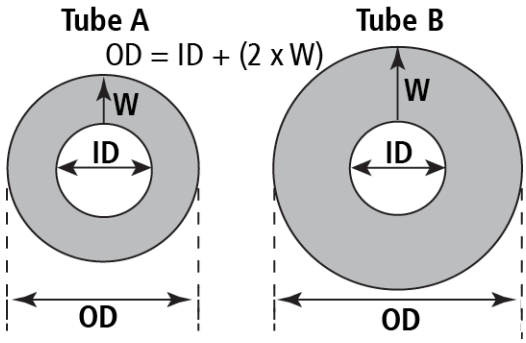

Fig. 2: Diagram that shows how a tubing's outer diameter (OD) is calculated by adding the inner diameter (ID)and twice the tubing width (W). OD = ID + (2 x W)

Note: In some applications, the inner diameter of the tube is more critical than the outer diameter. Since tubing comes in several wall thicknesses, it is important to use all dimensions (ID + 2 x Wall = OD) to determine the most appropriate Sensor size. In Fig. 1, both tubes have the same ID, but the wall thickness of Tube B is greater than Tube A, so that the OD of Tube B is bigger and uses a larger Sensor. In some cases, the larger Sensor size will have a higher flow scale and a less sensitive measurement than a smaller Sensor size (see specifications).

Ultrasound That Measures Volume Flow, Not Velocity

Using wide-beam illumination, transducers pass ultrasonic signals back and forth, alternately intersecting flowing blood in upstream and downstream directions. The transit time of the ultrasonic beam is decreased when traveling downstream with the blood flow and increased when traveling upstream against the flow. The difference between the integrated transit times is a measure of volume flow.

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Transonic Systems Inc. is a global manufacturer of innovative biomedical measurement equipment. Founded in 1983, Transonic sells "gold standard" transit-time ultrasound flowmeters and monitors for surgical, hemodialysis, pediatric critical care, perfusion, interventional radiology and research applications. In addition, Transonic provides pressure and pressure volume systems, laser Doppler flowmeters and telemetry systems.

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