T400-Series Technical Note

Ultrasound Probe Calibration Correction Factors

A. Description of Operation

1. The Transonic blood Flowmeter uses full-flow illumination ultrasonic transit-time technology to measure volume flow (not velocity) directly. Unlike systems that measure velocity along a line through the flow or at a point in the vessel, no assumptions about velocity profile or cross-sectional area need to be made. In the Transonic system, a wide beam of ultrasound fully illuminates the ultrasonic window of the Sensor, including the complete cross-sectional area of the vessel within. First, a burst of ultrasound is transmitted by the downstream transducer. After passing through the vessel and its surrounding tissues, the ultrasound is received by the upstream transducer, amplified and sent to a phase detector. The average speed of the ultrasound signal is slowed down by the flow because it travels against the flow. The "transit-time" of the ultrasound signal (= time to travel from one transducer to the other) increases. The Transonic phase detector senses this arrival time as a phase difference between the received signal and a reference signal from a master oscillator. This phase difference is stored in electronic memory.

   On the next part of the cycle, the functions of transmitter and receiver are reversed. The ultrasound signal now starts at the upstream transducer, travels along with the flow in the downstream direction and is received by the downstream transducer. This transit-time signal is made smaller by the flow. The phase measurement to this received signal is also stored in electronic memory.

   The upstream and downstream phase "readings" are then subtracted from each other. The difference gives a signal proportional to the volume flow which is independent of the vessel dimensions.

(Continued on next side.)

B. Tranducer Description & Operation

1. Mechanical Configurations of Transonic® Flowprobes

All Transonic® Flowsensors employ a two-transducer reflector configuration as illustrated in Fig. 1. on next page.

The Flowsensor consists of:

- An epoxy Probe head which contains two all-enclosed ultrasonic transducers (Lead-Zirconate-Titanate) and their connecting wiring,
- A "reflector bracket" assembly (made from stainless steel or ceramic, depending on the application) which serves to define an ultrasonic-sensing window through which volume flow is measured, and
- A silicone-coated cable with Probe connector to connect the Probe (via a Probe extension cable, in most instances) to the bench-top Flowmeter model.

Various configurations of this basic design exist. These have been built in response to user-preferences for different application sites, as well as the different flow conduits encountered during surgery (arteries, veins, laboratory tubing).

2. Functioning of Transonic Flowprobes

"Probe" also refers to "Sensor" in the following. During operation, ultrasound travels in a V-shape reflected pathway between the two ultrasonic transducers (Fig. 1). The downstream-upstream difference in ultrasound transit-time Flowprobe varies proportional to the volume flow perpendicularly crossing the ultrasonic sensing window:

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Ultrasound Probe Calibration Correction Factors Cont.

B. Tranducer Description & Operation cont.

2. Functioning of Transonic Flowprobes cont.

$Tu - Td = \{\text{Tan}(\theta\sigma) + \text{Tan}(90 - \theta)\} * \{KfQ/c^2\}$

where:

Tu = Upstream Transit Time
Td = Downstream Transit Time
K = Geometrical Constant
f = Transmission Frequency
c = Velocity of ultrasound in the liquid and in the surrounding medium
θ = Angle between Acoustic & Flow Axes (Fig. I.)
Q = Volume Flow

A digital memory unit (EEPROM) enclosed within the Probe connector conveys to the Meter the Probe operating parameters (frequency of operation, transmit burst length, transmit signal amplitude, period after start of transmit signal when the received signal must be measured), the calibration factor for the Probe in use, and the Probe size/style and serial number. The Meter's gain is adjusted accordingly, resulting in a direct readout of flow in ml/ min or L/ min.

Tu – Td = {Tan (qs) + Tan (90 - q) } is constant. With a fluid change, the only change is the (KfQ/ c^2) term.

Use K1 determined for 6% saline at 37°C,
c1 = 1575 m/sec

Determine K2 of 20°C water,
c2 = 1480 m/sec
C2 =.9397 C1
C2^2 =.883C1^2

Set the two equations equal.
K2fQ/.883C1^2 = K1fQ/C1^2
K2/.883 = K1
K2 = .883K1.

This indicates that the calibration factor for 20°C water should be .883 that of your calibration factor for 37°C 6% saline. If you use K1, your reading will be too high.

C. Flow Correction of Flow for Ultrasound Velocity

The calibration (gain) of the Probe depends upon c = Velocity of ultrasound in the liquid and surrounding medium. Ideally the fluid used for calibration should be blood at body temperature.

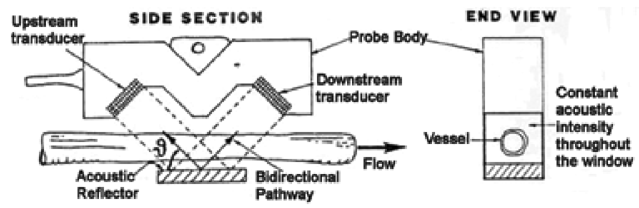

Fig. I: Volume flow is measured directly by illuminating both vessel and surrounding area with a wide beam of ultrasound (see end view). The reflective acoustic pathway makes this measurement respond to only the axial component of flow.

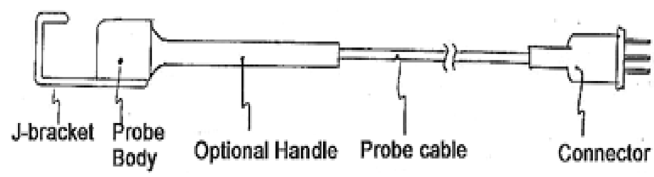

Fig. 2: Sample Probe for acute perivascular application in arteries and veins.

The acoustic velocity of the fluid can also be temperature dependant. However, it is not always practical to use blood for calibration or testing.

The table below lists the ultrasound velocities for water and the correction factor in percent. This can be used adjust the display results for the proper result of body temperature blood.

The ultrasound velocity in blood @ 37°C is 1560 – 1590 m/sec. For the correction factor we use 1575 m/sec as the ultrasound velocity of blood.

$$\text{Correction factor} = \frac{(\text{Test fluid } c^2 \text{-(Blood } c^2)}{(\text{Blood } c^2) * 100}$$

Fluid	Temperature (°C)	Ultrasound Velocity (m/sec)	Correction % of Displayed Value
6% saline	37°	1575	None needed; we use this to model blood
Water	20°	1480	-11.6997
Water	25)	1497	-9.6595
Water	30°	1509	-8.20535
Water	37	1517	-7.22947

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Ultrasound Probe Calibration Correction Factors Cont.

D. Accuracy Specifications and Temperature

Our stated accuracy specifications of +/- 15% take into account variations from Probe to Probe and Meter to Meter. They also take into account variations caused by the user during application. The graph below illustrates the change or error associated with temperature from 23° C to 35° C is < 2% (using cow blood).

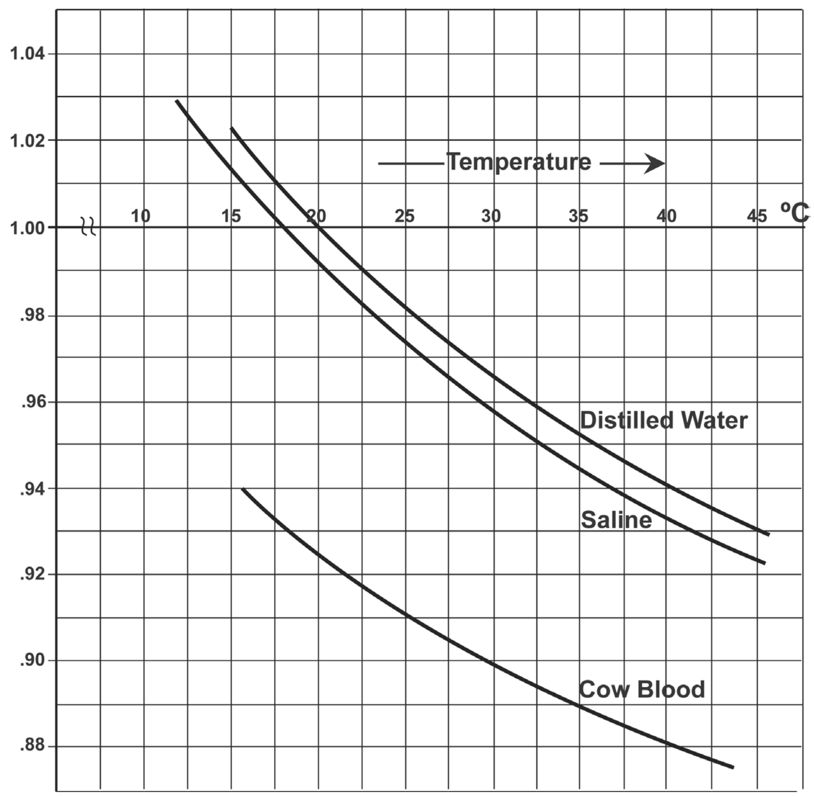
The description uses an example of a Probe calibrated (adjusted) to read properly on distilled water at 20°C. If after this adjustment takes place, a reading on cow blood will read 88% of what is expected. In order to get back to true flow on cow blood, the display would need to be divided by .88 (or multiplied by 1.13)

For Probes that are calibrated for blood at body temperature this example can be used as well. In this case, the Probe is intended for use on 37°C cow blood. If someone were to use 20°C-distilled water, the reading would be 13% too high.

As a rule, a Probe calibrated for body temperature blood will read high when compared to room temperature water and should be adjusted down.

Flow Readout Correction Factors

For Transonic Flowsensors calibrated at:
20º (distilled water) or 18º (saline)



Example: If the calibration of a cannulating Flowsensor is adjusted (via a resistor within its connector) for distilled water at 21°C, then the same Sensor will read 0.883 of the true flow when it is used on cow blood at 37°C.

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