Comparison Notes
Ultrasonic Transit-Time Flow Measurement

Single-Path vs. Multiple-Path Flow Measurement

The multiple-path configurations provided via Accusonic flowmeter systems provide much greater flowrate accuracy than can be achieved via flowmeters (such as the Badger flowmeter) limited to a single acoustic transit-time path across the flow cross-section velocity profile.

In addition, crossed-path configurations available with Accusonic flowmeter installations provide compensation to maintain flowrate measurement accuracy in the presence of off-axis (cross-flow) velocity components that are present at metering locations downstream from bends or other sources of disturbances to axial flow. Such cross-flow compensation is not available with any other flow measurement technology presently available.

The issues of flow velocity-profile estimation and effects of cross-flow on flowrate measurement accuracy are further discussed below.

Open Channels & Partially Filled Pipes

The Accusonic Model 7510 Flowmeter utilizes the internationally accepted multiple-path ultrasonic transit-time method to determine flowrate in open channels in compliance with International Standard ISO 6416 (ref. 1). Water level measurements, together with accurately measured as-built dimensions of the installation, are required to calculate the flow area, and to determine the ratio of the path elevations to that of the water surface.

Flowrate Accuracy Depends on the Number of Acoustic Paths

When only one path is submerged and operational, the average water velocity in the channel must be estimated based on an assumed vertically velocity profile (ISO 6416 clause 2.8.6 & Table 4, presented below), and the single-path velocity measurement must be related to the assumed velocity profile. Since flow depth generally changes and varies over a range for any given application, specifying the relation between the measured velocity at one elevation to the average velocity corresponding to the velocity profile for a given flow situation is not a straightforward procedure.

With the Model 7510 flowmeter when only one path is submerged, flowrate is computed from the measured variables Water Level and the Single-Path Velocity, and the fixed parameters describing the flow conduit cross-section.

Flowrate Determination with Single Acoustic Path Submerged

Q = (Flow Units Scale)*(Cross-Section Flow Area)*(Single-Path Velocity)*(Path Position Coeff.)

where: Cross-Section Flow Area = the cross-section area of flow at the measured water (depth).

The Model 7510 flowmeter path position coefficient is obtained by interpolation from the following look-up table (from ISO 6416, Table 4). Note that this is closely related to the theoretical open-channel vertical velocity distribution used by the U.S. Geological Survey (USGS), as noted in ASTM D 5389-93: *Standard Test Method for Open Channel Flow Measurement by Acoustic Velocity Meter Systems* (Ref. 2).

Ratio of path depth below surface to depth of water	Ratio of mean velocity to single-path velocity in the vertical.
0.1	0.846
0.2	0.863
0.3	0.882
0.4	0.908
0.5	0.937
0.6	0.979
0.7	1.039
0.8	1.154
0.9	1.424
0.95	1.650 (extrapolation)

Note that if a single-path velocity estimation procedure is used that does not utilize a procedure similar to the above for relating the measured path velocity to the mean flow velocity as a function of the path elevation in relation to the total water depth (i.e., taking account of varying water depth conditions), flowrate estimation error can approach ± 15%. If it is possible to calibrate the system by carrying out a check gauging, then this uncertainty can be reduced to ± 10% using the methods described in ISO 6416.

Flowrate Determination with Multiple Paths Submerged

With the Accusonic Model 7510 Flowmeter, when paths at more than one elevation are submerged and operational, flowrate is determined via the "mean-section" method, (ISO 6416 clause 2.8.4.4).

In addition, the Accusonic Model 7510 flowmeter estimates the water velocity at the surface by a weighted extrapolation of the velocities from the uppermost two paths below the surface, and uses this to more accurately model the vertical velocity profile.

The uncertainty of the open-channel flowrate measurement when paths at 2 elevations are operational is approximately ± 5% to 7%, based on ISO 748 (1997) Table E4.

With 3 paths operational, the open-channel flowrate uncertainty becomes ± 2% to 3%.

In addition to enhanced flowrate measurement accuracy due to the above-noted considerations, multiple-path transit-time flowmeters offer an inherent built-in redundancy that allows the flowmeter to continue operating in a reasonably accurate fashion even if one or two acoustic paths become inoperative due to severe fouling or covering by debris.

Cross-Flow Effects on Flowrate Measurement Accuracy

In addition to the increased flowrate measurement uncertainties (errors) associated with estimation of the actual mean flow velocity based upon single-path or point-velocity measurements taken within a limited region of the flow cross section, susceptibility of flowmetering systems to cross-flow error due to off-axis flow velocity components may also be a significant consideration.

This is discussed in ASTM D-5389 (Sec. 13.1.3, Ref. 2) which notes:

"This may be the largest potential source of errors for a single-path velocity measurement...each 1° error in assumed (axial) direction of flow...will result in a 1.76% error in velocity measurement. This error increases as the path angle increases. If two crossed 45° paths are used and the outputs averaged, for practical purposes, this error is zero".

Note that Accusonic flowmeters typically utilize a 45° acoustic path (crossing) angle, as called for in the ASTM standard noted above, and Accusonic flowmeter systems always provide the option of utilizing crossed-path configurations, at multiple elevations across the flow, to effectively mitigate cross-flow induced errors such as noted above.

Utilizing crossed-path configurations is not possible with single-path transit-time flowmeters. In addition, the Badger transit-time flowmeter utilizes ~ 65° acoustic path angle, which is inherently more sensitive (x 2) to cross-flow error as noted above.

Full-Pipe Flow Measurement

In general, the same factors noted in the above discussions apply to the measurement and determination of flowrate accuracy in full-pipe applications, namely:

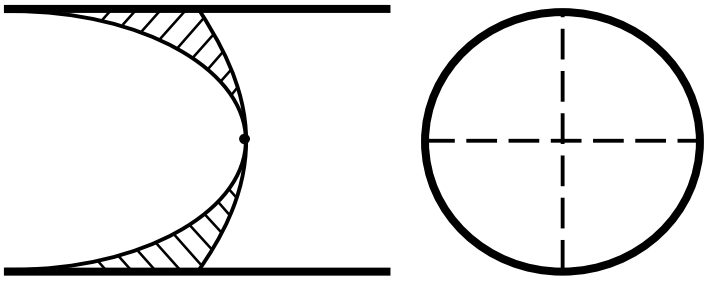
- Determination of the true average velocity in the presence of a velocity profile.
- Minimizing or eliminating cross-flow measurement error when off-axis velocities are present.

The figures presented below graphically show how the presence of multiple acoustic paths can be used to greatly reduce the flow measurement uncertainty arising from velocity profile effects. In particular, note that:

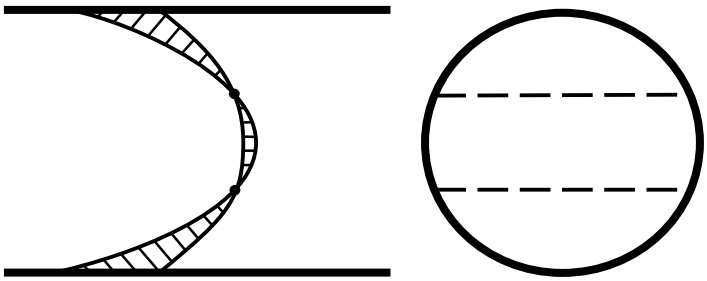
- Multiple-chordal-path measurements closely determine the actual shape of the velocity profile, providing enhanced flowrate accuracy under actual conditions (i.e., for varying flow velocity profiles or for non-ideal hydraulic flow conditions).
- Flowmeters that utilize only single diametrical paths must use a correction factor to account for these velocity profile-related errors. Such correction factors allow accurate flowrate determination only under known, ideal conditions. These errors can be as much as ± 5% to 10% under varying flow ranges and conditions.
- Steep path angles used with single-path flowmeters are typically greater than 65°-70° with respect to the pipe axis and are much more sensitive to error effects associated with any non-axial flow velocities that may occur (a factor of 3 times worse than with the standard Accusonic 45° path angle).

Velocity Profile Uncertainty

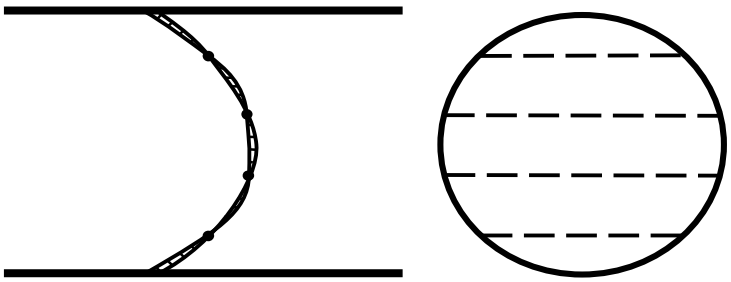
Single-Path (or Multiple-Paths Through the Pipe Center)



Two-Path Configuration



Four-Path Configuration



Summary

- Flowrate accuracy to within ±0.5% of true flow can be achieved using 4-path chordal path configurations such as offered via standard Accusonic flowmeter systems.
- Accuracy within ±1% can be maintained close to bends or other flow disturbances by using 4-path x 4-path crossed-plane configurations under good conditions.
- Single-path flowmeter accuracy within ±5% is the best that can be expected under ideal conditions, but actual uncertainties are typically ± 7% to ± 10% or more.