

Controlotron's WideBeam™, Cavity-Free™ Ultrasonic Flowmeters Achieve Process and Natural Gas Custody Transfer Accuracy and Performance

Controlotron's WideBeam™, Cavity-Free™ ultrasonic flowmeters have been proven to meet the recently released API standards for liquid custody transfer. This same Cavity-Free technology is now available for gas applications and will meet AGA-9 standards for custody transfer.

The two major types of ultrasonic flowmeters available for gas custody transfer measurement are conventional 'insert' type meters and Controlotron's unique WideBeam™, 'Cavity-Free' design.

Old School: Typical 'insert' ultrasonic flowmeters use sensors that are inserted into the meter body; the signal is transmitted directly between facing transducer pairs with or without bounces off the pipe walls. This design results in the inclusion of internal cavities within the meter body. Such wells or cavities can cause maintenance, leakage and pressure containment issues. Cavities in the meter body will also cause eddy currents in the flow that can cause non-linear performance. The alignment of these 'facing' sensor pairs is also crucial, requiring expensive castings and milling procedures. The result is a complex geometrical architecture that must remain stable over wide temperature and pressure ranges. Manufacturers employ a variety of multiple path and multiple 'bounce' architectures to achieve acceptable flow profile averaging with complex software algorithms.



Figure 1
Controlotron's SonicGas™ Cavity-Free Flowmeter

New School: Controlotron's WideBeam™ sensors are applied externally to a precision, flanged pipe section; this patented signal injection technology provides a signal that is refracted into the Gas stream, so as not to require cavities or wells and leaving the structural integrity of the pipe intact. The resulting meter body is a simple measurement section; with no flow profile distortion, superior repeatability and stable zero behavior. (See Figure 1) Since the sensors do not intrude into the meter body, there is no special extraction tool required. In addition:

- There are no potential leakage paths
- There is no flow profile distortion induced by the sensors or wells
- There is no place for dirt or oil to collect that might cause beam interference.

The benefits of this simple measurement meter body with no cavities or wells are obvious. However, the technological challenges of developing this technology were significant. A refractive technology, such as Controlotron's WideBeam™ design, must:

- Be capable of adapting to changes in the refraction angle due to gas pressure, temperature and composition
- Deliver acceptable rangeability despite beam blowing effects that would tend to move the signals as flow velocity increases (there are similar issues with insert type sensors)
- Have linear performance over a wide range of Reynolds' numbers despite having a non-chordal design.

These challenges were overcome by utilizing the same WideBeam™ signal injection technique that has made Controlotron a leader in ultrasonic liquid flow measurement for over 40 years. (See Figure 2.) The WideBeam™ technique uses transducers that are specifically matched to the sonic resonance properties of the pipe wall. Controlotron manufactures specific transducer ranges for each pipe material and wall thickness to produce a stable, coherent signal within the pipe wall. In effect, the pipe is used as a precision sounding board and waveguide for the ultrasonic signal.

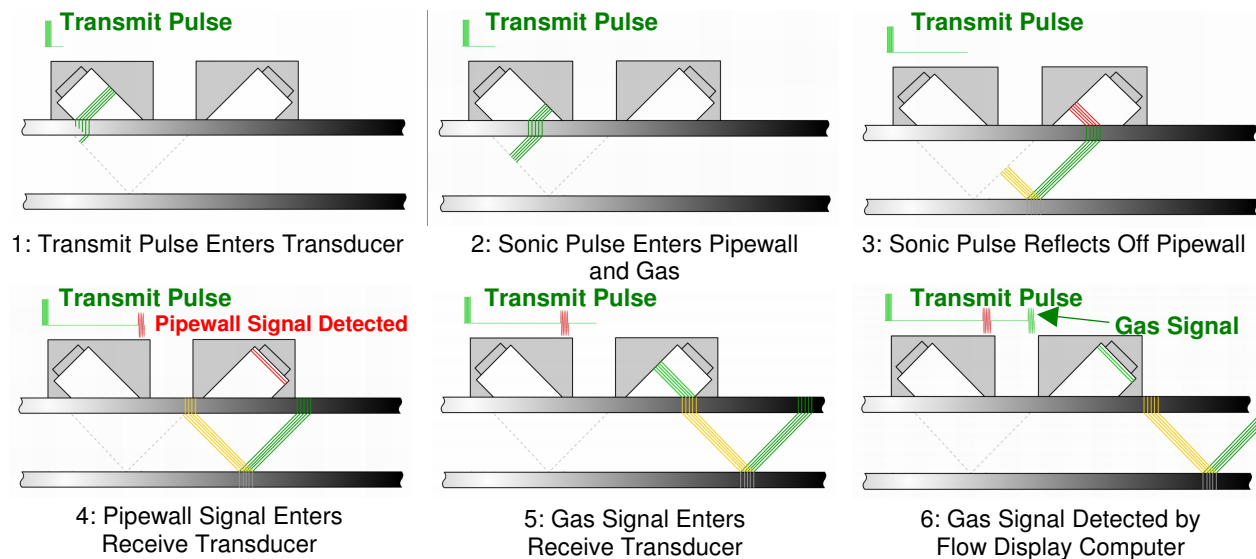


Figure 2

Note: Signal travels within the pipe wall

The “wave guide” action of the pipe wall acts to lengthen the active transmission area of the transducer. The effective ultrasonic emitting surface becomes several times the length of the actual transducer, producing the characteristic wide, phase coherent ultrasonic signal in the medium to be measured (gas or liquid). The ‘waveguide’ property of the tuned system permits operation over widely changing conditions. As pressure, temperature and gas composition changes – or as beam blowing occurs with higher flow velocity - the effective refraction angle of the injected signal changes and the signal falls at different places on the inside of the pipe. (See Figure 3.) No matter where the signal ‘lands’, once it hits the pipe, the waveguide action of the pipe carries the signal to the receiving transducer with no distortion. The signal processing algorithms accurately measure the arrival time and transit-time difference between the upstream / downstream receive signals. These timing measurements determine the flow rate very accurately and determine the Sonic Velocity of the Gas to high precision. In fact, the accuracy of the sonic velocity measurement is testimony to the precision and accuracy of the WideBeam™ system.

This waveguide action is especially important in dealing with beam blowing, as the signal paths are dramatically different between upstream and downstream. Beam blowing causes the signal sent upstream, against the flow, to take a shorter, steeper path through the fluid while the downstream path becomes shallower and longer. (See Figure 3.) Transit-time correlation can only be performed if each signal travels through different lengths of pipe wall without distortion. WideBeam™ signal injection assures that the two signals arrive through the pipe wall undistorted.

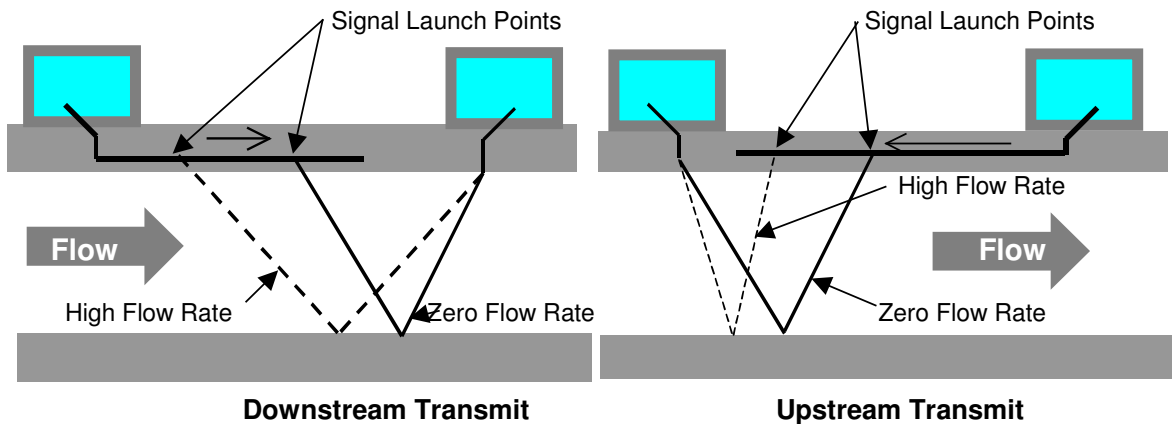


Figure 3

Impact of Beam Blowing

System uses signal from any launch point, providing accurate flow information regardless of beam blowing or signal refraction.

Without the patented WideBeam™ pipe matching, refractive systems cannot achieve the stability, accuracy and rangeability over typical application conditions that are required for custody transfer applications. Typical inexpensive field clamp-on devices do not have this technology and capability.

It should be noted that the minimum pressure required for the externally mounted, refractive technique is typically higher than for most insert-type systems. Depending on specific application conditions; such as type and grade of piping, 10 to 15 bar is typically required for Custody Transfer performance with WideBeam™ systems on steel pipe. For plastic pipe and some alternative metal pipes, atmospheric pressure is sufficient.

Controlotron WideBeam™ systems are available in several configurations depending on the specific application conditions and user requirements. However, the preferred configuration is dual-beam, reflect mode. Since the refractive technique must employ diametral path signal injection, the system takes advantage of the ability to reflect the signal off the far wall. This enables mounting of the transducers on the same side of the pipe, which has additional far-reaching benefits.

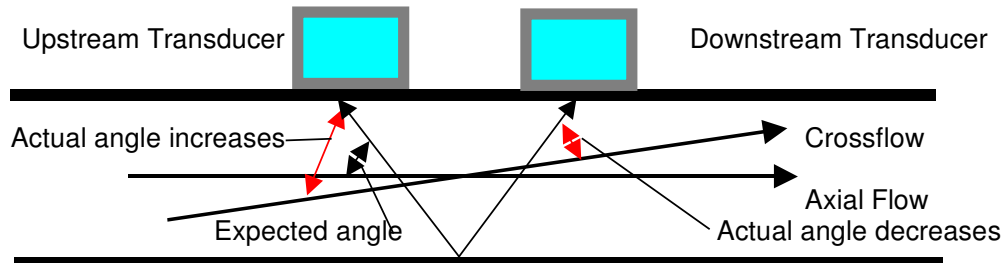


Figure 4
Diametric Reflect Mode impact on Crossflow and Swirl

The first, most obvious benefit of diametral operation is direct cancellation of cross-flow effects and minimal impact from swirl. (See Figure 4) However, Controlotron achieves another benefit from same-side mounting: Zeromatic Path™ – dynamic “zero” under flow conditions. When a transducer sends a signal into the pipe wall, the signal actually takes two distinct paths to reach the receiving transducer. The flow measurement path is the path that the signal takes as it: (Refer to Figure 2 above)

1. Refracts into the gas
2. Reflects off the far wall
3. Falls on the inside surface of the transmitting wall
4. Is carried by the waveguide action of the pipe wall to the receiving transducer.

However, a second signal actually reaches the receiving transducer first. Since only a portion of the signal injected into the pipe wall enters the gas (due to highly dissimilar sonic impedance factors), the remaining signal is carried by the waveguide properties of the pipe wall directly to the receiving transducer through the pipe wall. Because this signal is not affected by the gas flow, it serves as a constant reference of Zero Flow. Therefore, this ‘Zeromatic Path™’, which is only active in Reflect Mode, eliminates the need to shut flow in order to set zero and provides a constant zero flow reference that eliminates all potential zero drift that is inherent in ultrasonic systems, since they all have a ‘live’ zero. Thus, deadband settings can be minimized or eliminated. This provides the potential of the system to be used as a single point leak detector in a blocked line test. Small leaks will be sensed and accumulated over time to show the direction of leaks through valves or corroded areas.

Additional paths provide better flow profile averaging and less error due to asymmetrical profile conditions. For the majority of Custody Transfer applications, Controlotron recommends a Dual Beam, Reflect mode system. Large pipes often benefit from a Four-Beam Reflect Mode configuration. For applications that prohibit the use of reflect mode operation (e.g. Large pipes with very high flow velocities), Four-Beam, Direct-X™ mounting is preferred. Direct-X™ mounting (See Figure 5) uses two pairs of transducers each in direct mode mounting, but mounted in opposing directions. This has the effect of canceling out crossflow and minimizing the impact of swirl. It should be

noted that the Zeromatic Path™ feature is not available when mounting in Direct-X configurations, as there is no direct pipe wall path between the transducer paths.

Chordal paths must also be specially configured in order to minimize crossflow and swirl errors. Pairs of paths should be mounted in opposition in order to achieve some cancellation of crossflow. An additional two pairs of transducers should be mounted in opposition, but symmetrically across the pipe in order to provide minimization of errors due to swirl. **Thus, a single Reflect Mode, Diametric beam has the crossflow and swirl cancellation impact of four chordal paths.**

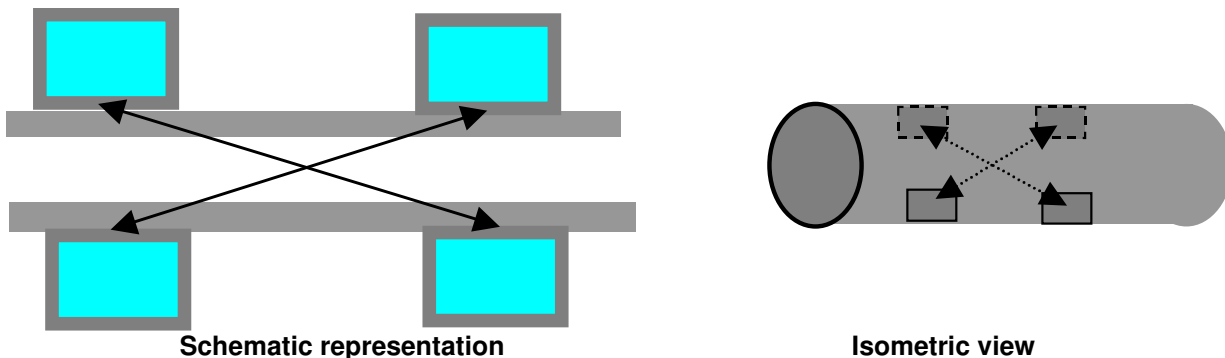


Figure 5
Direct-X™ Mounting Configuration

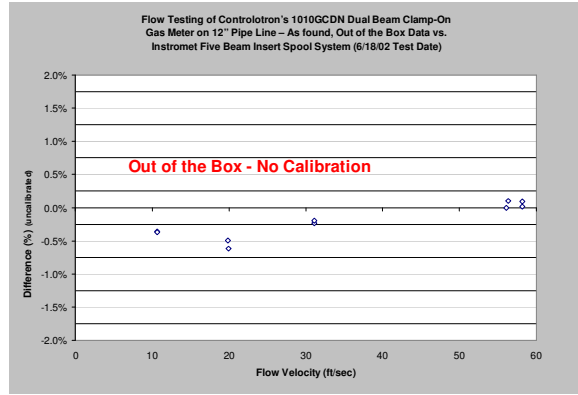
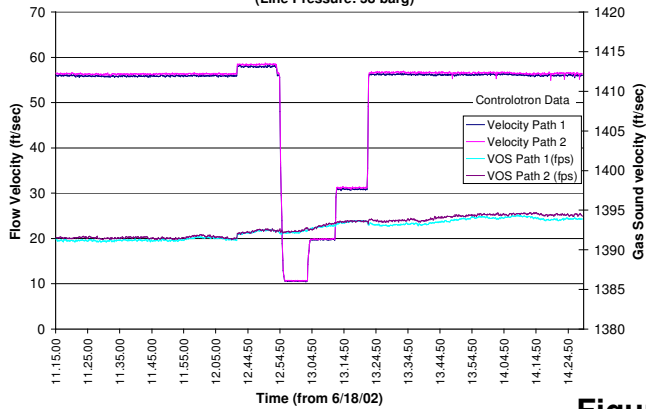
How many beams make sense? It depends on the type of system. Insert systems employ a very narrow beam of the approximate diameter of the crystals, where only natural beam spread insures that the signal will not be “blown” away from the receive transducer. WideBeam™ systems take a much larger ‘slice’ of the flow information with each transmission because it uses the pipe wall as a resonant sounding board, which greatly extends the effective emitting and receiving surface of the transducers. Each WideBeam™ transmission contains a much better representation of average flow than an insert-type transmission. However, the beams of refractive systems must be across the diameter of the pipe and cannot be arranged as chordal geometries.

Chordal-based designs offered a theoretical advantage in that they are thought to be Reynolds’ Number insensitive. However, in part due to local flow profile disturbances near the cavities and the inherent limited information acquired by each transmission of the ‘narrow’ beam, these theoretical benefits begin to pale when compared to the overall benefits offered by the WideBeam™, Cavity-Free design. In addition, recent data suggest that Reynolds’ numbers does have an influence on the performance of chordal systems. WideBeam™ designs include Reynolds’ Number compensation and when applied, offer equal or better linearity and rangeability than insert chordal systems. In addition, chordal type designs typically must employ up to four times as many paths in order to provide opposing / symmetric transducer pairs for cross-flow and swirl cancellation – a feature of a single pair of WideBeam™ transducers mounted in reflect mode. It should be noted that manufacturers generally suggest avoiding the use of the meters within the Transition Region from Laminar to Turbulent flow – despite chordal designs.

Controlotron’s WideBeam, Field Installed Check Meters have been used successfully and tested at several customer facilities and testing labs. (See Figures 6, 7, and 8.)



Dual Beam Reflect Mount Installation at Yslosky LA, USA
(Line Pressure: 58 barg)



Example of typical test results, conducted on 6/18/02 show "out of the box" performance meeting AGA-9 (as compared to "a reference" insert ultrasonic 5-Path meter) for a Dual Path, Field-Clamp-on, WideBeam™ gas flowmeter installation at an El Paso pipeline facility. (Test results show good correlation of both Flow and Speed of Sound measurements for Path 1 and Path 2 Data.)

Figure 6

Test Setup and Results, System 1010GC vs. Insert Ultrasonic Meter

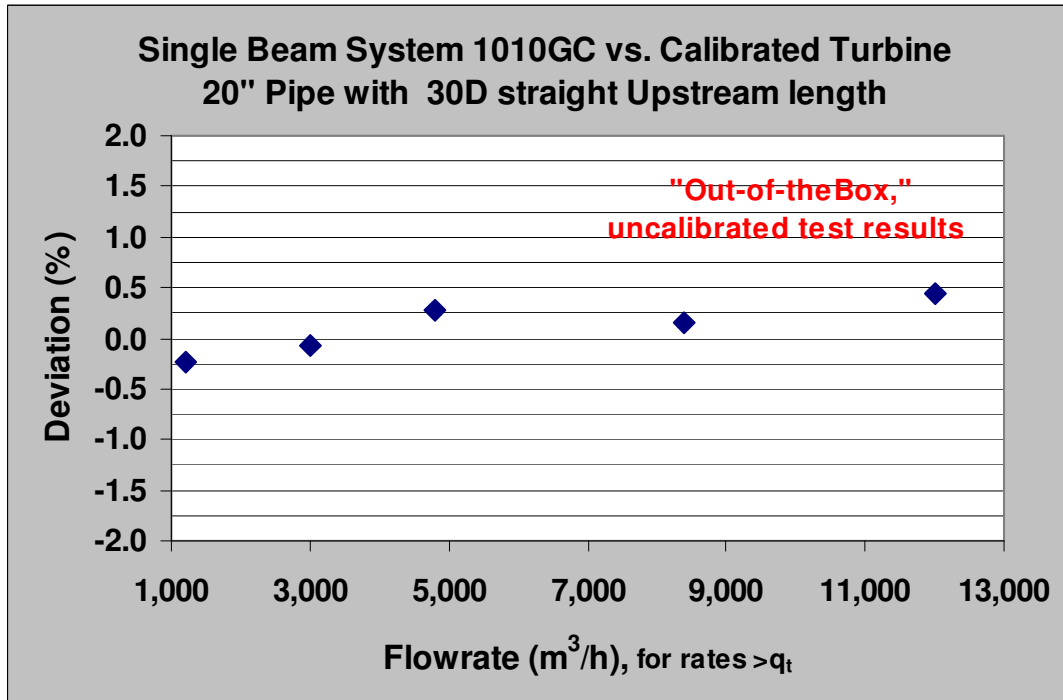


Figure 7

Test Results, System 1010GC vs. Turbine Flowmeter

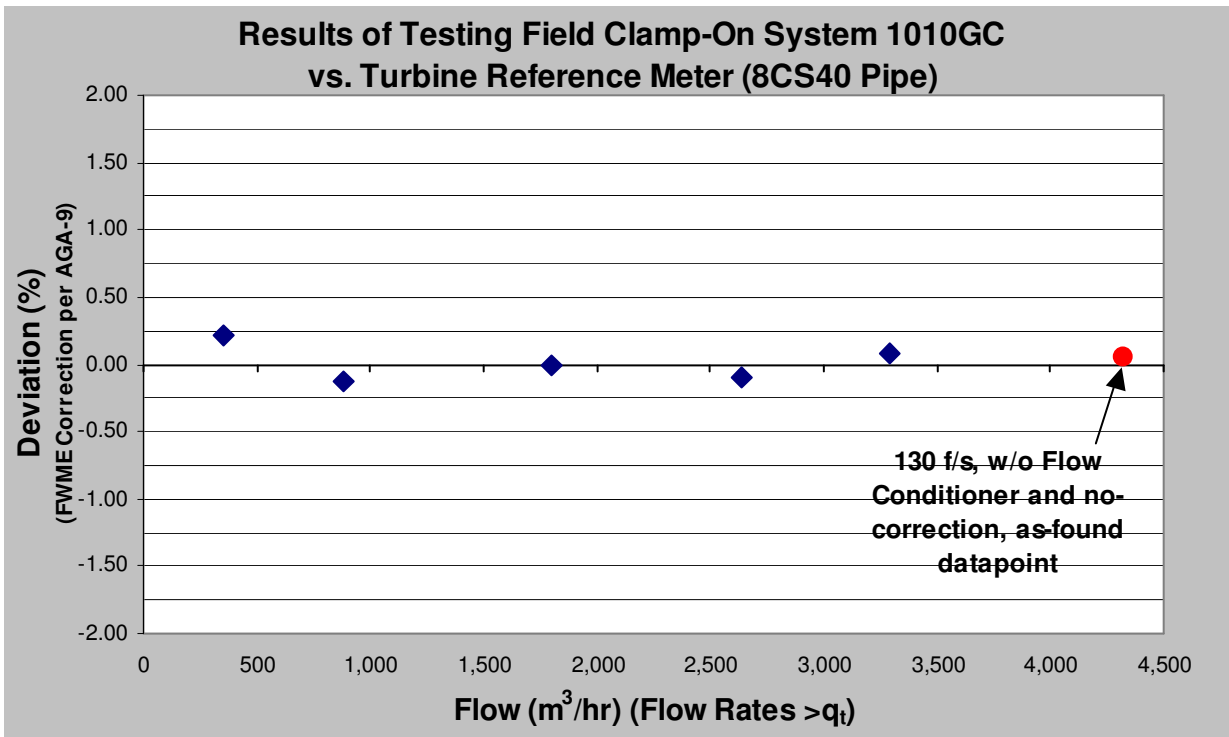


Figure 8
Results of Testing at TCC

Figure 8 shows the results of testing a field-installed Controlotron System 1010GC vs. a turbine meter. The uncalibrated plot shows the actual, uncorrected results. The “calibrated” plot shows a linear calibration around zero. From this plot it can be seen that the 1010GC results are within $\pm 0.2\%$, well within AGA-9 requirements.

Conclusion

Controlotron’s WideBeam, Cavity-Free Ultrasonic flowmeters provide benefits in total cost of ownership, maintainability, and reliability while providing equal or better performance than conventional (Old School) insertion type ultrasonic flowmeters.

External Transducer Mounting Advantages

1. External Mounting is cavity-free, with no chance of dirt or oil build up, condensation, pooling, and corrosion – all of which can block the sonic beam and impact linearity and accuracy.
2. External mounting requires no special extraction tool for transducer replacement or inspection. Transducer installation, inspection, and service can be done easily and at full pipeline pressure.
3. External Mounting provides no additional potential leak paths.
4. External mounting results in a simple meter body geometry, which is temperature stable, and has no complex transducer alignment issues. This should translate to lower price and lower maintenance costs.
5. External mounting enables field-clamp-on products to provide simple field installation without cutting pipe or stopping flow.

6. External mounting, in Reflect Mode offers better zero stability by employing a continuously active Zeromatic Path.
7. Externally mounted transducers operate at significantly higher frequencies than insert transducers. This makes them highly immune to environmental noise that has been a source of problems for insert sensors.
8. External Mounting requires fewer paths than chordal techniques as cross-flow is cancelled out in each path (in reflect or same-side mounting), and the diametric configuration is highly tolerant of swirl conditions. In addition, using a reflect-mode configuration, the path-length is typically more than twice as long as a typical chordal path and, due to WideBeam transmission, represents a much wider sample of flow.