Transit Time Flow Measurement

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Transit time ultrasonic flow measurement is based on the principle of sound energy traversing the fluid or gas in a pipe both upstream and downstream where the time difference is impacted proportionally depending on the flow rate.

The transit time method of measurement is the most commonly used in ultrasonic metering. A pulse or pulses are transmitted to and from transducers through the liquid to the opposing transducer positioned further downstream. Sound waves travel faster with the direction of flow and slower against the direction of flow. The resulting time difference between the upstream transmission and downstream transmission is proportional to the flow velocity. Hence, a zero time difference would cause the flow meter to report zero flow (*Figure 1*).

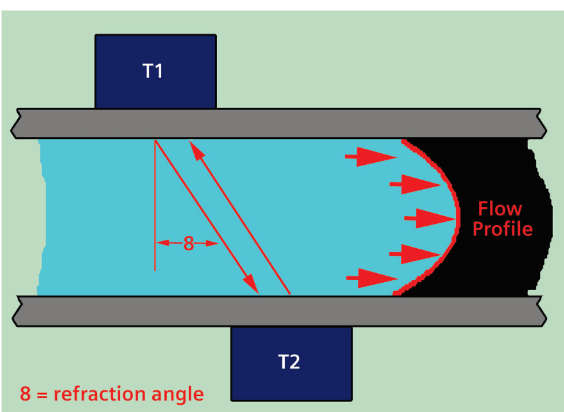

Figure 1: T1/T2 transit/receive ultrasonic signals where the difference in time is proportional to flow rate

Ultrasonic flow meters have great advantages over traditional metering that include:

- Non-intrusive measurement, allowing for virtually zero pressure drop
- No wear mechanism, reducing or eliminating maintenance costs
- Mounting sensors external to existing pipe greatly reduces installation costs
- Very large turn down ratio, typically 400:1

There are two primary forms of transit time measurement available in today's market; externally mounted diametral and insertion type chordal (*Figure 2*).

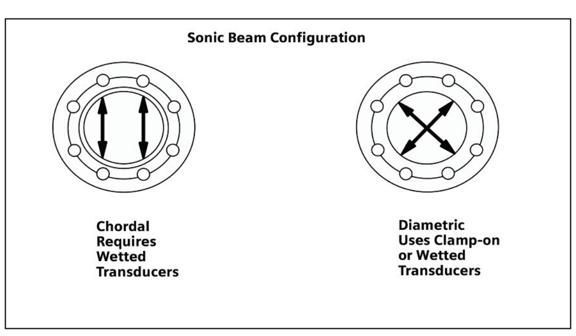

Figure 2: Orientation differences between Diametral and Chordal configurations

Both forms of measurement have their advantages and disadvantages and both can produce excellent performance results when properly installed. However, one must consider the potential performance issues associated with each type.

Diametral Measurement

Diametral measurement is achieved by placing two transducers in an offset axial distance in line with the pipe; this method causes the signals from one or multiple paths to pass through the center of the pipe and velocity stream. Multiple transducer pairs can be externally placed around the circumference of the pipe to improve accuracy. Placing the transducers on the outside of an already existing pipe will also greatly reduce installation costs.

Diametral measurement is burdened with the need to know the flow profile; this is accomplished by calculating the Reynolds number (a dimensionless number equal to the ratio of inertial to viscous forces). Once this is known, the calculation compensates for the flow profile and an accurate measurement is achieved. However, convoluted upstream piping can impact the accuracy of determining the correct flow profile and this can lead to measurement errors.

Chordal Measurement

Chordal measurement is achieved by placing two or more pairs of transducers as shown in *Figure 2*. This form of measurement is almost always done with insert type meters in the form of spool sections.

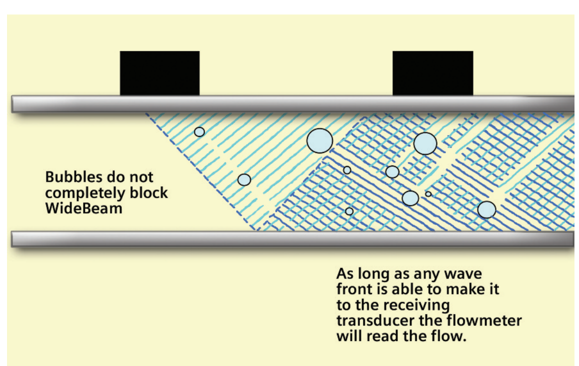

Figure 3: Representation of Wide Beam operation with entrained water/gas

Chordal measurement can more easily determine the flow profile based on the relative readings of each chord with the use of sophisticated software. However, this type of measurement has to have cavities in the pipe wall at the location of the transducers. Such cavities can cause flow profile disturbance and can produce a self-generated misrepresentation of the flow profile that can lead to measurement errors. Chordal type meters are also subject to buildup of paraffin within the cavities when measuring high viscous liquids. This can create operational failures that require corrective maintenance.

Flow Profile Considerations

Ultrasonic meters can be affected by distortions in the velocity flow profile that can, given the amount of distortion, lead to erroneous measurement errors. Straight upstream piping is an important factor when employing ultrasonic meters in high accuracy applications since valves and bends can cause vortices and swirl. These disturbances can cause errors in the measurement of flow profile and result in errors in the flow measurement.

Manufacturers of ultrasonic meters determine the flow profile and correct, as best as possible, by means of Reynolds number. It is well accepted that laminar flow is generally found for Reynolds numbers less than 2.000 and turbulent flow for Reynolds numbers greater than 10.000. The laminar and turbulent regions are generally well known and proper compensation can be made to produce highly accurate measurement.

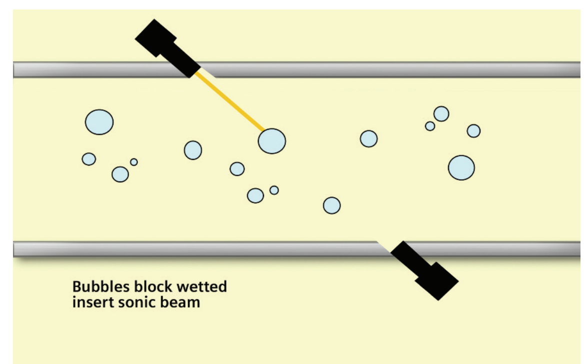

Figure 4: Representation of narrow beam (shear mode) with entrained water/gas

The region between these two is known as the transition region. The transition region is problematic in terms of ultrasonic flow measurement since it is unpredictable and difficult to measure.

Many users and manufacturers have adopted the use of flow conditioners to help reduce or completely eliminate flow profile distortions in applications where high accuracy is required but straight pipe run is not available. However, use of flow conditioners tends to negate some advantages of ultrasonic meters since they are inserted into the flow stream and can increase the pressure drop.

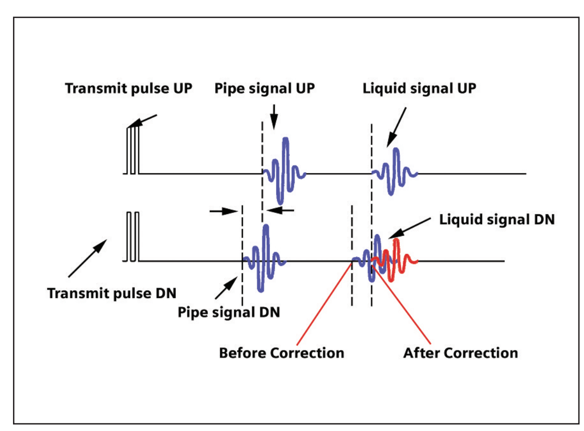

Figure 5: Representation of dynamic automatic zero function

WideBeam® Measurement Technique

The WideBeam principle utilizes externally mounted transducers that inject an ultrasonic beam into the pipe wall that matches the intrinsic sonic waveguide properties of the metal pipe. This creates a collimated transverse wave in the pipe wall that does not suffer from the internal pipe wall sonic reflections that cause major distortion of sonic waves. Basically, this technique rings the pipe at its resonant frequency.

To accomplish the WideBeam mode of operation, it is necessary that the transducer operates at the wave guide frequency of the pipe wall, which is a function of the wall thickness and the pipe material.

WideBeam technology has numerous advantages that enhance the ability of the Ultrasonic meter to maintain operation in difficult applications and improve accuracy compared to normal shear mode ultrasonic meters.

Less sensitive to aerated liquids

WideBeam technology allows sonic energy to pass through a wide swath of the liquid stream, lowering the potential for the sonic beam to be interrupted by air bubbles or solids (*Figure 3 and 4*).

Auto zeroing

Zero drift, as a result of temperature changes in the transducer crystals, has historically been a concern as the zero drift can impact the error of ultrasonic measurement. This drift is typically insignificant in applications with low accuracy requirements. However, it has become a more critical concern as accuracy requirements have increased with the advances in technology that allow custody transfer performance to be achieved.

As a result of the wide beam technology, a method of effectively eliminating zero drift has been developed that utilizes the sonic signature that travels down the pipe wall to the receiving transducer as a marker to any drift in the zero adjustment. This marker is fixed. Any difference between the arrival time of the pipe signal relative to the liquid signal can be adjusted on a continuous basis, effectively removing any drift not caused by actual flow (*Figure 5*).

Hydrocarbon Applications

Ultrasonic flow meters are being increasingly used in the Hydrocarbon industry. They are being used on applications such as:

- Custody transfer
- Check metering
- Line balance (leak detection)
- Marine loading/unloading
- Blending applications
- Well production
- FPSOs

Ultrasonic Meter Provability

Since ultrasonic meters measure flow velocity by taking multiple sample measurements every second (Up/vs. Dn timing difference), the sampling rate of this

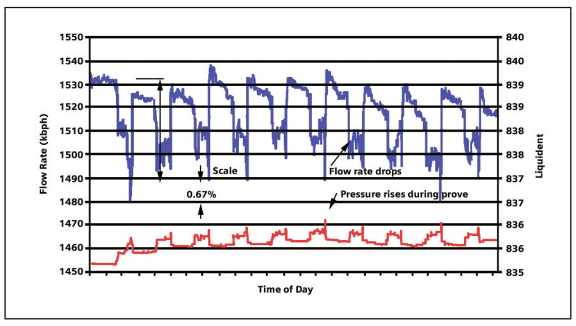

Figure 6: Trends showing behavior of flow rate during prove runs

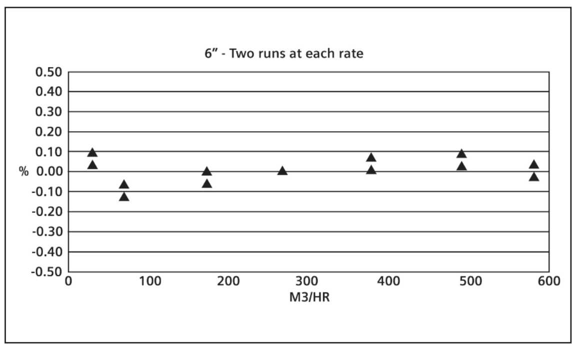

Figure 7 a: Actual calibration data for Wide beam Ultrasonic meter installed on 12 inch pipe

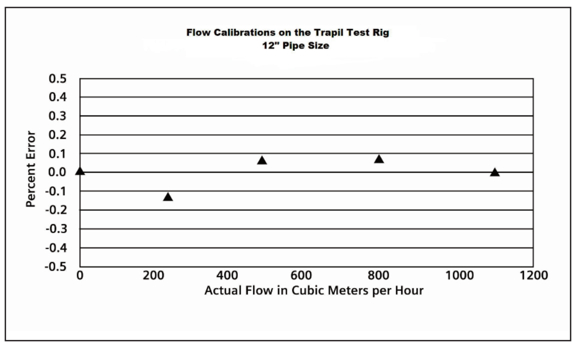

Figure 7 b: Actual calibration data with repeatability points for Wide beam Ultrasonic meter installed on 6 inch pipe

Liquid Ultrasonic Meter Task Group
TOTALIZER COMPARISON BETWEEN DOCK LINE #3 TURBINE VERSES CONTROLOTRON 1010 UFM

Batch End		Batch Start		Turbine Batch Volume		UFM Batch Volume		UFM /Turbine Deviation %	UFM /Turbine Deviation BBL	Batch Averages			
Date	Time	Date	Time	Gross BBL	Net BBL	Gross BBL	Net BBL			API@60 °F	Temperature [° F]	SG@60 °F	Gross Flow rate [bbl/Hr]
03/23/01	2:56:55	03/22/01	11:43:00	69447	65030	67071	64923	-0.165	-107	58.0	71.3	0.7466	4757.7
03/24/01	17:43:13	03/23/01	2:56:55	16204	15182	15648	15190	0.053	8	59.6	69.8	0.7406	5208.8
03/24/01	23:49:34	03/24/01	17:43:14	26679	25076	26015	25039	-0.148	-37	33.2	76.0	0.8591	4786.8
03/25/01	4:40:05	03/24/01	23:49:35	21298	20011	20750	19994	-0.085	-17	33.1	76.7	0.8598	4798.6
03/25/01	10:52:33	03/25/01	4:40:05	26644	25073	26002	25095	0.088	22	32.2	72.9	0.8644	4703.3
03/26/01	15:30:27	03/25/01	10:52:33	21811	20513	21308	20511	-0.010	-2	32.2	74.3	0.8646	4672.2
03/26/01	20:44:02	03/26/01	18:46:24	4813	4535	4696	4529	-0.132	-6	32.5	70.1	0.8629	2485.1
03/28/01	17:51:58	03/28/01	9:05:37	24344	22996	23767	23009	0.056	13	32.5	67.5	0.8628	4380.2
03/29/01	18:03:30	03/28/01	17:51:58	26560	25067	25953	25061	-0.024	-6	32.7	68.0	0.8616	4380.9
03/30/01	0:51:46	03/29/01	18:03:30	26669	25159	26060	25124	-0.139	-35	32.7	68.4	0.8615	4075.6
							Average=	-0.051					
04/03/01	8:48:57	03/30/01	0:51:46	53101	50094	51855	50069	-0.050	-25	32.9	68.2	0.8609	4399.3
04/03/01	15:21:39	04/03/01	8:48:58	26568	24987	25943	24987	0.000	0	32.3	74.5	0.8639	4177.5
04/03/01	19:59:22	04/03/01	15:21:39	21430	20110	20913	20089	-0.105	-21	32.9	79.6	0.8609	5140.0
04/04/01	23:24:36	04/03/01	19:59:22	26768	25121	26083	25103	-0.072	-18	33.0	79.0	0.8603	4709.9
04/08/01	20:43:25	04/04/01	23:24:37	26830	25196	26104	25170	-0.103	-26	33.1	75.5	0.8595	4057.2
04/11/01	10:14:38	04/08/01	20:43:26	133226	124384	128719	124477	0.075	93	43.3	84.5	0.8095	5247.5
04/11/01	17:58:27	04/11/01	10:14:38	26846	25106	26162	25099	-0.028	-7	35.1	85.0	0.8494	5126.2
04/12/01	6:55:59	04/11/01	17:58:28	16058	15020	15625	14998	-0.147	-22	35.2	84.6	0.8489	5075.4
04/12/01	19:53:58	04/12/01	6:55:59	26782	25051	26065	25058	0.028	7	35.0	84.7	0.8499	4481.5
04/13/01	2:17:39	04/12/01	19:53:59	21379	19986	20764	19986	0.000	0	34.9	85.8	0.8505	4172.3
04/13/01	17:46:01	04/13/01	2:17:39	32202	30095	31290	30082	-0.043	-13	34.3	86.9	0.8535	4072.3
04/15/01	16:35:35	04/13/01	17:46:01	26620	24875	25857	24855	-0.080	-20	34.5	86.9	0.8524	4020.8
04/15/01	23:39:56	04/15/01	16:35:36	26772	25021	25958	24960	-0.244	-61	35.0	86.4	0.8500	4097.0
							Average=	-0.059					

Figure 8: Typical achieved performance of Widebeam Ultrasonic flow meters

measurement plays an important role in the meters ability to be proved. The small flow rate changes that occur during a prove run, which are typically averaged by traditional meters, are actually "seen" and measured by ultrasonic meters (*Figure 6*).

Therefore, a very high degree of sampling rate is required to average out these variances to produce the adequate repeatability necessary for proving work against a master meter. The sampling rate of ultrasonic meters varies by manufacturer and can be as high as 80 Hz, (80 cycles/second). At this rate, it has been shown that ultrasonic meters can produce the necessary repeatability need for small volume proving.

Achievable Data Results of Ultrasonic Flow Meters (actual data)

Below are only a few samples of achieved performance of ultrasonic meters. (*Figure 8*)

Conclusion

Ultrasonic, Transit-Time flow meters offer unique advantages and high value for many oil and gas industry applications. It is important to understand the differences between the different technologies in order to make the right choice for every set of application conditions, desired level of performance and budget. It is hoped that this paper has provided some insight regarding what questions to ask manufacturers when considering their instruments for use.

Figure 9: James Doorhy, Product Manager at Siemens CoC Ultrasonic Flow

Reference Materials
- American Petroleum Institute
- International School of Hydrocarbon Measurement

New Corrosion-Resistant, Submersible Level Probe

GE Sensing & Inspection Technologies has introduced a new corrosion-resistant, submersible level probe which offers a reliable, accurate and economical solution to level measurement in a wide variety of applications. The new SLP has been developed to allow trouble-free operation in tasks ranging from level measurement in single tanks to multiple-point level data gathering in high value commodity storage facilities.

The SLP is completely hermetically sealed as a result of its innovative, mechanically robust construction, incorporating corrosion-resistant plastic materials. Consequently, it can be immersed in a wide range of fluids, from hydrocarbons to chemicals and pesticides. It can measure levels up to 70 m H2o, to an accuracy of 0.5%, in operating environments ranging from -40°C to +80°C.

The new sensor measures level by measuring hydrostatic pressure, which is a simple, well-established technique. This offers significant advantages over ultrasonic level measurement. For example, there are no problems with establishing line of sight between the transmitter and the fluid level, and there is no possibility that foaming, installation hardware or floating objects can disrupt readings. Pressure transmitters are not subject to flood damage and, being submerged, they are protected from vandalism.

Typical applications of the new sensor, which is available in both gauge and absolute versions and requires just a 10VDC, 2mA power supply, include handling a wide range of corrosive fluids in the chemicals and petrochemicals industries, monitoring the levels of silages and chemicals in the agricultural sector and operating in petrol stations and tank farms. It can also be used for environmental monitoring, especially around industrial facilities and sites where there is a potential for pollution, while the fact that it can be connected to data loggers and wireless data systems makes it an ideal, economical solution in inventory control and remote data collection.

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