WHITE PAPER

Differentiating Between Doppler & Transit Time Ultrasonic Flow Meters

Ultrasonic flow meters are non-intrusive devices that use acoustic vibrations to measure the flow rate of liquid. There are two types, Doppler and transit time. Both are designed to clamp onto the outside of the pipe without breaking the line or interrupting the flow. This also eliminates pressure losses and prevents leaking, which is common with an in-line flow meter. In addition, the flow meter does not come in contact with the liquid, thereby preventing corrosion or deterioration of the sensors. The Doppler and transit time flow meters operate on a similar principle, but the technology varies significantly. To obtain accurate measurements, it's important to know which flow meter to use for your application.

DOPPLER ULTRASONIC FLOW METERS

The Doppler ultrasonic flow meter operates on the principle of the Doppler Effect, which was documented by Austrian physicist and mathematician Christian Johann Doppler in 1842. He stated that the frequencies of the sound waves received by an observer are dependent upon the motion of the source or observer in relation to the source of the sound. A Doppler ultrasonic flow meter uses a transducer to emit an ultrasonic beam into the stream flowing through the pipe. For the flow meter to operate, there must be solid particles or air bubbles in the stream to reflect the ultrasonic beam. The motion of particles shifts the frequency of the beam, which is received by a second transducer.

FD613 Series

The flow meter measures the frequency shift, which is linearly proportional to the flow rate. This value is multiplied by the internal diameter of the pipe to derive volumetric flow as shown below:

$\Delta f = 2f_T \sin\theta \bullet V_F/V_S$

By Snell's Law (the law of refraction):

$\sin\theta_T/V_T = \sin\theta/V_S$

$V_F = \Delta f/f_T \bullet V_T/\sin\theta_T = K\Delta f$

Where:

V_T = Sonic velocity of transmitter material
θ_T = Angle of transmitter beam
K = Calibration factor
V_F = Flow velocity
Δf = Doppler frequency shift
V_S = Sonic velocity of fluid
f_T = Transmitter frequency
θ = Angle of f_T entry into liquid

Christian Johann Doppler

Volumetric flow rate = $K \bullet V_F \bullet D^2$

Where:
K = Constant
D = Inner diameter of the pipe

Whereas the Doppler ultrasonic flow meter relies on particles flowing in the liquid to operate, consideration must be given to the lower limits for concentrations and sizes of solids or bubbles. In addition, the liquid must flow at a rate high enough to keep the solids suspended.

TRANSIT TIME ULTRASONIC FLOW METERS

Transit time ultrasonic flow meters measure the difference in time from when an ultrasonic signal is transmitted from the first transducer until it crosses the pipe and is received by the second transducer. A comparison is made of upstream and downstream measurements. If there is no flow, the travel time will be the same in both directions. When flow is present, sound moves faster if traveling in the same direction and slower if moving against it. Since the ultrasonic signal must traverse the pipe to be received by the sensor, the liquid cannot be comprised of a significant amount of solids or bubbles, or the high frequency sound will be abated and too weak to travel across the pipe.

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OMEGA®

The difference in the upstream and downstream measurements taken over the same path is used to calculate the flow through the pipe:

$V = K \bullet D/\sin 2\theta \bullet 1/(T_0 - t)^2 \, \Delta T$

Where:

V = Mean velocity of flowing fluid
K = Constant
D = Inner diameter of the pipe
θ = Incident angle of ultrasonic waves
T_0 = Zero flow transit time
$\Delta T = T_1 - T_2$
T_1 = Transit time of waves from upstream transmitter to downstream receiver
T_2 = Transit time of waves from downstream transmitter to upstream transmitter
t = Transit time of waves through pipe wall and lining

The above equation shows that the flow velocity of the fluid is directly proportional to the difference in the upstream and downstream measurements.

The transit time ultrasonic flow meter has three possible transducer configurations: Z, V and W. All are recognized as a single measuring path, whereas the ultrasonic beam follows a single path. In all three configurations, the output produced by the transducers is converted to a current, frequency or voltage signal. The preferred configuration is determined by factors such as:

- Pipe size
- Space available for mounting the transducers
- Condition of the internal walls of the pipe
- Type of lining
- The characteristics of the flowing liquid

In the "Z" configuration, the transducers are positioned on opposite sides of the pipe with one downstream from the other. Usually, the distance downstream is approximately D/2, where D equals the diameter of the pipe. The optimum distance is calculated by a converter. This arrangement is only advisable under conditions where there is limited space, high turbidity, a mortar lining or a thick build-up of scale on the interior walls of the pipe. It should be avoided for installations on small pipes, where the accuracy of its measurements tends to degrade.

The "V" configuration is recommended for most installations. This arrangement places the two transducers on the same side of the pipe within approximately a diameter of the pipe from each other. A rail attachment clamps on the pipe and allows the transducers to be slid horizontally to position them the calculated distance apart.

A "W" configuration is most often used for installations on pipes with diameters of ½ inch to 1½ inches. In this arrangement, the ultrasonic signal rebounds from the wall three times; therefore, it must travel a greater distance. High turbidity liquids, and scale or deposit build-up on the interior of the pipe wall can diminish accuracy.

FACTORS INFLUENCING ACCURACY OF ULTRASONIC FLOW METERS

The accuracy of ultrasonic flow meter measurements relies on proper mounting. Large temperature changes in the pipe or a significant amount of vibration may affect the alignment of the transducers and acoustic coupling to the pipe. These factors must be accounted for during installation. In addition, to provide an accurate volumetric flow rate, all ultrasonic flow meters require that the pipe be full. A Doppler ultrasonic flow meter on a partially filled pipe will continue to generate flow velocity measurements if both transducers are mounted below the fluid level in the pipe.

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CONCLUSION

Ultrasonic flow meters are a non-contact means of measuring flow velocity. They are clamp-on devices that attach to the exterior of the pipe and enable measurement of corrosive liquids without damage to sensors. The two types of ultrasonic flow meters, Doppler and transit time, each function by way of two different technologies. An understanding of how each operates enables the selection of the appropriate flow meter. The Doppler ultrasonic flow meter must have particles or bubbles to reflect the ultrasonic signals. It is best used for dirty or aerated liquids such as wastewater and slurries. A significant amount of solids or bubbles in the liquid will weaken the signal emitted by the transit time ultrasonic flow meter. Therefore, it is best used with clean liquids such as water or oil.

Source

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