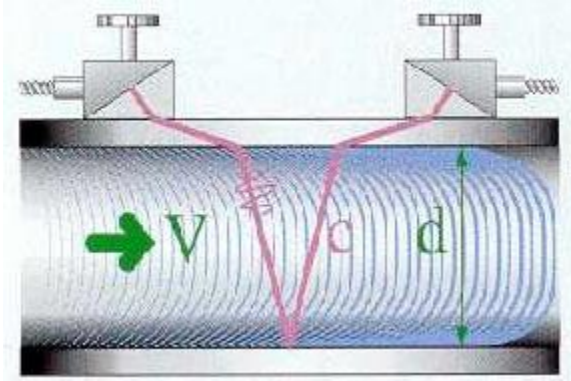


Clamp-on Ultrasonic Flowmeters - Measuring Principle



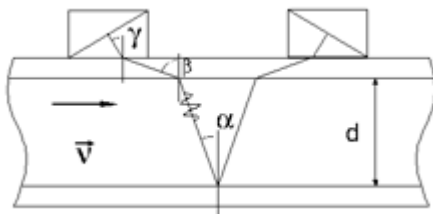
The flow measurements are made by penetrating the pipe with ultrasound. Time differences, frequency variations or phase shifts of the ultrasonic signals caused by the flowing liquid are subsequently evaluated.

The measurement of flow is based on the principle that sound waves traveling in the direction of flow of the fluid require less time than when traveling in the opposite direction. The difference in transit times of the ultrasonic signals is an indication for the flow rate of the fluid. Since ultrasonic signals can also penetrate solid materials, the transducers can be mounted onto the outside of the

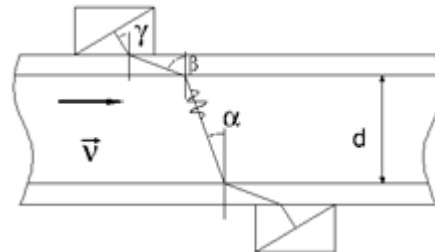
pipe. Fast digital signal processors and sophisticated signal analysis guarantee reliable measuring results even under difficult conditions where previously ultrasonic flowmeters had failed.

Transit-time principle

Transit-time flowmeters utilize two transducers, which function as both ultrasonic transmitters and receivers. The transducers are clamped to the outside of a closed pipe at a specific distance from each other. This distance is calculated by the flowmeter after all pipe and medium parameters have been entered into the instrument.

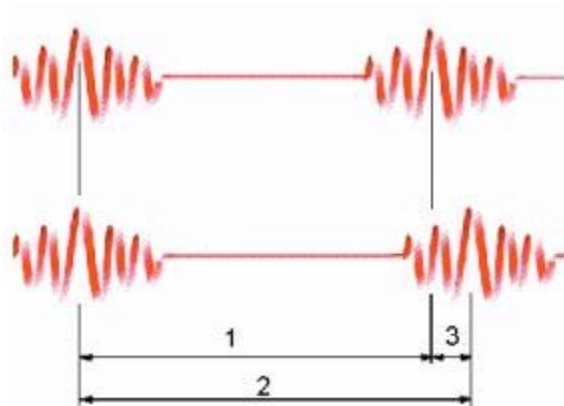


Reflection Mode



Diagonal Mode

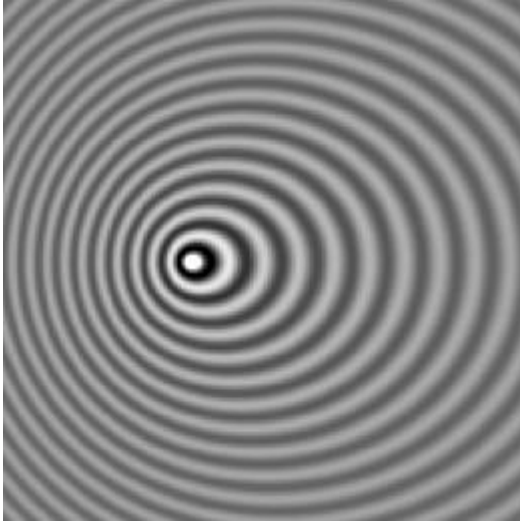
The transducers can be mounted in reflection or in diagonal mode. This selection is based on pipe and liquid characteristics.



The flowmeter operates by alternatively transmitting and receiving ultrasonic signal pulses between the two transducers. The ultrasonic signals are first transmitted in the direction of the fluid (1) and then against fluid flow (2). Since sound energy in a moving liquid is carried faster when it travels in the direction of flow than against it, a time difference (3) between the signals' time-of-flight will occur. If the fluid is not moving, the time difference is zero and the flowmeter will indicate zero flow. The transit-time (or time-of-flight) of the signals is accurately measured in both flow directions and the difference in time calculated. The time difference of the ultrasonic signals is proportional to the flow velocity in the pipe.

The measured flow velocity is multiplied with the cross-sectional area of the pipe; hence the flow rate of the fluid can be calculated. Using the transit-time technique, accuracies of 1 % of measured value can be achieved without process calibration.

Doppler Flow Measurement



The **Doppler effect**, named after Christian Doppler, is the apparent change in frequency and wavelength of a wave that is perceived by an observer moving relative to the source of the waves. For waves, such as sound waves, that propagate in a wave medium, the velocity of the observer and the source are reckoned relative to the medium in which the waves are transmitted. The total Doppler effect may therefore result from either motion of the source or motion of the observer.

For waves that travel through a medium (sound, ultrasound, etc...) the relationship between observed frequency f' and emitted frequency f is given by:

$$f' = \left(\frac{v + v_o}{v - v_s} \right) f$$

where

v is the velocity of the waves (340 m/s for sound)

v_o is the velocity of the observer and

v_s is the velocity of the source (the thing emitting the sound)

For sign convention on velocity: a positive value is used if the motion is towards the other, and a negative value if the motion is away from the other

It is important to realize that the frequency of the sounds that the source *emits* does not actually change. To understand what happens, consider the following analogy. Someone throws one ball every second in a man's direction. Assume that balls travel with constant velocity. If the thrower is stationary, the man will receive one ball every second. However, if the thrower is moving towards the man, he will receive balls more frequently because the balls will be less spaced out. The converse is true if the thrower is moving away from the man. So it is actually the *wavelength* which is affected; as a consequence, the perceived frequency is also affected.

If the moving source is emitting waves through a medium with an actual frequency f_0 , then an observer stationary relative to the medium detects waves with a frequency f given by:

$$f = f_0 \left(\frac{v}{v + v_{s,r}} \right)$$

where v is the speed of the waves in the medium and $v_{s,r}$ is the speed of the source with respect to the medium (positive if moving away from the observer, negative if moving towards the observer), radial to the observer.

A similar analysis for a moving observer and a stationary source yields the observed frequency (the observer's velocity being represented as v_o):

$$f = f_0 \left(1 - \frac{v_o}{v} \right)$$

where the same convention applies : v_o is positive if the observer is moving away from the source, and negative if the observer is moving towards the source.

Doppler flow meters use sound the pulse reflection principle to measure liquid flow rates. Solids or bubbles in suspension in the liquid reflect the sound back to the receiving transducer with a change in wavelength and an associated shift in frequency proportional to the flow velocity.

