GE Panametrics Transit-Time
Flow Measurement Technique

With this flow measurement method, two transducers (1 pair) are utilized as both ultrasonic-signal generators (transmitters) and receivers. This is accomplished through the use of piezoelectric crystal technology. Piezoelectricity literally means electricity resulting from pressure and an ultrasonic signal is nothing more than a pressure wave that exists at frequencies above that of typical human hearing (ie. > 20 kHz).

When a piezoelectric crystal is impacted by an ultrasonic pressure wave, the result is an electric output of relative magnitude and frequency to that of the incident or received wave.

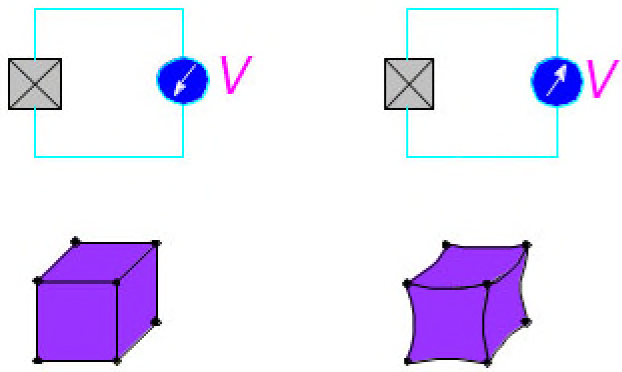


Figure 1 No Pressure on Crystal | Pressure on Crystal
CRYSTAL OPERATING AS RECEIVER

Conversely, these materials will generate mechanical force when an electrical current is applied. Piezoelectric materials respond to electric current by changing shape.

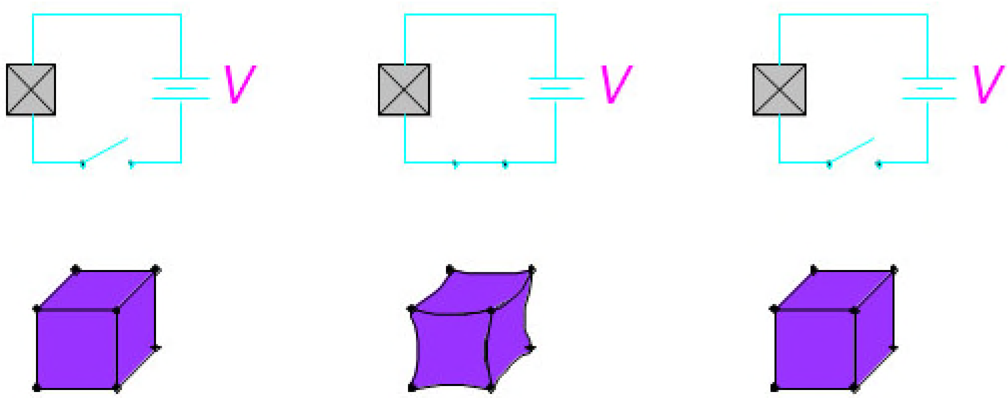


Figure 2 Crystal is Disconnected | Crystal is Charged | Crystal is Disconnected Again
CRYSTAL OPERATING AS TRANSMITTER

It is this "transceiver" (transmit and receive) quality of piezoelectric crystals that enable them to be used for Transit-Time flow measurement. When mounted on a pipe, they are in acoustic communication with each other, meaning that the second transducer can receive ultrasonic signals transmitted by the first transducer and vice versa. In operation, each transducer functions as a transmitter, generating a certain number of acoustic pulses, and then as a receiver for an identical number of pulses.

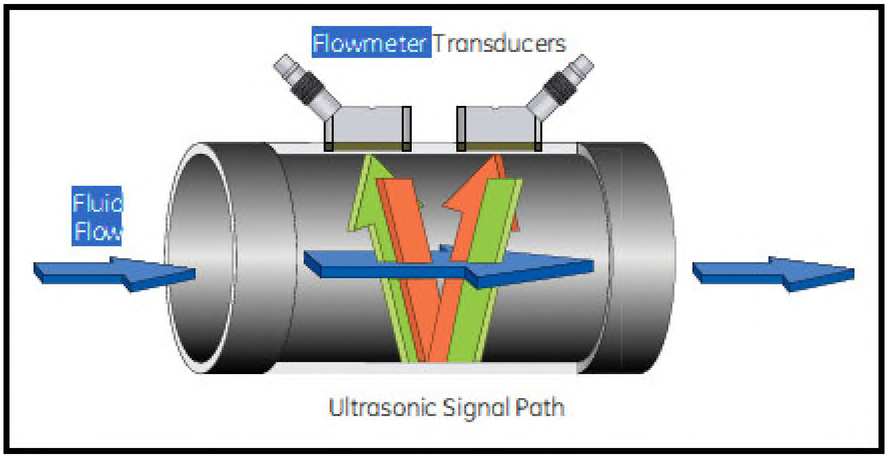
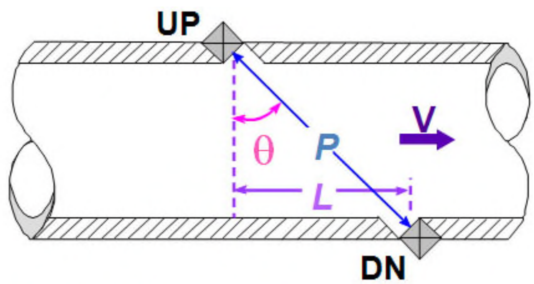


Figure 3 Basic Arrangement of Dual Traverse Clamp-on Transit-Time Flowmeter

The time interval between transmission and reception of the ultrasonic signals is measured in each direction. When the liquid in the pipe is not flowing, the transit-time downstream equals the transit-time upstream. When the liquid is flowing, the transit-time downstream is less than the transit-time upstream.

$$\text{DISTANCE} = \text{RATE} \times \text{TIME}$$

$$\text{TIME} = \frac{\text{DISTANCE}}{\text{RATE}}$$



NO FLOW

$$t_{up} = \frac{P}{c}$$

$$t_{dn} = \frac{P}{c}$$

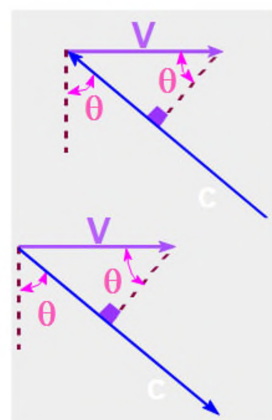
$$\Delta t = t_{up} - t_{dn} = 0$$

WITH FLOW

$$t_{up} = \frac{P}{c - V\sin\theta}$$

$$t_{dn} = \frac{P}{c + V\sin\theta}$$

$$\Delta t = t_{up} - t_{dn}$$



The difference between the downstream and upstream transit times is proportional to the velocity of the flowing liquid, and its sign indicates the direction of flow. For simplicity, the inverse of the 2 transit-times are used allowing a simple form of the resultant flow equation as follows:

$$\frac{1}{t_{up}} = \frac{c - V\sin\theta}{P} \quad \& \quad \frac{1}{t_{dn}} = \frac{c + V\sin\theta}{P}$$

$$\Delta t = \frac{1}{t_{dn}} - \frac{1}{t_{up}} = \frac{c + V\sin\theta}{P} - \frac{c - V\sin\theta}{P}$$

$$\frac{1}{t_{up}} - \frac{1}{t_{dn}} = \frac{2V\sin\theta}{P}$$

$$V = \frac{P}{2\sin\theta}\left(\frac{1}{t_{dn}} - \frac{1}{t_{up}}\right).$$

Since $\sin\theta = \frac{L}{P}$.

$$V = \frac{P^2}{2L}\left(\frac{1}{t_{dn}} - \frac{1}{t_{up}}\right).$$

Note that the soundspeed of the fluid has no effect on the flow measurement (velocity). In terms of variables, velocity is a function of the 2 transit-times only. With the large scale application of digital electronics into electronic instrumentation in the 1980's, this measurement is now both accurate and stable. Note also that the location of the transducers relative to each other (ie. path length P and axial length L) can also impact the accuracy of the flow measurement if there are not measured carefully. Although they are constants for any given application / installation, it is required that the values used in the flow computer be accurate to that which exists on the pipe.

Solving for volumetric flow requires the area averaged flow velocity to be multiplied by the cross-sectional area. Since the velocity measurement is made across the flow profile (one or more times depending upon the number of traverses), it inherently provides for a reasonable integration of the flow profile in the installed axis. Issues of less than fully developed flow profile may be solved by either alignment the measurement axis or additional measurement paths on multiple (other) axes. Further discussion on this is beyond the scope of this overview of the transit-time measurement technique.