Selection of flowmeters:

Selecting a flowmeter can be an easy or a difficult task depending on the requirements. It is important to remember that there is no universal flowmeter that will be appropriate for every application. The selection process can be driven by many factors. Here we will list some of them

1. Accuracy requirements in the particular application
2. Repeatabililty requirements in the particular application
3. Price /economic constraints
4. Personal or company preference
5. Brand preference
6. Robustness or ability to work in harsh or hazardous type conditions
7. Size
8. Ease of installation
9. Longevity
10. Response time
11. Special requirements

Since currently there is exists no single type of flowmeter that meets everyone's requirements, it is possible for several companies around the world to manufacture and develop many types of flow measurement devices which are sold/supplied into various industries. This short training course has not been designed to serve as a recommendation tool since this task must be left to the manufacturers, consultants and engineers and technical sales personnel. Instead, we will take a look at some of the more prominent designs and measurement techniques of flowmeters to broaden the understanding of the reader.

Variable Area flow meters (also referred to as Rotameters)

Despite the growing popularity of other flowmeter types, the variable area flowmeter continues to command a major portion of the industrial market. Although it has not enjoyed the same degree of publicity granted more exotic meter forms in technical literature, continuing innovations and developments in variable-area metering have greatly enhanced the capabilities of this popular flow monitor. Their basic advantages--relatively low cost, accurate and reliable performance, simplicity, and inherent versatility--remain valid today. Available in a wide variety of metals and plastics, and with current alarm and control options, variable area meters can be used with a wide variety of liquid, gas, and steam applications.

Perhaps the best known of the variable area meter family is the "rotameter," first patented in the United States in 1868. In its basic form, the rotameter consists of a vertically oriented tapered glass tube with the large end at the top, and a metering float which is free to move within the tube. Fluid flow causes the float to begin to rise in the tube as the upward pressure differential and buoyancy of the fluid overcome the effect of gravity.

The float will rise until the annular area between the float and tube increases sufficiently to allow a state of dynamic equilibrium between the (upward) pressure differential and buoyancy factors, and (downward) gravity factors. The height of the float is an indication of flow rate, and the tube can be graduated in appropriate flow units.

These meters typically can have up to a 12 to 1 turndown (ratio of maximum to minimum measures flow), and industrial accuracies of +/- 2% or even 1% of the full scale rating.

To meet the demands of a variety of industrial requirements, a variety of constructions has become common. Glass is often replaced with various plastic or metal components, with some form of magnetic position sensing being used in the latter case. The use of magnetic float sensing is also used for alarm and signal transmission functions, in many cases.

SLOTTED TUBE FLOWMETERS

Another variation of industrial variable area meters uses a slotted cylinder and piston rather than a tapered tube (see figure). This piston portion of the meter float travels within a precision-honed cylinder, with the piston acting as the fourth side of the slot. As with tapered tube meters, fluid flow raises the piston until sufficient slot area is exposed to bring all forces into dynamic equilibrium. To assure constant buoyancy, a "snorkel" device allows the top of the unit to fill with fluid in liquid applications.

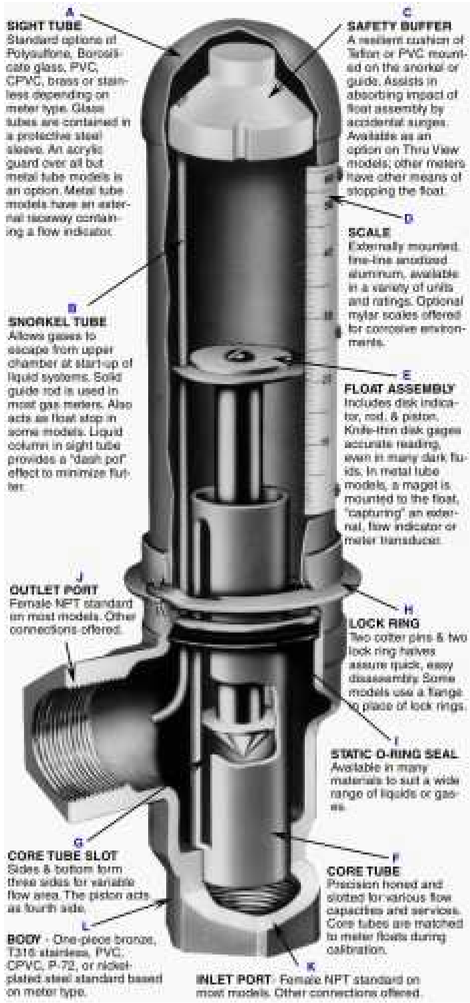
The metering cylinder and piston are contained within a T-shaped body, and flow is read by means of a knife-edged disk supported by an extension from the piston. This disk moves up and down in response to flow within a transparent sight tube containing an externally mounted scale. As the tube is cylindrical and the disk always close to its walls, flow can be read in dirty fluids. If a transparent sight tube cannot be used, a magnet is added to the float and an external indicator used. Use of a magnet on or encapsulated in the float also provides alarm and control functions with appropriate accessories.

Advantages of this meter style include more compact and less costly construction, high rangeabilities of 25 to 1, and easy access to flow internals for cleaning or changing meter capacity without removing the unit from the pipeline. Standard accuracy is +/-2% full scale, with +/-1% calibrations as an option, and repeatability +/-0.3% of rate. Pressure drops are reasonably low, and similar to tapered tube models.

VANE AND PISTON FLOWMETERS

Yet another style of variable area meter incorporates a spring-loaded orifice and tapered plug or a vane within a "bowl." Fluid flow moves the vane or orifice, exposing a greater area around the tapered plug or within the bowl until equilibrium is achieved. Flow is read by means of a pointer mechanically positioned by the vane, or by a magnetic indicator. Although use of a spring does have drawbacks in terms of pressure drop and repeatability, the principal flow element does not rely on gravity and, therefore, these meters can be mounted in any position.

Accuracies vary from +/-2% to +/-5%, depending on the model, and average repeatability is +/-1%. Rangeability is usually 6 or 10 to 1. Because of the incorporation of the spring, pressure drops are high (often expressed in pounds rather than inches W. C. as with other variable area meters), and generally go up from 2 psig.



Differential Pressure Meters

The use of differential pressure as an inferred measurement of a liquid's rate of flow is well known. Differential pressure flowmeters are, by far, the most common units in use today. Estimates are that over 50 percent of all liquid flow measurement applications use this type of technology.

The basic operating principle of differential pressure flowmeters is based on the knowledge that the pressure drop across the meter is proportional to the square of the flow rate. The flow rate is obtained by measuring the pressure differential and extracting the square root.

Differential pressure flowmeters, like most flowmeters, have a primary and secondary element. The primary element causes a change in kinetic energy, which creates the differential pressure in the pipe. The unit must be properly matched to the pipe size, flow conditions, and the liquid's properties. And, the measurement accuracy of the element must be good over a reasonable range. The secondary element measures the differential pressure and provides the signal or read-out that is converted to the actual flow value.

Orifices are the most widely liquid flowmeters in use today. An orifice is simply a flat piece of metal with a specific-sized hole bored in it. Most orifices are of the concentric type, but eccentric, conical (quadrant), and segmental designs are also available.

An orifice plate is a very simple device installed in a straight run of pipe. The orifice plate contains a hole smaller than the pipe diameter. The flow constricts, experiences a pressure drop, and then the differential pressure can be related to a flow.

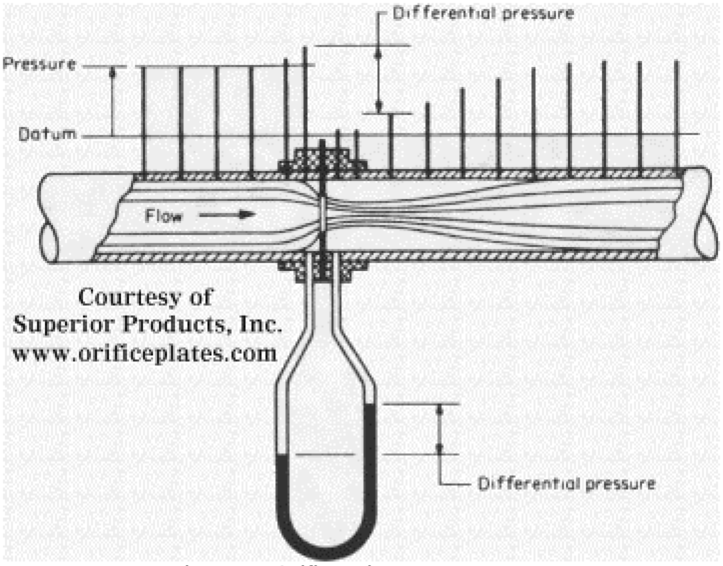
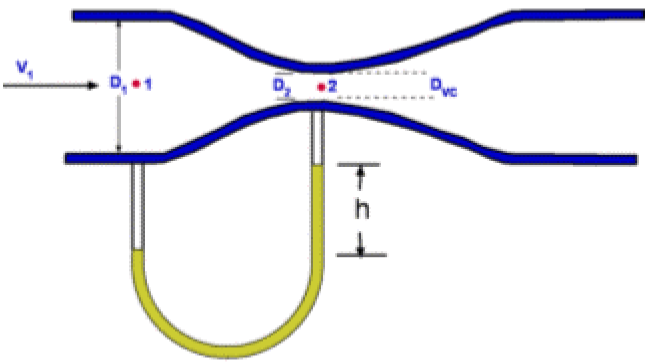


Figure 1: Orifice Plate Arrangement

In practice, the orifice plate is installed in the pipe between two flanges. Acting as the primary device, the orifice constricts the flow of liquid to produce a differential pressure across the plate. Pressure taps on either side of the plate are used to detect the difference. Major advantages of orifices are that they have no moving parts and their cost does not increase significantly with pipe size.

The segmental wedge is a variation of the segmental orifice. It is a restriction orifice primarily designed to measure the flow of liquids containing solids. The unit has the ability to measure flows at low Reynolds numbers and still maintain the desired square-root relationship. Its design is simple, and there is only one critical dimension the wedge gap. Pressure drop through the unit is only about half that of conventional orifices. Integral wedge assemblies combine the wedge element and pressure taps into a one-piece pipe coupling bolted to a conventional pressure transmitter. No special piping or fittings are needed to install the device in a pipeline. Metering accuracy of all orifice flowmeters depends on the installation conditions, the orifice area ratio, and the physical properties of the liquid being measured.

Venturi tubes have the advantage of being able to handle large flow volumes at low pressure drops. A venturi tube is essentially a section of pipe with a tapered entrance and a straight throat. As liquid passes through the throat, its velocity increases, causing a pressure differential between the inlet and outlet regions.



Fig, 19 Venturi Tube

The flowmeters have no moving parts. They can be installed in large diameter pipes using flanged, welded or threaded-end fittings. Four or more pressure taps are usually installed with the unit to average the measured pressure. Venturi tubes can be used with most liquids, including those having a high solids content.

Fig 20 Flow Nozzle

Flow Nozzles, at high velocities, can handle approximately 60 percent greater liquid flow than orifice plates having the same pressure drop. Liquids with suspended solids can also be metered. However, use of the units is not recommended for highly viscous liquids or those containing large amounts of sticky solids.

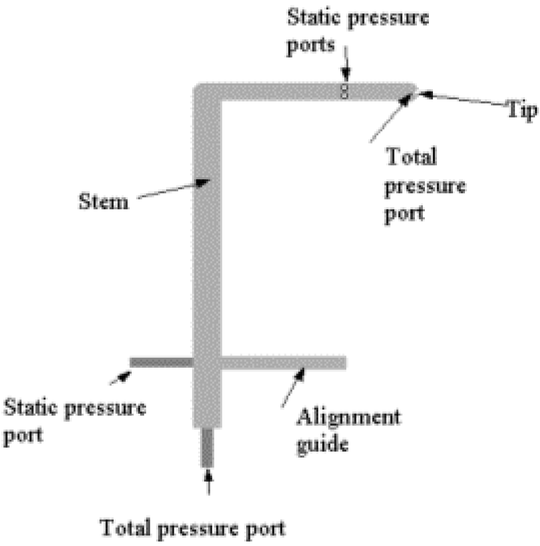


Fig. 21 Pitot tube

Pitot tubes sense two pressures simultaneously, impact and static. The impact unit consists of a tube with one end bent at right angles toward the flow direction. The static tube's end is closed, but a small slot is located in the side of the unit. The tubes can be mounted separately in a pipe or combined in a single casing. Pitot tubes are generally installed by welding a coupling on a pipe and inserting the probe through the coupling. Use of most pitot tubes is limited to single point measurements. The units are susceptible to plugging by foreign material in the liquid. Advantages of pitot tubes are low cost, absence of moving parts, easy installation, and minimum pressure drop.

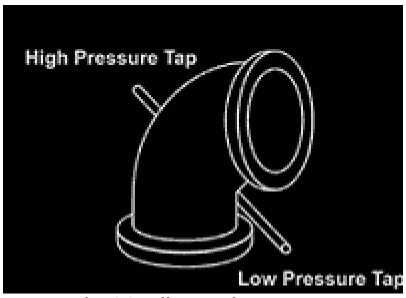


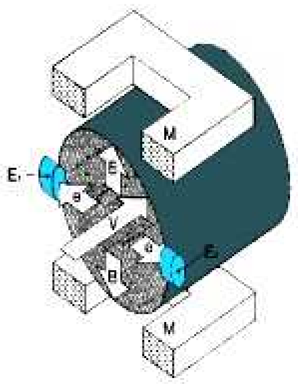
Fig 22 Elbow Flow meter

Elbow meters operate on the principle that when liquid travels in a circular path, centrifugal force is exerted along the outer edges. Thus, when liquid flows through a pipe elbow, the force on the elbow's interior surface is proportional to the density of the liquid times the square of its velocity. In addition, the force is inversely proportional to the elbow's radius. Any 90 deg. pipe elbow can serve as a liquid flowmeter. All that is required is the placement of two small holes in the elbow's midpoint (45 deg. point) for piezometer taps. Pressure-sensing lines can be attached to the taps by using any convenient method.

Target meters sense and measure forces caused by liquid impacting on a target or drag-disk suspended in the liquid stream. A direct indication of the liquid flow rate is achieved by measuring the force exerted on the target. In its simplest form, the meter consists only of a hinged, swinging plate that moves outward, along with the liquid stream. In such cases, the device serves as a flow indicator. A more sophisticated version uses a precision, low-level force transducer sensing element. The force of the target caused by the liquid flow is sensed by a strain gage. The output signal from the gage is indicative of the flow rate. Target meters are useful for measuring flows of dirty or corrosive liquids. Some manufacturers also apply them to certain steam applications.

Electromagnetic Flowmeters (Magmeters)

The operating principle of magnetic flowmeters is based upon Faraday's Law of electromagnetic induction,
" It states that a voltage will be induced in a conductor moving through a magnetic field."



Faraday's Law :
E=kBDV Where
E = Induced Voltage,
B = Strength of the magentic field,
D = Conductor Width,
V = Velocity of the conductor

The magnitude of the induced voltage E is directly proportional to the velocity of the conductor V, conductor width D, and the strength of the magnetic field B. Magnetic field coils placed on opposite sides of the pipe generate a magnetic field. As the conductive process liquid moves through the field with average velocity V, electrodes sense the induced voltage. The width of the conductor is represented by the distance between electrodes. An insulating liner prevents the signal from shorting to the pipe wall. The only variable in this application of Faraday's law is the velocity of the conductive liquid V because field strength is controlled constant and electrode spacing is fixed. Therefore, the output voltage E is directly proportional to liquid velocity, resulting in the linear output of a magnetic resulting in the linear output of a magnetic flowmeter

Magnetic flowmeters are based on Faraday's Law of Magnetic Induction. In a magnetic flowmeter, the liquid acts as a conductor as it flows through the pipe. This induces a voltage which is proportional to the average flow velocity - the faster the flow rate, the higher the voltage. This voltage is picked up by sensing electrodes mounted in the meter tube and sent to the transmitter which takes the voltage and calculates the flow rate based on the cross sectional area of the meter tube.

Where to use

- High percentage of solids

- Sludges, slurries, minerals, paper, sewage - flows with high levels of solids which cannot be measured other types of meters.
- Obstructionless measurement
- Nothing projects into the flow stream, no head loss, no parts to maintain.
- Very corrosive liquids
- Acids, caustics and corrosive chemical additives are isolated from the meter by inert linings and electrodes.
- Conductive Liquids
- Liquids where conductivity is at sufficient levels to induce measurable voltage

Turbine Flow meters

Turbine type flowmetering devices are applied worldwide to the measurement and control of liquid products in the industrial, chemical and petroleum marketplaces. Significant advantages associated with the use of turbine flowmeters, in lieu of other metering principles, make increased future use inevitable. Newcomers to the field of flow measurement should become familiar with fundamental characteristics and conditions surrounding the turbine flowmeter in order to better understand its usage. Consequently, this article is provided as a brief guide to the operation and application of turbine flowmeters for liquid product measurement.

The basic construction of the turbine flowmeter incorporates a bladed turbine rotor installed in a flow tube. The rotor is suspended axially in the direction of flow through the tube. The turbine flowmeter is a transducer, which senses the momentum of the flowing stream. The bladed rotor rotates on its axis in proportion to the rate of the liquid flow through the tube.

TURBINE ROTATION
As the liquid product strikes the front edge of the rotor blades, a low-pressure area is produced between the upstream cone and the rotor hub.
The blades of the turbine rotor will tend to travel toward this low-pressure area as a result of this pressure differential across the blades. The pressure differential (or pressure drop) constitutes the energy expended to produce movement of the rotor. The initial tendency of the rotor is to travel downstream in the form of axial thrust. But since the rotor is restrained from excessive downstream movement, the only resulting movement is rotation.
Fluid flowing through the meter impacts an angular velocity to the turbine rotor blades, which is directly proportional to the linear velocity of the liquid. The degree of the angular velocity or number of revolutions per minute of the turbine rotor is determined by the angle of the rotor blades to the flowing stream of the approach velocity.

ROTOR BALANCE
With axial thrust forcing the turbine rotor downstream, the friction resulting from contact between the turbine rotor and the downstream cone would cause excessive wear if there were not some means of balancing the turbine rotor on its axis between the upstream and the downstream cone.
Bernoulli's Principle states that when flow velocity decreases, the static pressure increases. Therefore, a high-pressure area exists at the downstream side of the turbine rotor exerting an upstream force on the rotor. As a result, the turbine rotor is hydraulically balanced on its axis.

SIGNAL OUTPUT
Electrical output is generated using the principle of reluctance. A pickup coil, wrapped around a permanent magnet, is installed on the exterior of the flow tube or the meter body immediately adjacent to the perimeter of the rotor (Figure 1). The magnet is the source of the magnetic flux field that cuts through the coil. Each blade of the turbine rotor passing in close proximity to the pickup coil causes a deflection in the existing magnetic field. This change in the reluctance of the magnetic circuit generates a voltage pulse within the pickup coil.
Each pulse generated represents a discrete amount of volumetric throughput. Dividing the total number of pulses generated by the specific amount of liquid product that passed through the turbine flowmeter determines the K-Factor. The K-Factor, expressed in pulses per unit volume, may be used with a factoring totalizer to provide an indication of volumetric throughput directly in engineering units. The totalizer continuously divides the incoming pulses by the K-Factor (or multiplies them with the inverse of the K-Factor) to provide factored totalization. The frequency of the pulse output, or number of pulses per unit time, is directly proportional to the rotational rate of the turbine rotor. Therefore, this frequency of the pulse output is proportional to the rate of the flow.

By dividing the pulse rate by the K-Factor, the volumetric throughput per unit time of the rate of flow can be determined. Frequency counters or converters are commonly used to provide instantaneous flow rate indication. Plotting the electrical signal output versus flow rate provides the characteristics profile or calibration curves for the turbine flowmeter.
Electrical output is also generated using the principle of inductance. A pickup coil is installed on the

exterior of the flow tube immediately adjacent to the perimeter of the turbine rotor. The magnetic source of the flux field in this type of output is either the rotor itself or small magnets installed in the rotor. In the case of the rotor, the material of construction would be nickel or some other easily magnetized flux field. The results are identical to that of the reluctance principal.

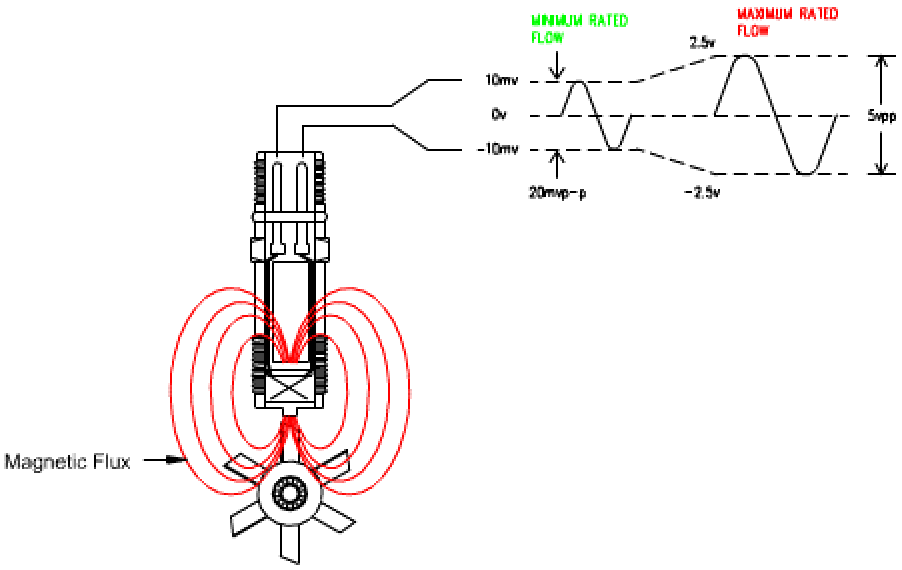


Figure 1

ACCURACY
The accuracy of a turbine flowmeter is derived from its output (electrical or mechanical) and is the measure of the deviation of an indicated measurement from the referenced standard. Turbine meter accuracy is dependent upon several items.
The accuracy must include the error associated with the calibration standard. In the USA, the National Institute of Standards and Technology represents the flow standard.
Linearity is the variation of the flowmeter K-factor from a nominal value of a point on a curve. Normally during calibration, a value is chosen which makes linearity fall in line with accuracy. Linearity may remain constant during meter life although the absolute accuracy level has changed.
Repeatability is the ability of a turbine flowmeter to reproduce its output indefinitely under constant operating conditions at any point over its specified operating range.

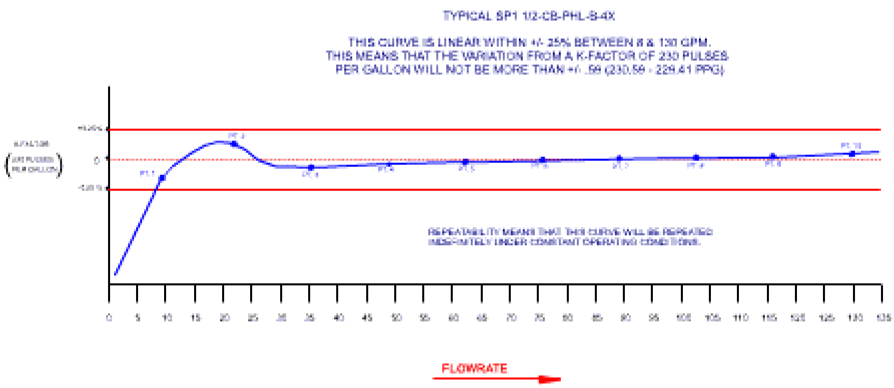


Figure 2 (click on the image to enlarge picture)

SPECIFIC GRAVITY
The specific gravity of a liquid is the ratio of its density to that of water at 4BC (39.2BF) and is dimensionless. While changes in specific gravity do not affect the average turbine meter K-factor value, the overall linear range of the flowmeter is changed (Figure 2). The linear range represents the minimum to the maximum flow rate within which the linearity of the flowmeter is specified.
As stated previously, the rotor rotates due to pressure differential across the rotor blades. Specific gravity is one of the factors affecting this pressure differential. As the specific gravity decreases, the pressure differential decreases. On a fluid with a low specific gravity and a low flow rate, the pressure differential across the blades is very low. This leaves almost no energy for turning the rotor. Consequently, the rotor cannot turn in proportion to the liquid throughput and the K-factor drops off.

Therefore, the angle of the rotor blades is changed to help compensate for the change to a lower specific gravity. This allows products with lower specific gravity's to be measured accurately by the turbine flowmeter.

VISCOSITY
Viscosity if the measure of the liquid products resistance to flow. Kinematics viscosity is the ratio of the absolute viscosity to the specific gravity, usually expressed in centistokes (cs), where the resistance to flow is measured in square millimeters per second (mm2/s).

VISCOSITY EFFECTS ON RANGEABILITY
Viscosity has two different effects on the turbine flowmeter rotor. First of all, the profile causes boundary layer thickness to increase as viscosity increases for a fixed volume. This means that rotor-blade shape and length will be important in determining the K-factor since the flow around the blade tip region changes with respect to viscosity. This boundary layer thickness causes the turbine flowmeter to be non-linear. Supplying a shroud around the turbine rotor, with the shroud outer diameter slightly smaller than the inside diameter of the flow tube, increases the viscosity and creates a drag (resistance to rotation). This drag offsets the non-linear effect of the boundary layer.
The second effect of viscosity is one of viscous shear-force change on the rotor and increased viscous drag within the bearing. These effects act to slow the rotor while the profile effect acts to speed the rotor. The relative magnitude of all these forces changes the Reynolds number.
As previously indicated, some turbine flowmeter designs introduce a device or shroud that introduces viscous drag, which eliminates the hump that normally, occurs in the transition region.
While linearity is affected by viscosity, repeatability is not.

FLOW RANGE
The minimum flow rate of a turbine flowmeter becomes a factor of viscosity versus the degree of accuracy. As product viscosity increases, the minimum flow rate required to maintain a specific degree of accuracy increases. The maximum rate of flow allowable becomes a factor of viscosity versus the pressure drop across the flowmeter. As the product viscosity increases, the maximum flow rate decreases in accordance with the maximum allowable pressure drop across the flowmeter. In order to arrive at the minimum and maximum rate of flow limits for a particular turbine flowmeter size and application these factors must first be determined:
· The viscosity of the product to be metered (or maximum value of viscosity for products with varying viscosity's at 37.8B (100BF).
· The degree of accuracy required.
· The maximum amount of pressure drop allowed across the flowmeter.

Using an area-of-operation diagram for a particular turbine flowmeter size and charting the factors for viscosity accuracy and pressure drop will determine the minimum and maximum flow rates.

Operating the flowmeter within this flow range will meet the operating requirements unique to that application. Technical bulletins providing area of operation for turbine flowmeter sizes with varying viscosity fluids can be obtained from the various meter manufacturers.

CAVITATION
Cavitation in a turbine flowmeter will take place when the local pressures fall close to or below the vapor pressure of the liquid product. The formation of bubbles and their collapse or local vaporization of product as it passes over the rotor blade surface can cause erratic behavior in the turbine flowmeter and excessive wear due to over speeding. Maintaining a system backpressure of 2 times the flowmeter pressure drop plus 25 times the product vapor pressure is sufficient to prevent cavitation as shown by the following formula:

BP= (P x 2) + (VP x 1.25)

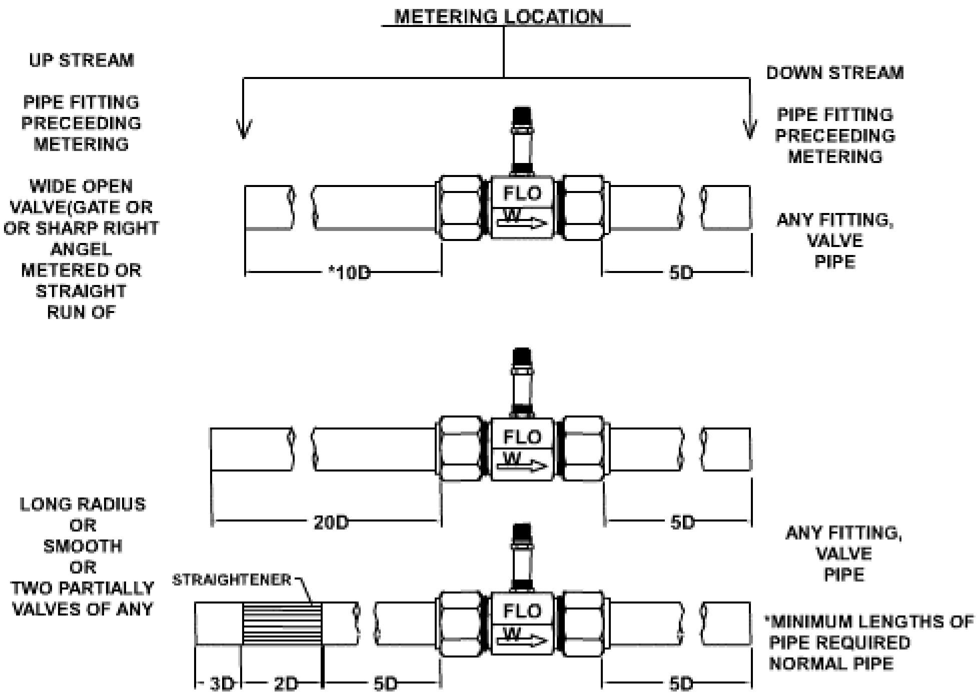
Where,
BP= Required back pressure
P= Pressure drop at maximum flow.
VP= Absolute vapor pressure at maximum temperature.

Cavitation usually causes the rotor to speed up at the high flow rate due to the increased flow volume and causes the accuracy curve of the turbine flowmeter to be adversely affected.

INSTALLATION
The term swirl is used to describe the rotational velocity or tangential velocity component of fluid flow in a pipe or tube. Depending on its degree and direction, swirl will change the angle of attack between the fluid and the turbine rotor blades, causing a different rotor speed at a constant flow rate to non-swirling conditions at the same flow rate. Liquid swirl and non-uniform velocity profiles may be introduced

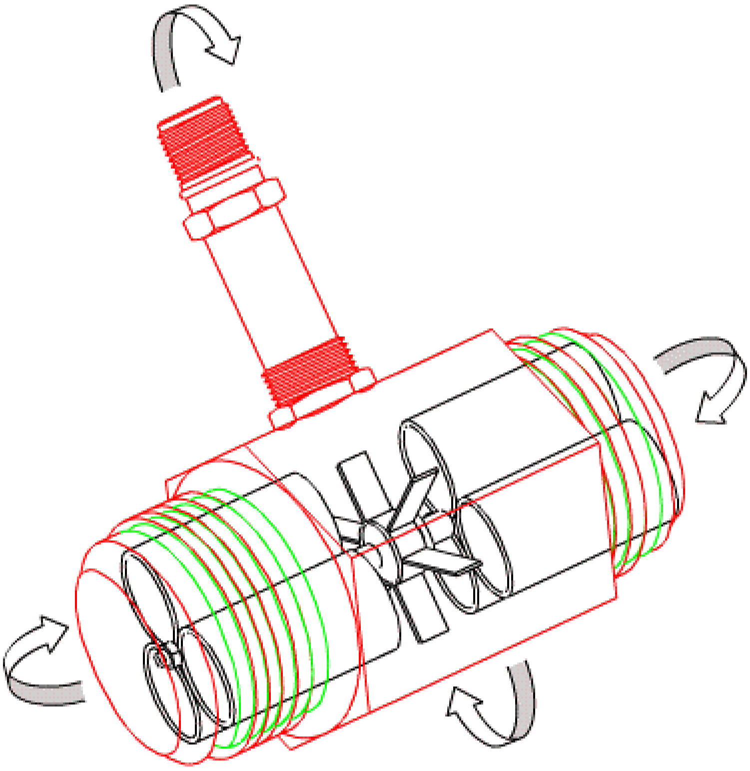
upstream of the turbine flowmeter by variations in piping configurations or projections and protrusions within the piping. Swirl may be effectively reduced or eliminated through the use of sufficient lengths of straight pipe or a combination of straight pipe and straightening vanes installed upstream of the turbine flowmeter.

3 TYPICAL METERING RUNS



APPLICATIONS
Turbine flowmeters, when first introduced, were used mainly by the aircraft industry in small sizes. Turbine flowmeters are now used on many applications (figure 3). Reasons for this increased used are sizes up to 12", weight and size versus flow rate, extended flow ranges, operating pressures up to 10,000 pounds per square inch, temperature range of -450°to 1000°F and a wide variety of construction materials including stainless steels.
In recent years, turbine flowmeters have been competing successfully with positive displacement flowmeters in many applications due to the economy of installation, low maintenance costs, weight, size and high flow rates per comparable connection size. You must exercise caution when making this comparison, especially on viscous products. Following the parameters outlined previously will prevent most misapplications of the turbine flowmeter.
When products are used in which viscosity changes with seasonal temperature, a proving run should be done at a time when the product temperature would be changing. For instance, fuel oil may change 50°F in ambient temperature between summer and winter. A change of this magnitude would affect the flowmeter curve and directly affect the flow range.
Increased expertise with electronics such as linearization is permitting turbine flowmeters to be used more widely (figure 4).

PROVING
Proving is a method of checking a measuring device against an accepted standard to determine the accuracy and repeatability of that measuring device. Turbine flowmeters should be proven immediately after installation, after repair, following removal from service (for any reason) when changing products, when product viscosity changes, or to chart the flow patterns of the flowmeter during a period of time. In general, provings should be quite frequent in the early history of an installation. When sufficient results have been gathered to establish meter factor versus flow rate curves for each product, frequently proving can taper off unless one of the aforementioned reasons for proving occurs.



Compliments of Sponsler USA

Figure 4: The turbine flowmeter position should not adversely affect velocity or the smooth rotation of the rotor. The rotor should decelerate and stop in a smooth uninterrupted fashion. An abrupt sticking motion indicates bearing failure.

METHODS
There are several different methods of proving. Volumetric proving consists of a measured volume of fluid being compared to a known standard, such as a seraphin can or piston prover.
Gravimetric proving entails measuring weight of a fluid by scale or load cell, then converting it by a known formula.
Master-meter proving is the comparison of a test flowmeter to another flowmeter previously calibrated in one of the above methods.

Turbine flowmeter manufacturers continue to respond to industry interest with improvements.

Ultrasonic Flowmeters

The ultrasonic flowmeter is now a more common flowmeter . It was originally looked down upon because many of them were misapplied in the beginning. Since that time, electronic circuits have improved and this has meant that ultrasonic flowmeters have been able to achieve accuracies that previously were unreachable . Doppler flowmeters were some of the first ultrasonic flowmeters on the market. The Doppler meter has had success on some blood flow indicating devices and difficult flows in pipes with higher solids and aeration but the transit time meter has become more popular in general measurements because of its ability to measure accurately in cleaner fluids.

Both types of ultrasonic flowmeters feature clamp-on or insert designs . Many of the designs are now becoming non-intrusive /non contact which enables them to measure fluids without disturbing flow profile. Since there are no mechanical parts, there is an added plus that they are more likely to keep working where other technologies may have problems with sensor fouling.

Figure 25 are typical examples of the ultrasonic flowmeters offered by several companies. Here are some of the capabilities of this technology.

The meter can measure pure water, wash water, sewage, process liquids, oils, and other light homogeneous liquids. The basic requirement is that the fluid be capable of ultrasonic wave propagation and have a reasonably axis-symmetrical flow.
Clamp-on types measure flow through the pipe without any wetted parts, ensuring that corrosion and other effects from the fluid will not deteriorate the sensors.
An added plus to the above is that clamp-on types simplify and speed up meter installation and minimize maintenance.

Fig 25. Ultrasonic Flowmeter (Concurrent Transit Time) – compliments of EESITEC Technologies

This design and others are portable, a feature particularly advantageous for backing up an already installed flowmeter or checking out existing meters in a number of locations.
.
Operation is linear and bidirectional.
Advances in digital signal processing have improved performance where the flowing fluid contains air or gas bubbles.
Some suppliers offer ultrasonic measurements of both level and flow velocity to calculate flow quantities in open channels with weirs or flumes. Others carry ultrasonic meters especially adapted to measure the flow rate of gases. This class of meter is attractive compared to conventional flow metering methods because, in addition to the points listed above, the meters inherently provide linear calibration; have wide rangeability; induce no or minimal pressure drop or disturbance in the flow stream and recently there has been a much wider acceptance regarding their reliability.

More about ultrasonic propagation techniques in flow measurement.

To detect flow through a pipe, ultrasonic flowmeters use acoustic waves or vibrations of a frequency .Depending on the design, they use either wetted or nonwetted transducers on the pipe perimeter to couple ultrasonic energy with the fluid flowing in the pipe.

Doppler Flowmeters. Doppler flowmeters are named for the Austrian physicist and mathematician Christian Johann Doppler (18031853), who in 1842 predicted that the frequencies of received sound waves depended on the motion of the source or observer relative to the propagating medium. To use the Doppler effect to measure flow in a pipe, one transducer transmits an ultrasonic into the flow stream .Liquid flowing through the pipe must contain sonically reflective materials such as solid particles or entrained air bubbles. The movement of these materials alters the frequency of the beam reflected onto a second, receiving transducer. The frequency shift is measured and used to calculate flow rate.

A basic math equation defining the Doppler flowmeters are:

$\Delta f = 2 f_T \sin\theta \bullet V_F / V_S$ (1) and by Snell's law:

$\sin\theta_T / V_T = \sin\theta / V_S$ (2) Thus, from Equations (1) and (2), we have:

$V_F = \Delta f / f_T \bullet V_T / \sin\theta_T = K \Delta f$ (3)

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

Equation (3) clearly shows that flow velocity is a linear function of the Doppler frequency shift. Now, because the inside diameter of the pipe, D, is known, volumetric flow rate (e.g., in gallons per minute) can be measured using the following expression:

$K \bullet V_F \bullet D^2$ (4)

where:

K = a constant dependent on the units of V_F and D

Transit-Time Flowmeters. Transit-time meters, as the name implies, measure the difference in the time of flight between signals transmitted alternately in the direction of, and against, the flow. This type of meter is commonly known as the transit time meter. Some manufacturers send signals through each other concurrently, this is known as Concurrent transit time.

Transit time flowmeters are becoming extremely popular . Their usage has widened even to the point where this technology is being used in domestic meters or submetering.

Calorimetric Flow meters

In the $3 billion dollar world market of flow metering, a little known jewel is gradually finding its way to acclaim…the calorimetric flow sensor. The use of the calorimetric principle in flow is now a standard in the industry. Significant advances over the past decade have enabled the calorimetric sensor to assume a very active and respected role in flow switching and flow metering of both liquids and gaseous mediums.

The most common use of these sensors is in flow no-flow applications for detecting the movement of air or liquids. Popular for their solid state construction with no moving parts, the calorimetric flow sensor is impervious to particulate matter that spells doom for mechanical type devices.

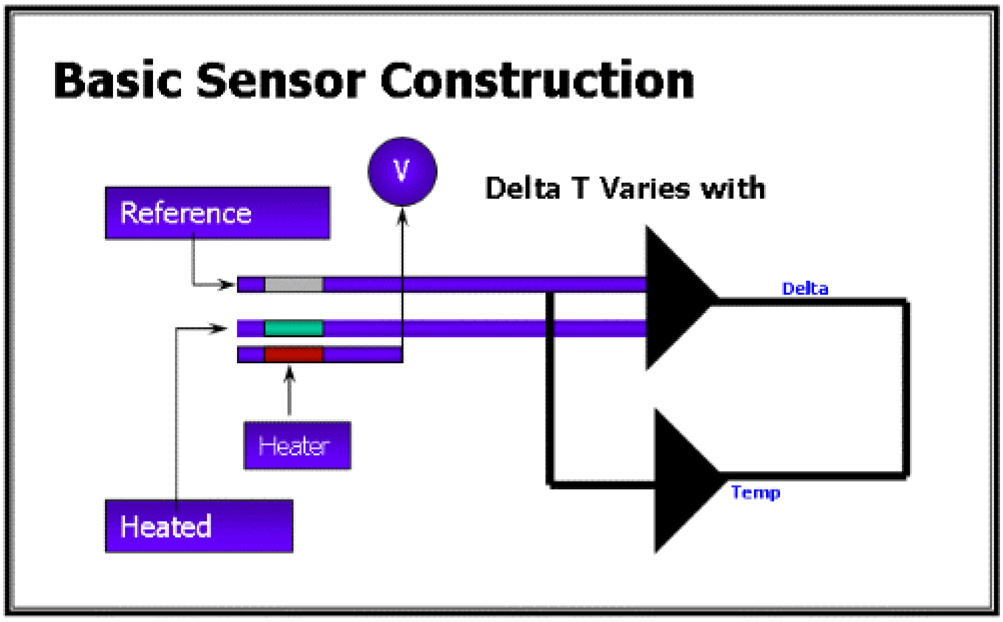
Historically, the calorimetric switching devices have been costly in comparison to mechanical switches, but with new technological breakthroughs in both electronic and mechanical construction, there are, now available, units that compete directly with their primitive counterparts.

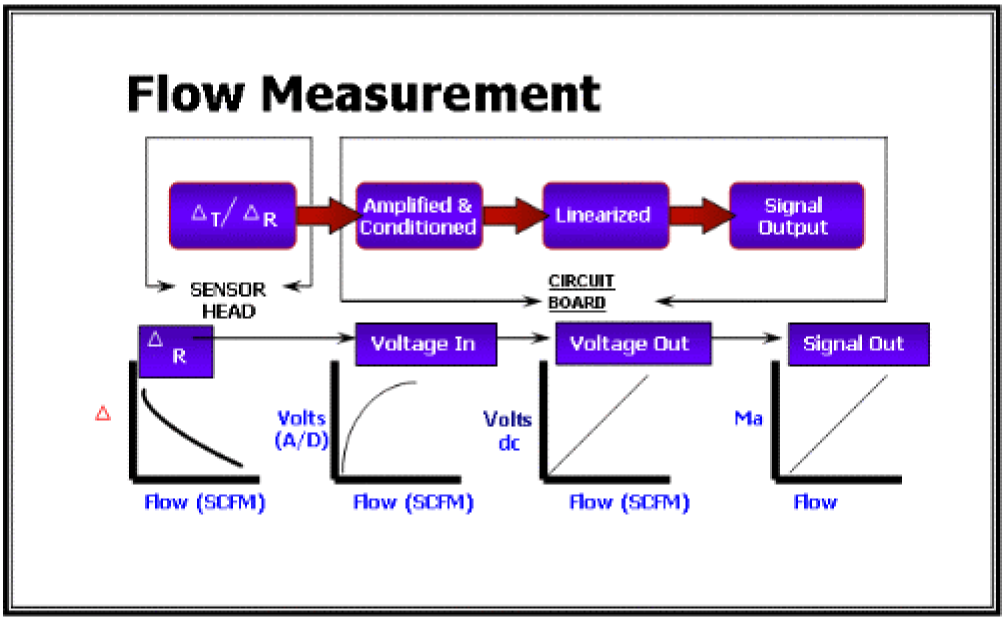
Traditional Paddle Switch

Modern Calorimetric sensor

Flow metering has also become a substantive part of the calorimetric sensor's function. The sensing technology, having no moving parts, allows measurement of flows so low as to be below the inertia threshold of turbine or paddlewheel sensors. This has made them very popular for chemical dosing, leak detection, etc. Also, extended range calorimetric sensors are now available that can enable measurements of much higher flow rates (up to 60 feet per second for some liquids) than previously thought possible with calorimetric technology.

The traditional calorimetric technology utilizes two PTC Thermistors, one of which is heated a predetermined amount above the other, which monitors the medium temperature. Flow of the medium conducts heat away from the sensor probe and the corresponding change in the heated Thermistor's resistance value is then amplified, linearized and converted into an output (switching or analog depending upon sensor type) proportional to the rate of flow.





The fact that calorimetric sensors do not require the medium to be electrically conductive (as would a mag meter for example) makes measurements of polymers, oil, grease, and numerous other mediums possible. The technology also is not based upon suspended particles for measurement accuracy (as would be the case with doppler type meters). The addition of optional specialty metals for use in the calorimetric construction (such as Hastelloy, Monel, Titanium etc.) allows measurements of innumerable aggressive medium such as chemicals and acids.

The calorimetric sensor's minimal power requirements have enabled the development of battery operated flow sensors for remote locations. These can be paired with wireless transmission devices to enable internet based monitoring or dial up fault alarming for such applications as loss of flow to pumps, leaking of pipes, and loss of lubrication oil flow or coolant flow in transportation.

Inherent in the design is the continual monitoring of the medium temperature, which enables the calorimetric sensor to also function as a temperature monitor. This provides the user with two sensors in one. This has been a popular feature with chiller manufacturers, as the same device can alarm if flow is lost, or temperature exceeds predetermined limits.

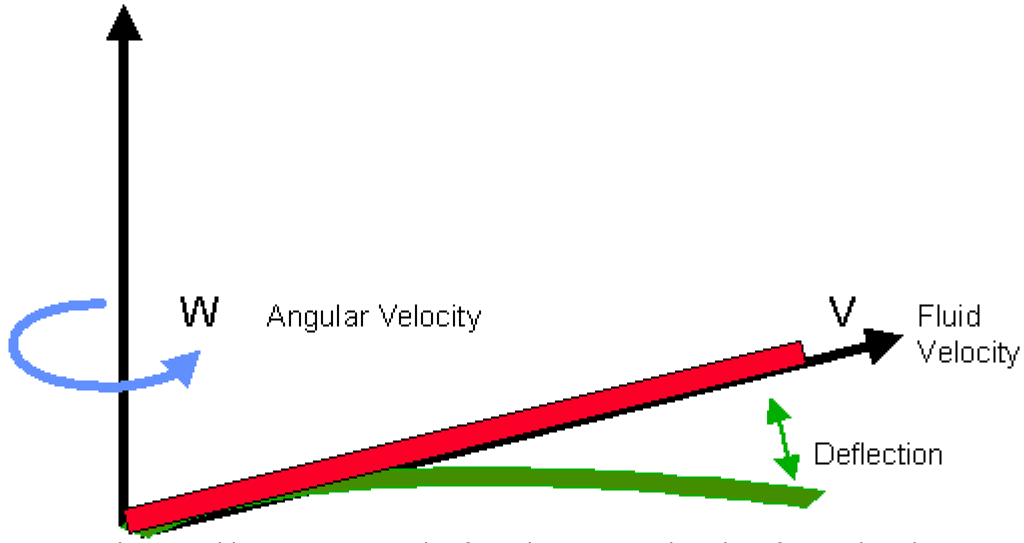
Microflow technology in calorimetric sensors has also enabled here-to-fore unrealizable low flow metering of less than 2 milliliters per hour of liquid flow.

In summary, the calorimetric flow sensor is the rising star of the flow sensing industry and offers capabilities unmatched by other flow measurement technologies.

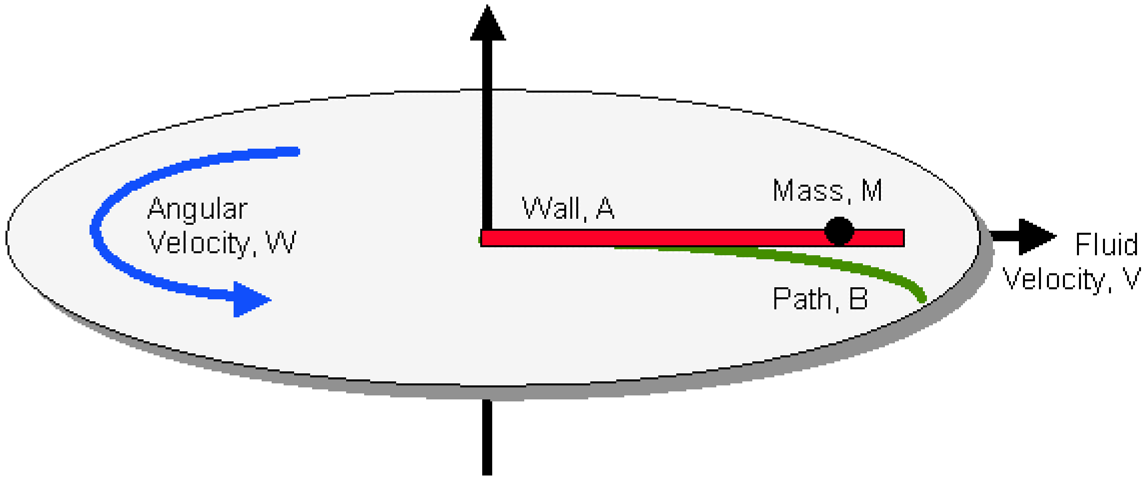
Coriolis Flow meters

What is the Coriolis Principle?

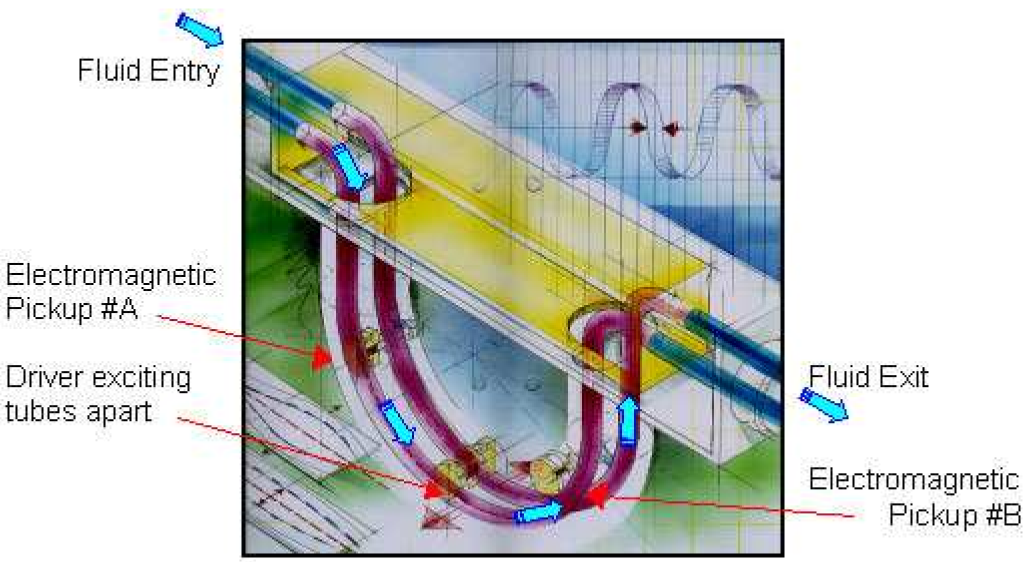
To some of us the Coriolis Principle is an exact science, but to most of us it is still a black art. Well, imagine a fluid flowing (at velocity V) in a rotating elastic tube as shown below. The fluid will deflect the tube.



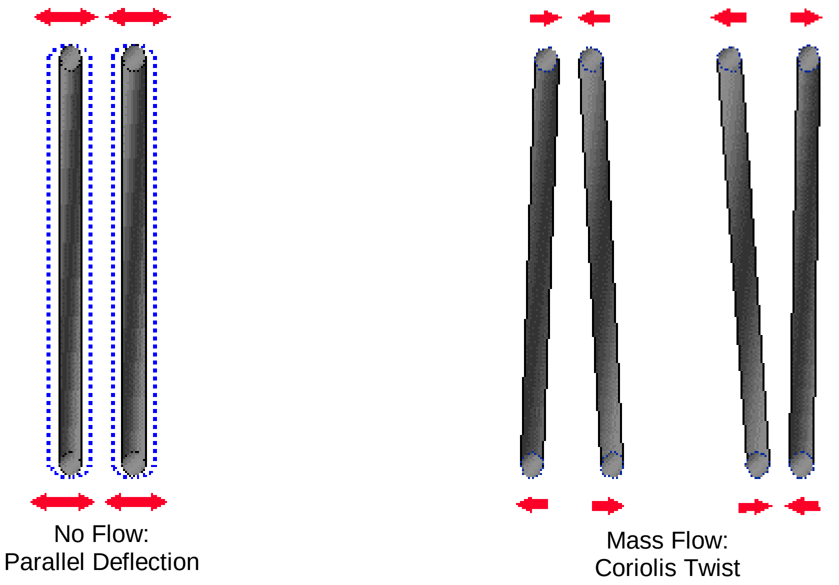
Further, consider a Mass M moving from the center to the edge of a rotating plate.
This Mass M will take path B as shown below



If the mass M is guided by Wall A (i.e. the tube), a Coriolis Force will be exerted on the wall as shown below.
CORIOLIS FORCE : Fc = -2 M V W
Now, consider the interior of the RotaMASS sensor as shown below

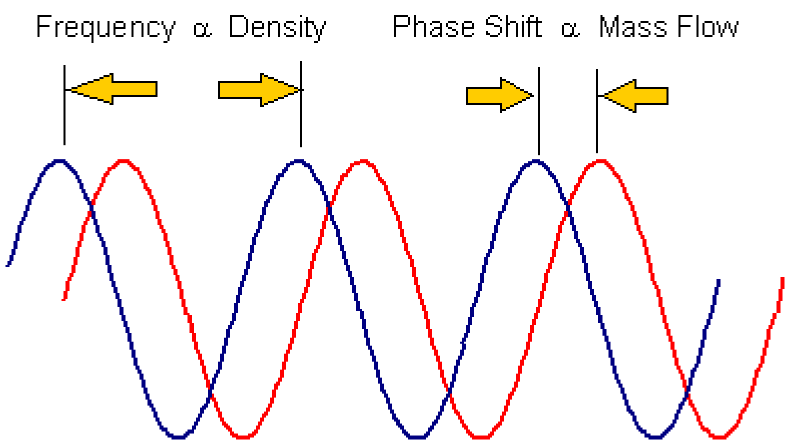


The tube walls guide the process fluid as it flows through the U-Tube pathway. With no fluid inside the tubes the Driver excites the tubes apart at a nominal 150Hz as shown below.



Now imagine fluid of Mass M flowing through and out of the RotaMASS tubes. As the fluid flows down the first half of the U-Tubes it will tend to deflect the tubes in towards each other. Conversely, when the fluid flows up the second half of the U-Tubes it will tend to deflect the tubes out away from each other. This Coriolis Twist action is shown above.

Now consider the diagram below. The baseline deflection of the tubes from the Driver is shown by the blue trend and the Coriolis Twist from the Pickup Coil is designated by the red trend.



Now the temperature of these tubes dramatically affects their flexibility. So temperature measurement is very critical as follows;