⑥ Flow Measurements

- A flow meter is an flow instrument that is used to indicate the amount of liquid, gas, or vapor moving through a pipe or conduit by measuring linear, non-linear, mass, or volumetric flow rates. Since flow control is often essential, measuring the flow of liquids and gasses is a critical need for many industrial applications – and there are many different types of flow meters that can be utilized depending on the nature of the application.

- Mass flow rate = Volume flow rate * density

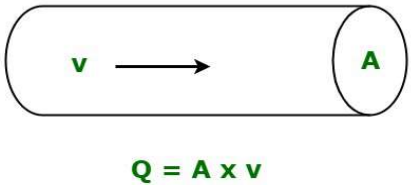
$$\dot{M} = Q * \rho$$

$$Q = V * A$$

V : Flow velocity

A : Cross Section Area

SCCM: Standard cubic CM / M

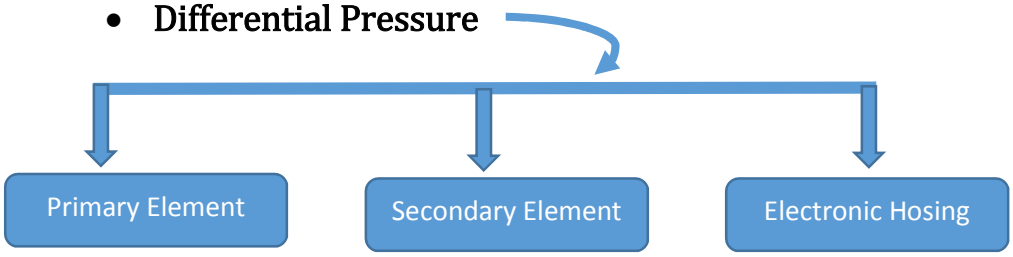


- $Q\ (m^3/s)$, (ft^3/s) , (GPM) , (SCCM)
- $\dot{M}$ (Kg /s)
- ρ (Kg/m^3)

flow Measurements

Obstructive

- Positive displacement (Oval Gear)
- Mechanical (Turbine)
- Vortex
- Rotameter
- Differential Pressure



- Orifice Plate
- Flow Nozzle
- Venturi Tube
- Pitot Tube
- Laminar Flow element
- Wedge Element

- Differential Capacitance
- Strain Gauge

Non Obstructive

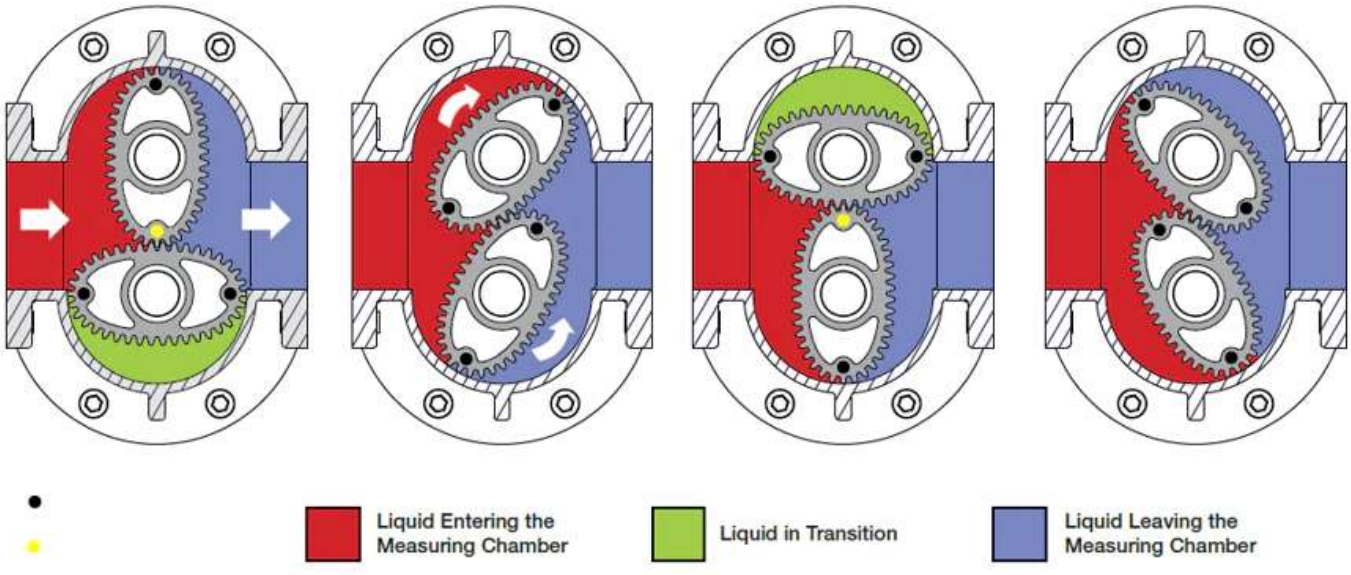
- Electromagnetic
- Ultrasonic
- Coriolis

① Positive displacement (Oval Gear)

- There are two oval gears inside the meter, the flow of the fluid causing the gear rotation every revolution called (Pocket).
- Counting the pocket frequency gives a measurements of the volumetric flow rate.
- A sensor detects the rotation of the gears to determine the volume flow rate of liquid.
- Rotational velocity is directly proportional to volume flow rate. (Q = VA)

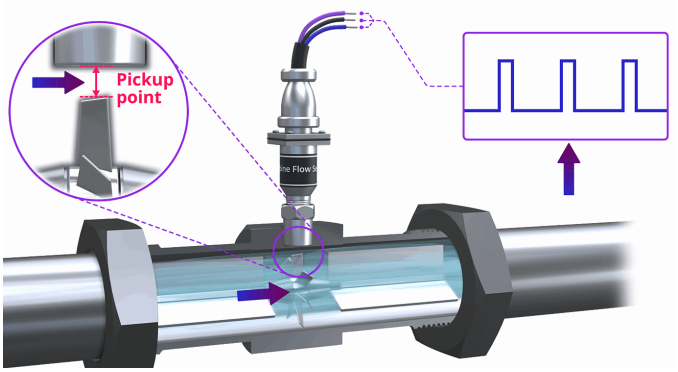
- Designed for use with higher-viscosity fluids.
- It's suitable for flow measurement for different measuring media (acid, alkali, chemical, petroleum, oil, food industries).
- The flowmeter can be made of (cast steel, stainless steel 316).
- The display meter has the functions of displaying cumulative flow, instantaneous flow and zero return.

Advantages:	Disadvantages:
• Accurate (0. 5%). • Simple to install. • Handling high pressure. • Working temperature = 160 °c	• Unsuitable for steam. • Unsuitable for high & low Temperature applications. • Unsuitable for low viscosity fluids including water. • Accuracy affected by bubbles present in fluids.

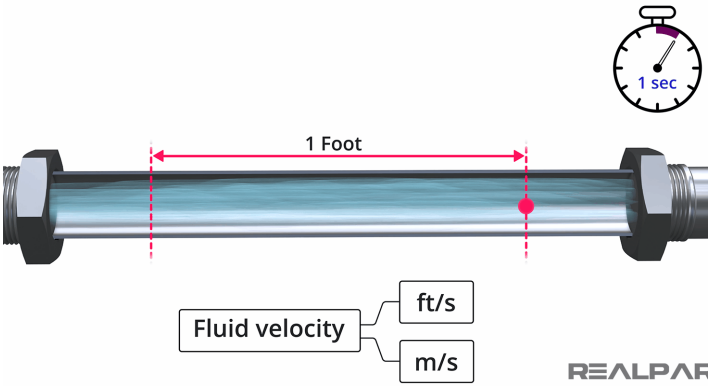


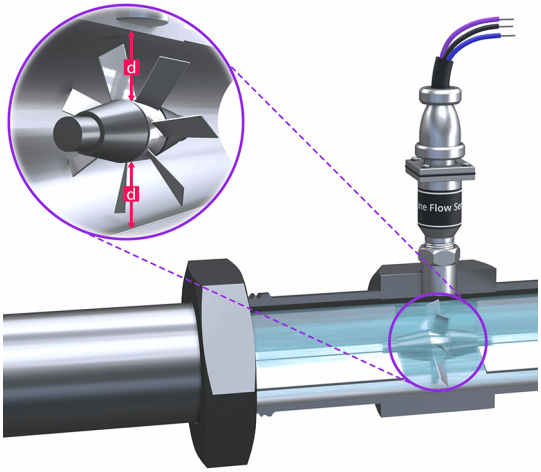
② Mechanical (Turbine):

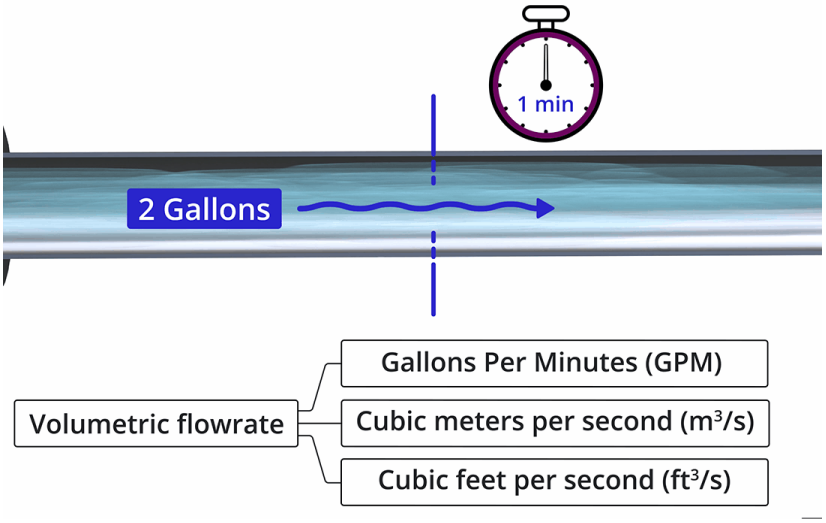
- A Turbine Flow Meter is inserted in a pipe directly in the flow path.
- The mechanical part of the Turbine Flow Meter has a turbine rotor placed in the path of a flowing stream.
- The only moving part of the Turbine Meter is the mechanical rotor.
- The rotational speed of the rotor depends upon the flow velocity.
- The rotor blades are usually made of stainless steel.
- As the rotor spins, the passage of each rotor blade past a pickup point will generate an electrical pulse.
- The electrical pulses are created in different ways depending upon the rotor blades themselves and the pickup unit characteristics.



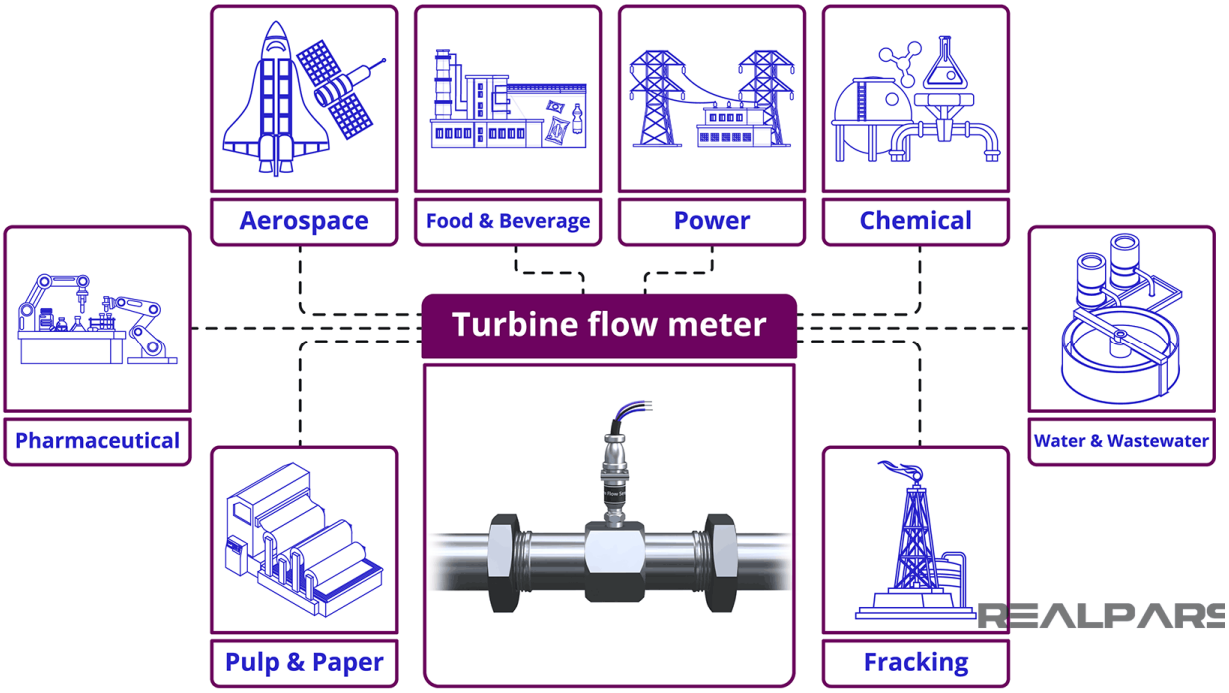
- the turbine rotor will turn at a different speed depending upon the fluid flow velocity.
- Fluid Velocity is a measurement of the distance a particle of a substance traveled per unit of time. Typical velocity units are feet per second or meters per second.
- Fluid Velocity plays a very important role in the operation of a Turbine Flow Meter, but in most applications, a Turbine Flow Meter is used to measure Volumetric Flowrate.
- Volumetric Flowrate indicates the volume of fluid that passes a point in a unit period of time.
- If you could count the number of gallons of liquid flowing past a certain point in one minute, you would be able to state the Volumetric Flowrate.
- Volumetric Flowrate is expressed in units such as:
  – gallons per minute (GPM)
  – cubic meters per second (m^3/s)
  – cubic feet per second (ft^3/s)







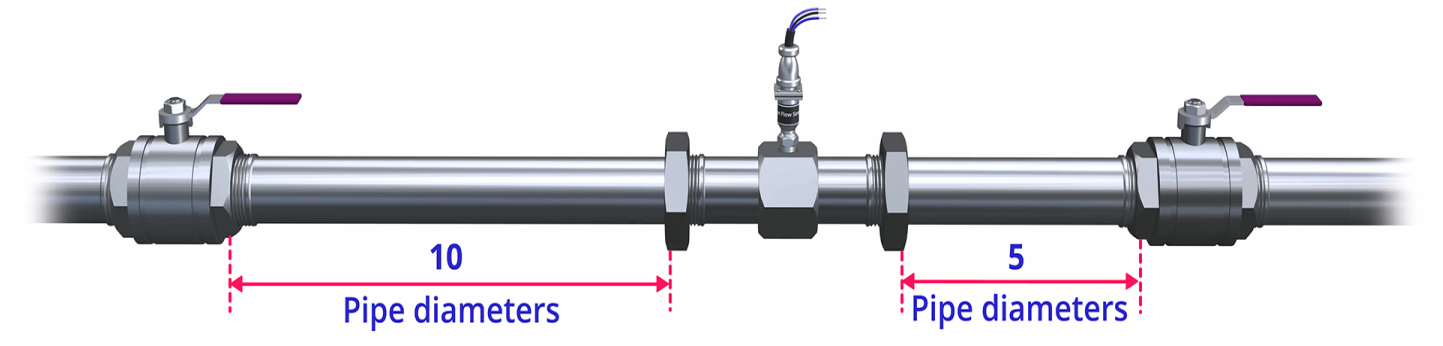
You will find Turbine Flow Meters in oil and gas including fracking, water and wastewater, chemical, power, food and beverage, aerospace, pharmaceutical, and pulp and paper.



Advantages:	Disadvantages:
• Accurate (0. 5%) can be improved 0.2 %. • The material of its body is stainless steel. • Suitable for { gases , liquids }.	• Not suitable with too high viscosity. • Need frequent calibration. • Deal only with clean liquids. • Max temperature = 120 °c

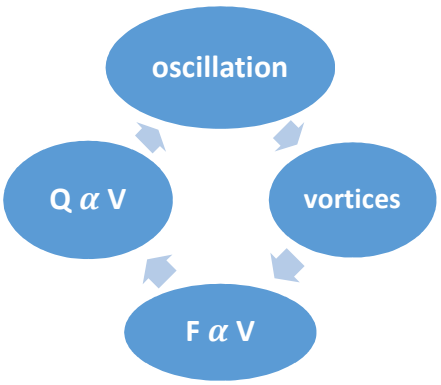
Installation of a turbine flow meter:

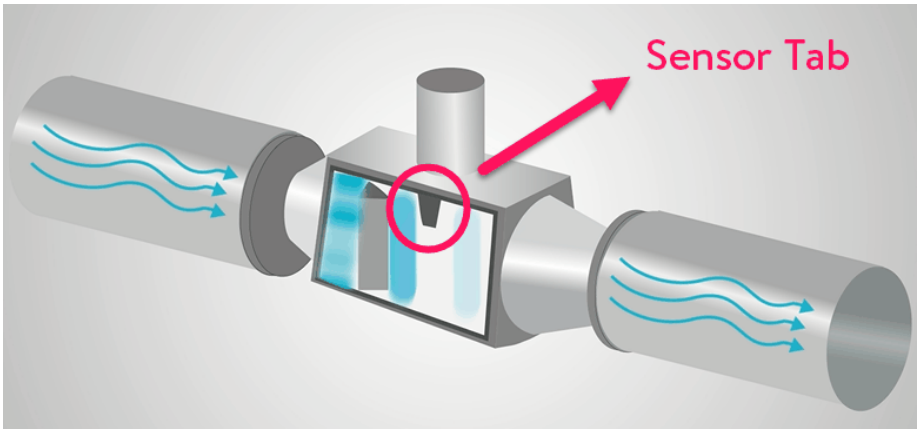
Typical installation requires 10 pipe diameters upstream of straight pipe and 5 pipe diameters downstream.



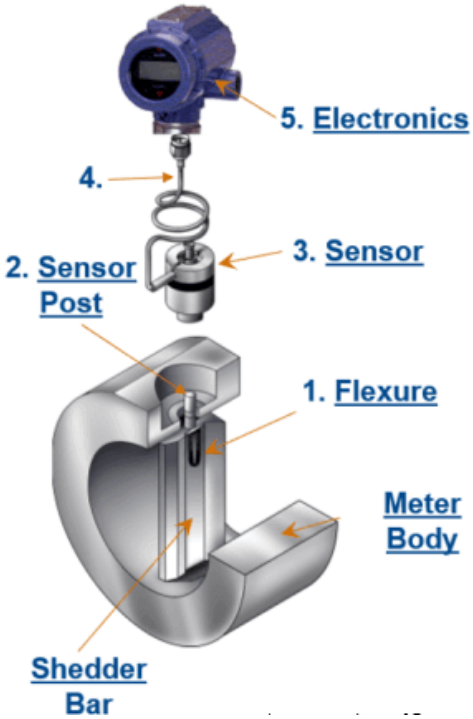
③ Vortex:

Vortex measures vortices, essentially, a sensor tab will bend and flex from side to side as the vortex passes. The bend and flex action will then produce an output frequency that is proportional to volumetric flow.

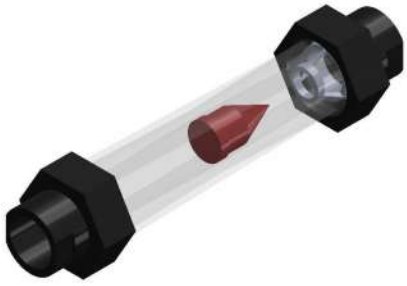




Advantages:	Disadvantages:
• Suitable for low viscosity liquids. • Suitable for { gases , steam }. • Low pressure loss. • High accuracy. • High stability. • Wide measurement range. • Reliable and advanced instruments.	• It has poor anti-vibration performance. • Can't measure dirty media.



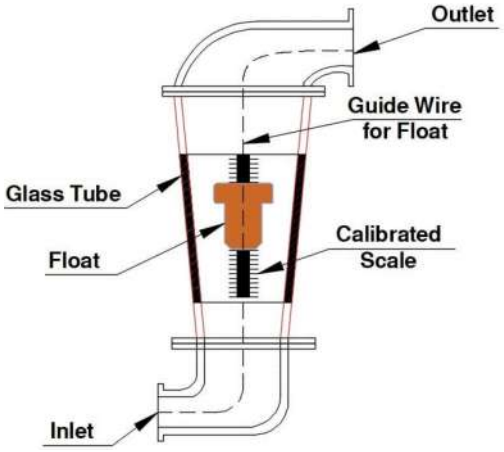
④ Rotameter:



- A rotameter is a device that measures the flow of fluid volume per unit of time in a closed tube.
- There are several types of rotameter applications, including chemical injection/dosing and tank blanketing.
- A rotameter is a gauge for measuring fluid flow using a graduated glass tube with an enclosed free float.
- Also known as variable area flow meters, rotameters are used to measure liquid or gas volumetric flow rates as they pass through the tapered tube of the rotameter.
- The flow of the liquid or gas raises the meter's float, increasing the area through which the media may pass. The larger the amount of flow, the higher the float is raised.
- A rotameter can be used for purge applications to keep process lines clear. In simple flow measurement, an alarm or an electrical output makes it possible to check flow conditions and control them continuously.

➢ How Rotameters Work?

- Fluid enters the tube from the bottom and escapes through the top. This fluid is the one whose flow is measured. The float will rest at the bottom of the tube when there is no flow in the instrument. In such a situation, the total diameter of the float is nearly equal to the inside diameter of the glass tube.
- The flow area of the annular opening increases when the fluid enters the tube, thus making the float move upwards. It moves upwards until the lifting strength produced from the difference in pressure across its upper and lower surfaces begins to equal the float weight.
- The lifting force and pressure difference will temporarily increase due to the flow rate increase in the rotameter. Afterward, the float travels to the top and increases the area in the annular opening.
- Due to this, the lifting force will decrease, and the force of the fluid will become the same as the float weight. The difference in pressure remains the same by changing the area of the annular opening in relation to the flow rate. The scale marked on the glass tube indicates the flow rate.



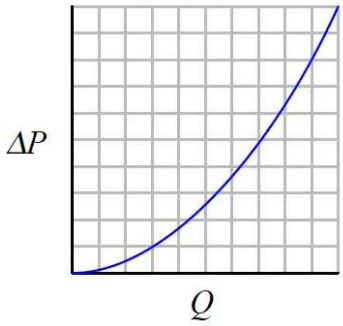
- When using rotameters, calibration must be undertaken for a given gas or fluid at a given set of conditions. Normally, the conditions are written on the sides of the flow meter along with its range of flow and the units of measurement. In using rotameters, one is always advised to correct the flow tube readings according to any changes in flow conditions. Usually, manufacturers detail the required corrections for the meters, but this is not always the case.

Advantages:	Disadvantages:
• Measuring very low to high flow rate. • No external power. • Simple. • Low cost. • Low pressure drop. • Repeatability. • Optional flow switches, alarms.	• Must be mounted vertically. • Low accurate with high flow rate.

⑤ Differential Pressure:

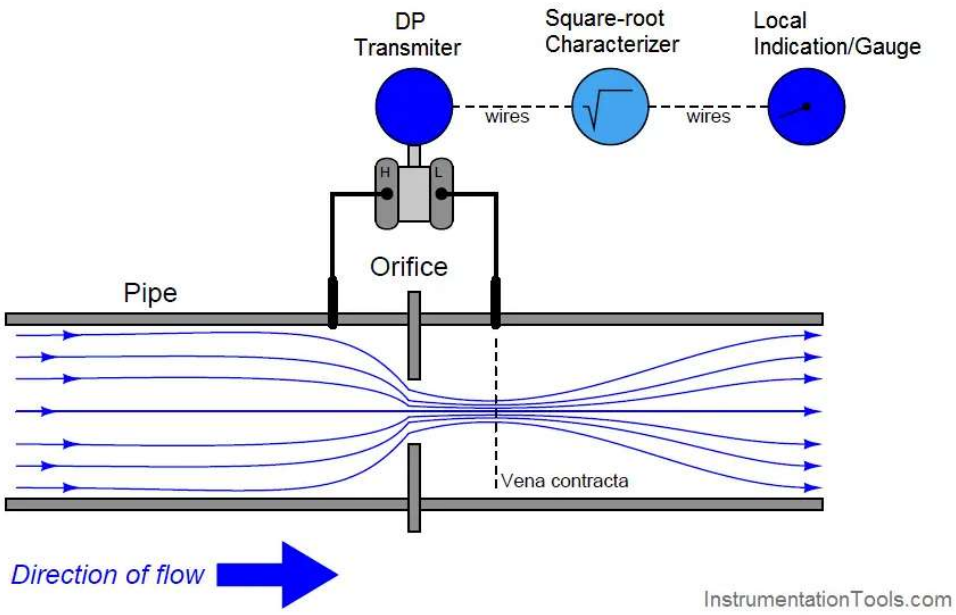
Primary element	Secondary element (Transducer)	Electronic hosing (Transmitter)
1- Orifice plate	Differential capacitance	
2- Flow nozzle	Strain gauge	
3- Venture tube		
4- Pitot tube		
5- Laminar flow element		
6- Wedge element		

- A common method of flow measurement is done by using a Differential Pressure Transmitter (also called a DP Transmitter). The Differential Pressure Transmitter often referred to as a Delta P transmitter.
- When plotted on a graph, the relationship between flow rate (Q) and differential pressure (ΔP) is quadratic, like one-half of a parabola. Differential pressure developed by a venturi, orifice plate, pitot tube, or any other acceleration-based flow element is proportional to the square of the flow rate.

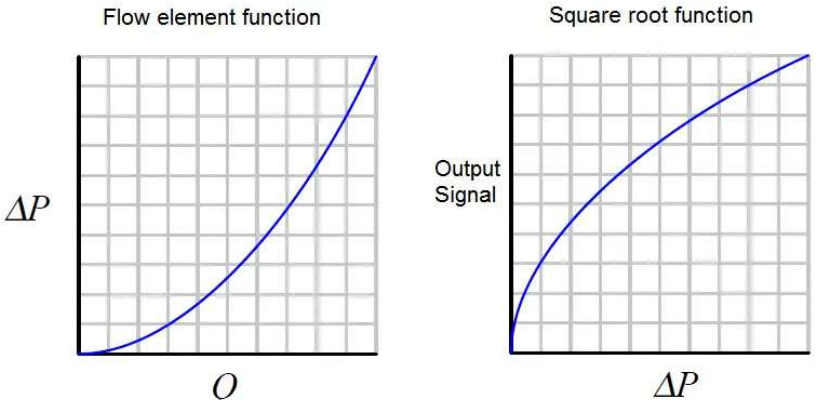


$$\Delta P \propto Q^2$$

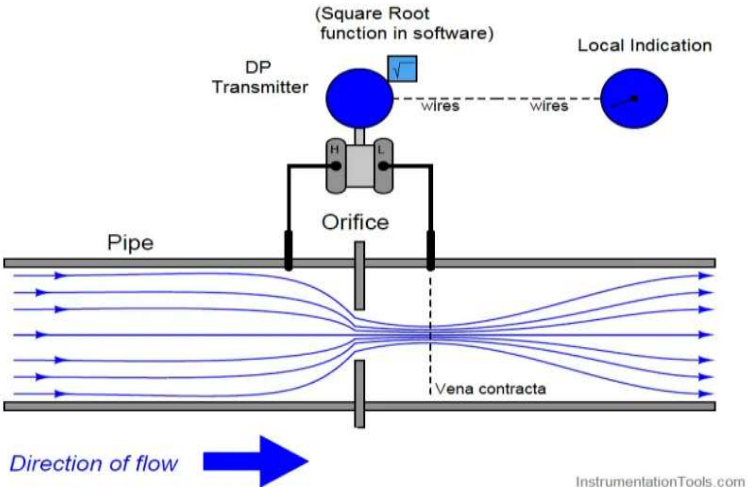
- Unfortunately, the Differential pressure across the orifice is not proportional to the flow rate but is actually proportional to the square of the flow rate. That's why in applications like this, we need a Square Root Extractor. Sometimes this square root function is built into the transmitter and sometimes a Square Root Extractor is a separate signal conditioning instrument connected to the output of the transmitter.

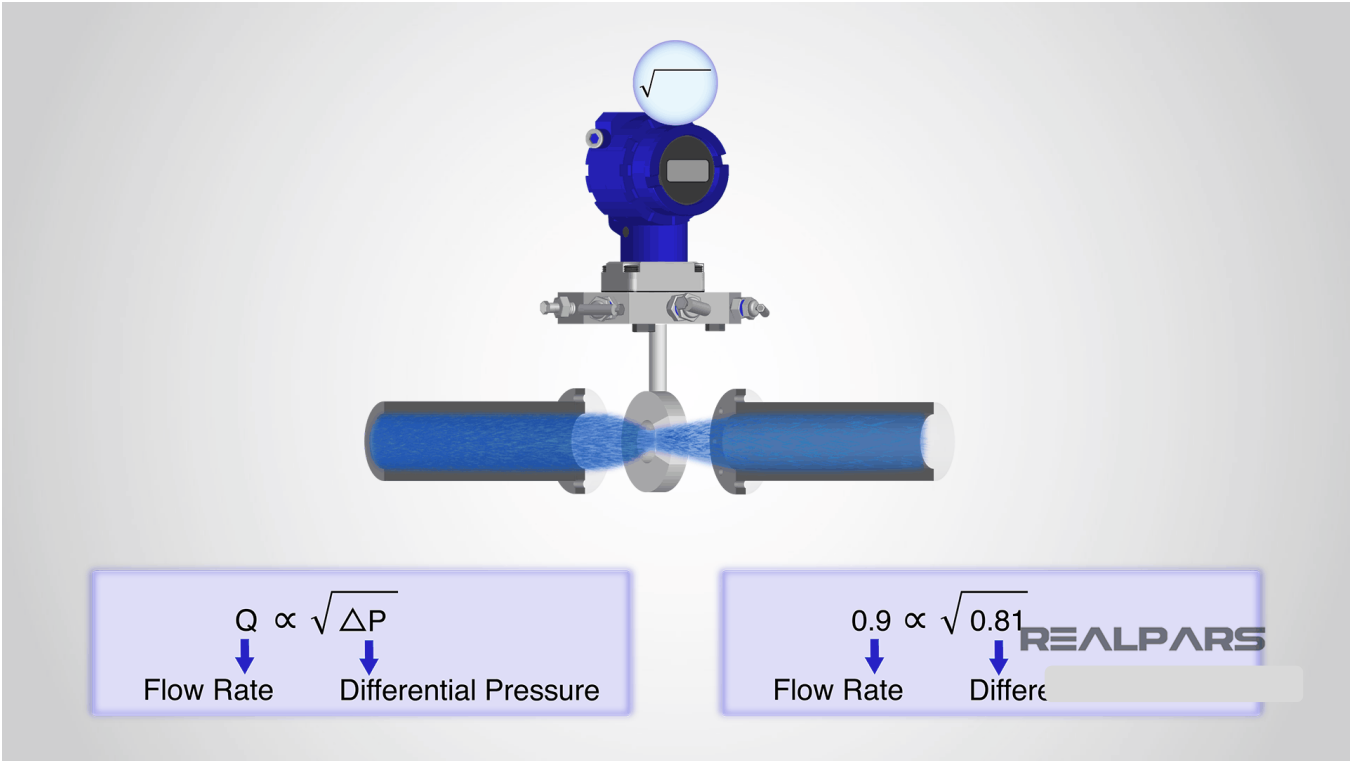


- The square-root function placed immediately after the flow element's "square" function – the result is an output signal that tracks linearly with flow rate (Q).



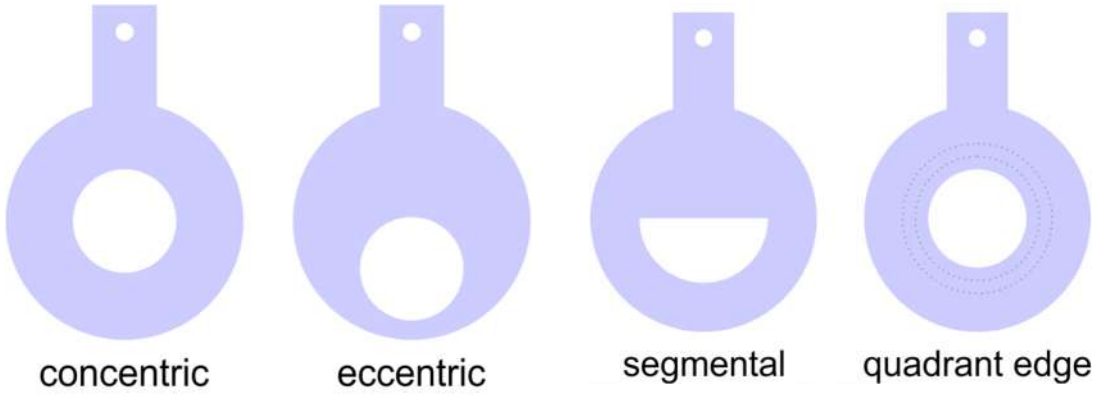
- If we are using square root extraction function which is available inside the transmitter (software configuration).
- This way, no external relay device is necessary to characterize the DP transmitter's signal into a flow rate signal.





Orifice plate :

- An Orifice Meter is basically a type of flow meter used to measure the rate of flow of Liquid or Gas, especially Steam, using the Differential Pressure Measurement principle.
- It is mainly used for robust applications as it is known for its durability and is very economical.
- As the name implies, it consists of an Orifice Plate which is the basic element of the instrument. When this Orifice Plate is placed in a line, a differential pressure is developed across the Orifice Plate.
- This pressure drop is linear and is in direct proportion to the flow rate of the liquid or gas.
- The Orifice plates in the Orifice meter, in general, are made up of stainless steel of varying grades.



- Orifice meters are built in different forms depending upon the application-specific requirement, The shape, size, and location of holes on the Orifice Plate describe the Orifice Meter Specifications as per the following:
  - Concentric Orifice Plate: used with pure liquid like gases.
  - Eccentric Orifice Plate: used for viscous flow.
  - Segment Orifice Plate: used for viscous flow.
  - Quadrant Edge Orifice Plate: used for crude oil, high-viscosity syrups or slurries.

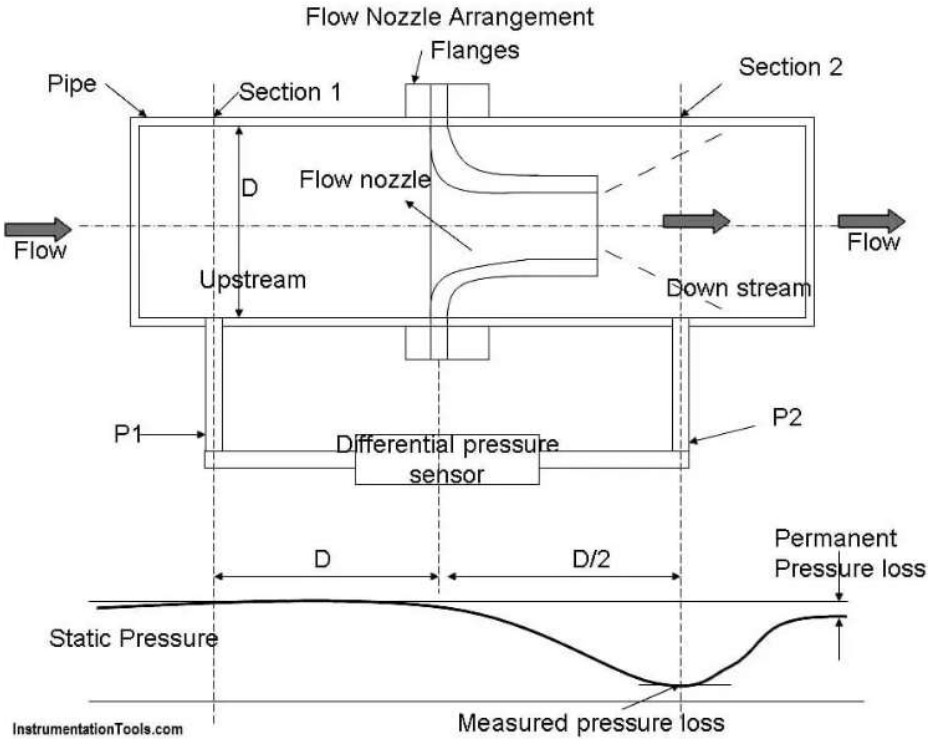
Advantages:	Disadvantages:
• very cheap. • Less space is required to Install. • Operational response can be designed with perfection. • Installation direction possibilities: Vertical / Horizontal / Inclined.	• At higher fluid velocity causes turbulences. • Solids in fluids causes damages. • Low life time.

Flow nozzle:

The main parts of flow nozzle arrangement used to measure flow rate are as follows:

1. A flow nozzle which is held between flanges of pipe carrying the fluid whose flow rate is being measured. The flow nozzle's area is minimum at its throat.
2. Openings are provided at two places 1 and 2 for attaching a differential pressure sensor (u-tube manometer, differential pressure gauge etc.,) as show in the diagram.

➢ Operation of Flow Nozzle

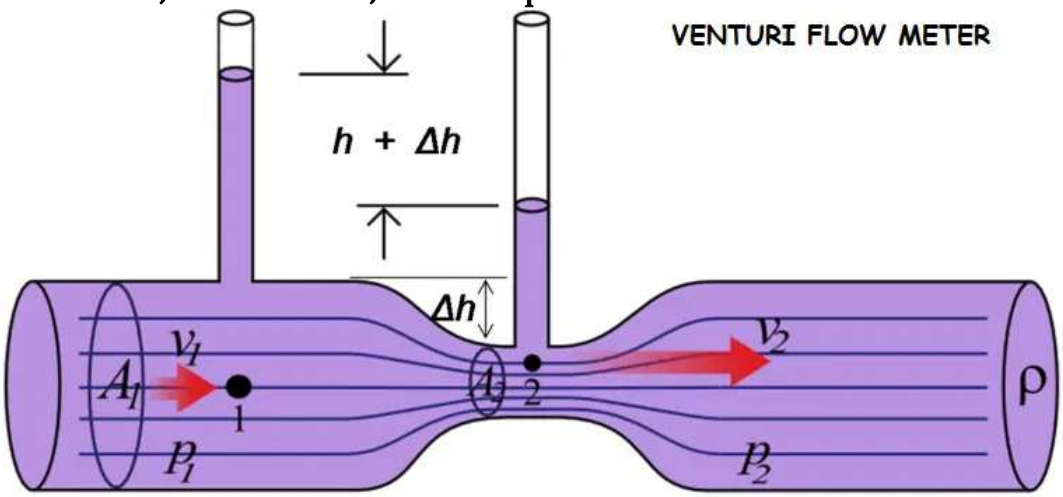


1. The fluid whose flow rate is to be measured enters the nozzle smoothly to the section called throat where the area is minimum.
2. Before entering the nozzle, the fluid pressure in the pipe is p1. As the fluid enters the nozzle, the fluid converges and due to this its pressure keeps on reducing until it reaches the minimum cross section area called throat. This minimum pressure p2 at the throat of the nozzle is maintained in the fluid for a small length after being discharged in the downstream also.
3. The differential pressure sensor attached between points 1 and 2 records the pressure difference (p1-p2) between these two points which becomes an indication of the flow rate of the fluid through the pipe when calibrated.

Advantages:	Disadvantages:
• Installation is easy and is cheaper when compared to venturi meter. • It is very compact • Has high coefficient of discharge.	• Pressure recovery is low • Maintenance is high • Installation is difficult when compared to orifice flow meter.

Venture tube:

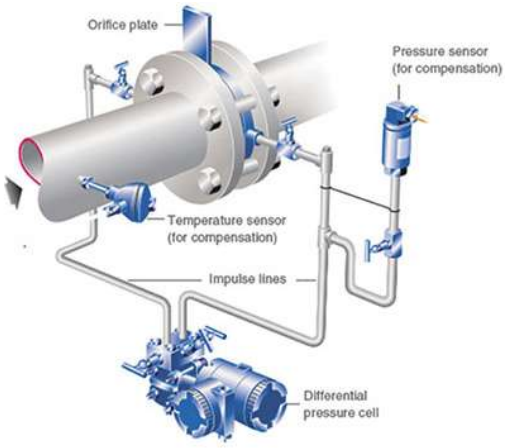
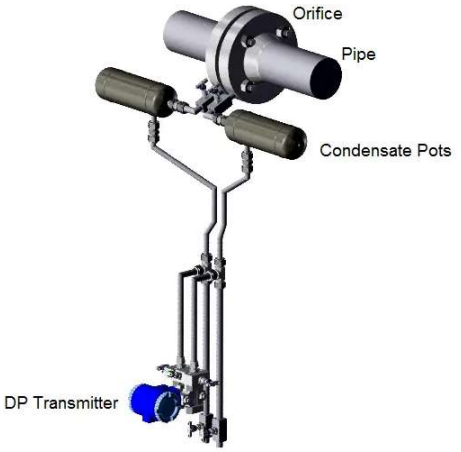
- The fluid whose flow rate is to be measured enters the entry section of the venturi meter with a pressure P1.
- As the fluid from the entry section of venturi meter flows into the converging section, its pressure keeps on reducing and attains a minimum value P2 when it enters the throat. That is, in the throat, the fluid pressure P2 will be minimal.



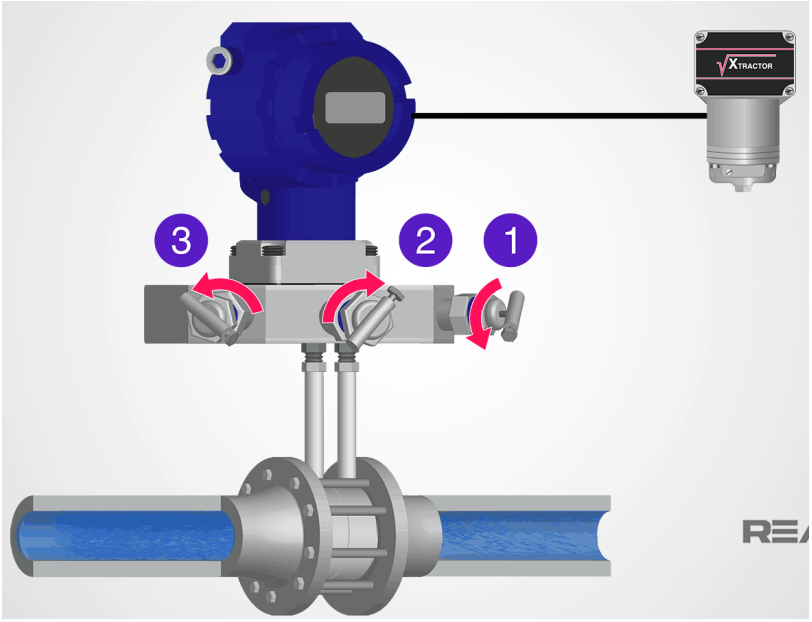
- The differential pressure sensor attached between the entry and throat section of the venturi meter records the pressure difference(P1-P2) which becomes an indication of the flow rate of the fluid through the pipe when calibrated.
- The diverging section has been provided to enable the fluid to regain its pressure and hence its kinetic energy. The lower the angle of the diverging section, the greater the recovery.

Advantages:	Disadvantages:
• Fewer changes of getting clogged with sediments • The coefficient of discharge is high. • Its behavior can be predicted perfectly. • Can be installed vertically, horizontally, or inclined. • Low-pressure drop (around 10% of Δp) • Lower sensitivity to installation effects than orifice plates • Less susceptibility to damage • More suitable for gas flows with entrained liquid.	• large in size. • Expensive initial cost, installation, and maintenance. • Greater cost to manufacture • Less experimental data than orifice plates

how to carry out piping delta p flow meter?

Gas	Liquid	Steam
Self-venting	Self-drain	Condensate
		

Calibration Procedure:



❖ Removing the Transmitter from Service

The transmitter must be removed from service before any checks or calibration can be performed. Let's go through the following steps:

– Close the Low-Pressure Block Valve

– Open the Equalizing Valve

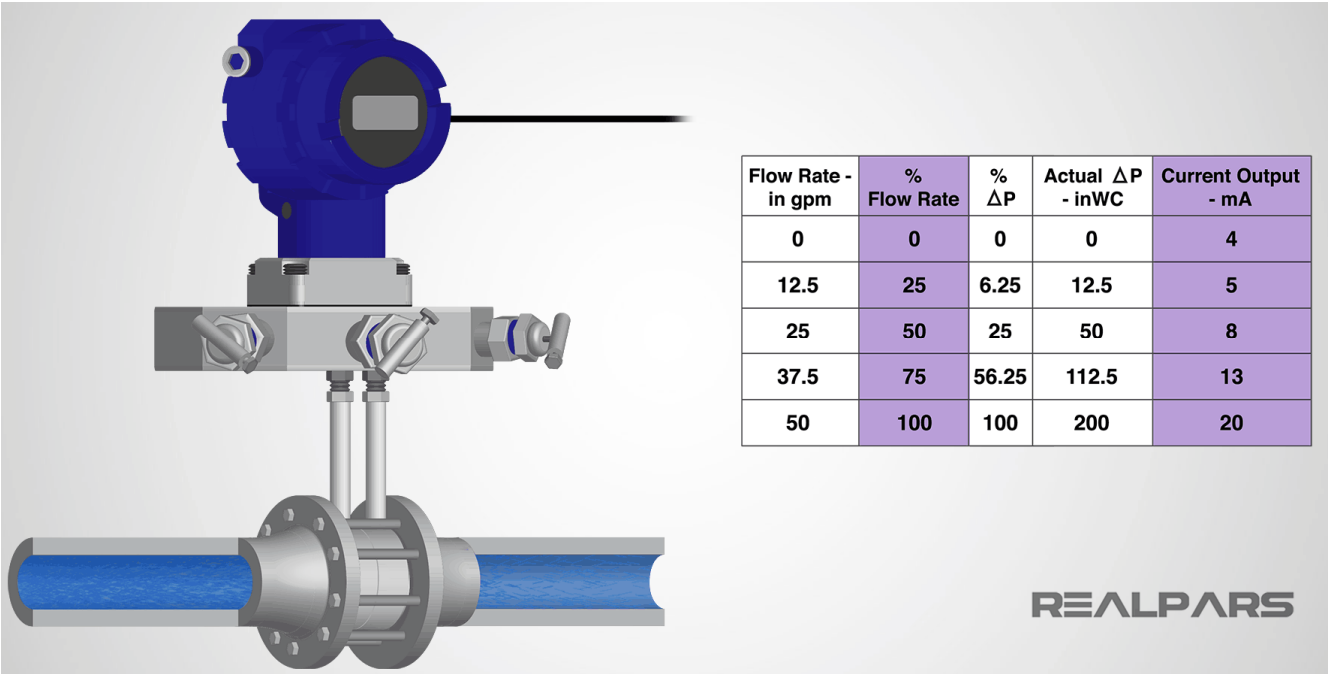
– Close the High-Pressure Block Valve

Calibration Chart

We are going to ignore the square root extractor for now as we will be looking at the output current from the flow transmitter.

The first thing we need is a calibration chart or table. A table like this or similar is usually kept on file at your place of work.

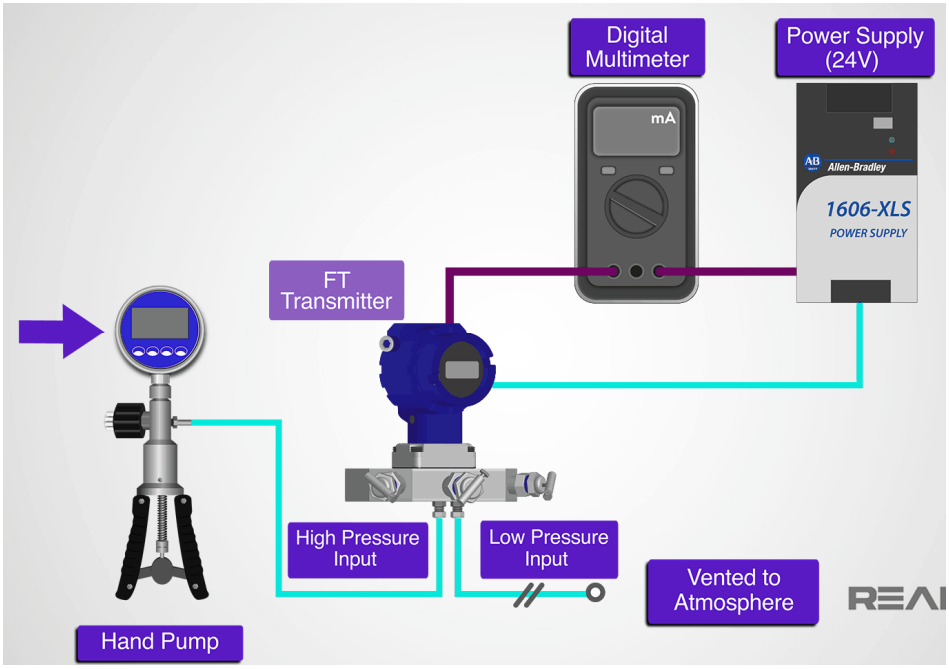
This table is important from a calibration perspective as it indicates what we need to apply to the transmitter, and what the expected current output will be.



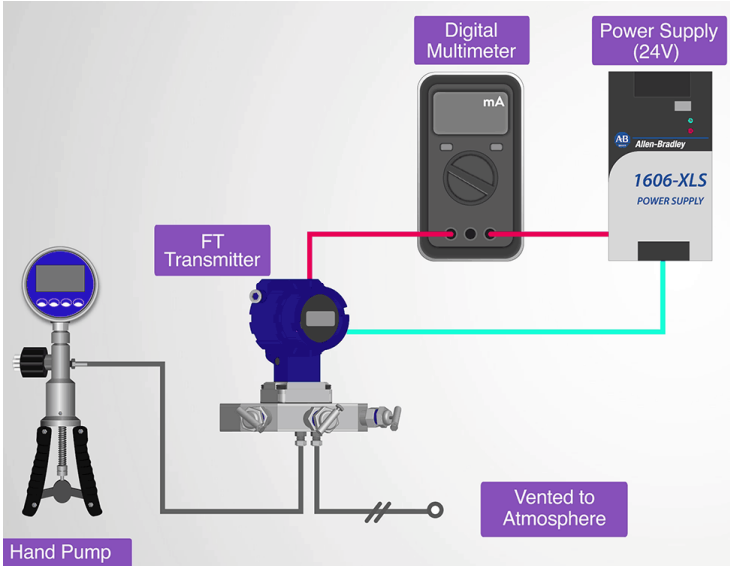
Flow Rate - in gpm	% Flow Rate	% ΔP	Actual ΔP - inWC	Current Output - mA
0	0	0	0	4
12.5	25	6.25	12.5	5
25	50	25	50	8
37.5	75	56.25	112.5	13
50	100	100	200	20

Calibration Setup

Here's the calibration setup. The scissor-type hand pump with a digital pressure readout is connected to the high-pressure side of the transmitter.
There are several different types of pressure sources used in the industry. Note that the low-pressure side of the transmitter is vented to the atmosphere.
A digital multimeter set to measure current is connected in series with the transmitter and the 24-volt power supply.

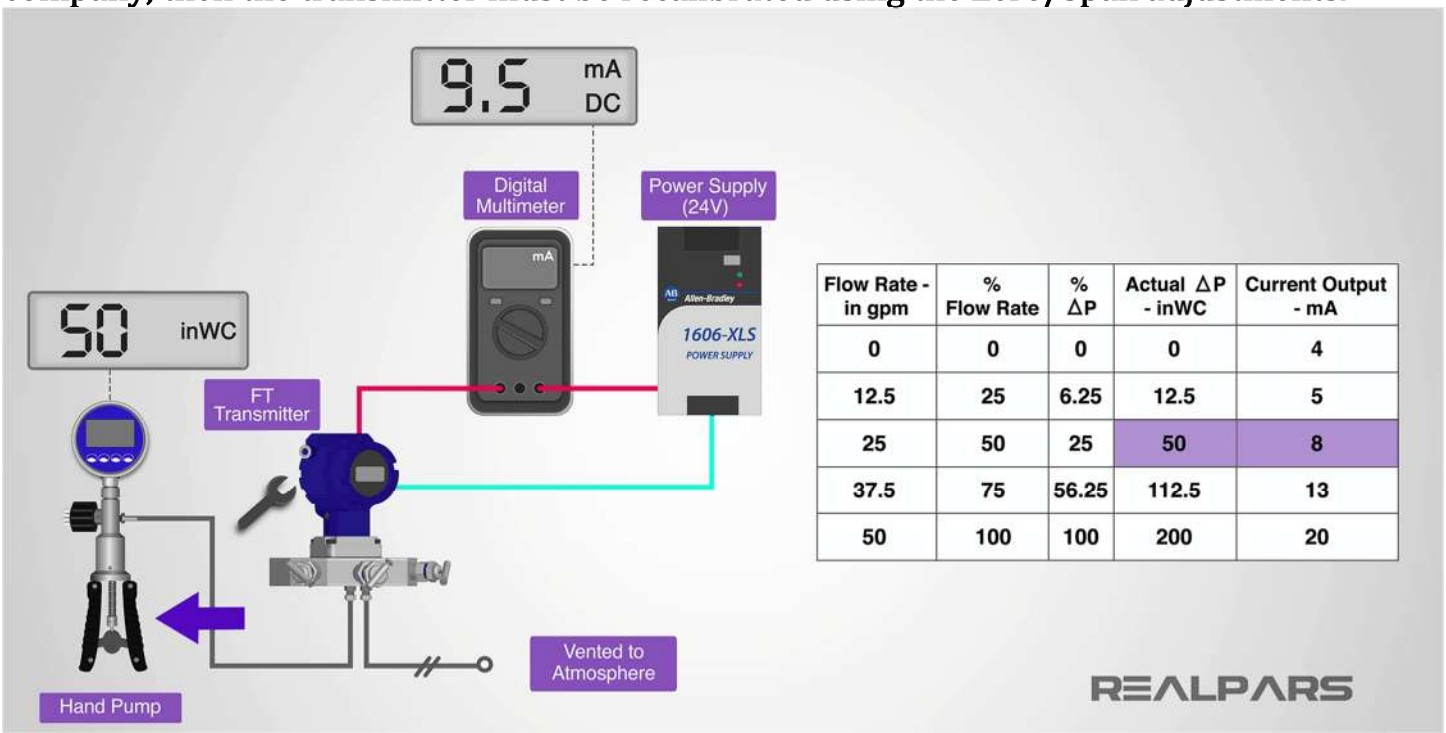


From the table, we can see that if we set the hand pump input pressure to 50 inches of Water Column, our multimeter should read 8 milliamps.



Flow Rate - in gpm	% Flow Rate	% ΔP	Actual ΔP - inWC	Current Output - mA
0	0	0	0	4
12.5	25	6.25	12.5	5
25	50	25	50	8
37.5	75	56.25	112.5	13
50	100	100	200	20

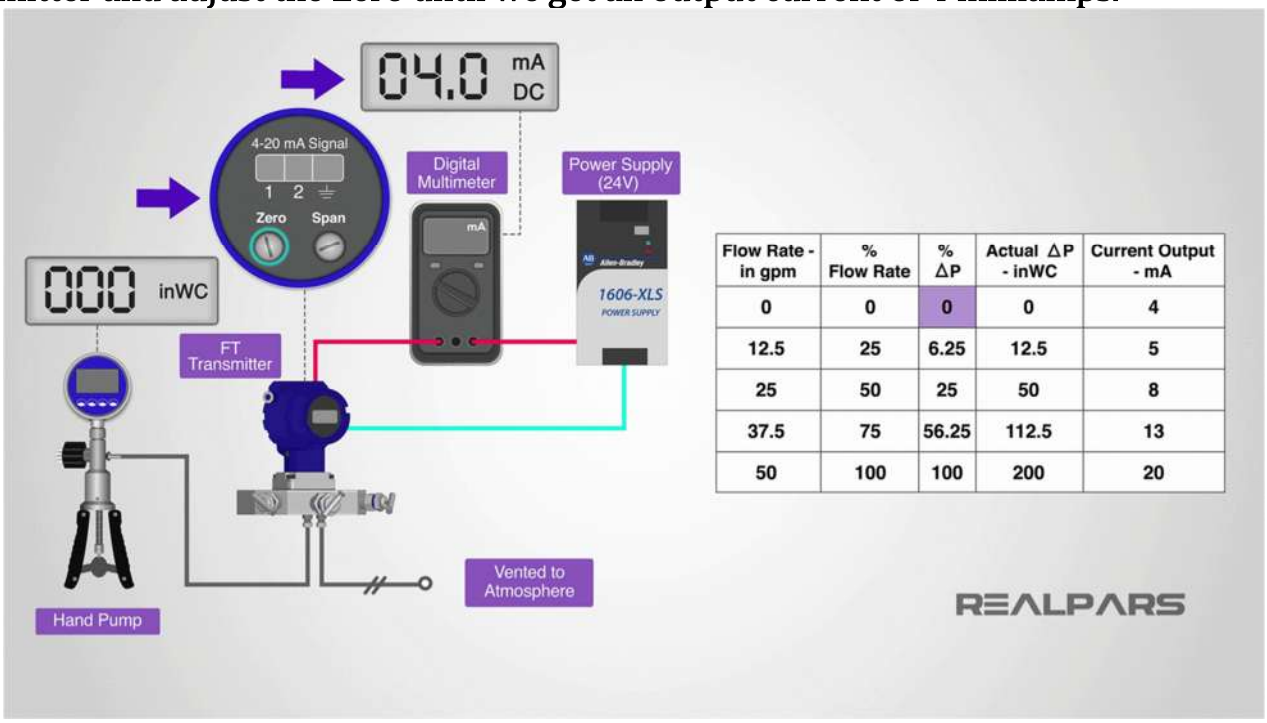
OK, now we've seen how the calibration table will work for us. We've got the transmitter all set up, let's do some testing.
First of all, we're going to check to see if the transmitter needs to be adjusted. We begin by applying the desired pressure input values from the calibration table to the high input on the flow transmitter and record the output current measured for each input value.
If the output currents measured are outside of the acceptable ranges as established by your company, then the transmitter must be recalibrated using the Zero/Span adjustments.



Flow Rate - in gpm	% Flow Rate	% ΔP	Actual ΔP - inWC	Current Output - mA
0	0	0	0	4
12.5	25	6.25	12.5	5
25	50	25	50	8
37.5	75	56.25	112.5	13
50	100	100	200	20

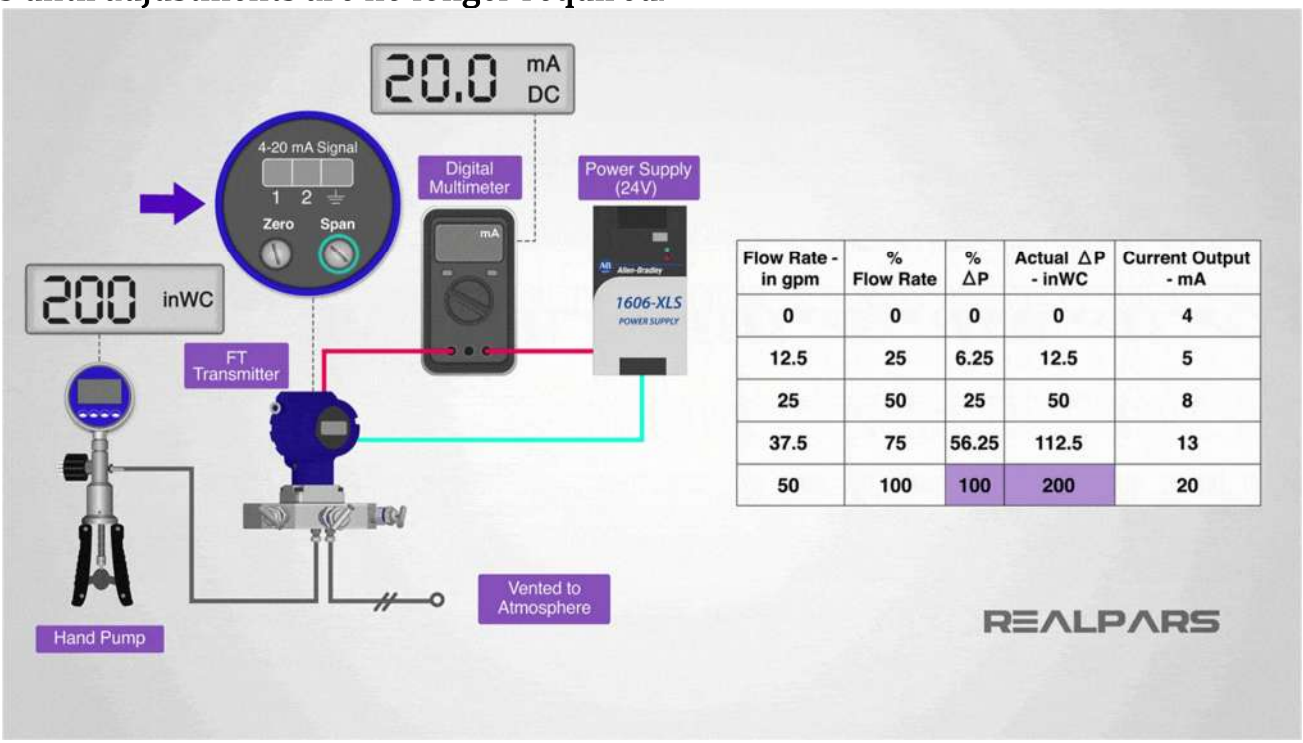
We perform the actual calibration using the Zero/Span adjustments on the transmitter

Apply the 0% input pressure value, which for us is 0 inches Water column, to the transmitter and adjust the Zero until we get an output current of 4 milliamps.



Flow Rate - in gpm	% Flow Rate	% ΔP	Actual ΔP - inWC	Current Output - mA
0	0	0	0	4
12.5	25	6.25	12.5	5
25	50	25	50	8
37.5	75	56.25	112.5	13
50	100	100	200	20

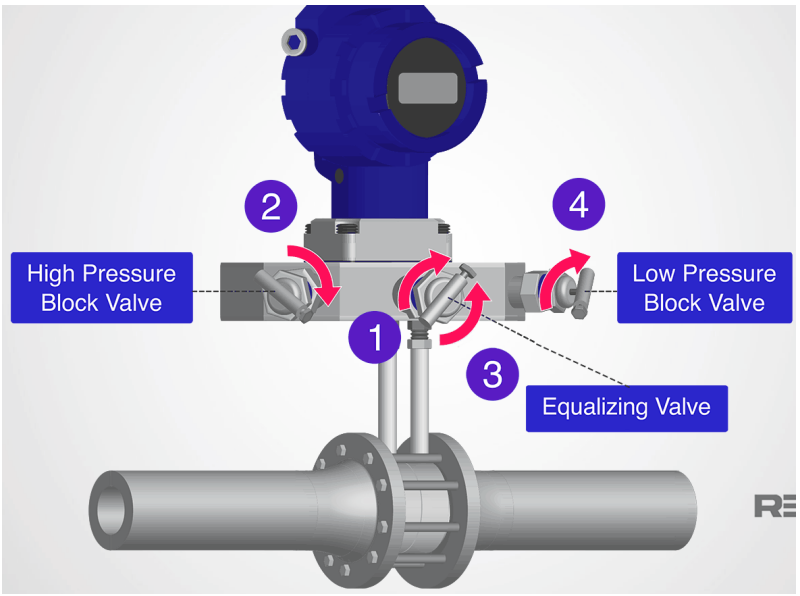
Apply the 100% input pressure value, which for us is 200 inches Water Column, to the transmitter and adjust the Span until we get an output current of 20 milliamps. Repeat the steps until adjustments are no longer required.



Flow Rate - in gpm	% Flow Rate	% ΔP	Actual ΔP - inWC	Current Output - mA
0	0	0	0	4
12.5	25	6.25	12.5	5
25	50	25	50	8
37.5	75	56.25	112.5	13
50	100	100	200	20

Returning the Transmitter to Service

Now that you've recalibrated, it's a good idea to apply all of the values from the calibration table and record the corresponding output current values.



Let's return the transmitter to service now that it's been calibrated.

– Begin with all valves closed

– Open the equalizing valve

– Open the High-Pressure Block Valve (slowly)

– Close the equalizing valve

– Open the Low-Pressure Block Valve

- Remember, we ignored the square root extractor when we calibrated the transmitter. Let's connect the square root extractor to the output of the transmitter and see what happens.

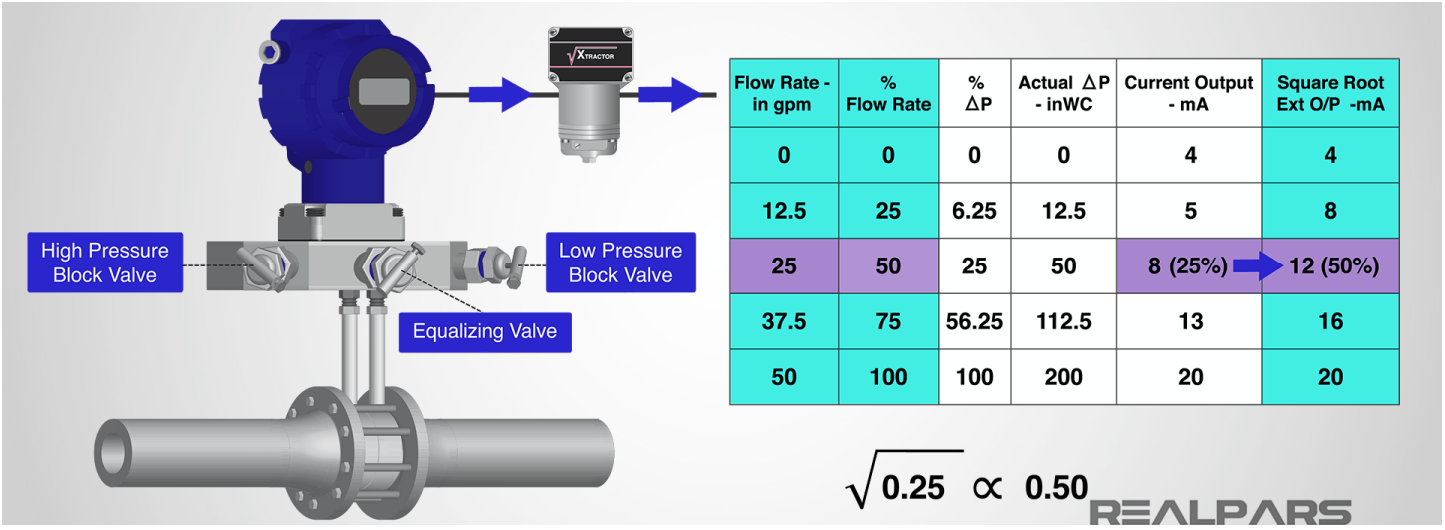
We now have a linear and directly proportional relationship between the flow rate and the current output of the square root extractor. Perfect! That's exactly what our PLC or DCS needs to see.

The math is a bit complicated, but let's try an example. When we have a 50% flow rate of 25 gallons per minute, the square root extractor output is 12 milliamps, or 50% as well. But, the Flow transmitter output is 8 milliamps or 25%.

How do we convert 8 milliamps to 12 milliamps?

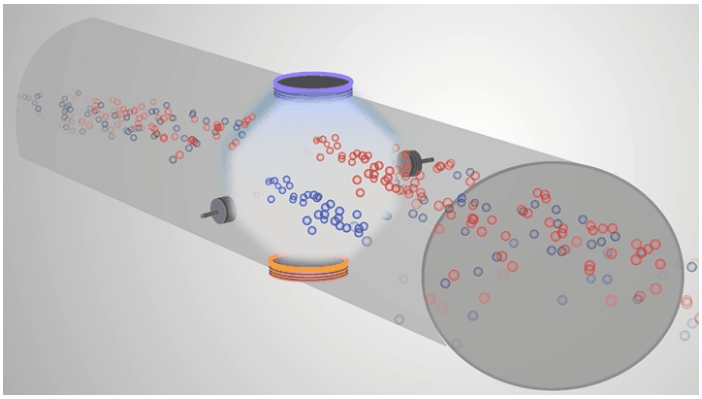
Very simply, the square root extractor will ensure that its output is the square root of its input.

The square root of 25% is 50%! Try the math on a calculator. So, with a Flow Transmitter output current of 8 milliamps, the square root extractor will produce an output current of 12 milliamps



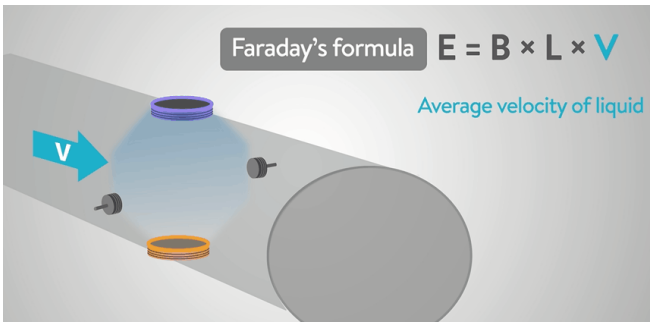
Flow Rate - in gpm	% Flow Rate	% ΔP	Actual ΔP - inWC	Current Output - mA	Square Root Ext O/P -mA
0	0	0	0	4	4
12.5	25	6.25	12.5	5	8
25	50	25	50	8 (25%)	12 (50%)
37.5	75	56.25	112.5	13	16
50	100	100	200	20	20

⑥ Electromagnetic:

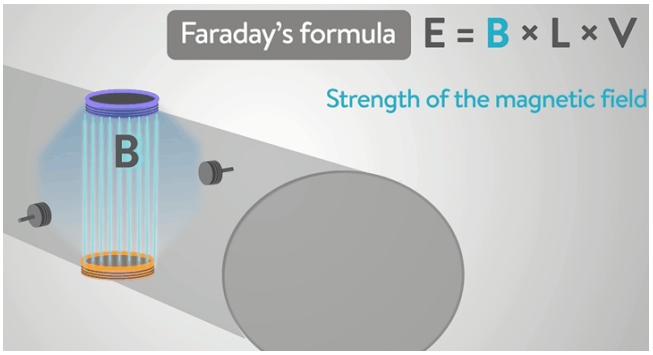


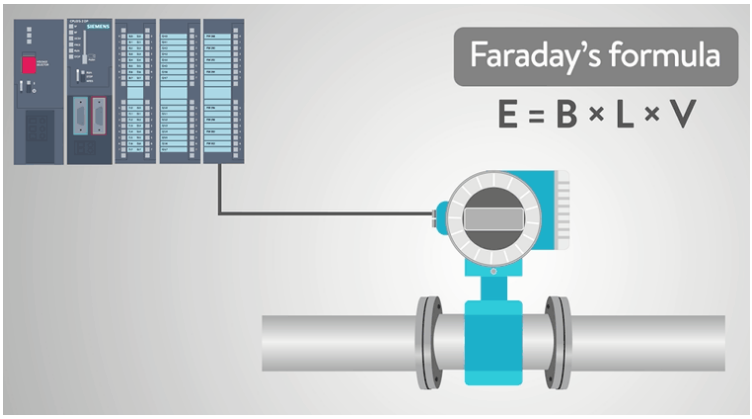
- The measured liquid must be water based or conductive.
- This makes the mag meter a great choice for waste water or process water that is considered fouled or dirty.
- Mag meters are volumetric meters that have no moving parts. This is ideal for those areas where you wouldn't want to be exposed to the measured liquid while working on the meter.

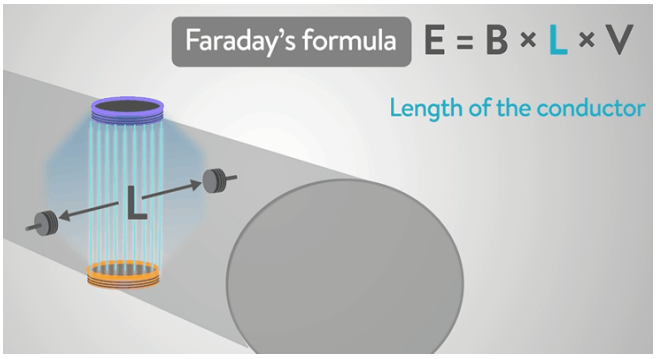
- The way a mag meter works is based on a formula called Faraday's formula. Firstly, again, the liquid must be conductive. A voltage is measured that is dependent on the average velocity of liquid times the strength of the magnetic field times the length of the conductor (this is the distance between the electrodes).



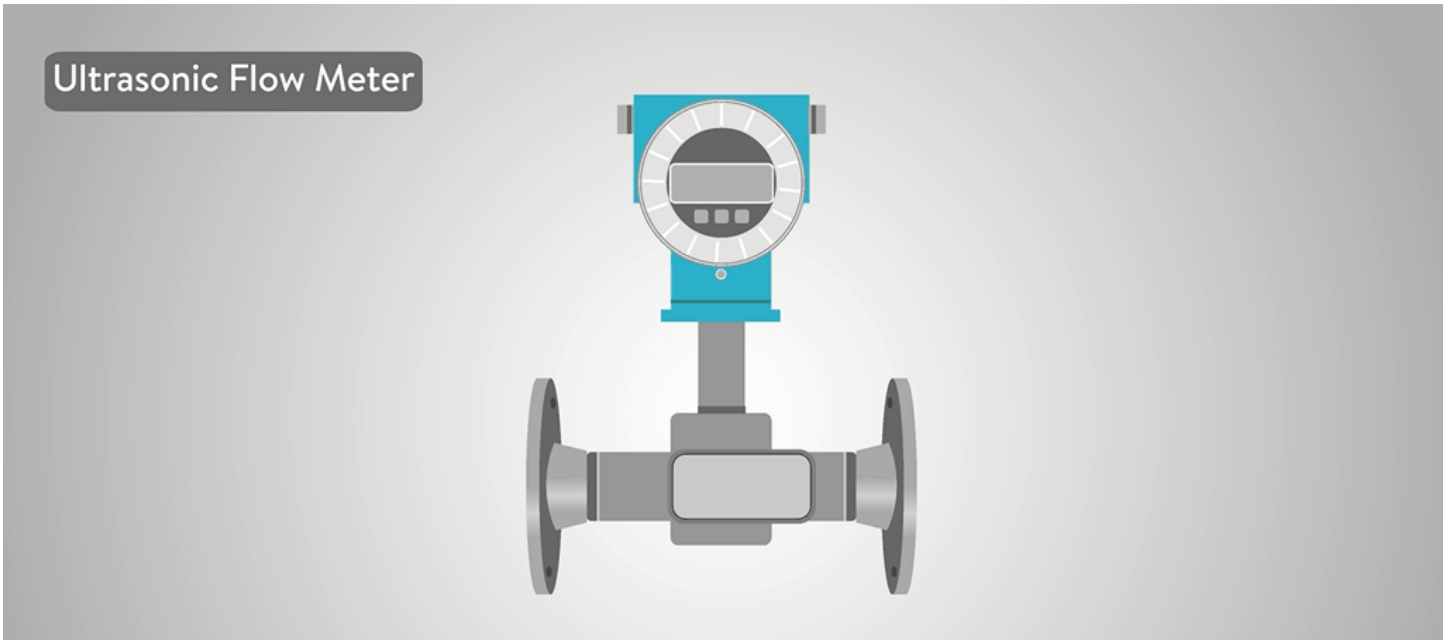
- We don't need to know Faraday's formula to use a mag meter. We don't necessarily even need to know what that formula is, we just know that whomever invented the mag meter used the formula to produce a signal voltage that can be measured by your automation process.



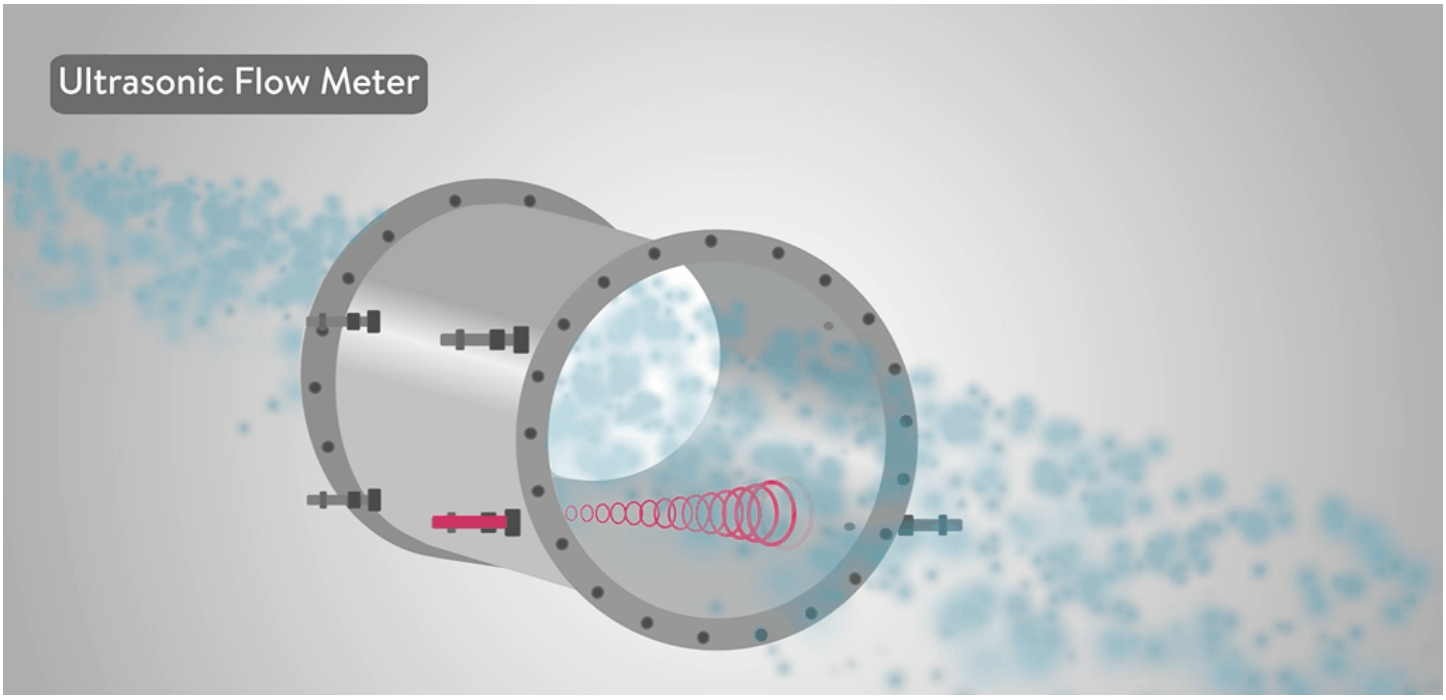




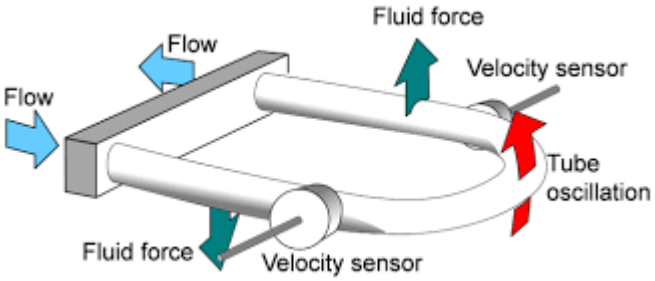
⑦ Ultrasonic:



- The principle behind these meters is that an ultrasonic signal is transmitted downstream or in the direction of the flow while another signal is transmitted upstream.
- The delta or differential time is used to calculate the velocity of the liquid.
- That velocity is then used to calculate the volumetric flow through the pipe.

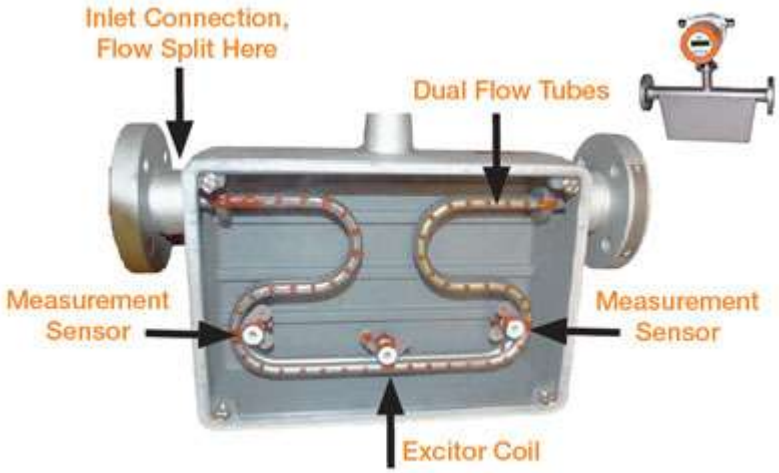


⑧ Coriolis:



Each Coriolis flowmeter has one or more measuring tubes which an exciter causes to oscillate artificially. As soon as the fluid starts to flow in the measuring tube, additional twisting is imposed on this oscillation due to the fluid's inertia. Two sensors detect this change of the tube oscillation in time and space as the "phase difference." This difference is a direct measure of the mass flow.

In addition, the fluid density can also be determined from the oscillation frequency of the measuring tubes. The temperature of the measuring tube is also registered to compensate thermal influences. The process temperature derived from this is available as an additional output signal.



Application Range:

- Chemical: containing chemical reaction system
- Petroleum: moisture content analysis
- Lipids: including vegetable oils, animal fats and other oils
- Textile printing and dyeing
- Fuel: crude oil, heavy oil, coal slurry, lubricant and other fuels
- Food: gas dissolving beverage, health drink and other liquid
- Transportation: pipeline liquid measurement
- High pressure fluid, like slurry flow measurement for oil drilling cementing.

Advantages:	Disadvantages:
• Extremely accurate and repeatable • Not affected by changes in media density • Good for applications where the media's properties aren't already well known • Do not require straight piping runs • Some models can also measure density, temperature, volumetric flow, or viscosity	• higher cost. • large and heavy. • Require an inline installation. • they are not good for dual-phase media.