# INDEX

## PART- I
## (INPUT DEVICES)

**Topic Description** **Page no**

## PRESSURE MEASUREMENT

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## PRINCIPLES OF PRESSURE MEASUREMENT

**General Theory**

Pressure is probably one of the most commonly measured variables in the power plant. It includes the measurement of steam pressure; feed water pressure, condenser pressure, lubricating oil pressure and many more. Pressure is actually the measurement of force acting on area of surface. We could represent this as:

Pressure = Force / Area

Or

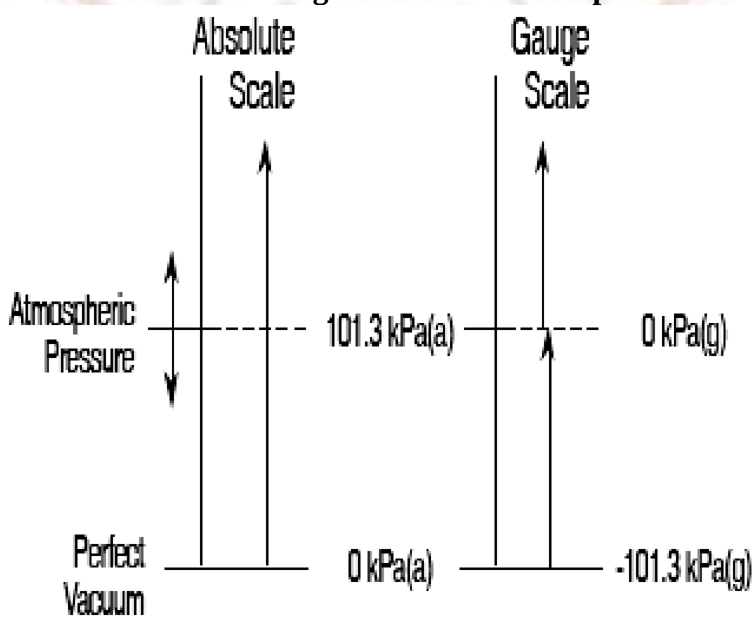
P = F / A

The units of measurement are either in pounds per square inch (PSI) in British units or Pascals (Pa) in metric. As one PSI is approximately 7000 Pa, we often use kPa and MPa as units of pressure.

**Pressure Scales**

Before we go into how pressure is sensed and measured, we have to establish a set of ground rules. Pressure varies depending on altitude above sea level, weather pressure fronts and other conditions. The measure of pressure is, therefore, relative and pressure measurements are stated as either *gauge* or *absolute*.

**Absolute Pressure = Gauge Pressure + Atmospheric Pressure**

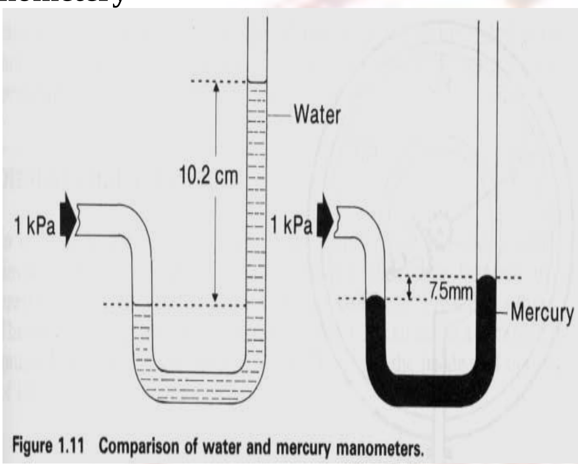



**Relationship between Absolute and Gauge Pressures**

**Types of pressure Measurement**

- Mechanical
  U-tube manometer, Bourdon tube, Diaphragm and Bellows
- Electrical
  Strain Gauge, Capacitive sensor, Potentiometric, Resonant Wire, Piezoelectric, Magnetic, Optical

**Manometery**



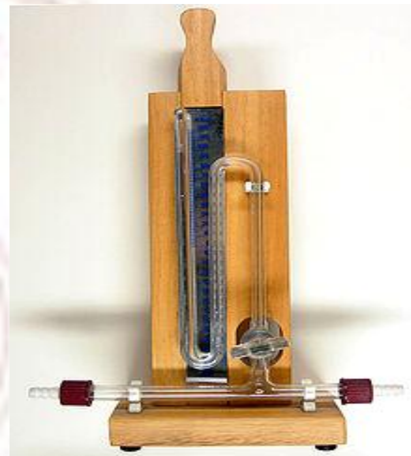
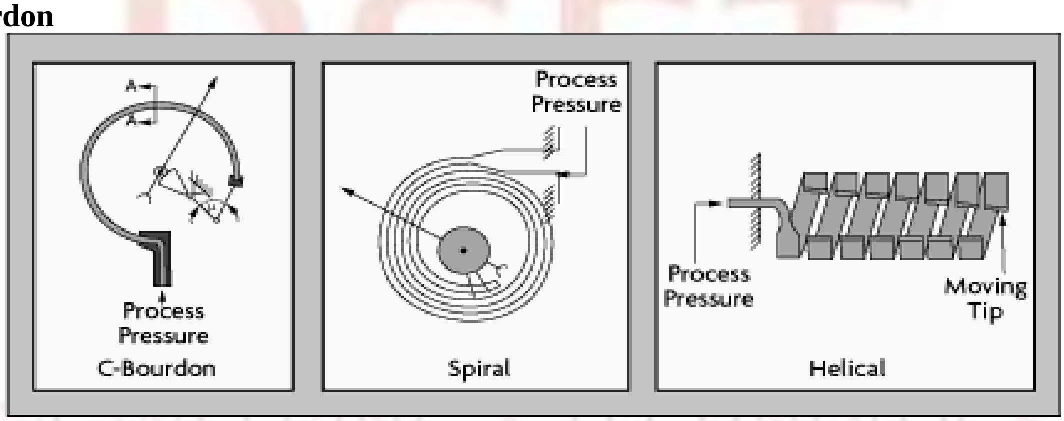



Figure1: mercury column

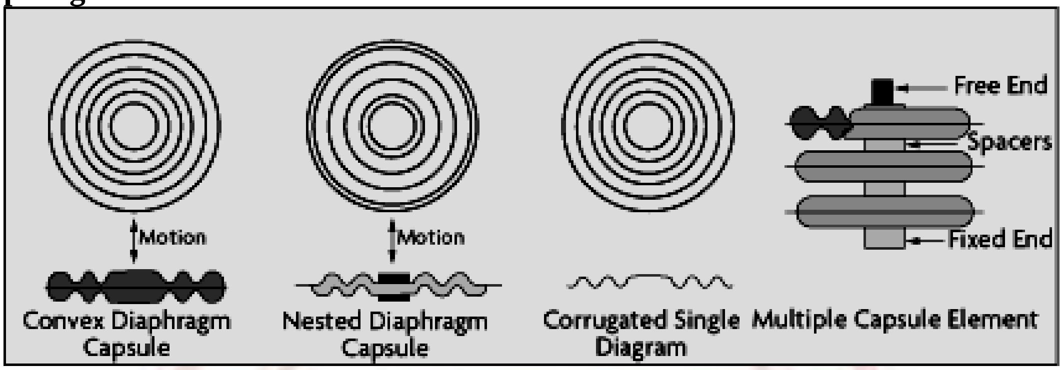
Manometers measure a pressure difference by balancing the weight of a fluid column between the two pressures of interest. Large pressure differences are measured with heavy fluids, such as mercury (e.g. 760 mm Hg = 1 atmosphere). Small pressure differences are measured by lighter fluids such as water (27.7 inch $H_2O$ = 1 psi; 1 cm $H_2O$ = 98.1 Pa). Typical in laboratories. **Pascal's law** or **the Principle of transmission of fluid-pressure** states that "pressure exerted anywhere in a confined incompressible fluid is transmitted equally in all directions throughout the fluid such that the pressure ratio (initial difference) remains same."

**Bourdon**



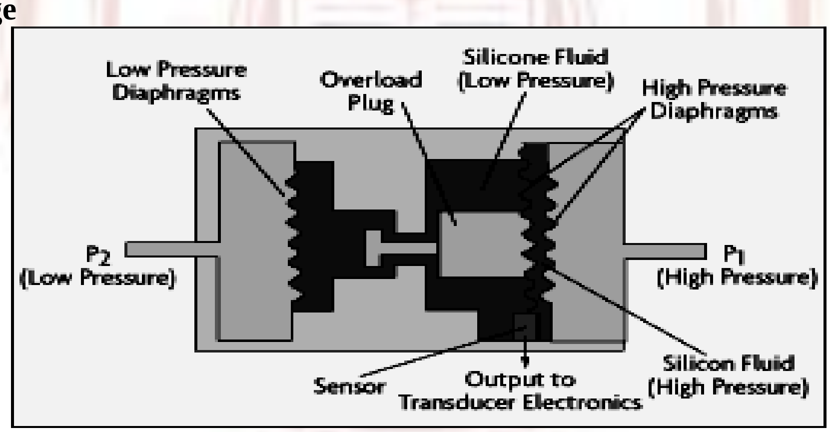

- Flexible element used as sensor.
- Pressure changes cause change in element position.
- Element connected to pointer to reference pressure
- Pressure from 10 PSI to 15,000 PSI

### Diaphragm and Bellows



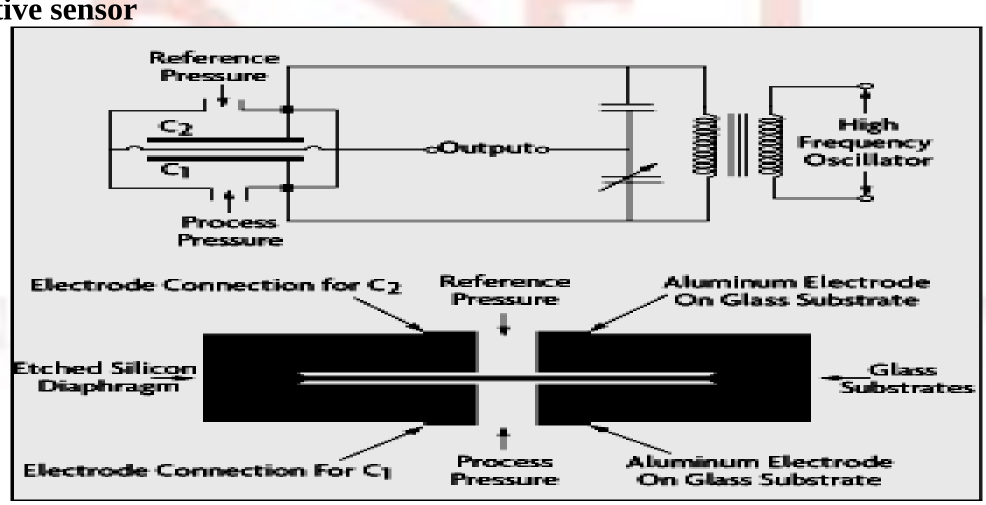

- Similar concept to Bourdon type.
- Widely used because they require less space and can be made from materials that resist corrosion.

### Strain gauge



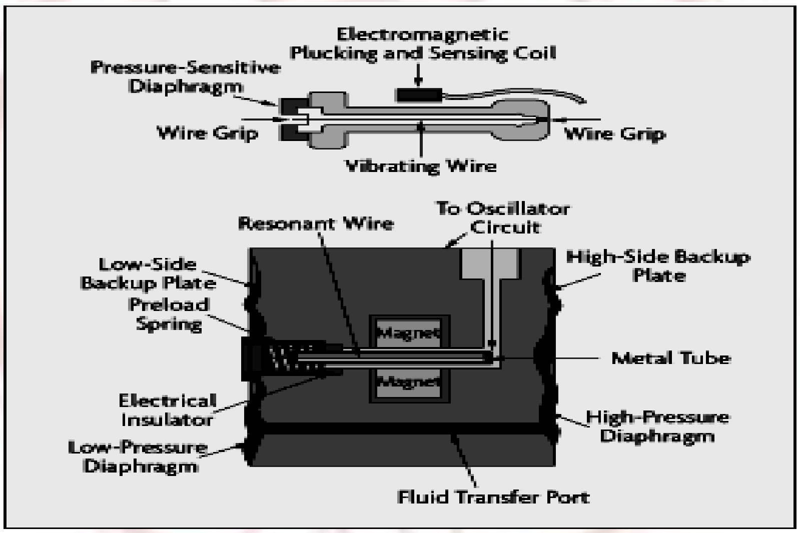

- Measures deflection of elastic diaphragm due to pressure difference across diaphragm.
- Widely used in industry.
- Used for small pressure ranges.
- Measurements tend to drift

### Capacitive sensor



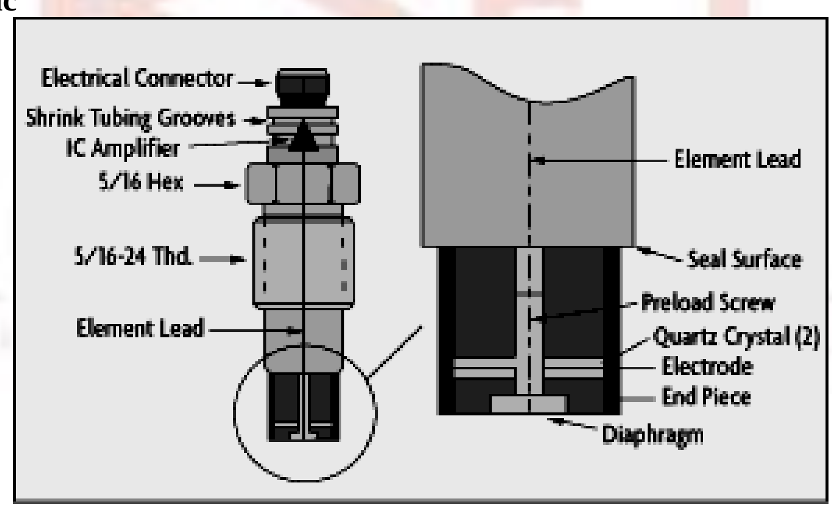
- Measures changes in capacitance of electrically charged electrodes from movement of metal diaphragm due to pressure difference across diaphragm.
- Can be operated in balanced or unbalanced mode.
  - Balanced always has capacitance of zero. Measures pressure indirectly by measuring drift in capacitor arms.
  - Unbalanced measures ratio between output voltage and excitation voltage.
- Widely used in industry.
- Large rangeability.

**Resonant wire**



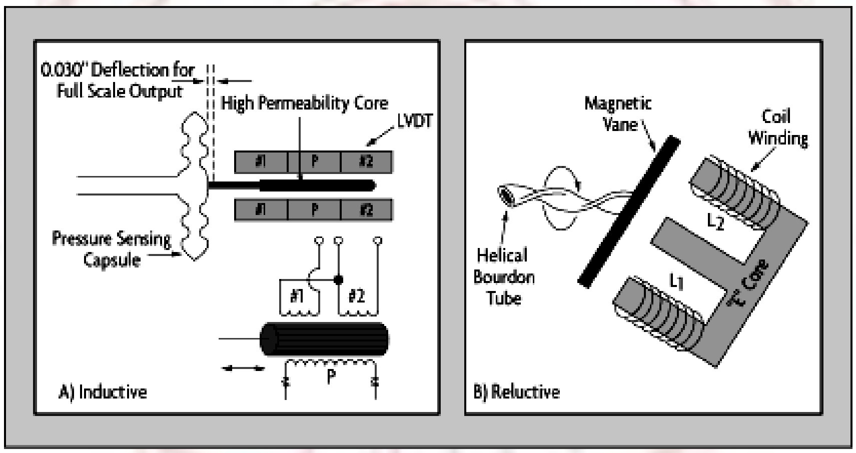

- Wire is oscillated at resonant frequency by oscillator circuit.
- Pressure changes cause change in wire tension which changes oscillatory frequency.
- Generates digital signal.
- Very precise, used for low differential pressure measurements.
- Sensitive to temperature variation and has non-linear output

**Piezoelectric**



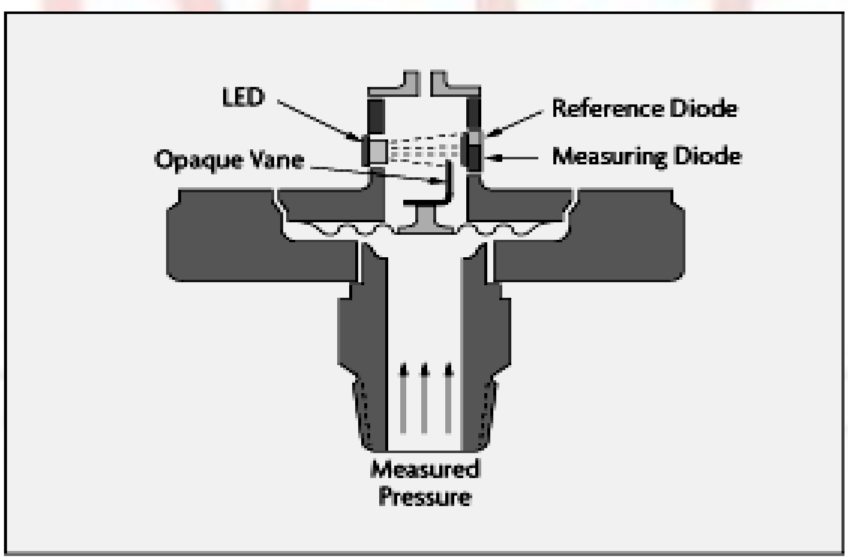
- Measures the charge developed across quartz crystal due to change in pressure.
- Charge decays rapidly making unsuitable for static pressure measurements.
- Sensors are very rugged. Pressure can be applied longitudinally or transversally.
- Used to measure dynamic pressure changes associated with explosions and pulsations.
- The output voltage of the piezoelectric crystal is proportional the change in its thickness.

**Magnetic**




- Measures induced current caused by movement of magnetic components from pressure changes.
- Used in applications where high resolution in small range is desired due to very high output signals.
- Sensitive to stray magnetic fields and temperature changes.

**Optical**



- Detects effects of minute motions due to process pressure changes through partial blocking of an LED
- Immune to temperature effects.
- Excellent stability and long-duration capability.

**Units of Measure**

| System | Length | Force | Mass | Time | Pressure |
|---|---|---|---|---|---|
| MKS | Meter | Newton | Kg | Sec | N/M2 = Pascal |
| CGS | CM | Dyne | Gram | Sec | D/CM2 |
| English | Inch | Pound | Slug | Sec | PSI |

**Pressure units**

| | Pascal (Pa) | Bar (bar) | Technical atmosphere (at) | Atmosphere (atm) | Torr (torr) | Pound-force per square inch (psi) |
|---|---|---|---|---|---|---|
| **1 Pa** | ≡ 1 N/$m^2$ | $10^{-5}$ | $1.0197\times10^{-5}$ | $9.8692\times10^{-6}$ | $7.5006\times10^{-3}$ | $145.04\times10^{-6}$ |
| **1 bar** | 100,000 | ≡ $10^6$ dyn/$cm^2$ | 1.0197 | 0.98692 | 750.06 | 14.5037744 |
| **1 at** | 98,066.5 | 0.980665 | ≡ 1 kgf/$cm^2$ | 0.96784 | 735.56 | 14.223 |
| **1 atm** | 101,325 | 1.01325 | 1.0332 | ≡ 1 atm | 760 | 14.696 |
| **1 torr** | 133.322 | $1.3332\times10^{-3}$ | $1.3595\times10^{-3}$ | $1.3158\times10^{-3}$ | ≡ 1 Torr; ≈ 1 mmHg | $19.337\times10^{-3}$ |
| **1 psi** | $6.894\times10^{3}$ | $68.948\times10^{-3}$ | $70.307\times10^{-3}$ | $68.046\times10^{-3}$ | 51.715 | ≡ 1 lbf/$in^2$ |

**Pressure measurement is important because of the following reasons:**

- Pressure is an important quantity that describes a system.
- Pressure is invariably an important process parameter.
- Pressure difference is used many a time as a means of measuring the flow rate.
- Pressure level spans some 18 orders of magnitude from the lowest to the highest pressures encountered in practice.
- The pressure measuring devices and the corresponding ranges

**Pressure gauge types and ranges**

| No. Type | Lower limit | Upper limit |
|---|---|---|
| | | |
| 1 Ionization gauge | $10^{-8}$ | $10^{-3}$ |
| 2 Pirani gauge | $10^{-4}$ | 1 |
| 3 McLeod gauge | $10^{-6}$ | 1 |
| 4 Manometers | $10^{-1}$ | $10^{4}$ |
| 5 Piezoelectric transducers | $10^{2}$ | $10^{6}$ |
| 6 Bellows type gauge | 10 | $10^{4}$ |
| 7 Diaphragm gauge | 1 | $10^{6}$ |
| 8 Bourdon gauge | 1 | $10^{7}$ |
| 9 Resistance gauge | $10^{4}$ | $10^{9}$ |

**Note: Entries in the Table are in mm of mercury (= Torr).**

**Useful units and conversion factors:**

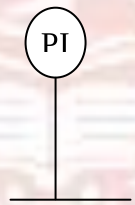
1. 1 Pascal or 1 Pa = 1 $N/m^2$,
2. 1 atmosphere = 760 mm mercury column = $1.013\times10^5$ Pa
3. 1 mm mercury column = 1 Torr
4. 1 Torr = $1.316\times10^{-3}$ atmosphere = 133.3 Pa
5. 1 bar = $10^5$ Pa

# PRESSURE GAUGES

**Description**

The differential pressure gauges are particularly intended for the monitoring of differential pressures in filter systems, pumps and pipeline systems in the heating, ventilation and air-conditioning sector, technical building equipment and in the water management industry. Apart from the display of the differential pressure, these applications require, as a rule, the display of the current working pressure. For this reason, a working pressure gauge is integrated in the DELTA-plus differential pressure gauge as a standard feature. An additional measuring point involving additional expenses for piping and mounting is thus no longer required.

**Symbol**




Flow sheet symbol

**Figure**


*Figure1: pressure gauge (Ashcroft)*


*Figure2: pressure gauge (A1-Honeywell)*

- As an in-process gauge or portable calibrator, the hand-held Model AI delivers long-lasting performance with enhanced accuracy. Accuracy of 0.05 % coupled with an enhanced resolution, 4½-digit display makes this unit an excellent transfer standard for calibrating pressure measuring equipment.
- The AI is rugged and features high/low pressure capture with a field-adjustable update rate from three-to-ten times per second. These units are manufactured from stainless steel and use sensor technology which has no moving parts, requires little recalibration and has excellent overpressure tolerance. NEMA 4 construction provides EMI and RFI protection. Units of measure are field-selectable, and the unit is offered with gage, absolute, vacuum, or compound reference.

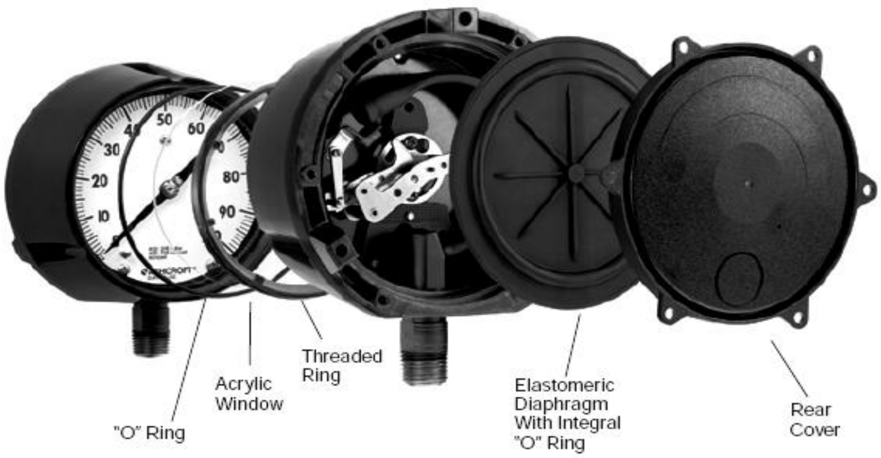



***Figure 3: exploded view of pressure gauge***

**SPECIFICATIONS**

***Functional***

- Service: Liquid, gas, and vapour.
- Pressure range: 0 psi-15, 50, 100, 200, 500, 750, 1000, 1500, 2000, 5000, 7500 psi -gage, absolute, vacuum, or compound
- Accuracy: 0.05% of full scale BSFL
- High and Low capture: Standard
- Update speed: adjustable from 3 to 10 per second
- Rating: NEMA 4
- Power, model AIW: one or two 9V alkaline batteries (included)
- Power model AIV: 11 Vdc to 32 Vdc @ 100 Ma (3ft cable included)
- Performance: Fights vibration and pulsations without liquid-filled headaches, Liquid-filled performance in a dry gauge

***Temperature Limits***

- Environmental temp: -18 °C to 82 °C (0 °F to 180 °F)
  (Operating standard)

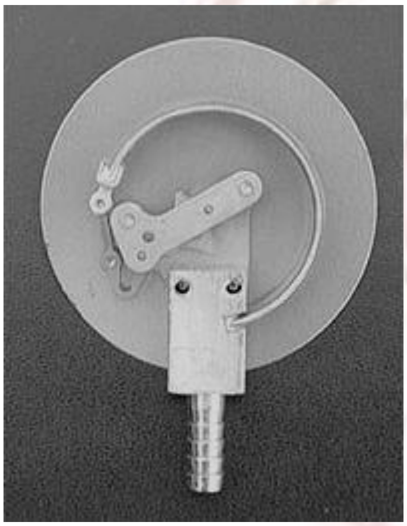
***Physical***

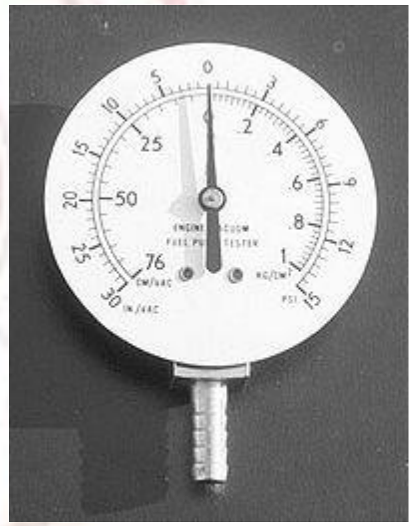
Materials of Construction

- Wetted parts: stainless steel
- Case Material: Black phenolic, solid front, or stainless steel
- Weather Protection: Dry Case: IP54 Liquid filled or hermetically sealed case:IP65
- Ring: Threaded reinforced black polypropylene
- Window: Glass
- Dial: Aluminum, white background, black figures and intervals.
- Pointer: Micrometer adjustable,
- Movement: Rotary, 400 SS, Teflon® coated pinion gear and segment
- Bourdon Tube and Socket: C510 Phos. bronze/brass brazed (A),316L SS/steel (R) 316L SS/316L SS (S), K Monel/ Monel (P)
- Connection Size: 1⁄4″, 1⁄2″ NPT
- Connection Location: Lower or back
- Stainless steel construction
- 4½ digit display with 0.5 in height or 4 LCD digits

**PRINCIPLE OF OPERATION**

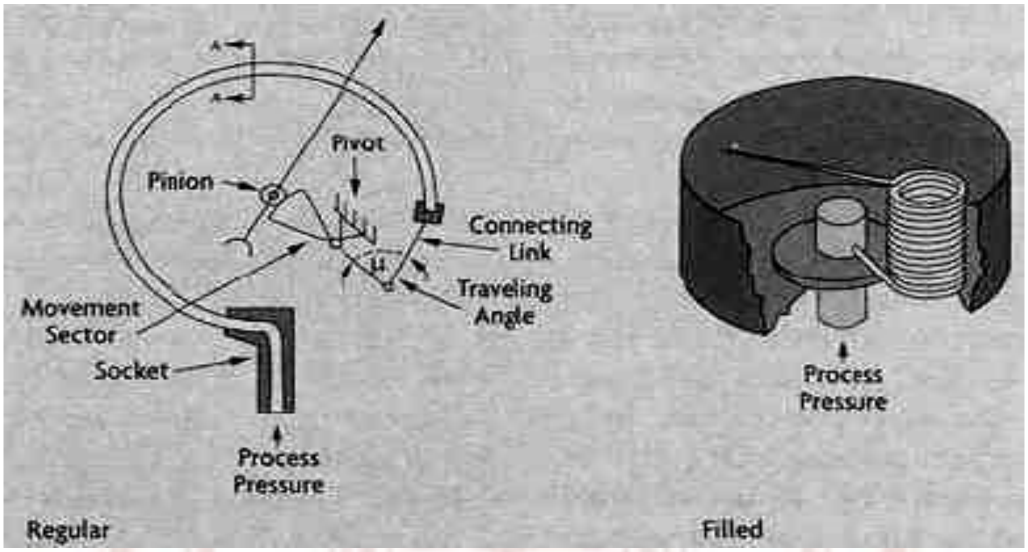
Most of our gauges are constructed with bourdon tubes to measure pressure and vacuum. The bourdon tube, which is a hollow metallic tube sealed at one end, flexes when pressure is applied. It flexes because it naturally wants to straighten out, but cannot because it is linked to a geared movement. As it tries to flex, this linear movement is changed to a rotational one by means of small gears. They in-turn cause the pointer to indicate the measured pressure. Gauges like this are designed for clean, non-clogging liquids and gases.





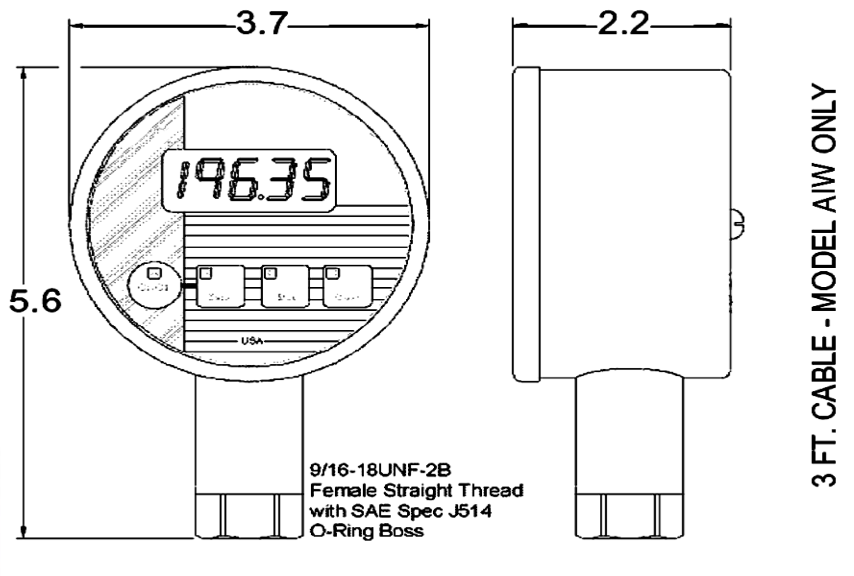
***Mechanical side with Bourdon tube*** ***Indicator side with card and dial***

The two most popular types of pressure gauges - dry and filled. The two most common causes for gauge failure are pipe vibration and water condensation (which can lead to freezing in colder environments).The delicate links pivots and pinions of a regular gauge are sensitive to both condensation and vibration. Filled gauges last longer because they have fewer moving parts and the housing is filled with a viscous glycol or silicon fluid. The fill in a gauge helps dampen pointer vibration and eliminates corrosion resulting from condensed water when installed in areas that have humid air
.




**INSTALLATION**

- The installation of pressure gauges shall in general be according to clause 3.6.4.6 of Instrumentation Design Criteria and as per the Hook-up drawing given
- Pressure gauges shall be mounted such that they may be easily removed and adjusted without deforming impulse lines. All pressure gauges shall be installed so as to minimize the length of impulse lines. Necessary isolation valves shall be provided for all pressure gauges
- **Location** – Whenever possible, gauges should be located to minimize the effects of vibration, extreme ambient temperatures and moisture. Dry locations away from very high thermal sources (ovens, boilers etc.) are preferred. If the mechanical vibration level is extreme, the gauge should be remotely located (usually on a wall) and connected to the pressure source via flexible tubing. Pressure gauges shall not be installed in such a way that it depends for support on the impulse piping. Pressure gauges shall not be mounted directly on lines where vibration is likely to be present
- **Gauge reuse** – ASME B40.100 recommends that gauges not be moved indiscriminately from one application to another. The cumulative number of pressure cycles on an in-service or previously used gauge is generally unknown, so it is generally safer to install a new gauge whenever and wherever possible. This will also minimize the possibility of a reaction with previous media.
- **Tightening of gauge** – Torque should never be applied to the gauge case. Instead, an open end or adjustable wrench should always be used on the wrench flats of the gauge socket to tighten the gauge into the fitting or pipe. NPT threads require the use of a suitable thread sealant, such as pipe dope or teflon tape, and must be tightened very securely to ensure a leak tight seal
- **Process isolation** – A shut-off valve should be installed between the gauge and the process in order to be able to isolate the gauge for inspection or replacement without shutting down the process.
- **Surface mounting** – Also known as wall mounting. Gauges should be kept free of piping strains. The gauge case mounting feet, if applicable, will ensure clearance between the pressure relieving back and the mounting surface.




Request certified drawing before designing mountings or fixtures.
Specifications subject to change without notice.

## CALIBRATION

**Calibration of Pressure Gages using Dead Weight Tester:**

Apparatus: There are three primary components of this device: a fluid that transmits the pressure, a weight and piston used to apply the pressure, and an attachment point for the gage to be calibrated. The weight applies a force over a precisely known area, thereby applying a known pressure to the fluid. The fluid is oil that is essentially incompressible. Since a dead weight tester is relatively compact the effect of elevation changes on the pressure are negligible. The pressure at the piston face, therefore, is equal to the pressure throughout the oil in the tester.

Secondary components of the dead weight tester are a reservoir and an adjusting piston. The reservoir accumulates oil displaced by the vertical piston during tests when a large range of weights are used for a given gage. The adjusting piston is used to make sure that the vertical piston is freely floating on the oil.

1. Attach the gage to the stem, B.
2. Select a weight and place it on the vertical piston, A.
3. Move the handle of the adjusting piston C to insure that the weight and piston are supported by oil, not the bottom stop.
4. Spin the vertical piston to insure it is floating freely.
5. Record the gage reading and the weight.
6. Repeat steps 2 through 5 for increasing and decreasing weights for each gage. Be sure to cover as much of the range of the gage that can be achieved with available weights.

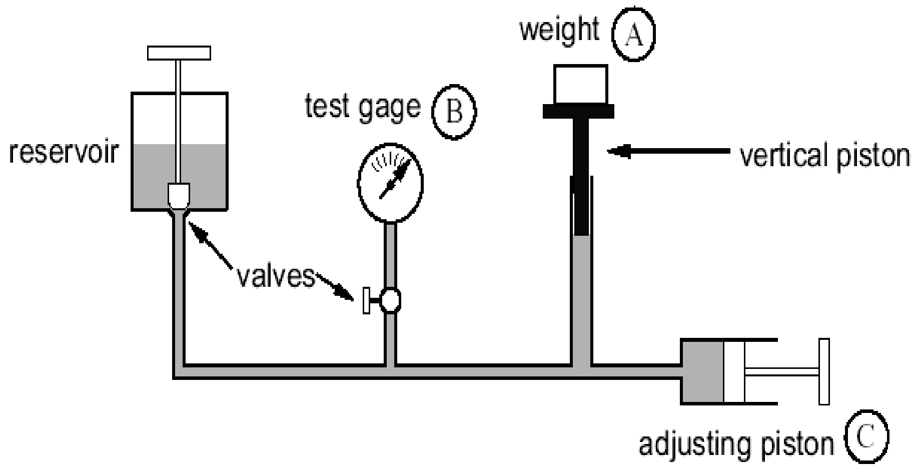



***Figure: Dead weight gage tester.***

**(Pascal's law** or **the Principle of transmission of fluid-pressure** states that "pressure exerted anywhere in a confined incompressible fluid is transmitted equally in all directions throughout the fluid such that the pressure ratio (initial difference) remains same.")

**Calibration chart:** After recording all the readings, it is necessary to calculate the errors associated with each test point using the following formula. ERROR in % = 100 × (TRUE VALUE - READING) ÷ RANGE. Plotting the individual errors (Figure1) makes it possible to visualize the total gauge characteristic. The plot should contain all four curves: upscale – before rap; upscale – after rap; downscale – before rap; downscale – after rap. "*Rap*" means lightly tapping the gauge before reading to remove friction as described in ASME B40.100.

**SELECTION CRITERIA**

- Since the accuracy of most pressure gauges is better in the middle portion of a gauge, you should always select a gauge with a range that is about double your maximum anticipated pressure. The maximum operating pressure should not exceed 80% of the full pressure range of the gauge.
- Standard pressure ranges are measured in PSI and most of the gauges you can purchase in our web store have dual PSI/metric scales in BAR or kPA. Very low pressure gauges have scales that measure in Inches of H2O, mm H2O, and Oz./Inch2. Vacuum gauges have scales in inches of mercury, while compound gauges have scales that measure in both vacuum and pressure.
- Our pressure gauges are available in 1-1/2" to 6" sizes (gauge size refers to the diameter of the dial, which is the viewing area of the gauge that shows the pressure scale and the pointer). Select a gauge size that is easily viewed where you'll have it installed. Obviously it has to fit within the physical space that you have. The dimensional drawings for our gauges are found here.
- Standard gauge connections are male NPT and they are located at the bottom or back of the gauge case. Our gauges are also available in panel mount configurations using either a U-Clamp or 3-Hole Flange around the case**.**

## CONFORMATION TO STANDARDS

| | | |
|---|---|---|
| BS EN 837-1:1998 | - | Pressure Gauges, Bourdon Tube Pressure Gauges, dimensions, Metrology, |
| BS EN 10204 | - | Metallic products- types of Inspection and Testing |
| IEC 60529 | - | Degrees of protection provided by enclosure (IP- Code) |
| ISO 9001 | - | Quality systems-model for quality assurance in design, development, production, installation and service |

## APPLICATIONS

Instrument for measuring the condition of a fluid (liquid or gas) that is specified by the force the fluid would apply, when at rest, to a unit area, such as pounds per square inch (psi) or Pascal (Pa). The reading on the gauge, called the gauge pressure, is always the difference between two pressures. When the lower of the pressures is that of the atmosphere, the total (or absolute) pressure is the sum of the gauge and atmospheric pressures.

## PARTIAL LIST OF SUPPLIERS

- Honeywell
- Ashcroft
- Hansen Technologies
- United electric controls
- Nason
- Dwyer
- Suco
- Hobbs
- Argus
- Rising Instruments

**PRESSURE REGULATORS**

**Description**

The pressure regulator is a complete pressure control loop, incorporating a sensor, a controller, and a valve.

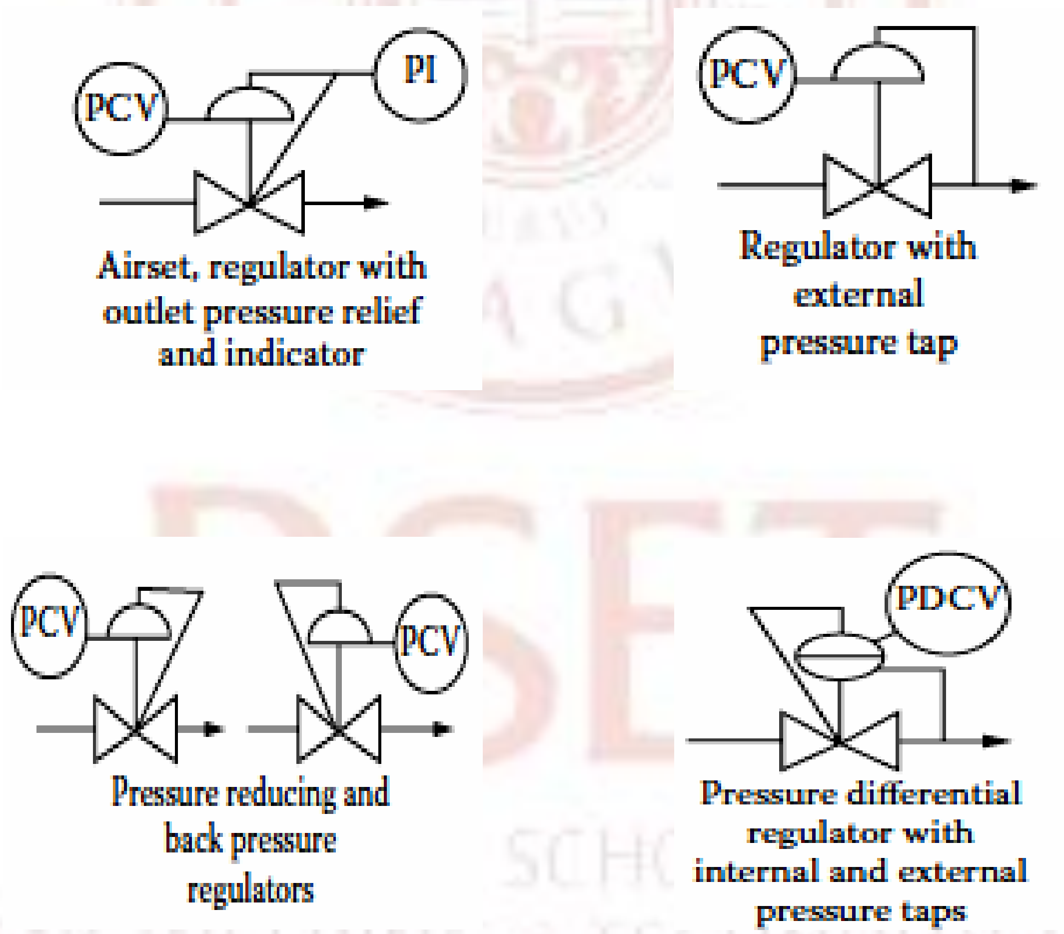
It is called a regulator (and not a controller) because it is mechanical and self-contained, requiring no external energy source.

In a regulator, the set point is integral, and remote set point adjustment is usually not possible.

All regulators are single mode (proportional only) and therefore they all have a set point droop, which results in an offset if the load (throughput) changes.

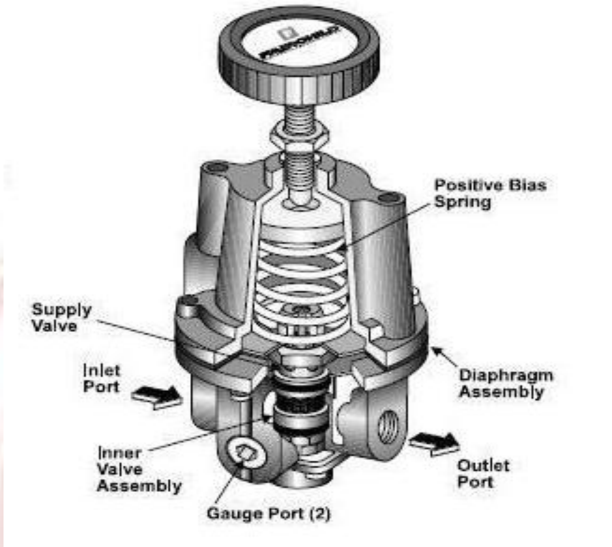
The available regulator materials of construction are limited, as is interchangeability with other services. Accessories are not available.

**Symbols**




*Pressure regulator flow sheet symbols*

**Figure**




*Pressure regulator*

**SPECIFICATIONS**

***Physical***

Regulator Types:

- A. Weight-loaded
- B. Spring-loaded
- C. Piloted 1/4 in. (6.25 mm) air regulator
- D. Internally piloted
- E. Externally piloted

Sizes:

- A. 1/2 to 6 in. (12.5 to 150 mm)
- B. 1/4 to 4 in. (6.25 to 100 mm)
- C. 1/4 in. (6.25 mm)
- D. 1/2 to 6 in. (12.5 to 150 mm)
- E. 3/4 to 12 in. (9.35 to 300 mm)

***Functional***

Design Inlet Pressure:

- B. Up to 6000 PSIG (41.4 MPa)
- D and E. Up to 1500 PSIG (10.35 MPa)
- A and C. Up to 500 PSIG (3.45 MPa)

Minimum Regulated Outlet:

- B and E. Down to 2 PSIG (13.8 kPa)

Pressure:

- A and D. Down to 0.5 PSIG (3.45 kPa)
- C. Down to 0.1 PSIG (0.69 kPa)

Droop or Offset:

- B. 5 to 80%
- E. 2 to 10%
- A and D. 1 to 2%
- C. 0.5%

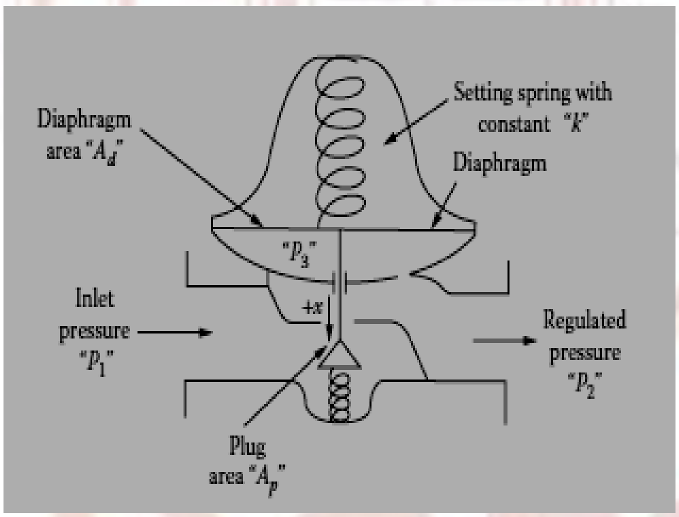
## CHARACTERISTICS

### Seating and Sensitivity

As shown in *Figure* below the balance of forces on the valve stem is

$$K \times x = A_p\,(P1 - P2) - A_d\,P3$$

Where $k$ = spring constant (lbf/in. or N/m)
$x$ = valve stem movement (in. or mm)
$A_p$ = port area (in.2 or mm2)
$P1$ = inlet pressure (PSIG or Pa)
$P2$ = outlet pressure or regulated pressure (PSIG or Pa)
$P3$ = diaphragm back-pressure (PSIG or Pa)
$A_d$ = diaphragm area (in.2 or mm2)




### Droop or Offset

- The regulator is a complete, self-contained feedback control loop with proportional-only control action. Thus, the regulated pressure will be offset by changes in the load disturbance variables (flow demand, in the case of a pressure-reducing valve).
- The offset in regulated pressure with changing flow is called droop.

### Minimizing Droop

- Regulator designs that minimize droop are available. Many of them place the feedback sensing line at a point of high velocity, either in the throat of a slight restriction or in the middle of the flowing fluid (Figure).
- The latter design uses the aspirating effect.
- Droop compensation can also be provided by a moving valve seat, which is called a pressure-compensating orifice that moves with upstream pressure.

**Sizing**

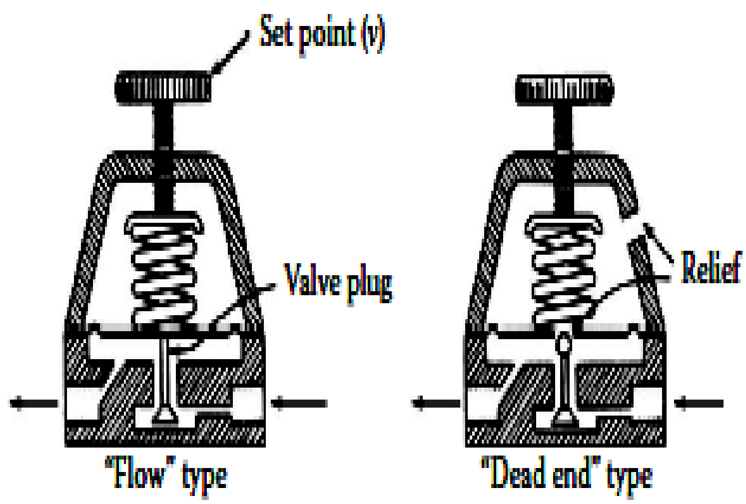
- Over sizing is the most common error in regulator selection.
- The droop characteristic makes a larger valve attractive, because a greater capacity is obtainable for the same droop.
- The larger valve also reduces noise because of its larger passages. These apparent advantages are offset by higher cost, severe seat wear, and poor regulation.
- The limitation on sizing is rangeability. Rangeability varies from 4 to 1 for a steam regulator, which cannot be operated close to its seat because of wire drawing, to over 50 to 1 for an air regulator.
- Regulators are sized on the basis of tabulated data or valve coefficients (*Cv*) provided by the manufacturer. Size is chosen to accommodate the maximum flow at minimum pressure drop.
- The valve should ideally operate at 50–60% open under normal conditions.

**Stability**

- Stability of the regulator installation depends on the open loop gain. For the regulator shown in Figure open loop gain is defined as

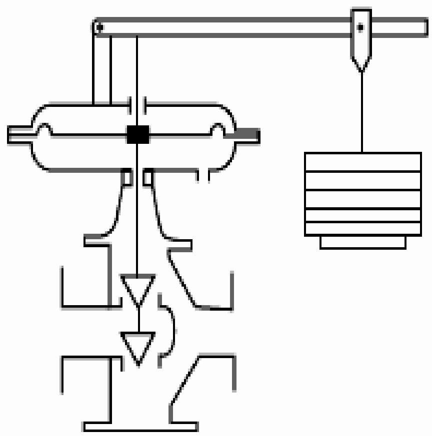
$$K_o = A_d (P_1^2 - P_2^2) / k \times P2$$

**PRINCIPLE OF OPERATION**



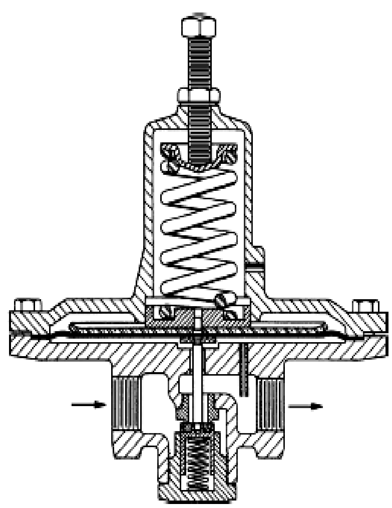

There are basically two types of pressure regulators. The *flow type* and the *dead-end type.* The flow type can reduce the flow to zero, but cannot allow for flow reversal. This is acceptable for most applications except for the dead ended air pressure control services. For them, if the outlet pressure is too high then the air has to be released to the atmosphere. The use of pressure regulators on liquid pressure control applications is not as likely to provide good control. This is because on noisy (very fast) liquid processes, the regulator is not likely to be fast enough to eliminate noise and, in fact, might amplify it. Generally it is better to control such processes with low gain (wide proportional) and long integral mode settings. Such settings are not available in regulators, as regulators are high gain, basic proportional controllers.

**Weight Loaded Pressure Regulator**



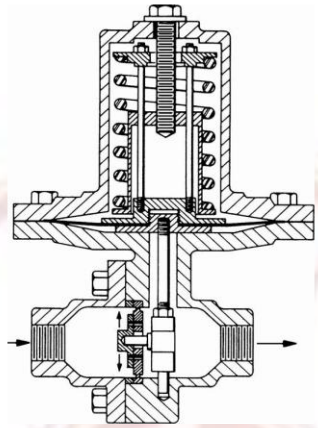
- The force in a spring changes as the spring is compressed. In a weight-loaded regulator, however, a weight provides a constant actuating force on the diaphragm, thus minimizing droop.
- Set-point changes are accomplished by adding weight or by changing the weight position
- Weight-actuated regulators are used to regulate gas pressures at 1 PSIG (6.9 kPa) or below when load changes are slow.
- It is not recommended for service where mechanical shock or vibration are present or for regulation of incompressible fluids.

**Spring Loaded Pressure Regulator**



- Figure shows one design of a spring-actuated regulator. The valve is normally closed. Turning the set-screw compresses the spring and opens the valve.
- Increasing downstream pressure acts beneath the diaphragm, thus raising it and closing the valve.
- Spring compression is adjusted to provide the desired downstream pressure at the demand flow.

**Spring-loaded vacuum regulator**



- When vacuum is to be regulated, the spring force is applied in the opposite direction than in case of the regulation of positive pressures. Figure shows a spring-actuated vacuum pressure regulator.
- The “air regulator” is a common type of spring-loaded regulator. It is a 1/4 in. (6.25 mm) air pressure regulator used to reduce instrument air pressure to a level compatible with pneumatic instruments. The term “air set” is also applied to these regulators.
- Bleed-type regulators have the ability to relieve excess regulated pressure. This design is recommended for dead-end (no flow) service. Various manufacturers supply air regulators having capacities from 10–60 SCFM (280–1680 lpm). These regulators are usually provided with an integral filter, hence the name “filter regulator.”

## INSTALLATION

Regulator installation is generally easier than regulator selection. The following installation suggestions will help ensure satisfactory regulator performance.

1) Steam regulators should be preceded by a separator and a trap.
2) All regulators should be preceded by a filter or strainer.
3) A valve bypass is recommended where it is necessary to service the regulator while continuing to supply users.
4) Use straight lengths of pipe upstream and downstream to reduce noise.
5) External feedback lines should be 1/4 in. (6.25 mm) pipe or tubing.

Guidelines for a stable installation are few. Difficulties are generally found after installation. Because the regulator has no adjustments it is costly to correct problems. The following steps can be considered in stabilizing an installed regulator.

1) Relocation of the pressure-sensing tap.
2) Redesign of the downstream piping to provide more volume.
3) Restricting the pressure feedback line, either by a needle valve in an external line or by filling an internal line and redrilling it to provide a smaller hole.

**CALIBRATION**

- Pressure Regulators are calibrated for the output pressure only. It has a pressure gauge at the output side.
- This gauge has to be independently calibrated from the standard source either air or through dead weight tester by taking out the gauge to the test bench. Gauge calibration error chart has to be independently kept.
- After calibration of the gauge, the gauge will be installed in the pressure regulator through a suitable sealant or packing (Teflon, Teflon sealant).
- After fixing the gage to the regulator, the pressure regulator has to be connected to air source of required pressure with the pressure source to the inlet pressure as per the data sheet of the pressure regulator.
- The pressure regulator knob is to be checked for its lubrications before connecting the air source.
- The output port of the air filter regulator has to connect to the test gauge with accuracy better than the output indicator which has been already installed in the regulator.

Method 1:

1) Note down the output pressure gauge in the data sheet.
2) Open the air source in the inlet side
3) Regulate the air pressure from zero to the required span.
4) Test gauge reading is noted for each increase in the pressure & the output is noted in the output gauge.

Method 2:

1) Use a pneumatic pressure regulator 10V.
2) Connect the supply to the pneumatic regulator.
3) Connect the 10V test gauge inlet port & regulate the pressure to see the output change & take the reading.

**SELECTION CRITERIA**

*Regulator Selection for Various Service Conditions*

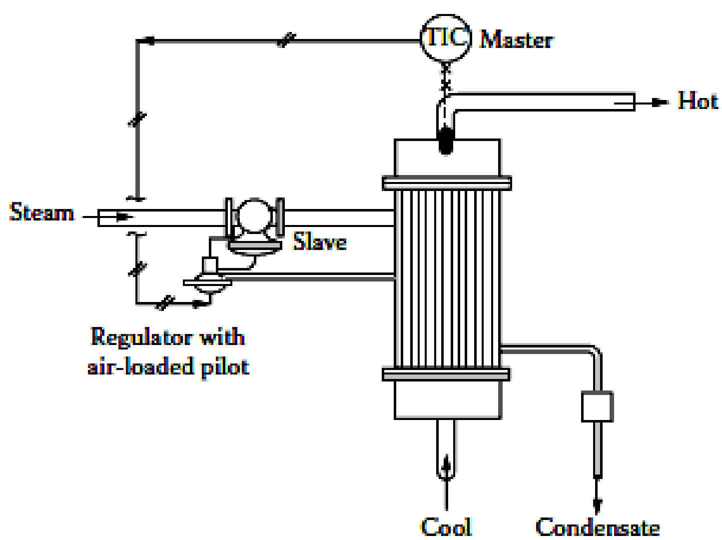
| *Recommended Regulator Type* | *Magnitude of Pressure Reduction* | *Supply Pressure Variations* | *Load Variations* |
|---|---|---|---|
| Spring-loaded | Moderate | Small | Moderate |
| Spring-loaded | Moderate | Large | Moderate |
| Pilot-operated | Moderate | Large | Large |
| Pilot-operated | Large (in one stage) | Moderate | Large |
| Pilot-operated first stage | Large (in two stages) | Large | Large (in first stage) |
| Spring-loaded or pilot-operated | Large (in two stages) | Large | Moderate (in second stage) |

## CONFORMATION TO STANDARDS

- ISA Form S20.51

## APPLICATIONS

- On purging applications, differential-pressure regulators are used to keep the purging media at a pressure higher than that of the process. This same regulator is also used in air bubbler type level measurement systems
- Oil-burner back-pressure regulators are installed in the oil return line. Their settings are modified according to the steam pressure in the boiler.
- In addition to regulators available for general service, the gas utility industry uses an extensive family of regulators designed specifically for gas service.
- Pressure regulators have been successfully used as cascade slaves receiving their set points from temperature control masters.




## PARTIAL LIST OF SUPPLIERS

- Placka
- Janatics
- Swagelok
- Fair Child
- Tescom
- Siemens

# PRESSURE SWITCHES

**Description**

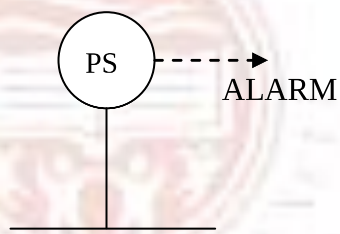
Pressure/Vacuum Switch is a switching device that senses a change in pressure /vacuum and opens or closes an electrical circuit when the set point is reached.

**Series III** custom switches offer a non-ferrous chamber and excellent set-point integrity at extreme temps. Features include low-contact resistance, wiping action, fast transfer time, gold-over silver contacts, an adjustable differential and top shock and vibration resistance.

**Series V** high-pressure switches offer excellent set-point integrity at extreme temps, wide fluid compatibility, and excellent response time. Like the Series III, these switches are best where hysteresis, fast transfer time, and low contact resistance are vital.

**Symbol**

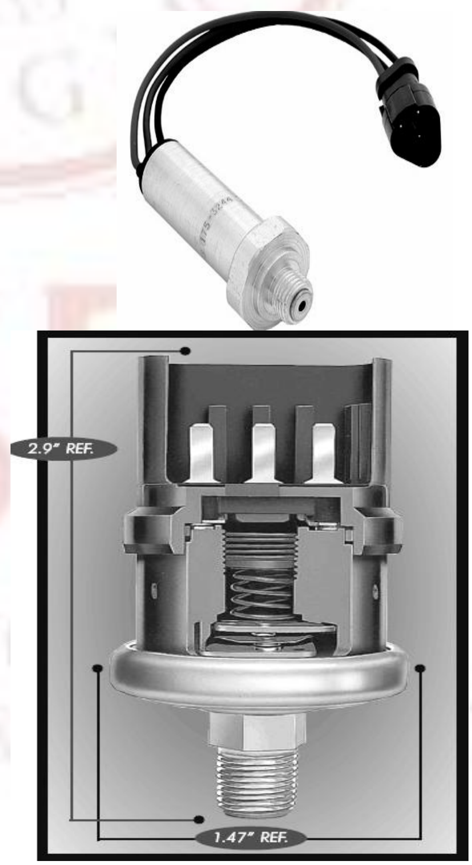
+



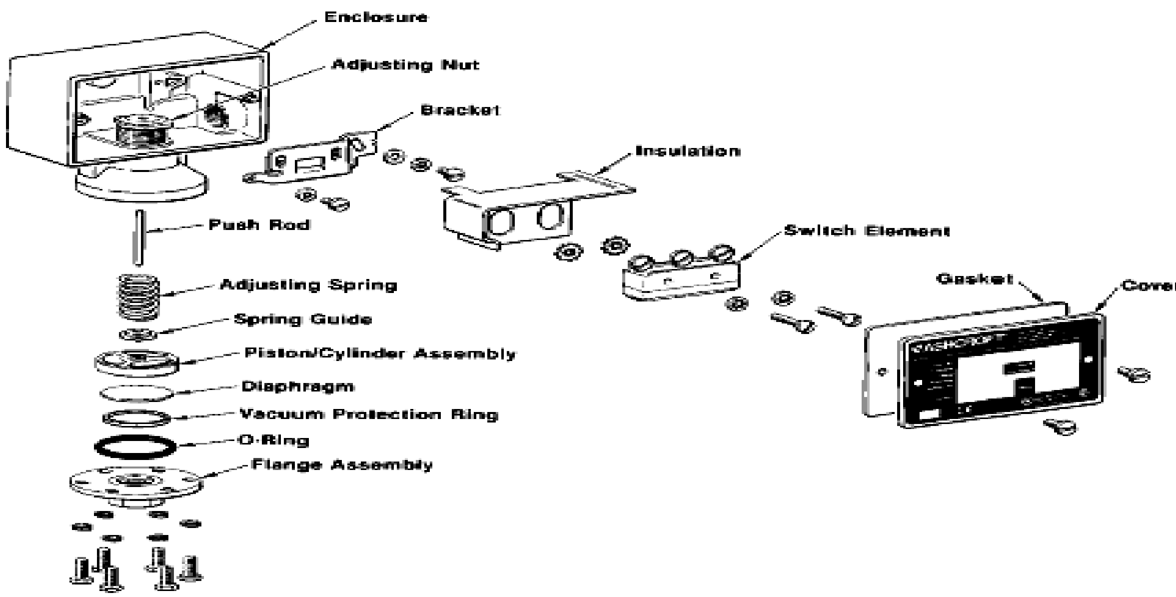

Flow sheet symbol

**Figure**


*Honeywell's Series III Pressure switch*




*Honeywell's Series V Pressure switch*




**SPECIFICATIONS**

***Functional***

- Set Point: Factory set
- Pressure: 200-1000 PSI
- Operating Pressure: 1000 PSI
- Proof Pressure: 2000 PSI
- Burst Pressure: 3000 PSI
- Accuracy: ± 2% of the adjustable range
- Circuitry Switch Type: SPDT Snap Action, Single or dual circuit
  : SPST-N.O; N.C; D.C
- Rating: 10Amp @ 125, 250, or 480 Vac; 0.3Amp @ 250 Vdc, Class B Limit switch
- Ratings Resistive: 15 AMP- 6 VDC ;8 AMP- 12 VDC; 4 AMP- 24 VDC
- Ratings Inductive: 1 AMP- 120 VAC ;0.5 AMP- 240 VAC

***Temperature limits***

- Operating : -20° to +165°F (-29° to +74°C)
- Ambient: -20° to 70°C
- Storage : -40° to +200°F (-40 °to +93°C)

***Physical***

Wetted Parts:

- Direct action blade contact type: Silver alloy, gold plated
- Process Fitting :Nickel Plated Aluminum
- Connector: 1/2-20 UNF (o-ring fitting)
- O-ring : Buna-N (Standard)
- Piston : 416 Stainless Steel
- Enclosure : Anodized Aluminum, Weatherproof IP67 / Flameproof IIA, IIB, IIC
- Ratings : NEMA 3
- Pressure Connection : 1/4" - 18 NPT Female
- Electrical Connection : 18" Free leads (terminal block on “T” model)

**Additional switch terminology**

***Set Point*** - The pre-determined pressure/vacuum value that is required to open or close the electrical contacts in the switch.

***System Pressure/Vacuum*** - This is the normal pressure/vacuum that would be present at the switch actuator. This value is important in order to apply the proper switch configuration. Even though the set point may be relatively low, the system pressure would continue to be applied to the switch actuator in most cases.

***Proof Pressure*** – The maximum pressure that the switch can have for a specified period of time without causing damage and still maintain set point integrity. This is determined under strict laboratory conditions including controlled rate of change and temperature. This value is for reference only. Consult factory for applications where switch must operate at pressures above nominal range or reference temperature (70°F).

***Burst Pressure*** – The maximum over pressure that may be applied to a pressure switch without causing leakage or rupture. This is normally at least 400% of nominal range for Ashcroft switches.

***Electrical Contacts*** – The elements in the switch that electrically respond to the media applied to the actuator. Snap action contacts with a "self-cleaning" wiping effect are used in Series III and Series Vswitches.Direct action blade contacts are used in the 5000 series

***Snap Action*** – In switch terminology, snap action generally refers to the action of contacts in the switch element. These contacts open and close quickly and snap closed with sufficient pressure to firmly establish an electrical circuit. The term distinguishes products from mercury bottle types that were subject to vibration problems.

***Pressure Switch Actuator*** - The member in the switch which receives the media and ultimately strokes the electrical contacts to open or close at the designated set point. The actuator in the Series III is a beryllium copper or silicone rubber diaphragm. An elastomeric diaphragm or piston actuator is used in the Series V. The 5000 Series uses a polyimide film diaphragm.

- *Normally Open (SPST-N.O.)* - A normally open switch does not conduct an electrical signal until the actuator is moved by the media causing the contacts to close.
- *Normally Closed (SPST-N.C.)* - A normally closed switch conducts electricity until the actuator is moved by the media causing the contacts to open.
- *Dual Circuit (SPDT)* - A normally open and normally closed circuit are contained in a switch
- *Dual Circuit (N.O. /N.O.)* - Switch contains two normally open circuits.
- *Dual Circuit (N.C. /N.C.)* - Switch contains two normally closed circuits.

***Dry Circuit Load*** - Typically this would be a very low electrical load associated with microprocessors when the open circuit voltage is .03V or less and the current is 40Ma.

***Resistive Load*** - A load in which the voltage is in phase with the current.

***Inductive Load*** - A load in which the voltage leads the current

***Capacitive Load*** - A load which the current leads the voltage

***Motor Load*** - The load of a motor at rated horsepower and speed.

***Differential*** - The difference between opening (actuation) pressure and the closing (de-actuation) set points. This is also referred to as "dead band". For example, a switch set at 150 PSI to open on increasing pressure and close at 95 PSI on decreasing pressure would have a differential of 55 PSI (150-95=55).

**PRINCIPLE OF OPERATION**

Pressure switches serve to energize or de-energize electrical circuits as a function of whether the process pressure is normal or abnormal. The electric contacts can be configured as single pole double throw (SPDT), in which case the switch is provided with one normally closed (NC) and one normally open (NO) contact. Alternately, the switch can be configured as double pole double throw (DPDT), in which case two SPDT switches are furnished, each of which can operate a separate electric circuit. The switch housings can meet any of the NEMA standards from Type 1 (general purpose) to Type 7 (explosion proof), or Type 12 (oil tight).

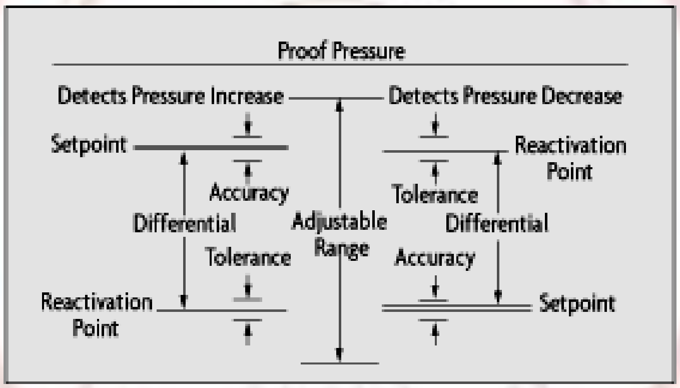
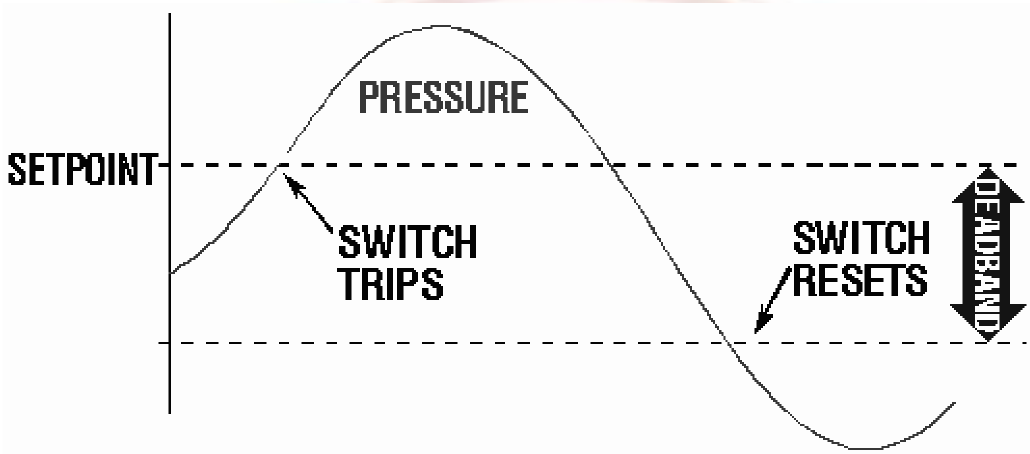



*Figure 3: Pressure Switch Terminology*

Figure 3 illustrates the terminology used to describe pressure switch functionality and performance. When the pressure reaches the set point (which is adjustable within the range), the switch signals an "abnormal condition" and it does not return to "normal" (the reactivation point) until the pressure moves away from the abnormal condition by the "differential" (also called dead-band). The precision of set point actuation is called its "accuracy," while the precision of reactivation is called "tolerance.Pressure Switch can be used to activate or de-activate equipment when pressure in a piping system either rises or falls to a set pressure. Liquid in the piping system acts against a diaphragm. The diaphragm works against a piston and spring, which triggers an electrical switch within the upper chamber of the unit. Spring pressure is set by simply threading the adjusting screw in or out.The series III switch contains a snap-action electric switch with three terminals. One is common, one is normally-open, and one is normally-closed. The normally-open switch will close upon reaching the set pressure, and the normally-closed switch will open when set pressure is reached. Set pressure can be reached by higher system pressure falling to the set value, or when lower system pressure rises to the set value.As an example, the switch can be set to actuate at 50 psi, rising pressure (switch actuates when pressure rises to 50 psi). When the pressure rises to 50 psi the normally-open contact will close, and the normally-closed contact will open. Therefore, depending on how the switch is wired, a light, or a pump, etc. can be energized or de-energized...or one item could be energized and another de-energized at the same moment. As the pressure continues to rise, no further changes occur.

***Hysteresis:***

If and when the pressure decreases, the switch will reverse, but not at 50 psi. Because of hysteresis (also known as "dead band"), the reversal will occur at approximately 40% lower pressure.




Dead band helps to prevent oscillation or "hunting." In other words, without sufficient dead band, the switch will be actuating and de-actuating too often. For applications where it is critical to de-actuate with less dead band, a 3-amp switch is available. See specifications below.

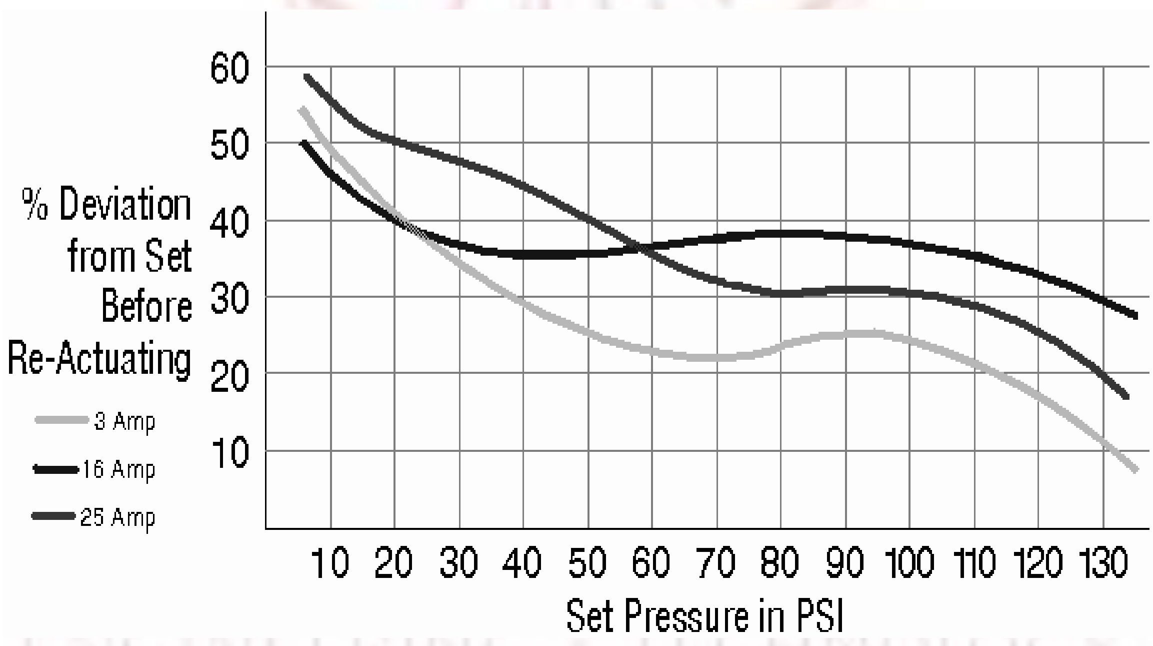



Chart above shows hysteresis or "deadband" as a percentage of set pressure. Shows where electrical switch will de-actuate under falling pressure, after actuating at set pressure.

**INSTALLATION**

- The pressure switch system is mounted in any orientation. Performance may vary if the switch is set in one orientation and changed to another; it should be set in the orientation in which it will be used.
- The switches have to be laboratory tested to 1,000,000 cycles. Cycle life in field use may vary due to amperage, chemical attack, temperature and pressure variations, or other environmental factors. For example, using the switch at its maximum amperage rating may dramatically reduce the life of the electrical switch. The electrical switch is readily replaceable
- In the event of strong pulsation in the system, bellows must be protected against fatigue failure by use of damping coil. The cycle frequency of the RT-E switch must be kept as low as possible. The vibration level must be kept as low as possible. Any overload of the RT-E switch must be prevented. Overloaded or damaged apparatus must be exchanged.
- On & off setting should not exceed the upper or lower range of the span.
  A pressure switch connected to the main pipe is not subjected to the flow and therefore is not fully exposed to the fluid temperature. Use of adequate length of impulse piping will greatly reduce excessive heating of the sensing element. For e.g., connection of 7.5 cm of 12 mm dia impulse piping will reduce water temperature of 100°C to 65°C at an ambient temperature of 50°C.
- Ensure that impulse pipe work applies no stress on sensing element housing and use spanners to hold pressure port / housing when connections are made.
- Select the range of the instrument such that the set value lies between 35 to 65% of the FSR.
- Scale Markings are for guidance only. Set the correct set value against precision master gauge.
- Pressure switches may also be mounted directly to the process by means of the standard 1/4 NPTF or optional 1/2 NPT pressure connection.

**[Note:** When installing switches, refer to instruction sheets included with each switch, the National Electrical Code, and any other local codes or requirements to assure safety.**]**

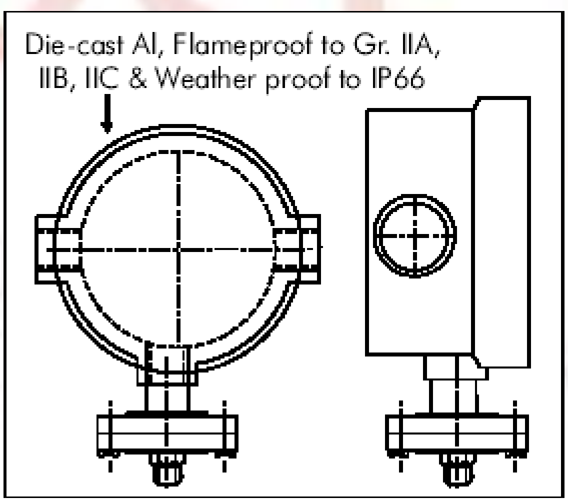
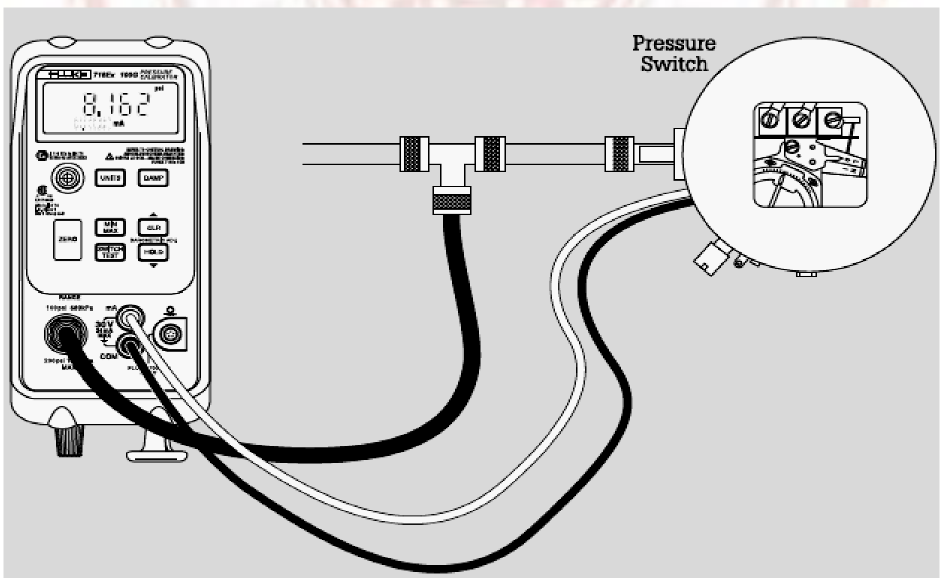



**Figure 3: pressure switch-flame proof**

## CALIBRATION

**Pressure switches calibration with the Fluke 718:**

1) Depressurize and isolate the pressure switch from the process.
2) Plumb the 718 and make connections as per the illustration.
3) Turn on the 718 and open the vent valve. Press the Zero button to clear the zero offset. Close the vent.
4) Press the Switch Test button to enter the switch test mode.
5) Apply pressure slowly with the hand pump until you approach the set point. Using the fine adjust vernier adjust the pressure until the switch opens and OPEN is displayed on the 718.
6) Release the pressure slowly using the fine adjust vernier until RCL is displayed.
7) Press the Switch Test button once to read the pressure values for switch opening and again to see the pressure at switch closing.
8) Press and hold the Switch Test button for 3 seconds to clear the test results and start over.
9) Adjust the pressure switch set point until the switch contacts open and close at the desired pressure.




**Pressure Switch Adjustment Procedure:**

1) Turn Main Calibration Screw clockwise to increase cut-in and cut-out pressure and turn counter-clockwise to decrease cut-in and cut-out pressure.
2) Turn Differential Pressure Screw clockwise to decrease cut-in pressure without affecting cut-out pressure and turn counter-clockwise to increase cut-in pressure*, without affecting cut-out pressure.
   CAUTION: Max.diff. Pressure is 20 psi. Do not adjust differential past 30 psi
   *Differential Pressure is defined as the difference between cut-out and cut-in pressure. Turning the Differential Pressure Screw clockwise increases the Differential Pressure, which increases the cut-out pressure without changing the cut-in pressure

**SELECTION CRITERIA**

**1. Actuator -** The actuator responds to changes in pressure, temperature or differential pressure and operates the switch element in response to these changes. The actuator is normally exposed to process fluid and must therefore be chemically compatible with it.

*Actuator type:* For nominal pressure ranges 0-15 psi through 0-3000 psi, the standard actuator is a diaphragm sealed piston. For high differential pressure actuator ranges, 3-15 to 60-600 psid, a dual diaphragm-sealed piston actuator is used. For ½ H2O pressure and differential pressure ranges, a diaphragm actuator is used.

**2. The Switching Function -** Most applications for alarm and shutdown are satisfied by single set point, fixed dead band models. For high/low or alarm and shutdown, the dual set point models may be selected. For pump, compressor, level and other control applications, an adjustable dead band model is often the best choice.

**3. The Switch Element -** Finally, the electrical switching element must be compatible with the electrical load being switched. For ease of selection, all electrical switching elements are snap acting, SPDT (single pole-double throw), or 2 (SPDT). Select a switch element with electrical rating that exceeds the electrical rating of the device being controlled by the switch. For better reliability and safety, optional hermetically sealed switching elements may be specified.

**4. Enclosure -** The enclosure protects the switch element and mechanism from the environment and has provisions for mounting and wiring. All switch enclosures are epoxy-coated aluminum or stainless steel for maximum corrosion resistance. Choose between watertight NEMA 4, 4X for most industrial applications and explosion-proof NEMA 7/9 for most process applications.

***NEMA (National Electrical Manufacturers Association)** – This group has defined several categories of enclosures, usually referred to as "types." Further, they designate certain features and capabilities for each type. For example, among other features, a NEMA 4 enclosure must include a threaded conduit connector, external mounting provision and cover gaskets. When selecting a NEMA 4 enclosure from any manufacturer, a buyer is assured of receiving these features.

**NEMA 4** – Watertight and dust tight enclosures intended for use indoors or outdoors to protect the equipment against splashing, falling or hose-directed water, external condensation and water seepage. They are also sleet-resistant.

**NEMA 4X** – Watertight, dust tight and corrosion resistant enclosures with same qualifications as NEMA 4, but with added corrosion resistance.

**NEMA 7** – Enclosures for indoor Class I, Division 1 hazardous locations with gas or vapor atmospheres.

**NEMA 9** – Enclosures for indoor Class II, Division1hazardous locations with combustible dust atmospheres.

**Division 1** – A National Electrical Code Classification of hazardous locations. In division 1 location, hazardous concentrations of flammable gases or vapors exist continuously, intermittently or periodically because of repair /leakage or breakdown or faulty operation of equipment or processes which might cause failure of electrical equipment. Explosion proof NEMA 7/9 enclosures are required in Division 1 location.

**Division 2** – In Division 2 hazardous locations, flammable or volatile liquid or flammable gases are handled or processed, but will normally be confined within closed containers or closed systems from which they can escape only in case of accidental rupture.

## CONFORMATION TO STANDARDS

- ABS - American Bureau of Shipping
- BV - Bureau Veritas
- CCS - China Classification Society
- RMRS - Russian Maritime Register of Shipping
- EU Declaration
- FM-Approvals
- CSA (optional) Class 3231 02, File No. 022355-0-000

## APPLICATIONS

- Machine Tools
- Compactors
- Hydraulic Power Units & Hydraulic Presses
- Automobiles: Hydraulic pressure switches have various uses in automobiles, to switch on a warning light if engine oil pressure falls below a safe level .To switch on brake lights automatically by detecting a rise in pressure in hydraulic brake pipes. In dust control systems (bag filter), a pressure switch is mounted on the header which will raise an alarm when air pressure in the header is less than necessary to gain or decline energy beyond the set value
- Compressors: pneumatic pressure switches are used for switching off an electrically driven gas compressor when a set pressure is achieved in the reservoir. Switching off a gas compressor, whenever there is no feed in the suction stage. In-cell charge control in a Nickel-metal hydride battery

## PARTIAL LIST OF SUPPLIERS

- Honeywell
- Danfoss
- Barksdale
- Switzer
- Hansen Technologies
- United electric controls
- Nason
- Dwyer
- Suco
- Hobbs
- Argus

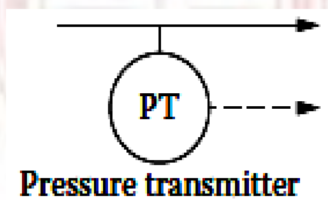
# DIFFERENTIAL PRESSURE TRANSMITTERS

**Description**

A transmitter is a transducer that responds to a measured variable by means of a sensing element and converts it to a standardized transmission signal that is a function only of the measured variable. The sensor can be an integral part of the transmitter, as in the case of a direct-connected pressure transmitter, or can be a separate part, as in the case of a thermocouple-actuate temperature transmitter. Some of the process variables which we can sense through transmitters are Pressure, Level, Flow, and Temp & Analyzer.

The pressure transmitter is one that converts the measured process variable range into a standard 3 to15 PSIG (0.2 to1.0-bar) output pressure signal. It operates on a principle of force balance, or more precisely, on a principle of moment balance.

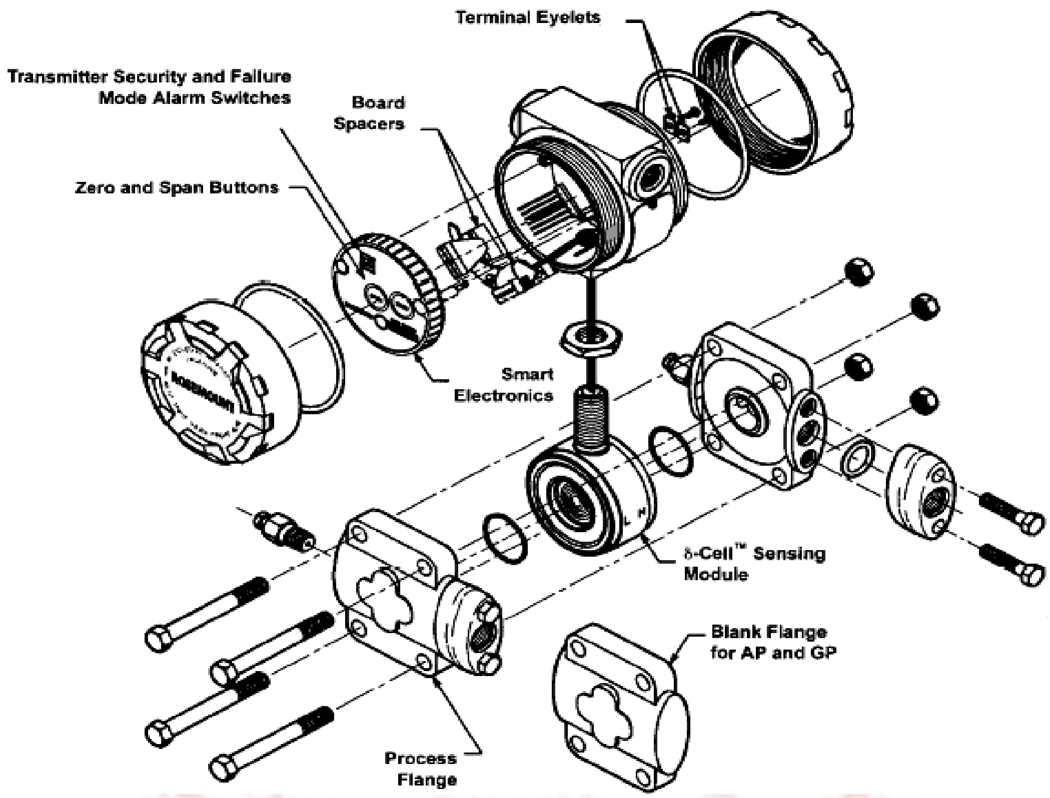
**Symbols**




**Figure**

***Rosemount differential pressure transmitter***

A DP transmitter is used to measure the gas pressure (in gauge scale) inside a vessel. In this case, the low-pressure side of the transmitter is vented to atmosphere and the high-pressure side is connected to the vessel through an isolating valve. The isolating valve facilitates the removal of the transmitter. The output of the DP transmitter is proportional to the gauge pressure of the gas, i.e., 4 mA when pressure is 20 kPa and 20 mA when pressure is 30 kPa.




***Exploded view of Rosemount DP transmitter***

## SPECIFICATIONS

### *Functional*

- Service: Liquid, gas, and vapour.
- Range: 2:0–50 to 0–250 inH2O (0–12.4 to 0–62.2 kPa).
  3:0–200 to 0–1,000 inH2O (0–49.7 to 0–248.6 kPa).
- Output: 4–20 mA dc. 1–5 V dc, low power.
- Power Supply: External power supply required.

### *Temperature Limits*

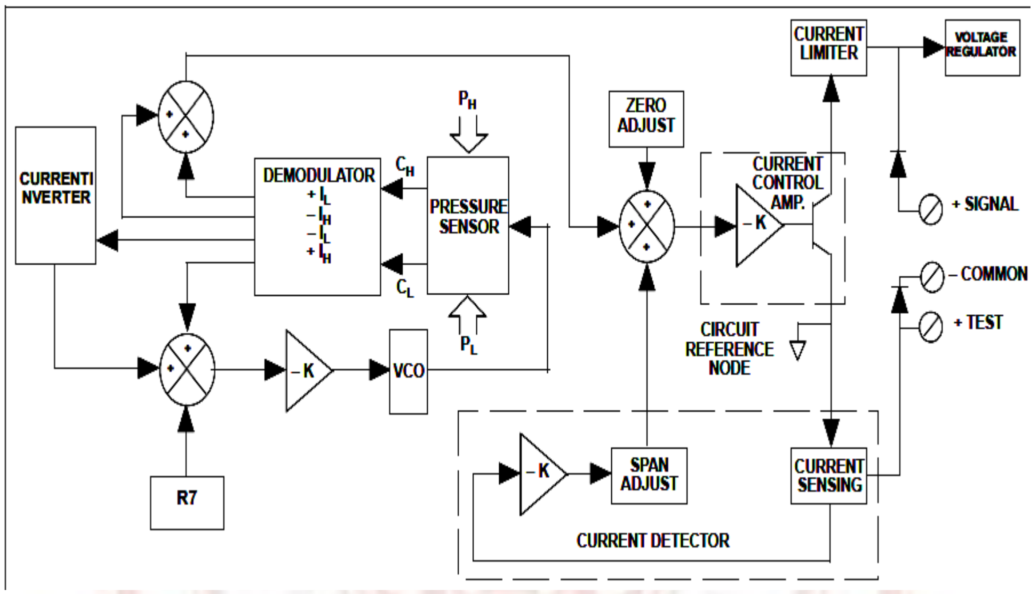
- Process: –20 to 220 °F (–29 to 104 °C)
- Ambient: –40 to 185 °F (–40 to 85 °C)
- Storage: –50 to 185 °F (–46 to 85 °C)

### *Physical*

Materials of Construction

- Isolating Diaphragms: 316L SST, Hastelloy C-276.
- Drain/Vent Valves (if selected): 316 SST, Hastelloy C.
- Flange: 316 SST.
- Adapters: Plated carbon steel, 316 SST.
- Wetted O-rings: Glass filled TFE.
- Fill Fluid: Silicone oil.
- Bolts: Plated carbon steel
- Electronics Housing: Low-copper aluminum. NEMA 4X.
- Paint: Epoxy-polyester.
- Process Connections: 1/4–18 NPT on 21/8-inch (54 mm) center or 1/2–14 NPT on 2-, 21/8- or 21/4-inch (51, 54, or 57 mm) centers with adapters.
- Electrical Connections: 1/2–14 NPT conduit connection, screw terminals, and internal grounding stud.

## PRINCIPLE OF OPERATION




### Input Loop

- The input loop consists of the voltage-controlled oscillator (VCO), the capacitive pressure cell, the demodulator, and the current inverter. These components act together as a feedback loop for the VCO control amplifier, which controls the frequency amplitude product of the VCO output such that the sum of the capacitance currents of the two cell halves equals the reference current through resistor R7.
- The difference of the capacitance currents is fed to the output loop as the electrical analog of the pressure input. This difference current is linear with diaphragm pressure, and is approximately zero at zero diaphragm pressure

### Output Loop

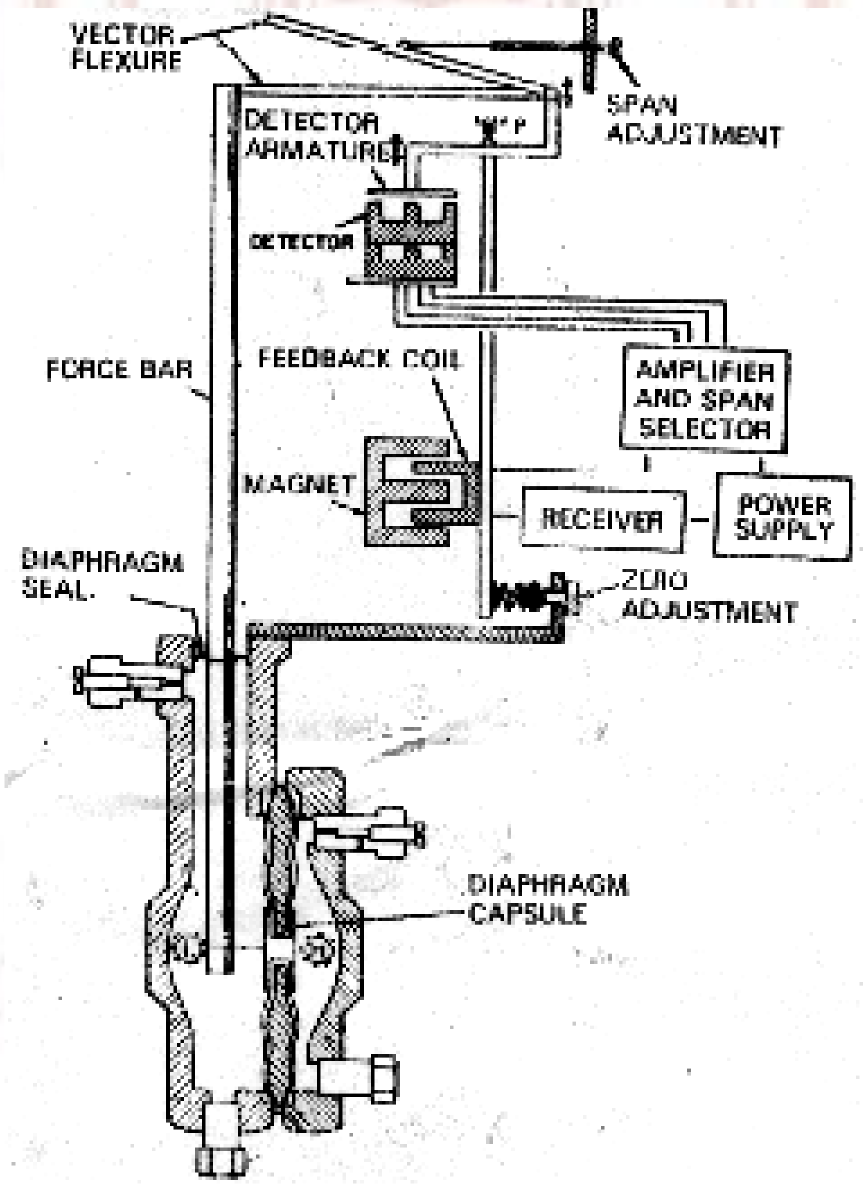
- The output loop for Code A consists of the current-sensing element and a current control amplifier that compares the span amplifier's output to the load current. Zero adjustment is incorporated in this loop.
- Current for powering the circuitry bypasses the current control amplifier and is returned at the circuit reference node so that total current flows through the current-sensing element.

## ELECTRONIC FORCE-BALANCE INSTRUMENT
## [Model BCE 13DM series DP transmitter]

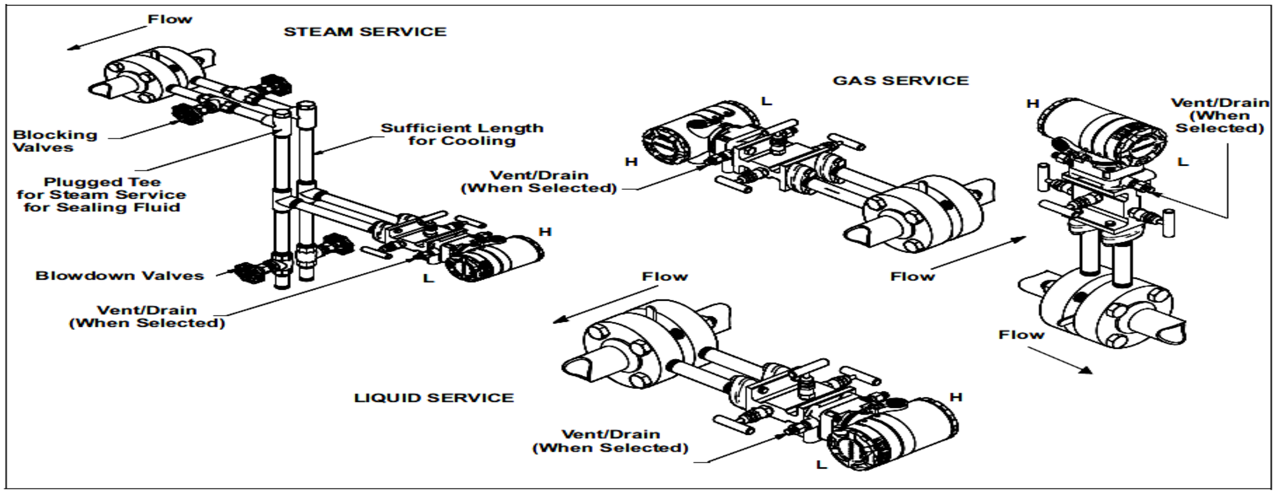
The BCE13DM series transmitter is an electronic force-balance instrument that continuously measures differential pressure and transmits it as a proportional current output signal. The transmitter is available with either a 4 to 20 ma or 10 to 50 ma dc output signal .the instrument is used in flow, liquid level, and other differential pressure applications

**Principle of operation- force balance type**

- The high and low pressures are connected to opposite sides of a twin–diaphragm capsule.
- The resulting differential pressure exerts a force on the capsule which is balanced by an opposing force from the feed back coil. Both force acts through the force bar and the vector flexure assembly. The diaphragm seal and the point P acts as fulcrums.
- Any movement of the force bar produces a minute movement of the detector armature, which changes the current flow in the detector secondary. The current amplified and applied simultaneously to the feedback coil and to the receiver. The force on the feed back coil balances the force on the capsule.
- The output current (4 to 20 ma or 10 to 50 ma), which establishes the force balance, is the transmitted signal and is proportional to the differential pressure. The signal is transmitted to a receiver to record, indicate and/or control.



## INSTALLATION




### Impulse piping

The best location for the transmitter in relation to the process pipe depends on the process material. Following are the general rules in determining transmitter location:

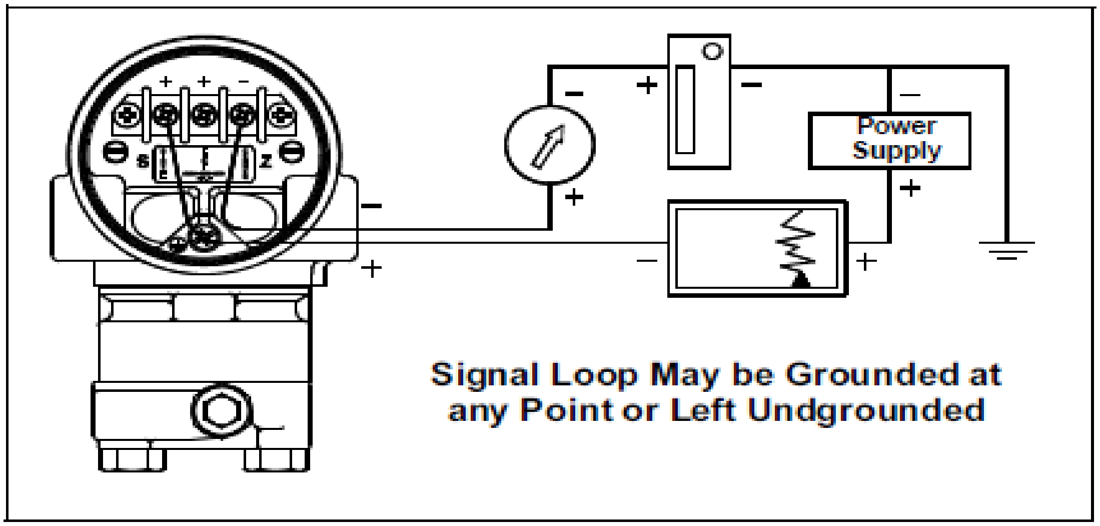
- Ensure that corrosive or hot process material does not come in contact with the transmitter. Ensure that sediment does not build up in the impulse piping.
- Ensure that the liquid head remains balanced on both legs of the impulse piping.
- Keep impulse piping as short as possible.
- Avoid ambient temperature gradients and fluctuations.
- Weatherize impulse piping to prevent freezing of process in impulse lines.
- For liquid pressure and differential pressure service, place taps to the sides of the line to prevent sediment deposits, and mount the transmitter beside or below these taps so gases can vent into the process line.
- For gas pressure and differential pressure service, place taps in top or side of line, and mount the transmitter beside or above the taps so liquid will drain into the process line.
- For the steam pressure and differential pressure service, place the taps to the side of the line, and mount the transmitter below to ensure that the impulse piping stays filled with condensate.

To minimize the potential for error, observe the following precautions:

- Make impulse piping as short as possible.
- Slope piping at least one in/ft (8 cm/m) up toward the process connection for liquid and steam.
- Slope piping at least one in/ft (8 cm/m) down toward the process connection for gas.
- Avoid high upoints in liquid lines and low points in gas lines.
- Keep both impulse legs at the same temperature.
- Use impulse piping of sufficient diameter to avoid friction effects.
- Drain all liquid/condensate from gas piping legs.
- Vent all gas from the liquid piping legs.
- Fill both piping legs to the same level when using a sealing fluid.
- Avoid purging through the transmitter. When purging, make the purge connection close to the process taps, and purge through equal lengths of the same size pipe.

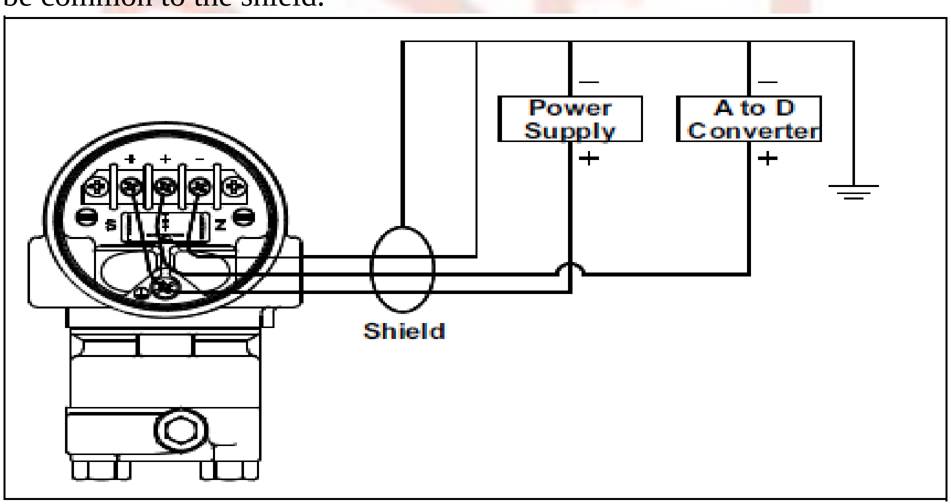
**Output Wiring-4-20mA Field wiring**

- Signal wiring need not be shielded, but twisted pairs should be used for best results. Do not run signal wiring in conduit or open trays with other power wires or near heavy electrical equipment. Signal wiring may be grounded or ungrounded at any point on the signal loop, but grounding is recommended at the power supply. The transmitter case may be grounded or ungrounded.
- Power supply regulation is not critical.
- Conduit connections on the transmitter housing should be sealed or plugged to avoid moisture accumulation in the housing.
- Maximum output current is limited to 33 mA dc.




**Output Wiring-1-5V dc Field wiring**

- When power supplies and readout devices are located close together, three-conductor shielded cables should be used. In this case, a single ground wire should be used for the transmitter common, the negative terminal of the power supply, and the negative terminal of the readout device. This ground should also be common to the shield.



## INSPECTION AND TESTING

### General

The manufacturer shall meet the inspection and testing requirements of BP RP 32-1.

### Factory testing

Each transmitter shall be hydrostatically pressure tested at a minimum 1.25 times the chamber rating.

For NACE MR 01-75 requirements, the particular transmitter shall be subjected to a NACE hardness test (or test sample of raw parts) on the chamber parts and blind (oval) flanges but not diaphragms.

### Factory inspection

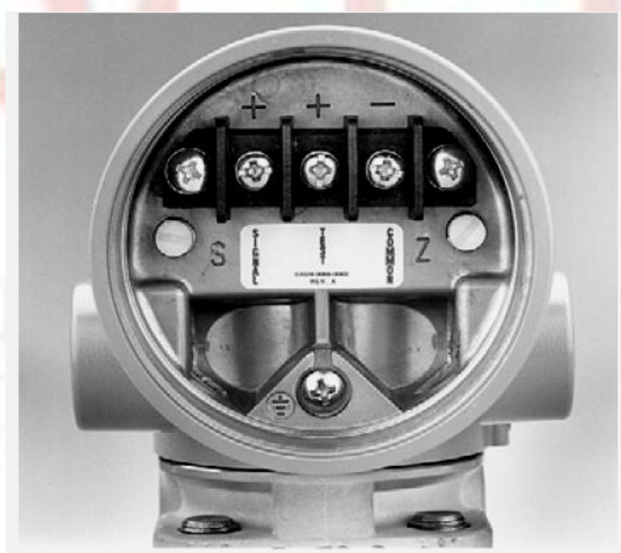
If specified in the purchase order the transmitter shall be inspected by the purchaser's designated inspector before dispatch unless otherwise specified. Inspection by the purchaser's inspector shall be restricted to the following.

- Visual examination and dimensional check of the process connection.
- Verification of testing as mentioned under factory testing.
- Verification of "type of protection" certificate or declaration
- Verification of NACE compliance if applicable.
- Verification of material certificate.

## CALIBRATION

### Zero and Span Adjustments

As with any transmitter that uses potentiometers for zero and span adjustments, the potential exists for movement of the potentiometer blades if the blades are kept in contact with the adjustment screws and the transmitter is subjected to temperature extremes or significant vibration. To prevent this from occurring, the final step in calibration requires backing off the screws slightly to break contact between the potentiometer blades and the adjustment screw slot surfaces (factory calibration procedures include this step).



**Recalibration Steps**

1. To recalibrate the transmitter, use an accurate pressure source, output meter, and follow these steps:
2. Apply a pressure that is equivalent to the lower calibrated value to the high side of the
   transmitter. Then turn the zero adjustment screw until the output of the transmitter is 4mA (1 V for Low Power).
3. Apply a pressure that is equivalent to the higher calibrated value to the high side of the transmitter. Then turn the span adjustment screw until the output of the transmitter is 20mA (5 V for Low Power).
4. Repeat Steps 1 and 2 as necessary to verify the 4 mA (1 V) and 20mA (5 V) readings. Adjusting the span potentiometer will have an effect of less than 1% of the calibrated span on the 4 mA (1 V) reading.
5. After adjusting the zero and span, back off the adjustment screws slightly to break contact between the potentiometer blades and the adjustment screw slot surfaces.

**SELECTION CRITERIA**

Selection criteria of the transmitter mainly depend upon the pressure range in use that is, low, medium and high as far as process is concerned for the Differential Pressure Transmitter and Pressure Transmitter. Typical industrial details are given below. Calibration Limits related to Pressure, Differential Pressure and Level Transmitter

- **Transmitter Ranges:-** 0 to 250 inches of H20 (0 to 62.2 kPa).
  0 to 1,000 inches of H20 (0 to 248.6 kPa).
- **Zero Elevation Suppression:-** 4 mA (1Vdc for Low Power) points adjustable.
  From –125 to 125 inH20 (–31.1 to 31.1 kPa).
  4 mA (1 V dc for Low Power) points is adjustable
  From – 500 to 500 inH2O (–124.3 to 124.3 kPa).
- **Minimum Span:-** 50 inH20 (12.4 kPa).
  200 inH20 (49.7 kPa).
- **Maximum Span:-** 250 inH20 (62.2 kPa).
  1,000 inH20 (248.6 kPa).

Transmitter selection consideration includes functional & performance specifications, material selection and desirable features.

**Temperatures:** Both the maximum process and ambient temperatures need to be considered. Again, it is good engineering practice to keep the electronics package as cool as possible.

**Pressure:** Both the operating pressure range and the maximum pressure should be considered. On differential pressure transmitters, overpressure may be accidentally applied to either the high or low side of the unit when a three-valve manifold is mis-sequenced. High overpressure capability eliminates a possible shut-down while the unit is being recalibrated or repaired. The static line pressure for differential transmitters should also be called out. Units are available on the market with standard line pressure capability from 500 to 6,000 psi

**Environment**: The transmitter should be capable of operating in environments with 0 to 100% relative humidity. The working fluid and the ambient environment should be considered for corrosiveness.

**DESIGN AND CONSTRUCTION**

**General:** The pressure and differential pressure transmitter shall be "smart" intrinsically safe (IS) units suitable for both analogue and digital simultaneous transmission using Honeywell DE protocol and non-volatile configuration data storage.
Smart transmitters used in control/indication services shall be used in digital mode. Smart transmitters used in safety services shall be used in analogue mode.
Hazardous area certification shall be suitable for area as specified in the data sheets for pressure & DP transmitters. All transmitters shall carry ATEX certification

**Electrical Certification**: The sensor/transmitter shall be intrinsically safe certified EExia for use with in an intrinsically safe circuit in accordance with the requirement of CENELEC standards EN 500014/50020

**Mounting Arrangements:** The sensor/transmitter shall be suitable to mount on 2" pipe support (stanchion) or direct mounting type
As specified in the related data sheets

**Accessories:** The differential pressure transmitter shall be supplied with three-valve type integral manifold. All the pressure transmitter shall be provided with a proprietary 2-way manifold (isolation and vent).The material shall be AISI 361 stainless steel as a minimum.
The transmitter shall be supplied with mounting brackets etc. as specified in the related data sheets

**Sensor:** Sensor fill fluid shall be silicon oil. The sensor material shall be suitable for process fluid as well as specified in related data sheets for pressure & differential pressure transmitters.
All electronic pressure transmitters shall be of the capacitance, strain gauge or resonant wire type, and shall be equipped with integral read out

**Body:** The transmitter shall have over range protection up to the maximum chamber rating on either side without temporary or permanent damage
The transmitter shall not have vent or drain connections in the body

**Output:** The transmitter output shall be both 4-20 mA with superimposed digital signal complying with Honeywell DE protocol. The transmitter power supply shall be nominally 24 VDC, arranged for two wire transmission, with a minimum power supply voltage of 12.5VDC.

**Electronics:** The transmitter electronics shall be solid state with appropriate smart circuitry. Printed circuit boards (PCB) shall be of a replaceable modular construction, be hermetically sealed or protected by a corrosion resistant coating (tropicalised). PCB shall be plug-in type vibration free supported. Signal wiring terminals and electronics shall be housed in separate compartments, so that the electronics remains sealed during electrical connection to the signal cable.

**Indication:** Transmitter shall be complete with an integral digital output meter with LCD read out capable of displaying the measured variable in engineering units as well as percentage value.

**Adjustment:** Zero and span adjustment shall not be non interactive and continuously adjustable

**Performance:** The transmitter accuracy, including the combined effect of linearity, hysterisis and repeatability shall be equal to or better than 0.1% with reference to IEC 60770, errors shall be expressed as percentage of calibrated span, unless stated otherwise

**Temperature compensation:** The transmitter electronics shall include facilities for the temperature compensation; the sensor characterization curve shall be stored for PROM

**Transmitter housing:** Transmitter electronics shall be field mounted type. Transmitter housing shall be cast aluminum (low copper) alloy epoxy coated. No aluminum is in its un-anodized form shall be used. No copper or its alloy shall be used except in a plated or tinned condition. The units shall be supplied in housing suitable for environmental condition as specified. The transmitter enclosure shall be weather proof to IP 65 as a minimum.QP-STD-R-001 –QP Technical standard for materials for sour service and NACE MR 01-75

**Wetted parts:** If specified in the related data sheets, transmitter shall be suitable for sour service (hydrogen sulphide) and also all wetted parts shall be manufactured and tested in accordance with. All wetted parts; the diaphragm and the chamber parts shall be as specified in the related data sheets for pressure and differential transmitters.

**Cable entry/connection:** The electrical signal entry cable shall be M20×1.5 ISO threaded and two such cable entries shall be provide. The unused cables entry shall be plugged off in compliance with the specified electrical safety. Signal wiring terminal shall be of screw type. All terminals of electrical connections shall be clearly numbered. The terminal polarity, where applicable shall be permanently marked,

**Tagging**: Transmitters shall be provided with an identification plate, with al data clearly stamped on a corrosion resistant plate permanently attached to each instrument by means of rivets or pins and shall indicate as a minimum the following

- Name of the manufacturer or trade mark
- Model number
- Serial number
- Instrument tag number
- Year of manufacturing
- Range and calibration (including units of measurement)
- Body rating (including units)
- Electrical safety (type of protection)
- Ingress protection

## CONFORMATION TO STANDARDS

- ATEX dir.94/9/EC : Atmosphere explosive (European Union Directive 94/9/EC)
- BS 5345 : Code of practice for selection, installation and maintenance of electrical apparatus for use in potentially explosive atmospheres
- BASEEFA : British approvals services for electrical equipment in flammable atmosphere
- ISO 9001 : Quality systems- model for quality assurance in design, development, production, installation and service
- NACE MR 01-75 : Sulphide stress cracking resistant metallic materials for oil field equipment
- BS EN 10204 : Metallic products- types of inspection documents
- IEC 60529 : Degrees of protection provided by enclosures (IP code)
- IEC 60770 : Transmitters for use in industrial process control systems

## APPLICATIONS

- Hydrostatic tank gauging
- Level Measurement
- HVAC- High Voltage Alternating Current
- Food
- Paper
- Pharmaceutical
- Sea and Nuclear Industries

## PARTIAL LIST OF SUPPLIERS

- Rosemount
- Yokogawa
- Honeywell
- ABB
- Siemens
- Fuji
- Foxboro

## TEMPERATURE MEASUREMENT

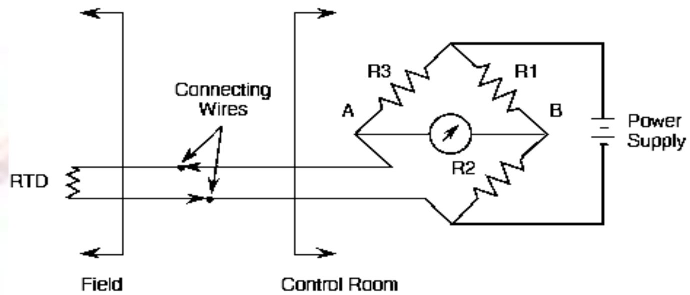
## INTRODUCTION TO TEMPERATURE MEASUREMENT

Every aspect of our lives, both at home and at work, is influenced by temperature. Temperature measuring devices have been in existence for centuries. The age-old mercury in glass thermometer is still used today. The principle of operation is ageless as the device itself. Its operation was based on the temperature expansion of fluids (mercury or alcohol). As the temperature increased the fluid in a small reservoir or bulb expanded and a small column of the fluid was forced up a tube. You will find the same theory is used in many modern thermostats today. In this module we will look at the theory and operation of some temperature measuring devices commonly found in a generating station. These include thermocouples, thermostats and resistive temperature devices. Thermocouples (T/C) and resistive temperature devices (RTD) are generally connected to control logic or instrumentation for continuous monitoring of temperature. Thermostats are used for direct positive control of the temperature of a system within preset limits.
The accurate measurement of temperature is a vital parameter in many fields. A critically important aspect of applying any temperature sensor is that of *traceable calibration* - a concept that has been developed to ensure that all measurements made are accurate and legally valid. Temperature can be measured via a diverse array of sensors. All of them infer temperature by sensing some change in a physical characteristic. Six types with which the engineer is likely to come into contact are:

1. Resistive temperature devices (RTDs and thermistors),
2. Thermocouples,
3. Infrared radiators,
4. Bimetallic devices,
5. Liquid expansion devices, and
6. Change-of-state devices.

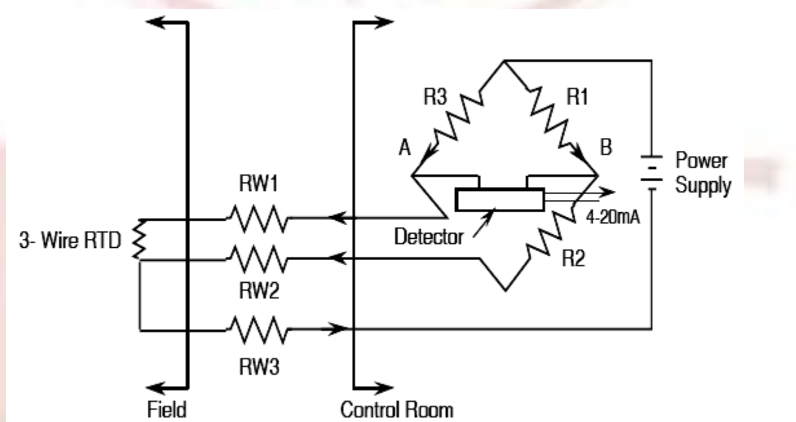
## RESISTANCE TEMPERATURE DETECTOR (RTD)

Every type of metal has a unique composition and has a different resistance to the flow of electrical current. This is termed the resistively constant for that metal. For most metals the change in electrical resistance is directly proportional to its change in temperature and is linear over a range of temperatures. This constant factor called the temperature coefficient of electrical resistance (short formed TCR) is the basis of resistance temperature detectors. The RTD can actually be regarded as a high precision wire wound resistor whose resistance varies with temperature. By measuring the resistance of the metal, its temperature can be determined. Several different pure metals (such as platinum, nickel and copper) can be used in the manufacture of an RTD. A typical RTD probe contains a coil of very fine metal wire, allowing for a large resistance change without a great space requirement. Usually, platinum RTDs are used as process temperature monitors because of their accuracy and linearity. To detect the small variations of resistance of the RTD, a temperature transmitter in the form of a Wheatstone bridge is generally used. The circuit compares the RTD value with three known and highly accurate resistors.




*Rtd* *RTD using a Wheatstone Bridge*

A Wheatstone bridge consisting of an RTD, three resistors, a voltmeter and a voltage source is illustrated in Figure 1. In this circuit, when the current flow in the meter is zero (the voltage at point A equals the voltage at point B) the bridge is said to be in null balance. This would be the zero or set point on the RTD temperature output. As the RTD temperature increases, the voltage read by the voltmeter increases. If a voltage transducer replaces the voltmeter, a 4-20 mA signal, which is proportional to the temperature range being monitored, can be generated.
As in the case of a thermocouple, a problem arises when the RTD is installed some distance away from the transmitter. Since the connecting wires are long, resistance of the wires changes as ambient temperature fluctuates. The variations in wire resistance would introduce an error in the transmitter. To eliminate this problem, a three-wire RTD is used.




*Three-Wired RTD*

The connecting wires (w1, w2, w3) are made the same length and therefore the same resistance. The power supply is connected to one end of the RTD and the top of the Wheatstone bridge. It can be seen that the resistance of the right leg of the Wheatstone bridge is R1 + R2 + RW2. The resistance of the left leg of the bridge is R3 + RW3 + RTD. Since RW1 = RW2, the result is that the resistances of the wires cancel and therefore the effect of the connecting wires is eliminated.

**RTD Advantages and Disadvantages**

**Advantages:**

• The response time compared to thermocouples is very fast in the order of fractions of a second.

• An RTD will not experience drift problems because it is not self powered.

• Within its range it is more accurate and has higher sensitivity than a thermocouple.

• In an installation where long leads are required, the RTD does not require special extension cable.

• Unlike thermocouples, radioactive radiation (beta, gamma and neutrons) has minimal effect on RTDs since the parameter measured is resistance, not voltage.

**Disadvantages:**

• Because the metal used for a RTD must be in its purest form, they are much more expensive than thermocouples.

• In general, an RTD is not capable of measuring as wide a temperature range as a thermocouple.

• A power supply failure can cause erroneous readings.

• Small changes in resistance are being measured, thus all connections must be tight and free of corrosion, which will create errors.

• Among the many uses in a nuclear station, RTDs can be found in the reactor area temperature measurement and fuel channel coolant temperature.

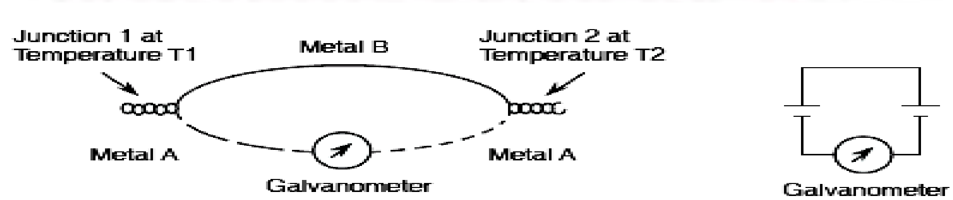
**Failure Modes:**

• An open circuit in the RTD or in the wiring between the RTD and the bridge will cause a high temperature reading.

• Loss of power or a short within the RTD will cause a low temperature reading.

**THERMOCOUPLE (T/C)**

A thermocouple consists of two pieces of dissimilar metals with their ends joined together (by twisting, soldering or welding). When heat is applied to the junction, a voltage, in the range of milli-volts (mV), is generated. A thermocouple is therefore said to be self-powered. Shown in Figure 3 is a completed thermocouple circuit.

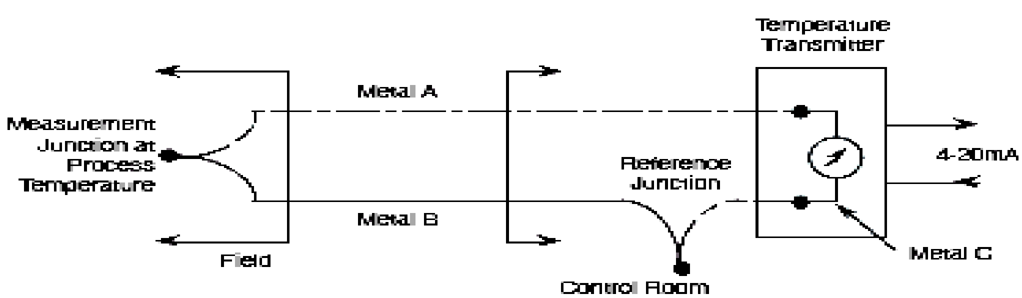




**A Thermocouple Circuit**

The voltage generated at each junction depends on junction temperature. If temperature T1 is higher than T2, then the voltage generated at Junction 1 will be higher than that at Junction 2. In the above circuit, the loop current shown on the galvanometer depends on the relative magnitude of the voltages at the two junctions. In order to use a thermocouple to measure process temperature, one end of the thermocouple has to be kept in contact with the process while the other end has to be kept at a constant temperature. The end that is in contact with the process is called the hot or measurement junction. The one that is kept at constant temperature is called cold or reference junction. The relationship between total circuit voltage (emf) and the emf at the junctions is:

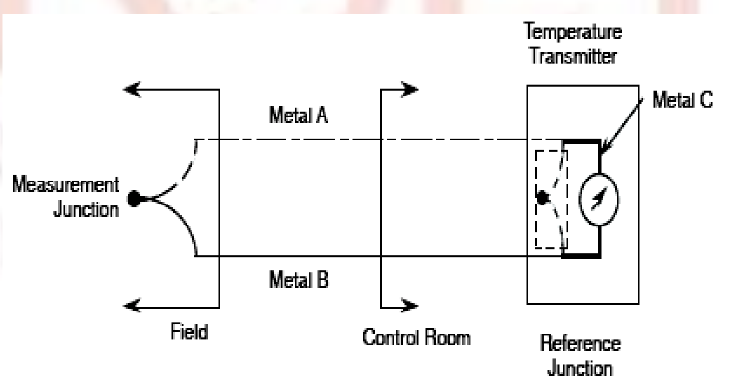
**Circuit emf = Measurement emf - Reference emf**

If circuit emf and reference emf are known, measurement emf can be calculated and the relative temperature determined. To convert the emf generated by a thermocouple to the standard 4-20 mA signal, a transmitter is needed. This kind of transmitter is called a temperature transmitter. Figure shows a simplified temperature transmitter connection.




**A Simplified Thermocouple Temperature Transmitter**

In Figure above, the temperature measurement circuit consists of a thermocouple connected directly to the temperature transmitter. The hot and cold junctions can be located wherever required to measure the temperature difference between the two junctions




**Typical Thermocouple Circuit**

In most situations, we need monitor the temperature rise of equipment to ensure the safe operation. Temperature rise of a device is the operating temperature using ambient or room temperature as a reference. To accomplish this hot junction is located in or on the device and the cold junction at the meter or transmitter as illustrated in figure above.

**Thermocouple Advantages and Disadvantages**

**Advantages:**

- Thermocouples are used on most transformers. The hot junction is inside the transformer oil and the cold junction at the meter mounted on the outside. With this simple and rugged installation, the meter directly reads the temperature rise of oil above the ambient temperature of the location.
- In general, thermocouples are used exclusively around the turbine hall because of their rugged construction and low cost.
- A thermocouple is capable of measuring a wider temperature range than an RTD.

**Disadvantages:**

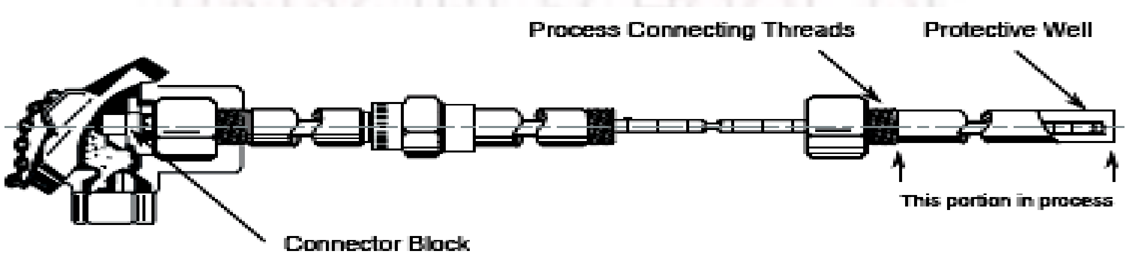
- If the thermocouple is located some distance away from the measuring device, expensive extension grade thermocouple wires or compensating cables have to be used.
- Thermocouples are not used in areas where high radiation fields are present (for example, in the reactor vault). Radioactive radiation (e.g., Beta radiation from neutron activation), will induce a voltage in the thermocouple wires. Since the signal from thermocouple is also a voltage, the induced voltage will cause an error in the temperature transmitter output.
- Thermocouples are slower in response than RTDs
- If the control logic is remotely located and temperature transmitters (milli-volt to milli- amp transducers) are used, a power supply failure will of course cause faulty readings.

**Failure Modes:**

An open circuit in the thermocouple detector means that there is no path for current flow, thus it will cause a low (off-scale) temperature reading. A short circuit in the thermocouple detector will also cause a low temperature reading because it creates a leakage current path to the ground and a smaller measured voltage

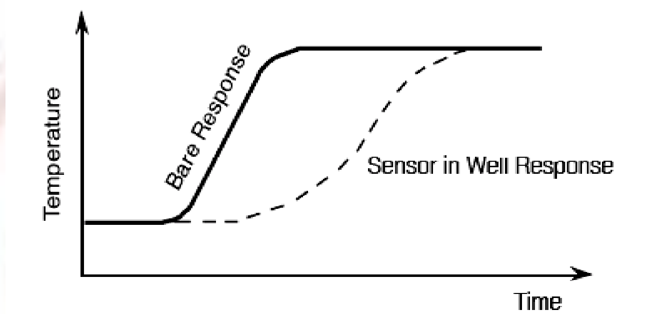
**THERMAL WELLS**

The process environment where temperature monitoring is required is often not only hot, but also pressurized and possibly chemically corrosive or radioactive. To facilitate removal of the temperature sensors (RTD and TC), for examination or replacement and to provide mechanical protection, the sensors are usually mounted inside thermal wells.




**Typical Thermal Well Installation**

A thermal well is basically a hollow metal tube with one end sealed. It is usually mounted permanently in the pipe work. The sensor is inserted into it and makes contact with the sealed end.
A drawback to thermal wells is their long response time because heat must be transferred through the well to the sensor. An example of the temperature response for bare and thermal well installed sensors is shown in fig. Minimizing the air space between the sensor and the well, however, can decrease this thermal lag.



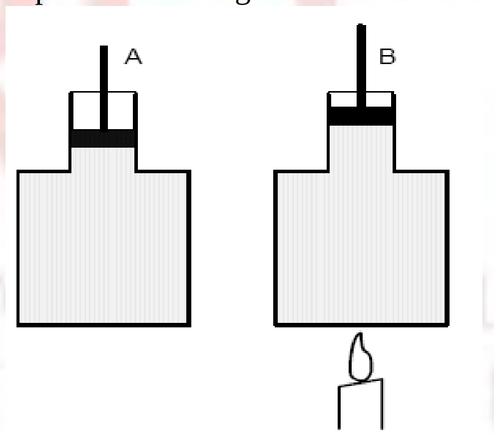

**Response Curves of Bare and Thermal Well Installation**

## THERMOSTATS

Thermostats have a different function than the resistive temperature detectors and thermocouples that we have just discussed. The thermostats directly regulate the temperature of a system by maintaining it constant or varying it over a specific range. The T/C or RTD could be used as the temperature-sensing element of a thermostat, but generally thermostats are direct acting devices.
The two common types of thermostats are:
Pressure cylinder
Bimetallic strip

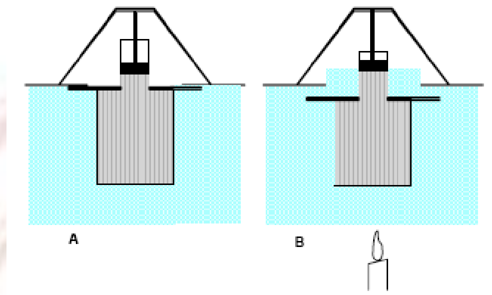
### Pressure Cylinders

The most common thermostat depends on the expansion of a fluid such as mercury or a solid with an increase in temperature as in figure




**Thermostat Pressure Cylinder**

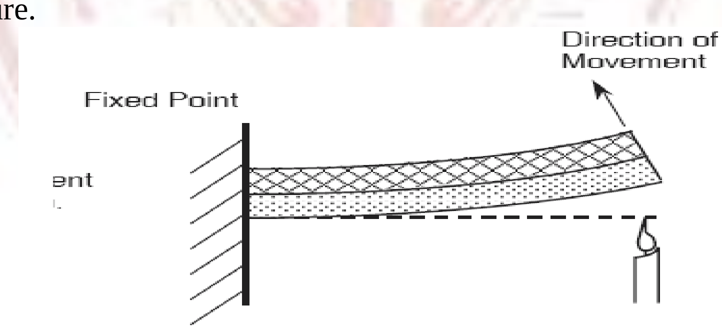
The plunger connected to the piston is used to force contacts open and closed to control valve positions or pump control. Often the plunger is directly connected to the valve as in figure below. This is the same principle as used in automobile water thermostats where the substance in the cylinder is a wax with a melting point of around 180**0** F.




**Thermostat Pressure Cylinder Application**

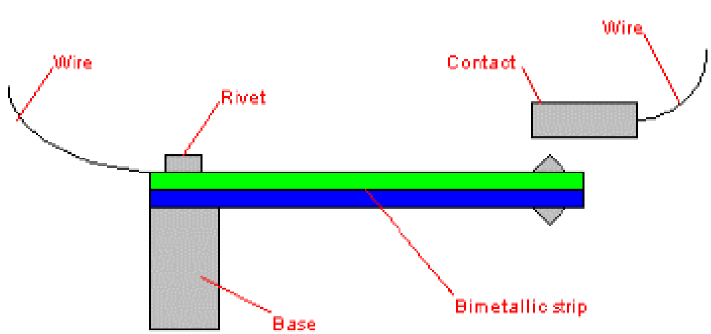
## Bimetallic Strips

A bimetallic strip is constructed by bonding two metals with different coefficients of thermal expansion as shown in figure. If heat is applied to one end of the strip, the metal with the higher coefficient of expansion will expand more readily than the lower one. As a result, the whole metallic strip will bend in the direction of the metal with the lower coefficient Figure.



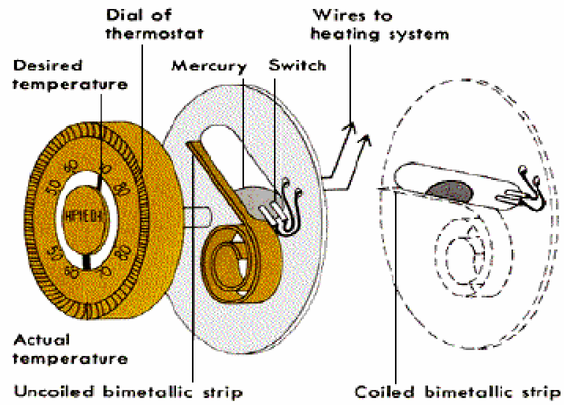

**Bimetallic Strip Bent after Heat is Applied**

When contacts are attached to the strip, it can be used as a fast acting thermostat to control air temperature as per figure below. One drawback is that there cannot be any flammable vapours surrounding the strip due to arcing generated across the contacts.




**Bimetallic Thermostat**

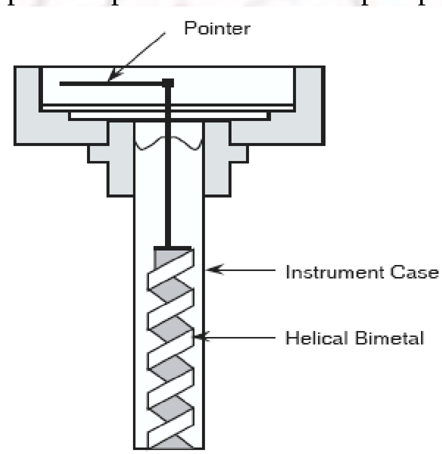
One main advantage of the bimetallic strip is that it can be used to operate over a range of temperatures when the strip is fashioned into a coil (for larger swing) and placed on an adjustable pivot (figure). Most room thermostats operate on this principle.


**Application of Bimetallic Strip**

## Bimetallic Thermometers

Another common configuration of the bimetallic strip is coiled in a helix to increase the swing or displacement similar to the coil above. In this shape, the strip is more rugged and less subject to vibration. A helical bimetallic thermometer is shown in figure below. Bimetallic thermometers in general are very rugged and require little maintenance. They are usually used to measure process parameters such as pump and bearing temperature.



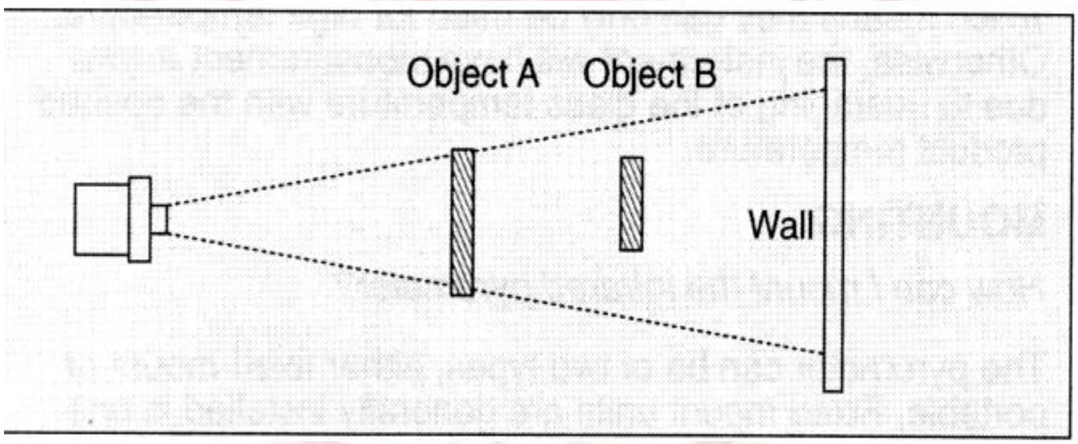

**Helical Bimetallic Thermometer**

## Infrared Thermometry

Infrared thermometers measure the amount of radiation emitted by an object. It is typically used to measure temperatures of rapidly moving objects, hot metals or molten steel stream in a steel mill or foundry where large distances and very high temperatures and hazardous conditions will make it difficult to insert the sensors and would affect results.

Factors that affect the infrared thermometry

1. Surface emissivity must be known. This can add a lot of error.
2. Reflection from other objects can introduce error as well.
3. Field of view of your camera.




*Field of view of your camera.*

Table 1. Summary of temperature sensors

<table>
<tr><th>Sensor Type</th><th>Limits of Application (°C)</th><th>Accuracy[1,2]</th><th>Dynamics: t (s)</th><th>Advantages</th><th>Disadvantages</th></tr>
<tr><td>Thermocouple</td><td colspan="5"></td></tr>
<tr><td>Type E:<br>chromel-constantan</td><td>-100 to 1000</td><td>±1.5 or 0.5% for 0 to 900 °C</td><td rowspan="4">see note 3</td><td rowspan="4">-good reproducibility<br><br>-wide range</td><td rowspan="4">-minimum span of 40 °C<br><br>-temperature vs. emf not exactly linear<br><br>-drift over time<br><br>-low emf corrupted by noise</td></tr>
<tr><td>Type J:<br>iron-constantan</td><td>0 to 750</td><td>±2.2 or 0.75%</td></tr>
<tr><td>type K:<br>chromel-nickel</td><td>0 to 1250</td><td>±2.2 or 0.75%</td></tr>
<tr><td>Type T:<br>copper-constantan</td><td>-160 to 400</td><td>±1.0 or 1.5% for -160 to 0 °C</td></tr>
</table>

| | | | | | |
|---|---|---|---|---|---|
| ***RTD*** | -200 to 650 | 0.15 + 0.2\|T\| | see note 3 | -good accuracy<br><br>-small span possible<br><br>-linearity | -self-heating<br><br>-less physically rugged<br><br>-self-heating error |
| ***Thermister*** | -40 to 150 | ± 0.10 °C | see note 3 | -good accuracy<br><br>-little drift | -highly nonlinear<br><br>-only small span<br><br>-less physically rugged<br><br>-drift |
| ***Bimetallic*** | - | ± 2% | - | -low cost<br><br>-physically rugged | -local display |
| ***Filled system*** | -200 to 800 | ± 1% | 1 to 10 | -simple and low cost<br><br>-no hazards | -not high temperatures<br><br>-sensitive to external pressure |

Notes:

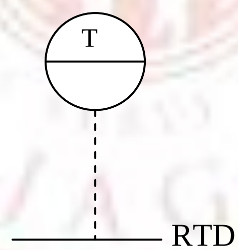
1. Accuracy is measured in °C or % of span, whichever is larger.
2. With RTDs, the inaccuracy increases approximately linearly with temperature deviation from 0 °C.
3. The dynamics depend strongly on the sheath or thermo well (material, diameter, and wall thickness), the location of the element in the sheath (i.e. bonded or air space, the fluid type, and the fluid velocity. Typical values are 2 to 5 seconds for high fluid velocities.

# RESISTANCE TEMPERATURE DETECTORS

**Description:**

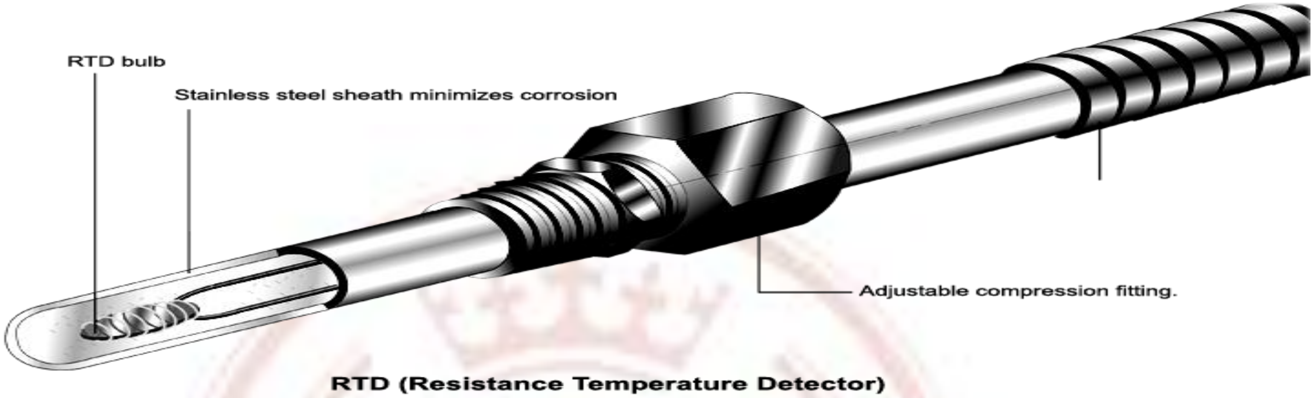
A resistance temperature detector (RTD) is a temperature sensor that senses temperature by means of changes in the magnitude of current through, or voltage across, an element whose electrical resistance varies with temperature. These types of sensors provide a change in resistance proportional to a change in temperature. They utilize a resistance element whose resistance changes with the ambient temperature in a precise and known manner. The resistance temperature detector may be connected in a bridge circuit which drives a display calibrated to show the temperature of the resistance element. Most metals become more resistant to the passage of an electrical current as the metal increases in temperature. The increase in resistance is generally proportional to rise in temperature. Thus, a constant current passed through a metal of varying resistance produces a variation in voltage that is proportional to the temperature change. Temperature ranges about [-196°C to 482°C] (Platinum).

**Symbol**




*Flow Sheet*

**Figure**




**PRINCIPLE OF OPERATION**

Resistance temperature detectors or RTDs measure temperature because of the physical principle of the positive temperature coefficient (PTC) of electrical resistance of metals.

**Resistance Measurement:** The resistance temperature detector may be connected in a bridge circuit which drives a display calibrated to show the temperature of the resistance element. Several different bridge circuits are used to determine the resistance. Bridge circuits help improve the accuracy of the measurements significantly. Bridge output voltage is a function of the RTD résistance.  Equations relating bridge voltage to temperature can be used

The resistance, "R", is directly proportional to a metal wire's length, "L", and inversely proportional to the cross-sectional area, "A":

$$\mathbf{R = \rho l/A \ldots. (1)}$$

Where ρ= the constant of proportionality or the resistivity of the material

$$\mathbf{R_t = R_0\, [1+\alpha\, (t-t_0)] \ldots\ldots\ldots\ldots. (2)}$$

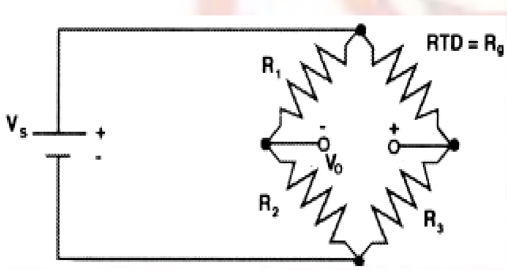
Where: $R_t$= resistance at temperature t

$R_0$= resistance at a standard temperature $t_0$

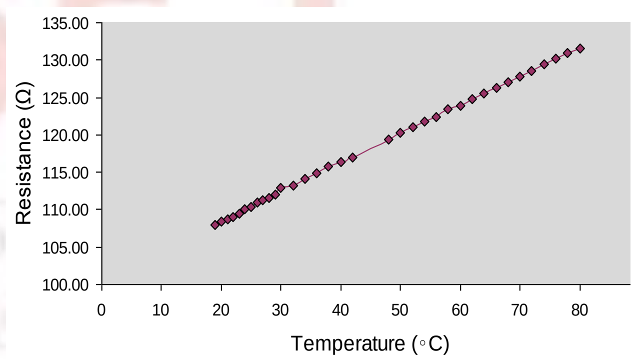
α = temperature coefficient of resistance (°$C^{-2}$)

Combining Equations **(1)** and **(2)**, setting $t_0$ to 0°C, and rearranging to the standard linear *y* = *mx*+*b* form, it is clear that resistance vs. temperature is linear with a slope equal to a:

$$\mathbf{R/R_0 = \alpha t + 1 \ldots\ldots\ldots\ldots\ldots\ldots. (3)}$$




*RTD using Wheatstone bridge*

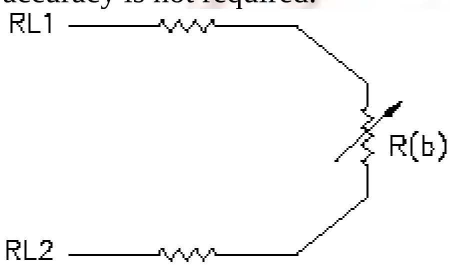



*Resistance vs. temperature graph*

**Measuring Circuit**:

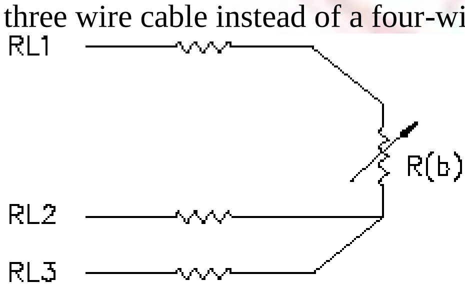
To use an RTD, a small voltage is passed through the element and then measured. The resistance of the element reduces the voltage and this voltage drop can be converted into a temperature measurement. With most RTD's, the higher the temperature, the higher the resistance.

**2-wire construction:** The following diagram represents a simple 2-wire RTD circuit. An instrument is hooked to one red wire and sends a voltage through that red wire, through the element and back through the other red wire. This reading is then converted to a temperature by the instrument.2-wire construction is the least accurate of the 3 types since there is no way of eliminating the lead wire resistance from the sensor measurement. 2-wire RTD's are mostly used with short lead wires or where close accuracy is not required.



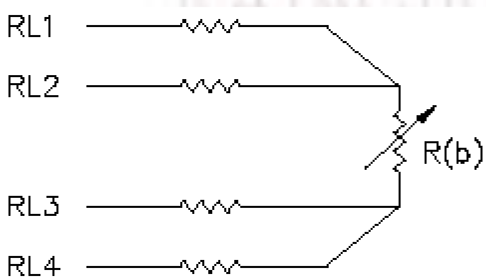

Measured resistance $R_t = R_1 + R_2 + R_b$

**3-wire construction** is most commonly **used in industrial applications** where the third wire provides a method for compensation of lead wire resistance, removing the average lead wire resistance from the sensor measurement. When long distances exist between the sensor and measurement/ control instrument, significant savings can be made in using a three wire cable instead of a four-wire cable.




Measured resistance $(R_{1+2+R\,b}) - (R_{2+3}) = (R_b)$

**4-wire construction** is **used primarily in the laboratory** where close accuracy is required. In a 4 wire RTD the actual resistance of the lead wires can be determined and removed from the sensor measurement. The 4-wire circuit is a true 4-wire bridge, which works by using wires 1 & 4 to power the circuit and wires 2 & 3 to read. This true bridge method will compensate for any differences in lead wire resistances. The 4-wire bridge circuit eliminates lead wires resistance electrically instead of mathematically.



**Potential Problems**

- RTDs are more fragile than thermocouples.
- An external current must be supplied to the RTD. This current can heat the RTD, altering the results. For situations with high heat transfer coefficients, this error is small since the heat is dissipated to air. For small diameter thermocouples and still air this error is the largest. Use the largest RTD possible and smallest external current possible to minimize this error.
- Be careful about the way you set up your measurement device. Attaching it can change the voltage.
- When the platinum is connected to copper connectors, a voltage difference will occur (as in thermocouples). This voltage must be subtracted off.

**DESIGN AND CONSTRUCTION**

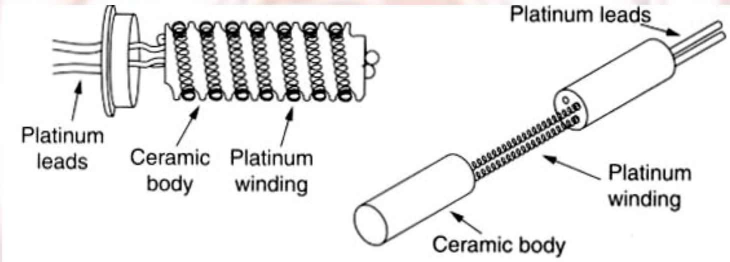



***Figure1: RTD geometry outer wound design and coiled design***

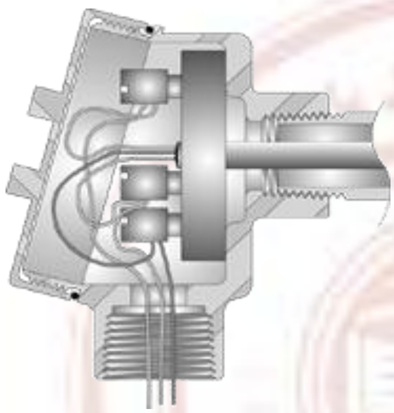
Resistance temperature detectors are usually fabricated by winding a fine diameter wire on a bobbin or mandrel which is made of a ceramic material such as aluminum oxide. Then, the wire-wound bobbin is coated with an cement-like insulating material and is installed in a protective tube

Platinum is the most commonly used metal for RTDs due to its stability and nearly linear temperature versus resistance relationship. Platinum also has the advantages of chemical inertness, a temperature coefficient of resistance that is suitably large in order to provide readily measurable resistance changes with temperature, and a resistance which does not drastically change with strain. Other types of RTDs include copper, nickel and nickel alloys.

- Platinum often used since it can be used for a wide temperature range and has excellent stability. Nickel or nickel alloys are used as well, but they aren't as accurate.
- In several common configurations, the platinum wire is exposed directly to air (called a bird-cage element), wound around a bobbin and then sealed in molten glass, or threaded through a ceramic cylinder.
- Metal film RTDs are new. To make these, a platinum or metal-glass slurry film is deposited onto a ceramic substrate. The substrate is then etched with a laser. These RTDs are very small but aren't as stable (and hence accurate).
- RTDs are more accurate but also larger and more expensive than thermocouples**.**
- Sheathing: stainless steel or iconel, glass, alumina, quartz
- Metal sheath can cause contamination at high temperatures and are best below 250ºC.
- At very high temperatures, quartz and high-purity alumina are best to prevent contamination

## INSTALLATION

The transition from the sensor lead wires to the field wiring is typically done in a connection head attached to the sensor. Terminal blocks are used to facilitate the connection. A typical terminal block/sensor connection is shown in the following figure.



RTD sensor assemblies typically use pipe threads (NPT) for the mechanical connections between the connection heads, extensions and thermo wells. For proper operation you should tighten the threads at least 1-2 turns past hand tight. This will ensure that the threads mate tightly, and that the proper sensor assembly length is obtained. To prevent thread galling RTD Company recommends that anti-seize compound or Teflon plumbing tape is used on all NPT threads.

## CALIBRATION

The most accurate calibration that you can do easily yourself is to use a constant temperature bath and NIST-traceable thermometers. You then can make your own calibration curve correlating temperature and voltage.

## SELECTION CRITERIA

RTDs can be selected as per their standardized curves and tolerances. The most common standardized curve is the 'DIN' curve. The curve describes the resistance vs. temperature characteristics of Platinum, 100 ohm sensor, the standardized tolerances, and the measurable temperature range. The DIN standard specifies a base resistance of 100 ohms at 0ºC, and a temperature coefficient of .0038500 ohms/ohms/ºC. The nominal output of a DIN RTD sensor is shown below:

| Degrees | 0°C | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
|---|---|---|---|---|---|---|---|---|---|---|
| 0 | 100.00 | 100.39 | 100.78 | 101.17 | 101.56 | 101.95 | 102.34 | 102.73 | 103.12 | 103.51 |
| 10 | 103.90 | 103.90 | 104.68 | 105.07 | 105.46 | 105.85 | 106.24 | 106.63 | 107.02 | 107.40 |
| 20 | 107.79 | 108.18 | 108.57 | 108.96 | 109.35 | 109.73 | 110.12 | 110.51 | 110.90 | 111.28 |
| 30 | 111.67 | 112.06 | 112.45 | 112.83 | 113.22 | 113.61 | 113.99 | 114.38 | 114.77 | 115.15 |
| 40 | 115.54 | 115.93 | 116.31 | 116.70 | 117.08 | 117.47 | 117.85 | 118.24 | 118.62 | 119.01 |
| 50 | 119.40 | 119.78 | 120.16 | 120.55 | 120.93 | 121.32 | 121.70 | 122.09 | 112.47 | 122.86 |
| 60 | 123.24 | 123.62 | 124.01 | 124.39 | 124.77 | 125.16 | 125.54 | 125.92 | 126.31 | 126.69 |
| 70 | 127.07 | 127.45 | 127.84 | 128.22 | 128.60 | 128.98 | 129.37 | 129.75 | 130.13 | 130.51 |
| 80 | 130.89 | 131.27 | 131.66 | 132.04 | 132.42 | 132.80 | 113.18 | 133.56 | 133.94 | 134.32 |
| 90 | 134.70 | 135.08 | 135.46 | 135.84 | 136.22 | 136.60 | 136.98 | 137.36 | 137.74 | 138.12 |
| 100 | 138.50 | 138.88 | 139.26 | 139.64 | 140.02 | 140.40 | 140.77 | 141.15 | 141.53 | 141.91 |

There are two standard tolerance classes for DIN RTDs. These tolerances are defined as follows:

DIN Class A Temperature tolerances: +/-(0.15 + .002|T|°C)
DIN Class B Temperature tolerances: +/-(0.3 + .005|T|°C)
DIN Class C Temperature tolerances: +/-(1.2 + .005|T|°C)

**CONFORMATION TO STANDARDS**

- ASTM Standards Related to Resistance Temperature Detectors
  - E 644-98 Standard Test Methods for Testing Industrial Resistance Thermometers
  - E 1137-97 Standard Specification for Industrial Platinum Resistance Thermometers
  - E 1652-00 Standard Specification for Magnesium Oxide and Aluminum Oxide Powder and Crushable Insulators Used in the Manufacture of Metal-Sheathed Platinum Resistance Thermometers, Base Metal Thermocouples, and Noble Metal Thermocouples
- DIN-German Industrial Standards Organization

  - DIN 43760 references nickel precision
  - DIN IEC 751 reference platinum precision resistance thermometers.

**APPLICATIONS**

RTDs find application in all kinds of industrial and laboratory thermometry.

- Precision process temperature control
  - Textile
  - Chemical
  - Food
  - Brewing
- Automatic temperature control
  - Test Chambers
  - Oven Temperature
  - Plastic Extruders
  - Injection Molders
  - Solder Pots
  - Bearing Temperature

**PARTIAL LIST OF SUPPLIERS**

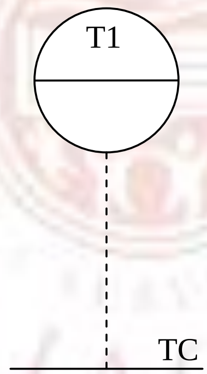
- Accutech
- Altek Industries Corp.
- Beckmann Industrial Corp.
- Bristol Babcock.
- Conax Buffalo Corp.
- Digitec.
- Durex International Corp.
- Electronic Instrumentation & Technology Inc.
- Foxboro Co.
- Hart Scientific Engineering
- Leico Industries Products Inc.
- Moore Industries
- Pyrometer Instrument Co.
- Rosemount Inc.
- RTD Co.
- Temperature Measurement Systems
- Thermo-Couple Products Co.
- Westcon
- Yokogawa Corp.

# THERMOCOUPLES

**Description**

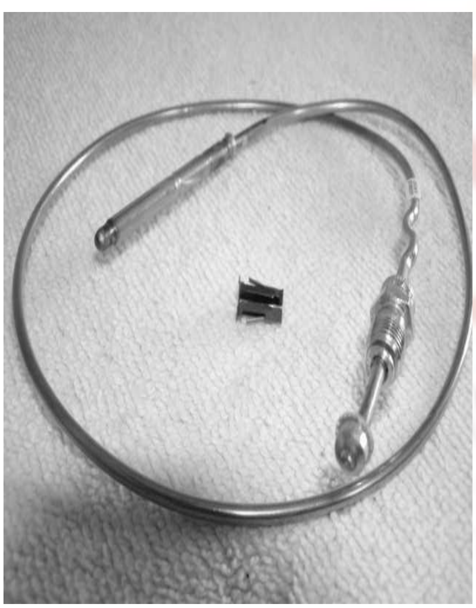
A thermocouple is a thermoelectric sensor device used to measure temperatures accurately. It consists of two dissimilar metals, joined together at one end. When the junction of the two metals is heated or cooled a voltage is produced that can be correlated back to the temperature. One junction is placed where the temperature is to be measured, and the other is kept at a constant lower (reference) temperature. A measuring instrument is connected in the electrical circuit. The temperature difference causes the development of an electromotive force that is approximately proportional to the difference between the temperatures of the two junctions. Temperature can be read from standard tables, or the instrument can be calibrated to display temperature directly. The thermocouple alloys are commonly available as wire. Temperature range about [-270 ºC -1820 ºC].

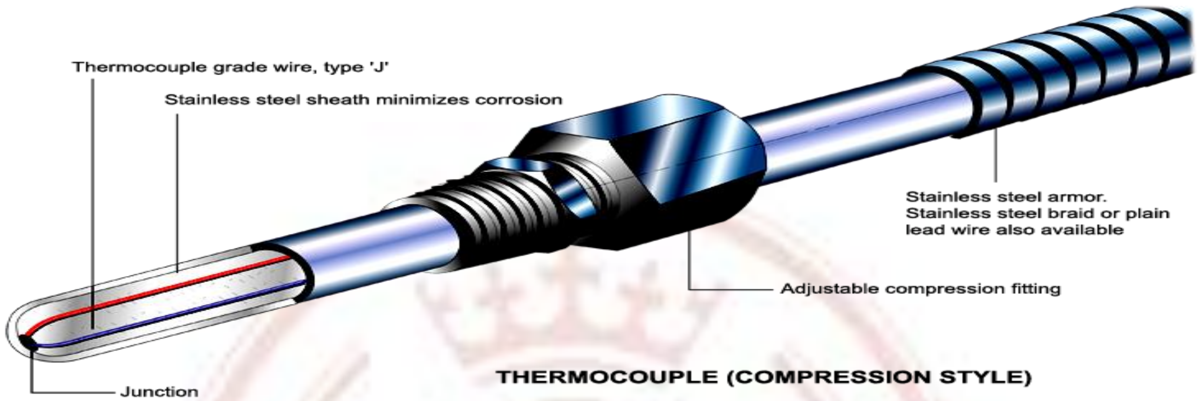
## Symbol




*Flow Sheet Symbol*

**FIGURE**






**Thermocouple types:** A large number of metal and alloy combinations have been studied as thermocouples, and the seven most widely used are listed in the table. The most accurate and reproducible are the platinum/rhodium thermocouples, types R and S, while the most widely used industrial thermocouples are probably types K, T, and E.

**Alloy combination of common thermocouple types**

- Type R – [Platinum-13% rhodium/platinum]
- Type S – [Platinum-10% rhodium/platinum]
- Type B– [Platinum-30% rhodium/platinum-6% rhodium] very poor below 50ºC;refer-ence junction temperature not important as voltage output is the same from 0 to 42 ºC
- Type E – [Nickel-chromium alloy/a copper-nickel alloy] good for low temperatures since dV/dT (a) is high for low temperatures
- Type J – [Iron/another slightly different copper-nickel alloy] cheap because one wire is iron; high sensitivity but also high uncertainty (iron impurities cause inaccuracy)
- Type T – [Copper/a copper-nickel alloy] good accuracy but low max temperature (400 ºC); one lead is copper, making connections easier; watch for heat being conducted along the copper wire, changing your surface temp
- Type K – [Nickel-chromium alloy/nickel-aluminum alloy] popular type since it has decent accuracy and a wide temperature range; some instability (drift) over time
- Type N – most stable over time when exposed to elevated temperatures for long periods

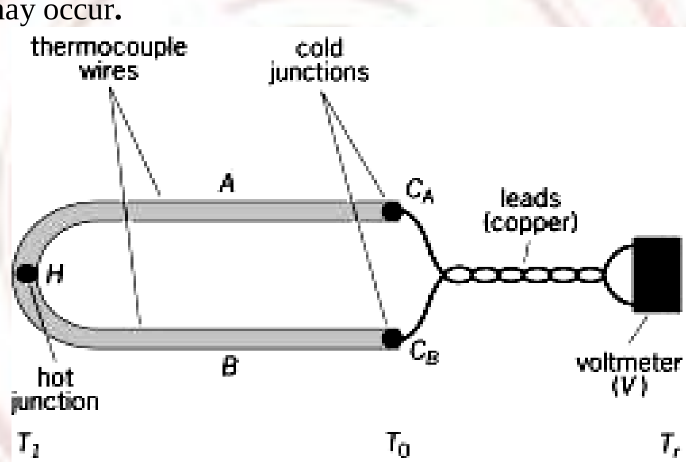
**Common thermocouple temperature ranges**

| Thermocouple Types | Calibration Temperature range | Std. limits of error | Spec. limits of error |
|---|---|---|---|
| **Type J** | 0°C–750°C (32°F–1382°F) | Greater of 2.2°C or 0.75% | Greater of 1.1°C or 0.4% |
| **Type K** | -200°C–1250°C (328°F–2282°F) | Greater of 2.2°C or 0.75% | Greater of 1.1°C or 0.4% |
| **Type E** | -200°C–900°C (328°F–1652°F) | Greater of 1.7°C or 0.5% | Greater of 1.0°C or 0.4% |
| **Type T** | -250°C–350°C (328°F–662°F) | Greater of 1.0°C or 0.75% | Greater of 0.5°C or 0.4% |
| **Type R** | -50°C–1768°C (58°F–3214°F) | | |
| **Type S** | -50°C–1768°C (58°F–3214°F) | | |

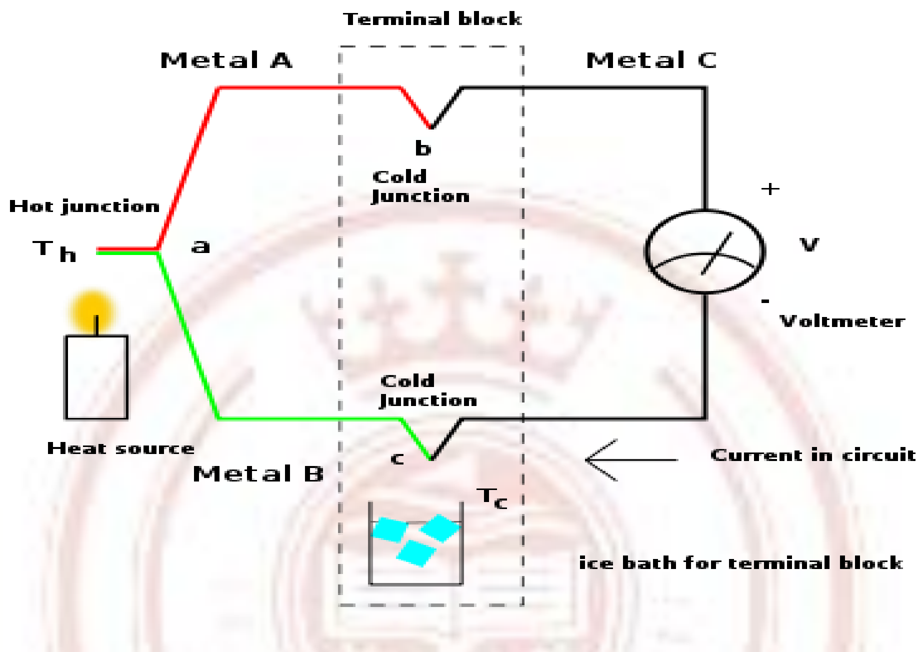
**PRINCIPLE OF OPERATION**

**Seebeck effect**

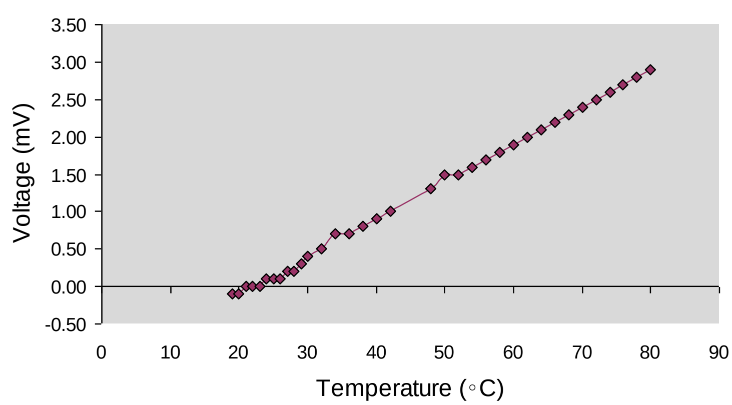
- If two wires of dissimilar metals are joined at both ends and one end is heated, current will flow.
- If the circuit is broken, there will be an open circuit voltage across the wires.
- Voltage is a function of temperature and metal types.
- For small DT's, the relationship with temperature is linear. For larger DT's, non-linearities may occur**.**



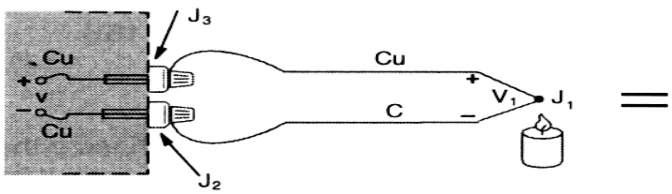

The basic circuit of a thermocouple is shown in the illustration. The thermocouple wires, made of different metals or alloys *A* and *B*, are joined together at one end *H*, called the hot (or measuring) junction, at a temperature $T_1$. The other ends, $C_A$ and $C_B$ (the cold or reference junctions), are maintained at a constant reference temperature $T_0$, usually but not necessarily 32°F (0°C). From the cold junctions, wires, usually of copper, lead to a voltmeter *V* at room temperature $T_r$. Due to the thermoelectric potential gradients being different along the wires *A* and *B*, there exists a potential difference between $C_A$ and $C_B$. This can be measured by the voltmeter, provided that $C_A$ and $C_B$ are at the same temperature and that the lead wires between $C_A$ and *V* and $C_B$ and *V* are identical (or that *V* is at the temperature $T_0$, which is unusual). Such a thermocouple will produce a thermoelectric emf between $C_A$ and $C_B$ which depends only upon the temperature difference $T_1 - T_0$.



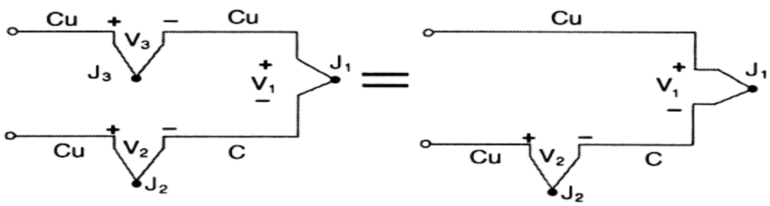

Thermocouple



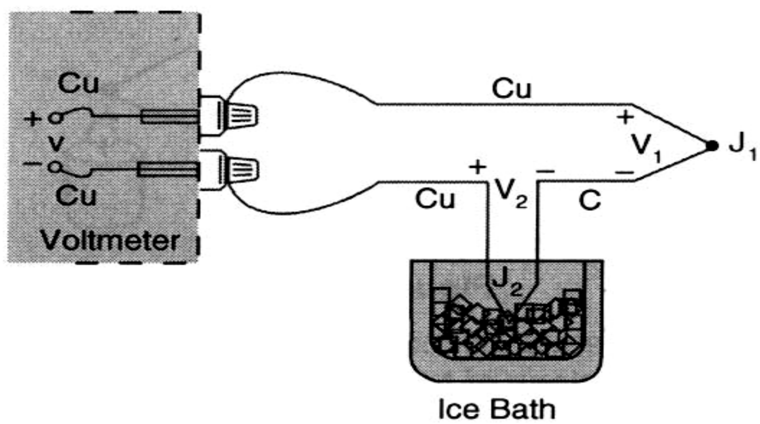

**Measuring the thermocouple voltage:** To measure a thermocouple Seebeck voltage, we cannot simply connect the thermocouple to a voltmeter or other measurement system because connecting the thermocouple wires to the measurement system creates additional thermoelectric circuits. Just created another junction. The displayed voltage will be proportional to the difference between J1 and J2 (and hence T1 and T2). Note that this is "Type T" thermocouple.



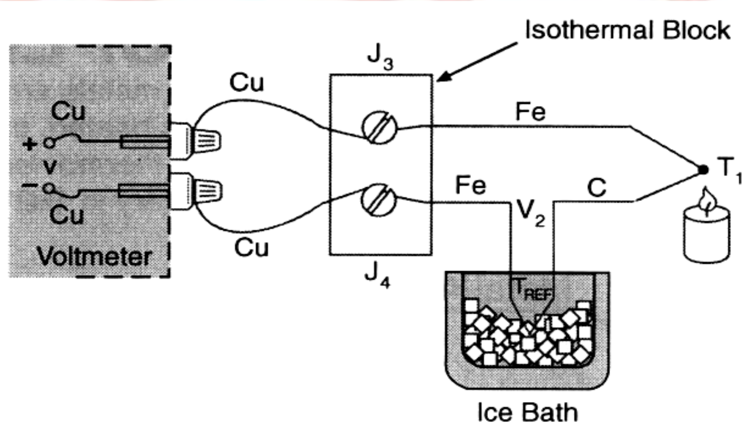

EQUIVALENT CIRCUITS




**External Reference Junction**: A solution is to put J2 in an ice-bath; then you know T2, and your output voltage will be proportional to T1-T2.




**Isothermal Block:** The block is an electrical insulator but good heat conductor. This way the voltages for J3 and J4 cancel out. Thermocouple data acquisition set-ups include these isothermal blocks.



If we eliminate the ice-bath, then the isothermal block temperature is our reference temperature $V = \alpha\left(T_1 - T_{block}\right)$

**Software Compensation:** To find the temperature of the block use a thermister or RTD. Once the temperature is known, the voltage associated with that temperature can be subtracted off. Thermocouples are used since it is cheaper, smaller, more flexible and rugged, and operate over a wider temperature range. Most data acquisition systems have software compensation built in.

**Hardware Compensation:** With hardware compensation, the temperature of the isothermal block again is measured, and then a battery is used to cancel out the voltage of the reference junction. This is also called an “electronic ice point reference”. With this reference, you can use a normal voltmeter instead of a thermocouple reader. You need a separate ice-point reference for every type of thermocouple.

**Sheathing and SLE:** “Special Limits of Error” wire can be used to improve accuracy. Sheathing of wires protects them from the environment (fracture, oxidation, etc.) and shields them from electrical interference. The sheath should extend completely through the medium of interest. Outside the medium of interest it can be reduced. Sometimes the bead is exposed and only the wire is covered by the sheath. In harsher environments, the bead is also covered. This will increase the time constant. Platinum wires should be sheathed in non-metallic sheaths since they have a problem with metallic vapor diffusion at high temperatures.

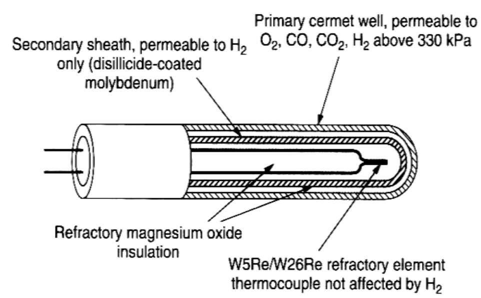



**Figure 8.13** A multi-layer protective sheath required for a high-temperature thermocouple used in a hostile environment

**Potential Problems**

*Poor bead construction:* Weld changed material characteristics because the weld temperature was too high. Large solder bead with temperature gradient across it

*Decalibration:* If thermocouples are used for very high or cold temperatures, wire properties can change due to diffusion of insulation or atmosphere particles into the wire, cold-working, or annealing. In homogeneities in the wire; these are especially bad in areas with large temperature gradients; esp. common in iron. Metallic sleeving can help reduce their effect on the final temperature reading.

*Shunt impedance:* As temperature goes up, the resistance of many insulation types goes down. At high enough temperatures, this creates a “virtual junction”. This is especially problematic for small diameter wires.

*Galvanic Action:* The dyes in some insulations form an electrolyte in the water. This creates a galvanic action with a resulting emf potentially many times that of the thermocouple. Use an appropriate shield for a wet environment. “T Type” thermocouples have less of a problem with this.

*Thermal shunting:* It takes energy to heat the thermocouple, which results in a small decrease in the surroundings’ temperature. For tiny spaces, this may be a problem. Use small wire (with a small thermal mass) to help alleviate this problem. Small-diameter wire is more susceptible to decalibration and shunt impedance problems. Extension wire helps alleviate this problem. Have short leads on the thermocouple, and connect them to the same type of extension wire which is larger. Extension wire has a smaller temperature range than normal wire.

*Noise:* Several types of circuit set-ups help reduce line-related noise. You can set your data acquisition system up with a filter; too. Small-diameter wires have more of a problem with noise.

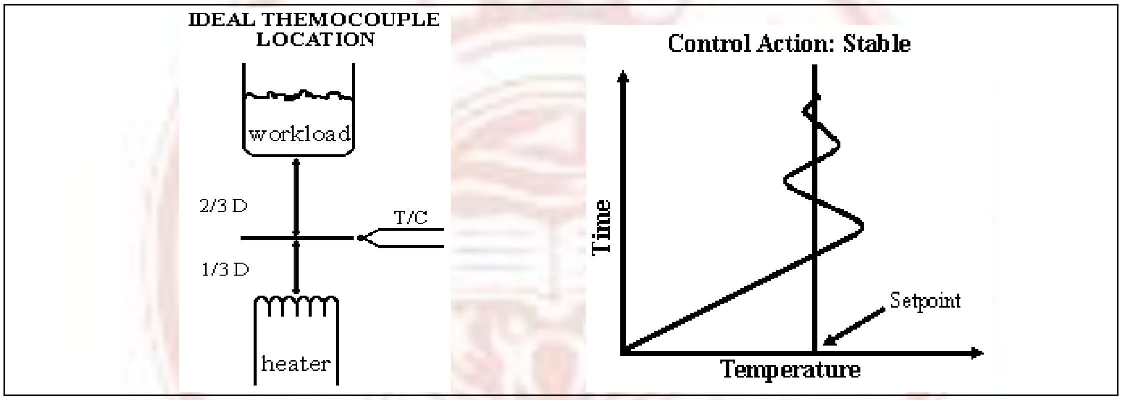
*Conduction along the thermocouple wire:* In areas of large temperature gradient, heat can be conducted along the thermocouple wire, changing the bead temperature. Small diameter wires conduct less of this heat. T-type thermocouples have more of a problem with this than most other types since one of the leads is made of copper which has a high thermal conductivity.

## INSTALLATION/SYSTEM ASSEMBLY

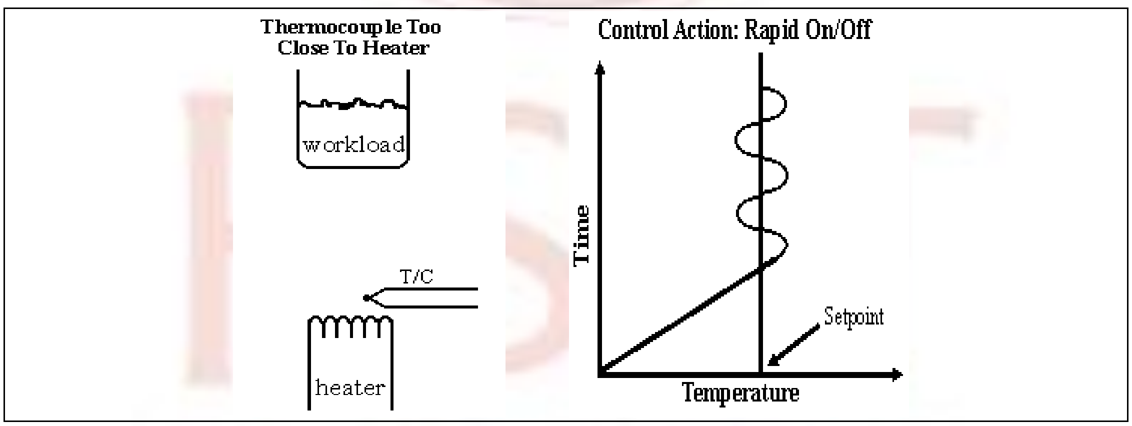
- Make sure materials are clean, esp. for high temperatures.
- Check the temperature range of materials. Materials may degrade significantly before the highest temperature listed.
- Make sure you have a good isothermal junction.
- Use enough wire that there are no temperature gradients where it’s connected to your DAQ system.
- If you’re using thermocouple connectors, use the right type for your wire.
- If you’re using a DAQ system, use the right set-up for thermocouples.
- Check the ice-point reference.
- Provide proper insulation for harsh environments.
- Pass a hair-dryer over the wire. The temperature reading should only change when you pass it over the bead.
- Mount a thermocouple only on a surface that is not electrically live (watch for this when measuring temperatures of electronics).

**Location**

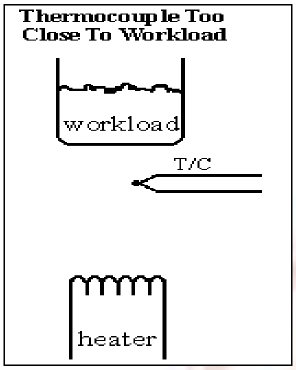
Proper location of the thermocouple is probably the most important factor in obtaining accurate temperature control. Thermocouples should be in a position to have a definite temperature relationship to the heat source and workload. A good 'rule of thumb' in locating thermocouples is to place them between the workload and heat source. The thermocouple should be located 1/3 the distance from the heat source and 2/3 the distance to the workload

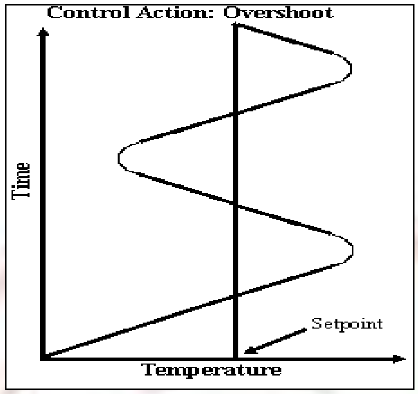


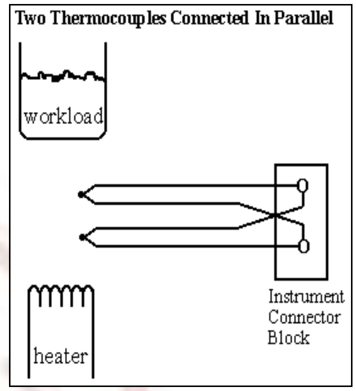

If a thermocouple is located too close to the heaters, a long warm-up time will result. The thermocouple will sense the heat before it reaches the workload, and this means rapid on/off action of the controller. In effect, the controller is controlling the heater and not the workload. In rare cases, voltage will be induced into the thermocouple circuit at high temperatures when located too near the heaters.



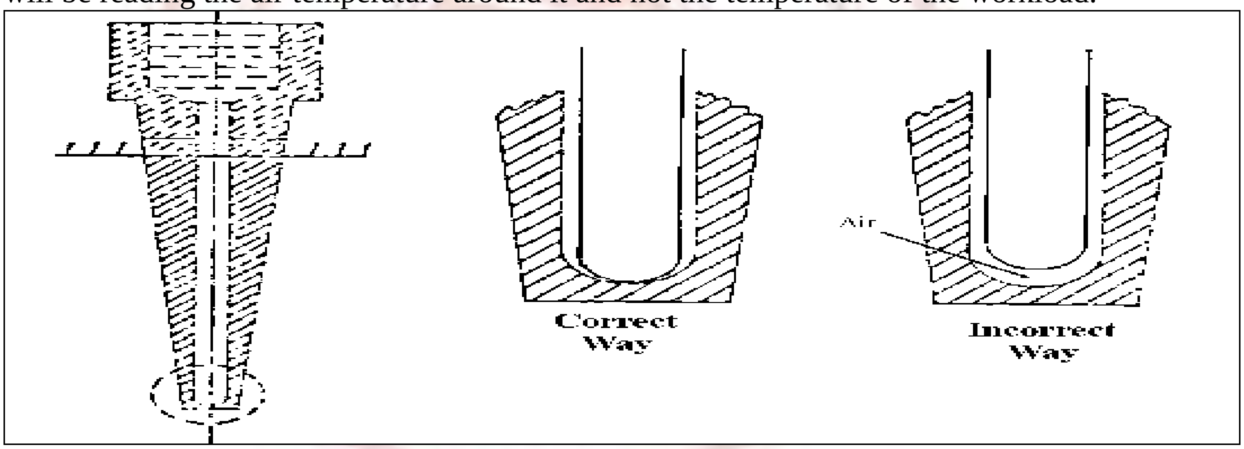

When a thermocouple is located too close to the workload, there is a substantial delay in sensing the proper control point and the result is overshooting the temperature. In most cases, it is better to be too close to the heaters than the workload as once a temperature point is passed, it becomes difficult to cool the workload unless a forced cooling system is used. Two thermocouples connected in parallel could be used, one located near the heaters and the other near the workload. Both will balance these two factors and provide closer contro




Another consideration in location is when locating a thermocouple in a thermocouple well. If it is not bottomed correctly, located at the bottom of the well, the thermocouple will be reading the air temperature around it and not the temperature of the workload.




**Bottoming of thermo well**

## CALIBRATION

1. Fill the thermo bath container with water and turn the thermo bath on. Heat the water to 30 degrees Celsius and turn the thermocouple device on. Connect each lead of the multimeter to one end of the thermocouple. This multimeter should be able to measure a voltage of 1 microvolt.
2. Place one junction of the thermocouple into the water and allow the voltage to stabilize. This occurs when the voltage stops fluctuating except for the last digit. Record the stable portion of the voltage from the multimeter.
3. Increase the water temperature to 35 degrees Celsius and record the stable voltage on the multimedia again. Repeat this procedure for each 5-degree increase in temperature from 35 to 60 degrees Celsius.
4. Measure the room temperature and look up the voltage for your thermocouple type at the room's temperature. For example, the voltage for a type K thermocouple at a temperature of 25 degrees Celsius is 1 mill volt. Add this value to each of the voltages you recorded in Steps 2 and 3.
5. Use the curve-fitting method of your choice to find the line that best fits your recorded data. The slope of this line provides the voltage increase for each degree of temperature increase. The voltage on a standard type K thermocouple should increase about 40 microvolt for every degree Celsius increase in temperature

## SELECTION CRITERIA

The following criteria are used in selecting a thermocouple:

- Temperature range
- Chemical resistance of the thermocouple or sheath material
- Abrasion and vibration resistance
- Installation requirements (may need to be compatible with existing equipment; existing holes may determine probe diameter)

## APPLICATIONS

Thermocouples are suitable for measuring over a large temperature range, up to 2300 °C. They are less suitable for applications where smaller temperature differences need to be measured with high accuracy. Applications include temperature measurement for kilns, gas turbine exhaust, diesel engines, and other industrial processes.

*Steel industry*: Type B, S, R and K thermocouples are used extensively in the steel and iron industries to monitor temperatures and chemistry throughout the steel making process. Disposable, immersible, type S thermocouples are regularly used in the electric arc furnace process to accurately measure the temperature of steel before tapping.

*Manufacturing*: Thermocouples can generally be used in the testing of prototype electrical and mechanical apparatus.

*Process plants*: Chemical production and petroleum refineries will usually employ computers for logging and limit testing the many temperatures associated with a process, typically numbering in the hundreds. For such cases a number of thermocouple leads will be brought to a common reference block (a large block of copper) containing the second thermocouple of each circuit. The temperature of the block is in turn measured by a thermistor.

## CONFORMATION TO STANDARDS

- ASTM - E 230-98e1
- ANSI - MC96.1
- SP1 Temperature Standards Committees, ISA.

## PARTIAL LIST OF SUPPLIERS

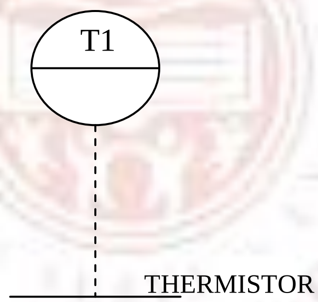
- ABB Kent-Taylor Inc.
- Accutech.
- Bailey Controls Co.
- Burns Engineering Inc.
- Honeywell
- Moore Industries.
- Foxboro
- Kaye Instruments
- Omega Engineering
- Omron Electronics
- Rosemount
- Temperature measurement systems Inc.

# THERMISTORS

## Description

Thermistors are thermally sensitive resistors composed of sintered semiconductor material which exhibits a large change in resistance proportional to a small change in temperature. The resistance is measured by passing a small, measured direct current (dc) through it and measuring the voltage drop produced. Thermistors are broadly classified as negative (NTC) or positive (PTC) temperature coefficient.Thermistors are widely used for temperature monitoring, control and compensation. They are extremely sensitive to temperature change, very accurate and interchangeable. They have a wide temperature envelope and can be hermetically sealed for use in humid environments. Temperature Range about [-45°C - 150°C]

## Symbol

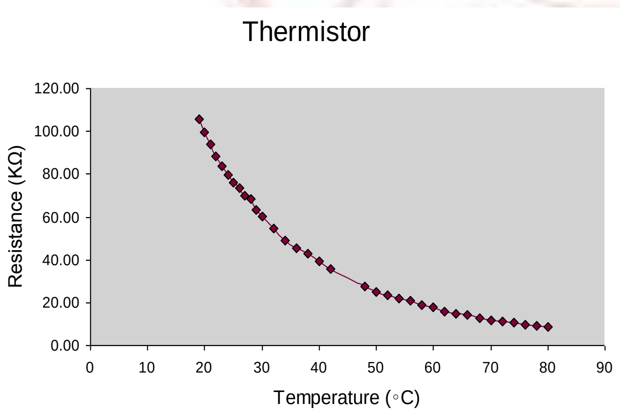



*Flow Sheet Symbol*

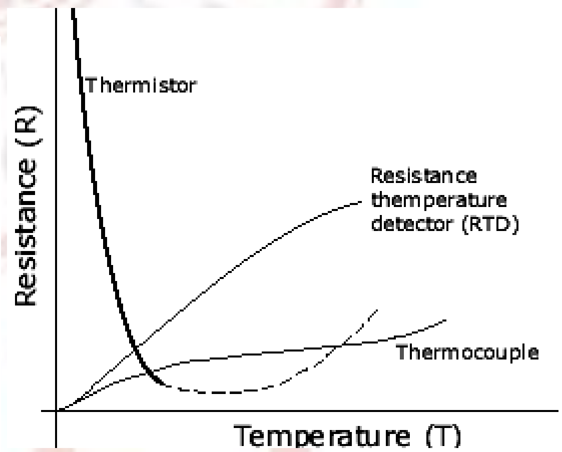
## Figure

## PRINCIPLE OF OPERATION

Thermistors are non-linear temperature dependent resistors with a high resistance temperature coefficient. Although positive temperature coefficient units are available, in practice, only thermistors with negative temperature coefficient (NTC type) are used for temperature measurement; that is their resistance will decrease with an increase in temperature. (Note: this is because the extra heat reduces electron mobility in the semiconductor.) The resistance can change by more than 1000 times. The NTC can be as large as several percent per degree Celsius, allowing the thermistor circuit to detect minute changes in temperature which could not be observed with an RTD or thermocouple circuit. Thermistors having positive temperature coefficient (PTC type) are only used for binary detection of a given temperature value. While the thermocouple is the most versatile temperature transducer and the PRTD is the most stable, the word that best describes the thermistor is sensitive. Of the three major categories of sensors, the thermistor exhibits by far the largest parameter change with temperature. The relationship between its resistance and the temperature is highly nonlinear. Furthermore, the resistance changes negatively and sharply with a positive change in temperature, as shown schematically below.




**Temperature versus resistance characteristics**




**Characteristics of three temperature transducers**

The thermistor resistance-temperature relationship can be approximated by Steinhart-Hart equation:

$$R = R_{\mathrm{Ref}} \cdot e^{\beta\left(\frac{1}{T} - \frac{1}{T_{\mathrm{Ref}}}\right)}$$

*Where: T* is temperature (in Kelvin),
*R* is the resistance of the thermistor (W),
$R_{Ref}$ is the resistance at $T_{Ref}$,
$T_{Ref}$ is the reference temperature, usually at room temp. (25 °C; 77 °F; 298.15 K),
β: calibration constant depending on thermistor material, usually between 3,000 and 5,000 K.

**Advantages and disadvantages**

Thermistors have desirable characteristics of small size, narrow spans, fast response and very high sensitivity (about 4%/deg C). Thermistors do not need cold junction compensation because its resistance is a function of absolute temperature and errors due to contact leads are insignificant. They are inexpensive and the stability increases with age.

However they are fragile and not suitable for wide spans. The change of resistance is nonlinear. Thermistors lack stability and hence drift of resistance values from the calibrated settings are high. This effect is more serious with thermistors made of semiconductor materials. Hence its use is limited up to 316 deg C.Most common cause for failure of thermistors is reaction with moisture and water which can damage the electrode material resulting in a downward shift in resistance. This is prevented by appropriate glass coating over the thermistor body. Other reasons are due to customer-induced failures, resulting from mishandling during lead splicing or potting.

**INSTALLATION**

NTC thermistors can be attached to extension leads or jacketed cable and assembled into various types of housings. The optimum materials, dimensions, and configuration for a probe assembly are determined by careful review of the application requirements

**CALIBRATION**

**The effect of temperature on a thermistor**

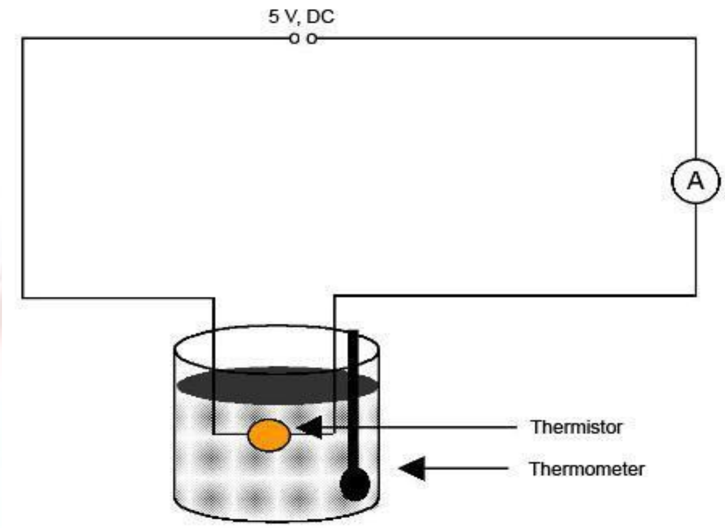
Place a thermistor and a thermometer into a beaker of hot water, and then compare and plot their results as the water cools. This experiment shows that the current through a thermistor increases with temperature, as more charge carriers become available.

***Apparatus and materials:***

- Timer or clock
- Leads, 4 mm
- Crocodile clip holder
- Thermometer -10°C to 110°C
- Thermistor – NTC type, e.g. 100 ohm at 25°C (available from Rapid Electronics).
- Power supply, 5 V, DC or four 1.5 V cells
- Beaker, 250 ml
- Kettle to provide hot water
- Digital multimeter, used as a milliammeter
- Heat-resistant mat
- Power supply, low voltage, DC, continuously variable or stepped supply with rheostat (>1 A)

***Procedure:***

- Set up the circuit as shown in the figure below.
- Pour boiling water into the beaker and take readings of the current through the thermistor as temperature falls. Record the results.
- Plot the graph of current/mA (y-axis) against temperature/ °C (x-axis).
- Assuming that the voltage is constant, describe how the conductance or resistance vary with temperature




**DESIGN AND CONSTRUCTION**

Thermistors use ceramic manufacturing technology consisting of high pressure forming and sintering at temperature upto1000 degree celcious and are manufactured from the oxides of the transition metals - manganese, cobalt, copper and nickel.

NTC thermistors are temperature dependant semiconductor resistors whose resistance decreases proportionally with increases in temperature. Mixture of different powered oxides of Mn, Fe,Ni,Cu, Ti, Zn and Co are used to make NTC thermistors Operating over a range of -200°C to + 1000°C, they are supplied in glass bead, disc, chips and probe formats. NTCs should be chosen when a continuous change of resistance is required over a wide temperature range. They offer mechanical, thermal and electrical stability, together with a high degree of sensitivity. NTCs are used in applications such as temperature measurement and control, temperature compensation, surge suppression and fluid flow measurement.

PTC thermistors are temperature dependent resistors whose resistance increases with increasing temperature are manufactured from barium titanate and should be chosen when a drastic change in resistance is required at a specific temperature or current level. They are used to protect circuits from overload, and can function as thermal switches or as ordinary thermometers.

PTCs can operate in the following modes:

- Temperature sensing, switching at temperatures ranging from 60°C to 180°C, e.g. protection of windings in electric motors and transformers.
- Solid state fuse to protect against excess current levels, ranging from several mA to several A (25°C ambient) and continuous voltages up to 600V and higher, e.g. power supplies for a wide range of electrical equipment.
- Liquid level sensor.

**SELECTION CRITERIA**

Selection of thermistors completely depends on the type of applications in which it is being used. It can be a PTC, an NTC or a Ceramic thermistor with respective temperature range etc. The high sensitivity of an NTC thermistor makes it an ideal candidate for temperature sensing applications. These low-cost NTC sensors are normally used for a temperature range of 40 °C to +300 °C.

Selection criteria for NTC thermistors are

- Temperature range
- Resistance range
- Measuring accuracy
- Environment (surrounding medium)
- Response time
- Dimensional requirements.

The most important considerations necessary when selecting standard PTC thermistors are resistance at 25ºC as well as the transition temperature.

- Base Resistance (R@25°C)
- Switch Temperature (Ts)
- Maximum Operating Voltage (Vmax)

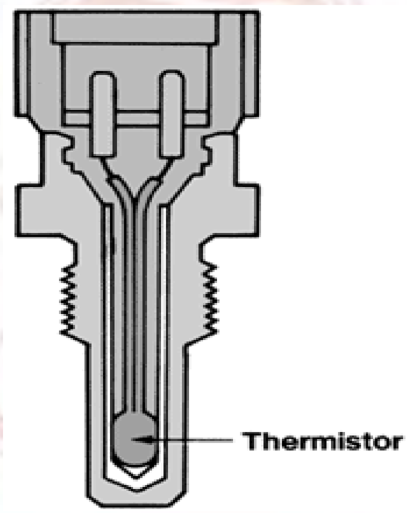
**CONFORMATION TO STANDARDS**

- GSFC S-311-P-18 in 1974
- MIL-PRF-23648.

**APPLICATIONS**

- PTC thermistors are used as a 'Fuse' for Short-circuit over-current protection.
- They are used for telecommunication applications.
- They are used for picture tube degaussing.
- PTC thermistors are used for time delay and switching applications.
- They are used for motor starting and are used as heating elements.
- They are used as a 'switch' for Motor starts degaussing.
- They are used as a 'temperature sensor' in measurement and control & over temperature protection circuits.
- They are used to limit temperature for motor protection and over temperature protection circuits.
- They are also used as 'level sensors' and 'limit indicators'.
- NTC thermistors are used as resistance thermometers in low-temperature measurements of the order of 10 K.
- NTC thermistors can be used as inrush-current limiting devices in power supply circuits. They present a higher resistance initially which prevents large currents from flowing at turn-on, and then heat up and become much lower resistance to allow higher current flow during normal operation. These thermistors are usually much larger than measuring type thermistors, and are purposely designed for this application.

- NTC thermistors are regularly used in automotive applications. For example, they monitor things like coolant temperature and/or oil temperature inside the engine and provide data to the ECU and, indirectly, to the dashboard.
- Thermistors are also commonly used in modern digital thermostats and to monitor the temperature of battery packs while charging.
- Thermistors are used as Air, Coolant, EGR, and Automatic Air Temperature sensors. All thermistors have two wires and are used to measure temperature changes. When placed in series with a fixed (pull-up) resistor, thermistors create a variable voltage drop circuit, which is ideal for use by computer circuits. Engine coolant temperature sensor (ECT) is shown below.



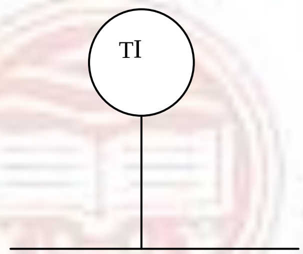

**PARTIAL LIST OF SUPPLIERS**

- Analogic Corp.
- Atkins Technical Inc.
- Ball Corp.
- Barber Colman Co.
- Beckman Industrial Corp.
- Conax Buffalo Corp.
- Digitec
- Hart Scientific Inc.
- Honeywell Inc.
- Mitsubishi International
- Omega Engineering Inc.
- Oven Industries Inc.
- Pyrometer Instrument Co.
- Thermometrics Inc.
- Vector

# TEMPERATURE INDICATORS

**Description:**
Temperature of an object determines the sensation of warmth or coldness felt by touching it. It is a measure of the average kinetic energy of the particles in a sample of matter, expressed in units of degrees on a standard scale. A temperature indicator is used to indicate temperature of an object

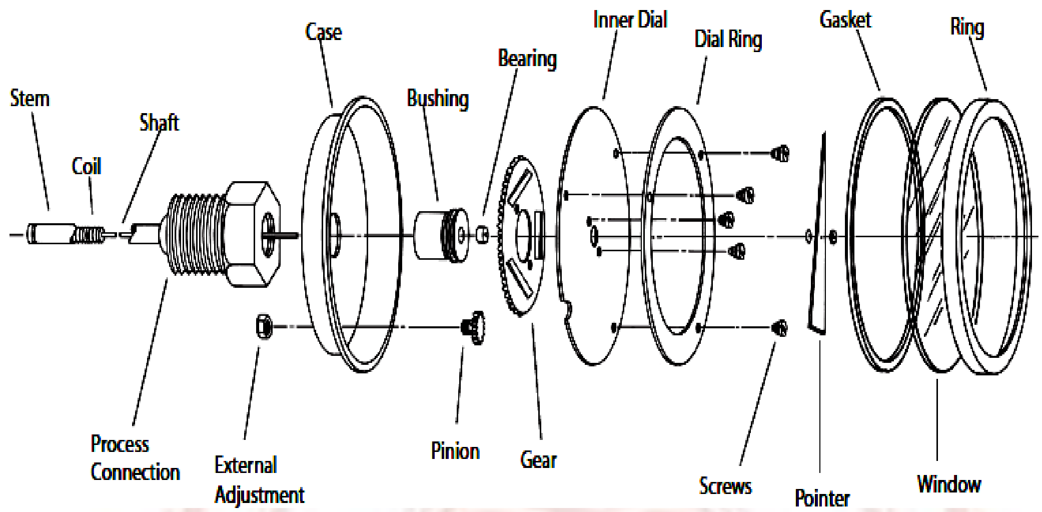
**Symbol**




Flow sheet symbol

**Figure**


***Figure 1: Ashcroft Bimetal Thermometers Series El, Grade A, (1%)***




**SPECIFICATIONS**

Ranges: -80/120°F — 200/1000°F; -50/50°C — 100/500°C
Maximum ambient temperature: 200°F (95°C).

Model: Ashcroft® Series: EI
Dial Sizes: 2, ½ 3, ½ 5½
Stem Length: 21/2½—24½ (1)
Case & Stem: 304 stainless steel, hermetically sealed
Stem Diameter: .250½
Window: Heavy-duty glass, plastic or shatterproof glass optional
Dial: Maxi vision®, black figures on white background
Pointer: Black
Connection: Plain, pointed plain, 1/4 NPT, 1/2NPT, 1/2 NPT union connection
Location: Every angle, Lower, Rear

| Options: | **Code:** | **Description** |
|---|---|---|
| | C4 | Individual calibration cert. |
| | XCS | Dual scale (2) |
| | XDM | Dial marking |
| | XNH | Stainless steel tag |
| | XNN | Paper tag |
| | XPD | Plastic window |
| | XSG | Shatter proof glass |
| | X3B | 3/8½ stem dia. with 1/2 NPT |
| | X02 | 1/4 NPT when 1/2 NPT is standard |
| | XS1 | Silicone free |

(1) Special or longer length available, consult factory
(2) Dual scale available with 3½ and 5½ case only
(3) Only available on rear connection

## PRICIPLE OF OPERATIONS

**Bimetallic thermometer**:-Different metals have different expansions for the same temperature rise. A bimetallic strip will have 2 identical strips of 2 different metals riveted together. If that strip is heated, strip bends such that one metal expends more compared to the other for the same temperature. This principle is used in bimetallic thermometers. The angular position versus temperature relation is established by calibration.

When used in thermometers, the bimetallic strip is normally wound into a flat spiral, a single helix, or a multiple helix. The end of the strip that is not fixed in position is fastened to the end of a pointer that moves over a circular scale.

Bimetallic thermometers are easily adapted for use as recording thermometers; a pen is attached to the pointer and positioned so that it marks on a revolving chart.

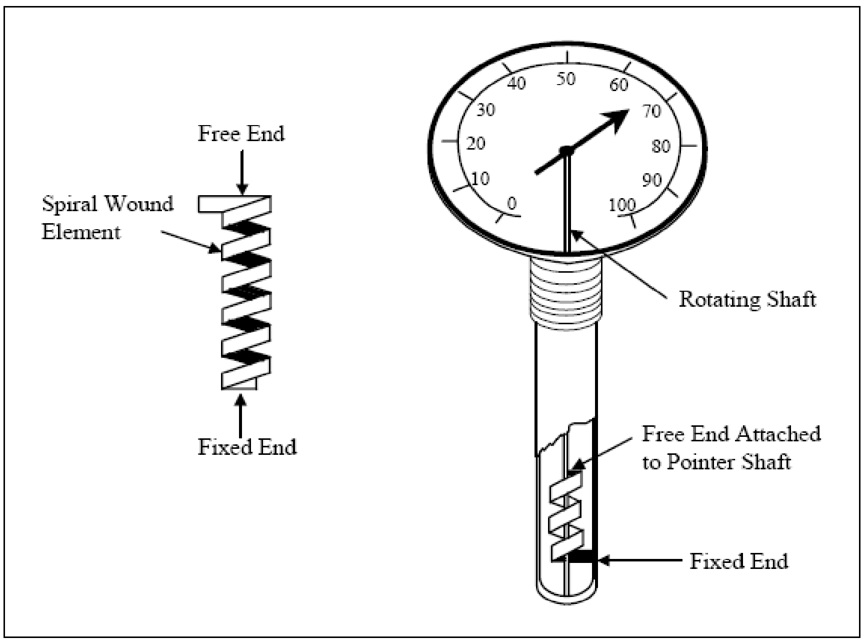
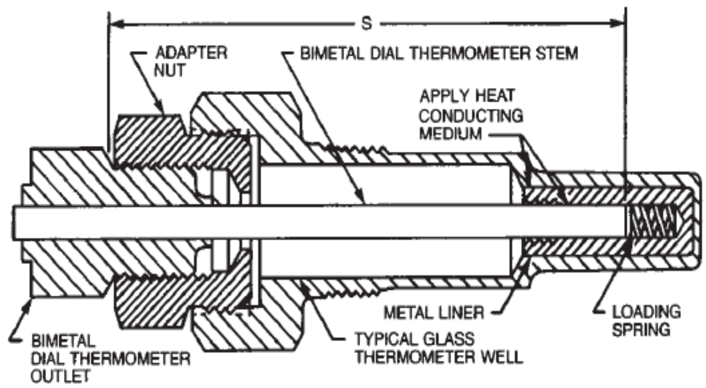



Figure 7-3. Bimetallic dial thermometer

## INSTALLATION

Assemble the adapter nut into the well and tighten securely. Before installing the Bimetal Dial Thermometer into the adapter and well, coat the lower 3″ section of the thermometer with a layer of heat conducting medium. This will improve the temperature response of the thermometer. The metal liner is then slipped over the end of the thermometer stem and a coating of heat conducting medium is applied to the outside wall of the liner. The thermometer and the liner are then inserted into the well and tightened in position. Do not tighten more than is necessary to prevent the thermometer from turning. Where service temperatures exceed 350°F the heat conducting medium may smoke when first subjected to a high temperature. This is caused by the vehicle, in the heat conducting medium, vaporizing and leaving the dry solids behind. This should not be cause for alarm. The dry solids will act equally well as a heat conducting medium for temperatures up to 1000°F.




The thermometer should be mounted at any convenient location where it will be subjected to the average temperature variations to be indicated.
Avoid bending the stem as this will cause misalignment of the internal parts, resulting in undue frictional errors.
To tighten the thermometer to the apparatus, use a wrench applied to the hexagon head of the threaded connection located just outside of the case

*Procedure*

- Locate the stem so that at least two inches will be subjected to the average temperature to be measured.
- Exposing the stem to a temperature in excess of the highest dial reading should be avoided.
- The thermometer is normally provided with a threaded connection. To tighten the thermometer to the apparatus or into the well, use an open-end wrench applied to the hexagon head of the threaded connection. Turn until reasonably tight, and then tighten still further in the same manner as a pipe elbow or similar pipe fitting until the scale is in the desired position for reading. Do not tighten by turning the thermometer case.

Install the dry type thermometer so that the maximum case temperature is kept below 200°F at all times. Install the liquid filled type thermometer so that the maximum case temperature is kept below 150°F at all times.
When a thermometer is equipped with a well, the well should be installed onto the apparatus first. The stem of the thermometer should then be coated with a heat conducting medium (a mixture of glycerin and graphite or Vaseline or any other heavy lubricant may be used), after which the thermometer stem is inserted, and tightened into the well.

*Maintenance of dial thermometers:* Aside from occasional testing, little or no maintenance is required. Be sure that the gasket glass cover is on the case at all times, as moisture and dirt inside the case will eventually cause the thermometer to lose its accuracy.
If the thermometer is used for measuring the temperature of a material that may harden and build up an insulating layer on the stem, the thermometer should be removed from the apparatus occasionally, and the stem cleaned. Observe this precaution to ensure the sensitivity of the instrument.

*Positioning the stem:* Before installation, the stem should be set to the desired angle as follows:

*Figure 1:* Loosen the four screws labeled "A" and "B" in Figure 1, until the harness revolves freely without twisting the flexible housing.

*Figure 2:* While holding the case, revolve the harness clockwise or counterclockwise, as indicated by arrows in Figure 2, to place the harness in a position that will permit flexing the stem in the desired direction with respect to the case. Then lock the two screws labeled "A."

*Figure 3:* Flex the stem to the desired angle with respect to the face of the thermometer, as shown in Figure 3, and then lock the two screws labeled "B."

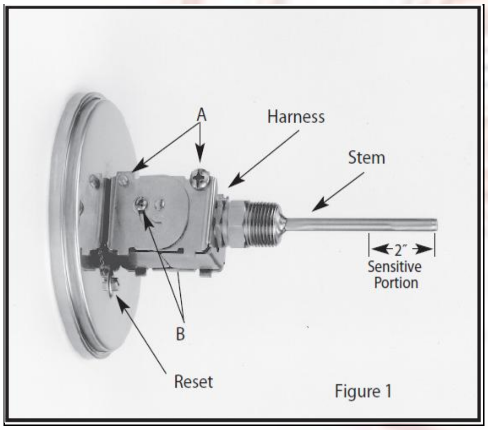



Figure 1

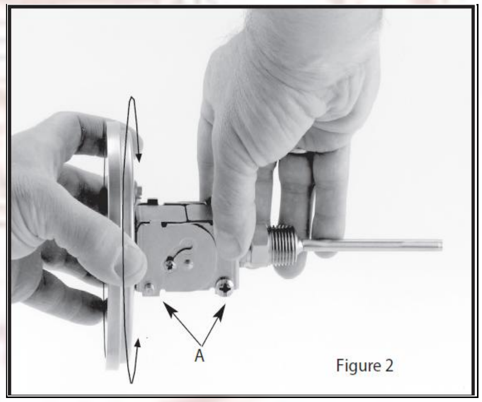



Figure 2

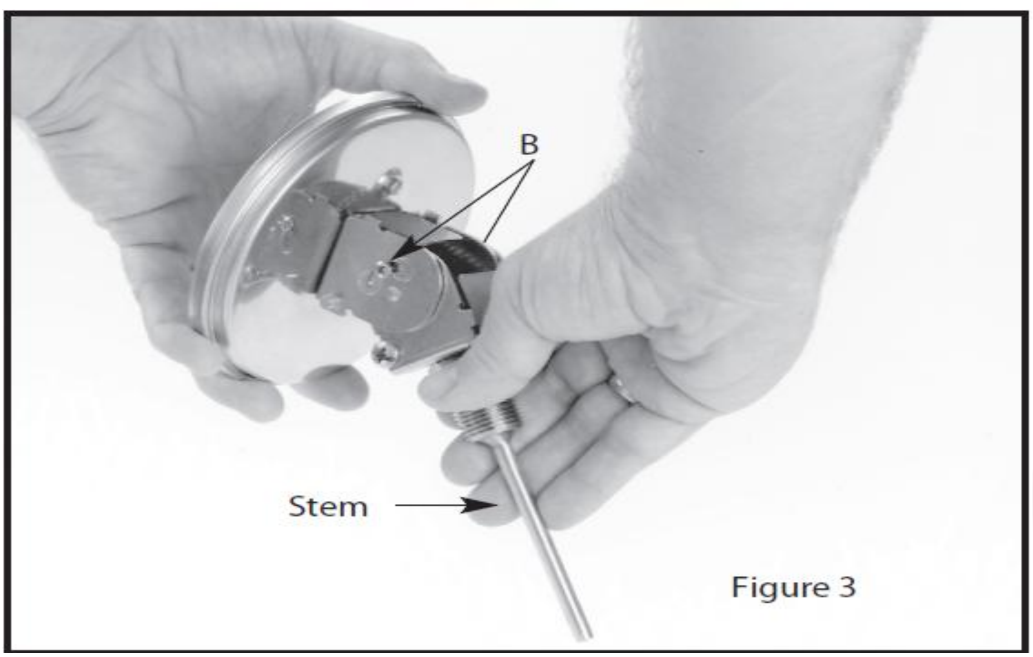



Figure 3

**CALIBRATION**

- Testing: Ashcroft Bimetal Dial Thermometers are carefully calibrated at the factory and under most operating conditions will retain their accuracy indefinitely. However, as in the case of all instruments, it is well to make periodic checks for accuracy against known standards.
- Adjustment: If it is necessary to make an adjustment to the thermometer proceed as follows: On thermometers fitted with an “External Adjustment” – Use a small wrench, small screwdriver or a coin to turn the slotted hexagon head in the back of the case until the pointer indicates the proper temperature on the dial.

**SELECTION CRITERIA**

- Temperature Ranges: Standard Fahrenheit and Celsius ranges have been established to encompass all normal temperature measurement requirements. A bimetal thermometer can be used at an operating temperature anywhere throughout its dial range. Provision should be made for extreme temperature conditions. No bimetal thermometer should be exposed continuously to process temperatures over 800°F (425°C).
- Operating Conditions: The maximum ambient temperature of the case should be no more than 200°F (95°C); liquid filled series 150°F (65°C). Temperatures beyond this value may cause discoloration of the dial or result in increased pressure inside the casing which would ultimately lead to failure of the window. The lowest ambient temperature should not exceed –40°F (–40°C).
- Pointers: The pointers are balanced to close tolerances, and the paint finishes are controlled to assure long-term stability under adverse ultraviolet conditions
- Thermo wells: Thermo wells must be used on any application where the stem of the bimetal thermometer may be exposed to pressure, corrosive fluids or high velocity. Additionally, the use of a thermo well permits instrument interchange or calibration check without disturbing or closing down the process.
- Cases: There are three case styles. The Cl series has no adjustment but is hermetically sealed. The hermetic seal prevents entry of moisture into the casing, minimizing the possibility of icing or fogging inside the case. The EL series provides the same features as the El plus the added benefit of liquid filling which prolongs instrument life. Potential wear problems caused by excessive vibration are minimized through dampening, and the liquid medium improves readability. The instruments are leak-tested to ensure the integrity of the joints. Case and stem material is 304 stainless steel.
- Coils: The bimetallic coils are carefully wound and inspected. Each is heat treated for optimum stability and over temperature capability.
- Bearings: The bearings are made of Teon or other low-friction material.
- Shafts: Shafts are made of specially drawn stainless steel wire with a very smooth finish
- Dials: The dials are based on computer calculated temperature deflection data and have the Maxi vision ® format to minimize parallax error.
- Windows: The standard window on EI and CI series are heavy-duty glass. Plastic and shatterproof glass are optional. The standard window on EL series is polycarbonate. No other options are available.

**CONFORMATION TO STANDARDS**

BP engineering standards

| | |
|---|---|
| RP 30-1 | : Instrumentation and control –Design & practice |

International Codes and Standards

| | |
|---|---|
| ANSI B31.3 | :- Chemical plant and petroleum refinery piping. |
| ANSI B1.20.2 | :- Pipe Thread general purpose |
| API PMC 40-1 | :- Bimetallic Thermometer |
| ASME section VII and XI | : - Boiler and pressure vessel code. |
| IEC 60529 | :- Degrees of protection by enclosures (IP codes) |
| ISO 9001 | :- Quality systems |
| | :-Model for Quality Assurance in Design, Development, Production, Installation and service**.** |

**APPLICATIONS**

- Heat treatment
- Furnace / Oven control
- Food processing
- Constant temp. Baths,
- Environmental chambers
- Plastic / Packaging / Pharmaceutical industry
- Cold Storage and Chilling plants
- Laboratory equipment etc.
- Meteorological

**PARTIAL LIST OF SUPPLIERS**

- Libratherm
- Elite Medical Instruments
- 4Physics
- sunny medical instruments LC.,CO
- Feature Products LTD.
- Ironia Marketing
- Tri-element international limited
- International biological laboratories
- Popular science apparatus workshops pvt ltd
- oasis instruments company

## TEMPERATURE SWITCHES

**Description**

A temperature switch is a sensor that upon the increase or decrease of a temperature opens or closes one or more electrical switching elements at a predetermined set point. Temperature switches generally are provided with a temperature responsive element which will open or close a switch when a predetermined minimum pressure or temperature is sensed by the responsive element. For protection against thermal overload, semiconductor switches are provided with integrated temperature sensors. The temperature sensors acquire the temperature of the power switch and convert this into a temperature-dependent, analog signal which then can be interpreted in a circuit. Temperature sensitive switches, such as a thermostat, typically comprise a temperature sensor which is used to open or close electrical contacts at specified temperatures. A bimetal strip of dissimilar metals is used as the sensing element for temperature sensitive switches. Temperature sensitive switches are often used for thermal protection purposes. If a device gets too hot, the temperature sensitive switch opens the electrical circuit, thereby eliminating power to the circuit. For example, temperature responsive tip-switches are particularly useful in connection with electric heaters.

**Symbol**


**Figure**

*Commercial temperature switch*

*Bimetal temperature switch*

**SPECIFICATIONS**

***Functional***

Operating Temperature Range: -29 °C to 177 °C [-20 °F to 350 °F]
Voltage: 30 Vac/Vdc
Reset Type: Automatic
Functional Properties: Open on rise
Amperage: 2.0 A resistive
Environmental Exposure Range: -65 °C to 260 °C [-85 °F to 500 °F]
Open Temperature: 15.6 °C [60 °F] max.
Close Temperature: 4.4 °C [40 °F] min.
Shock: MIL-STD-202, Method 213; 100 G
Vibration: MIL-STD-202, Method 204; 20 G

***Physical***

Dielectric Strength: MIL-STD-202, Method 301; 1250 Vac 60 Hz - Terminal to Case
Insulation Resistance: MIL-STD-202, Method 302; 500 MOhm
Contact Resistance: MIL-STD-202, Method 307; 0.050 Ohm max.
Moisture Resistance: MIL-STD-202, Method 106
Hermetic Seal: MIL-STD-202, Method 112; Cond. C
Mounting: No bracket
Contact Material: Silver
Housing Material: Steel housing hermetically sealed with glass-to-metal seal at terminal junction
Agency Approvals and Standards: Acceptance testing performed in accordance to Mil-PRF-24236, Table

**PRINCIPLE OF OPERATION**

The temperature switch will control electrical circuits in response to changes in pressure or temperature.
The temperature transducer is also a diaphragm piston type pressure sensor converting pressure to a mechanical force. The internal pressure is the vapor pressure of a chemical in a contained volume that is in direct relation to the temperature.
The switch incorporates an adjustable spring force that opposes the transducer piston force. When the transducer force is greater than the spring force, the piston rod mechanism moves to operate an electrical snap switch. When the transducer force is less than the spring force the piston rod mechanism moves to restore the electrical snap switch to the normal position.

**INSTALLATION**

The temperature switch air bleed line is installed into a tee ahead of the pneumatic operator in the air control line. A 0.02" restrictor is required in the air control line to restrict the pneumatic signal and ensure proper operation of the temperature switch. A pipe tee must be installed ahead of the steam trap in the condensate line for insertion of the temperature switch (1/2" Tee for model 90 and 3/4" x 1/2" Tee for all other models) (Fig.)

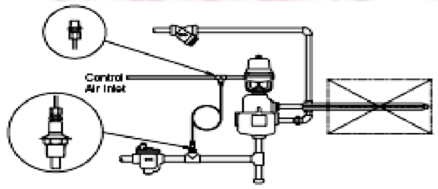



**Figure 1. Temperature Switch Installation**

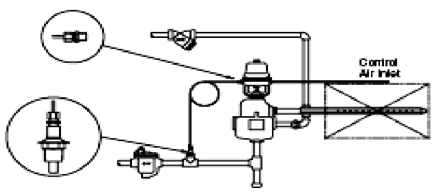



**Figure 2. Alternate Inlet Installation**

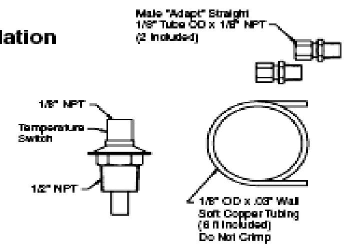



**Figure 3. Included in kit**

**Some precautions to observe**

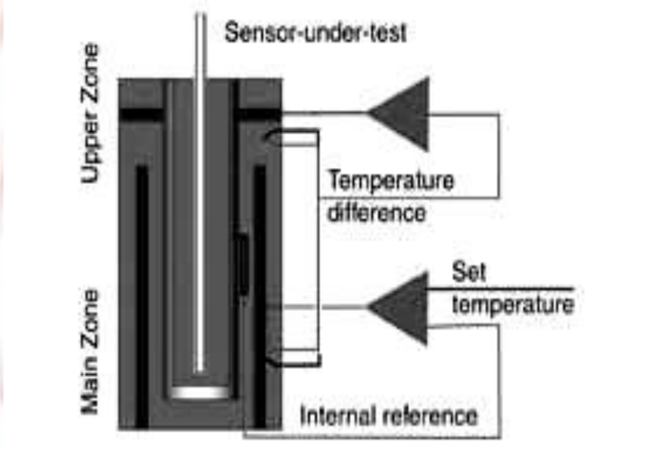
Do not loosen the screws holding the precision switch element (s) or mounting bracket in place. Nameplate PROOF temperature should not be exceeded. Intermittent operation up to proof temperature is permissible; however, some change of set point may be noted. Operation and correct set point actuation should be routinely tested.

**CALIBRATION**

The RTC series of calibrators provides precision temperature calibration of sensors, whatever the type or format. This is accomplished through an innovative active triple zone heating technology. The RTC-700 features our new active triple-zone heating technology. Each heating zone is independently controlled for precision temperature calibration. The homogeneity in the lower part is close to that of a laboratory liquid bath.

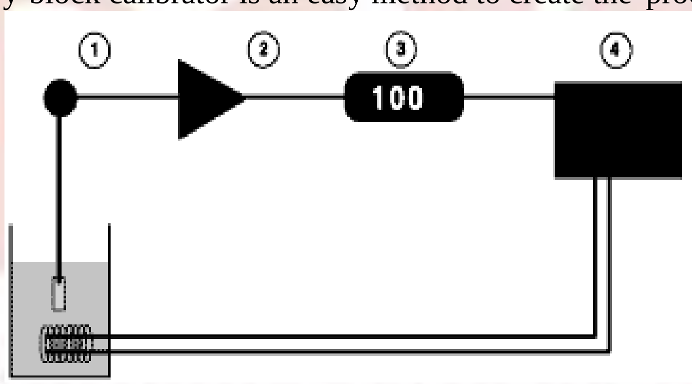

JOFRA RTC series temperature calibrator

Based upon new RTC-700 is able to perform a unique combination of high speed and high accuracy. Time is money! This is why all the new RTC calibrators have an increased calibration speed compared to all other calibrators. The implication is savings in both production downtime and general calibration costs.
The two lower zones ensure optimum heat dissipation throughout the entire calibration zone. The upper zone compensates for heat loss from the sensor-under-test and from the open top. This design also eliminates the need for extra insulation of sensors-under-test and makes it possible to calibrate liquid-filled and other mechanical sensors.




*True temperature calibration*

In order to maintain consistent quality of manufactured products, it is necessary to do periodic calibrations on process sensors and instruments. There are several philosophies for calibration of measurement and control circuits. The basis of the chosen method should always be to include the temperature sensor. It does not make any sense only to calibrate and adjust the electronic part of the loop. A rule of thumb says that only 10% of the total error is in the electronics, the other 90% is due to the sensing element. So it is essential that the temperature sensor is tested, meaning physically exposed to the desired temperature. A dry-block calibrator is an easy method to create the 'process' temperature.




The output from the sensor can be taken from anywhere in the loop. And the rest of the loop may be tested electronically.
1. The raw sensor output
2. After a transmitter (4-20 mA)
3. Manual reading on an indicator
4. The control data in the control room

## SELECTION CRITERIA

| Model/Description | Enclosure | Switch Function | Comments | Setpoints |
|---|---|---|---|---|
| GT - Temperature Switches - G Series Nema 4 Temperature Switches  | Watertight 316 Stainless Steel NEMA 4, 4X, IP65 | Single or dual set point, fixed or adjustable deadband, SPDT or (2) SPDT contacts | Remote or Direct mount bulbs, Stainless Steel construction | -40 to 750°F |
| LT - Temperature Switches - L Series Nema 4 Temperature Switches  | Watertight epoxy coated aluminum NEMA4, 4X, IP66 | Single or dual setpoint, fixed or adjustable deadband, SPDT or (2) SPDT contacts | Remote and Direct mount bulbs, Stainless Steel construction | -40 to 750°F |
| PT-N7 – Temperature Switches - P Series Temperature Switches  | Watertight epoxy coated aluminum NEMA 4, 4X or explosion proof , NEMA 7/9, IP66 | Single or dual set point, fixed or adjustable deadband, SPDT or (2) SPDT contacts | Remote or Direct mount bulbs, Stainless Steel construction | -40 to 750°F |
| T400 – Temperature Switches - B Series Temperature Switches  | Watertight epoxy-coated aluminum NEMA 4, 4X, IP66 | Single set point, fixed deadband, SPDT or (2) SPDT contacts | Remote or Direct mount bulbs, Stainless Steel construction | -40 to 750°F |
| T700 – Temperature Switches - B Series Temperature Switches  | Explosion proof, NEMA 7/9, IP66 | Single set point, fixed deadband, SPDT or (2) SPDT contacts | Remote or Direct mount bulbs, Stainless Steel construction | -40 to 750°F |

**CONFORMATION TO STANDARDS**

- NEMA

**APPLICATIONS**

- Electronics compartment temperature control
- Cold plate temperature monitoring and control
- Optics and instrumentation temperature control
- Surface and strip heater control
- Battery charge rate and heater control
- Rocket motors and thrusters
- Overheat protection
- Electric motor pre-heater control
- Hydraulic/pneumatic actuator freeze protection systems
- Environmental control system limit indication and control

**PARTIAL LIST OF SUPPLIERS**

- Honeywell
- Hydac
- Danfoss
- ASCO
- Svel Sensors & Controls
- National Engineering (Kolkata)
- Omron Electronics LLC
- Reliance Controls Corporation
- Rockwell Automation
- Schneider Electric

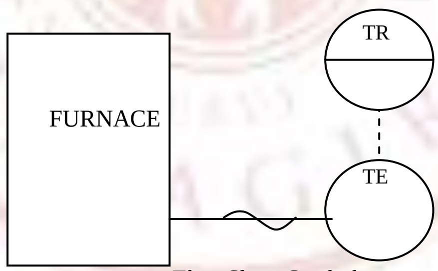
# PYROMETER

**Description**

A pyrometer is a non-contact temperature measuring device. It is typically used to measure temperatures of rapidly moving hot metals or molten steel stream in a steel mill or foundry. Generally the term is applied to instruments measuring temperatures above 600 degrees Celsius .Pyrometers are specialist temperature measuring devices with a very fast response time and a very high operating temperature range. It may have a response time as low as 5 milliseconds and can accurately measure the temperature without contact with the material. The instrument is used for measuring temperature by the change of electrical resistance within a thermocouple. It is a millivoltometer calibrated in degrees of temperature. The optical signal collected by the pyrometer is transmitted through a rugged, flexible, fiber optic light guide to a remote electronic signal conditioner. The signal conditioner provides the following linear 4 to 20mA outputs for further analysis.

- Profile - a high speed signal sent to the data acquisition system for data logging
- Peak - the highest temperature on the blade array
- Average - the average temperature of the blade array
- Average Peak - the average of the highest temperature of each of the blades

**Symbol**




*Flow Sheet Symbol*

**Figure**

*Figure 1: An optical pyrometer*

**SPECIFICATIONS**

***Functional***
Measurement range: 1000 to 2000 °C/1830 to 3632 °F
Measuring Modes: Advanced 'Melt master', Continuous (CONT), Peak Hold (PEAK), Minimum Hold (VALLEY)
Calculating Modes: Maximum (MAX), Mean (MEAN), Minimum (Min)
Focusing range: fixed at 5m/16.4ft
Target size: 29mm/1.1in at 5m/16.4ft
Spectral response: 0.55µm
Emissivity adjustment: 0.10 to 1.20 in 0.01 step graduations
Response time: 30ms
Display updates time: 0.5s
Accuracy :$\leq$ 0.25 %( K) Of reading
Repeatability :$\leq$ 0.1 %( K) Of reading
Operating temp: Range0 to 50°C/32 to 122°F
Power requirement: One MN1604/6LR61/PP3 battery
Output: RS232, Bluetooth (C100B only)
***Physical***
Standard accessories: Lens cap, protection window/filter, battery, wrist strap
Optical System: 9° field of view with 1/3° measurement area. Single-lens-reflex system
Sealing: IP54/NEMA3
Weight:0.83kg/1.8lb
Indication: 4 digits LCD in viewfinder 1° increments
: Display held for 30 seconds after switch off
: blinking display warns that temperature is out of measurable range.

**PRINCIPLE OF OPERATION**

A pyrometer works by analyzing the thermal radiation emitted by a hot object under test using sensor such as a thermocouple.

A pyrometer has an optical system and detector. The optical system focuses the thermal radiation onto the detector. The output signal of the detector (Temperature *T*) is related to the thermal radiation or irradiance j* of the target object through the Stefan–Boltzmann law, the constant of proportionality σ, called the Stefan-Boltzmann constant and the emissivity ε of the object.

$$J^* = \varepsilon\sigma T4$$

This output is used to infer the object's temperature. Thus, there is no need for direct contact between the pyrometer and the object, as there is with thermocouple and Resistance temperature detector (RTDs).

A radiation pyrometer is a non-contact temperature sensor that infers the temperature of an object by detecting its naturally emitted thermal radiation. An optical system collects the visible and infrared energy from an object and focuses it on a detector, as shown in figure below. The detector converts the collected energy into an electrical signal to drive a temperature display or control unit.

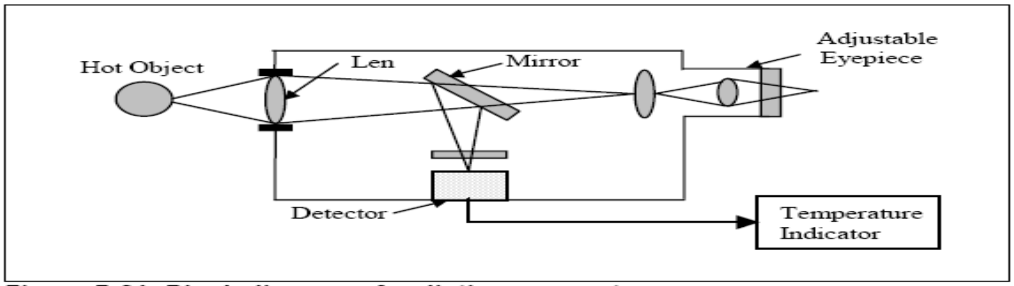



Figure 7-21. Block diagram of radiation pyrometer

The detector receives the photon energy from the optical system and converts it into an electrical signal. Two types of detectors are used: thermal (thermopile) and photon (photomultiplier tubes). Photon detectors are much faster than the thermopile type. This enables you to use the photon type for measuring the temperature of small objects moving at high speed.

**INSTALLATION**

**Mounting:** The pyrometer can be of two types, either fixed-mount or portable. Fixed mount units are generally installed in one location to continuously monitor a given process. They usually operate on line power, and are aimed at a single point. The output from this type of instrument can be a locator remote display, along with an analog output that can be used for another display or control loop. Battery powered, portable infrared ‘‘guns’’ are also available; these units have all the features of the fixed mount devices, usually without the analog output for control purposes. Generally these units are utilized in maintenance, diagnostics, quality control, and spot measurements of critical processes.

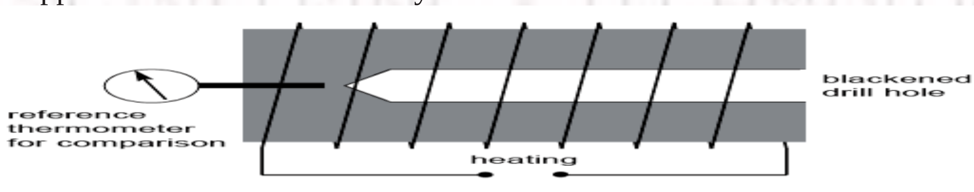
**DESIGN AND CONSTRUCTION**

The manufacturer of the radiation pyrometer selects the detector and optical elements to yield the optimum compromise based upon the conflicting parameters of cost, accuracy, speed of response, and usable temperature range. The user should be cognizant of how the different detectors and optical elements affect the range of wavelengths over which a thermometer responds. The spectral response of a pyrometer will determine whether a usable measurement is possible, given the presence of atmospheric absorption, or reflections from other objects, or trying to measure the temperature of materials like glass or plastics.

**CALIBRATION**

Every pyrometer is properly calibrated by the manufacturer before dispatch. A certificate accompanies the equipment. To ensure long-term reliability, pyrometers must be regularly checked and, if necessary, recalibrated. A black body furnace is required for this. The depth of the cavity should be at least six times as long as its diameter because the emission coefficient of nearly 1 is reached by multiple reflections in the cavity.

The inner surface of the cavity is heated evenly, and the pyrometer is set to the value of the reference thermometer used for comparisons. Recalibration is also necessary when the equipment is being repaired or modified. Calibrations are done by the manufacturer or by an approved calibration laboratory.



**SELECTION CRITERIA**

- The critical considerations for any infrared pyrometer include field of view (target size and distance), type of surface being measured (emissivity considerations), spectral response (for atmospheric effects or transmission through surfaces), temperature range and mounting (handheld portable or fixed mount). Other considerations include response time, environment, mounting limitations, viewing port or window applications, and desired signal processing.
- First, the instrument must respond quickly enough to process changes for accurate temperature recording or control.
- Typical response times for infrared thermometers are in the 0.1 to 1 second range. Next, the unit must be able to function within the environment, at the ambient temperature.
- Other considerations include physical mounting limitations, viewing port/window applications (measuring through glass), and the desired signal processing to produce the desired output for further analysis, display or control..

**CONFORMATION TO STANDARDS**

- ISO/IEC 17025:1999.
- Calibration traceable to NIST

**APPLICATIONS**

- The measurement of moving objects or any surfaces that can not be reached or can not be touched
- Smelter Industry: Temperature is a fundamental parameter in metallurgical furnace operations. Reliable and continuous measurement of the melt temperature is essential for effective control of the operation. Smelting rates can be maximized, slag can be produced at the optimum temperature, fuel consumption is minimized and refractory life may also be lengthened. Thermocouples were the traditional devices used for this purpose, but they are unsuitable for continuous measurement because they rapidly dissolve
- In industries where the ambient temperature is very high and normal temperature measuring techniques cannot be implemented, such as hot metals, plastic film and glass processing. In such cases, where the vessel temperature is very high and the product is exposed to the atmosphere Non-contact type temperature measuring methods like Radiation Pyrometery is used.
- Low-temperature applications include infrared photographs to locate internal bleeding in accident victims, aerial photography to detect air pollution etc.

**PARTIAL LIST OF SUPPLIERS**

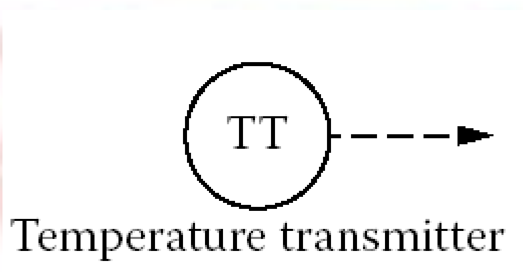
- Land
- SPI Corp
- Bartec US Corporation
- Wintronics
- Monroe Infrared technology
- Williamson Corporation
- Pyrometer Instrument Company, Inc. Northvale, New Jersey, USA.
- Spectrodyne, Colmar, PA, USA.

## TEMPERATURE TRANSMITTER

**Description**

A temperature transmitter is a device used to sense a temperature and transmit an output representative of the sensed temperature. Temperature transmitters are used in controlling industrial processes by sensing a temperature of the process and transmitting the information to a remote location. The temperature transmitter output can be communicated over the loop to a control room, or the output can be communicated to another process device such that the process can be monitored and controlled

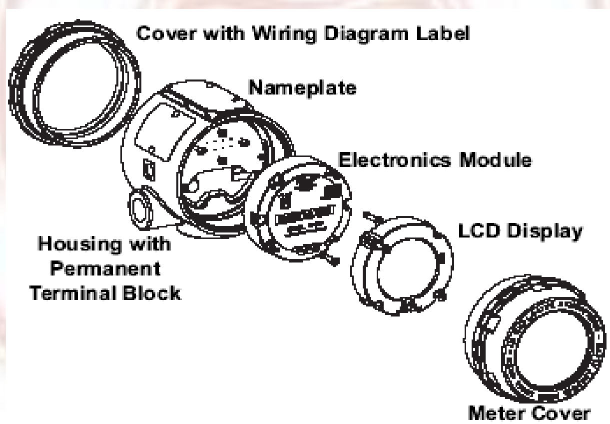
**Symbol**




**Figure**

*Rosemount temperature transmitter*

The temperature transmitter generally includes housing and a temperature probe which attaches to the housing. In order to monitor a process temperature, the transmitter includes a temperature sensor, such as a resistance temperature device (RTD) or a thermocouple. An RTD changes resistance in response to a change in temperature. By measuring the resistance of the RTD, temperature can be calculated. A thermocouple provides a voltage in response to a temperature change. Typically, the temperature transmitter is located in a remote location and coupled to a control room over a 4-20 mA current loop. A temperature sensor is placed in the process fluid and provides an output related to temperature of the process fluid.




*Exploded view of Rosemount temperature transmitter*

## SPECIFICATIONS

### *Functional*

- Inputs signal: User-selectable
- Output Signal**:** 4-20 mA or 0-10 VDC, 2 wire device for humidity/temperature
- Sensor type: RTD (pt 100), thermocouple.
- Power Requirements:
    - External power supply required: 12.0 to 42.4 V dc
    - Power Supply Effect: Less than ±0.005% of span per volt
- Isolation: Input/output isolation tested up to 500 V ac (707 V dc) at 50/60 Hz.
- Relative Humidity Range: 0 to 100% Relative humidity.
- Accuracy: When using a Pt 100 (α = 0.00385) sensor input with a 0 to 100 °C
    - Digital Accuracy: ±0.10 °C
    - D/A accuracy: ±0.02% of 100 °C or ±0.02 °C, Total = ±0.12 °C.
- Stability:
    - RTDs - ±0.1% of reading or 0.1 °C, for 24 months.
    - Thermocouples - ±0.1% of reading or 0.1 °C, for 12 months.
- Update Time: Approx. 0.5 sec for a single sensor (1 sec for dual sensors).

***Temperature Limits:***

- Operating limit: With LCD (1): –40 to 185 °F; –20 to 85 °C
  Without LCD: –40 to 185 °F; –40 to 85 °C
- Storage limit: With LCD (1): –50 to 185 °F; –45 to 85 °C
  Without LCD: –60 to 250 °F; –50 to 120 °C
- Temperature Range**:** -40 to 140°F (-40 to 60°C).
- Compensated Temperature Range**:** -40 to 140°F (-20 to 60°C).

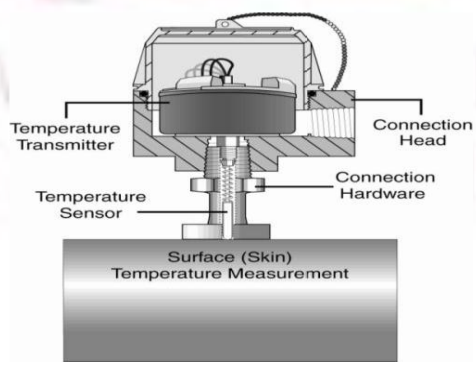
  [Temperature Effects Eg: When using a Pt 100 ($\alpha$ = 0.00385) sensor input with a 0 to100 °C span at 30 °C ambient temperature, Digital Tem Effects=0.0015°C/°C × (30°– 20°) = 0.015°C ]

***Physical***

Materials of Construction

- Electronics Housing: Low-copper aluminum or CF-8M (cast version of 316 SST) Paint or Polyurethane
- Cover O-rings: Buna-N
- Electrical Connections: Screw terminal block.
- Conduit Connections: Field mount housing: ½–14 NPT conduit entries, PG13.5 (PG11), M20 X 1.5 (CM20), or JIS G ½.
- Mounting: attached directly to the sensor. Optional mounting brackets (codes B4&B5) for remote mounting
- Enclosure Ratings: NEMA 4X, CSA Enclosure Type 4X, IP66, and IP68.
- Transient Protection: IEEE C62.41-1991 (IEEE 587)/ Location Categories B3.
- Loop resistance added by protector: 22 ohms max.
- Nominal clamping voltages: 90 V (common mode), 77 V
- SIS Safety Failure Values: IEC 61508 Safety Certified SIL 2 and SIL 3 Claim Limit
- Safety accuracy: 2.0 %(1) or 2 °C (3.6 °F), whichever is greater
- Safety response time: 5 seconds
- HART Communicator Connections: 375 Field Communicator connections are permanently fixed to Power/signal block.

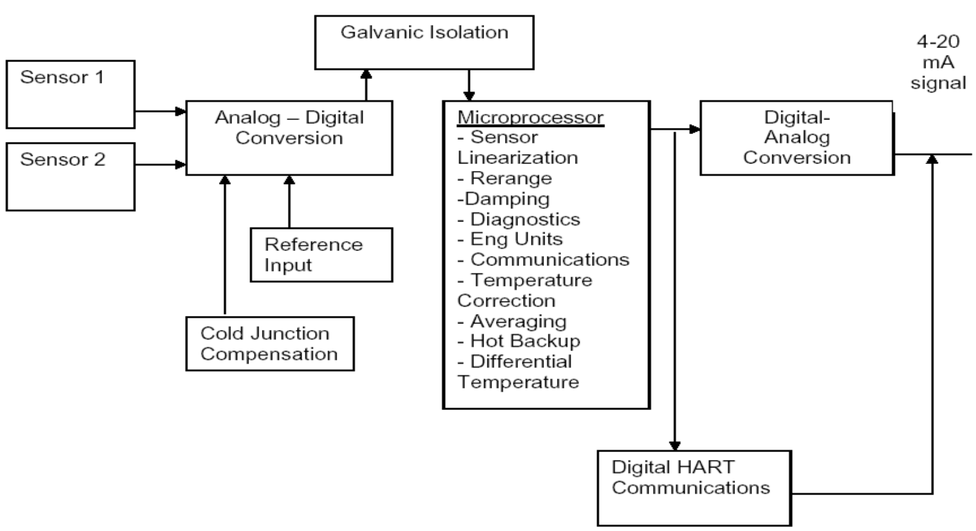
**PRINCIPLE OF OPERATION**



**Transmitter sensor:_** A temperature transmitter can utilize a sensing element based on a solid state device (voltage or current output), or thermistor (resistance change) sensing element, but most use either a thermocouple (TC) or resistance temperature device (RTD). Since they are the most popular, thermocouple and RTD-based temperature transmitters are presented here. Thermocouples and RTDs for use with temperature transmitters are available from many sources and will have similar characteristics if ordering the same type**.**

The transmitter injects a current into the temperature sensor and the resultant voltage drop across the temperature sensor is used to measure resistance. The voltage is converted into a digital format using an analog to digital converter and provided to a microprocessor. The microprocessor converts the measured voltage into a digital value representative of temperature.

Temperature sensors having temperature-dependent properties which can be measured electrically include resistors, semiconductor devices such as diodes, and thermocouples. A common type of temperature sensor utilizes a positive temperature coefficient (PTC) silicon detector which has a resistance that varies in relation to the ambient temperature. Thus, the sensors can be connected to a control circuit to provide an input signal which indicates ambient temperature. The resistance temperature detector (RTD) takes advantage of the principal that the resistivity of metals is dependent upon temperature. A resistance thermometer has a sensing resistor having an electrical resistance varying with temperature. The temperature sensor is driven by a constant current source in order to develop voltages across the changing resistance of the sensing resistor. The thermistor is a temperature sensitive resistor and is generally composed of semi-conductor materials. The integrated circuit temperature sensor has also been used to measure temperatures. The integrated circuit sensor typically employs an integrated diode whose output characteristics are dependent upon temperature. Temperature sensing in high temperature environments such as automotive vehicle exhaust systems, is typically done using thermistors constructed of materials capable of withstanding the high temperature environment. Digital temperature sensors are typically used to generate a temperature reference for the circuits on the chip or other integrated chips.



**Temperature transmitters are commonly available in three form factors, based upon application requirements**

**Head Mount**

Head mount transmitter packaging (sometimes referred to as "hockey pucks" due to their size and shape) are the most flexible Temperature transmitter form factor. The compact design enables mounting in a variety of housings and in space-constrained applications.


**Field Mount**

Field mount packaging is the most physically rugged form factor available for Temperature transmitters. This packaging is distinguished by its larger physical size, dual-compartment housing, and a generously proportioned, easy to read LCD meter.


**Rail Mount**

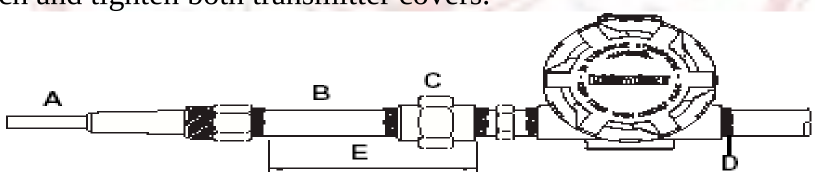
Rail mount transmitter packaging features a clip that allows assembly into any industry-standard DIN-rail application. Industry-standard DIN Rail design allows installation in a multitude of enclosure options

## INSTALLATION

Mount the transmitter at a high point in the conduit run to prevent moisture from draining into the transmitter housing.

**Field Mount Installation**

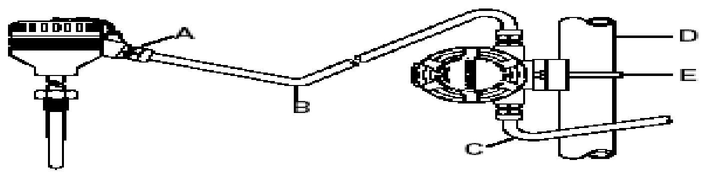
1) Mount the thermo well to the process container wall. Install and tighten thermo well and perform a leak check.
2) Attach any necessary unions, couplings, and extension fittings. Seal the fitting threads with an approved thread sealant, such as silicone or PTFE tape (if required).
3) Screw the sensor into the thermo well or directly into the process (depending on installation requirements).
4) Verify all sealing requirements.
5) Attach the transmitter to the thermo well/sensor assembly. Seal all threads with an approved thread sealant, such as silicone or PTFE tape (if required).
6) Install field wiring conduit into the open transmitter conduit entry (for remote mounting) and feed wires into the transmitter housing.
7) Pull the field wiring leads into the terminal side of the housing.
8) Attach the sensor leads to the transmitter sensor terminals (the wiring diagram is located inside the housing cover).
9) Attach and tighten both transmitter covers.



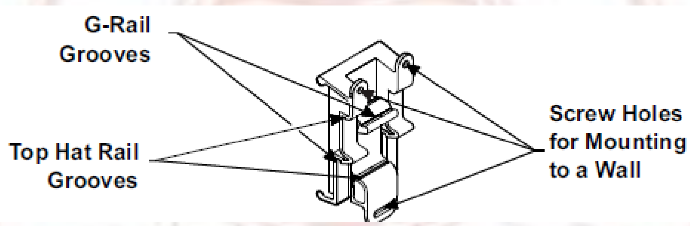

A = Thermo well
B = Extension (Nipple)
C = Union or Coupling
D = Conduit for Field Wiring (dc power)
E = Extension Fitting Length
D = Conduit for Field Wiring (dc power)

**Remote Mount Installation**

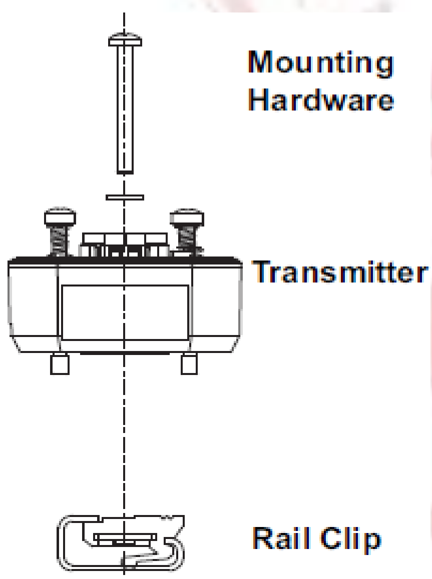
1) Mount the thermo well to the process container wall. Install and tighten thermo wells and perform a leak check.
2) Attach a connection head to the thermo well.
3) Insert sensor into the thermo well and wire the sensor to the connection head (the wiring diagram is located inside the connection head).
4) Mount the transmitter to a 2-in. (50 mm) pipe or a panel using one of the optional mounting bracket (B4 bracket is shown below).
5) Attach cable glands to the shielded cable running from the connection head to the transmitter conduit entry.
6) Run the shielded cable from the opposite conduit entry on the transmitter back to the control room.
7) Insert shielded cable leads through the cable entries into the connection head/ transmitter. Connect and tighten cable glands.
8) Connect the shielded cable leads to connection head terminals (located inside the connection head) and to sensor wiring terminals (located inside the transmitter housing).



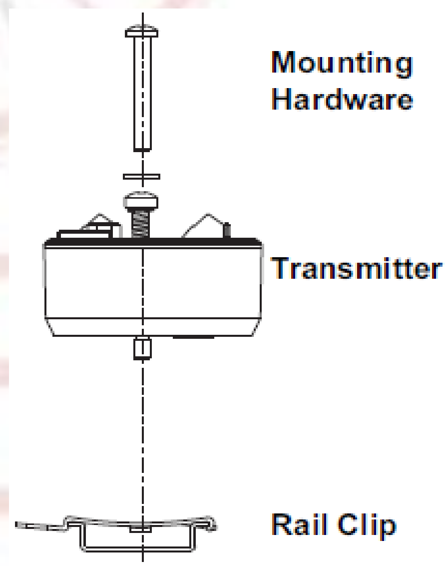

*Remote mounting of transmitter*
A = Cable Gland
B = Shielded Cable from Sensor to Transmitter
C = Shielded Cable from Transmitter to Control Room
D = 2-in. (50 mm) pipe
E = B4 Mounting Bracket




*Universal Clip for mounting transmitter to a Wall or a Rail*



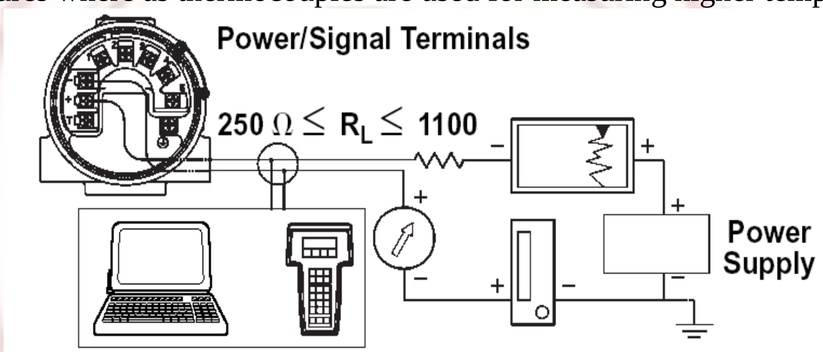

*G-Rail (asymmetric)*




*Top Hat Rail (symmetric)*

**CALIBRATION**

- The transmitter will be ranged by a programming device, say for example an application where process temperatures need to be measured between 0-100 degrees, the transmitter will be ranged 0-100 degrees and thus give an output proportional to the temperature measured by the sensing element. 0 degrees = 4mA, 100 degrees = 20mA.
- An excitation supply will be connected to the transmitter and the 4-20mA will flow in this loop back to the measuring instrument.
- It is necessary to use the correct type of sensor for the application to get the best accuracy when measuring.RTD's are generally used for measuring lower temperatures where as thermocouples are used for measuring higher temperatures.





**The JOFRA ATC series (Advanced Temperature Calibrators) combines accuracy of laboratory temperature sources with the speed and portability of field dry-block calibrators.**


**Nagman ETC 600 (Ranges: 50°C to 600°C)**

**Calibration: reference table for Pt RTD**

| °C | Ω | °C | Ω |
|---|---|---|---|
| -200 | 18.52 | +160 | 161.05 |
| -190 | 22.83 | +170 | 164.77 |
| -180 | 27.10 | +180 | 168.48 |
| -170 | 31.34 | +190 | 172.17 |
| -160 | 35.54 | +200 | 175.86 |
| -150 | 39.72 | +210 | 179.53 |
| -140 | 43.88 | +220 | 183.19 |
| -130 | 48.00 | +230 | 186.84 |
| -120 | 52.11 | +240 | 190.47 |
| -110 | 56.19 | +250 | 194.10 |
| -100 | 60.26 | +260 | 197.71 |
| -90 | 64.30 | +270 | 201.31 |
| -80 | 68.33 | +280 | 204.90 |
| -70 | 72.33 | +290 | 208.48 |
| -60 | 76.33 | +300 | 212.05 |
| -50 | 80.31 | +310 | 215.61 |
| -40 | 84.27 | +320 | 219.15 |
| -30 | 88.22 | +330 | 222.68 |
| -20 | 92.16 | +340 | 226.21 |
| -10 | 96.09 | +350 | 229.72 |
| 0 | 100.00 | +360 | 233.21 |
| +10 | 103.90 | +370 | 236.70 |
| +20 | 107.79 | +380 | 240.18 |
| +30 | 111.67 | +390 | 243.64 |
| +40 | 115.54 | +400 | 247.09 |
| +50 | 119.40 | +410 | 250.53 |
| +60 | 123.24 | +420 | 253.96 |
| +70 | 127.08 | +430 | 257.38 |
| +80 | 130.90 | +440 | 260.78 |
| +90 | 134.71 | +450 | 264.18 |
| +100 | 138.51 | +460 | 267.56 |
| +110 | 142.29 | +470 | 270.93 |
| +120 | 146.07 | +480 | 274.29 |
| +130 | 149.83 | +490 | 277.64 |
| +140 | 153.58 | +500 | 280.98 |

Nominal Resistance: 100 ohms @ 0°

**SELECTION CRITERIA**

- Temperature transmitters shall be integral with the sensing element assembly.
- The sensing element shall be RTD 3 wire type or thermo couple.
- The RTD element length shall be selected to suit the Thermo well insertion length.
- All RTD's shall be platinum 100 ohms at 0 degree centigrade to DIN 43760.
- The thermocouple characteristics shall conform to IEC 584-1 and the RTD shall be platinum 100 ohms at 0 centigrade to IEC 751 and complete with a flanged thermo wells.
- Welding of flange well shall be full penetration type. Weld shall be dye penetrate checked as per BS 5500.
- FLANGE-Gasket contact surface finish for RTJ flanges shall be 63 RMS (MAX) and shall confirm to ANSI B16.5.
- For temperature up to 350 centigrade, measurement shall be by means of platinum resistance temperature detectors, 100 ohm at 0 centigrade to BS 1904, with RTD/current transmitters.
- Transmitters shall include an LCD indicator scaled in engineering units, and shall be mounted integrally in the head of the detecting element where access permits, otherwise remotely mounted. Where the transmitter indicator is not readily visible a separate loop powered indicator shall be provided.
- Thermocouples shall only be used above 350 centigrade, or when it can show that the mechanical construction of an item does not permit the fitting of an RTD.
- Surface metal temperatures shall be measured by thermocouples secured to the surface.
- Thermocouples shall normally be the mineral-insulated metal- sheathed type, isolated from earth. Characteristic of mV versus temperature shall conform to BS-4937.
- Thermocouples shall be Type K (Chromel-Alumel) for the temperature range –20 degree centigrade to 1000 degree centigrade. For temperature above 1000 degree centigrade, Type R (Platinum/13 % Rhodium-Platinum) shall be used.
- Transmitters shall be "SMART" type and use HART protocol for communication.
- Smart type transmitters shall be supplied with required number of hand held calibrators.
- Transmitters shall be immune to Radio frequency interference due to walkie-talkie, paging system, communication system etc. All electronic modules shall be designed for short circuit protection.
- Transmitters shall be able to withstand an overpressure equal to the body rating.
- The Electronic TT shall be provided with ½"NPT (F) cable entries.
- The transmitter signal range shall be 4-20mA, DC, 2 wire type and capable of delivering the rated current signal into external load of 600 ohms when powered with 24V DC.
- All transmitters shall be provided with integral output meters. The output meter shall be suitable for use in the hazardous area.
- The change in out put due to change in ambient temperature (10 degree Celsius) should be very minimum.

- The range shall be selected so that the normal operating temperature shall fall in the middle third of the span. .
- Electronic TT shall have externally adjustable zero and span. Setting adjustment shall have locking arrangement.

**Material selection**

- Wetted parts of Thermo well shall conform to NACE MR-01-75 (Latest edition).
- Transmitter body studs shall be high tensile stainless steel, or other corrosion-resistant material for higher stress levels.
- Instrument parts shall be resistant to the corrosive properties of the process fluid and ambient conditions to which they are exposed.
- In addition to weatherproof, the Electronic TT enclosure shall be explosion-proof to NEMA-4X and certified by statutory bodies like UL/FM/BASEEFA or equal for use in hazardous area (CL 1, DIV.1, and GR.D).

**CONFORMATION TO STANDARDS**

BP engineering standards

- RP 30-1 : Instrumentation and control Design & practice

International Codes and Standards

- ANSI B31.3 : Chemical plant and petroleum refinery piping.
- ANSI B1.20.2 : Pipe Thread general purpose
- API PMC 40-1 : Bimetallic Thermometer
- ASME section VII and XI : Boiler and pressure vessel code.
- IEC 60529 : Degrees of protection by enclosures (IP Codes)
- ISO 9001 : Quality systems
  : Model for Quality Assurance in Design, Development, Production, Installation and service.

**APPLICATIONS**

- *Designed for Harsh Environments*: The 3144P is designed with a dual-compartment housing that provides the highest reliability in harsh environments. The dual-compartment housing provides isolation between the electronics and terminal compartments. The large terminal block allows for easier wire installation. Enhanced EMI rejection and filtering result in unmatched stability in process measurement.
- *Certified for use in SIS Applications*: The 3144P is certified to IEC61508 for non-redundant use in SIL 1 and 2 Safety Instrumented Systems and redundant use in SIL 3 Safety Instrumented Systems. In allowable installations, the 3144P HART electronics can be upgraded to safety certified electronics.
- *Advanced Temperature Diagnostics*: The advanced 3144P powers Plant Web® by communicating important temperature diagnostics and Plant Web alerts to ensure process health and enable multi-sensor architecture
- *Diagnostic Logging*: The 3144P Temperature Transmitter keeps a record of any diagnostic information and logs the item to the database. The log is retained as long as the device has power or can be reset by the user via the 375 or AMS.

- *Statistical Process Monitoring (SPM):* Detect abnormal process situations with a means and standard deviation calculation by the transmitter.
- *Thermocouple Diagnostic*: Use the transmitter to monitor the resistance of thermocouple loops in order to detect drift conditions or changing wiring conditions.

**PARTIAL LIST OF SUPPLIERS**:

- Ametek
- Barksdale
- Danfoss
- Dwyer Instruments
- Endress + Hauser
- Fischer & Porter
- Fisher Controls
- Foxboro
- Great Lakes Instruments
- Greyline Instruments
- HiTech Technologies
- Honeywell
- Inor Transmitter
- Love Controls
- Magnetrol
- MKS Instruments
- Moore Industries
- Neutronics
- Pyrometer Instrument
- Rosemount
- Sensidyne
- Thermo Electric
- Transicoil
- Yokogawa
- Ambetronics Engineers Pvt. Ltd.
- ACCURATE INDIA
- Mecord Systems & Services
- Shri Instruments
- Industrial Furnaces & Controls
- Systech Automation Systems
- Techno Instruments
- Konark Equipment
- Lectrotek Systems Pvt. Ltd.
- Spa Instruments (I) Pvt. Ltd.
- Kevin Technologies Pvt Ltd
- Digital Marketing Systems Pvt. Ltd
- Analogik Electronics Corporation
- Rishabh Instruments Pvt. Ltd
- Radix
- Chemtrols Engineering Ltd.

**LEVEL MEASUREMENT**

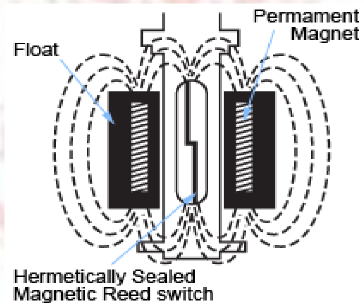
| Topic Description | Page no |
|---|---|

# INTRODUCTION TO LEVEL MEASUREMENT

## Description

Measurement of material levels contained in a tank or silo is an integral activity in any controlled process. Level measurement sensors fall into two main types. Point level measurement sensors which are used to detect whether material in the container has reached a preset level condition. Continuous level sensors which measure fluid/material level within a range, rather than at one point. Very simple systems employ external sight glasses or tubes to view the height and hence the volume of the fluid. Others utilize floats or other such sensors connected to devices that produce an analog output signal, either voltage or current directly correlated with the level in the vessel. Level is usually reported as percentage of the vessel span, rather than in length (e.g., m). Level sensors can be located in the vessel holding the material/fluid or in an external "leg" which acts as a manometer. Various types of sensors are used for the measurement of level. The following gives a short description of such devices.

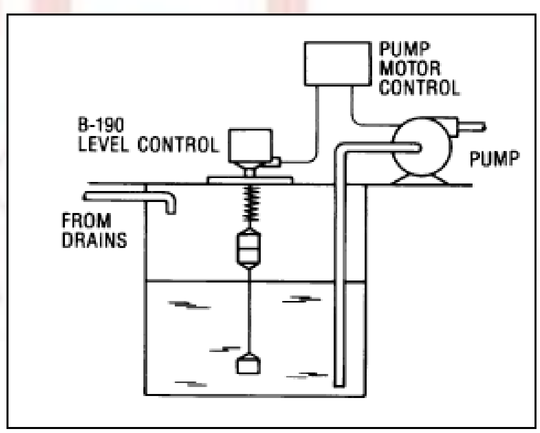
***Float:*** In these point level sensors, a magnetic float moves with the liquid surface, actuating a hermetically sealed "reed switch" in the stem. The simple, low-maintenance design installs readily; minimizes shock, vibration, and pressure; and works with a variety of media. The reed switch can be single pole, single throw (SPST) or single pole, double throw (SPDT). The float of material that is lighter than the fluid follows the movement of the liquid level. The position of the float, perhaps attached to a rod, can be determined to measure the level.




**Reed-Relay Float Switch**

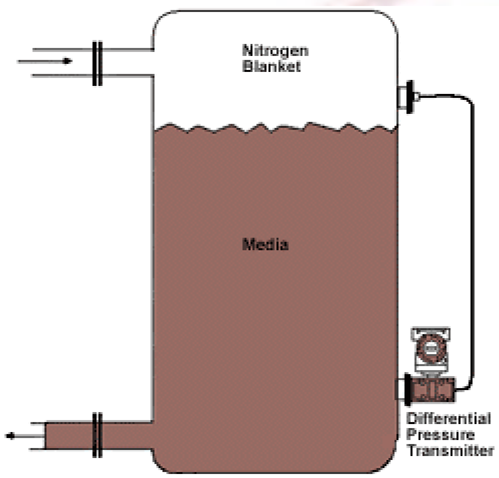
***Displacement:*** By Archimedes principle, a body immersed in a liquid is buoyed by a force equal to the weight of the liquid displaced by the body. Thus, a body that is denser than the liquid can be placed in the vessel, and the amount of liquid displaced by the body, measured by the weight of the body when in the liquid, can be used to determine the level.

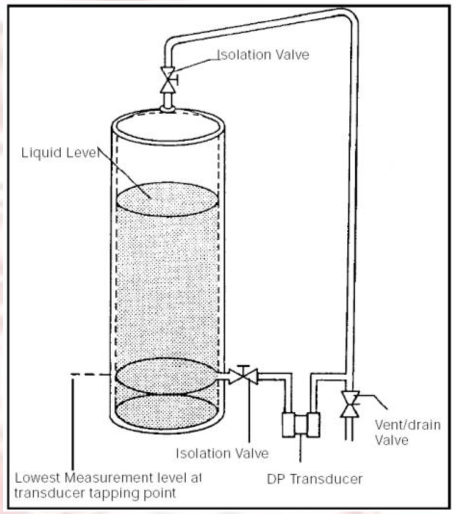
**Displacement level transmitter**




**Displacement level transmitter**

***Differential pressure:*** The difference in pressures between to points in a vessel depends on the fluids between these two points. If the difference in densities between the fluids is significant, which is certainly true for a vapor and liquid and can be true for two different liquids, the difference in pressure can be used to determine the interface level between the fluids. Usually, a seal liquid is used in the two connecting pipes (legs) to prevent plugging at the sensing points.



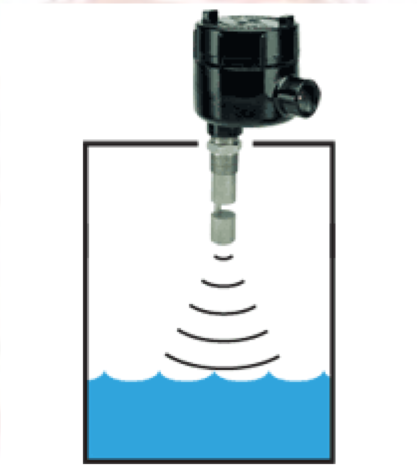




***Capacitance:*** A capacitance probe can be immersed in the liquid of the tank, and the capacitance between the probe and the vessel wall depends on the level. By measuring the capacitance of the liquid, the level of the tank can be determined. Capacitance sensors can handle point or continuous level measurement. They use a probe to monitor liquid level changes in the tank, electronically conditioning the output to capacitive and resistive values, which are converted to analog signals. The probe and the vessel wall equate to two plates of a capacitor, the liquid to the dielectric medium. Because the signal emanates from level changes alone, material build-up on the probe has no effect. Non-conductive fluid vessels may dictate dual probes or an external conducting strip. The probe, which can be rigid or flexible, commonly employs conducting wire insulated with PTFE. Rigid probes offer higher stability, especially in turbulent systems, where swaying of the probe can cause signal fluctuations.

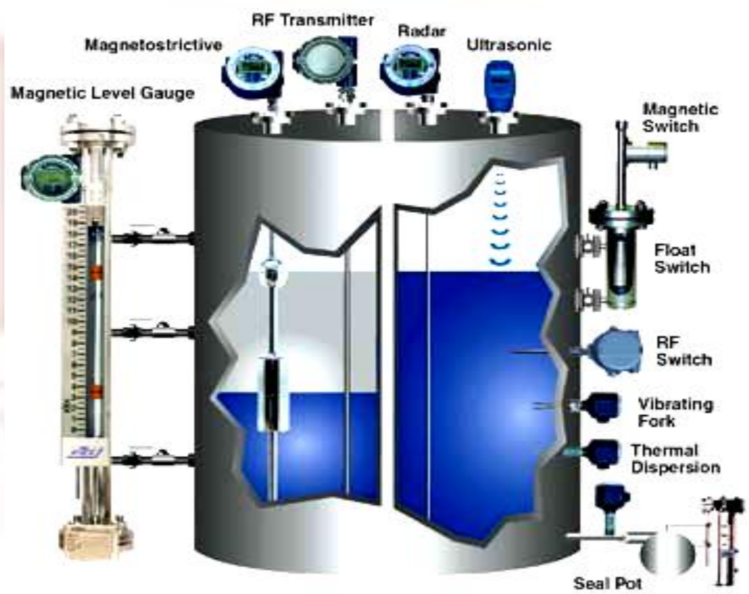
**Capacitance Continuous Level Measurement Probes**

***Ultrasonic Sensors*: A** low-energy ultrasonic device within these sensors measures liquid level at a certain point. Consisting of a field-mounted sensor and integral solid state amplifier, contact ultrasonic sensors have no moving parts and require no calibration. Typically, they are equipped with terminal blocks for connection of a power source and external control devices. The ultrasonic signal crosses a one-half inch gap in the sensor, controlling relay switches when the gap contains liquid. The sensing level is midway along the gap for horizontally mounted sensors, at the top of the gap for vertically mounted sensors. As liquid falls below this level, the ultrasonic signal attenuates and ultimately switches the relay to its prior state. These sensors are used in vessels or pipes to automatically operate pumps, solenoid valves, and high/low alarms. Two would be required to fill and empty tanks, and to meter liquid volumes. Compatible with most liquids, they are unaffected by coatings, clinging droplets, foam, and vapor. However, highly aerated liquids and liquids viscous enough to clog the sensor gap may cause problems.

***Radar Level Sensor*:** In applications requiring non-contact measurement of liquid levels, an ultrasonic transmitter is the logical extension of ultrasonic sensors. They are ideal where vapor, dust, or a foaming surface prevents ultrasonic measurement. Their radar sensor uses microwave pulse technology to track target liquids from the antenna tip to the bottom of a tank.



**Non-contact Ultrasonic Sensor**




**Level measurement devices**

**Table 1. Level sensors**

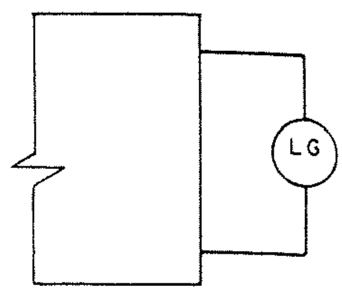
| Sensor | Limits of Application | Accuracy | Dynamics | Advantages | Disadvantages |
|---|---|---|---|---|---|
| **Float** | up to 1 m | - | - | -can be used for switches | -cannot be used with sticky fluids which coat the float |
| **displacement** | 0.3-3 m | - | - | -good accuracy | -limited range<br><br>-cost of external mounting for high pressures |
| **differential pressure** | essentially no upper limit | - | - | -good accuracy<br><br>-large range<br><br>-applicable to slurries with use of sealed lines | -assumes constant density<br><br>-sealed lines sensitive to temperature |
| **capacitance** | up to 30 m | - | - | -applicable for slurries<br><br>-level switch for many difficult fluids | -affected by density variations |

# LEVEL GAUGES

**Description**

Gauges are commonly used for indicating fill levels in liquid holding tanks. Liquid level gauges are frequently employed to monitor the level in a liquefied petroleum gas (LPG) tank or heating oil tanks. The Babbitt LG-Series magnetic level gauge consists of a float chamber, a float, and an external indication device. The float chamber is basically a column of 2 1/2 inch pipe with process connections to match those of the storage tank, reactor, drum, column or other equipment where level is to be measured. These connections may be side couplings or flanges, or top and bottom flanges.

**Symbol**




*Flow Sheet Symbol*

**Figure**

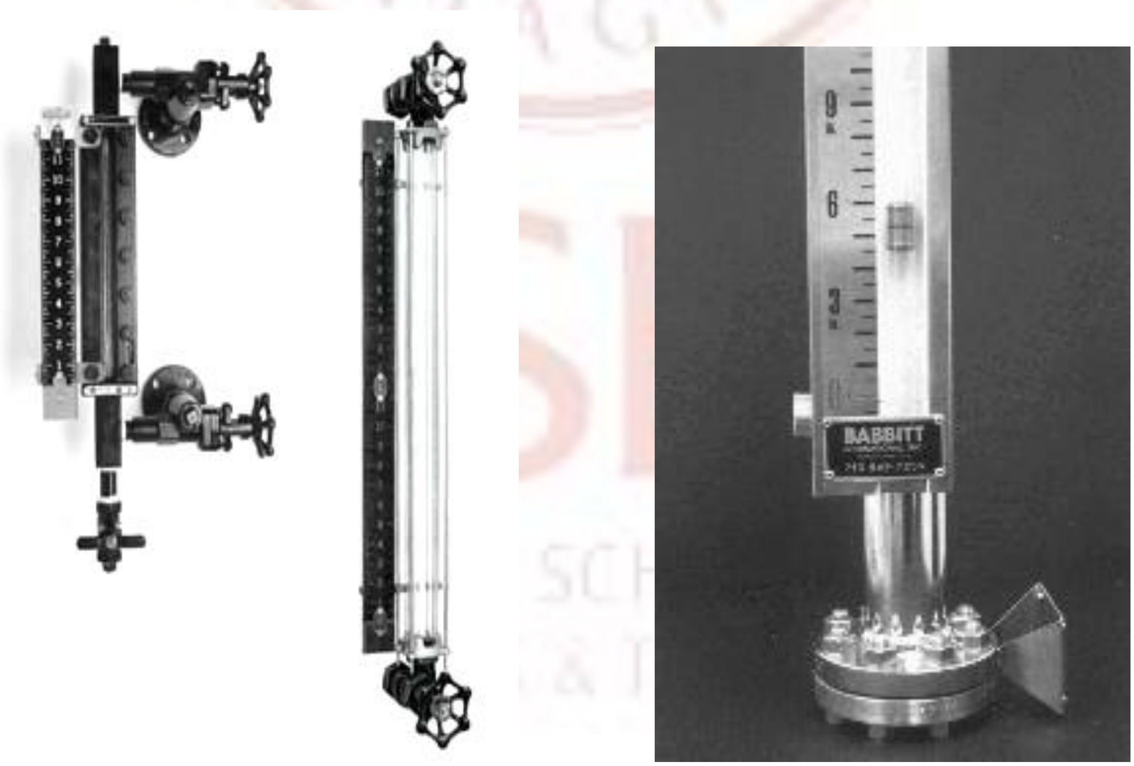


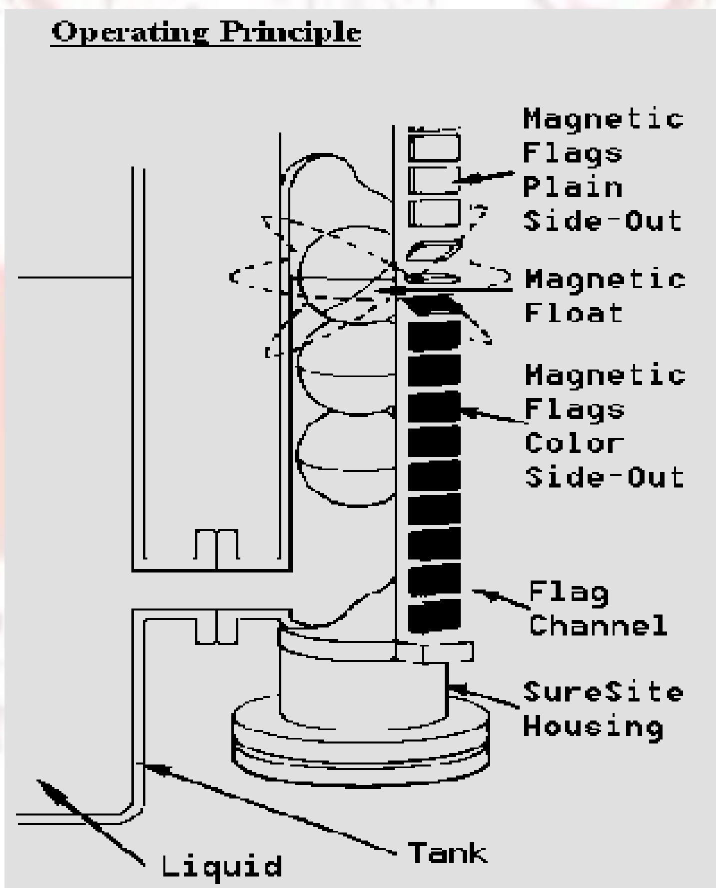

*Figure: 1 Magnetic Liquid Level gauge*

**SPECIFICATIONS**

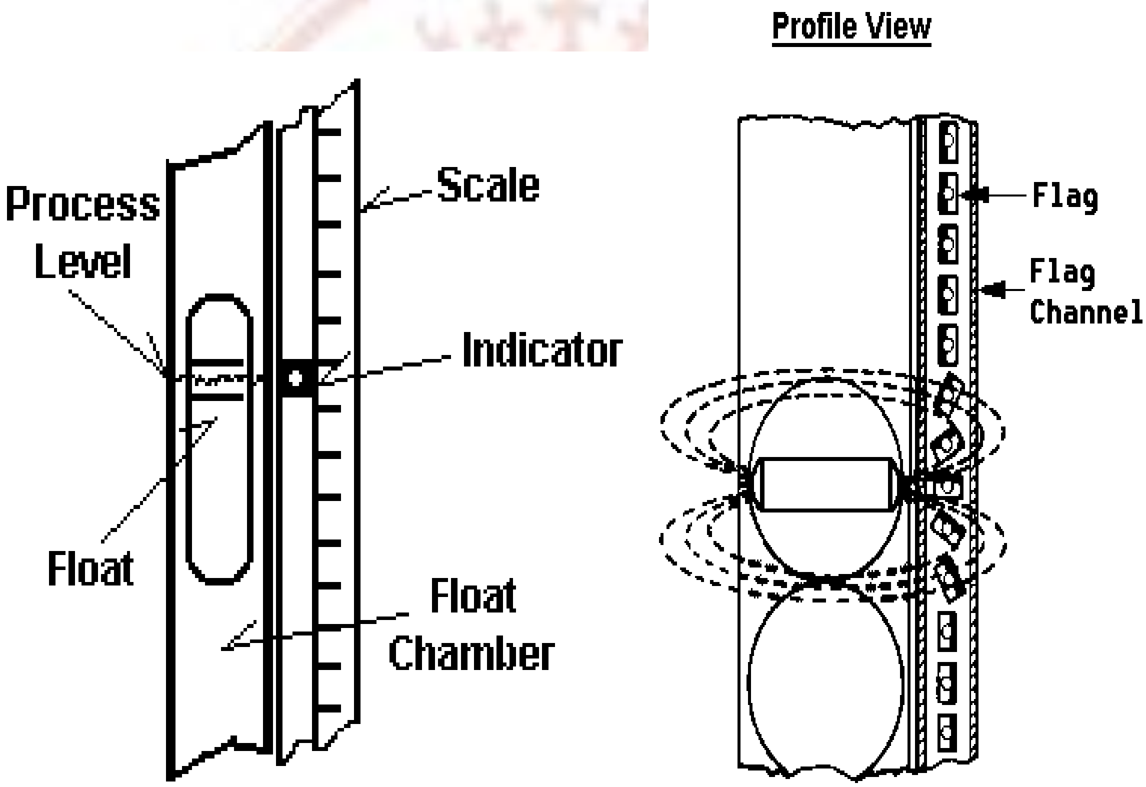
- Material : All wetted parts and external metal parts are stainless steel.
  : Indicator tube is glass or polycarbonate.
- Float chamber (standard) : 2 ½ inch pipe with RF slip-on/blind drain flange
- Pressure range : Up to 4000 psig
- Min.specific gravity : 0.25
- Temperature rating : -200°F to +1100°F continuous
- Scale : Feet and inches standard with ½ inch scale divisions;
- Resolution : Approximately ¼ inch
- Indicator : 7/8 inch diameter by 11/4 inch long, brightly coloured red
- Testing : Hydrostatic tested to the pressure rating specified
- Welding : Boiler/piping codes ASME B31.1/B31.3

**PRINCIPLE OF OPERATION**

Magnetic level gauges utilize a float that contains one or more magnets. As the float rises and falls its magnetic field passes up and down the level column. The level indicator follows the magnetic field. There are two general types of indicators used. The bullet type is a single point indicator that travels up and down a tubular guide while being attracted by the float magnet. The flag type is a strip of many small colored flags which rotate when the float magnet passes them as shown.

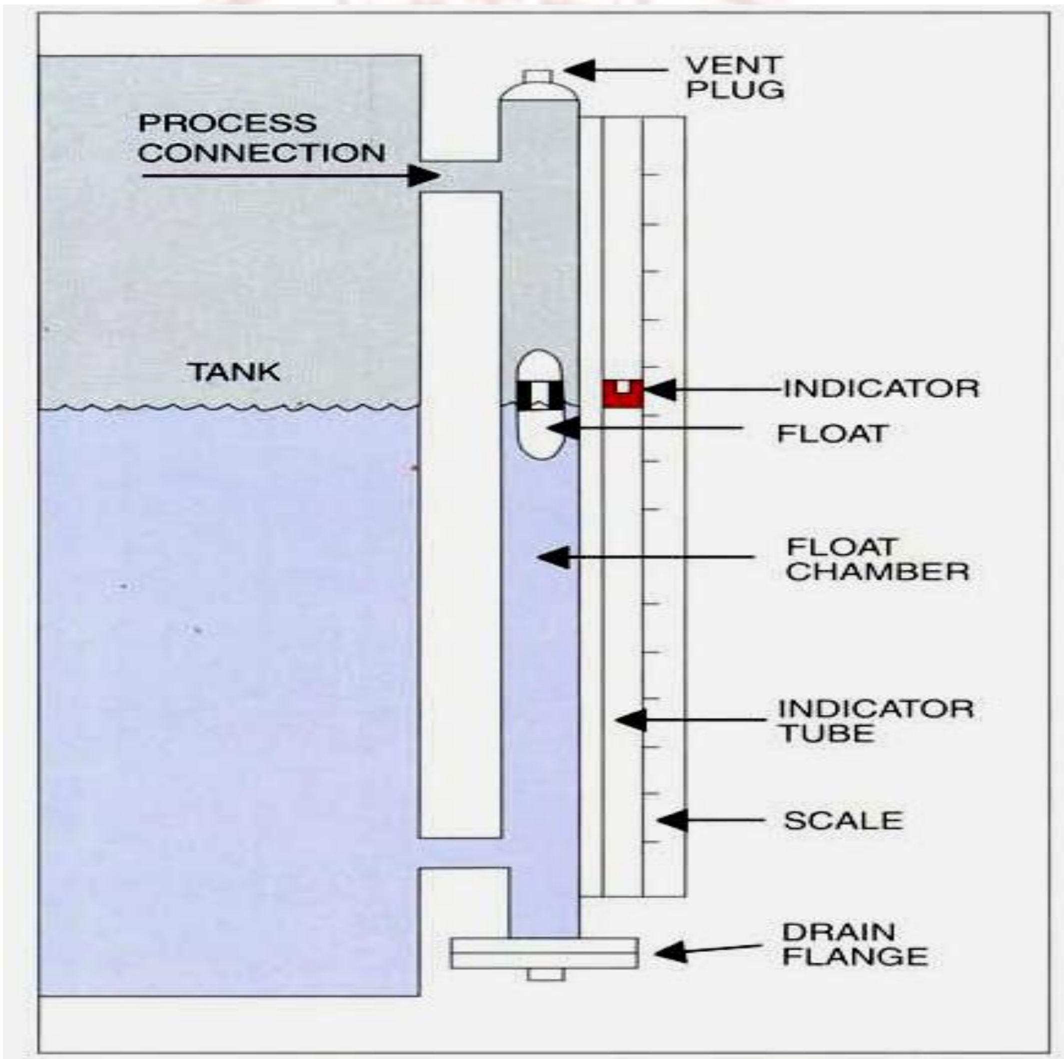


If the magnetic attraction between the float magnet and indicator is broken or incorrect, the level reading will be false. The strength of the magnetic attraction must be kept high during all situations. Generally, floats have one strong magnet or a number of magnets to provide a strong magnetic field in all horizontal directions. The magnetic field must also remain strong when exposed to high temperatures and may require special high temperature magnets.




- Flag type indicators need to be designed to only have one area where the flags are turning colors as shown in Figure.
- This should be where the float is. Flags should all be the same color below the float magnet.
- Red, orange and yellow are highly visible colors that are often used.
- The float moves up and down inside the chamber as the process level changes.
- The float type is determined by the process fluid specific gravity, pressure and temperature. Also, the materials of construction must be compatible with the process fluid.
- The float must be light enough to maintain buoyancy and have properties that allow it to withstand the pressure and temperature combination. The each float is engineered for proper buoyancy for each particular application for level or interface measurement.
- Contained inside the sealed float is a very strong magnet assembly. The indicator tube and scale assembly is attached to the outside of the float chamber.

- Inside the transparent, hermetically-sealed indicator tube is a light-weight magnetized indicator. This indicator is magnetically coupled with to the float and moves up and down inside the indicator tube as the float moves up and down with the rising and falling of the liquid level in the vessel.
- The indicator is brightly colored and allows the operator to read the level from 100 feet away. The only moving parts are the float and the indicator. An optional Flipper/Roller style indicator is also offered.



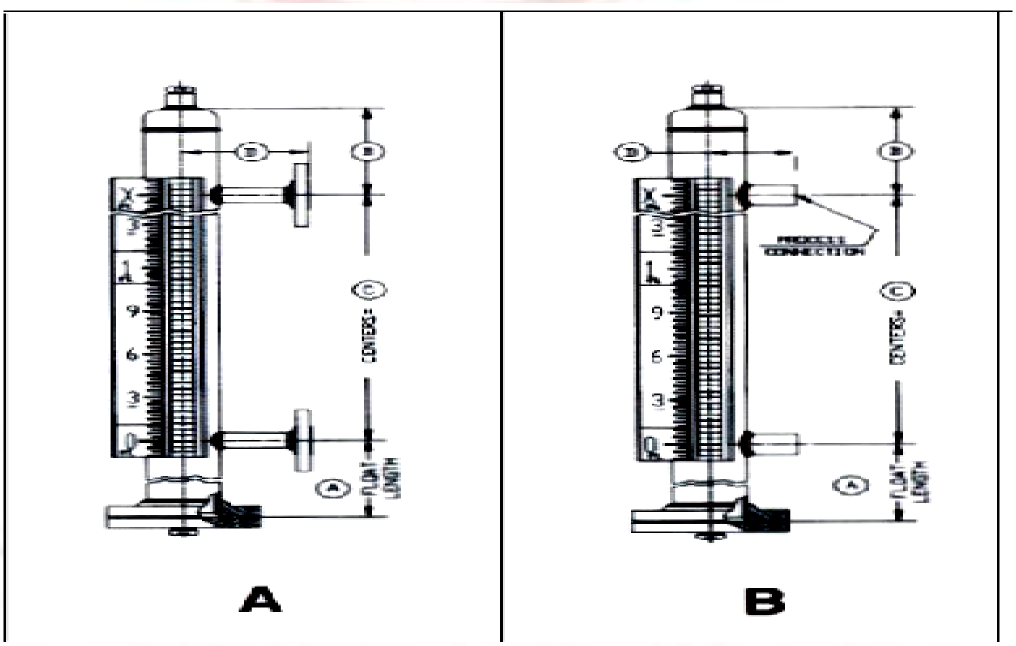

- The Babbitt LG-series level indicator uses a time-proven method to indicate liquid levels which offers many advantages over conventional sight glasses or electronic level sensors.
- In cases of extreme pressures and temperatures, or corrosive and hazardous materials, these gauges perform where others fail thus eliminating dangerous situations for plant personnel.
- The standard material for the LG-Series float chamber is 316 Stainless Steel; however it can be made of any non-magnetic material that is compatible with the media being measured.

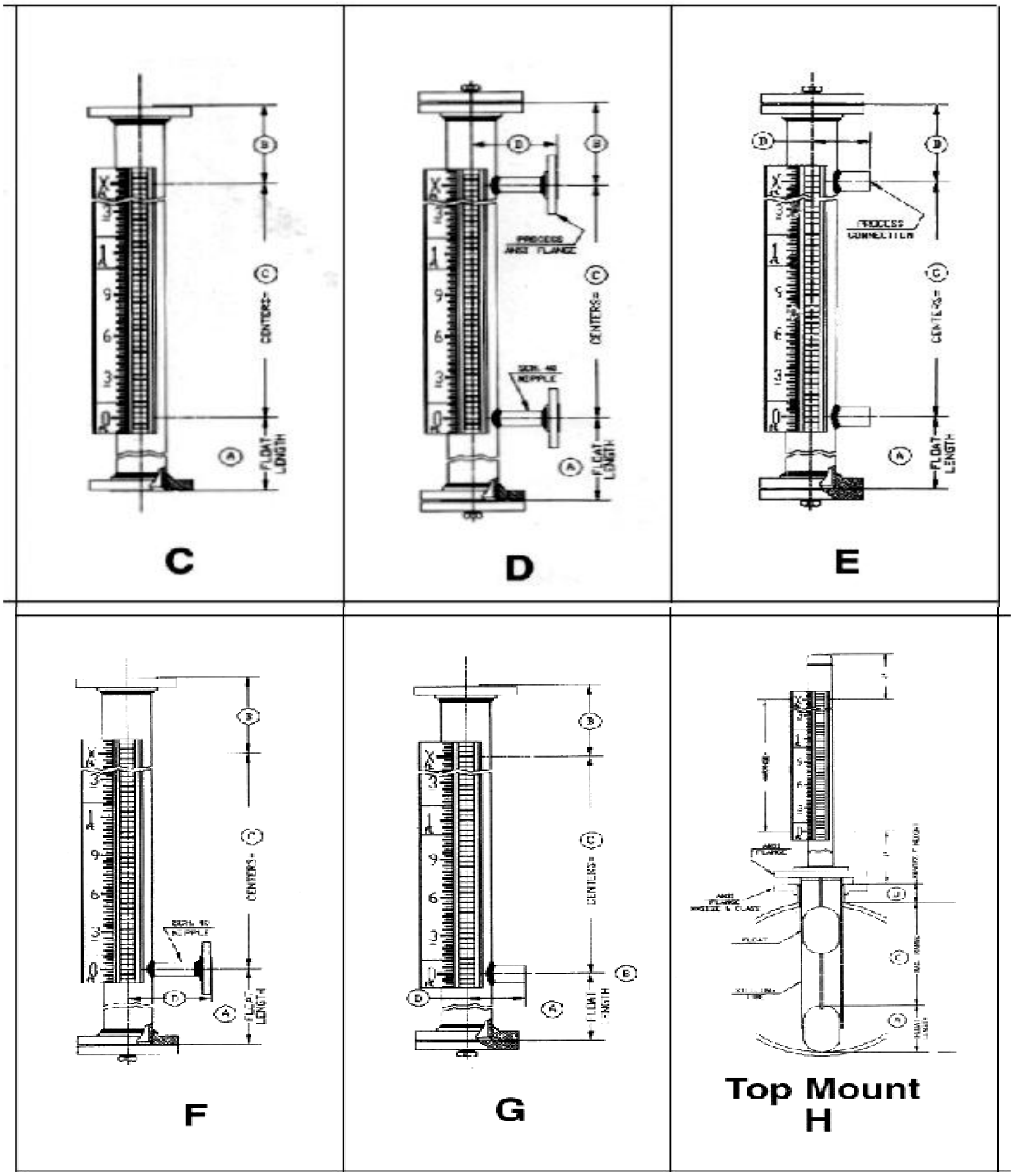
**INSTALLATION**

- The float chamber should always be leveled vertically. If it is not leveled vertically, the float may become magnetically uncoupled from the bird. Should this happen during installation, simply use a permanent magnet or magnet tool (available from Babbitt) to pull the bird back up to the float's magnetic field.
- Valves should be installed between the process vessel and level gage to allow draining, cleaning, etc.
- Standard block valves may be used and can be ordered with the gage from Babbitt or supplied by the customer. All gages are shipped complete with 0.125 inch composition gaskets
- When flipper indicators are purchased with a Babbitt gage no installation is necessary. However, if the indicator is removed or a retrofit kit is purchased for a gage already in service, the following should be noted:
  1. The mounting clamps connecting the flipper assembly to gage chamber, are adjustable to most manufacturers' standard (i.e.: 1 ½" to 2 ½" pipe).
  2. If the gage is in service and there is liquid in the tank, only the individual flippers adjacent to the float will rotate to red when the indicator assembly is clamped on.
  3. To reset indicator to show true level, the operator can
     a. Run a magnet along window of indicator from 0 to where red is showing as noted in item 2.

        OR

     b. Drain gage to empty to zero the indicator, then fill again and as float rises with the level indicator will then be set and read properly(red = liquid, silver = vapor space)






## TESTING

***Pressure testing:***

- All Babbitt gages are hydrostatically test to 1.5 time the specified pressure rating prior to shipment to insure pressure tolerance. However, the gage should be blocked in or the float removed if the process vessel is to be pressure tested in the field by the customer as most vessels are tested at much higher pressures than the maximum operating process pressure.
- While the float chamber is capable of withstanding these higher pressures, the float is not and may collapse under vessel tests.
- Should floats be damaged during testing, replacements are supplied at the customer’s expense.
- To insure proper operation of the level gage, the following steps should be taken:

a. Make sure that operating conditions (temperature, pressure, specific gravity, etc.) are within maximum rating of the gage. Each gage has a permanent nameplate at the bottom of the scale indicating process specifications, serial number, tag number etc.
b. Install float. The float is marked “TOP” to insure proper orientation.

   - On STYLE E Level Gages (Top Mount) remove float stop.
   - STYLE A Level Gages is supplied with floats stops which should be installed between top and bottom process connections.

c. The float chamber should be closed with no openings to the atmosphere. Check to see that all drain and vent plugs are securely in place and any vent and drain valves are closed.
d. When the gage is mounted and ready to be put into service, the TOP process connection valve should be opened first and should be opened slowly to allow any pressure to equalize. This allows process fluid or vapor to enter the gage slowly and reach operating pressure and temperature at a reasonable rate.
e. When the gage has reached process pressure, then open the bottom process connection and installation should be complete.

**SELECTION CRITERIA**

- Selecting a magnetic level gauge needs to be done carefully, because there are a number of problems that can develop. After installing a variety of brands of magnetic level gauges a local plant developed some undesirable experiences.
- The basic problem was incorrect level indication during process upsets and rapid changes in liquid level. The following features are to be noted.

  a) The indicator should cover the entire measurement height. The case may be hermetically sealed to avoid contamination.
  b) The column contains the process fluid and float. Check that the float is designed for minimum specific gravity that suits your application. If specific gravity varies ask the supplier to provide an estimate of the float heights at the minimum, normal and maximum specific gravities. This will show how much error may be caused by the specific gravity changes
  c) There are many process connections and orientations available. The bottom of the chamber must be able to be opened to allow removal of the float. Top and bottom flanges may be used in dirty applications to provide access for cleaning. Each flanged connection should include a shock spring attached to the blind mating flange.
  d) Most suppliers provide accessories such as transmitters and level switches that operate from the float magnet. Check if there are any restrictions in the mounting positions of these accessories.
  e) Some manufacturers provide flexible insulation for the chamber, as an option. This option allows easy removal for maintenance access.

**CONFORMATION TO STANDARDS**.

- ANSI/ASME B31.1 or B31.3
- CRN Canadian Registration Number.

**APPLICATIONS**

- Magnetic level gauges may be used for applications where a level gauge glass may be unsafe, an environmental risk or to increase the visibility of the level indication.
- High pressures, high and low temperatures, toxic and corrosive services can be risky applications for level gauge glasses.
- Some chemical services can attack the glass material causing breakage or discoloration Liquid-liquid Interfaces can be very difficult to read in a gauge glass. Magnetic level gauges can also be fitted with level switches and transmitters.

**PARTIAL LIST OF SUPPLIERS**

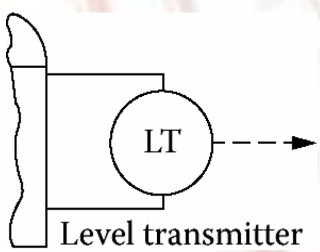
- Babbitt
- IMO Gems Sensors
- Jerguson
- Krohne
- K-Tek Corporation
- Magnetrol
- Ponar
- Cedaspe
- Miselli
- Heinrich
- Bieri
- Berthold

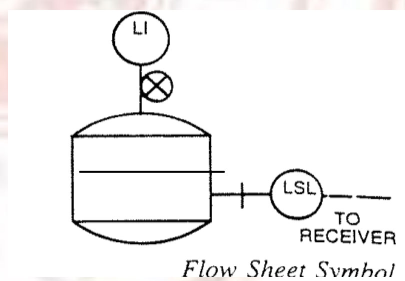
# FLOAT OPERATED LEVEL TRANSMITTER

**Description**

Level Transmitters or Level Transducers are used to measure the level of a liquid or bulk solid material (as well as slurries) within a specified space, and to provide electrical output about these measurements that are proportional to the input level. Level transmitters are designed to measure level based on either a point level or continuous level readings. Point level transmitters provide output when a specific level measurement is reached. This output is generally in the form of an audible alarm or an electrical charge to actuate a switch. Continuous level transmitters measure level with in a specified range and provide output as a continuous reading of the level. Level transmitters can operate through a wide range of temperatures, pressure, vapor gas mixtures, and process conditions

**Symbols**

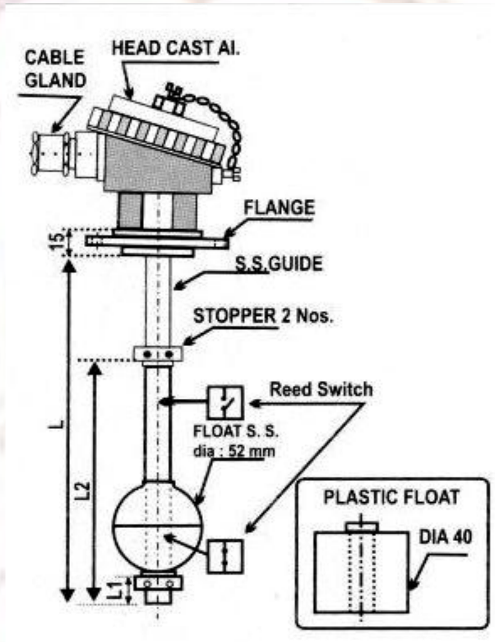



**Figure**

***Figure 1: Cirrus top mounted Magnetic float Level transmitters***

Cirrus top mounted Magnetic float level transmitters are used for continuous level measurement and control of any liquid that is chemically compatible with its wetted parts. It has accuracy up to 0.5% FSD and can be used up to 90 deg C temp. & 20 kg/cm2 pressure. The maximum length that can be supplied is 3 meters. It is available in different material of construction like SS304, SS316, PVC and PP & with different Float sizes. The enclosure is IP56/IP65/Ex-proof Gr IIA & IIB approved to suit various service condition & application.




**SPECIFICATIONS**

***Functional***

| | |
|---|---|
| Range | : 0.5 to 2 m |
| Measuring Range | : 3 meters max |
| Power Supply | : 24 V DC |
| Output | : 4 - 20 mA (2 wires), 1 to 5VDC |
| Temperature. | : Amb. ~ 110 °C |
| Max.Temperature | : 60 °C (PP) / 90 °C (SS) |
| Pressure | : 20 bar |
| Test pressure | : 3 kg/sqcm (PP)/10 Kg/sqcm (SS) |
| Accuracy | : +/- 10 mm, Up to 0.5% FSD |
| Min Sp Gravity | : 0.7 |
| Max Press | : 10 KG/CM2 |
| Wiring System | : 2 wire/ 3 wire |

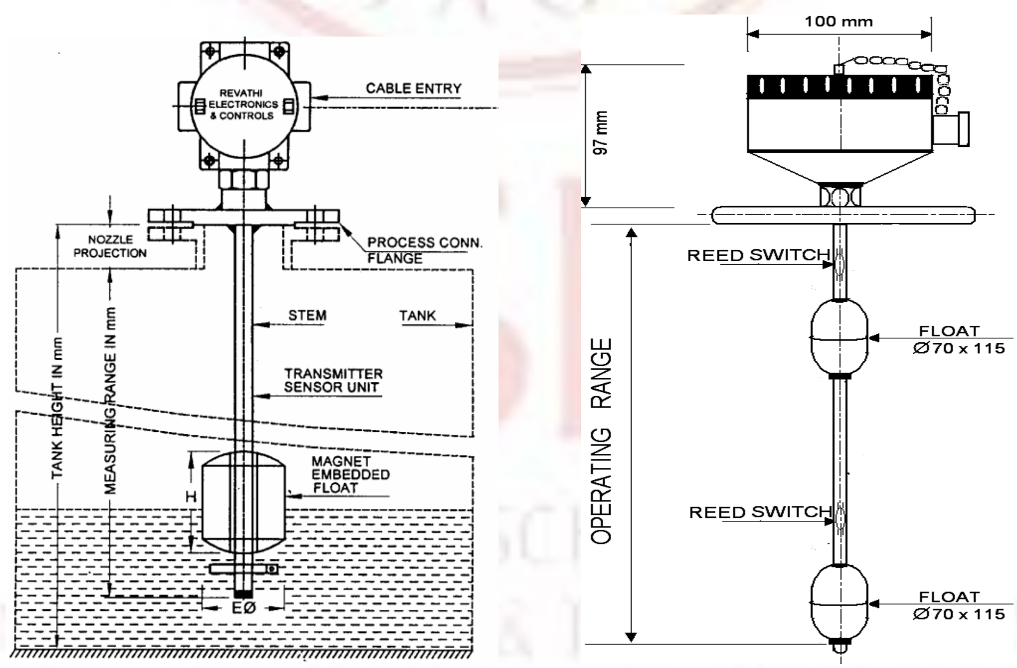
***Physical***

| | |
|---|---|
| Installation | : Top Mounted |
| Construction | : Stainless steel / PP |
| Housing | : Aluminium (IP65 / Eex ia) |
| Wetted Parts | : SS304, SS316 or PP |
| Float | : SS 316, Magnetic |
| Process Connection | : Flanged to BS/ ANSI/ ASA/DIN |
| Min Liquid Sp. Gr. | : 0.7 |

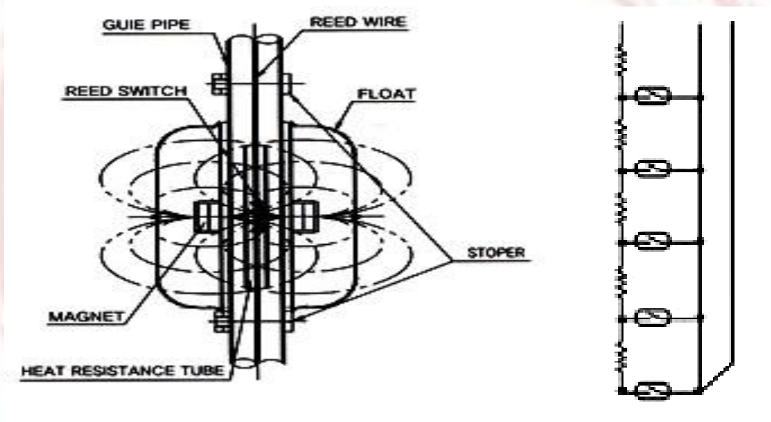
| | |
|---|---|
| MOC | : SS304/ 316/ PP & PVDF |
| Enclosure | : Cast AL IP-66 / Ex-proof Gr.IIA-IIB & IIC |
| Resolution | : 5/12 mm |
| Process con | : flanged / screwed |
| Options | : Intrinsically Safe Design |
| Terminal Enclosure | : Cast Aluminium,weather proof to IP 56/65 and Ex. Proof for Gr. II A & II B/ Gr IIC |
| Conduit Connection | : Brass, 1/2" ET or 1/2" NPT, 2" 150 # ASA flange / 65 NB for pp ver. |

**PRINCIPLE OF OPERATION**

Magnetic float Level transmitters are made for continuous Level measurement of liquids. Transmitter consists of float & guide tube (Stem) assembly in a non-magnetic material and Number of closely spaced glass encapsulated reed switches & resistors are placed inside the guide tube .the magnetic float traverses up and down between the operating range with the rise and fall of liquid Level. The magnetic float actuates the magnetic sensor circuitry inside the stem.The operation is similar to a sliding resistance potentiometer. The output value of array changes in corresponds to rise and fall of liquid Level; this output value of array is sensed by a transmitter circuitry which converts the signals into 4-20 mA current output proportional to the liquid Level inside tank. Due to its easy mounting, different material of construction & reliable operation these transmitters are widely used for Level measurement of various liquids, including liquids having foam or fumes inside their storage thanks. Using this method of control you can sense and regulate levels of gas to fluid interface applications as well as many fluid to fluid interfaces.

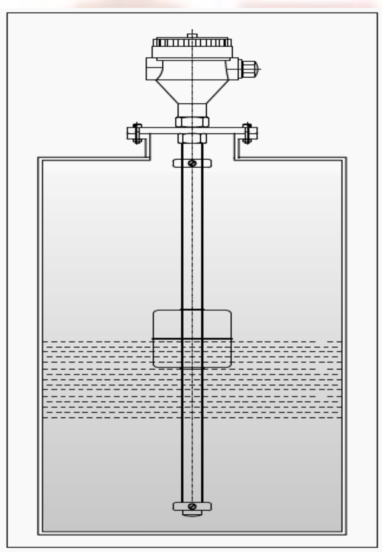



**Sensor technology**: It employs a magnet embedded float and a reed switch basis which is installed through the top of the tank. The floats which contain permanent magnets move freely between their stops rising or falling with liquid level movement. Hermetically sealed within the tube are a chain of closely spaced reed switches & resistors, completely isolated from the medium. The series of reed switches is combined with resistors to form a voltage divider. As the magnetic float moves the magnet's field actuates the reed switch sensor circuitry inside the stem in a "2-3-2 at-a-time" sequence, while the stoppers restrict overrun and prevent the reed switch returning to its original position. Stopper positions should not be changed. This cuts out a series of resistors kept sealed inside the stem. With every movement of the float, either one additional switch closes or opens. The output is sensed by a transmitter circuitry which converts it into current signals of 4-20 mA proportional to the liquid Level inside tank which is then transmitted to remote area i.e. say pump room or control room.




**INSTALLATION**

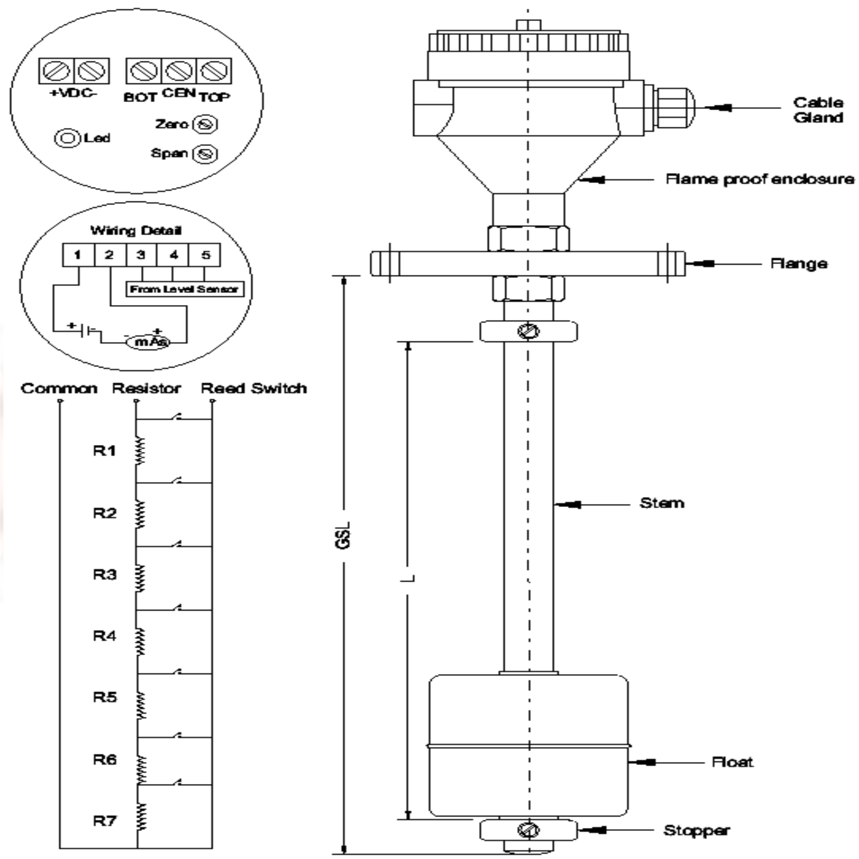
Float-Point may be installed through the top wall of any tank or flange, using a standard 2" NPT tank adapter or blind flange. If the top is not available, Flow line's side mount bracket, LM50-1001, enables Float-Point to be installed directly to the side wall or lip of the tank.



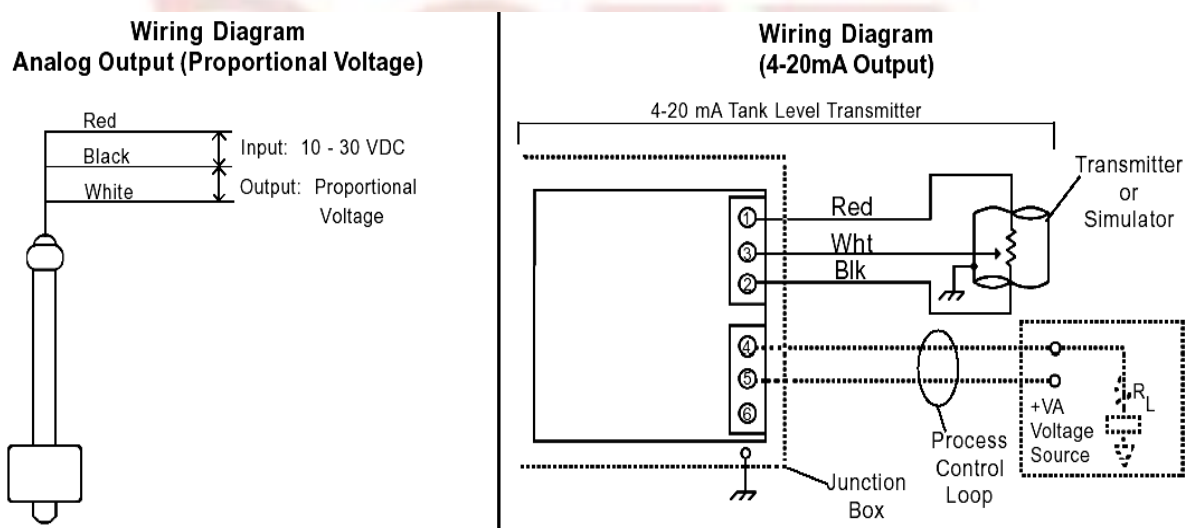
*Typical installation inside tanks*

**Wiring and Electrical:**

The supply voltage used should never exceed 30 VDC. Electrical wiring of the switch should be performed in accordance with all applicable national, state, and local codes.




**Wiring diagram**



**CALIBRATION**

The unit maybe calibrated in the tank where it will be used. Simply locate the float where you want the zero, and adjust zero volume, then move the float to the span position and adjust another span volume.

**Steps:**

A. Calibration should be performed with the probe disconnected from the signal conditioner. Turn off power to loop. Disconnect the red, black and white wires from terminals 1, 2, and 3.

B. Adjust both the null and span potentiometers at approximately mid-range. ***Figure 1***

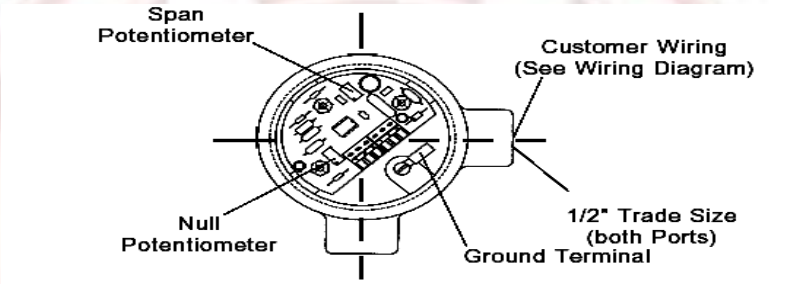



***Figure: 1***

C. Wire as shown per (***Figure 2)***, connecting a jumper wire in place of the black and white probe wires. Connect an ammeter in series to monitor loop current. Apply power to loop. Adjust null pot for 4mA.

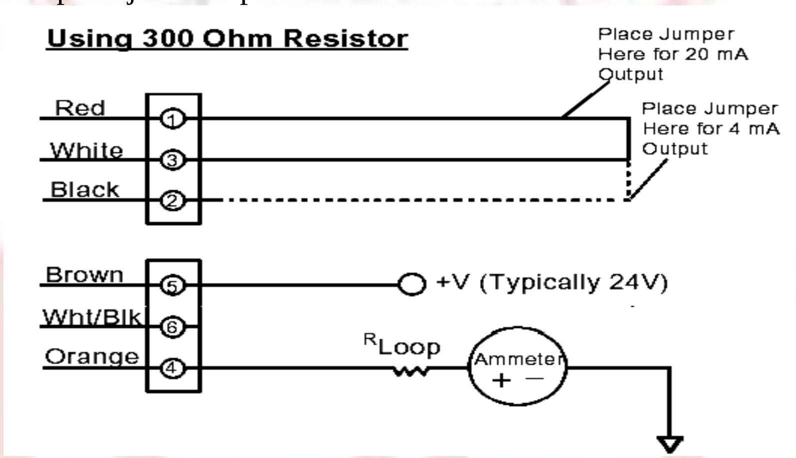



***Figure: 2***

D. Remove power from loop. Reposition the jumper wire in place of red and white probe wires. Reapply power and with the span pot, set the output current to 20mA.

E. Repeat Steps C and D for final adjustment.

F. If power is maintained during jumper connections, current level may increase to 36mA. This is normal. Current will return to regular readings when connections are made.

**Troubleshooting:** Verify proper wiring, power supply, and loop resistance. If transmitter is not functioning properly, isolate the transmitter from the system and wire per ***Figure 3.*** Meter should read 4mA with float at bottom and 20mA with float on top of transmitter. If unit is still not operating properly,

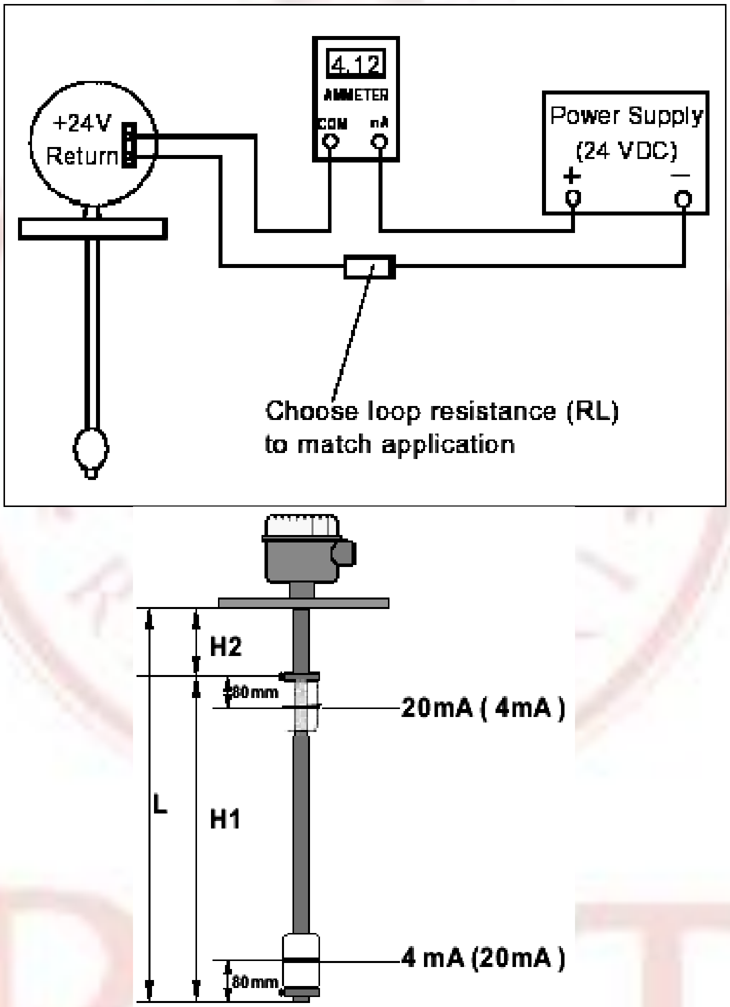



**Figure 3**

## SELECTION CRITERIA

(See specifications)

## CONFORMATION TO STANDARDS

- ASME B31.1/B31.3,
- ATEX & PED approvals.
- CSA
- FM
- UL

**APPLICATIONS**

Float operated devices used in pressurized tanks that require a seal between the process and the indicator. In installation where no external power source is available, the float level indicator can be used to obtain remote indication. When the level of the tank rises, the float moves up enabling a read out to indicate the level.

Also float operated level indicators offers a simple and cost effective method to detect the level in various other areas such as

- Oils
- Acids
- Juices
- Water
- Diesel
- Boilers
- Propane Tanks
- Alkylation Unit
- Chemical Storage
- Feed Water Tank
- Petro chemical Tank
- Condensate
- soap solution
- dyes foaming solutions
- Food grade liquids etc.

**PARTIAL LIST OF SUPPLIERS**

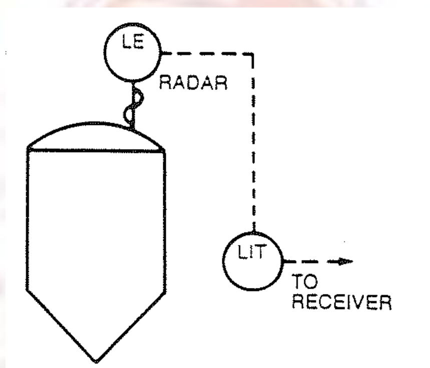
- Flow-tech
- Magnetrol
- Tech-trol
- Alpha pneumatic
- Flui-tech
- Innovative controls
- Aqua meass
- Clark Relaince - Jerguson

# DISPLACER LEVEL TRANSMITTER

**Description**

The Mobrey MLT100 Level Transmitter is one of the most advanced displacer based devices on the market, coupling the time proven buoyancy principle with state of the art electronics in an instrument of high reliability and stability. Special care has been taken in design to ensure a small mounting envelope is maintained, resulting in reduced weight and associated savings in mounting. The displacer element is made to length for each order, and is suspended below the head on a stable spring arrangement which is designed to minimize friction effects and improve performance. The transmitter can be mounted directly into a vessel or may be externally mounted in a chamber to allow isolation for planned maintenance or in-situ calibration checks

**Symbol**




*Flow Sheet Symbol*

**Figure**


***Mobrey MLT100 Displacer Level Transmitter***

**SPECIFICATIONS**

***Functional***

- Output : 4–20 mA / HART digital
- Range : 11.8 to 118 in. / 300 to 3000 mm (to order)
- Max. Operating Pressure : 2900 psi (200 bar)
- Min. Operating Pressure : Full vacuum
- Max. Operating Temperature : 608 °F (320°C) non-condensing; 608 °F (320°C) condensing with remote electronics
- Min. Operating Temperature : –76 °F (–60 °C)
- Ambient temperature : –40 to 176 °F / –40 to 80 °C (subject to process temperature.)
- Accuracy : < ±1% of output span
- Repeatability : ±0.2% of output span
- Linearity : 0.2% of output span
- Resolution : 0.1% of output span
- Hysteresis : 0.3% of output span
- Power Supply : 12 to 40 Vdc loop-powered
- Specific Gravity Range : Standard: 0.5 to 1.5
- Interface : 0.1 differences
- Turndown : 3: 1
- Power consumption : 21 mA / 40 V: 840 mW maximum

**PRINCIPLE OF OPERATION**

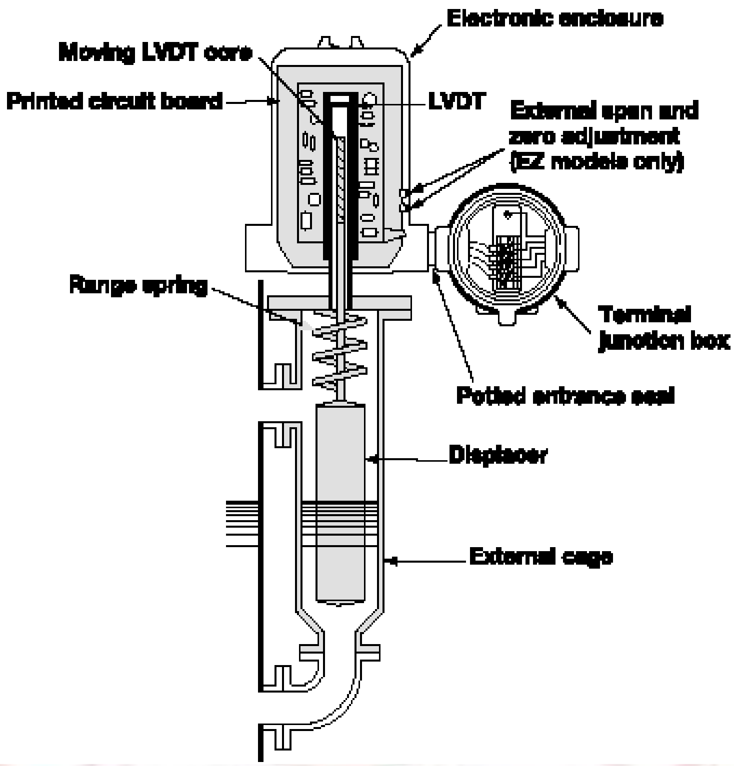
Changing process liquid level causes the displacer element, which is supported by a spring, to rise or fall. An armature, located in the pressure tube of the head, is directly linked to the displacer and moves vertically with the displacer element. In the enclosure and around the outside of the pressure tube is a Linear Variable Differential Transducer (LVDT) which provides an output proportional to the position of the armature. Voltage signal from the LDVT is converted into a 4-20mA output signal. The pressure tube is made of stainless steel and is welded to the enclosure fitting effectively containing the process and temperature. This design ensures process conditions are contained and isolated in the pressure vessel.

The displacer length is determined by the operating range (span) specified, the S.G., pressure, and temperature of the process. The diameter and weight is factory calculated to ensure the correct operation and providing accurate 4-20mA output.

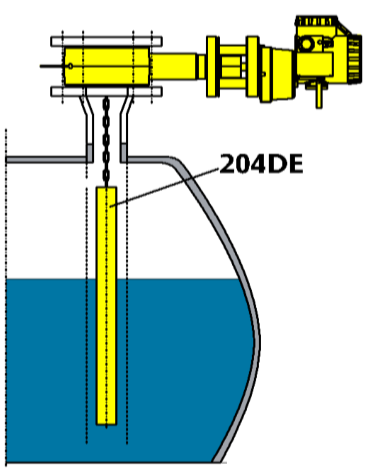
Each transmitter is fitted with a visible LED which flashes once every 3 seconds to show the instrument is operating and functioning correctly. The instrument span or zero may be adjusted on line by using the unique calibration plug and a magnet screwdriver.

The 4 - 20 mA output from the head is proportional to the level or contents in the vessel, or may be set to follow an interface.

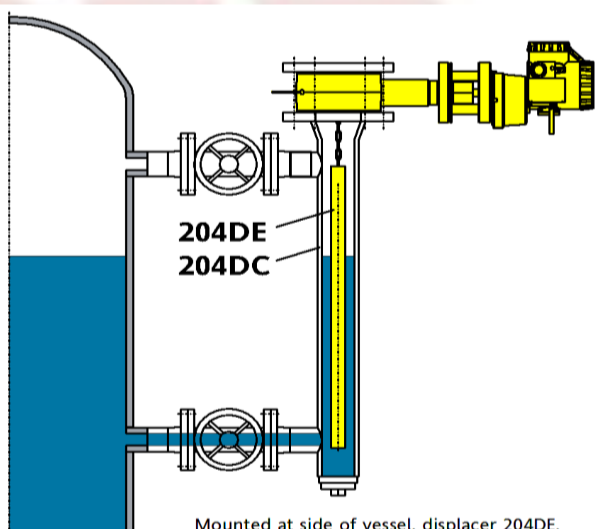
SMART electronics mean digital communication is possible. The Mobrey transmitter supports the HART protocol, which is superimposed on the 4-20Ma signal. Thus the user can operate the transmitter without digital communications, or can take advantage of the many features of HART such as remote calibration, re-ranging, on-line diagnostics and multidrop installations.




The new 244LD intelligent buoyancy transmitter can continuously measure level, interface or density for process and tank control. The transmitter theory of operation is based on Archimedes buoyancy principle. It is very rugged, has a long life cycle and requires low maintenance. The 244LD is extremely reliable and very precise even at extreme process temperatures and pressure. Level and interface can be measured in the range of a few cm and up to more than 50 m. The 244LD can be manufactured in various materials and pressure ratings for the optimal adaptation to the process at the lowest price. The 244LD joins the experience of Foxboro Eckardt with most advanced digital technology



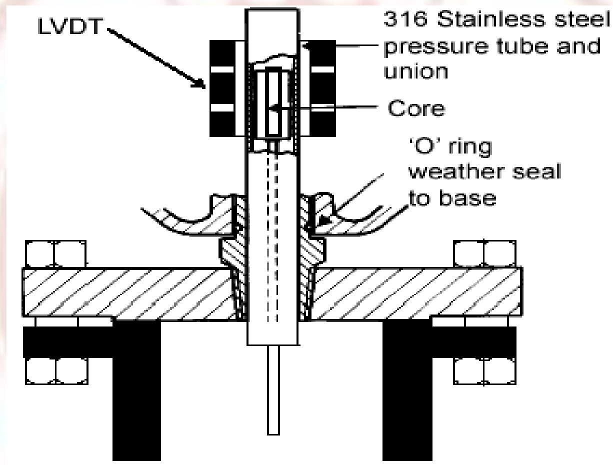

Mounted on top of vessel

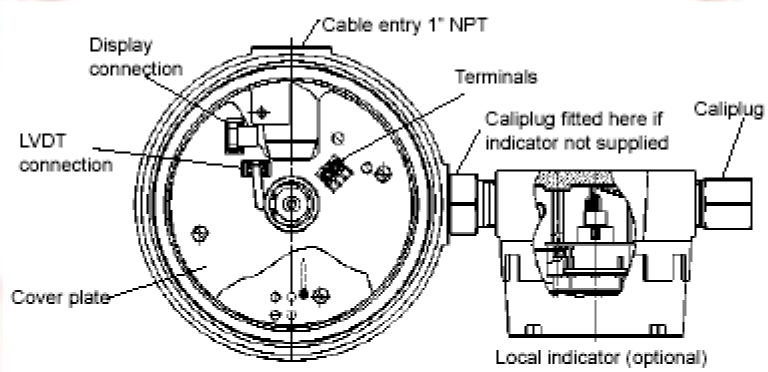


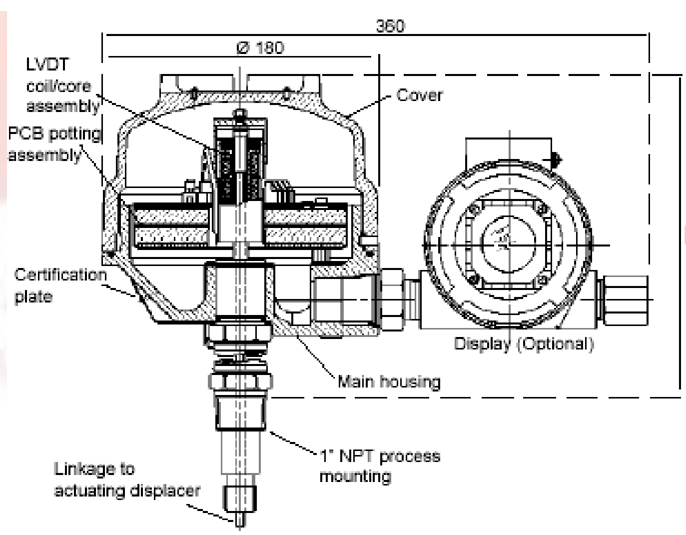

Mounted at side of vessel, displacer 204DE, with displacer chamber 204DC

**INSTALLATION**

- It is recommended the transmitter be mounted no closer than 12 inches (0.3 m) to the wall to avoid losing echo size.
- Avoid applications where heavy condensation could form on the transmitter.
- If the transmitter is mounted in a stand-off or nozzle, the transmitter face should protrude at least 0.2 in. (5 mm) into the tank.
- In environments where direct sunlight can cause high surface temperatures on exposed instruments, a sun-shade, or remote temperature sensor option, is recommended.



## CONSTRUCTION

**Transmitter head:** The transmitter head is cast iron with a paint finish of two part Epoxy white paint suitable for offshore or coastal use. Weatherproof rating IP66 / IP67. Wetted parts are made from stainless steel which include the displacer element, trim and pressure tube, except for the spring which is manufactured from a specialist corrosion resistant spring material, which is a high alloy Nimonic suitable for corrosive liquids and high temperature Nimonic, chosen for its stability and repeatability under changing process conditions.

**Chamber:** Where a chamber is specified, the material used will be to the customer's specification or to suit the application. Only certified materials to ANSI and ASTM are used. Welding is qualified to ASME IX and designed in accordance with ANSI B31.3. All pressure retaining parts are hydrostatically pressure tested to a minimum of 1.50 times working pressures. Other NDT including radiography & dye penetrant testing is available when specified at time of order. Inspection by customers or their appointed agents is welcome provided this is requested at time of order. Options: Wet side materials in alloy C276 (UNS N10276), alloy 625 (UNS N06625) and others on request. Compliance with NACE mr-01-75 for sour service duty.

## CALIBRATION

**Field adjustments:** The transmitter is configured by the factory to operate in the process conditions advised at the time of order, and the displacer element dimensions are chosen to suit the maximum required span. However, provisions are made to check the calibration once on site and fine tune the calibration with the instrument in an empty vessel at 20°C, or with the instrument at operating conditions.

**Local calibration:** Several adjustments may be made in the field using the unique "Magnetic Scroller" (MS) and the Calibration plug. The MS is a calibration tool with a magnetic tip, and is used to access and adjust certain operating parameters. The level transmitter is fitted with a calibration plug, which contains docking ports for the MS along with the heartbeat LED. The adjustments which may be made are as follows:

**Setting the 4 mA and 20 mA points:** May be accomplished locally at the transmitter by using the MS to "zero" the device with the level at the required 4 mA point, to the "Span" the device with the level at the 20 mA point. The Zero and Span settings are non-interactive. An additional feature is the ability to span the instrument without the vessel being filled to the 20 mA point. In this case, the vessel is filled to a known level and the output increased to give the corresponding mA level. The 20 mA point is then electronically calculated by the instrument provided the output is linear.

**Setting the damping:** The user can field set the damping (smoothing or response time) using the MS, to a value up to 100 seconds.

**Remote calibration:** Remote calibration is not necessary for standard 4-20 mA operation. Alternatively, the ranging may be accomplished by using a "SMART Communicator" to establish digital communications and set the 4 and 20 mA points electronically, without the need for changing the liquid level using HART protocol.

**Local indication (optional):** A multi-function LCD indicator housed in a cast aluminum explosion proof enclosure. The 2 line display can be programmed to show output in percentage, engineering units and other operating parameters using the smart communicator.

**CONFORMATION TO STANDARDS**

| | |
|---|---|
| Factory Mutual (FM) Approvals | : Intrinsically Safe Approval |
| | : Intrinsically Safe for Class I, Div.1, Groups A, B, C and D |
| | : Intrinsically Safe for Class I, Zone 0, AEx ia IIC |
| Canadian Standards Association CSA | : Intrinsically Safe Approval |
| | : Intrinsically Safe for Class I, Div. 1, Groups A, B, C, and D |
| | : Intrinsically Safe for Class 1, Zone 0, Ex ia IIC |
| ATEX Intrinsically Safe Approval | : Intrinsically Safe for II 1 G, EEx ia IIC |
| IECEx Approval | : Intrinsically Safe for Zone 0, Ex ia IIC |

CENELEC EEx d IIc T6 Certificate No. Ex 97D1291X
CENELEC EEx ia IIc T5 (-40°C to +40°C) Certificate No.Ex97D2379X
CENELEC EEx ia IIc T4 (-40°C to +80°C) Certificate No.Ex97D2379X

**APPLICATIONS**

The transmitter will operate in most level measurement applications including:

- Level, contents or interface measurement
- Knock-out pots
- Condensate drums
- Separators
- Flash vessels
- Storage vessels
- Receiver tanks

Most liquids can be measured, with consideration, at operating process temperatures between -76°F to +608°F and pressures between full vacuum and 2200 PSIG (up to 3705 as a special). Typical liquid S.G. range is from 0.25 to 1.5, and interface applications with an S.G. difference of 0.1 are also practical. The range of the instrument is dependent only upon the length of the element specified, though lengths over 10 feet are considered the longest available.

**PARTIAL LIST OF SUPPLIERS**

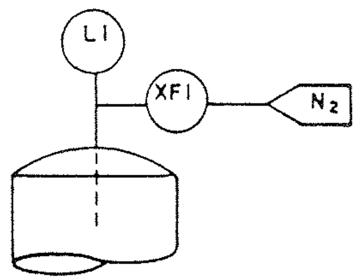
- Rosemount
- Siemens
- Honeywell
- Yokogawa
- Micro motion
- Foxboro
- Mobrey

# AIR PURGE (BUBBLER) LEVEL TRANSMITTER

**Description**

Bubbler systems are ideal for level measurement of open channel run off systems or duct and tank situations where debris, foam, steam, or surface turbulence makes standard methods of level measurement impractical. Air bubbler systems contain no moving parts, making them suitable for measuring the level of sewage, drainage water, sewage sludge, night soil, or water with large quantities of suspended solids. The only part of the sensor that contacts the liquid is a bubble tube which is chemically compatible with the material whose level is to be measured. Since the point of measurement has no electrical components, the technique is a good choice for classified “Hazardous Areas”. The control portion of the system can be located safely away, with the pneumatic plumbing isolating the hazardous from the safe area

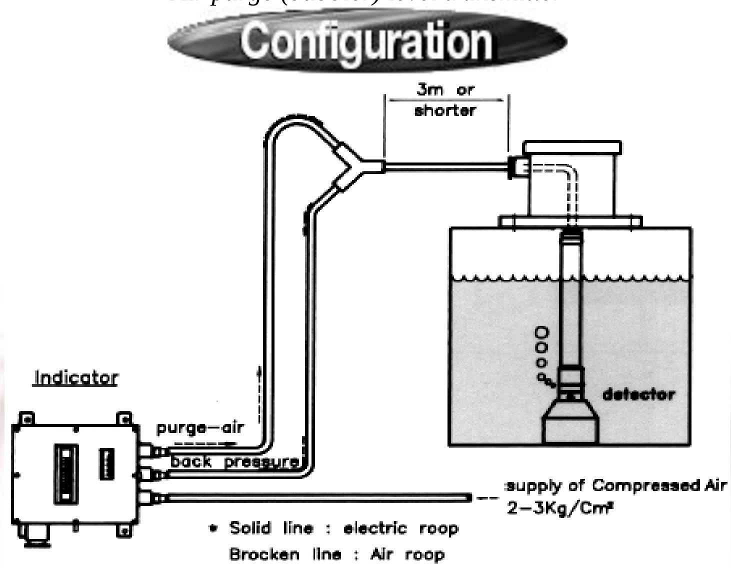
**Symbol**




*Flow Sheet Symbol*

**Figure**

*Air purge (bubbler) level transmitter*




**SPECIFICATIONS**

***Functional***

- Range : 0-50 psi or 0-115 feet water column or equivalent, full scale.
- Gas Input : 1.0 to 7.0 SCFH, regulated on-board to a pressure between 120% or 3 psi, whichever is greater, and 200% of full scale liquid head.
- Electrical Input P200 : 10-42 VDC
- Electrical Output P200 : 2-wire, 4-20 mA into 700 Ohms at 24 VDC or 2-wire, 10-50 mA into 280 Ohms at 24 VDC
- Max blow-down pressure : 150 psi.
- Max onboard regulated press. : 60 psi.
- Accuracy : 0.25% of span guaranteed; 0.2% of span typical. (Includes linearity, hysteresis &repeatability errors.)
- Sensitivity : 0.02% of span guaranteed
- Repeatability : 0.1% of span guaranteed; 0.05% of span typical.
- Operating Temperature : 300F to 1610F
- Thermal Sensitivity : 0.007% of span per 0F guaranteed for zero and span.
- RFI/EMI Effect Meets or exceeds SAMA PMC 33.1, 1978, 2-abc: 0.1% of span at 10 volts/meter

***Physical***

- Environmental P/I : NEMA 4X and explosion-proof, standard. Entire plate assembly fits in an optional NEMA 4 enclosure for further protection.
- Available Options : NEMA 4X enclosure with or without digital readout, remote

**PRINCIPLE OF OPERATION**

The air bubble system level measurement is simple and proven level measurement for dirty/waste water treatment. The bubble tube is the only component in contact with the liquid.

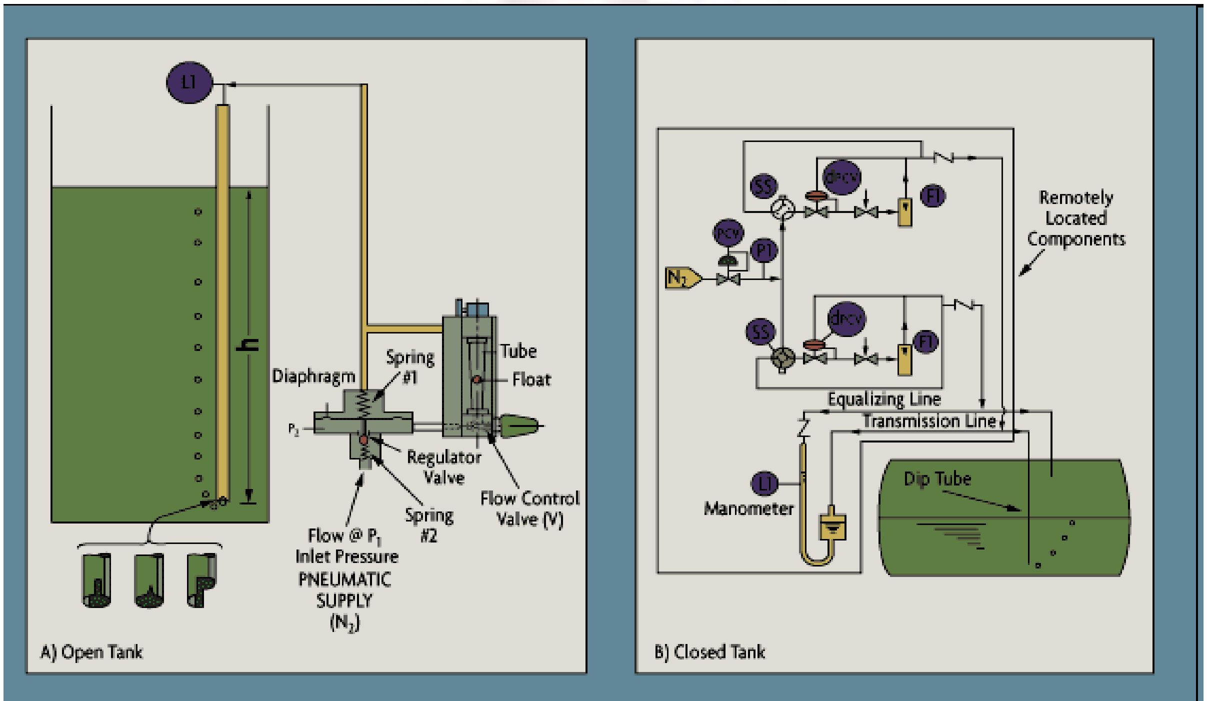



Figure 7-4: Bubbler Tube Measurement System

- Bubble a small flow of air from a submerged dip-tube and then measure the resulting air back-pressure, which can be converted into an analog output, 4~20mA DC. The field indicator is provided by the control unit.
- In the L100 Bubble-Tube Liquid Level System, the level is measured in a vented vessel by measuring the pressure required to force a gas into the liquid at a point beneath the surface. This method allows for level measurement without liquid entering the piping or the instrument.
- A pressure regulator and constant-flow regulator combine to establish a consistent flow of clean air or gas to a bubble pipe immersed a fixed distance in the tank. The flow is regulated to a very low level, building up pressure in the end of the bubble pipe. Thereafter, pressure is kept at this value by the escape of air bubbles through the liquid. Changes in the measured level cause the gas pressure to build or drop. An integral P200 is then used at this point to measure the back pressure and transmit an electrical signal proportional to the level or volume of liquid.
- The presence of the high-quality, industry-leading P/I Transmitter in the L100 Bubble-Tube Level System provides the user with an established and recognized electronic interface. Since the totally solid-state P200 transmitter is typically capable of accuracies of 0.10% of span, the entire L100 System may be expected to maintain 0.25% accuracy. Additionally the L100 may be used in indoor or outdoor hazardous areas due to the NEMA 4 design and the FM & CSA explosion-proof and FM & CSA intrinsically safe certifications of the P200.

- The L100 provides for a variety of features which simplify the application of bubble-tube techniques to liquid level. Over-pressure relief and back-flow check valves are used to protect the P200 and are supplied as standard equipment in every system along with a flow meter to read purge flow. Provision for manual blow down of the bubble pipe by high pressure air is included to allow the user to clear any obstructions form the bubble pipe. Figure 1 shows a labeled drawing of the L100 System, and Figures 2 through 4 give functional representations of the technique. Note in Figure 5 the small V-notch in the bottom of the pipe which allows the air to exit in a steady stream rather than in intermittent large bubbles.
- The L100 System provides two possible means of accurate measurement. Although a very well-regulated constant air flow is provided by the L100, the following formula and table show that a significant pressure drop may occur in long lengths of tubing between the bubble system and the tank:

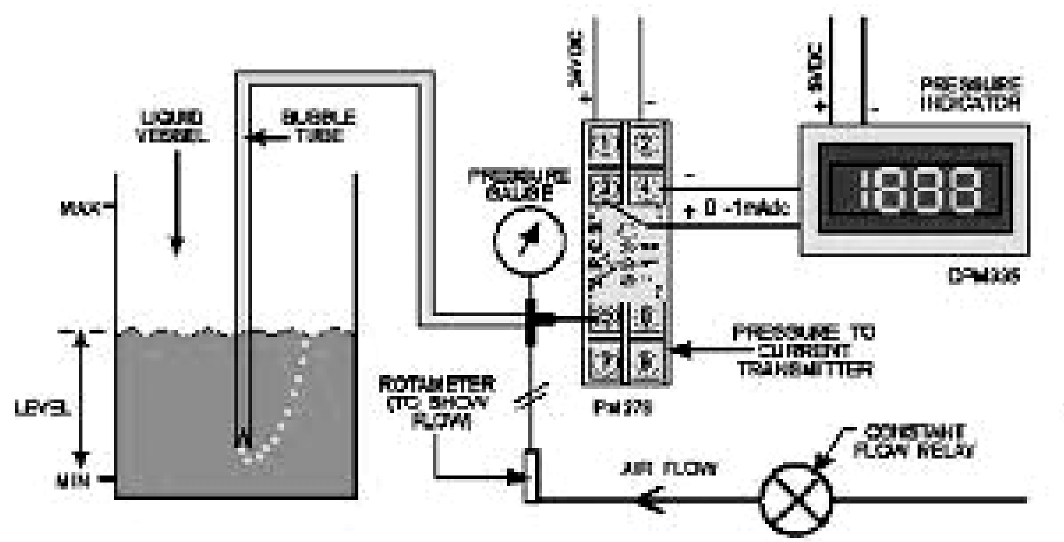
**PD = (K x A x L) ÷ 1000**

Where: PD = Pressure drop in inches of water.

K = Coefficient which is a function of the tubing.

A = Air flow in standard cubic feet per hour.

L = Length of tubing in feet




Features:

- Can be used with highly viscous liquids
- 4 ~ 20mA output
- On-site or remote displays
- Easy maintenance
- No moving parts
- Control unit consists of pressure elements, needle valve, V/I converter and indicator.
- Even if sludge or suspended solids is clogged in the bubble tube, it can be blown out by operating the bypass valve.
- There are two kinds of bubble tube. One is an easy installation flexible PVC hose and another is 304SS tube which can be used in high temperature.

## INSTALLATION

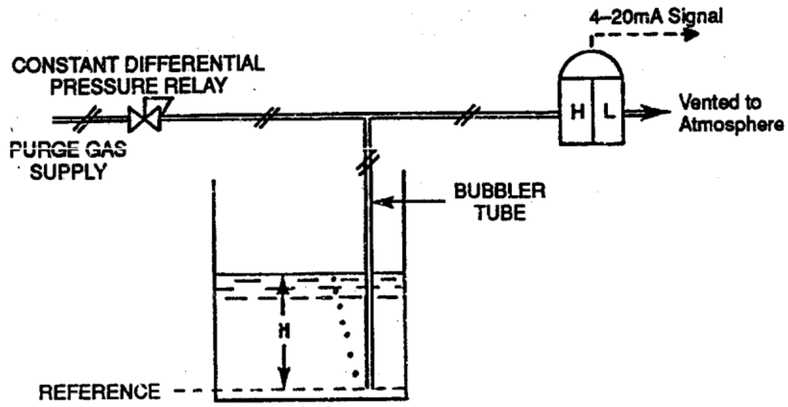



Figure 8: Bubbler Level Measurement System in an Open Tank.

## Dip Tube Considerations

A poorly constructed or mounted Dip Tube will impair the accuracy and reliability of the Bubble-Tube Liquid Level System. Some problems and causes are on the following.

**Problem**

- Fluctuating Transducer Output Signal
- Transmitter Zero Shift

**Cause**

- Poorly supported Dip Tube, (tube allowed to move).
- V-notch omitted from tube opening, See Figure 5
- Turbulence within tank, (not related to dip tube design).
- Changes in pressure drop due to long length of tube before dip tube or other restriction.
- Narrowing of dip tube air passage, due to corrosion

**Checking for Leaks**

Before the Bubble-Tube Liquid Level System can operate properly, all leaks must be eliminated. The test pressure must be conservatively selected to prevent damaging the P/I Transducer by over pressurizing the sensor. The test pressure be no more than one and a half (1—) times the full scale operating pressure. The full scale operating pressure can be determined by showing the following equation:

**Pressure (psig) = column height in inches x (.036psig ũ 1 in. column) x sg.**

sg. = specific gravity; water = 1

A pressure increase can be accomplished by turning the knob of the pressure regulator clockwise. The pressure gauge mounted on the same pressure regulator will indicate regulator output. Should the tank be dry and the dip tube accessible, seal the end of the dip tube while checking the Air Rate Indicator for signs of air flow. A leak in the system will cause the black ball to float within the tube.

To inspect for leaks where the dip tube is not accessible or the tank partially full, a water-soap solution must be applied to all joints. All leaks must be eliminated before the system will operate correctly

## CALIBRATION

- ***Output shift correction:*** Correcting for Output Shifts Unpredictable pressure drops caused by the configuration of the piping will cause both the zero and full scale readings to be higher than expected. To determine if an output shift has occurred, the tank will have to be empty or full, or the pipe carrying the pneumatic signal to the dip tube will have to be disconnected from the dip tube. With the tank empty or the supply pipe disconnected from the dip tube. With the tank empty or the supply pipe disconnected from the dip tube, the output of the P/I Transducer should be zero based or 4 mA on a 4-20 mA scale. If the zero or full scale reading is higher than 4 or 20 mA respectively, an output shift has occurred.
- The L100 Bubble-Tube Liquid Level System has been calibrated at the factory for the service and column height specified on the customers purchase order. Calibration can be affected by restrictions in the piping system due to the length of piping before the bubble-tube or the size of the piping as well as volume of gas being forced down the bubble-tube. It is important to keep the size of the piping as large as economically feasible and the length as short as possible while reducing the gas flow to that which will still provide accurate readings; approx. 1.5 SCFH.
- ***Zero and Span adjustment:*** An output shift due to piping affects the zero and span calibration equally. For example, a system with a zero scale output of 4.23 mA will have a full scale output of 20.23 mA. Making an adjustment to the zero potentiometer of the P/I Transducer will cause both the zero and full scale readings to change simultaneously and equally. Do not adjust span potentiometer.

## SELECTION CRITERIA

(Refer typical specifications).

## CONFORMATION TO STANDARDS

- NEMA 4X Enclosures,
- NIST Traceable calibration.
- RFI/EMI Effect – Must at least meet or exceed SAMA PMC 33.1, 1978.

**APPLICATIONS**

Used to measure the level of corrosive, slurry, or viscous process liquids contained in open tanks. However it can be used for pressurized tanks up to the pressure of the air supply

- Waste water treatment process
- Hydraulic equipment
- Cooling water chemical liquid
- Milk beverage
- Unicipal water
- Level in a Lift Station
- Tank level when foam is present
- Can be used with atmospheres other than air.

**PARTIAL LIST OF SUPPLIERS**

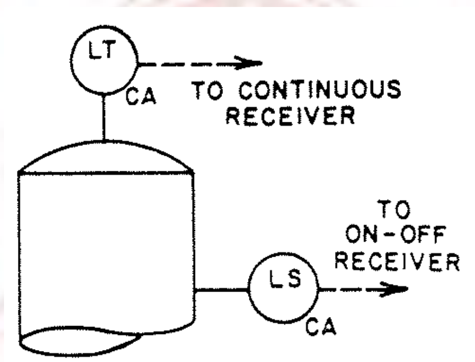
- Switzer
- Foxboro
- Siemens
- Seojin instech co.ltd
- King gauge engineering corp.
- Control Air Inc.

# CAPACITANCE LEVEL TRANSMITTER

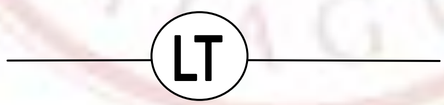
**Description**

Capacitance level Transmitter utilizes the capacitance formed between the sensing probe and the reference probe which is the metallic vessel wall to calculate the level of the liquid/medium inside the vessel according to the capacitance theory that the capacitance and vessel are proportional increased. Capacitor can be formed when a level sensing electrode is installed in a vessel. The metal rod of the electrode acts as one plate of the capacitor and the tank wall (or reference electrode in a non-metallic vessel) acts as the other plate.

**Symbol**




Flow sheet symbol




**Figure**

**SPECIFICATIONS**

***Functional***

- Technical
  - Input Measuring range: 1 to 3300 pF
  - Span Min.:3.3 pF
- Output
  - Solid-state switch
  - Output : Galvanically isolated
  - Protection: Bipolar
  - Max. switching voltage : 30 V (DC)
    : 30 V peak (AC)
  - Max. load current 82 mA
  - Voltage drop < 1 V, typical at 50 mA
  - Time delay (pre or post switching) 1 to 60 s
  - Loop current : 3.6 to 22 mA/22 to 3.6 mA (2-wire current loop)
- Accuracy (transmitter)
  - Temperature stability: 0.15 pF (0 pF) or < 0.25 %( typically < 0.1%) of actual measured value, whichever is greater over the full temperature range
  - Non-linearity and repeatability: < 0.1% of range and actual measured value respectively
  - Accuracy Deviation: < 0.1% of measured value
- Installation condition
  - Location: Indoor/outdoor
  - Ambient temperature (transmitter) -40 to +85 °C (-40 to +185 °F)2)
  - Installation category: II
  - Pollution degree: 4
  - Relative dielectric constant εr: Min. 1.5
- Process temperature: Temperature rating of process seal is pressure dependent.
  - Standard (PFA): -50 to +200 °C (-58 to +392 °F)
  - Cryogenic version: -200 to +200 °C (-328 to +392 °F)
- Process pressure: Pressure rating of process seal is temperature dependent.
  - Standard (PFA): -1 to 150 bar g (2175 psi g)
- Power supply**:** 12 to 33 V DC

***Physical***

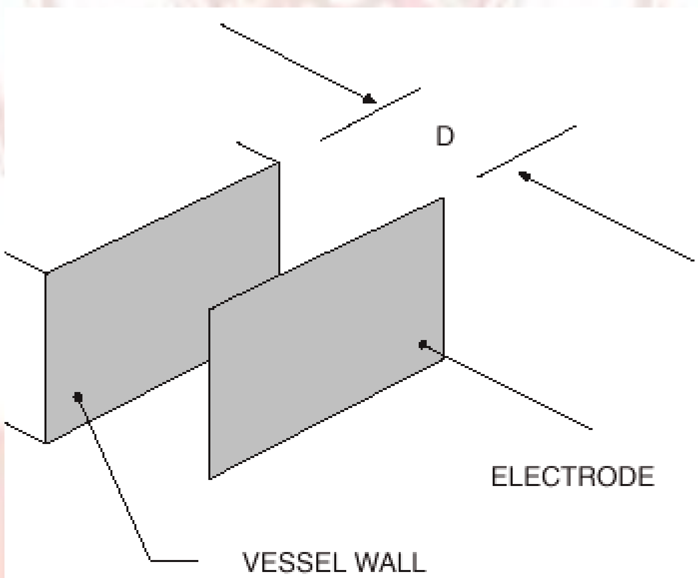
- Wetted parts material:
  - Standard rod: 316L stainless steel
  - Probe insulation (rod): PFA, enamel
  - Cable: 316 stainless steel/ 316 stainless steel PFA
- Probe diameter
  - Rod version: 16 mm (0.63") or 24 mm (0.95")
  - Cable version: 9 mm (0.35") with PFA jacket, 6 mm (0.24") without PFA jacket

**PRINCIPLE OF OPERATION**

A capacitor is formed when a level sensing electrode is installed in a vessel. The metal rod of the electrode acts as one plate of the capacitor and the tank wall (or reference electrode in a non-metallic vessel) acts as the other plate. As level rises, the air or gas normally surrounding the electrode is displaced by material having a different dielectric constant. A change in the value of the capacitor takes place because the dielectric between the plates has changed. RF (radio frequency) capacitance instruments detect this change and convert it into a relay actuation or a proportional output signal. The capacitance relationship is illustrated with the following equation:

$$C = 0.225\,K\,(A/D)$$

*Where: C* = Capacitance in Pico Farads
*K* = Dielectric constant of material
*A* = Area of plates in square inches
*D* = Distance between the plates in inches




The dielectric constant is a numerical value on a scale of 1 to 100 which relates to the ability of the dielectric (material between the plates) to store an electrostatic charge. The dielectric constant of a material is determined in an actual test cell. Values for many materials are published by the National Institute of Standards and Technology.

In actual practice, capacitance change is produced in different ways depending on the material being measured and the level electrode selection. However, the basic principle always applies. If a higher dielectric material replaces a lower one, the total capacitance output of the system will increase. If the electrode is made larger (effectively increasing the surface area) the capacitance output increases; if the distance between measuring electrode and reference decreases, then the capacitance output decreases.

**Level measurement can be organized into three basic categories:**

- the measurement of non-conductive materials,
- conductive materials and
- Proximity or non-contacting measurement.

**Non-Conductive Materials**— As previously stated, capacitance changes as material comes between the plates of the capacitor. For example, suppose the sensor and the metal wall is measuring the increasing level of a non-conductive hydrocarbon. Figure depicts a typical system.

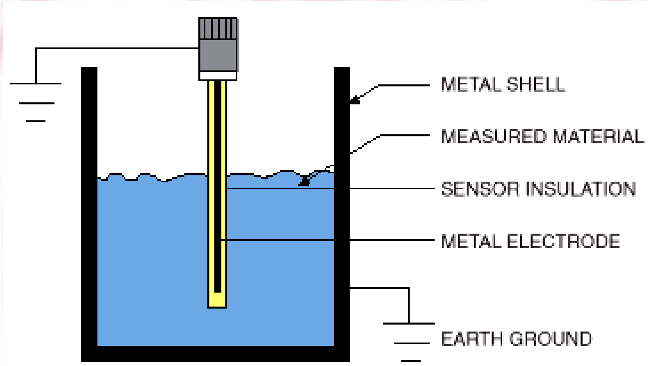



**Figure 1- Capacitive Measurement In Non-Conductive Media**

While the actual capacitive equation is very complex, it can be approximated for the above example as follows:

- C = 0.225 (K air x A air) /D air + 0.225 (K material × A material )/D material

Since the electrode and tank wall are fixed in place, the distance between them will not vary. Similarly, the dielectric of air and of the measured material remain constant (air is 1 and the hydrocarbon is 10). Consequently, the capacitance output of the system example can be reduced to this very basic equation:

- *C* = (1 x *A air*) + (10 ×*A material* )

As this equation demonstrates, the more material in the tank, the higher the capacitance output will be. The capacitance is directly proportional to the level of the measured material.

**Conductive Materials**— The same logic for nonconductive materials applies for conductive materials, except that conductive material acts as the ground plate of the capacitor, rather than the tank wall. This changes the distance aspect of the equation, whereby the output would be comparatively higher than for a non-conductive material. However, it still remains fixed; therefore, as level rises on the vertically mounted sensor, the output increases proportionally.

**NOTE:** A material is considered conductive when it has a conductivity value of greater than 10 micro Siemens/cm. A non-insulated level sensing electrode must NOT come in contact with conductive material, in which case the sensor will act like a switch.

**Proximity (non-contacting) Measurements**— the level sensing electrode is normally a flat plate mounted parallel to the surface of the material. The material, if conductive, acts as the ground plate of the capacitor. As level rises to the sensor plate, the effective distance between plates is decreased, thus causing an increase in capacitance. In nonconductive materials, the vessel acts as the ground plate and the mass of material between the plates is the variable. In the measurement of non-conductive and conductive materials, the area changes and the distance is fixed. Proximity level measurement is exactly the opposite in that the area is fixed, but distance varies. Proximity level measurement does not produce a linear output and can only be used when the level varies by several inches.

**INSTALLATION**

Some typical level sensor installations for measuring conductive and non-conductive materials and for proximity level measurement are shown in Figures.

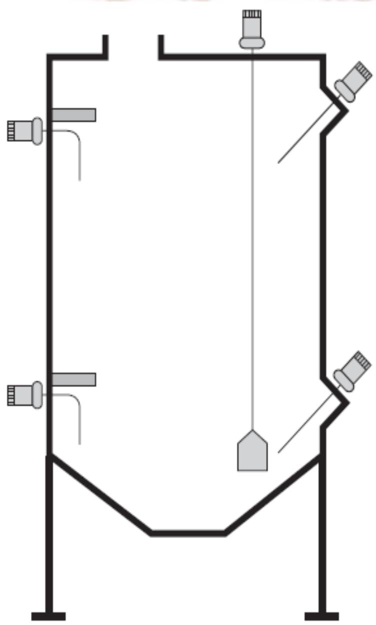


Figure 2

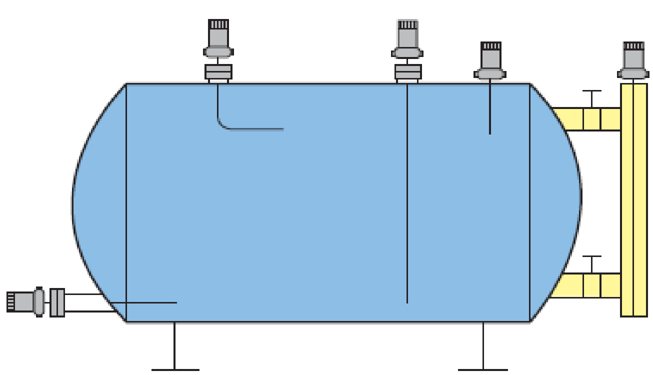


Figure 3

*Electrode Location*— Mounting positions should be carefully considered. They must be clear of the inflow of material as impingement during a filling cycle can cause serious fluctuations in the capacitance generated. Side mounted electrodes with point level controls are typically mounted at a downward angle to allow the measured material to drain or fall from the electrode surface. Electrodes mounted in nozzles should contain a metal "sheath" extending a few inches past the nozzle length. The sheath renders that part of the electrode insensitive to capacitance change, and therefore, ignores the material which may build up in the nozzle.

## CALIBRATION

**Field Calibration Required:**

Capacitive level transmitters must always be calibrated for zero and span in the field. The concentric probe can be tested in a bucket or small tank of the liquid to be measured; all other probes must be calibrated after final installation by changing the material level and adjusting the zero and span pots.

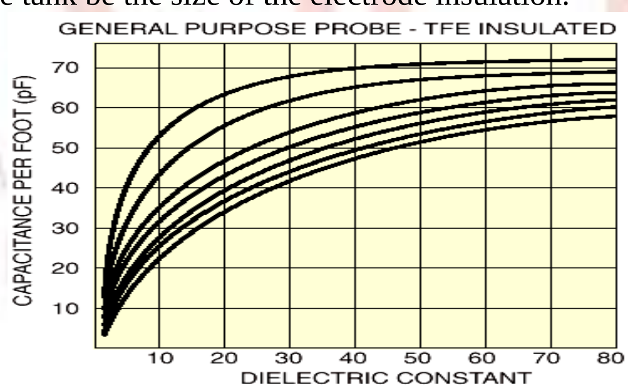
*Unlined Plastic Tanks:* Due to the low gains in large tanks, concentric probes are recommended for unlined plastic tanks to minimize this effect and to provide a ground reference.

*Large Diameter Metal Tanks for Low Dielectric Fluids (such as Hydrocarbons*) : Due to the low gains in large tanks, concentric probes are recommended for metal tanks greater than 20 foot diameter used to measure low dielectric fluids (such as hydrocarbons). Also, if concentric probe is impractical, mount closer to tank wall if possible.

## SELECTION CRITERIA

Selecting the proper level sensing electrode and installing it in the proper location are important factors that contribute to the success of any application. A thorough understanding of these factors is required.

***Electrode Selection***— The electrode is the primary measuring element and must be capable of producing sufficient capacitance change as it becomes submerged in the measured material. Several electrode types are offered, each having specific design characteristics. Capacitance (per foot of submersion) vs. dielectric constant curves are published for each type as installed in various size vessels. For non-conductive materials, these curves are non-linear. Figure 4 shows a typical set of curves. As the size of the tank gets smaller, the capacitance per foot of submersion increases. A conductive material essentially makes the tank be the size of the electrode insulation.




**Note:** Continuous level transmitter applications require a minimum span of 10.0 pF and a maximum span of 10,000 pF.

Table A lists basic capacitance values for different electrodes and tank sizes.

| Table A—Capacitance Values (pF per foot) | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|
| | Non-Conductive Materials/Tank Diameter | | | | | | | | | Conductive Material (Saturation Capacitance) |
| | Dielectric = 2 | | | Dielectric = 20 | | | Dielectric = 80 | | | |
| Type of Sensor | 1" | 24" | 96" | 1" | 24" | 96" | 1" | 24" | 96" | |
| **General Purpose (LV5000 Series):** | | | | | | | | | | |
| TFE Teflon® Insulated | 15 pF | 4 pF | 2 pF | 63 pF | 39 pF | 34 pF | 73 pF | 62 pF | 58 pF | 76 pF |
| Polyethylene Insulated | 16 pF | 6 pF | 3 pF | 123 pF | 57 pF | 46 pF | 167 pF | 120 pF | 117 pF | 189 pF |
| PVDF Insulated | 18 pF | 7 pF | 4 pF | 178 pF | 68 pF | 50 pF | 280 pF | 169 pF | 142 pF | 350 pF |
| **Heavy Duty (LV5100 Series):** | | | | | | | | | | |
| TFE Insulated | 35 pF | 6 pF | 4 pF | 74 pF | 44 pF | 36 pF | 78 pF | 66 pF | 62 pF | 79 pF |
| Polyethylene Insulated | 48 pF | 5 pF | 3 pF | 172 pF | 66 pF | 52 pF | 190 pF | 131 pF | 116 pF | 198 pF |
| PVDF Insulated | 52 pF | 8 pF | 5 pF | 282 pF | 78 pF | 58 pF | 340 pF | 190 pF | 158 pF | 365 pF |
| **Enhanced Performance (LV5200 Series):** | | | | | | | | | | |
| PFA Teflon® Insulated | 23 pF | 5 pF | 3 pF | 147 pF | 160 pF | 48 pF | 187 pF | 128 pF | 114 pF | 207 pF |
| Polyethylene Insulated | 22 pF | 8 pF | 5 pF | 260 pF | 78 pF | 58 pF | 410 pF | 210 pF | 165 pF | 518 pF |
| PVDF Insulated | 25 pF | 10 pF | 8 pF | 330 pF | 80 pF | 60 pF | 640 pF | 260 pF | 205 pF | 950 pF |
| **Flexible Cable (LV5300 Series):** | | | | | | | | | | |
| PFA Teflon® Insulated | 14 pF | 5 pF | 3 pF | 50 pF | 34 pF | 30 pF | 57 pF | 49 pF | 30 pF | 58 pF |
| Polyethylene Insulated | 17 pF | 5 pF | 3 pF | 103 pF | 52 pF | 43 pF | 132 pF | 101 pF | 91 pF | 146 pF |
| PVDF Insulated | 18 pF | 5 pF | 3 pF | 154 pF | 62 pF | 48 pF | 222 pF | 145 pF | 128 pF | 254 pF |
| **Concentric (LV 5500 Series)** | | | | | | | | | | |
| Teflon® | 25 | | | 67 | | | 75 | | | 76 |
| Polyethylene | 25 | | | 142 | | | 175 | | | 189 |
| Kynar | 35 | | | 220 | | | 305 | | | 350 |

***Capacitance level probe selection—***

- The simplest applications are clean, non-coating conductive liquids (such as many water-based liquids) in metallic tanks. An insulated probe must be used, and the fluid is grounded to the probe through the tank. The capacitance change per foot = the saturation capacitance.
- Clean, non-coating conductive liquids (such as many water-based liquids) in non-metallic tanks require the use of a concentric probe. The capacitance change per foot = the saturation capacitance. Clean, non-coating non-conductive liquids (such as many hydrocarbons) in non-metallic tanks require the use of a concentric probe. The capacitance change per foot depends upon the dielectric constant of the material**.**
- Clean, non-coating non-conductive liquids (such as many hydrocarbons) in metallic tanks require special consideration. A bare (un-insulated) probe can be used, but one must insure that the probe does not come in contact with any conductive liquid that may contaminate the non-conductive liquid (such as water in oil). If this occurs, the output will be driven to full scale, regardless of the actual level in the tank. Note that an insulated probe can also be used.
- The probe's metal fitting must be grounded to the metal tank wall, and the distance from the tank wall to the probe must be constant along the entire length of the probe, to provide a linear change in analog output per change in fluid height. If this is not the case (i.e. the tank is "irregular" in shape), or if the tank is greater than 15 ft in diameter, a concentric probe should be used. The capacitance change per foot depends upon the dielectric constant of the material, as well as the tank diameter.
- After making a preliminary probe selection based upon the above considerations, it is important to insure that the capacitance of the probe selected meets the following limitations:

- The capacitance at zero level in the tank is less than 500 pFd, and the maximum capacitance at full span level is more than 10 pFd but less than 10,000 pFd. Also, the zero to span ratio must not exceed 10 to 1. That is, if the zero pf value is 200, the span must be at least 20 pf.

**CONFORMATION TO STANDARDS**

- ATEX **:**ATEX II 1/2D 2D IP6X T
- IEC **:**IEC Ex ia IIC T6
- FM **:** FM (NI) CL I, DIV2, GP ABCD
- CE conformity**:** EMVG (89/336/EWG), Emission: EN 61326: 2004 (class B),

**APPLICATIONS**

- Boiler Drum level measurement
- Caustic level control in the service tank of the product line of an electrolyser plant.
- Steam drum level control
- Feed brine level control
- Separator drums level control in gas plants.

**PARTIAL LIST OF SUPPLIERS**

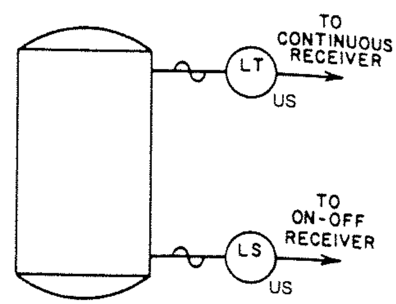
- Omega
- Rosemount
- Siemens
- Intempco
- Honeywell
- Foxboro eckardt
- Yokogawa

# ULTRASONIC LEVEL TRANSMITTER

**Description**

The ultrasonic level Indicator is a low-cost, non contact and easy-to-install level measurement device. It is able to meet the every-day needs of commercial production, as well serving a more specialized role in the technologically-advanced aero-space industry, thus placing it firmly in the category of high-level measurement technology. Unlike other level indicators with limited uses, the easy-to-install. Ultrasonic level indicator is a highly-accurate device with enough specialized uses to ensure that the needs of the customer are met. Rosemount 3100 Series is a liquid level transmitter based on ultrasonic technology that is suitable for many liquid applications.

**Symbol**




Flow Sheet Symbol

**Figure**

*Rosemount 3101 Ultrasonic Level Transmitters*


*Grey line SL T32 Ultra sonic Level monitor*

**SPECIFICATIONS**

***Functional***

- Product Rosemount : Rosemount 3100 Series level transmitters:
- Measurement principle : Ultrasonic, time-of-flight.

***Performance***

- Temp compensation : Rosemount 3101: Automatic Integral temperature.
- Measurement range : Rosemount 3101: 1 to 26 ft (0.3 to 8 m)
  : Rosemount 3102: 1 to 36 ft (0.3 to 11 m)
  : Rosemount 3105: 1 to 36 ft (0.3 to 11 m)
- Level resolution : Better than 1/16" (1 mm)
- Level accuracy : Rosemount 3101± 0.2 in. (5 mm) for <3.3 ft (1 m),
  : ± 0.5% of measured distance for >3.3 ft (1 m)
- Blanking distance : 12 in. (0.3 m) also called dead zone
- Update interval : 1 second

***Electrical***

- Power supply : Loop-powered (two-wire)
  : Rosemount 3101: 12 to 30 Vdc
  : Rosemount 3102: 12 to 40 Vdc
  : Rosemount 3105: 12 to 40 Vdc (non-hazardous area)
  : 12 to 30 Vdc (hazardous area).
- Current Output : Rosemount 3101: Analog 4–20 mA
  : Rosemount 3102: Analog 4–20 mA, HART.
  : Rosemount 3105: Analog 4–20 mA, HART.
- Relay output (3102) : Two integral signal relays, SPST rated 1A @ 30VDC (Inductive) and 2A @ 30VDC

***Environmental***

- Ambient temperature : Rosemount 3101: –4 to 158 °F (–20 to 70 °C)
  : Rosemount 3102 and 3105:–40 to 158 °F (–40 to 70 °C)
- Process temperature : Rosemount 3101:–4 to 158 °F (–20 to 70 °C)
  : Rosemount 3102 and 3105:–22 to 158 °F (–30 to 70 °C)
- Process pressure : –4 to 44 psi (–0.25 to 3.0 bar)

***Physical***

Materials of construction

- Wet-side material : l PVDF.
- Body and cover material : Polyurethane-covered Aluminum.
- Cover seal : Silicone rubber.
- Cover screws : 316 Stainless Steel.
- Transducer body seal : EPDM.
- Mounting thread size : 2-in. NPT or 2-in. BSP.
- Ingress protection : NEMA 4X, IP 66.
- Certifications : CE-mark, FM, CSA, ATEX, or IECEx
- Electromagnetic compatibility: EN61326 (Class B)

**PRINCIPLE OF OPERATION**

Both ultrasonic and sonic level instruments operate on the basic principle of using sound waves to determine fluid level. The frequency range for ultrasonic methods is ~20–200 kHz, and sonic types use a frequency of 10 kHz. As a top-of-tank mounted transducer directs waves downward in bursts onto the surface of the material whose level is to be measured. Echoes of these waves return to the transducer, which performs calculations to convert the distance of wave travel into a measure of level in the tank. A piezoelectric crystal inside the transducer converts electrical pulses into sound energy that travels in the form of a wave at the established frequency and at a constant speed in a given medium. The medium is normally air over the material's surface but it could be a blanket of nitrogen or some other vapor. The sound waves are emitted in bursts and received back at the transducer as echoes. The instrument measures the time for the bursts to travel down to the reflecting surface and return. This time will be proportional to the distance from the transducer to the surface and can be used to determine the level of fluid in the tank.

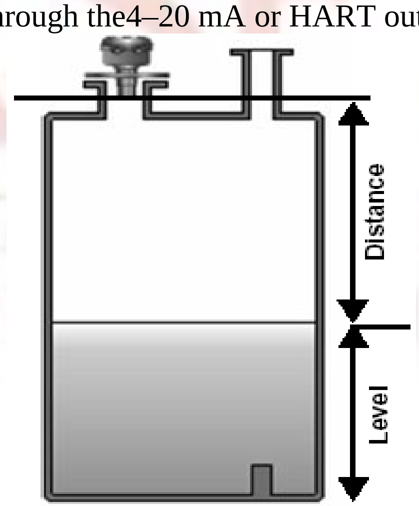
Ultrasonic or sonic methods can also be used for point level measurement, although it is a relatively expensive solution. An ultrasonic gap technique is an alternative way to measure point level with low-viscosity liquids. A transmit crystal is activated on one side of a "measurement gap" and a receive crystal listens on the opposite side. The signal from the receive crystal is analyzed for the presence or absence of tank contents in the measurement gap. These no contact devices are available in models that can convert readings into 4–20 mA outputs to DCSs, PLCs, or other remote controls.

**Measurement principle:** Ultrasonic pulse signals are transmitted and reflected from the liquid surface. The transmitter 'listens' for reflected signals (echoes) and measures the time-delay between transmitting and receiving. The distance to the liquid surface is automatically calculated using the computed time-delay.

***Distance = Speed of sound in air * (Time-delay / 2)***

An integral temperature sensor continuously measures the air temperature around the transmitter. It then computes the *speed of sound in air*, automatically compensating the *Distance* for temperature effects.

**Level measurement:** When programmed with the bottom reference of the application, usually the tank bottom and the transmitter will calculate the liquid depth (Level). The calculated Level can be sent through the4–20 mA or HART output.

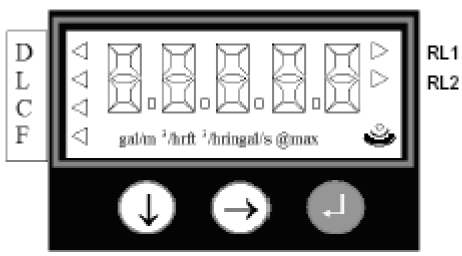


## DESIGN AND CONSTRUCTION


***PVDF transmitter wetted part***

**Housing:** The housing is available in aluminum, and has two 1/2–14 NPT cable/conduit entries.  Wetted parts are made of corrosion resistant PVDF.

**Integral display and push buttons:** The central area of the display allows up to five alphanumeric measurement or data characters to assist when programming.



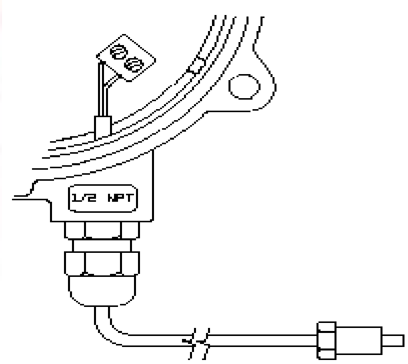

Integral push-buttons and display

**Threaded Connection:** Threads: 2-in. BSPT or 2-in. NPT.

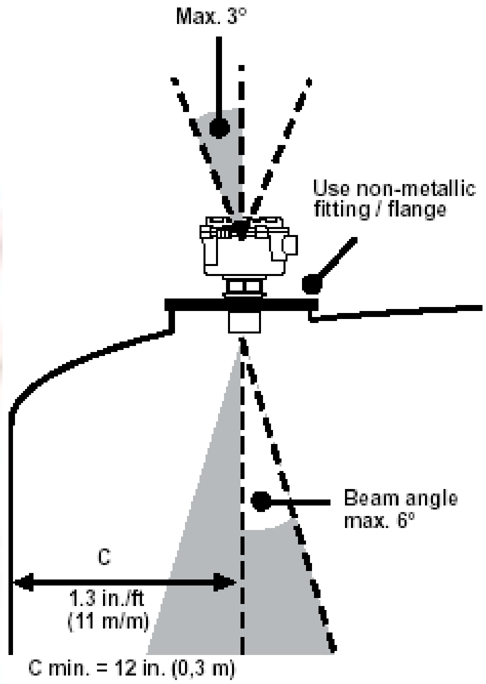
**Signal output:** The 3101 has an analog 4–20 mA output, which is powered by the voltage supplied to the transmitter.

**Power supply:** The 3100 Series requires an external power supply. For 3101: 12 to 30 Vdc

**Remote temperature sensor:** All models have an integrated sensor for automatically compensating for temperature effects. For transmitter installations where the integral temperature sensor is not representative of the air / medium temperature in the process, the use of an external temperature sensor improves reliability. The sensor is installed in between the transmitter and the liquid surface, or in a shaded area of an open channel.



**INSTALLATION**




**Mounting considerations**

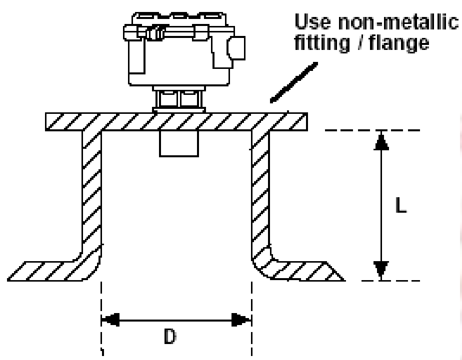
a. The transmitter should be mounted above the liquid surface using the 2-in. thread provided. To help mounting, optional flanges and bracket kits are available.
b. Mount the transmitter vertically to ensure a *maximum echo size* received.
c. Obstructions within the beam angle generate strong false echoes; so position the transmitter to avoid this situation.
d. To avoid detecting unwanted objects in the tank or well, maintain a distance of at least 1.3 in. from the center line of the transmitter for every foot (11 cm for every meter) range to the obstruction.
e. It is recommended the transmitter be mounted no closer than 12 inches (0.3 m) to the wall to avoid losing echo size.
f. Avoid applications where heavy condensation could form on the transmitter.
g. If the transmitter is mounted in a stand-off or nozzle, the transmitter face should protrude at least 0.2 in. (5 mm) into the tank.
h. In environments where direct sunlight can cause high surface temperatures on exposed instruments, a sun-shade, or remote temperature sensor option, is recommended.

**Liquid surface conditions**

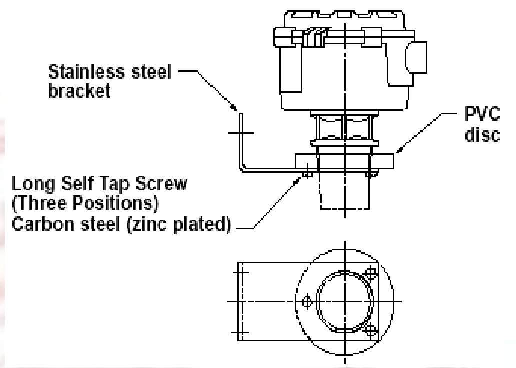
a. Foaming liquids (are poor ultrasonic reflectors) can reduce the size of the returned echo. An ultrasonic transmitter should be mounted over an area of clear liquid.
b. Do not mount the transmitter directly over any inlet stream.
c. A still-pipe can be used to avoid foam and turbulence.

**In-tank effects**

a. Stirrers or agitators can cause a vortex, so try to mount the transmitter off-center of any vortex to maximize the return echo.
b. As stirrer blades become uncovered, they create echoes as they pass through the ultrasonic beam. The transmitter can be tuned on-site to ignore these false echoes.

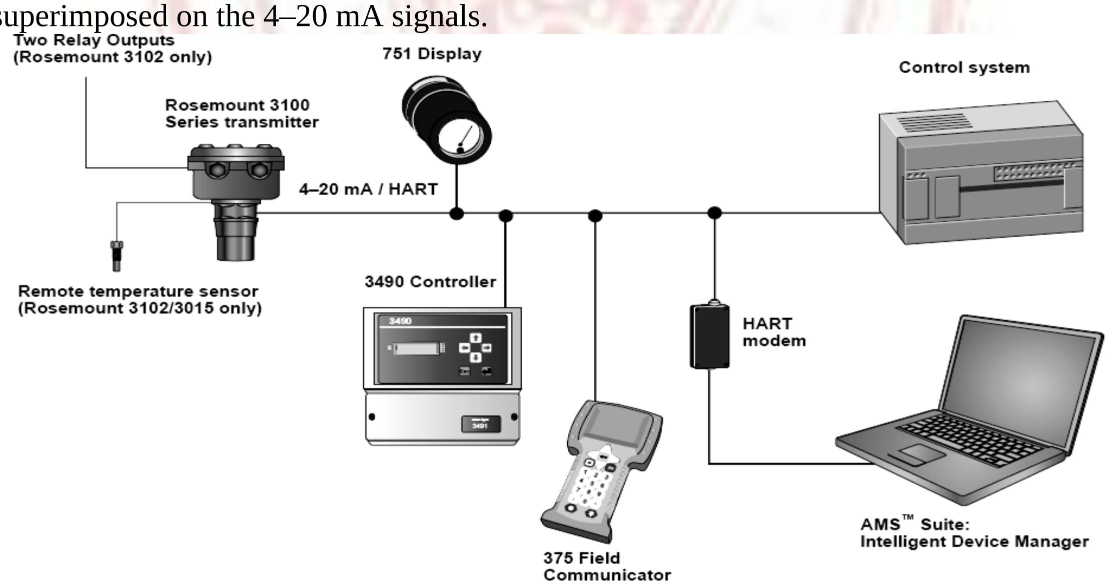



*Mounting in a nozzle or stand-off*

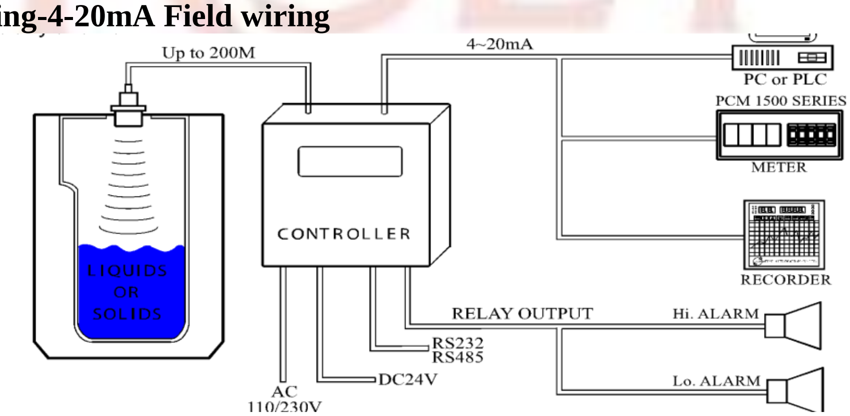



*Mounting with optional bracket kit*

**System Integration:** The Rosemount 3100 Series transmitter uses the same two wires for power supply and communication. The 3100 Series requires an external power supply: 3101: 12 to 30 Vdc. Measurement data is transmitted as an analog 4–20 mA signals as standard. On The Rosemount 3102 and Rosemount 3105, a digital HART signal is superimposed on the 4–20 mA signals.




**Output Wiring-4-20mA Field wiring**



**CALIBRATION**

- Instrument calibration is carried out during start-up after installation of SL level meter. It involves simple site calibration which utilizes factory calibrated data to re-calibrate the instruments. This includes setting instrument to work, changing of instrument range, calibration of 4mA & 20mA output current.
- Calibration is easy with the built-in 3 button keypad. The SLT32 offers simple menu selection of measurement units (gallons, liters etc.), calculates volume in horizontal round tanks, or flow rate (and total) through any flume or weir.
- Range full scale: Range full scale is printed as `RANGE F.S.' in the converter unit. This is for the adjustment of full scale range of the instrument. i.e. when the tank is full.
- Range zero: Range zero scale is printed as `RANGE ZERO' in the converter unit. This is for the adjustment of range zero of the instrument. i.e. when the tank is empty
- Zero offset: Zero offset is printed as `ZERO OFFSET' in the converter unit. This is for the correction of level offset due to sensor position. i.e. to offset the reading to match the actual water level.

**SELECTION CRITERIA**

- For hazardous locations, the ultrasonic sensor is rated Intrinsically Safe with an optional safety barrier. The standard PVC Sensor (optional Teflon) is rated for measurement ranges up to 32 ft/10 m, or use the optional PVC Sensor rated for 50 ft/15.6 m measurement range. Options include 3 additional control relays (6 total) and a built-in 50,000 point Data Logger.
- Explosion-proof type model: rt3000a measuring range: 0～10m and 0-12m blind spot: 0.25m～0.6m measurement accuracy± 3mm or 3 ~.
- Ultrasonic flow meter has high accuracy, better reliable, high quality and low price. it widely used in measuring water, chemical, petro chemical, sea water, sewage

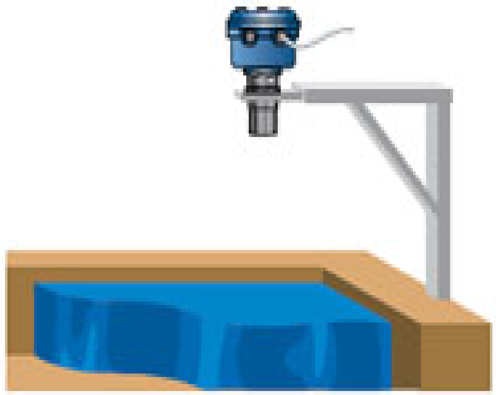
**CONFORMATION TO STANDARDS**

- Factory Mutual (FM) Approvals : Intrinsically Safe for Class I, Div. 1, Groups A, B, C and D
  : Intrinsically Safe for Class I, Zone 0, AEx ia IIC
- Canadian Standards Association : Intrinsically Safe for Class I, Div. 1, Groups A, B, C, and D
  : Intrinsically Safe for Class 1, Zone 0, Ex ia IIC
- ATEX Intrinsically Safe Approval : Intrinsically Safe for II 1 G, EEx ia IIC
- IECEx Approval : Intrinsically Safe for Zone 0, Ex ia IIC

**APPLICATIONS**

- Level measurement (height above datum).
- Distance measurement (distance from a datum).
- Volume measurement.
- Differential level measurement.
- Open channel flow measurement.
- Pump control
- Motion control
- Roll diameter
- Loop control
- Liquid level
- Solids level
- People detection
- Security
- Proximity sensing
- Dimensioning, Positioning and much more.

**Storage Tanks Vertical Tanks** **Buffer Tanks Horizontal Tanks**



Open Air Applications

Open channel Flow

**PARTIAL LIST OF SUPPLIERS**

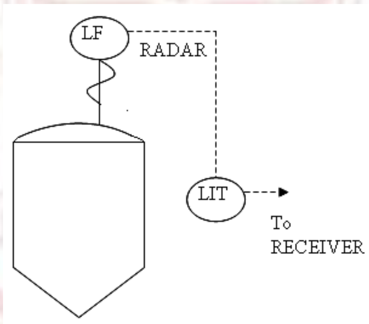
- Rosemount
- Siemens
- Honeywell
- Yokogawa

# RADAR LEVEL METERS

## Description

Radar, an acronym for the phrase radio detection and ranging, was applied to military use in the 1930s to detect the presence of aircraft. Today, radar has many useful applications. Types of radar signals: The two most common types of radar waves or signals used for level measurement are Pulse radar and Frequency Modulated Continuous Wave, or FMCW for short. *Pulse Radar* -Pulse radar gauges, frequently referred to as time of-flight radar, transmit a short, non-continuous pulse signal. *FMCW Radar* -Unlike pulse radar, FMCW radar gauges transmit a continuous signal that changes in frequency. When the signal reaches the surface of the material, the signal is reflected back to the radar gauge. The Rosemount 5400 Series is a reliable 2-wire radar level transmitter for liquids and slurries. It measures level directly and is unaffected by most fluid property changes, including temperature, pressure, vapor gas mixture, density, turbulence, bubbling/boiling, dielectric, pH, viscosity, crystallization, etc.

## Symbol




## Figure

***Rosemount 5400 Series radar level transmitter***

## SPECIFICATIONS

### *Functional*

- Radar Level Transmitter Power
  AC: 115 VAC, 60 Hz (± 20%), 1.7 VA
  DC: 12 to 30 VDC, 0.07 Amps max. @ 24 VDC
- Radar Level Transmitter Outputs
  Signal: 4-20 mA, 6.1 uA resolution; 750 ohms
  Communication: RS232
- Accuracy: ±0.25% of maximum sensor range (in air)
- Frequency: 6.3 GHz
- Transmitter Power: 50 uW average
- Operating Temp: -40°C to 60°C (-40°F to 140°F)
- Ambient Temp : -40°C to 80°C (-40°F to 176°F)
- Storage Temp : -50°C to 90°C (-58°F to 194°F)
- Operating Pressure:150 psi max
- Beam Angle:12 degrees
- Calibration: Push-button or optional programmable

### *Physical*

- Process connection: 2" NPT
- Conduit Entry:1/2" NPT standard
- Housing: Aluminum or 316L stainless steel
- Ingress Protection: NEMA 4 (IP65)
- Approvals: FCC Part 15 - low-power communication device
- Weight:3.6Lbs (1.63Kg)
- Dimensions: 4" diameter x 18" long (10cm dia. x 45.7cm long)
- Antenna: Polypropylene over dielectric rod
- Installation Category: Class II

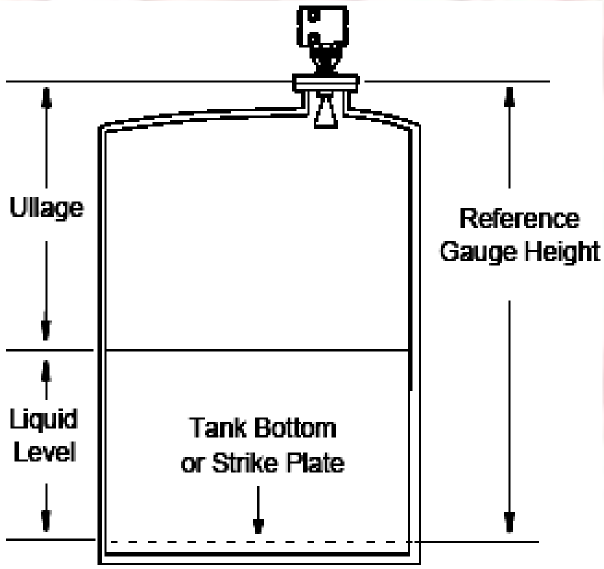
### *Performance*

- Measurement Principle: Pulsed, free propagating Radar; 5402: ~26 GHz; 5401: ~6 GHz
- Maximum Measuring Range: 115 ft (35 m) from flange
- Instrument Accuracy at ref. conditions (1): 5402: ± 0.1 in. (± 3 mm) ; 5401: ± 0.4 in. (± 10 mm)
- Repeatability: ± 0.04 in. (± 1 mm) at 16.4 ft (5 m) distance
- Resolution: 0.04 in. (1 mm)
- Near Zone Distance: 1.3 ft (0.4 m) from lower end of the antenna
- Near Zone Accuracy: 5402: ± 0.6 in. (± 15 mm); 5401: ± 1.2 in. (± 30 mm)
- Transition Zone (2): 6 in. (150 mm) from lower end of the antenna
- Minimum Dielectric Constant: $\xi$ r = 1.4
- Temperature Drift: 0.05 %/10 K in temperature range -40°F to 176°F (-40°C to 80°C)
- Update Interval: 1 second
- Max Level Rate: 1.6 in. /s (40 mm/s) as default, adjustable to 7.1 in. /s (180 mm/s)

## PRINCIPLE OF OPERATION

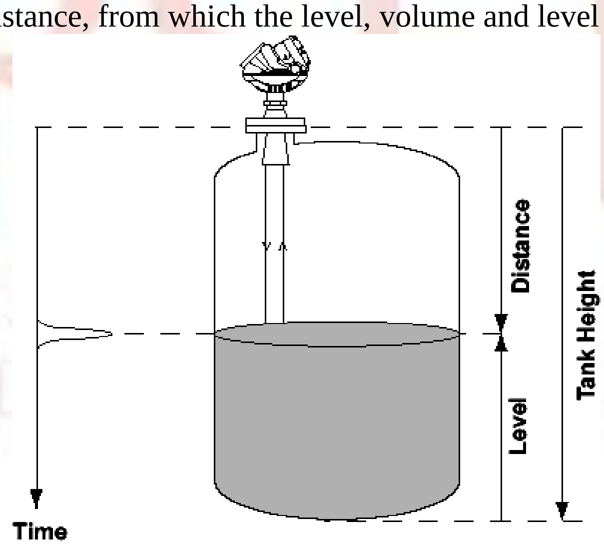
Radar gauges determine the level of a product in a tank by measuring the *Ullege* (also called “outage”). The ullage, or vapor space, is the distance from the radar gauge mounting location to the surface of the material .The level measurement is determined by subtracting the *ullage* from the distance the radar gauge is mounted above the tank bottom (or reference gauge height.)

The *reference gauge height* is the fixed distance from the bottom of the tank (or strike plate) to the face of the radar gauge mounting flange. The reference gauge height establishes a reference point from which all level and calibration measurements are taken.



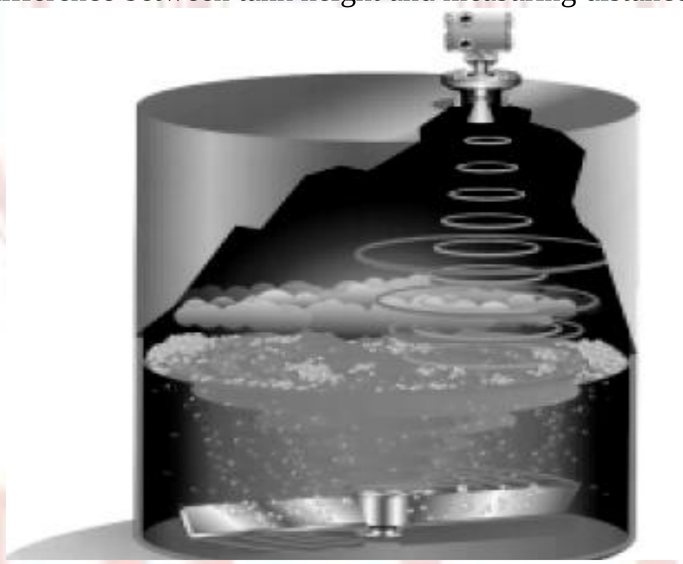

Level = Reference Gauge Height – Ullage

**Measuring principle:** The distance to the surface is measured by short radar pulses, which are transmitted from the antenna at the tank top. When a radar pulse reaches a media with a different dielectric constant, part of the energy is reflected back to the transmitter. The time difference between the transmitted and the reflected pulse is proportional to the distance, from which the level, volume and level rate, are calculated.



***Frequency Modulated Continuous Wave (FMCW)***

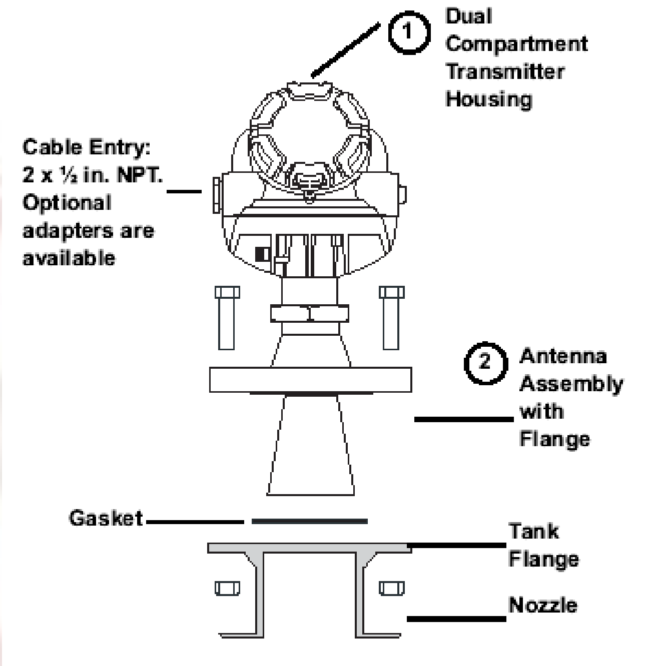
- A radar signal is emitted via an antenna, reflected on the product surface and received after a time t. The radar principle used is FMCW (Frequency Modulated Continuous Wave). The FMCW-radar transmits a high frequency signal whose frequency increases linearly during the measurement phase (called the frequency sweep).
- The signal is emitted, reflected on the measuring surface and received with a time delay, t. Delay time, $t=2d/c$, where d is the distance to the product surface and c is the speed of light in the gas above the product. For further signal processing the difference $\Delta f$ is calculated from the actual transmit frequency and the receive frequency.
- The difference is directly proportional to the distance. A large frequency difference corresponds to a large distance and vice versa. The frequency difference $\Delta f$ is transformed via a Fourier transformation (FFT) into a frequency spectrum and then the distance is calculated from the spectrum. The level results from the difference between tank height and measuring distance



## DESIGN AND CONSTRUCTION

### Components

The Rosemount 5400 Series transmitter consists of the transmitter housing and an antenna assembly. The transmitter housing contains all radar electronics. The *radar electronics* is the heart of the radar level transmitter. It produces an electromagnetic wave by using an oscillator that converts direct current (dc) power into a microwave frequency or signal. It also receives the return signal. The signal passes from the electronics through a w*aveguide*. The waveguide is the entire path from the electronics to the antenna. The antenna assembly seals off the tank atmosphere from the transmitter housing and its surroundings. The 5400 Series is delivered as a single assembly for easy out-of-box installation, with no special tools. The transmitter is available with Intrinsically Safe (1) / Non-Incendive or Explosion-proof / Flameproof approvals.




**1 Transmitter housing**

There are two models available with different frequencies: the 5402 (~26 GHz, K-band) and the 5401 (~6 GHz, C-band). The models utilize different frequencies, and antennas, so transmitter housings are not interchangeable. The transmitter housing has two integral ½-in. NPT cable entries for conduit / cable connections. Adapters to other connection types are available. The dual-compartment housing separates cabling from the electronics for increased moisture resistance. The transmitter housing can be rotated and removed from the antenna assembly for service or replacement, without opening the tank.

**2 Antenna assembly**

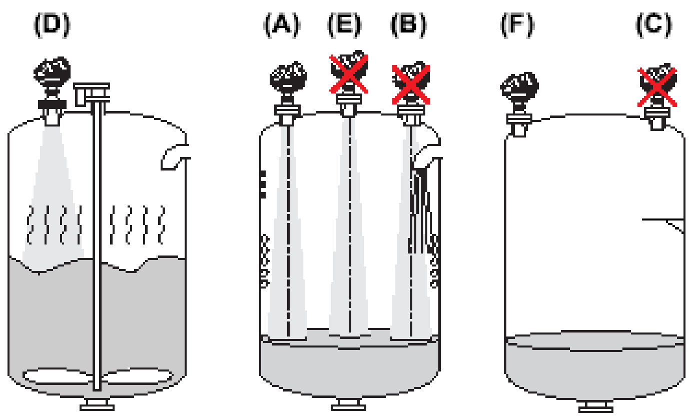
The antenna assembly is the only part in contact the tank atmosphere, and it consists of an antenna, an O-ring, a tank seal, a flange or a thread (NPT). It is typically a cone shaped device made of non-corrosive stainless steel. The *antenna* focuses the radar beam and controls the signal beam width by helping to keep the signal focused on its target so it doesn't spread out over the entire tank and give false echoes. The size of the antenna is inversely proportional to the frequency; the higher the frequency the smaller the antenna.

The Rosemount 5400 Series Radar Level transmitters are equipped with high performance cone, rod and process seal antennas in various sizes and materials. It is generally recommended that is to use the largest possible antenna be used to achieve highest gain.

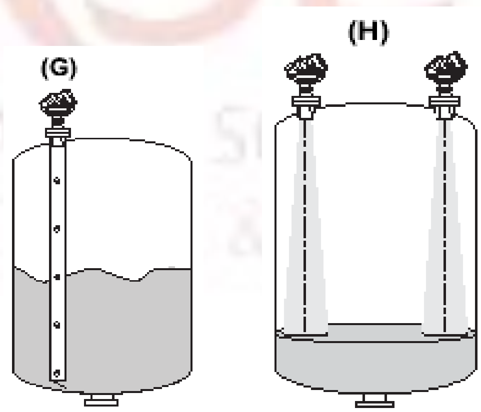
**INSTALLATION**

**Mounting location:**

- For optimal performance, the transmitter should be installed in locations with a clear and unobstructed view of the level surface (A)
- Filling inlets creating turbulence (B), and stationary metallic objects with horizontal surfaces (C) should be kept at a distance, outside the signal.
- Agitators with large horizontal blades may reduce the performance of the transmitter, so install the transmitter in a location where this effect is minimized.
- Vertical or slanted blades are often invisible to radar, but create turbulence (D)
- Do not install the transmitter in the center of the tank (E)
- Because of circular polarization, there is no clearance distance requirement from the tank wall if it is flat and free from obstructions such as heating coils and ladders (F). Usually, the optimal location is 1/3 of the radius from the tank wall




- The antenna is normally aligned vertically. A metal bridle / still-pipe can be used to avoid disturbing objects, turbulence, and foam (G)
- The walls in non-metallic tanks are invisible to the radar signal, so nearby objects outside the tank may be detected
- Choose the largest possible antenna diameter for installation. A larger antenna concentrates the radar beam, and will be less susceptible to obstruction interference. It also assures maximum antenna gain
- Multiple 5400 transmitters can be used in the same tank without interfering with each other (H)



**Process connections:**

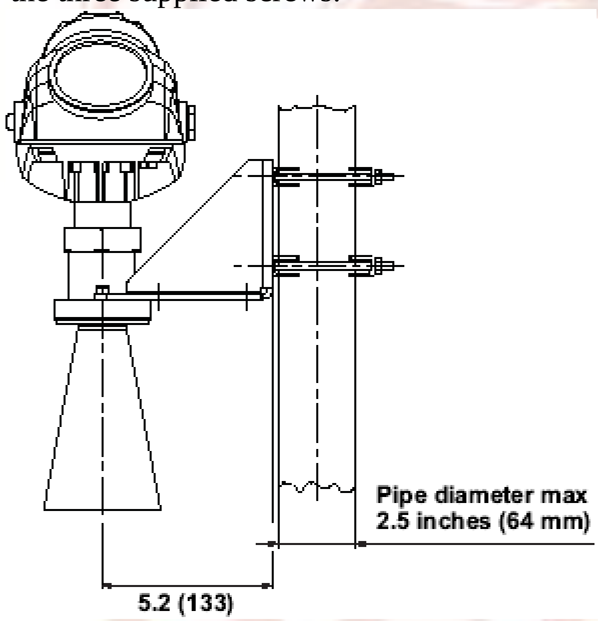
Bracket mounting is available for Rosemount 5401 and 5402 with SST Cone Antenna (2S-8S) and Rosemount 5401 with Rod Antenna (3R-4R)

***Bracket mounting on pipe***

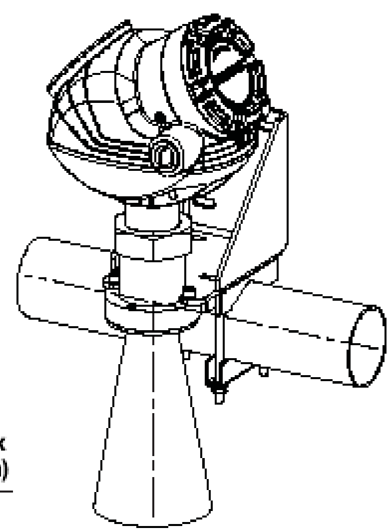
- Put the two U-bolts through the holes of the bracket. Holes are available for both vertical and horizontal pipe mounting.
- Put the clamping brackets on the U-bolts and around the pipe.
- Fasten the bracket to the pipe using the four supplied nuts.
- Mount the transmitter with antenna to the bracket. Secure with the three supplied screws.

***Bracket mounting on wall***

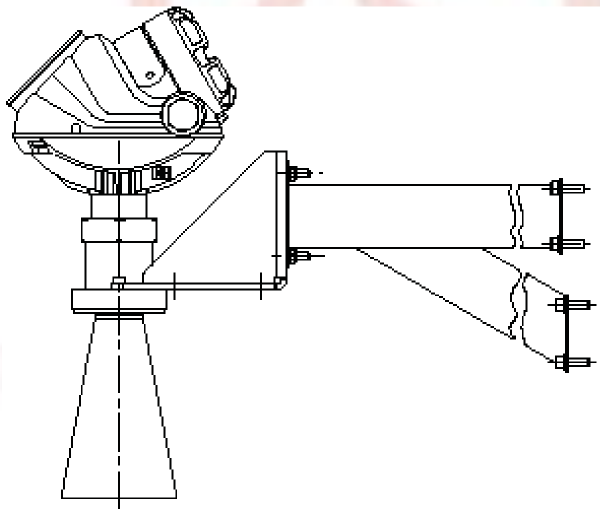
- Mount the bracket directly to the wall with screws suitable for the purpose.
- Mount the transmitter with antenna to the bracket, and secure the installation with the three supplied screws.



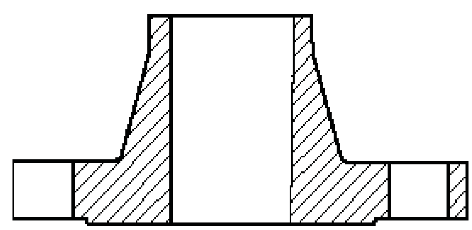

***Pipe mounting (vertical pipe)***



***Pipe mounting (horizontal pipe)***



***Wall mounting***

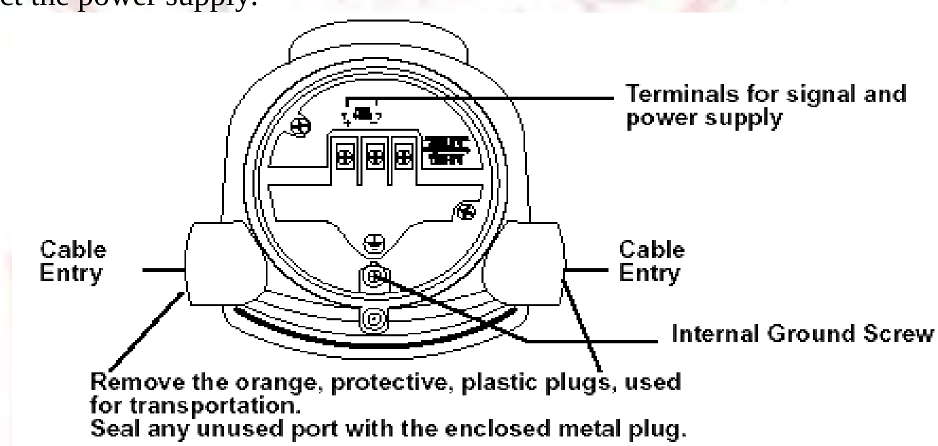


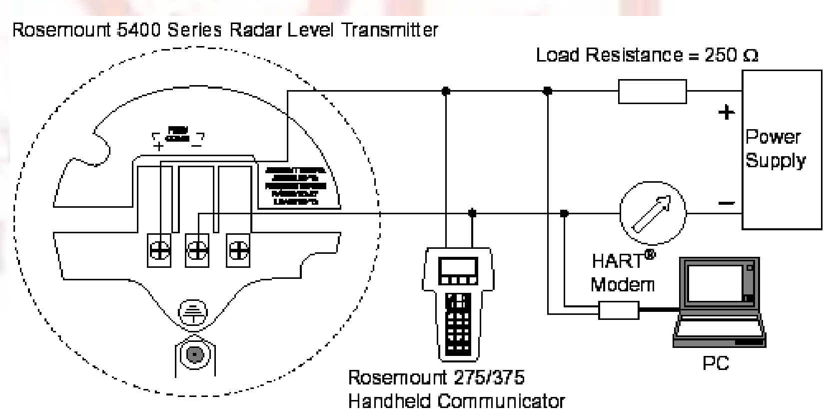
***Standard Flanges Cone and Rod Antennas***

**Wiring connections**
It is recommended that shielded twisted pair wiring (18-12 AWG), is suitable for the supply voltage and approved for use in hazardous areas. The 5400 Series transmitter operates using a power supply ranging from 16-42.4 V dc (16-30 V dc in IS applications, 20-42.4 V dc in Explosion-proof/Flameproof applications). The Rosemount 275/375 Handheld Communicator requires a minimum load resistance (RL) of 250 Ohms within the loop in order to function properly, see diagrams below

**To Connect the Transmitter**

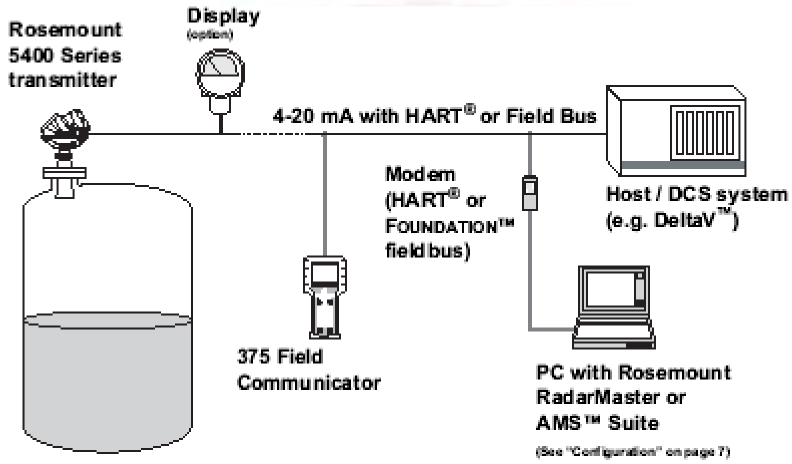
- Make sure the housing is grounded in accordance with Hazardous Locations Certifications, national, and local electrical codes.
- Make sure the power supply is disconnected.
- Remove the terminal block cover
- Pull the cable through the cable gland/conduit. For Explosion-proof/ Flameproof installations, use cable glands or conduit entry devices certified Explosion-proof or Flameproof. Install the wiring with a drip loop, with the bottom of the loop lower than the cable/conduit entry. Connect wires
- Remove the orange, protective, plastic plugs, used for transportation. Seal any unused port with the enclosed metal plug.
- Mount the cover and tighten the cable gland, making sure the cover is on securely to meet explosion-proof requirements. For ATEX, IECEx, NEPSI and TIIS installations, lock the cover with the Locking screw.
- Connect the power supply.



## System Integration

The Rosemount 5400 Series is a loop-powered device (it uses the same two wires for power supply and communication) that supports both FOUNDATION™ field bus, and the analog 4-20 mA with superimposed digital HART®




**SELECTION CRITERIA**

*Nozzle considerations:* Special considerations may have to be taken due to the nozzle, depending on the selection of transmitter model and antenna.

*Valves:* The 5400 Series transmitter can be isolated from the process by using a valve:

- Use a full-port ball valve
- The 5402 is required, and the Process Seal Antenna is the preferred choice, since it does not require a spool piece.
- The cone antenna can also be used
- Ensure there is no edge between the ball valve and the nozzle / pipe, the inside should be smooth.
- Valves can be combined with pipes.

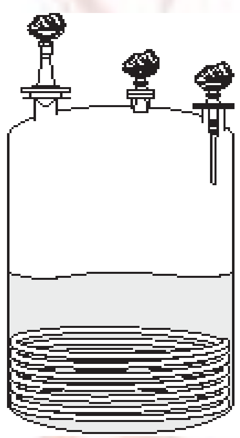
**CONFORMATION TO STANDARDS**

- Factory Mutual (FM) Approvals : Intrinsically Safe Approval
  : Intrinsically Safe for Class I, Div.1, Groups A, B, C and D
  : Intrinsically Safe for Class I, Zone 0, AEx ia IIC
- Canadian Standards Association : Intrinsically Safe Approval
  : Intrinsically Safe for Class I, Div. 1, Groups A, B, C, and D
  : Intrinsically Safe for Class 1, Zone 0, Ex ia IIC
- ATEX Intrinsically Safe Approval : Intrinsically Safe for II 1 G, EEx ia IIC
- IECEx Approval : Intrinsically Safe for Zone 0, Ex ia IIC
- CENELEC EEx d IIc T6 Certificate No. Ex 97D1291X
- CENELEC EEx ia IIc T5 (-40°C to +40°C) Certificate No.Ex97D2379X
- CENELEC EEx ia IIc T4 (-40°C to +80°C) Certificate No.Ex97D2379X

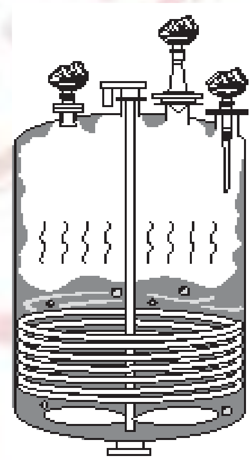
## APPLICATIONS

Radar gauges are a non-contacting method of measuring level. The gauges provide an attractive alternative in processes where a standard insertion device becomes fouled or corroded. The gauges are insensitive to many problematic liquid characteristics such as changing density, dielectric, or conductivity. The advanced radar technology of the gauges provides accurate level measurement not found in other level technologies, while emitting safe signals in the microwave range. Its applications include...

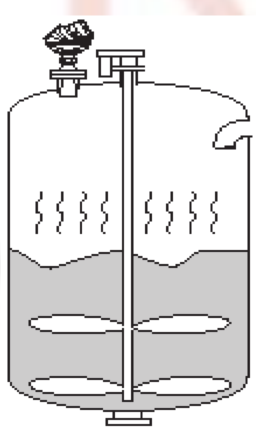
- Temperature
- Pressure
- Analysis
- Batching Systems
- Tanks, vessels, and containers with calm surfaces
- Overfill and under fill detection
- Sludge's and slurries: Applications like mud, pulp-stock and lime slurries are ideal for non-contacting measurement.
- Corrosives: Radar measurement is ideal for most corrosive products, such as caustics, acids, solvents and many other chemicals.
- Sticky, viscous and crystallizing products.
- Reactor vessels
- Underground tanks



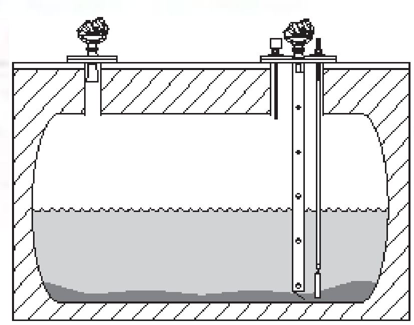
**Corrosives**



**Sticky, viscous and crystallizing products**



**Reactor vessels**



**Underground tanks**

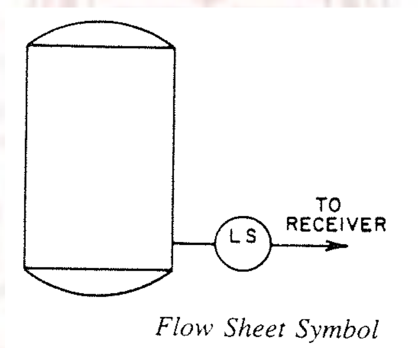
**PARTIAL LIST OF SUPPLIERS**

- Endress + Hauser Instruments
- Siemens
- Krohne
- TN Technologies Inc.
- Vega Controls

# VIBRATING FORK LEVEL SWITCH

**Description**
Vibrating fork level sensor uses the principal of tuning fork vibration technology. When a tuning fork is struck, it vibrates. This vibration occurs at what is known as the forks 'natural frequency'. This frequency will vary depending on the relative size, shape, and material of the forks. Vibrating short fork technology, making it suitable for virtually all liquid applications. Features include a complete range of process connections, wide choice of housing and wetted parts materials, four different switching functions, extended fork lengths, hazardous area, self checking and condition monitoring, and overfill approvals. The 2120 can withstand temperatures up to 302°F (150°C) and pressures to 1450 psig (100 bar). This combination of features makes it configurable to almost all requirements.

**Symbol**




**Figure**

***The Rosemount 2110 vibrating fork liquid point level switch***

**SPECIFICATIONS**

***Functional***

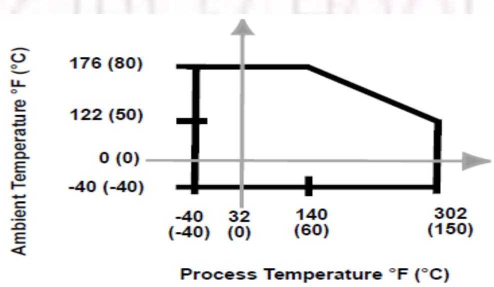
- Maximum Operating Pressure:- Final rating depends on tank connection
- Hygienic Connection:- 435 psig (30 bar)
- Threaded Connection
- Liquid Density:- Minimum 37.5 lb/ft3 (600 kg/m3)
- Liquid Viscosity Range:- 0.2 to 10,000 cP (centipoises)
- Solids Content and Coating: - Maximum recommended diameter of solid particles in the liquid is 0.2-in. (5 mm).For coating product, avoid bridging of forks.
- Switching delay:- 1 sec dry to wet/wet to dry
- CIP (Clean In Place):-Withstands steam cleaning routines up to 302°F (150°C)
- Hysteresis (water):- ±0.039-in. (± 1mm) nom.
- Switching point (water):- 0.5-in. (13mm) from tip (vertical) / from edge (horizontal) of fork (this will vary with different liquid densities)

***Electrical***

- Switching mode:- User selectable (Dry =on or Wet =on) by selecting plug wiring
- Cable connection:-Via 4-way plug provided - DIN43650. Max. Conductor size - 15AWG. Orientation 4-position (90/180/270/360 deg).
- Conductor size:- Maximum 0.06 inch2 (1.5 mm2)
- Cable gland:- PG9 provided - cable diameter 0.24 to 0.31-in. (6 to 8 mm)
- Protection: - Reverse polarity insensitive. Missing load / short circuit protection
- Grounding: - The 2110 should always be grounded either through the terminals or using the external ground connection provided.

***Physical***

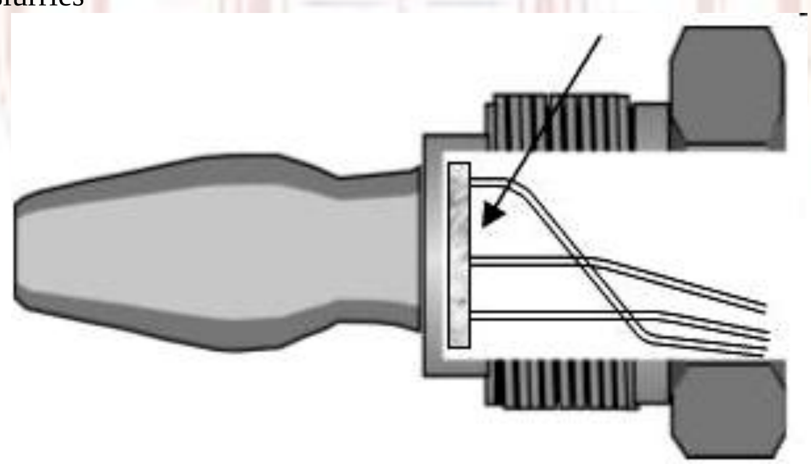
- Process material:-316L Stainless Steel (1.4404) For Tri-Clamp connection hand polished to better than 0.8 µm. Gasket material for 1 in. BSPP (G1) is Non-asbestos BS7531 Grade X carbon fiber with rubber binder.
- Housing materials:-
  Body: 304 SST with polyester label
  LED window: Flame retardant Polyamide (Pa12) UL94 V2
  Plug: Polyamide glass reinforced
  Plug seals: Nitrile butadiene rubber 122-in. (50 mm)
- Mounting:- 3/4-in. BSPT (R) or NPT; 1-in. BSPT (R) or BSPP (G) thread, or Hygienic 2-in. (51 mm) Tri-clamp fitting
- Ingress of Protection Rating:- IP66/67 to EN60529
- Temperature

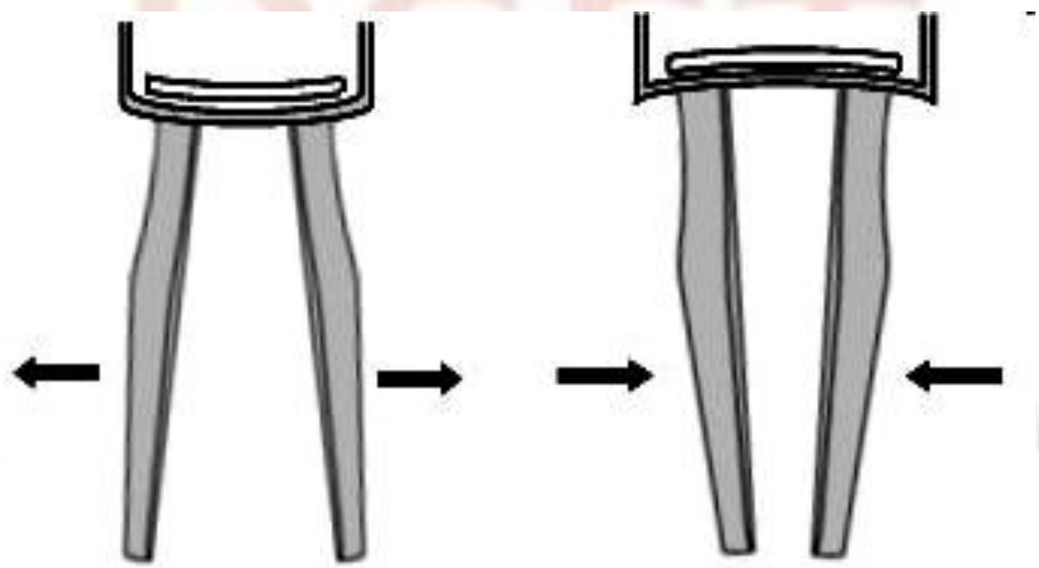


## PRINCIPLE OF OPERATION

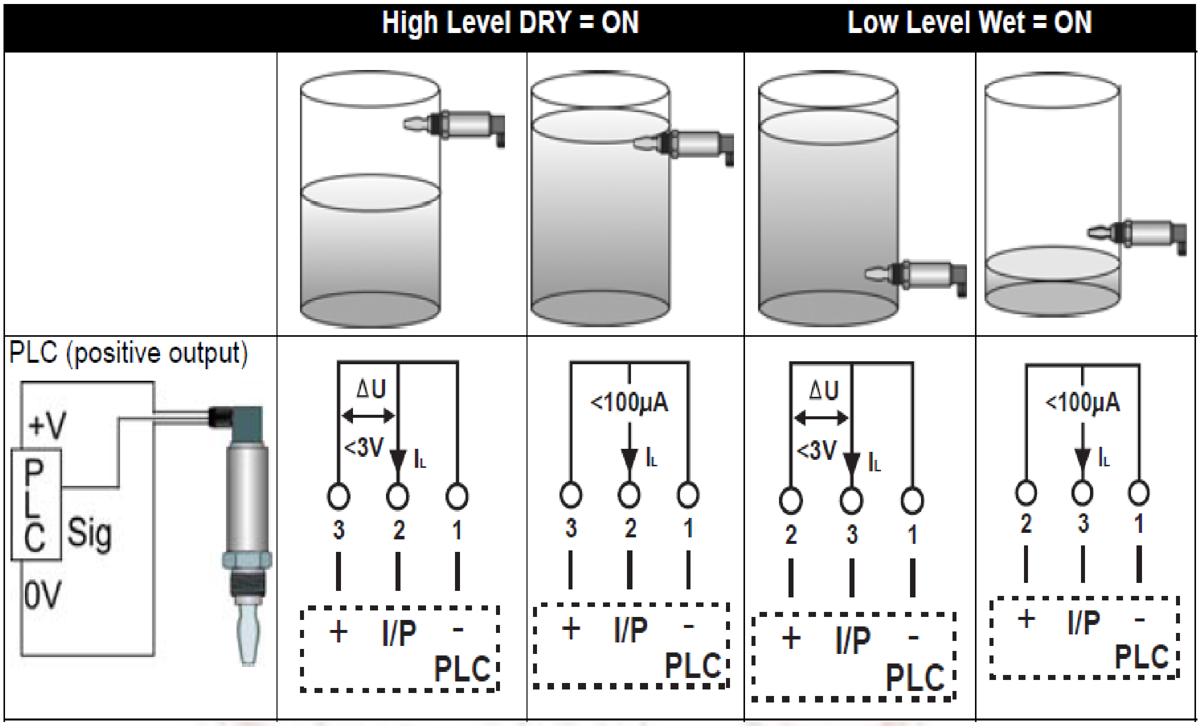
The Rosemount 2110 is a liquid point level switch designed using the principle of a tuning fork The Vibration forks are driven to their natural frequency of oscillation by a piezo-electric crystal. Changes to this frequency are continuously monitored. When the 2100 is used as a low alarm, the liquid in the vessel drains down past the fork, resulting in a change of natural frequency; this is detected by the electronics which switch the output state. When used as a high alarm, the liquid rises in the vessel, makes contact with the fork and again the output switches**.**

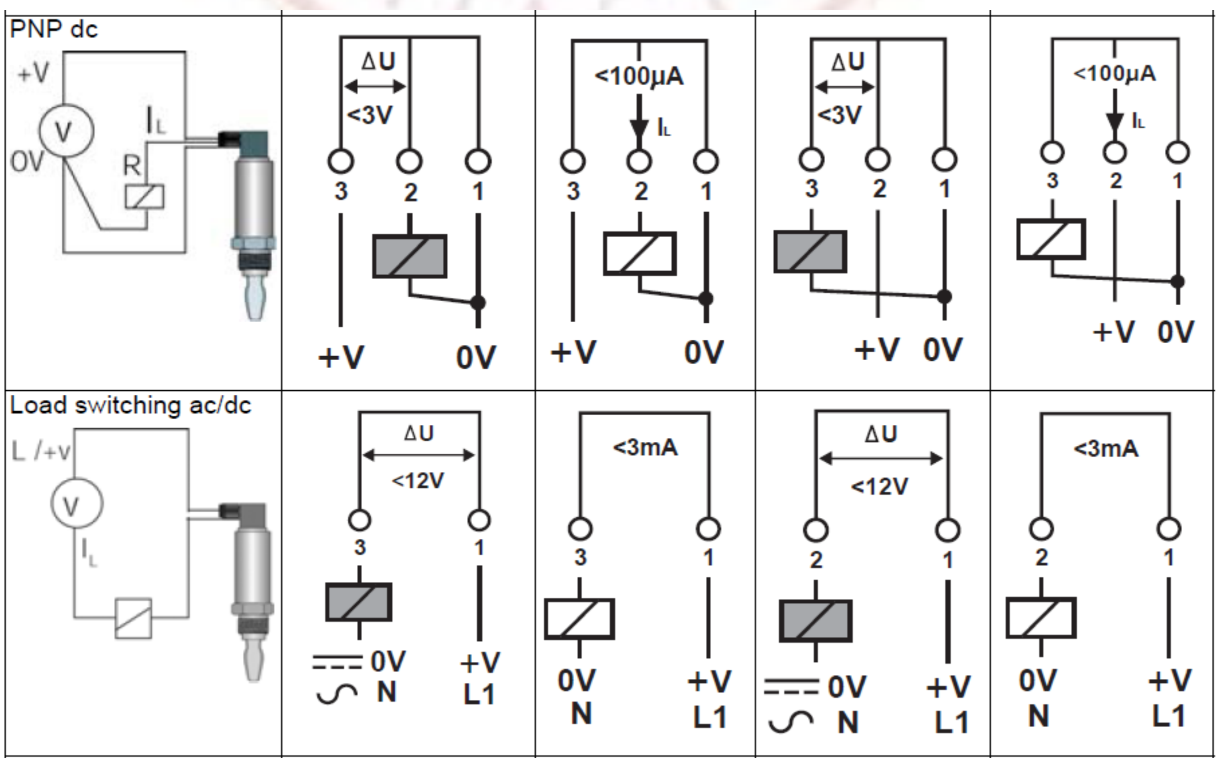
**Short fork technology**: The natural frequency (~1300Hz) of the fork is chosen to avoid interference from plant vibration which may cause false switching. This also gives short fork length for minimal intrusion into vessel and pipe. Using Short Fork Technology, the Rosemount 2100 is designed for use in virtually all liquid applications. Extensive research has maximized the operational effectiveness of the fork design making it suitable for almost all liquids, including coating liquids (avoid bridging of forks), aerated liquids, and slurries





## Function


High Level DRY = ON
Low Level Wet = ON
PLC (positive output)
+V
PLC
Sig
0V
ΔU
<3V
<100μA
IL
3 2 1
2 3 1
+ I/P -
PLC


PNP dc
+V
V
0V
IL
R
ΔU
<3V
<100μA
3 2 1
+V 0V
Load switching ac/dc
L /+v
ΔU
<12V
<3mA
3 1
2 1
0V
N
+V
L1

**DESIGN AND CONSTRUCTION**

The Rosemount 2110 is a liquid point level switch based on the vibrating short fork technology. The Rosemount 2110 Level Switch consists of switch housing, tank connection and fork. The tank connection and the forks are the only wetted parts.

**Fork Design**

The “fast drip” fork design (the liquid is drawn away from the fork tips) makes detection quicker and more sensitive especially in high viscosity liquids.


**Heartbeat LED**

The Rosemount 2110 has a status indicating heartbeat LED which can be seen at all times through a window in the housing. The LED will flash (once per second) when the 2110 is 'off' and will be constantly lit when it is 'on'. The LED gives constant indication that the 2110 is functioning correctly (different flash rates indicate different faults) and gives a local indication of the process state.

**Magnetic Test Point**

A magnetic test point is indicated on the side of the housing, allowing the user to perform a functional test of the 2110. By touching a magnet to the target the 2110 output will change state for as long as the magnet is present.

**Electrical Hookup**

The industry standard DIN 43650 plug/socket is used for fast connection. The polarity insensitivity and short circuit protection make electrical hookup safe and easy.

**INSTALLATION**

Before you install the Rosemount 2110 Level Switch, consider specific installation recommendations and mounting requirements

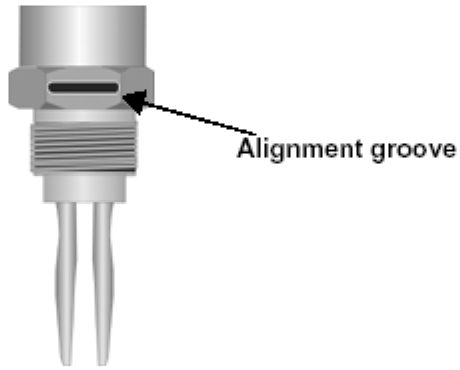
**Recommended Installation:**

- Always install in the normally “on” state.
- For high level is Dry on.
- For low level is wet on.
- Always ensure the system is tested by using the local magnetic test point during commissioning.
- Ensure sufficient room for mounting and electrical connection
- Avoid installing the 2110 where it will be exposed to liquid entering the tank at the fill point.
- Avoid heavy splashing on the forks.
- Ensure that the forks do not come into contact with the tank wall or any internal fittings or obstructions.
- Ensure there is sufficient distance between build-up on the tank wall and the fork.

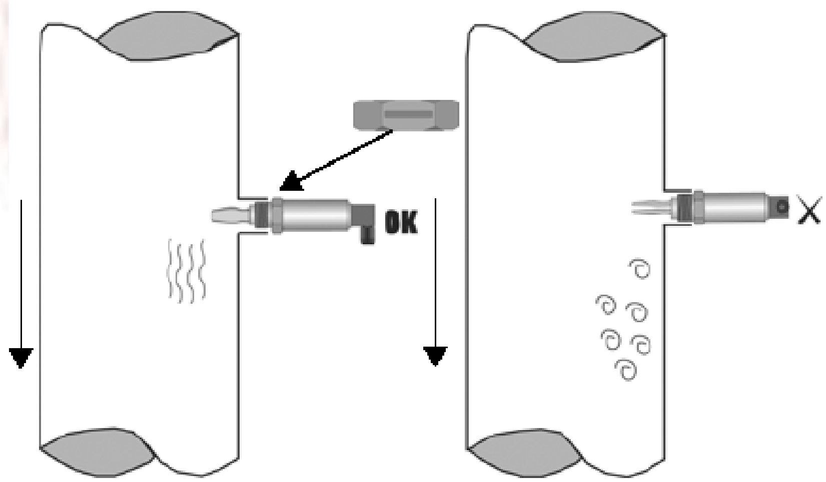
**Installation Considerations:**

- Ensure liquid is inside the temperature and pressure ranges (see specifications).
- Check that the liquid is inside recommended viscosity range 0.2 to 10,000 cP.
- Install in any orientation in tank containing liquid.
- Always install in the normally “on” state
- For high level recommendation is Dry = on
- For low level recommendation is Wet = on
- Always ensure the system is tested by using the local magnetic test point during commissioning
- Ensure sufficient room for mounting and electrical connection
- Ensure that the forks do not come into contact with the tank wall or any internal fittings or obstructions.
- Ensure the fork does not come into contact with the tank wall of any internal fitting.
- Avoid installing the 2110 where it will be exposed to liquid entering the tank at the fill point.
- Avoid heavy splashing on fork
- Avoid product buildup
- Ensure no risk of bridging the forks.
- Ensure there is sufficient distance between build-up on the tank wall and the fork.
- Ensure installation does not create tank crevices around the forks where liquid may connect (important in high viscosity and high density liquids).
- Extra consideration is needed if the plant vibration is close to the 1300 Hz operating frequency of the 2110.
- Ensure sufficient clearance for the fork so highly viscous liquids quickly flow off the forks.
- Extra consideration is needed if the plant vibration is close to the 1300 Hz operating frequency of the 2110.

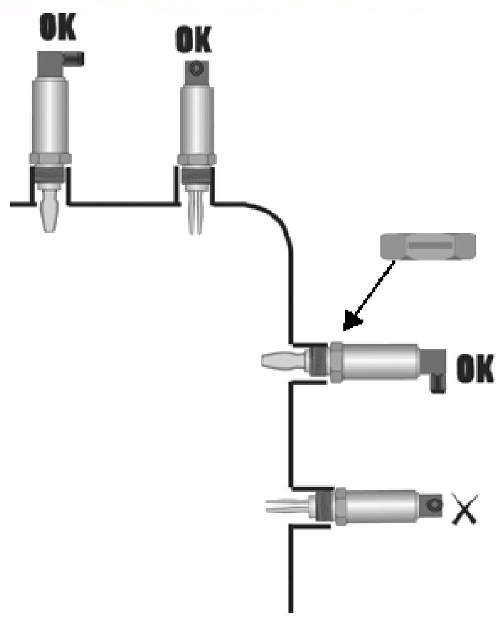
**Correct Fork Alignment**



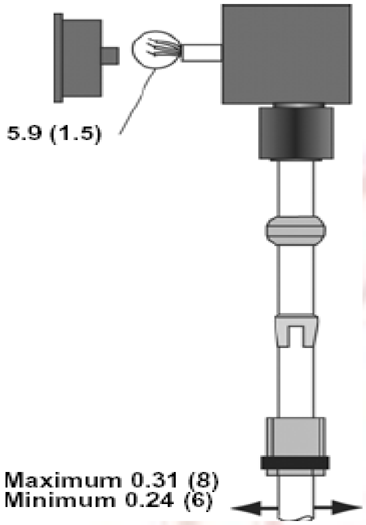

**Pipe Installation**




**Vessel Installation**

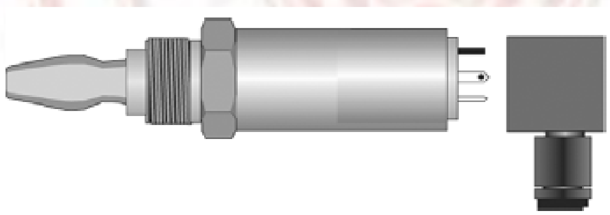


**Wiring diagram:** The 2110 is IP66 and IP67 when correctly assembled with the supplied connector and suitable cable.

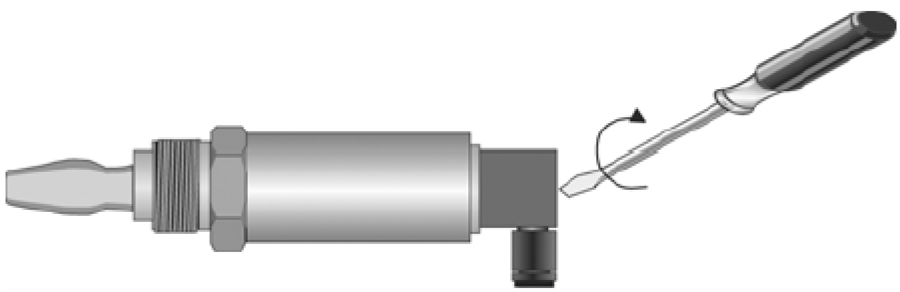




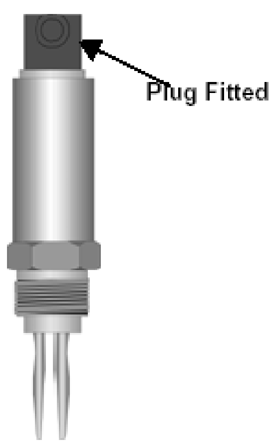
*Insert cable into plug housing and connect to terminals.* *Ensure both seals are in place to maintain the weatherproof rating.*



*Fit plug to body.*



*Tighten the screw.*

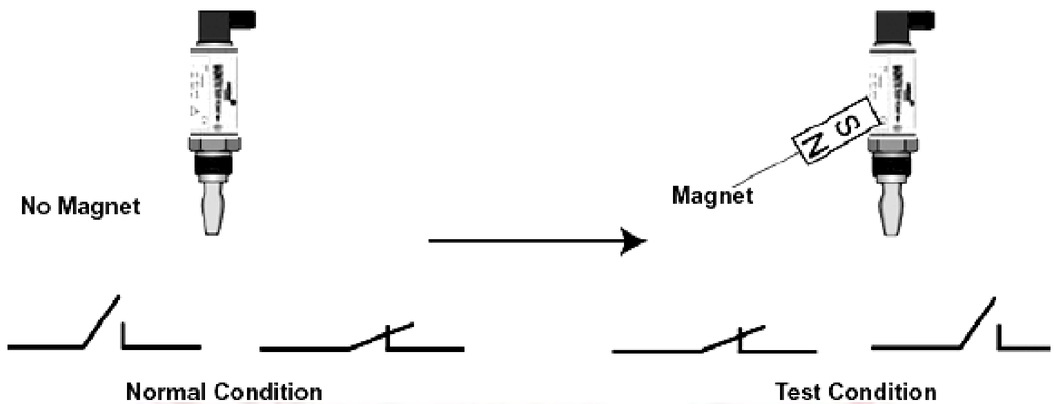



*Plug fitted.*

## INSPECTION AND TESTING

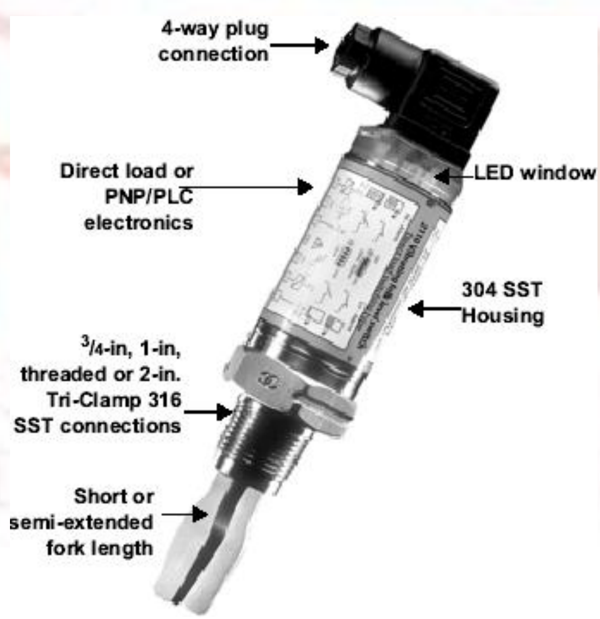
Visually examine the 2120 for damage. If it is damaged, do not use. Check connector and seals are correctly fitted, also that the connector fixing screw and gland are tight. Ensure the LED flash rate is 1 Hz or continually on.

**Magnetic Test Point**
A magnetic test point is marked on the side of the housing allowing a functional test of the 2110. By touching a magnet on the target the 2110 output will change state for as long as the magnet is present.




## SELECTION CRITERIA

The Rosemount 2110 level switch is a compact switch with a rugged stainless steel body and forks for use in a wide range of liquid applications. Economical 3/4-in. or 1-in. threaded mounting in pipes or tanks or hygienic mounting for food industry use. Direct load switching suits all supplies or PNP output for direct interface to



**Switch Housing**
The housing is built in rugged stainless steel with a polyamide LED window. It has a 4 way plug connection, DIN43650, with 4 position orientation and cable gland supplied.
**Electronics**
Standard two core cable with any power supply from 21 to 264 V ac (50/60 Hz)/dc is used to connect the 2110 in series with the load and achieve direct load switching. The output acts as a simple SPST switch that change with liquid presence. Alternatively use the 24V dc solid state PNP output for direct interface to PLCs.
**Tank Connection and Fork**
Wetted material is 316 SST and forks are available in short or semi-extended lengths.
**Threaded Connection**
Threads: 3/4-in. NPT or BSPT (R), 1-in. BSPT (R) or BSPP (G)
Material: 316L SST
**Hygienic Connection**
Fittings: 2-in. (51 mm) Tri-Clamp, 1-in. BSPP (G) O-ring seal
Material: 316L SST
Accessories: Where hygiene is important, a companion mounting boss which is for use with the 1-in. BSPP or the industry standard 2-in. (51mm) Tri-Clamp connection. The Tri-clamp comes with a hand polished wet side and surface finish (Ra) better than 0.8μm to meet the principle design criteria of the most stringent hygienic requirements.

**APPLICATIONS**

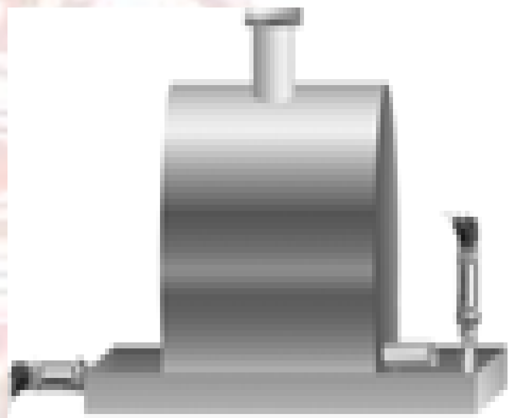
- Chemical
- Pulp & Paper
- Food & Beverage
- Oil & Gas and LNG Power
- Refining Water & Wastewater
- Overfill Protection: - Spillage caused by overfilling can be hazardous to people and the environment, resulting in lost product, and clean up costs. The 2110 is a limit level switch used to signal overfills at any time.
- Pump Protection: - With the short forks projecting only 2-in. (50 mm) (dependant on connection type), the 2110 can be installed in even small diameter pipes. The 2110 is ideal for reliable pump control and can be used to protect against pumps running dry.

***Over fill protection***

***Pump protection***

- High and Low Level Alarm: - Maximum and minimum level detection in tanks containing many different types of liquids are an ideal application for the 2110. The robust 2110 operates continuously at temperatures up to 302°F (150°C) and operating pressure up to 1450 psig (100 bar) making it perfect for use as a high or low level alarm.
- Leak Detection: - Flanges, gaskets, seals, and corrosive liquids – they all have the potential to leak at the most inconvenient times. A level switch can quickly and accurately detect any leakage and thereby eliminating cost.

***High and Low Level Alarm***



***Leak Detection***

**CONFORMATION TO STANDARDS**

- Declaration of Conformity:
  FMEDA Report:
  SIL Declaration (IEC 61508): IS Namur Vibrating Fork Level Sensor
  IS Namur Vibrating Fork Level Sensor

**PARTIAL LIST OF SUPPLIERS**

- Honeywell
- Foxboro
- Emerson Rosemount
- Fuji
- Fisher
- Anderson

## FLOW MEASUREMENT

| Topic Description | Page no |
|---|---|

# Introduction to Flow Measurement

Flow measurement is critical to determine the amount of material purchased and sold, and in these applications, very accurate flow measurement is required. In addition, flows throughout the process should be regulated near their desired values with small variability; in these applications, good reproducibility is usually sufficient. Flowing systems require energy, typically provided by pumps and compressors, to produce a pressure difference as the driving force, and flow sensors should introduce a small flow resistance, increasing the process energy consumption as little as possible. Most flow sensors require straight sections of piping before and after the sensor; this requirement places restrictions on acceptable process designs, which can be partially compensated by straightening vanes placed in the piping. The sensors discussed in this subsection are for clean fluids flowing in a pipe; special considerations are required for concentrated slurries, flow in an open conduit, and other process situations.

Several sensors rely on the **pressure drop or head** occurring as a fluid flows by a resistance; an example is given in Figure 1. The relationship between flow rate and pressure difference is determined by the Bernoulli equation, assuming that changes in elevation, work and heat transfer are negligible.

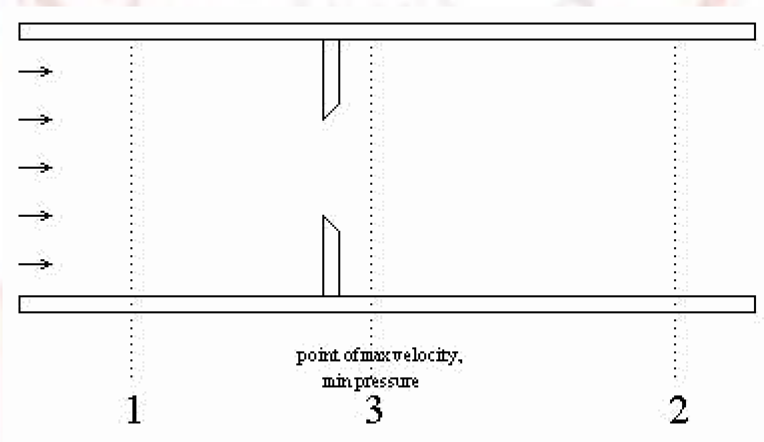



**Figure 1**. Orifice flow meter

**Bernoulli's equation**

$$\frac{P_1}{\rho g} + \frac{1}{2g} v_1^2 = \frac{P_3}{\rho g} + \frac{1}{2g} v_3^2 + \Sigma f \qquad \textbf{(1)}$$

Where $\Sigma f$ represents the total friction loss that is usually assumed negligible. This equation can be simplified and rearranged to give (Foust et. al, 1981; Janna, 1993)

**General head meter equation**

$$F_1 = A_1 V_1 = C_{meter} Y A_3 \sqrt{\frac{2(P_1 - P_3)}{\rho(1 - A_3^2 / A_1^2)}} \qquad \textbf{(2)}$$

The meter coefficient, $C_{meter}$, accounts for all non-idealities, including friction losses, and depends on the type of meter, the ratio of cross sectional areas and the Reynolds number. The compressibility factor, Y, accounts for the expansion of compressible gases; it is 1.0 for incompressible fluids. These two factors can be estimated from correlations (ASME, 1959; Janna, 1993) or can be determined through calibration. Equation (3) is used for designing head flow meters for specific plant operating conditions.

When the process is operating, the meter parameters are fixed, and the pressure difference is measured. Then, the flow can be calculated from the meter equation, using the appropriate values for $C_{meter}$ and Y. All constants are combined, leading to the following relationship.

**Relationship for installed head meter**

$$F = C_0 \sqrt{\frac{(P_1 - P_3)}{\rho_0}} \tag{3}$$

In the usual situation in which only reproducibility is required, the fluid density is not measured and is assumed constant; the simplified calculation is where the density is assumed to be its design value of $r_o$. This is a good assumption for liquid and can provide acceptable accuracy for gases in some situations. Again, all constants can be combined (including $r_o$) into $C_1$ to give the following relationship.

**Relationship for installed head meter with constant density**

$$F = C_0 \sqrt{P_1 - P_3} \tag{4}$$

If the density of a gas varies significantly because of variation in temperature and pressure (but not average molecular weight), correction is usually based on the ideal gas law using low cost sensors to measure T and P according to

**Relationship for installed head meter, gas with constant MW, changing T and P**

$$F = C_0 \sqrt{\frac{(P_1 - P_3)}{\rho_0}} \sqrt{\frac{P_0 T}{P T_0}} \tag{5}$$

Where the density (assumed constant at $r_o$), temperature ($T_o$) and pressure ($P_o$) were the base case values used in determining $C_o$. If the density varies significantly due to composition changes and high accuracy is required, the real-time value of fluid density (r) can be measured by an on-stream analyzer for use as $r_o$ in equation (4) (Clevett, 1985).

The flow is determined from equation (5) by taking the square root of the measured pressure difference, which can be measured by many methods. A U-tube manometer provides an excellent visual display for laboratory experiments but is not typically used industrially. For industrial practice a diaphragm is used for measuring the pressure drop; a diaphragm with one pressure on each side will deform according to the pressure difference.

Note that the pressure in the pipe increases after the vena contracta where the flow cross section returns to its original value, but because of the meter resistance, the pressure downstream of the meter ($P_3$) is **lower** than upstream pressure ($P_1$). This is the **"non-recoverable" pressure drop** of the meter that requires energy, e.g., compressor work, to overcome and increases the cost of plant operation. The non-recoverable pressure losses for three important head meters are given in Figure 5.

The low pressure at the point of highest velocity creates the possibility for the liquid to partially vaporize; it might remain partially vaporized after the sensor (called **flashing**) or it might return to a liquid as the pressure increases after the lowest pressure point (called **cavitation**). We want to avoid any vaporization to ensure proper sensor operation and to retain the relationship between pressure difference and flow. Vaporization can be prevented by maintaining the inlet pressure sufficiently high and the inlet temperature sufficiently low.

Some typical **head meters** are described briefly in the following.

***Orifice*:** An orifice plate is a restriction with an opening smaller than the pipe diameter which is inserted in the pipe; the typical orifice plate has a concentric, sharp edged opening, as shown in Figure 1. Because of the smaller area the fluid velocity increases, causing a corresponding decrease in pressure. The flow rate can be calculated from the measured pressure drop across the orifice plate, $P_1$-$P_3$. The orifice plate is the most commonly used flow sensor, but it creates a rather large non-recoverable pressure due to the turbulence around the plate, leading to high energy consumption (Foust, 1981).

***Venturi Tube:*** The venturi tube shown in Figure 2 is similar to an orifice meter, but it is designed to nearly eliminate boundary layer separation, and thus form drag. The change in cross-sectional area in the venturi tube causes a pressure change between the convergent section and the throat, and the flow rate can be determined from this pressure drop. Although more expensive that an orifice plate; the venturi tube introduces substantially lower non-recoverable pressure drops (Foust, 1981).

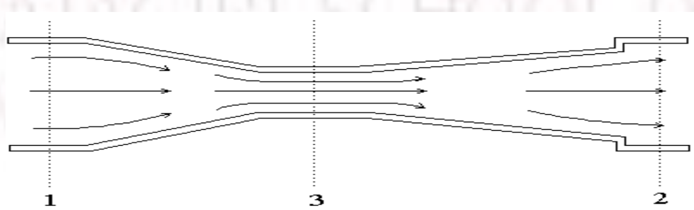



**Figure 2**. Venturi flow meter

***Flow Nozzle*:** A flow nozzle consists of a restriction with an elliptical contour approach section that terminates in a cylindrical throat section. Pressure drop between the locations one pipe diameter upstream and one-half pipe diameter downstream is measured. Flow nozzles provide an intermediate pressure drop between orifice plates and venturi tubes; also, they are applicable to some slurry systems.

***Elbow meter*:** A differential pressure exists when a flowing fluid changes direction due to a pipe turn or elbow, as shown in Figure 3 below. The pressure difference results from the centrifugal force. Since pipe elbows exist in plants, the cost for these meters is very low. However, the accuracy is very poor; there are only applied when reproducibility is sufficient and other flow measurements would be very costly.

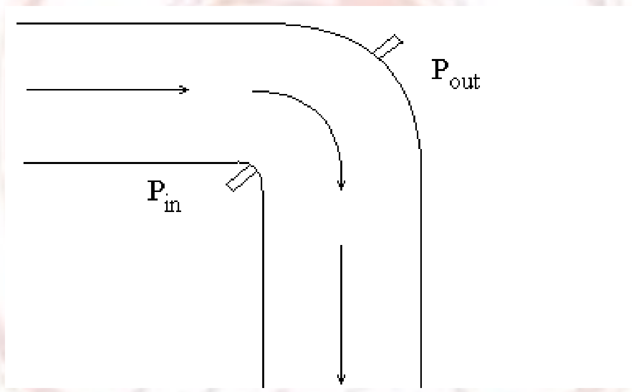



***Figure 3**. Elbow flow meter.*

***Pitot tube and annubar:*** The pitot tube, shown in Figure 4 below, measures the static and dynamic pressures of the fluid at **one point** in the pipe. The flow rate can be determined from the difference between the static and dynamic pressures which is the velocity head of the fluid flow. An annubar consists of several pitot tubes placed across a pipe to provide an approximation to the **velocity profile**, and the total flow can be determined based on the multiple measurements. Both the pitot tube and annubar contribute very small pressure drops, but they are not physically strong and should be used only with clean fluids.

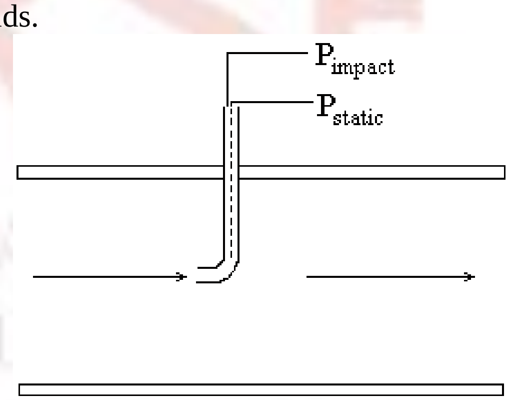



***Figure 4.** Pitot flow meter.*

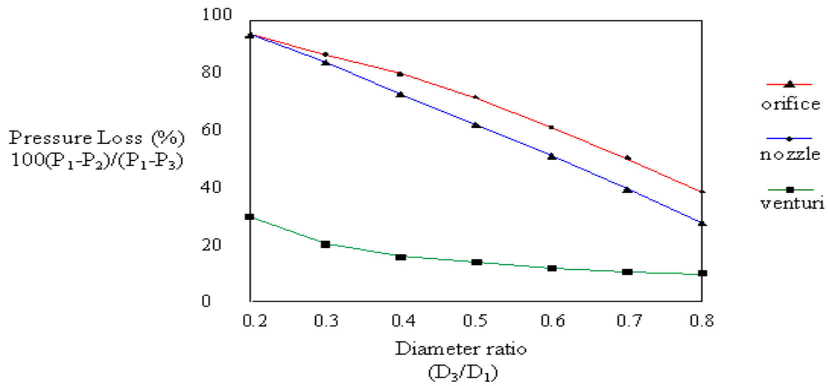



***Figure 5***. *Flow meter non-recoverable pressure losses (Andrews and Williams, Vol 1, 1979)*

The following flow sensors are based on physical principles other than head.

***Turbine*:** As fluid flows through the turbine, it causes the turbine to rotate with an angular velocity that is proportional to the fluid flow rate. The frequency of rotation can be measured and used to determine flow. This sensor should not be used for slurries or systems experiencing large, rapid flow or pressure variation.

***Vortex shedding*:** Fluid vortices are formed against the body introduced in the pipe. These vortices are produced from the downstream face in a oscillatory manner. The shedding is sensed using a thermistor and the frequency of shedding is proportional to volumetric flow rate.

***Positive displacement*:** In these sensors, the fluid is separated into individual volumetric elements and the number of elements per unit time is measured. These sensors provide high accuracy over a large range. An example is a wet test meter.

**Table 1. Summary of flow sensors**

| Sensor | Rangeability[1] | Accuracy[2] | Dynamics (s) | Advantages | Disadvantages |
|---|---|---|---|---|---|
| **orifice** | 3.5:1 | 2-4% of full span | - | -low cost<br><br>-extensive industrial practice | -high pressure loss<br><br>-plugging with slurries |
| **venturi** | 3.5:1 | 1% of full span | - | -lower pressure loss than orifice<br><br>-slurries do not plug | -high cost<br><br>-line under 15 cm |
| **flow nozzle** | 3.5:1 | 2% full span | - | -good for slurry service<br><br>-intermediate pressure loss | -higher cost than orifice plate<br><br>-limited pipe sizes |

| | | | | | |
|---|---|---|---|---|---|
| **Elbow meter** | 3:1 | 5-10% of full span | - | -low pressure loss | -very poor accuracy |
| **annubar** | 3:1 | 0.5-1.5% of full span | - | -low pressure loss<br><br>-large pipe diameters | -poor performance with dirty or sticky fluids |
| **turbine** | 20:1 | 0.25% of measurement | - | -wide rangeability<br><br>-good accuracy | -high cost<br><br>-strainer needed, especially for slurries |
| **vortex shedding** | 10:1 | 1% of measurement | - | -wide rangeability<br><br>-insensitive to variations in density, temperature, pressure, and viscosity | -expensive |
| **positive displacement** | 10:1 or greater | 0.5% of measurement | - | -high reangeability<br><br>-good accuracy | -high pressure drop<br><br>-damaged by flow surge |

**Notes:**

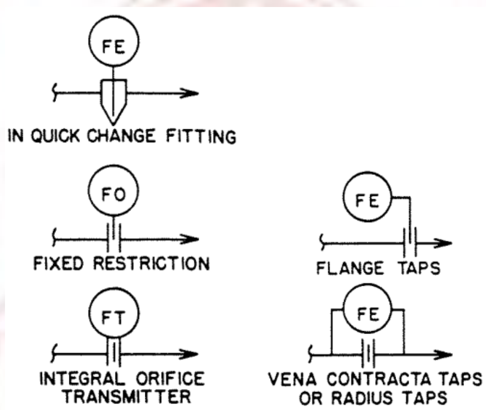
1. Accuracy is measured in °C or % of span, whichever is larger.
2. With RTDs, the inaccuracy increases approximately linearly with temperature deviation from 0 °C.
3. The dynamics depend strongly on the sheath or thermo well (material, diameter, and wall thickness), the location of the element in the sheath (i.e. bonded or air space, the fluid type, and the fluid velocity. Typical values are 2 to 5 seconds for high fluid velocities.

# ORIFICE FLOW METER

**Description**

An orifice plate is a device used for measuring the rate of fluid flow. Orifice plate is one in a group known as head loss devices or differential pressure flow meters. An orifice is simply a flat (thin) piece of metal plate with a specific-sized hole bored in the middle.In simple terms the pipeline fluid is passed through a restriction, and the pressure differential is measured across that restriction. Most orifices are of the concentric type, but eccentric, conical (quadrant), and segmental designs are also available. Other flow meters in the differential pressure group include venturis and nozzles.

**Symbols**




*Flow Sheet Symbol*

**Figure**

**SPECIFICATIONS**

***Functional specifications***

Service and Flow Range: Liquid, gas or vapor turbulent flow, for pipe Reynolds Numbers greater than the following

- AGA-3 : 4,000
- ASME MFC-3M : 5,000 and 170 D (whichever is higher)
- ISO-5167 : 5,000 and 170 D (whichever is higher)

Temperature Limit (Based on flange rating per ANSI B16.5.)

- For ANSI Flange Rating300# : -100°F to 700°F
- Flange rating 600#, 900#, 1500# : -350°F to1000°F
- Temperature Range (Orifice) : -320 to 1200 °F (-196 to 649 °C)
- Pipe Sizes : 2-in. to 24-in. (50 mm to 600 mm).

Maximum Working Pressure (Based on flange rating per ANSI B16.5.)

***Physical specification***

Materials of Construction

- Orifice Plate : 304/304L or 316/316L Stainless Steel ASTM A240; DIN 1.4571(316Ti SST); Alloy C-276 ASTM B575; or Alloy 400 ASTM B127.
- Orifice Bore Sizes : Standard bore sizes are in 1/8-in. (3.2 mm) increments from ½-in. (12.7 mm) to 4-in. (101.6 mm) and in 1/4-in. (6.3 mm) increments from 41/4 to 6-in. (107.95 mm to 152.4 mm).
- Flange Unions : Orifice Flanges (ANSI B16.36): Carbon Steel ASTM A105 /A350; Stainless Steel ASTM A182; Alloy C-276 ASTM B564/575; or Alloy 400 ASTM B564/127; DIN 1.4571 (316Ti SST); DIN 1.0460 (carbon steel)

Flange Mounting Hardware

- Studs : Carbon Steel ASTM A193 Grade B7M
- Nuts : Carbon Steel ASTM A194 Gr 2H
- Pipe Plugs : Match flange material
- Gaskets : Non-asbestos ring type, Durlon® 8500 Green, Klingersil C4400, or equivalent
- Pressure Taps : Pressure tap connections are ½ -in. (12.7 mm) NPT and 180° apart as standard.
- Tap hole diameter : ¼-in. (6.35 mm) for 2-in. (51 mm) & 2 ½ -in. (63.5 mm) size, 3/8-in. (9.6 mm) for 3-in.(76.2 mm) size, and ½-in. (12.7 mm) for 4-in. (101.6 mm) and larger sizes.

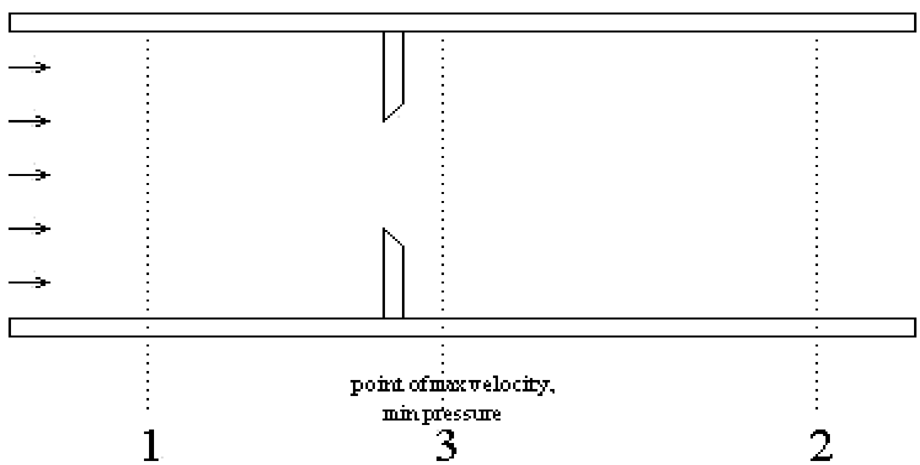
**PRINCIPLE OF OPERATION**

**The Bernoulli Equation**: Based on the work of Daniel Bernoulli; the relationship between the velocity of fluid passing through the orifice is proportional to the square root of the pressure loss across it. Assuming a horizontal flow (neglecting the minor elevation differences between measuring points) the Bernoulli Equation can be modified to

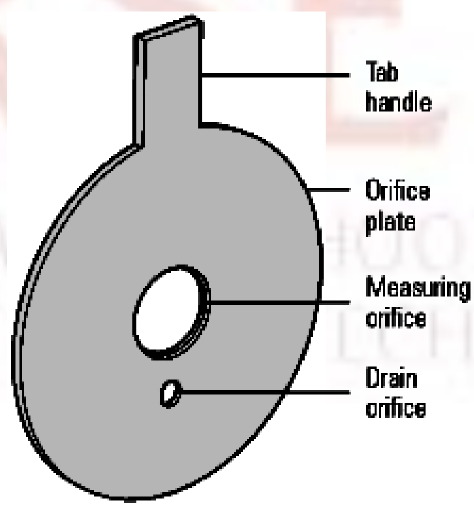
$$P_1 + 1/2\,\rho\,V_1^2 = P_2 + 1/2\,\rho\,V_2^2 \ldots\ldots\ldots\ldots (1)$$

Where; V = flow velocity
P = pressure
ρ = density

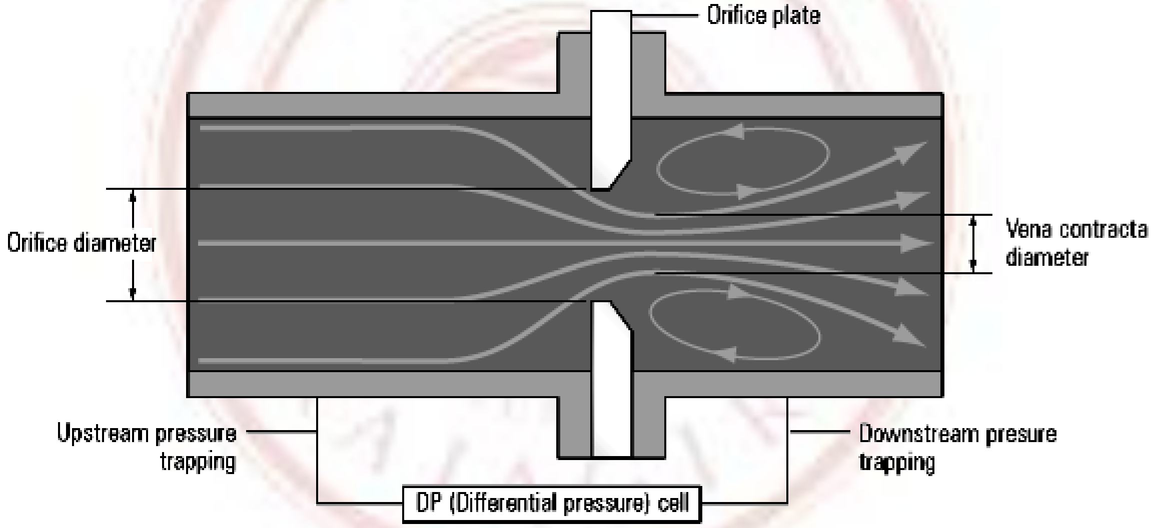
In a flow metering device based on the Bernoulli Equation the downstream pressure after an obstruction will be lower than the upstream pressure before. The relationship between the pressure of the fluid and the velocity of the fluid is that when the velocity increases, the pressure decreases and vice versa. To understand orifice, nozzle and venturi meters it's therefore necessary to explore the Bernoulli Equation.



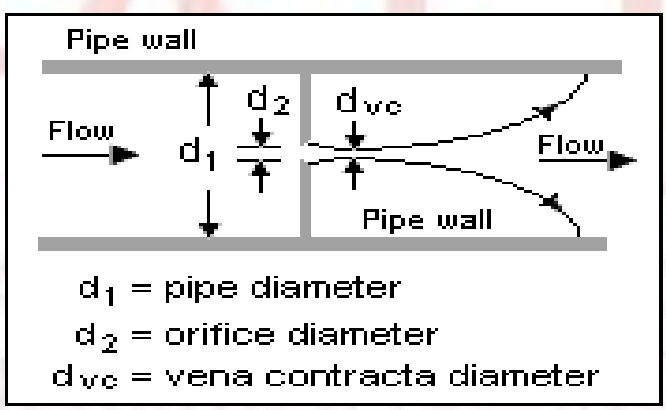

With an orifice plate flow meter, the restriction is in the form of a plate which has a hole concentric with the pipeline is usually placed in a pipe in which fluid flows. This is referred to as the primary element.



When the fluid reaches the orifice plate, with the hole in the middle, the fluid is forced to converge to go through the small hole. The point of maximum convergence actually occurs shortly downstream of the physical orifice, at the so-called vena contracta point. As it does so, the velocity and the pressure changes. Beyond the vena contracta, the fluid expands and the velocity and pressure change once again. By measuring the difference in fluid pressure between the normal pipe section and at the vena contracta, the volumetric and mass flow rates can be obtained from Bernoulli's equation. To measure the differential pressure when the fluid is flowing, connections are made from the upstream and downstream pressure tapings, to a secondary device known as a DP (Differential Pressure) cell.




The ß ratio; this is the relationship between the orifice diameter and the pipe diameter and would typically be a value of 0.7.




$$\beta = \frac{d_2 \text{ (orifice diameter)}}{d_1 \text{ (pipe diameter)}}$$

**Incompressible flow through an orifice:** By assuming steady-state, incompressible (constant fluid density), inviscid, laminar flow in a horizontal pipe (no change in elevation) with negligible frictional losses, Bernoulli's equation reduces to an equation relating the conservation of energy between two points on the same streamline:

$P_1 + 1/2 \cdot \rho \cdot V_1^2 = P_2 + 1/2 \cdot \rho \cdot V_2^2$ or

$P_1 - P_2 = 1/2 \cdot \rho \cdot V_2^2 - 1/2 \cdot \rho \cdot V_1^2$

By continuity equation

$Q = A_1 \cdot V_1 = A_2 \cdot V_2$ or

$V1 = Q/A_1$ and $V_2 = Q/A_2$

$P_1 - P_2 = 1/2 \cdot \rho \cdot (Q/A_2)^2 - 1/2 \cdot \rho \cdot (Q/A_1)^2$

Solving for Q:

$$Q = A_2 \sqrt{\frac{2\,(P_1 - P_2)/\rho}{1 - (A_2/A_1)^2}}$$

And

$$Q = A_2 \sqrt{\frac{1}{1 - (d_2/d_1)^4}}\ \sqrt{2\,(P_1 - P_2)/\rho}$$

The above expression for Q gives the theoretical volume flow rate. Introducing the beta factor $\beta = d_2 / d_1$ as well as the coefficient of discharge $C_d$:

$$Q = C_d\, A_2 \sqrt{\frac{1}{1 - \beta^4}}\ \sqrt{2\,(P_1 - P_2)/\rho}$$

And finally introducing the meter coefficient C to obtain the final equation for the volumetric flow of the fluid through the orifice:

$$C = \frac{C_d}{\sqrt{1 - \beta^4}}$$

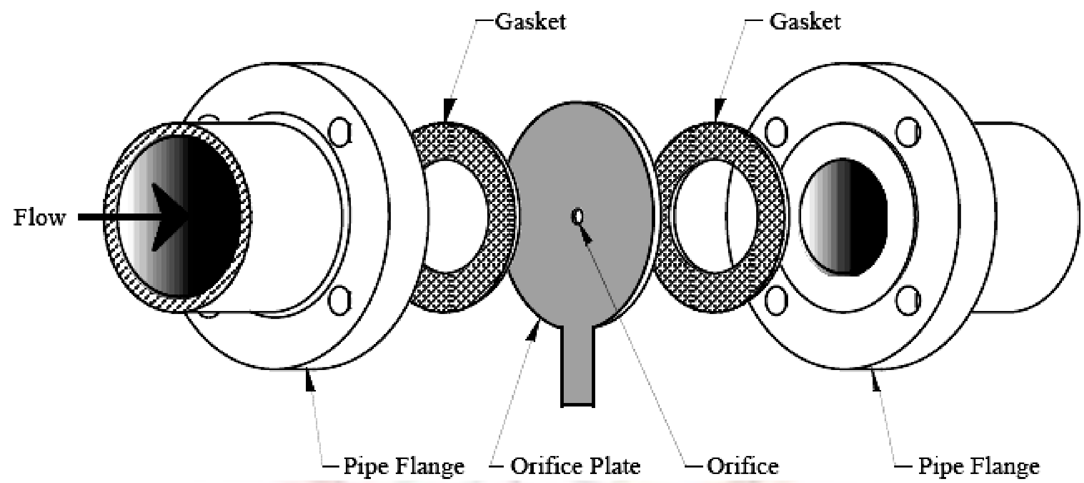
$$Q = C\, A_2 \sqrt{2\,(P_1 - P_2)/\rho} \quad \text{......... (1)}$$

Multiplying by the density of the fluid to obtain the equation for the mass flow rate at any section in the pipe:

$$\dot{m} = \rho\, Q = C\, A_2 \sqrt{2\,\rho\,(P_1 - P_2)} \quad \text{......... (2)}$$

Where: $\boldsymbol{Q}$ = volumetric flow rate (at any cross-section), m³/s
$\dot{m}$= mass flow rate (at any cross-section), kg/s
$\boldsymbol{C}$ = orifice flow coefficient, dimensionless; $\boldsymbol{C_d}$= coefficient of discharge, dimensionless
$\boldsymbol{V_1}$= upstream fluid velocity, m/s; $\boldsymbol{V_2}$ = fluid velocity through the orifice hole, m/s
$\boldsymbol{P_1}$ = fluid upstream pressure, Pa kg/ (m·s²); $\boldsymbol{P_2}$ = fluid downstream pressure, kg/ (m·s²)
$\boldsymbol{A_1}$= cross-sectional area of the pipe, m²; $\boldsymbol{A_2}$ = cross-sectional area of the orifice hole, m²
$\boldsymbol{d_1}$ = diameter of the pipe, m; $\boldsymbol{d_2}$= diameter of the orifice hole, m
$\boldsymbol{\beta}$= ratio of orifice hole diameter to pipe diameter, dimensionless
$\boldsymbol{\rho}$ = fluid density, kg/m³

**DESIGN AND CONSTRUCTION**




The main parts of an orifice flow meter are as follows:

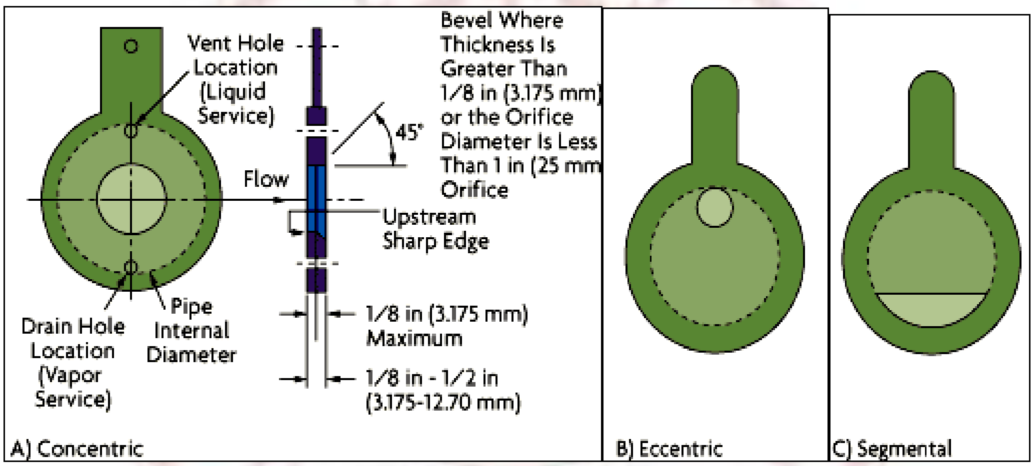
- A stainless steel orifice plate which is held between flanges of a pipe carrying the fluid whose flow rate is being measured.
- It should be noted that for a certain distance before and after the orifice plate fitted between the flanges, the pipe carrying the fluid should be straight in order to maintain laminar flow conditions.
- Openings are provided at two places 1 and 2 for attaching a differential pressure sensor (U-tube manometer, differential pressure gauge etc)

**Flow meter design**: To design flow meters as described in BS 1042.

- Calculates pipe diameter (corrected to operating temperature), beta ratio, coefficient of discharge, Reynolds number, exact differential pressure, pressure drop, tolerance limit etc.
- Performs calculations for liquids, gas, steam and natural gas. For natural gas, correction factors Fb, Fpb, Ftb, Ftf, Fgr, Fpv, Fr etc. are calculated based on AGA3, ANSI/API standards.
- Vent hole correction factor and Reynolds number are calculated based on temperature and pressure variation in the fluid stream.
- Appropriate messages are displayed if the calculated parameters are unsuitable as per the standards.
- Upstream and downstream straight length is calculated based on the type of pipe fittings selected

## Sizing the Orifice Plate

Orifice sizing programs usually allow the user to select the flow equation desired from among several. The orifice plate can be made of any material, although stainless steel is the most common. The thickness of the plate used (1/8-1/2") is a function of the line size, the process temperature, the pressure, and the differential pressure. The traditional orifice is a thin circular plate (with a tab for handling and for data).



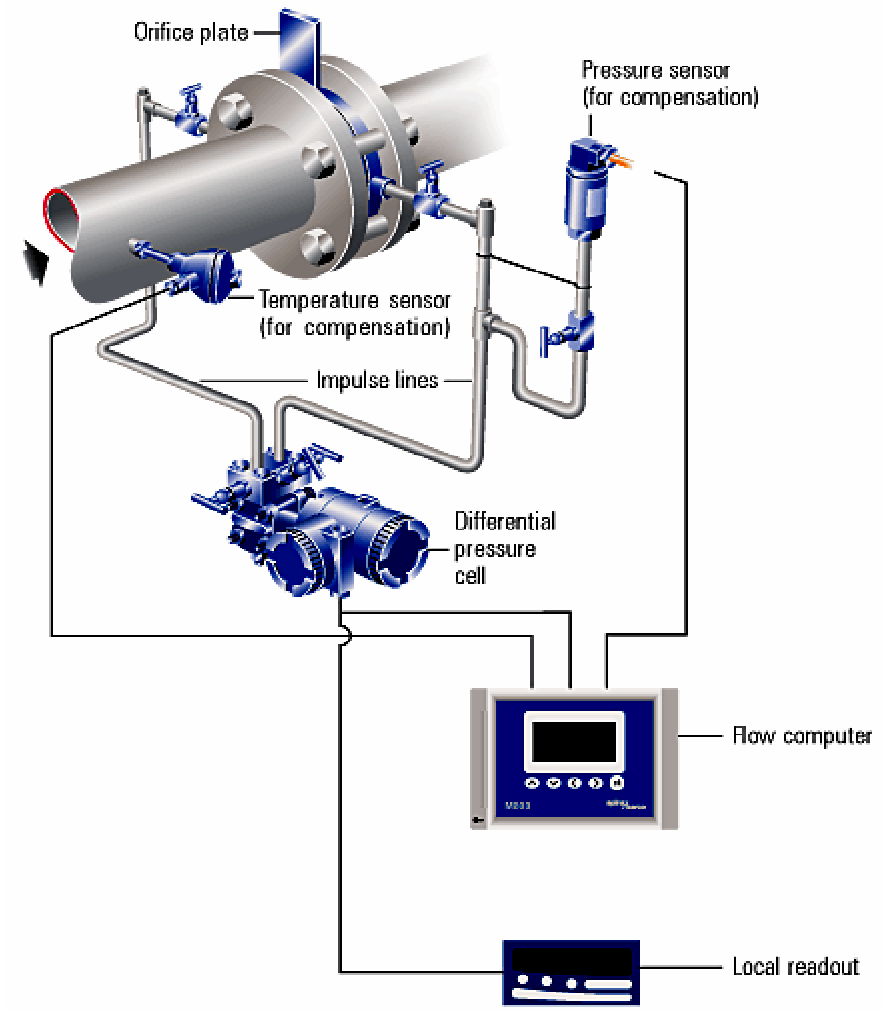

The concentric orifice plate has a sharp (square-edged) concentric bore that provides an almost pure line contact between the plate and the fluid, with negligible friction drag at the boundary. The beta (or diameter) ratios of concentric orifice plates range from 0.25 to 0.75. The maximum velocity and minimum static pressure occurs at some 0.35 to 0.85 pipe diameters downstream from the orifice plate. That point is called the vena contracta. Measuring the differential pressure at a location close to the orifice plate minimizes the effect of pipe roughness, since friction has an effect on the fluid and the pipe wall.

The eccentric orifice is similar to the concentric except that the opening is offset from the pipe's centerline. The opening of the segmental orifice is a segment of a circle. If the secondary phase is a gas, the opening of an eccentric orifice will be located towards the top of the pipe. If the secondary phase is a liquid in a gas or slurry in a liquid stream, the opening should be at the bottom of the pipe. The drainage area of the segmental orifice is greater than that of the eccentric orifice, and, therefore, it is preferred in applications with high proportions of the secondary phase.

The size and orientation of the pressure taps are a function of both the pipe size and the type of process fluid. The recommended maximum diameter of pressure tap holes through the pipe or flange is 1/4" for pipes under 2" in diameter, 3/8" for 2" and 3" pipes, 1/2" for 4 to 8" and 3/4" for larger pipes. Both taps should be of the same diameter, and, where the hole breaks through the inside pipe surface, it should be square with no roughness, burrs, or wire edges. Connections to pressure holes should be made by nipples, couplings, or adaptors welded to the outside surface of the pipe. Although it is a simple device, the orifice plate is, in principle, a precision instrument. Under ideal conditions, the inaccuracy of an orifice plate can be in the range of 0.75-1.5% AR.

## INSTALLATION

In practice, the orifice plate is installed into the pipeline between the two flanges of an orifice union. This method of installation is cost-effective, but it calls for a process shutdown whenever the plate is removed for maintenance or inspection. In contrast, an orifice fitting allows the orifice to be removed from the process without depressurizing the line and shutting down flow. In such fittings, the universal orifice plate, a circular plate with no tab, is used. 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.




***Orifice plate flow meter installation***

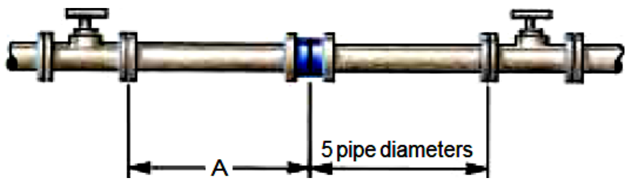
From the DP cell, the information may be fed to a simple flow indicator, or to a flow computer along with temperature and/or pressure data, which enables the system to compensate for changes in fluid density.

In horizontal lines carrying vapors, water (or condensate) can build up against the upstream face of the orifice. To prevent this, a drain hole may be drilled in the plate at the bottom of the pipe. Clearly, the effect of this must be taken into account when the orifice plate dimensions are determined

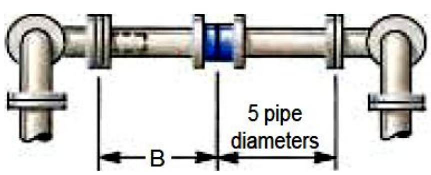
**Installation considerations:** Correct sizing and installation of orifice plates is absolutely essential. A few of the most important points from ISO 5167 are discussed below: **Pressure tapings -** Small bore pipes (referred to as impulse lines) connect the upstream and downstream pressure tapping of the orifice plate to a Differential Pressure or DP cell.

The positioning of the pressure tapping can be varied. The most common locations are:

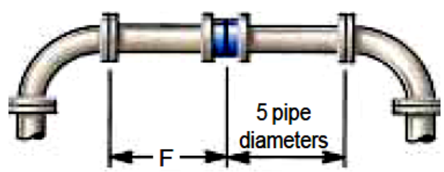
- From the flanges (or carrier) containing the orifice plate. This is convenient, but care needs to be taken with tapping at the bottom of the pipe, because they may become clogged.
- One pipe diameter on the upstream side and 0.5 x pipe diameter on the downstream side. This is less convenient, but potentially more accurate as the differential pressure measured is at its greatest at the vena contracta, which occurs at this position.
- The nature and geometry of the preceding obstruction. A few obstruction examples are shown in Figure:



Fully open full way valve



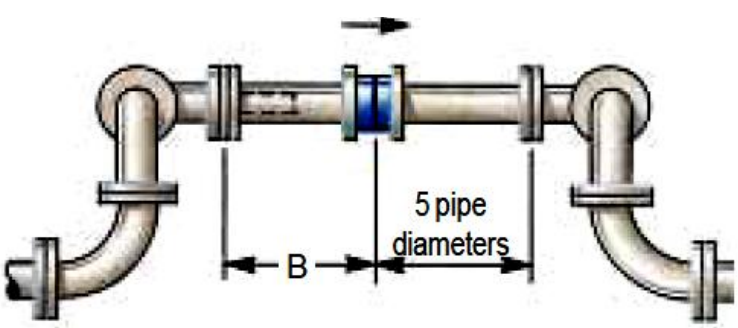
Two bends at right angles with straightening veins.



Right angle bends

***Orifice plate installations***

**Corner tapping -** These are generally used on smaller orifice plates where space restrictions mean flanged tapping are difficult to manufacture. **Pipe work -** There is a requirement for a minimum of five straight pipe diameters downstream of the orifice plate, to reduce the effects of disturbance caused by the pipe work.



Three bends at right angles with straightening veins

## CALIBRATION

**Technology involved:** The flow path is obstructed with a primary element and the difference in pressure is measured before and after the primary element

**Procedure:** The orifice plate with its nose facing the flow stream is placed at the center of a duct at the affixed and the two tapping from it connected to the manometer after the latter is properly leveled and its initial reading taken.
The pressure tapping from the orifice meter is connected to the inclined tube manometer after suitably leveling it taking its initial reading by adjusting the duct-regulating device at the duct outlet. The quantities as measured by the two devices are then calculated and compared by plotting a graph.

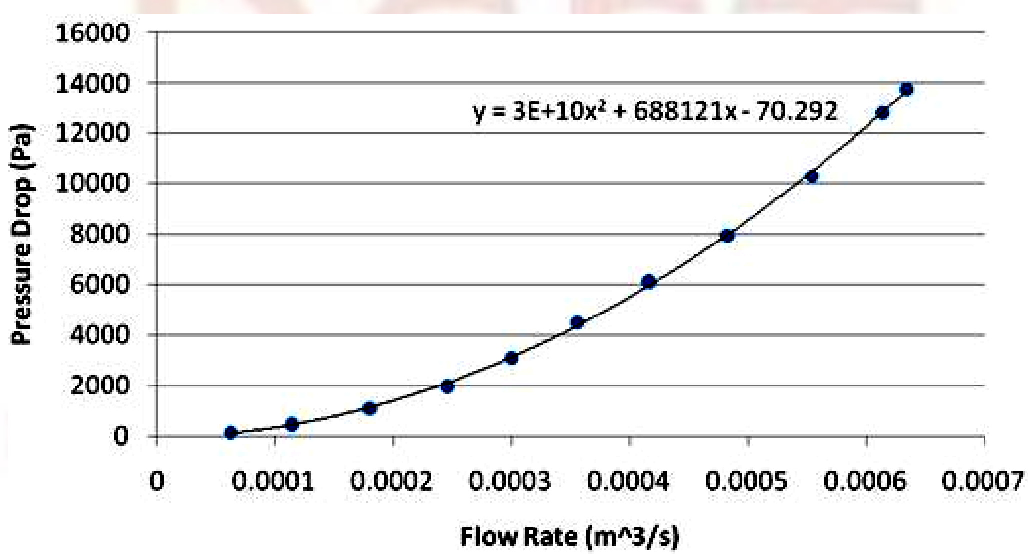
**Computations:** The orifice plate consists of a plate with a hole in its center. It is placed in a conduit so that the flow passes only through the hole at its center. Measurement of the pressure drop across the conduit provides a means of determining the flow rate in the conduit. If $A_1$ is the conduit area and $A_2$ be the orifice hole area then

$$Q_{theory} = A_2 / \{1-(A_2/A_1)\}^2 \{2g\,(h)\,(\gamma_m/\gamma - 1)\}^{1/2}$$

Where

- g= acceleration due to gravity
- h= pressure difference between the inlet and the outlet of the orifice
- $\gamma_m$= specific weight of the manometric liquid
- $\gamma = \rho g$; $\rho$= Density of the manometric liquid.

The calibration curve for an orifice meter will depend on the size of the orifice, the size of the pipe and the pressure loss over the meter. Typical calibration curves have pressure (or head) loss on the vertical (y) axis and flow rate on the horizontal (x) axis (fig below).




*Orifice pressure drop versus flow rate graph*

## SELECTION CRITERIA

**Flow meter selection procedure:** The selection begins with the option of the type of fluid to be metered. The procedure is then to examine, in more detail the basic areas which define the application as follows:

- Performance considerations, which include meter rangeability, pressure loss, overall approximate error etc.
- Fluid property considerations, which include fluid type (liquid or gas), temperature, pressure, viscosity, density etc.
- Installation and maintenance considerations like the upstream straight-length of the pipe required, maximum and minimum line size, service etc.
- Environmental considerations such as temperature effects, pressure effects etc.
- Economic consideration like relative prevailing cost, life expectancy, maintenance etc.

**Input data (**Selection**):**

The following data has to be supplied by the user for selection.

- Fluid type: Liquid, gas, steam
- Fluid characteristics: viscous, clean, dirty, conductive etc.
- Meter range
- Pressure loss
- Field application
- Operating conditions: max. Temperature, max. Pressure, line size, minimum Reynolds number etc.

**Output data (**Selection**):**

The following specification of the selected meter is given as output:

- Flow meter selected
- Installation condition
- Construction material
- Relative price
- Relative life
- Specification
- Advantages and disadvantages
- Overall approximate error etc

**Orifice plate selection recommendation**

- The concentric orifice plate is recommended for clean liquids, gases, and steam flows when Reynolds numbers range from 20,000 to $10^7$ in pipes under six inches
- Quadrant-edged and conical orifice plates are recommended when the Reynolds number is under 10,000.
- Flange taps, corner, and radius taps can all be used with quadrant-edged orifices, but only corner taps should be used with a conical orifice.
- Eccentric and segmental orifice plates are better suited for multi-phase fluids in horizontal lines.
- For the measurement of low flow rates, a d/p cell with an integral orifice may be the best choice. In this design, the total process flow passes through the d/p cell, eliminating the need for lead lines.

**CONFORMATION TO STANDARDS**

- BS 1042 and ISO 5167.
- BS 4504 PN16, PN25 and PN40.
- BS 10 Table H.
- ANSI B 16.5 class 150, 300 and 600.
- Japanese Industrial Standard JIS 20.

**APPLICATIONS**

The orifice flow meter is the most common head-type flow measuring device. It can be used for liquids, vapors and gases.

- The concentric orifice plate is used to measure flow rates of pure fluids.
- The eccentric and segmental orifice plates are used to measure flow rates of fluids containing suspended materials such as solids, oil mixed with water and wet steam.
- Natural Gas Transmission
- Chemical and Pharmaceutical
- Processing
- Power Generation
- Refinery and Petrochemical

**LIST OF SUPPLIERS**

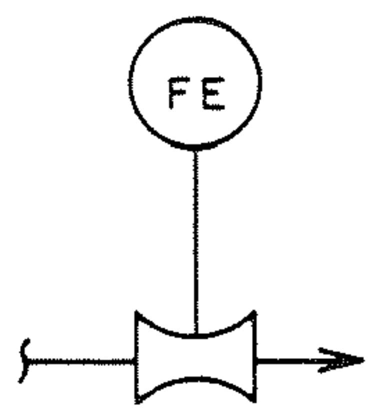
- ABB
- Crane Manufacturing Inc.
- Daniel Flow Products Inc.
- Honeywell
- Scott and Fetzer
- Rosemount Inc.
- Fischer & Porter
- Mobrey
- Flowtech instruments
- Roc-Master

# VENTURI METER

**Description**

A Venturi meter is used to measure the flow through a pipeline. A Venturi tube (or simply a venturi) is a section of piping consisting of an inlet converging conical section leading to a small diameter cylindrical section called the throat, followed by a diverging conical section leading to a cylindrical exit (see the adjacent drawing). A venturi gives a pressure differential that can be used to measure fluid (gas or liquid) flow rates, but it has countless other applications.

**Symbol**




*Flow Sheet Symbol*

**Figure**

*Venturi flow sensor*

**SPECIFICATIONS**

- Applications: Liquids, gases and steam

**SSL - Classical (Herschel) Design / VISSL - Insert Version**

- Pipe Sizes: ½ to 60 inches and larger (13 to 1524 mm)
- Pressure & Temperature: Varies, dependent upon materials of construction
- Pressure Loss: 6% of DP maximum
- Turndown Ratio: 10:1
- Process Connections: SSL; NPT, flanged, butt weld, socket weld, grooved
- VISSL; Insert fits between pair of flanges
- Instrument Connections: NPT, socket weld, flanged
- Accuracy: ±1% of reading uncalibrated; ±0.5% of reading calibrated
- Standard Beta Ratios: 0.35, 0.49, 0.63 and 0.75; exact sizing available to provide custom beta ratios

**SSM - Hydraulic Shape Design (Nozzle Type) / VISSM - Insert Version**

- Pipe Sizes ½ to 60 inches and larger (13 to 1524 mm)
- Pressure & Temperature: Varies, dependent upon materials of construction
- Pressure Loss: 6% of DP maximum
- Turndown Ratio: 10:1
- Process Connections: SSM; NPT, _ anged, butt weld, socket weld, grooved
- VISSM; Insert fits between pair of flanges
- Instrument Connections: NPT, socket weld, flanged
- Accuracy: ±1% of reading uncalibrated; ±0.5% of reading calibrated
- Standard Beta Ratios: 0.35, 0.49, 0.63 and 0.75; exact sizing available to provide custom beta ratios

**LPL - Low-Loss Design (Short Form) / VILPL - Insert Version**

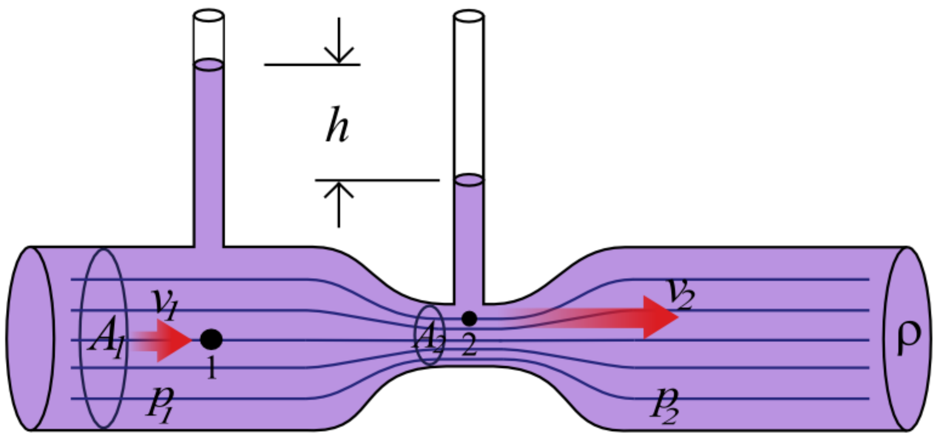
- Pipe Sizes: ½ to 60 inches and larger (13 to 1524 mm)
- Pressure & Temperature: Varies, dependent upon materials of construction
- Pressure Loss: 3% of DP maximum
- Turndown Ratio: 10:1
- Process Connections: LPL; NPT, flanged, butt weld, socket weld, grooved
- VILPL; Insert fits between pair of flanges
- Instrument Connections: NPT, socket weld
- Accuracy: ±3-5% of reading uncalibrated; ±0.5% of reading calibrated
- Standard Beta Ratios: -10, -20, -38, -65; exact sizing available to provide custom beta ratios

**CV Series**

- Pipe Sizes: 2 to 16 inches and larger (51 to 406 mm)
- Pressure: 300 PSIG (2070 kPa) maximum
- Temperature: 250 °F (120 °C) maximum
- Process Connections: NPT, butt weld, flanged, grooved
- Instrument Connections: NPT
- Standard Beta Ratios: -38, -65

**PRINCIPLE OF OPERATION**

In order to understand the principles of a Venturi meter, we must first review two basic concepts based on the principle of Bernoulli's equation: The first term in this equation is referred to as the pressure head. The second term is referred to as the elevation head. The third term is referred to as the velocity head. Head is energy per unit weight, as energy is in units of (weight * length), head has length units. Pressure head is the energy per unit weight stored in the fluid due to the pressure the fluid is under. Elevation head is the potential energy per unit weight stored in the fluid due to its elevation measured above a datum elevation. Velocity head is the kinetic energy per unit weight stored in the fluid due to speed and direction the fluid is moving.




The total amount of head at point 1 must equal the total amount of head at point 2.The meter uses a narrowing throat in the pipe which then expands back to the original pipe diameter, by measuring the pressure head at both points on the meter; we can calculate the velocity of the fluid. Using the theory of continuity, which states that total flow, must remain constant:

$$\mathbf{Q = vA}$$

The Q term being the total flow, it is equal to the velocity v multiplied by the cross-sectional area A.

Since **Q1 = Q2, v1A1 = v2A2**

A venturi Meter is a device used to measure the flow speed of a fluid in a pipe. At the throat, the area is reduce from (A) to (a) and the velocity is increased from (v) to (V). Note that at the throat where the velocity is the greatest, the pressure is least. This we know from Bernoulli's equation, which is:

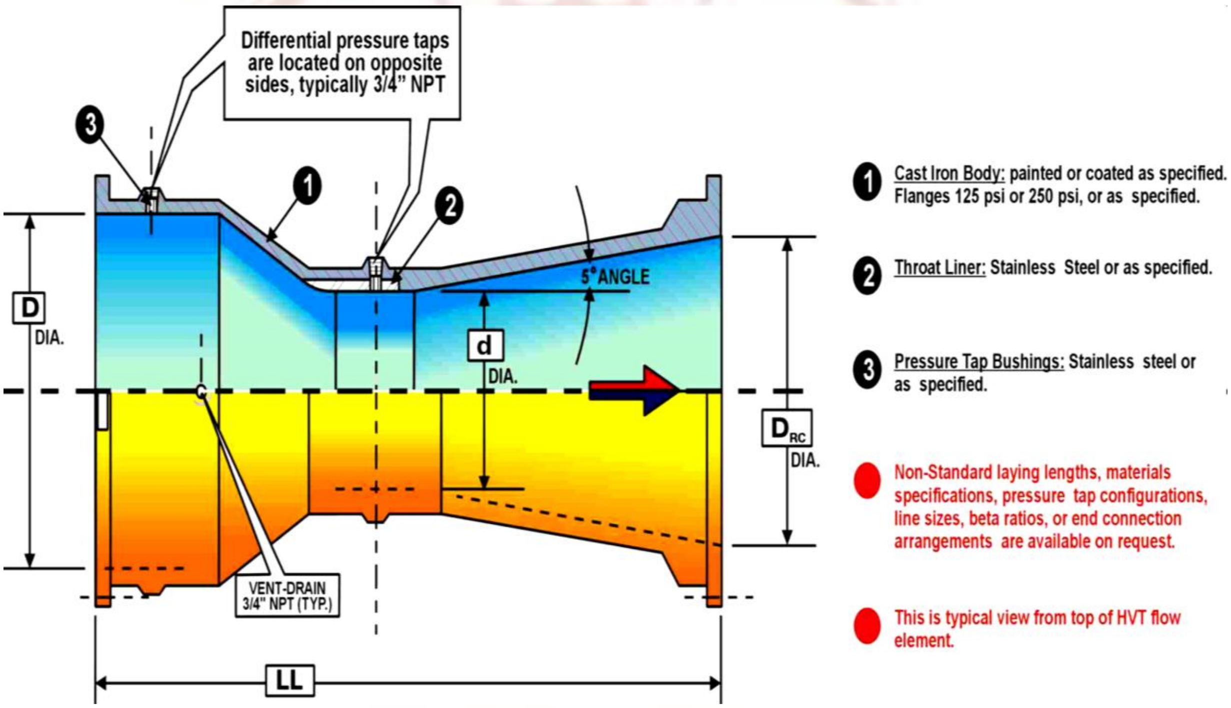
$$\mathbf{P1 + 1/2\ V12 + gy1 = P2 + 1/2\ V22 + gy2.}$$

This equation addresses the conservation of energy involving a fluid. We can use a form of this equation and the equation of continuity, A*v = const. The Venturi tubes can be calibrated to read and record the volume flow rate (A*v) of a fluid through a pipe or a hose. With these values recorded, the velocity of the fluid through the hose can be calculated. It can be seen that a change in pressure due to a change in the area will create a corresponding change in the velocity of the flow. In the upstream cone of the Venturi meter, velocity is increased, pressure is decreased Pressure drop in the upstream cone is utilized to measure the rate of flow through the instrument Velocity is then decreased and pressure is largely recovered in the down stream cone Mostly used for liquids, water

**Disadvantages of Venturi meter**: Highly expensive Occupies considerable space (L/D ratio of appr.50) cannot be altered for measuring pressure beyond a maximum velocity.

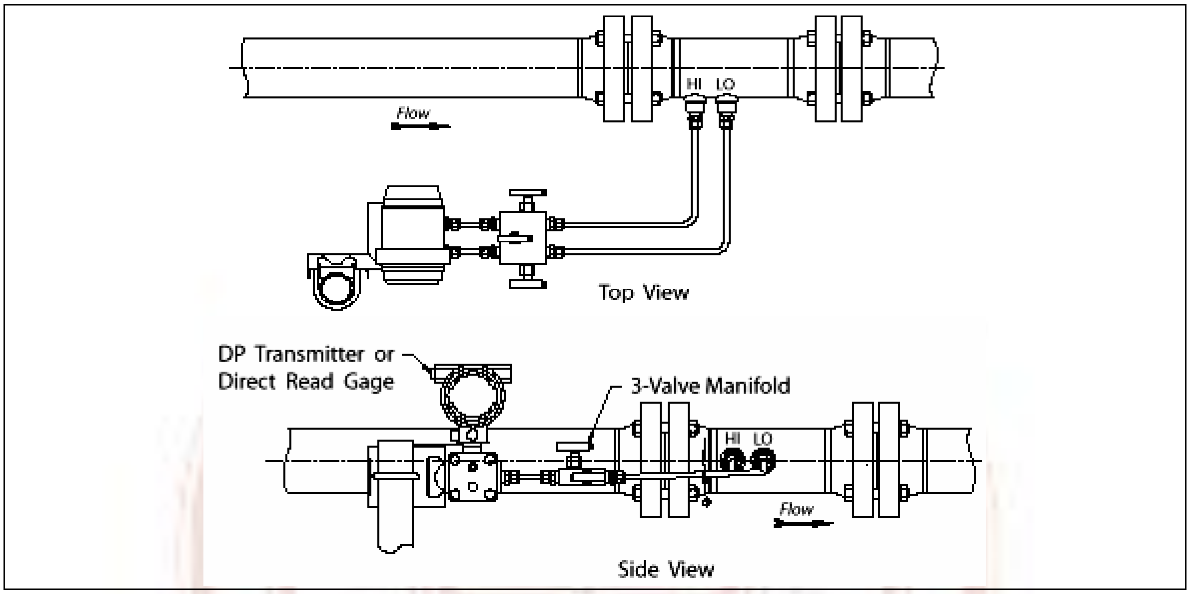
- Example: Kerosene (SG=0.85) flows through the Venturi meter shown in Fig. E3.11 with flow rates between 0.005 and 0.050$m^3$/s. Determine the range in pressure difference, p1-p2, needed to measure these flow rates.

**DESIGN AND CONSTRUCTION**

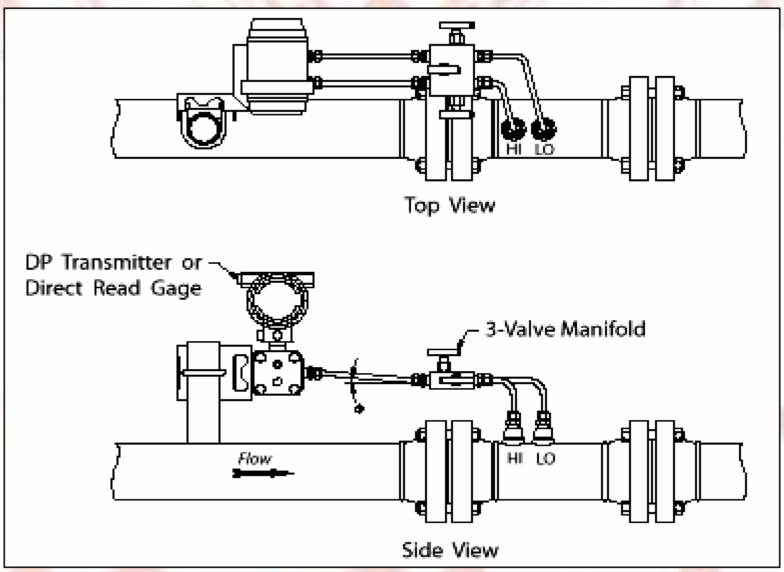



**INSTALLATION**

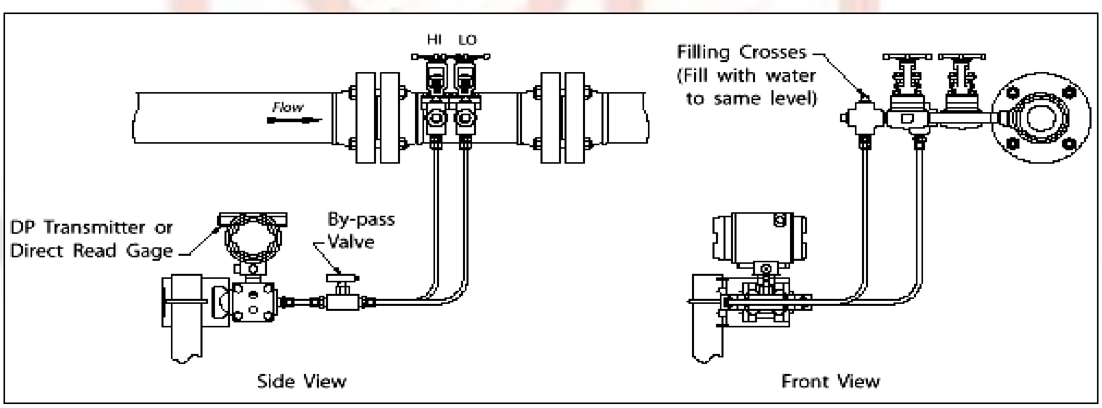
**Straight Pipe Run Requirements**
The recommended minimum length of the upstream side of the Venturi flow element depends on the type of fitting at the start of the straight run and the pipe configuration.
**Selecting a Mounting Location**
The primary Venturi station can be installed in any position on vertical or horizontal lines. However, on horizontal liquid lines where the risk of gas/gas entrapment in the meter tubing is prevalent, it is recommended to install the element with the connections below the horizontal center line. For horizontal air or gas lines, it is recommended to install the element with the connection above the horizontal centerline. For steam lines, to protect the transmitter, it is recommended to install the element so that the connections are in the horizontal centerline on meters with the instrument taps in the same plane.
Vertical installations may introduce a slight hydrostatic head effect, which must be considered when zeroing a transmitter. The use of a 3-valve manifold is recommended particularly for zeroing a transmitter. Before installation of any Venturi element, inspect for damage, particularly at the sealing surfaces.



*Typical horizontal installation for liquids*



*Typical horizontal installation for gas*



*Typical horizontal installation for steam*

**Line Installation**

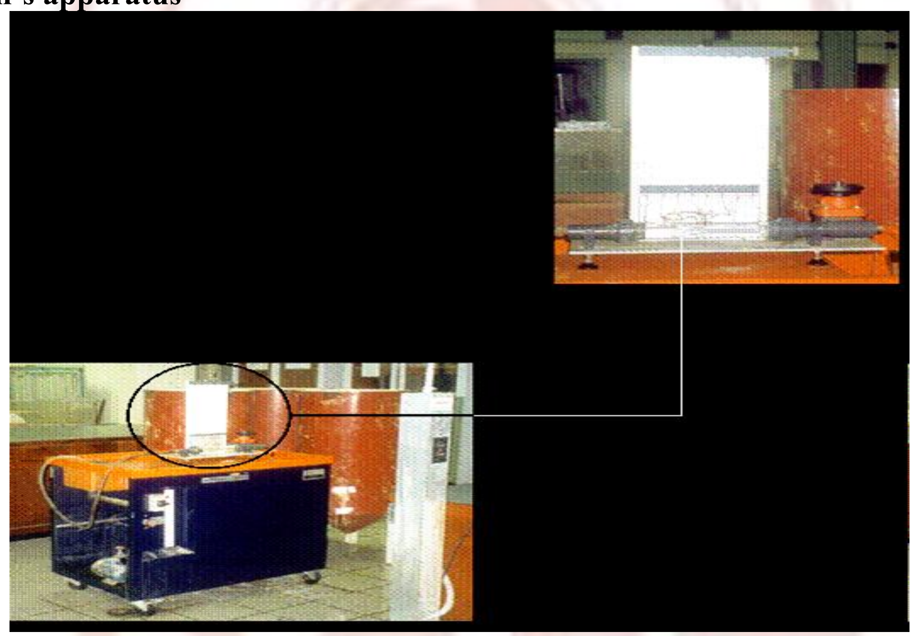
All flanged Venturi flow elements require a gasket between the process line connection and the mating flange. Select gaskets that match the pressure rating of the Venturi flanges and resist corrosive attack of the process fluid.

**Differential Pressure Connections**

The high pressure connection is always on the upstream side of the flow direction arrow and the low pressure connection on the downstream side. Fittings used must be able to withstand the process temperature and pressure conditions, as well as provide proper corrosion resistance.

## CALIBRATION

**Bernoulli's apparatus**



## SELECTION CRITERIA

- Brass Model UA - Venturi Balancing Data: GPM Flow v. Differential Pressure
- Steel Models VW, VG, VF, AW, AG, AF, EG, EF, ER: Venturi GPM Flow v. Differential Pressure - 16 to 775 GPM
- Steel Venturi Selection Procedure – Models VW, VG and VF - Sizes 2" to 14"

## APPLICATIONS

- Venturi meters are used in pipelines at wastewater collection systems and treatment plants. They are used in wastewater pipes because their overall design structure allows for solids to pass through it instead of collecting in front of it. The temperatures and pressures of chemicals in a pipeline do not affect the accuracy of a Venturi flow meter and because of this they are used in crude oil pipelines. Crude oil pipelines, such as the ones in Alaska, are exposed to extreme temperatures during the long arctic winter months. Another advantage of using the Venturi meter in such volatile and frigid environments is that it has no moving parts; there is no risk of them freezing and breaking due to thermal expansion.

- The venturi in carburetors is used to measure airflow in a car engine and to ensure that a correct amount of fuel is fed to the gas combustion engine when needed during driving. The air and fuel mixture must be evenly distributed to the engine in order for it to work properly. The temperatures of air and fuel are constantly changing due to the shift in temperatures that occur in an engine during idling, acceleration, high speeds, and low speeds. The venturi meter allows the carburetor to adjust and calibrate the distribution of fuel and air to the engine as needed.

**CONFORMATION TO STANDARDS**

- ISO (1991) or ASME (1971). : For geometry and specifications for venturi tubes
- ISO 5167: Flow rate, orifice diameter, or differential pressure computations

**PARTIAL LIST OF SUPPLIERS**

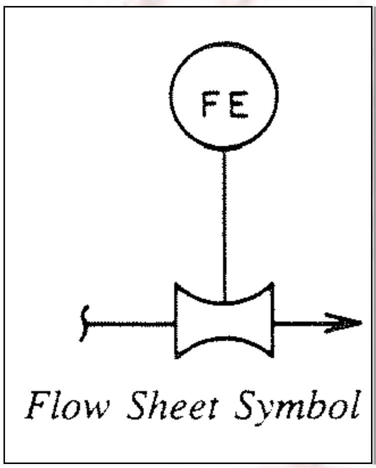
- ABB Kent Taylor
- Bethlehem Corp.
- Daniel Flow Products Inc.
- Digital Valve Co.
- Fischer & Porter Co.
- Fox Valve Development Corp.
- FTI Industries
- West Coast Research Corp.

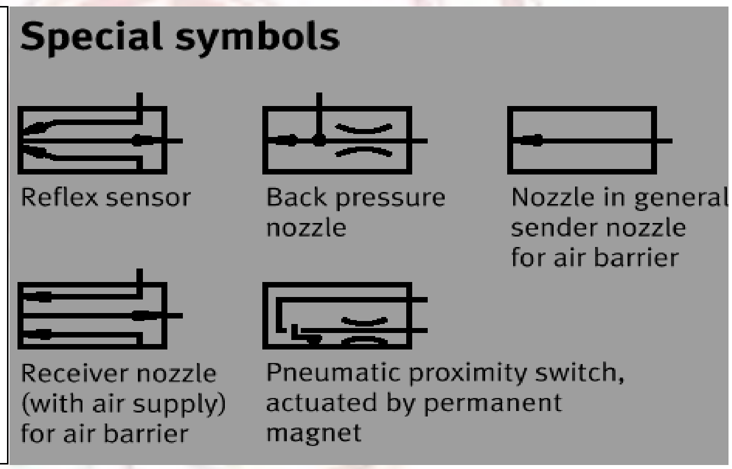
# FLOW NOZZLE

**Description**

A nozzle is a mechanical device designed to control the direction or characteristics of a fluid flow as it exits (or enters) an enclosed chamber or pipe via an orifice. A nozzle is often a pipe or tube of varying cross sectional area and it can be used to direct or modify the flow of a fluid (liquid or gas). Nozzles are frequently used to control the rate of flow, speed, direction, mass, shape, and/or the pressure of the stream that emerges from them.

**Symbol**




**Figure**

## SPECIFICATIONS

### Nozzle Material

- **Aluminum:** Aluminum is a bluish, silver-white, malleable, ductile, light, trivalent metallic element that has good electrical and thermal conductivity, high reflectivity, and resistance to oxidation.
- **Brass:** Brass is an alloy of copper and zinc often with additional elements such as lead or tin; it is characterized by good strength, excellent high temperature ductility and reasonable cold ductility, good conductivity, excellent corrosion resistance, good bearing properties and low magnetic permeability.
- **Bronze:** Bronze is an alloy of copper with other elements such as aluminum, silicon or tin (aluminum bronze, silicon bronze, tin bronze, etc.)
- **Carbide:** Carbide is a class of very hard industrial materials; tungsten carbide is one widely used example.
- **Ceramic:** Ceramics are a class of materials including many compositions; it can have advantageous properties such as low friction and resistance to high temperature.
- **Copper:** Copper is a common reddish-metallic element that is ductile and malleable and is one of the best conductors of heat and electricity; copper tube and fittings are frequently used in plumbing applications.
- **Steel - Carbon & Alloy:** Generic classification for general purpose carbon steel, mild steel or steel alloys containing additions of chrome, nickel, molybdenum, vanadium or other elements to alter hardenability characteristics, toughness, hardness, corrosion resistance, and/or strength. "Blackpipe" is typically made of carbon steel.
- **Steel – Stainless:** Stainless steel is chemical and corrosion resistant and can have relatively high pressure ratings; this selection includes all grades of stainless steel.
- **Thermoplastic:** Thermoplastic includes all grades of thermoplastic materials, such as ABS, nylon, fluoropolymers, etc.

### Technology

- **Pressurized / Hydraulic:** Flow though nozzle is forced by pressurized line; reduced flow area through nozzle orifice increases fluid speed and breaks into droplets.
- **Air Assist / Pneumatic:** Fluid is picked up by the flow of compressed air and forced through orifice; shear force of motive flow breaks fluid into droplets.
- **Ultrasonic:** Electrically-driven oscillation of nozzle at ultrasonic frequencies breaks fluid into droplets; almost no pressurization is required. Ultrasonic nozzles are frequently used in precision cleaning or manufacturing applications.

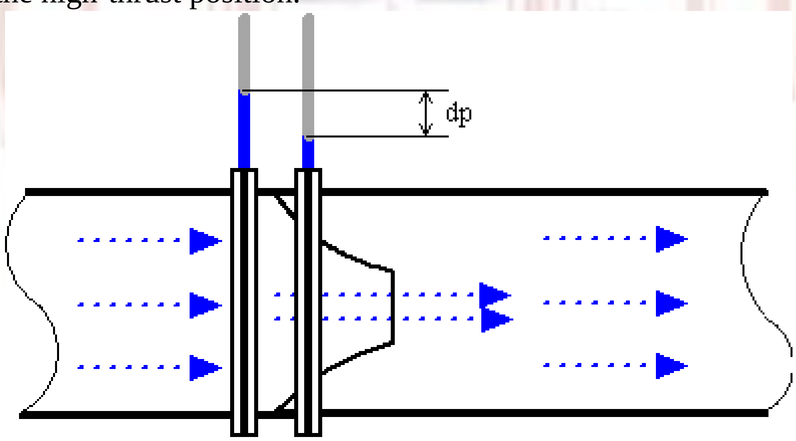
### Nozzle Form

- **In-line:** Pipe or lines mount with straight-through nozzle flow.
- **Right Angle:** Pipe or line mount with right-angle bend in the nozzle.
- **Handheld / Pistol:** Handheld nozzle assembly resembling a pistol grip, typically with a flow control trigger.
- **Handheld / Wand:** Handheld configuration with a long tube or wand for manual spray direction

- **Adjustable Flow / Pattern:** Flow or spray pattern may be adjusted via manual or other means.
- **Adjustable Position / Direction:** Nozzle may be manipulated or actuated to different position or spray direction.

**PRINCIPLE OF OPERATION**

The primary objective of a nozzle is to expand the exhaust stream to, or near to, atmospheric pressure, and form it into a high speed jet to propel the vehicle. The energy to accelerate the stream comes from the temperature and pressure of the gas- the gas expands adiabatically, when done against a nozzle, this largely reversibly (and hence efficiently), cools and expands and accelerates the gas. The hotter and higher the pressure the gas entering the nozzle, the faster the exhaust jet can become. Engines that are required to generate thrust quickly, from idle, use a variable area propelling nozzle in its open configuration to keep thrust to a minimum while maintaining high engine rpm. When thrust is needed, initiating a go-around for example, it is simple and quick to close the nozzle to the high-thrust position.




**Ideal flow theory**

The flow of fluids, both liquids and gases (incompressible and compressible, respectively) is governed by the equations of continuity (mass flow rate,) and energy. Let us write these mass and energy equations for two stations - (1) entrance to the nozzle and (2) the throat of restriction.

$$AV_1 \rho_1 = a V_2 \rho_2 \ \ldots\ldots\ldots\ldots\ (1)$$

Where: A = the duct area

a = the throat area

$V_1$ and $V_2$ = fluid velocities at points (1) and (2)

$\rho_1$ and $\rho_2$ = fluid densities at points (1) and (2)

The Energy Equation for the same two cross-section points is:

$$\frac{P_1}{\rho_1} + \frac{V_1^2}{2g_c} + u_{i1} = \frac{P_2}{\rho_2} + \frac{V_2^2}{2g_c} + u_{i2} \qquad (2)$$

For incompressible fluids, density and temperature may taken as unchanging ($\rho1 = \rho2 = \rho$) and $ui_1 = ui_2$ (assuming no appreciable change in liquid temperature).
Equations (1) and (2) are then readily combined to yield the classical result for nozzle exit velocity:

$$V_2^2 = 2g_c \left[\frac{\Delta P}{\rho}\right]\left[\frac{1}{1-\beta^4}\right] \qquad (3)$$

where: $\Delta P = P_1 - P_2$

$$\beta = \frac{d}{D}$$

$$\beta^2 = \frac{a}{A}$$

**The mass flow rate, $\dot{m} = \rho a V_2$, is then expressed as:**

$$\dot{m}^2 = a^2\left[\frac{2g_c\,\rho\,\Delta P}{1-\beta^4}\right] \qquad (4)$$

**Compressible flow**

The case of gaseous (compressible) flow, including viscous friction, is more involved. We are obliged to introduce, in addition to the mass continuity and energy equations, an equation of state relating the intensive properties of the fluid - temperature, pressure, density. For moderate temperatures and pressures (the majority of cases), we can use the ideal gas law:

$$P = \rho RT \qquad (5)$$

where: $R$ = gas constant, $ft \cdot lb_f/lb_m\ ^\circ R$
= $R$/Molecular Weight
= 1545.33/29 (for air)
= 53.3

**Discharge coefficient**

The actual mass flow rate through the nozzle is diminished from the theoretical value by the existence of a fluid boundary layer. Therefore, the application of a "discharge coefficient" (CD) to the theoretical value is required to obtain the actual flow rate.
In the absence of extensive procedures for obtaining the proper discharge coefficient, various empirical formulations have been suggested for arriving at suitable values of CD.

From elementary boundary-layer theory it is known that the discharge coefficient is a function of Reynolds Number (Rd).

One formulation recommended:

$$C_D = .9975 - .00653 \left[\frac{10^6}{R_d}\right]^a$$

**Types of nozzles**

**Jets**

A **gas jet**, **fluid jet**, or **hydro jet** is a nozzle intended to eject gas or fluid in a coherent stream into a surrounding medium. Gas jets are commonly found in gas stoves, ovens, or barbecues. Gas jets were commonly used for light before the development of electric light. Other types of fluid jets are found in carburetors, where smooth calibrated orifices are used to regulate the flow of fuel into an engine, and in Jacuzzis or spas. Another specialized jet is the laminar. This is a water jet that contains devices to smooth out the pressure and flow, and gives laminar flow, as its name suggests. This gives better results for fountains.

**High velocity nozzles**

The goal is to increase the kinetic energy of the flowing medium at the expense of its pressure and internal energy. Nozzles can be described as *convergent* (narrowing down from a wide diameter to a smaller diameter in the direction of the flow) or *divergent* (expanding from a smaller diameter to a larger one). It has a convergent section followed by a divergent section and is often called a convergent-divergent nozzle.

**Propelling nozzles**

A jet exhaust produces a net thrust from the energy obtained from combusting fuel which is added to the inducted air. This hot air is passed through a high speed nozzle, a *propelling nozzle* which enormously increases its kinetic energy. For a given mass flow, greater thrust is obtained with a higher exhaust velocity, but the best energy efficiency is obtained when the exhaust speed is well matched with the airspeed. Supersonic jet engines, like those employed in fighters and SST aircraft (e.g. Concorde), need high exhaust speeds. Subsonic jet engines employ relatively low, subsonic, exhaust velocities. They thus employ simple convergent nozzles. In addition, bypass nozzles are employed giving even lower speeds.

**Magnetic nozzles**

Magnetic nozzles have also been proposed for some types of propulsion, in which the flow of plasma is directed by magnetic fields instead of wall made of solid matter.

**Spray nozzles**

A spray nozzle is a device that facilitates the formation of spray. When a liquid is dispersed as a stream of droplets (atomization), it is called a spray. Spray nozzles are used to achieve two primary functions: increase liquid surface area to enhance evaporation, or distribute a liquid over an area. Many nozzles produce a very fine spray of liquids.

**Shaping nozzles**

Some nozzles are shaped to produce a stream that is of a particular shape. For example extrusion molding is a way of producing lengths of metals or plastics or other materials with a particular cross-section. This nozzle is typically referred to as a die

**Vacuum nozzles**

Vacuum cleaner nozzles come in several different shapes.

## DESIGN FUNDAMENTALS

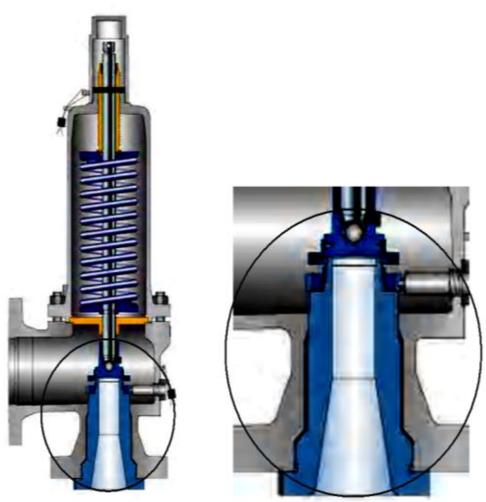
**Full nozzle and semi nozzle design**

The nozzle is a primary pressure- containing component in a safety valve that forms a part or all of the inlet flow passage.

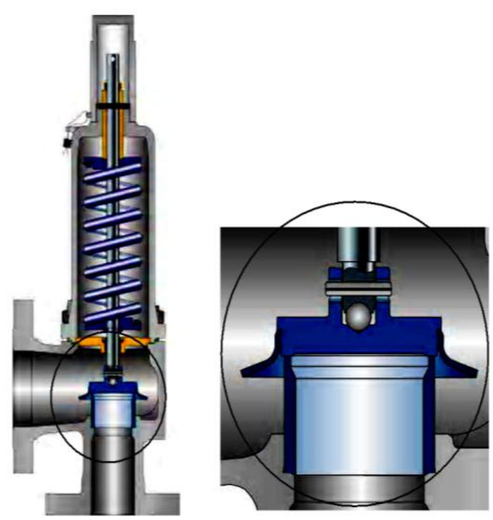
• Full nozzle: the nozzle forms all of the inlet flow passage and is typically threaded into the valve body

• Semi nozzle: the nozzle forms only a part of the inlet flow passage and is typically not removable from the valve body

Most nozzles and discs are made from stainless steel to avoid corrosion and to ensure trouble free valve performance. Selection of other corrosion resistant materials may be advisable depending on the application.



Full nozzle design - LESER Type 526



Semi nozzle design - LESER Type 441

## SELECTION CRITERIA OF A FULL NOZZLE OR A SEMI NOZZLE DESIGN

| Criteria | Full Nozzle | Semi Nozzle |
|---|---|---|
| Regional Preference | USA and regions where the API standard is the dominating standard | Europe<br>USA for ASME I applications |
| Design Standard | Design per API 526 / API 520 required | No design standard required |
| Application (corrosion) | Together with a disc in stainless steel, all permanently wetted parts have excellent corrosion resistance. In corrosive process applications selection of a carbon steel body material is possible. | The valve body will be permanently in contact with the medium.<br>A carbon steel body material can be selected for non corrosive applications, e.g. utility, air, steam, water.<br>A stainless steel body material should be selected for corrosive process applications. |
| Pressure | All pressure ranges | Max set pressure approx. 100 bar / 1450 psig |
| Capacity | In most cases according to API orifice designations. | In most cases full bore designs with maximum capacity relative to the valve size. |
| Repair | A full nozzle is typically removable and can either be replaced or repaired outside of the valve body | A semi nozzle can typically not be removed. Repair is possible inside of the valve body with lapping tools. To repair major damages of the seat, the complet body must be taken on a lathe. |
| Cost | Full nozzle designs require more machining and material and are less cost effective than semi nozzle designs. | A semi nozzle design requires less machining and less material than a full nozzle design thus being more cost effective. |

## CONFORMATION TO STANDARDS

- ISO, ASME : Calculation Standards
- ASME : Dimensions Standards

## APPLICATIONS

- Absorber Towers
- Air Wash
- Automated Spraying
- Cooling: In Process
- De scaling
- Air control
- Airless Spraying
- Coatings & Additives
- Washing- Tank
- Cooling: gas
- Dust control
- Etching & Rinsing
- Foam control
- Scrubbers- Gas conditioning
- Spray drying
- Washing: conveyor
- Fire protection
- Humidification
- Scrubbers- Wet
- Spray ponds- Evaporating & Cooling

**PARTIAL LIST OF SUPPLIERS**

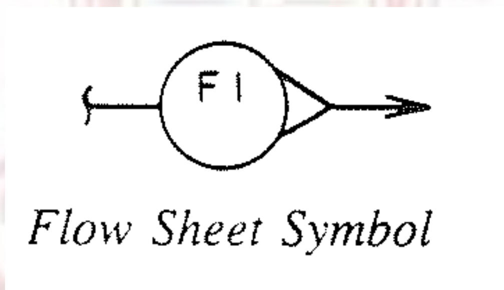
- Filter Machines Pvt. Ltd, Gujarat
- Bohra Engg &Trading corporation, Mumbai
- Sri durga industries,chennai
- Spraytech maharashtra
- R.K.Metals, Haryana
- Armtec corporation, Maharashtra
- Quench technologies,Delhi
- D.M Enterprises, Guragon

# VARIABLE AREA METER (ROTAMETERS)

**Description**

A Rota meter is a device that measures the flow rate of liquid or gas in a closed tube. It belongs to a class of meters called variable area meters, which measure flow rate by allowing the cross-sectional area the fluid travels through to vary, causing some measurable effect. The rotameter consists of a vertical, tapered, transparent tube containing a float. The float moves upward as the fluid flow increases. A variable ring or annulus is created between the outer diameter of the float and the inner wall of the tube. As the float moves upward in the tube, the area of the annulus increases. The float will continue to move upward until a pressure drop across the float, which is unique for each rotameter, is reached. This pressure drop across the float is constant regardless of the flow rate. Graduations are etched on the side of the tube so that an instantaneous reading may be observed.

**Symbol**




**Figure**


*Acrylic body Rota meter and glass tube Rota meter*

**SPECIFICATION**

***Functional***

- Standard accuracy : ±3% of FS( Full scale)
- Repeatability : ±0.5% FS ( Full scale)
- Max.Operating press. : 200 psig at 200°f (13.8 bars at 93°c) for tube sizes 3, 4, 5 & 6; 125 psig at 200°f (8.6 bars at 93°c) for tube sizes 8 & 9
- Max.Operating temp. : 200°f (93°c)
- Flow range : 100 to 40,000 LPH for water & 0.5 to 450 m3/hr for air
- Scale Length : 175 -200 mm Aprox.
- Rangeability : 10 : 1
- Line size : ½ in. to 4 in.

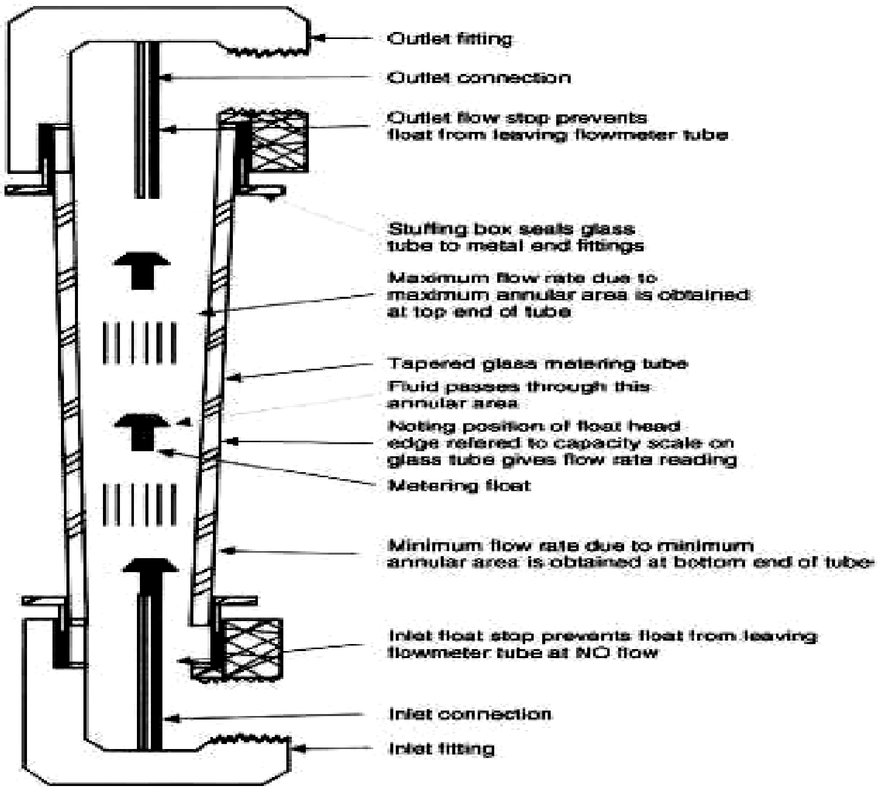
***Physical***

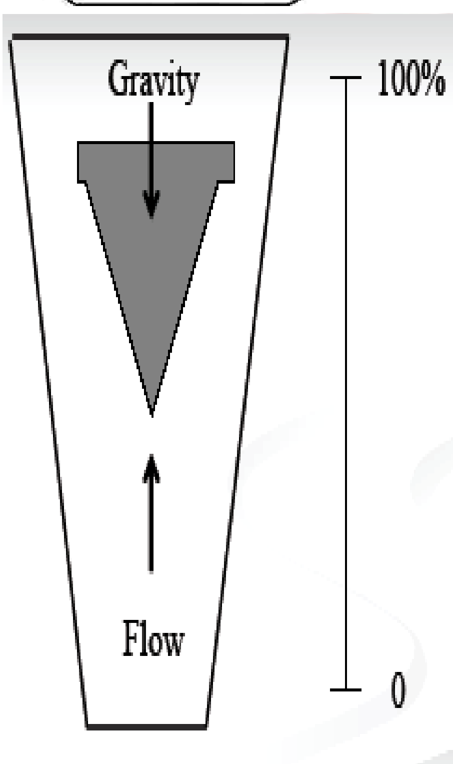
- Flow tubes : heavy walled precision formed borosilicate glass
- Floats : 316 stainless steel, PTFE, PVC, PP
- Tube shield : polycarbonate
- Wetted parts : 316 stainless steel ,SS 304, CS, PP, PTFE Lined
- Scale : PVC, Aluminium, SS Engraved.
- End Connection : Flanged, Threaded M/F
- Mounting : Online or Flush Panel, field
- Accessories : High & Low Flow alarm
- Seals : viton® o-rings standard; optional buna-n,PTFE/kalrez®, EPR viton® and kalrez® are registered trademarks of DuPont dow elastomers

**PRINCIPLE OF OPERATION**

**Variable Area Principle:** The Rota meter's operation is based on the variable area principle: fluid flow raises a float in a tapered tube, increasing the area for passage of the fluid. The greater the flow, the higher the float is raised. The height of the float is directly proportional to the flow rate. With liquids, the float is raised by a combination of the buoyancy of the liquid and the velocity head of the fluid. With gases, buoyancy is negligible, and the float responds to the velocity head alone. The float moves up or down in the tube in proportion to the fluid flow rate and the annular area between the float and the tube wall. The float reaches a stable position in the tube when the upward force exerted by the flowing fluid equals the downward gravitational force exerted by the weight of the float. A change in flow rate upsets this balance of forces. The float then moves up or down, changing the annular area until it again reaches a position where the forces are in equilibrium. To satisfy the force equation, the rotameter float assumes a distinct position for every constant flow rate. However, it is important to note that because the float position is gravity dependent, Rota meters must be vertically oriented and mounted.

A Rota meter consists of a tapered tube, typically made of glass, with a float inside that is pushed up by flow and pulled down by gravity. At a higher flow rate more area (between the float and the tube) is needed to accommodate the flow, so the float rises. The floats are made in many different shapes, with spheres and ellipsoids being the most common.




*Operation of Rota meter*

The float is shaped so that it rotates axially as the fluid passes. This allows you to tell if the float is stuck since it will only rotate if it is free. Readings are usually taken at the top of the widest part of the float; the center for an ellipsoid, or the top for a cylinder. Some manufacturers may use a different standard, so it is always best to check the documentation provided with the device. Note that the "float" does not actually float in the fluid: it has to have a higher density than the fluid, otherwise it will float to the top even if there is no flow.

**Advantages**

- A Rota meter requires no external power or fuel; it uses only the inherent properties of the fluid, along with gravity, to measure flow rate.
- A Rota meter is also a relatively simple device that can be mass manufactured out of cheap materials, allowing for its widespread use.
- It has a linear scale, a relatively long measurement range, and low pressure drop.
- It is simple to install and maintain.

**Flow Rate Analysis.**

The forces acting on the bob lead to equilibrium between the weights of the bob $\rho_b g V_b$ acting downwards; the buoyancy force $\rho g V_b$ and the drag force $F_d$ acting upwards.

$$\rho_b \, g V_b = \rho g \, V_b + F_d$$

Where: $V_b$ is the volume and
$g$ is the gravitational acceleration:
$\rho$ is the density of the fluid and $\rho_b$ is the density of the bob

The drag force results from the flow field surrounding the bob and particularly from the wake of the bob. In flow analyses based on similarity principles, these influences are accounted for by empirical coefficient $C$L or $C$T in the drag law for:

**Laminar flow** $F_d = C_L \, \mu D_b U$
**Turbulent flow** $F_d = C_T \, \rho D_b^2 U^2$

Where: $D_b$ = maximum bob diameter
U = velocity in the annular gap around the bob at the minimum cross-section.
$\mu$ = fluid viscosity

**The volume flow rate through the Rota meter is:**

$$Q = \pi/4 \, (D_b - D_b^2) \, U$$
$$Q = m \, \pi/4 \, D_b^2 \, U$$

Where D, the tube diameter at the height of the bob and $m$, the open area ratio, given as:

$$m = (D_b - D_b^2) / D_b^2$$

**For laminar flow:**

$$Q_L = \alpha D_b^4 \frac{(\rho_b - \rho) g}{\mu}$$

$$\alpha = \frac{\pi m K}{4C_L}$$

Where the parameter α is defined in terms of a constant $K = Vb/D^3b$ characteristic of the shape of the bob:

**For turbulent flow:**

$$Q_T = \beta D_b^{5/2} \sqrt{\frac{(\rho_b - \rho) g}{\rho}}$$

$$\beta = \frac{\pi m}{4} \sqrt{\frac{K}{C_T}}$$

With either laminar or turbulent flow through the rota meter, the flow rate is proportional to *m*. If the cross-sectional area of the tube is made to increase linearly with length, i.e.

$$D = D_b (1 + h \tan ø)$$

Then since the cone angle ø of the tube is small, and the flow rate is directly proportional to the height *h* of the bob.

$$m = 2 h \tan ø$$

**INSTALLATION**

Rota meters must be mounted vertically with the flow upwards in the metering section. Aside from this limitation, Rota meters offer complete freedom of installation. They can be mounted directly in a pipeline, in front or behind a control panel or directly on the operating machinery. In most industrial applications, a bypass piping configuration is recommended. By adding three valves and some piping, the Rotameter may be removed completely for servicing or replacement without affecting the flow in the system

- The installation of Rota meter shall in general be according to clause 3.6.4.6 of Instrumentation Design Criteria.
- Rota meters shall be installed vertically with the outlet connection at the top and the inlet connection at the bottom.
- Rota meters shall be installed as received. A level plumb shall be used to check for proper installation.
- The Rota meter location shall be free from vibration.
- The Rota meter shall be located with sufficient clearance for maintenance purposes, including float removal, without dismantling the meter body from the pipeline
- Elbows, valves & other fittings shall not be closer than 5 pipe diameters upstream.
- The meters shall be provided with two full-bore isolating valves and by-pass valve for maintenance. A check valve shall be installed downstream, where backflow may be expected in gas service, or where there is the possibility of liquid hammer

**INSPECTION & TESTING:**

- Calibration, inspection and testing requirements shall in general be as per clause 3.6.4.7 of Instrumentation Design Criteria.
- In addition Rota meters shall be checked and tested after installation
- The transmitting mechanism of the Rota meters shall be checked by mechanically raising and lowering the float and then checking the output.

**CALIBRATION**

**Flow Calibration:** You will perform the rotameter calibration on the experimental equipment that we also use to calibrate obstruction flow meters, meters that generate a pressure drop to indicate flow. To prevent pushing mercury into the flow system, you must elevate the mercury reservoir that connects to a series of manometers used to measure the pressure drop across the obstruction flow meters. Before elevating the reservoir, you must loosen the reservoir's seal cap and open the Teflon stopcock. This procedure allows mercury to fill up in the manometer legs as you raise the reservoir. Next, check the copper storage tank's fluid level. If the level reads below the "Fill to this level" mark, add tap water using the vinyl garden hose. A centrifugal pump, the type used in this experiment, will cavitate (suck air) if the fluid level is too low. Excessive cavitations could damage the pump's impeller. To prevent any sudden flow surges, you should close the flow control valve before turning on the pump. No pump damage will occur with this valve closed because the fluid just spins inside the pump head. If the pump runs too long in a deadheaded configuration, the viscous energy dissipated inside the pump will eventually rise the temperature high enough to boil the water. (This will occur when the suction pressure equals the vapor pressure of the fluid inside the pump.)

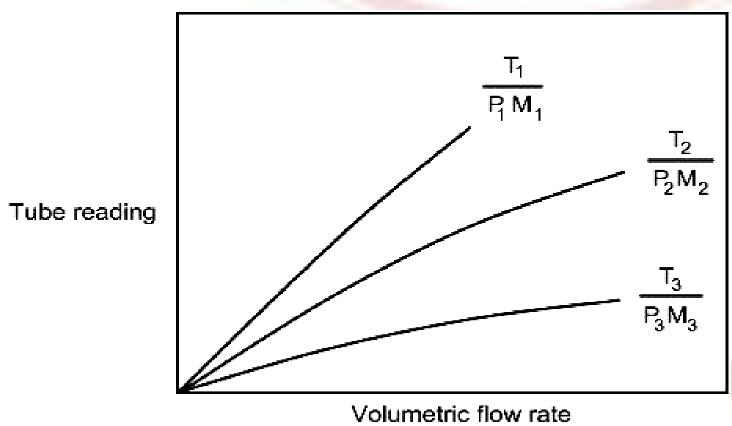
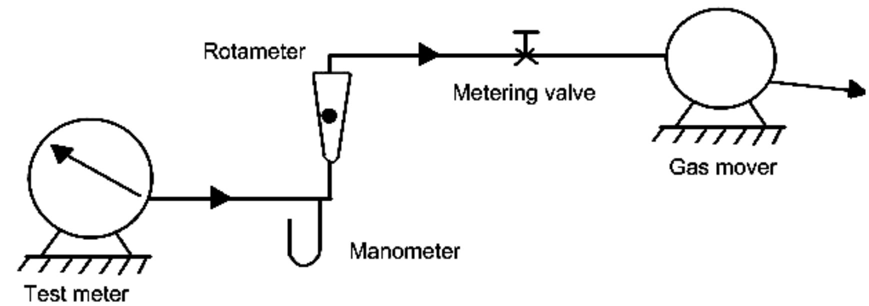



***Figure: Calibration curve Flow***

**Gas Calibration:** Flow through the calibration train is controlled by the metering valve. At various settings of the rotameter float, measurements are made of the flow rate through the train and of the pressure and temperature of the gas stream at the rotameter. The temperature of the gas stream is usually assumed to be the same as the temperature of the ambient air. If the test meter significantly affects the pressure or temperature of the gas stream, measurements should also be made of the actual pressure and temperature at the test meter. A typical rotameter calibration curve is illustrated



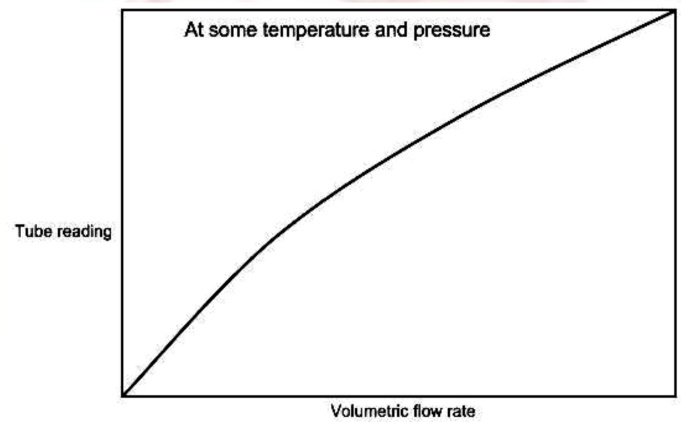
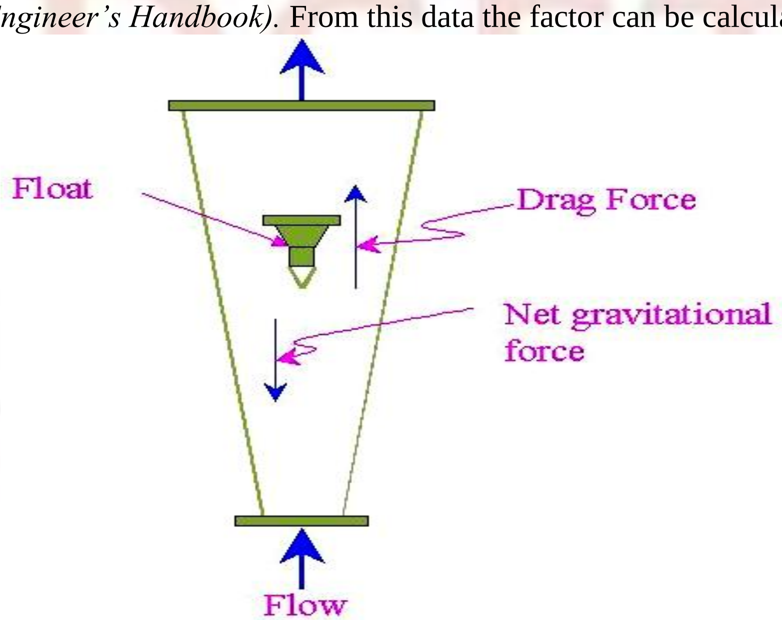




***Figure Calibration curve Gas & Temperature***

To determine an existing flow rate, measurements must be made of the gas temperature and pressure as well as the float position. Data from the manufacturer of the rotameter will yield information on the diameter of the tube at the various float positions and on the diameter and mast of the float. The apparent molecular weight of the gas being metered can be calculated if the composition of the gas stream is known. The viscosity of the gas stream can be determined if the temperature of the gas stream is known (see Perry's *Chemical Engineer's Handbook).* From this data the factor can be calculated.



## SELECTION CRITERIA

- Selecting the Right Flow meter Size: There are certain factors which affect the measurement of a fluid's flow rate with a rotameter. The fluid's temperature, pressure and specific gravity all impact gas flow measurements.
- With the variety of types and sizes available, the correct Rotameter can be found for practically any application. One of the first considerations is the fluid to be metered and its operating conditions. Is the fluid particularly corrosive so that special tube, fitting and float materials are required? Are operating temperatures, pressures and/or shock levels high enough to make glass metering tubes undesirable?
- The next step is to determine the style of float for the application. As noted the equation defining Rotameter performance is Q = KA v-2gh: The factor "K" is the discharge coefficient of the annulus between the tube and the float. It is influenced by the viscosity of the fluid and by the shape of the float. By choosing an appropriate float shape, "K" can be held constant over a fairly wide range of viscosities. The ball, plumb bob and the streamlined floats are quite sensitive to viscosity variations; with the ball being affected to the greatest extent. The full viscosity compensating float is unaffected by a viscosity change of two orders of magnitude.
- Another term affecting Rotameter accuracy is the head loss "h". This value is a function of the weight of the float, its specific gravity, and the specific gravity of the metered fluid. Changes in fluid density will therefore cause an error in flow readings.
- The last step is to select the proper size meter for a given flow rate. Most manufacturers list capacities in terms of two standard fluids: water at 700 F and air at 700 F and 14.7 psia. Using float selection curves, capacity tables, and factor tables as supplied by manufacturers, it is a simple matter to select a proper flow meter for the job at hand. Flow capacities (ranges) for the flow meters for air at standard conditions are 14.7 psia (101.3 KPa Abs) and 70°F (21°C). Sizing a meter for a gas other than air, or for the specific application pressure and/or temperature, requires that we first determine the equivalent flow capacity in air at standard conditions. Once determined, the flow capacity tables can be applied directly. The Schutte and Koerting curves and tables are excerpts from the company's complete series. For liquids, the viscosity and specific gravity of the fluid being measured must be known. For gas service, the density of the gas in the meter must be known. This is usually derived through knowledge of the temperature and pressure in the meter, plus the density of the gas at standard conditions, or through the use of thermo dynamic tables. Following are other questions of consideration while selecting a Rota meter
- What is the minimum and maximum flow rate for the flow meter?
- What is the minimum and maximum process temperature?
- What is the size of the pipe?
- Would you like a direct reading Rota meter or is a look up table acceptable?
- What accuracy do you need?
- Do you require a valve to regulate the flow?
- Will there be back pressure?

## CONFORMATION TO STANDARDS

- ISO 9001:2008 : Quality/Safety Certifications

## APPLICATIONS

Rota meter shall be used as the flow-measuring element wherever dictated by the process requirements. In general Rota meter shall be used when:

- Linear flow rate signal characteristics are required.
- Extremely low flow rate measurement is involved.
- Rangeability is greater than 3 to 1.
- Chemical and Process Industries
- Pharmaceuticals and Drug Industry
- Mining and Aluminium Complexes
- Dairy and Food Industry
- Effluent Treatment Plants
- Water and Severage Boards
- Pulp Paper and Rayon Industry
- Steel Plants
- Petrochemicals
- Fertilizers

## PARTIAL LIST OF SUPPLIERS

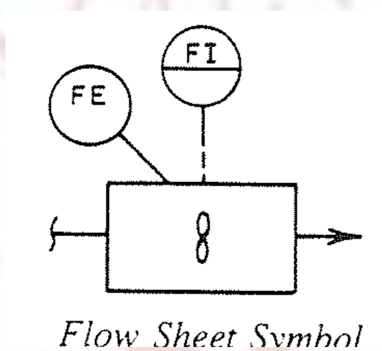
- Rotex
- Vogtlin
- Escrow
- Brooks Armored
- Rota Yokogawa
- Instrumart
- Fitzer instruments
- Flow Tech Instruments
- Flow Network Industrial Sensing Solutions
- Aalborg Instruments & Controls Inc.
- ABB Automation Instrumentation Division
- Blue-White Industries
- Brooks Instrument
- Cole-Parmer Instrument Co.
- Dwyer Instruments Inc.
- Key Instruments
- King Instrument Co.
- Krohne Inc.
- Matheson Instruments
- Omega Engineering Inc.
- Penberthy
- USFilter/Wallace & Tiernan Products

# TURBINE FLOW METER

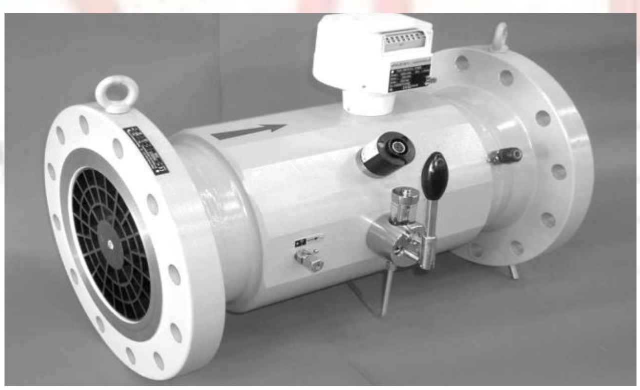
**Description**

A turbine is a rotary engine that extracts energy from a fluid flow and converts it into useful work. The simplest turbines have one moving part, a rotor assembly, which is a shaft or drum with blades attached. Moving fluid acts on the blades, or the blades react to the flow, so that they move and impart rotational energy to the rotor. Early turbine examples are windmills and water wheels. The flow meter is a volumetric measuring turbine type. The flowing fluid engages the vaned rotor causing it to rotate at an angular velocity proportional to the fluid flow rate. The angular velocity of the rotor results in the generation of an electrical signal (AC sine wave type) in the pickup. The summation of the pulsing electrical signal is related directly to total flow. The frequency of the signal relates directly to flow rate. The vaned rotor is the only moving part of the flow meter. The turbine flow meter (better described as an axial turbine) translates the mechanical action of the turbine rotating in the liquid flow around an axis into a user-readable rate of flow (gpm, lpm, etc). The turbine tends to have all the flow traveling around it. The turbine wheel is set in the path of a fluid stream. The flowing fluid impinges on the turbine blades, imparting a force to the blade surface and setting the rotor in motion. When a steady rotation speed has been reached, the speed is proportional to fluid velocity.

**Symbol**




**Figure**



*Axial turbine flow meter*

## SPECIFICATIONS

***Functional***

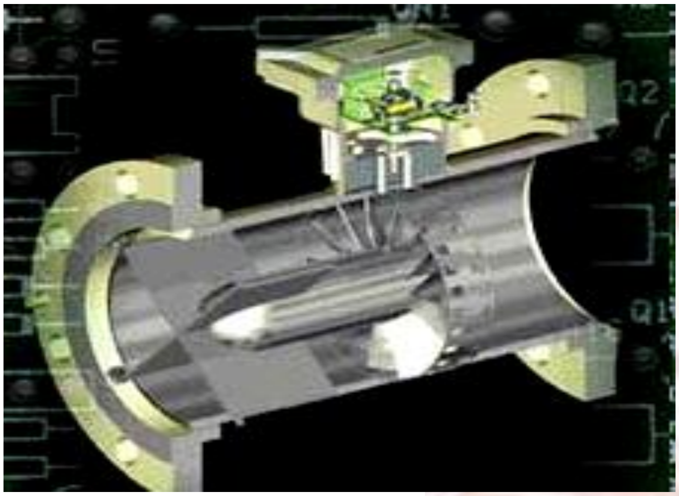
- Flow rate range from: 0.025 Am3/hr to 25,500 Am3/hr, for gases and 0.036 m3/hr to 13,000 m3/hr, (82,000 barrels per hour), for liquids.
- Operating temperature range span:-270 C to 650 C, (-450 F to 1200 F).
- Operating pressure range span: coarse vacuum to 414 MPa, (60,000 psi).
- Range ability: typically between 10:1 and 100:1.

***Terminologies used***

- **Range ability**: It is defined as the ratio of flow rates over which the linearity specification applies.
- **Gas Volumetric Flow Rate**: Gas volumetric flow rate range is the range of flow in volume/time.
- **Liquid Volumetric Flow Rate**: Liquid volumetric flow rate range is the range of flow in volume/time
- **Operating Temperature**: The temperature range over which the device must operate.
- **Operating Pressure**: Operating pressure is the maximum head pressure of the process media that devices can withstand.
- **Velocity Flow Rate**: Velocity flow range is range of flow in distance/time.
- **Non-Invasive**: Non-invasive flow meters do not require mounting directly in the process flow and can be used in closed piping systems. Ultrasonic flow meters such as Doppler devices may use this type of mounting to read the flow through the pipe.

## PRINCIPLE OF OPERATION

The flow meter is a volumetric measuring turbine type. The flowing fluid engages the vaned rotor causing it to rotate at an angular velocity proportional to the fluid flow rate. The angular velocity of the rotor results in the generation of an electrical signal (AC sine wave type) in the pickup. The summation of the pulsing electrical signal is related directly to total flow. The frequency of the signal relates directly to flow rate. The vaned rotor is the only moving part of the flow meter.



*Rotor of Turbine flow meter*

**Crossection of turbine flow meter**

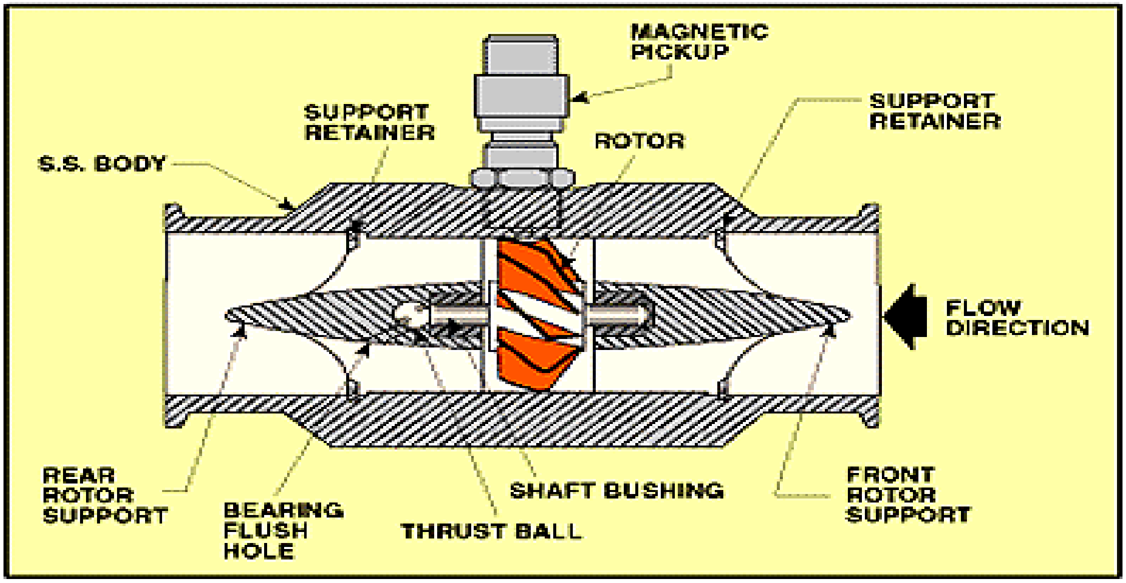



Figure 5: Turbine flowmeter consists of a multiple-bladed, free-spinning, permeable metal rotor housed in a non-magnetic stainless steel body. In operation, the rotating blades generate a frequency signal proportional to the liquid flow rate, which is sensed by the magnetic pickup and transferred to a read-out indicator

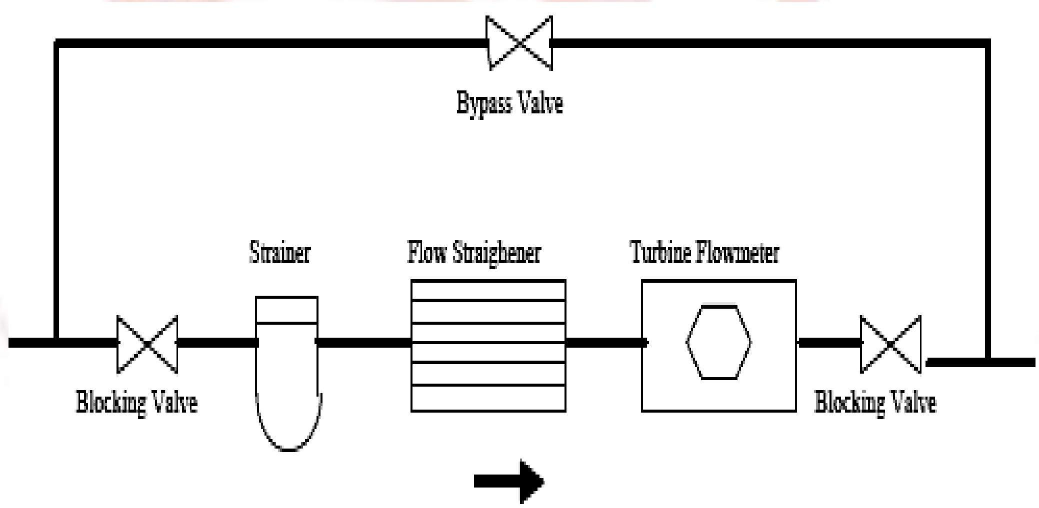
- There is many different manufacturing design of turbine flow meters, but in general they are all based on the same simple principle: If a fluid moves through a pipe and acts on the vanes of a turbine, the turbine will start to spin and rotate. The rate of spin is measured to calculate the flow.
- The turndown ratios may be more than 100:1 if the turbine meter is calibrated for a single fluid and used at constant conditions. Accuracy may be better than +/-0, 1%.
- The turbine flow meter (better described as an axial turbine) translates the mechanical action of the turbine rotating in the liquid flow around an axis into a user-readable rate of flow (gpm, lpm, etc.). The turbine tends to have all the flow traveling around it.
- The turbine wheel is set in the path of a fluid stream. The flowing fluid impinges on the turbine blades, imparting a force to the blade surface and setting the rotor in motion. When a steady rotation speed has been reached, the speed is proportional to fluid velocity.
- Turbine flow meters are used for the measurement of natural gas and liquid flow.
- The flow meter pickup senses the motion of the rotor and converts it to a pulsing electrical signal which is of a discrete, digital nature. The standard pickup for turbine flow meters larger than 1 inch produces a high level sinusoidal output. To produce this, the pickup generates a relatively high magnetic field. The signal may be transmitted up to 200 feet without amplification. A flow range of 10:1 or better is common with this pickup type.
- The modern axial turbine flow meter, when properly installed and calibrated, is a reliable device capable of providing the highest accuracies attainable by any currently available flow sensor for both liquid and gas volumetric flow measurement

## INSTALLATION

- Upon receipt of the turbine flow meter a visual inspection should be performed checking for any indications of damage which may have occurred during shipment. Inspect all packing material carefully to prevent the loss of meter parts or auxiliary components which may have been packed with the shipment. Refer to the packing list/invoice for a detailed list of items included in the shipment.
- The meter housing is marked by a flow direction arrow and the inlet is marked 'IN' and the outlet is marked 'OUT'. The meter must be installed in the piping in the correct orientation to ensure the most accurate and reliable operation. Care should be taken in the proper selection of the mating fittings. Size, type of material, and pressure rating should be the same as the flow meter supplied. The correct gaskets and bolts should be utilized.
- The flow meter may be installed horizontally or vertically for liquid service without affecting the meter calibration, however, in gas applications the meter must be installed horizontally for proper operation. When it is expected that flow will be intermittent, the meter should not be mounted at a low point in the piping system. Solids which settle or congeal in the meter may affect meter performance.
- In order to achieve optimum electrical signal output from the flow meter, due consideration must be given to its isolation from ambient electrical interference such as nearby motors, transformers, and solenoids.

**Impulse Piping**

- As stated in the Principle of Flow meter Operation, the fluid moving through the Flow meter engages the vaned rotor. Swirl present in the fluid ahead of the meter can change the effective angle of engagement and, therefore, cause a deviation from the supplied calibration (performed under controlled flow conditions). Turbine meters are constructed with flow straighteners to minimize the affects of fluid swirl and a non-uniform velocity profile is adequate for most installations. However, it is good practice to maintain a minimum straight run of pipe approximately 10 pipe diameters ahead of the inlet and 5 pipe diameters following the outlet. Proper installation of the flow meter minimizes the negative effects of fluid swirl.



## CALIBRATION

- A 10-point water calibration over the extended range of the meter may be requested at no additional charge. Additional calibration points may be requested within the linear range or in the extended range at additional cost. Fluids other than water are used to simulate viscosity conditions from 2 to 300 centistokes. Where it is necessary to document flow meter performance for viscous service, the flow meter calibration simulates the viscosity, as well as, the flow rate anticipated in actual service.
- Universal Viscosity Calibration (UVC) curves may be documented for each Turbine Flow meter where this information is required to achieve maximum flow meter accuracy in medium to high viscosity service.
- In general, any flow meter size may be supplied with a UVC. However, since smaller meter sizes (under one inch) display the largest sensitivity of calibration factor to viscosity, it is this size range which is the most likely to be considered for a UVC.
- The UVC may be utilized to determine the K-Factor either graphically, or in the case of an intelligent instrument, algorithmically, for a measured set of flowing conditions.
- A standard viscosity calibration which consists of ten repeated points for each viscosity required. A typical UVC curve requires three sets of ten points plotted as a continuous curve. In addition, Hoffer offers a ten point single viscosity (up to 300 centistokes) calibration at a nominal additional fee.

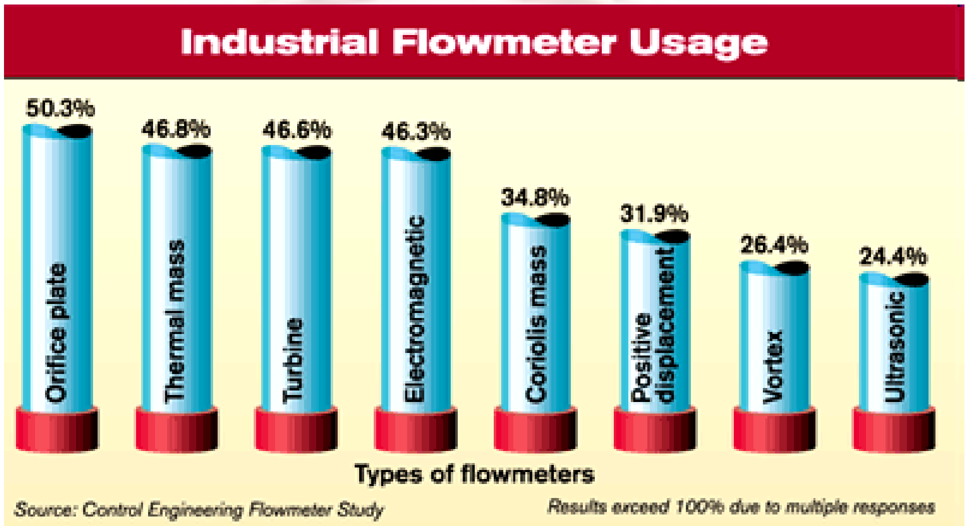
## INSPECTION AND TESTING

- The internal components of the turbine flow meter are precision components which must be handled with care, and therefore, only qualified personnel should service the flow meter.

## SELECTION CRITERIA

- Turbine flow meters are designed for use in a clean fluid service. However, the service fluid may carry some particulate material which would need to be removed before reaching the flow meter. Under these conditions a strainer/filter may be required to reduce the potential hazard of fouling or damage that may be caused by foreign matter. Strainer/filters are recommended to be used with the Hoffer Mini-Flow Series meters.
- The explosion proof requirements of UL Class I, Group C and D, Class II, and NEMA 4X are routinely provided for by enclosing the pickup coil in a suitable housing. Signal conditioners and converters can readily be mounted on the flow meter. Hoffer Turbine Flow meters is inherently safer since they require no through holes eliminating the possibility of a leak.
- In industry axial turbine flow meters are used to measure volume flows of gases and liquids. They are considered reliable flow meters and at suitable conditions can attain high accuracies in the order of 0.1% for liquids and 0.25% for gases.

An accuracy up to 0.02% can reached for high accuracy meters at ideal flow conditions (Wadlow, 1998). Turbine flow meters of different design are used in a broad variety of application for example in the chemical, petrochemical, food and aerospace industry. The internal diameter of these flow meters can vary from very small, e.g. 6 mm, to very large, e.g. 760 mm.




## APPLICATIONS

- Industrial application
- Cryogenic application
- Sanitary application

## CONFORMATION TO STANDARDS

- DN 4 to 100
- ATEX,
- AGA
- API

## PARTIAL LIST OF SUPPLIERS

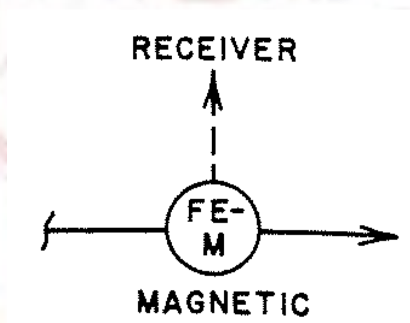
- Hoffer Flow controls
- Woltmann flow meter
- Vortex
- Fitzer
- Anderson instrument
- Blancett
- Aqua metro
- Bop & Reuther messtecknick
- Hoffer flow controls Inc.

# MAGNETIC FLOW METER

**Description**

A magnetic flow meter, also called an electromagnetic flow meter or simply 'magmeter', is a volumetric flow meter which measures pipe flow rate by measuring the voltage generated, as a conductive fluid passes through a magnetic field generated by the flow meter.The magnetic flow meter does not have any movable parts or other obstructions inside the measuring tube; so it creates no pressure drop as part of its pipe flow measurement. Hence they are ideal for applications where low pressure drop and low maintenance are required and is ideal for wastewater applications or any dirty liquid which is conductive or water based. Magnetic flow meters will generally not work with hydrocarbons; distilled water and much non-aqueous solutions. In order for its flow to be measured by a magnetic flow meter, a fluid must have a conductivity of at least 5 ms/cm.It is one of the most accurate industrial flow meter types. Magnetic flow meters are therefore extensively used in such industries as chemicals, food, iron & steel, pulp & paper, and water supply. In contrast with many other flow meter technologies, magnetic flow meter technology produces signals that are linear with flow. As such, the turndown associated with magnetic flow meters can approach 20:1 or better without sacrificing accuracy

**Symbol**




*Flow Sheet Symbol*

**Figure**

***Yokogawa AXF series magnetic flow meters***

## SPECIFICATIONS

***Functional***

- Current output : 4 to 20 mA DC, two-wire system
- Output range : 3.8 to 20.5 mA (–1.25 to 103.13%)
- Contact rating : 30 V DC, 120 mA DC
- Low level : 0 to 2 V DC
- Supply Voltage type : 14.7 - 35 Vdc general-purpose & explosion proof
  : 14.7 to 32 V DC for lightning protector
- Max. Operating Press : 145 PSIG
- Max. Process Temp : -10 to 230°F
- Min. Liquid Conductivity : 5uS/cm
- Fluid temperature : -10 to 120°C; (14 to 250°F)
- Accuracy : ±3% of rate for flow > 0.07 X flowmax
  : ± 0.0021 X flowmax for flow < 0.07 X flowmax
- Optional : ±1.5% of rate for flow > 0.07 X flowmax
  : ± 0.001 X flowmax for flow < 0.07 X flowmax
- Repeatability : ±0.2% of flow rate
- Creep Suppression : Adjustable from 1 to 10% of full scale
- Response Time : Adjustable from 5-40 seconds
- Turndown Ratio : 100: 1

***Electrical***

- Power Requirements : 24 VAC/VDC +10%/-20% @ 6 VA max
  : Electrical Concessions Plug per DIN 43650
- Coil Excitation Frequency : 6.25 Hz
- Warm-Up time : 30 minutes
- Display : Two line LCD rate and total, Selectable between US and metric units

***Physical***

Materials of Construction

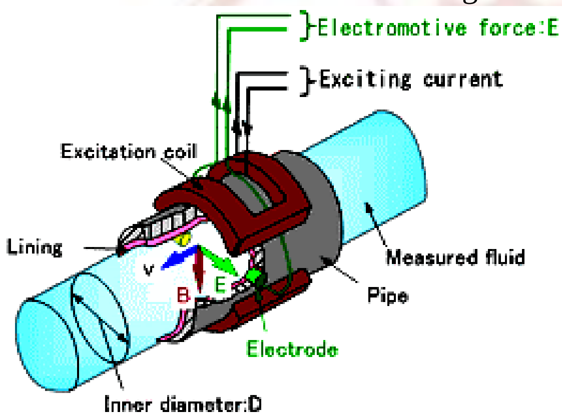
- Body : PEEK or PVDF depending on meter size
- Electrodes : Hastelloy C
- Communication Signal : BRAIN or HART communication signal (Superimposed on 4 to 20 mA DC signals
- Communication Distance : Up to a distance of 2 km
- Protection : IP66, IP67, JIS C0920 immersion-proof type; General-purpose Use/TIIS Flameproof type; Explosion proof type except for TIIS
- Converter Coating : Corrosion-resistant coating
- Converter Material : Aluminum alloy
- Electrical Connection : ANSI 1/2 NPT female; ISO M20 x 1.5 female; JIS G1/2 (PF1/2) female
- Terminal Connection : M4 size screw terminal
- Line Size : Inline models: 10 ~ 1200 mm (0.4 ~ 48 inch)
  : Insertion models: 75 mm (3 in) and up
- Enclosure : NEMA-4X (IP-67)

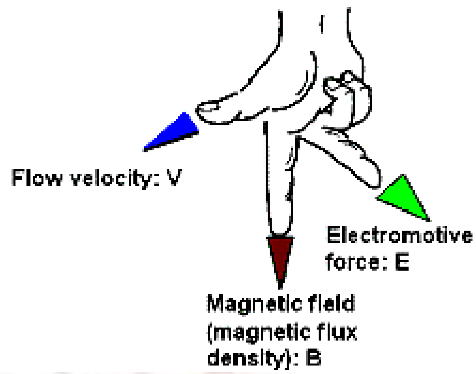
## PRINCIPLE OF OPERATION

**Faradays law of electro magnetic induction**: Faraday’s Law states that the voltage induced across any conductor as it moves at right angles through a magnetic field is proportional to the velocity of that conductor.

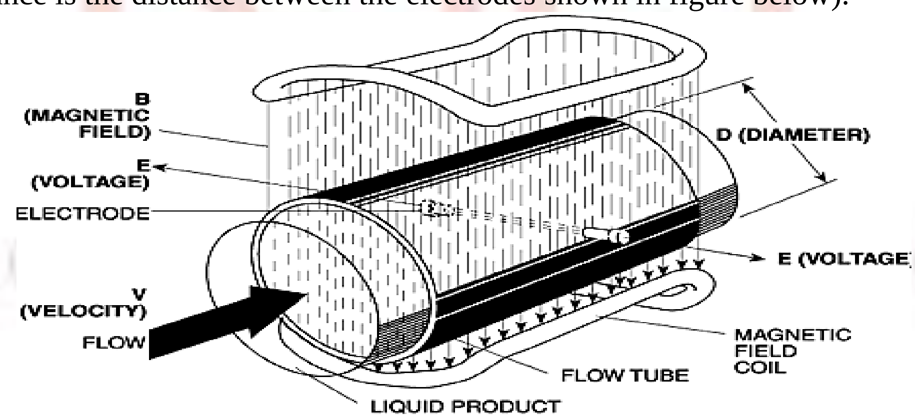
**Faraday's Formula: $E \alpha V \times B \times D$**

Where: E = the voltage generated in a conductor;
V = the velocity of the conductor; B = the magnetic field strength;
D = the length of the conductor

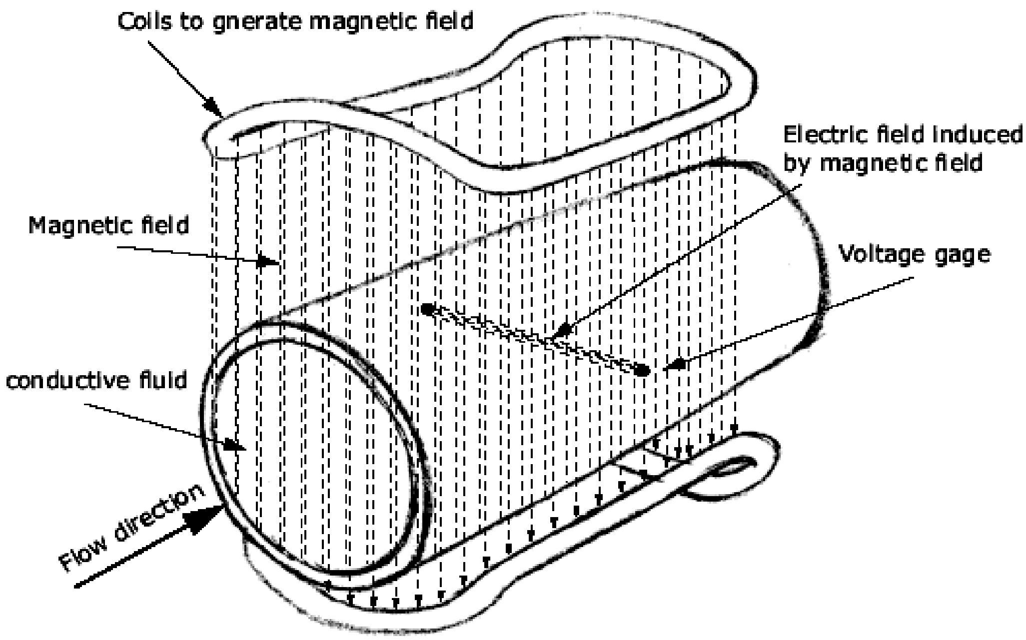



The operation of a magnetic flow meter is based on Faraday’s Law, which states that when conductive fluids pass through a magnetic field they generate electromotive force in proportion to flow velocity. The electromotive force is generated in a direction perpendicular to the direction of the fluid motion and the magnetic field, according to Fleming’s Right-hand Rule. The magnetic flow meter detects this electromotive force by using a pair of electrodes installed inside the measuring tube, calculates the flow rate, converts it to 4-20 mA and pulse signals, and outputs them. To apply this principle to flow measurement with a magnetic flow meter, it is necessary first that the fluid being measured must be electrically conductive. As applied to the design of magnetic flow meters, Faraday's Law indicates that signal voltage (E) is dependent on the average liquid velocity (V) the magnetic field strength (B) and the length of the conductor (D) (which in this instance is the distance between the electrodes shown in figure below).

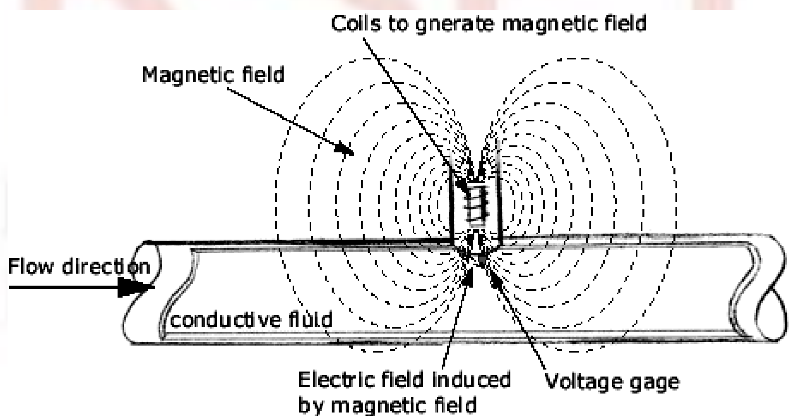


In the case of wafer-style magnetic flow meters, a magnetic field is established throughout the entire cross-section of the flow tube (Figure1).If this magnetic field is considered as the measuring element of the magnetic flow meter, it can be seen that the measuring element is exposed to the hydraulic conditions throughout the entire cross-section of the flow meter. A typical magnetic flow meter places electric coils around (inline model) / near (insertion model) the pipe of the flow to be measured and sets up a pair of electrodes across the pipe wall (inline model) or at the tip of the flow meter (insertion model). If the targeted fluid is electrically conductive, i.e., a conductor, its passing through the pipe is equivalent to a conductor cutting across the magnetic field. This induces changes in voltage reading between the electrodes. The higher the flow speed, the higher the voltage.




***The operation principle of inline magnetic flow meters***

With insertion-style flow meters, the magnetic field radiates outward from the inserted probe (Figure 2)




***The operation principle of insertion magnetic flow meters***

## INSTALLATION

**Installation Considerations:** Select a location for the sensor where the flow profile is fully developed and not affected by any disturbances. A minimum of 10 pipe diameters of straight run upstream and 5 diameters downstream is recommended. Some situations may require 20 pipe diameters or more upstream to insure a fully developed turbulent flow profile. The insertion magmeter is sensitive to air bubbles at the electrodes. If there is any question that the pipe is absolutely full, mount the sensor at a 45 to 135 angle.

- This flow meter should be installed away from sources of strong electromagnetic field. These sources include large electric motors, generators and transformers. The use of ferromagnetic process connectors should also be avoided as they can affect the propagation of the magnetic field generated by the flow meter.
- If metal connections are required, use stainless steel, bronze or copper which are no ferromagnetic.
- The flow meter can be installed in any orientation. It is essential though, that the pipe be full.
- The flow meter's calibration assumes a full pipe. If the pipe is not full, measuring errors will result.
- A minimum straight piping of length requirement of 10 pipe diameters of the nominal flow meter tube diameter measuring upstream and 5 pipe diameters of the flow meter diameter measuring tube downstream is required. These straight piping runs should have no bends, elbow, tees reducers, valves.
- In all cases a reducing bushing must be installed at the flow meter inlet and outlet to reduce from the fitting size to the required pipe diameter for the inlet and outlet straight piping runs.
- Valves or other shut-off devices should be installed downstream of the flow meter in order to keep the piping filled when the system if not operating. If the piping upstream of the flow meter drains when the system is shut down, a check valve should be installed in order to keep the flow meter filled with liquid. These precautions will minimize the effects of water hammer when the system is started.
- For installation in horizontal pipe runs, the formation of gas pockets in the pipe can cause measuring errors. Gas pocket formation can be minimized if the horizontal piping run is plumbed in at a slight up angle of 3-5 degrees
- When piping into a horizontal piping run, the meter should be installed with the electronics housing either in the 12 o'clock or 6 o'clock positions. This will put the measuring electrodes in a horizontal axis and will insure that the measuring electrodes are not insulated by air pockets at the top of the pipe
- Entrained gas bubbles carried along in the pipe can cause measuring errors. To avoid this, the meter should never be installed at the high point in a system.

**Auto-Zero:** In traditional ac magnetic flow meters, it is necessary after installation of the meter to "null" or "zero" the unit. This is accomplished by manual adjustment which requires that the flow meter be filled with process liquid in a no-flow condition. Any signal present under full pipe, no-flow conditions is considered to be an error signal. The ac field magnetic flow meter is therefore "nulled" to eliminate the impact of these error signals.

**CALIBRATION**

Generally to calibrate any SMART flow transmitters, we need to give direct ranges and fluid specifications through HART Communicator. To check whether it is giving correct output, we need to cross check the output of flow meter pipe should be kept in a measured tank for a specified time and compare the same with flow meter reading.

**Introduction**

In measurement and control loops where the process flow is conductive liquid, magnetic flow meters can be used to measure flow. As fluid passes through the meter's magnetic field, the fluid acts as a conductor. The change in potential varies directly with the fluid velocity.

Input and Output Standards

Disconnect the flow tube from the transmitter. A magnetic flow meter calibrator simulates the signal provided by the electrodes in the flow tube. The operating voltage and frequency range of the calibrator must match those of the magnetic flow meter. Select the maximum output signal using the calibrator range switch. The signal options include 5, 10, or 30 mV AC. The magnetic flow meter calibrator has predetermined test point, so the percent output knob is used to set each output for a five-point check. Since output is in milliamps, a mille ammeter is the appropriate output measurement standard for this calibration setup.

Five-Point Check

To begin the calibration of a magnetic flow meter, calculate the input signal value. The input signal is equal to the upper range multiplied by the calibration factor and by the phase band factor. These values are indicated on the instrument's data plate.

Input Signal = Upper Range **x** Calibration Factor **x** Phase Band Factor

Record the output values at each test point and from this data determine if the instrument is within manufacturer's specifications. The following formula tells if the range of error is within manufacturer's specifications:

Accuracy = (Deviation / Span) * 100

Deviation = Expected Value - Actual Value

Adjust zero at the lowest point in the instrument's range by turning the zero adjust screw until the output reading is correct. Then adjust span, and, since zero and span often interact, verify both until no further adjustment is necessary.

To conclude the calibration, recheck the upscale and downscale readings to verify that the instrument is properly calibrated.

**SELECTION CRITERIA**

When selecting among different models of magnetic flow meters, the engineer should review the physical characteristics of liquids to be metered. These characteristics include:

*Conductivity*: Even water varies in conductivity, due to the various ions present. Deionized water and distilled water are not adequately conductive.

*Chemical and/or pharmaceutical* solutions are often not adequately conductive. The concentration level of the solutions can also affect conductivity. Therefore, this variable should also be considered.

*Temperature* affects conductivity. Therefore, the temperature of the liquid being considered should also be known. The key and only constant rule is that liquid conductivity must be above minimum µ S/cm requirement specified for individual product.

*Acids/Caustics*: Generic descriptions of chemical solutions may not adequately describe all component substances. Detailed descriptions should be confirmed to select chemically compatible materials of construction.

*Velocity*: The liquid velocity should be maintained within the specified flow range of the meter for proper operation. However, applications monitoring abrasive slurries, sludge or greases will require special consideration.

*Abrasive Slurries*: Mildly abrasive slurries can be handled by magnetic flow meters. Flow velocity should be maintained at 6 ft/sec or slower to minimize the risk of abrasion damage. However, velocities should not be allowed to fall below 4 ft/sec to prevent suspended solids from settling out of the flow stream.

*Sludge and Greases*: Sludges and grease-bearing liquids should flow at higher velocities (approximately 6 ft/sec minimum) to minimize coating of electrodes.

**APPLICATIONS**

Most liquids or slurries are adequate electrical conductors to be measured by electro-magnetic flow meters. If the liquid conductivity is equal to 20 micro Siemens per centimeter or greater, most of the conventional magnetic flow meters can be used. Application areas include such as the following.

- Environmental Engineering / Water & Waste Water Treatment
- Pulp & Paper
- Cellulose
- Pharmaceuticals
- Food & Beverage
- Mining
- Chemical Processing
- Agricultural Fertilizer / Fertilizer Batching
- Liquid Feed & Batching
- Heating, Refrigeration, Ventilation & Air Conditioning

**CONFORMATION TO STANDARDS**

- FM & CSA hazardous area approval : Sensors – CLASS 1, DIV. 2, GROUPS A B C
- FM APPROVED, CSA CERTIFIED : Intrinsically safe electrodes
- ATEX — II 2 (i) G EEx e m ia IIC T4 - ZONE 1 ZONE 0

**LIST OF SUPPLIERS**

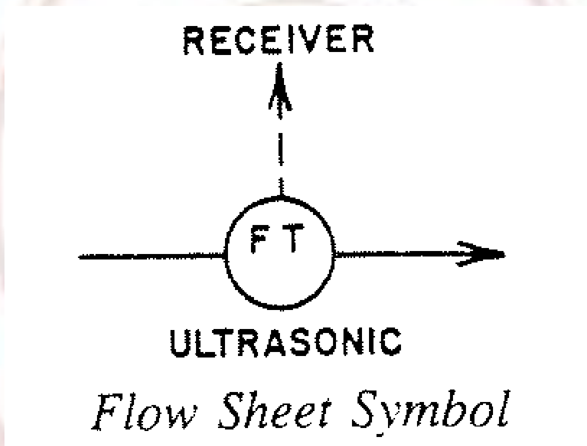
- ABB Kent-Taylor Inc.
- Accudyne Systems Inc.
- Baily Control Co.
- Rosemount.
- Foxboro
- Fischer & Porter Co.
- Honeywell
- Toshiba International
- Yokogawa Electric

# ULTRASONIC FLOW METER

**Description**

An ultrasonic flow meter measures the velocity of any liquid or gas through a pipe using ultrasonic transducers. The results get slightly affected by temperature, density or viscosity of the flowing medium. Maintenance is inexpensive because there are no moving parts. Some may be able to measure liquid level as well. With the level measurement and pipe size, flow rate and total discharge can be calculated.

**Symbol**




**Figure**


*Ultra sonic flow meter*

## SPECIFICATIONS

- Medium compatibility Hydrazine, MON, MMH, IPA, GHe, GN2, GAr, De ionized H20
- Flow rate measurement range : 0 - 300 g/s (adaptive to customer requirements)
- Operating pressure range : > 26 barA
- Proof pressure factor : 2 x MEOP
- Burst pressure : 4 x MEOP
- External leakage : < 10-8 scc/s GHe
- Measurement accuracy : ± 0.05 % FS
- Power supply voltage : 12 - 100 Vdc, single or dual
- Power consumption : < 3.5 W
- Output signals Digital : DS16, RS232 (optional analogue -5 / +5 Vdc)
- Mass : < 200 g (flow tube) ; < 700 g (electronics box)
- Fluidic interface Weld able : 3/8” tube stub or screwed AS4395 fitting, customer adaptive
- Wetted materials : Ti6Al4V or AISI 316L
- Environmental temp. range : -40 - +75 °C non-operating ; -20 - +70 °C operating
- EMC requirements : According MIL-STD-461

## PRINCIPLE OF OPERATION

Measurements are made by sending bursts of signals through a pipe. 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. At zero velocity, the transit time or delta T is zero. If we know the diameter of the pipe, the pipe wall thickness and the pipe wall material the angle of refraction can be calculated automatically and we will know how far apart to space our transducers. 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.

**Types**

- Ultrasonic flow meters work with at least three different types:
- Transmission (contra propagating transit-time) flow meters
- Reflection (Doppler) flow meters
- Open-channel flow meters

**Transit time**

The most commonly used ultrasonic flow meter is the transit-time flow meter which is used for liquids and gases. Transit-time flow meters work by measuring the time of flight difference between an ultrasonic pulse sent in the flow direction and an ultrasound pulse sent opposite the flow direction. This time difference is a measure for the average velocity of the fluid along the path of the ultrasound beam. By using the absolute transit time and the distance between the ultrasound transducers, the current speed of sound is easily found. The measuring effect can be adversely affected by many things including gas and solid content. By using at least 3 transducers, an "ultrasonic anemometer" measures wind speed and direction in open air, with no moving parts.

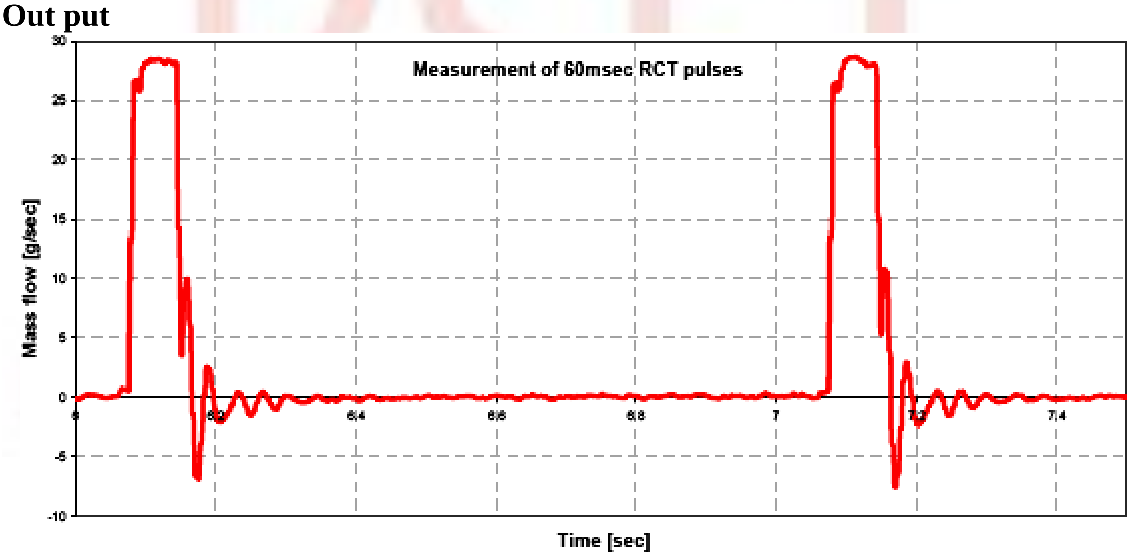
**Doppler**

Doppler flow meters are used for slurries, liquids with bubbles, gases with sound reflecting particles, or single phase turbulent clean liquids. Measurement of the Doppler shift resulting in reflecting an ultrasonic beam off either small particles in the fluid, air bubbles in the fluid, or the flowing fluid's turbulence is another recent, accurate innovation made possible by electronics.

**Open channel**

Open channel flow measurement is based on upstream levels in front of flumes or weirs although in-channel devices using cross-correlation and Doppler are also used. Ultrasonic open channel flow meters are widely used to measure flows in streams, rivers and where hydraulic head is an issue. Many examples of open channel flow meter exist in the world today with varying degrees of accuracy.

**Out put**



**APPLICATIONS**

- They are suitable for the measurement of most liquids including water, hydrocarbons, corrosive and abrasive liquids. The only prerequisites for successful measurement are that the pipe is full, the media conducts sonic energy and that the pipe wall is in good condition. Doppler meters also require there to be enough entrained material to reflect the sonic transmission off. Whereas transit time flow meters work well between 0-5 percent, Doppler flow meter works well in the 0.1-10% band.
- Clamp on technology has been extensively developed to measure gas applications. Gas clamp on flow meters from Panametrics and Controlotron are now capable of measuring mass gas flow in pipes above 1" with minimum pressures of 6 bar.
- Oil & Gas
- Water & Wastewater
- Building Services
- Pharmaceutical
- Energy Monitoring
- Mining & Aggregates
- Process & Manufacturing

**CONFORMATION TO STANDARDS**

- CEx FMG 09.0014X

**PARTIAL LIST OF SUPPLIERS**

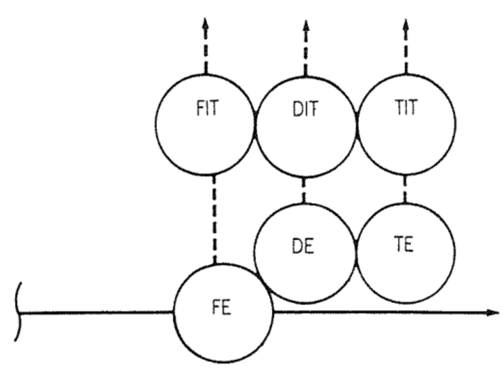
- Tianjin Sure Instrument Science & Technology Co., LTD
- Dynameters Shanghai Co.Ltd
- A.YITE Group
- Adept fluidyne (p) ltd.
- Magnetrol
- Dwyer
- Yokogawa
- Cameron
- Kronhe
- Siemens
- Grey line
- Flexim
- Ultra flex

# MASS FLOW METER

**Description**

A mass flow meter is an instrument which provides a direct indication of the quantity or mass, as opposed to volume or velocity, of material being transferred through a pipeline. Mass flow meters measure the mass flow rate rather than the volumetric flow rate of material. Fluid mass flow meters are known for providing an output representative of the mass flow of a target fluid through a conduit. Mass flow meters have sensing means which respond to mass flow rate as compared to volume flow rate. One class of mass measuring flow meters is based on the well-known Coriolis Effect. Coriolis flow meters are direct mass measuring flow meters. The Coriolis mass flow meter facilitates high precision measurement of a mass flow rate, since it directly measures the mass flow rate based on the Coriolis force generated in proportion to the mass flow rate of a fluid flowing through one or more of vibrating measuring pipes. A typical Coriolis mass flow meter includes one or more conduits that are connected inline in a pipeline or other transport system and convey material.

**Symbol**




*Flow Sheet Symbol*

**Figure**

***Micro motion*** *ELITE®* ***coriolis mass flow meter***

**SPECIFICATIONS**

***Functional***

- Can report mass flow, liquid volume flow, gas standard volume flow, density, temperature, or drive gain
- Mass Flow Accuracy Liquid : ± 0.10%
- Mass Flow Accuracy Gas : ± 0.35%
- Vol. Flow Accuracy Liquid : ± 0.10%
- Density Accuracy Liquid : ±0.0005 g/cm$^3$
- Temperature Rating :-400 to 400° F (-240 to 204 °C)
- Pressure Rating : Up to 6000 psi (413 bar)
- Flow range : 0.075 – 20,000 lb/min (2 – 545,000 kg/h)
- Process Line Size : 1/8” – 6” (DN2 – DN150)
- Power supply : DC 17–36 VDC; Loop resistance up to 600
- External power : 17 to 36 VDC
- Output : linear with process from 11.9 to 20.25 mA
- Input/output signals : One passive 12–20 mA output; Isolated to ±50 VDC from earth ground

***Electrical***

- Ambient temperature effect : On mA output: ±0.005% of span per °C
- Ambient temperature limits : Operating and storage: (–40 to +60 °C) below 20 °C LCD responsiveness decreases and LCD may become difficult to read. Above 55 °C, some darkening of the LCD panel may occur.
- Humidity limits : 5 to 95% relative humidity, non-condensing at 60 °C
- Vibration limits : Meets IEC68.2.6, endurance sweep, 5 to 2000 Hz, 50 sweep cycles at 1.0 g
- Input and output connections : One pair of wiring terminals for transmitter input/output, digital communications, and power. Screw terminals accept solid or stranded conductors, 26 to 14 AWG (0.14 to 2.5 mm2).
- Digital communications : Two clips for temporary connection to HART/Bell 202 terminals.
- User interface : Standard user interface with LCD panel Suitable for hazardous area installation.

***Physical***

- Housing : NEMA 4X (IP67) polyurethane-painted cast aluminum or 316L stainless steel; Available with1/2 inch NPT or M20 conduit connections
- Mounting : Integral-mount or extended-mount
- Wetted parts : SST Nickel alloy; 316L or 304L Hastelloy C22
- Junction box : 300-series stainless steel or polyurethane-painted aluminum; NEMA 4X (IP65)
- Core processor : 300-series stainless steel or polyurethane-painted aluminum; NEMA 4X (IP65)

## PRINCIPLE OF OPERATION

The micro motion flow meter measures fluid mass in motion. A flow meter is comprised of a sensor and a signal processing transmitter. Each sensor consists of one or more flow tubes enclosed in a sensor housing .the principle of operation is same for all sensors. The sensor operates by application of Newton's second law of motion:

**Force = mass× acceleration (F=ma)**

The flow meter uses this law to determine the precise amount of mass flowing through the sensor tubes. In coriolis flow meters that have dual parallel flow tubes, process fluid entering the sensor is split with half of the fluid passing through each flow tube (figure 1).

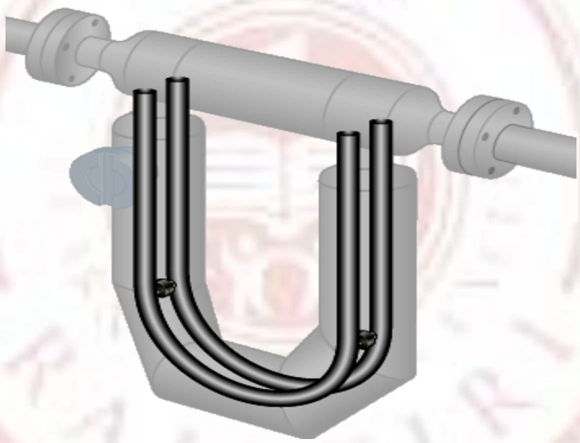
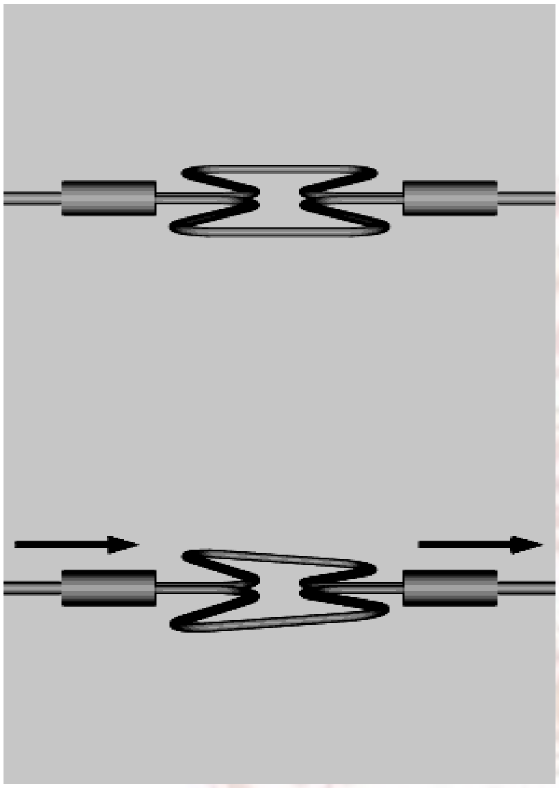


***Figure 1: side view of flow tube inside the sensor housing***

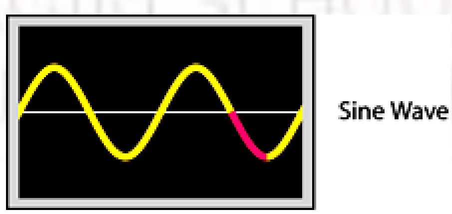
During operation, a drive coil is energized causing the tubes to oscillate in opposition to one another. Inside the sensor housing, the flow tube is vibrated at its natural frequency by an electromagnetic drive coil located at the center of the bend tube. The vibration is similar to that of a tuning fork, covering less than a tenth of an inch and completing a full cycle about 80 times each second. By vibrating in opposition, the Coriolis flow tubes are balanced and isolated from external vibration or movement of the flow meter. As the fluid flows into the sensor tube, it is forced to take on the vertical momentum of the vibrating tube. When the tube is moving upward during half of its vibration cycle, the fluid flowing into the sensor resists being forced upward by pushing down on the tube. Having the tubes upward momentum as it travels around the tube bend, the fluid flowing out of the sensor resists having its vertical motion decreased by pushing up on the tube. This causes the flow tube to twist (figure below). When the tube is moving downward during the second half of its vibration cycle it twists in the opposite direction .This tube twisting characteristics is called the Coriolis Effect.



*Rotating mass flow meter illustrating the operating principle when fluid is flowing though the tubes the tubes twist slightly*

Due to Newton's second law of motion the amount of sensor tube twist is directly proportional to the mass flow rate of the fluid flowing through the tube. The electromagnetic velocity detectors located on each side of the flow tube measures the velocity of the vibrating tube. The two velocity signals are sent to the transmitter where they are processed and converted to an out put signal proportional to the mass flow rate. Sensor tube twist is proportional to the mass flow and is determined by measuring the time difference exhibited by the velocity detector signals. During zero flow conditions no tube twist occurs and both sides of the tube cross the mid point simultaneously. With the flow a twist occurs along with a resultant time difference between the mid point crossing. The time difference appears as a phase shift between the two velocity signals and indicates the mass flow

Pick-offs magnet and coil assemblies are mounted on the opposing flow tubes. Pickoff coils are mounted on the side legs of one flow tube, and magnets are mounted on the side legs of the opposing flow tube. Each coil moves through the uniform magnetic field of the adjacent magnet. The voltage generated from each pickoff coil creates a sine wave.



Because the magnets are mounted on one tube, and the coils on the opposing tube, the sine waves generated represent the motion of one tube relative to the other. The flow tubes oscillate in opposition to one another, similar to a tuning fork. Both pickoffs (the one on the inlet side and the one on the outlet side) generate sine wave signals continuously when the tubes are oscillating. When there is no flow, the sine waves coincide. During a no flow condition, there is no Coriolis Effect. Thus the inlet motion and outlet motion is in phases and the sine waves coincide with each other.

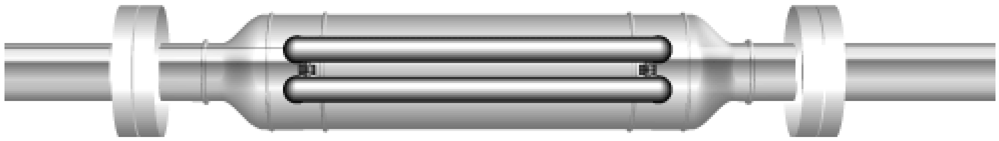
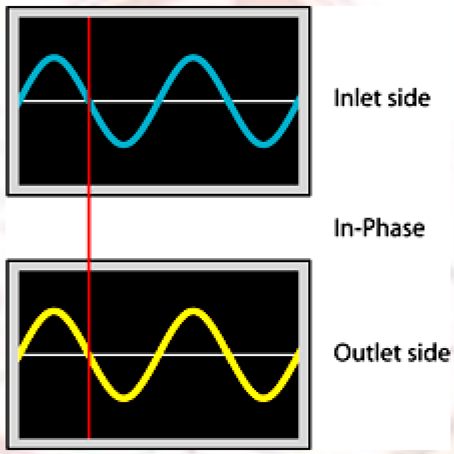


***Figure 3: No flow curved tube***




***Inlet and outlet motion in phase***

When fluid is moving through the sensor's tubes, Coriolis forces are induced in both the inlet and outlet legs of both flow tubes. These forces cause the flow tubes to twist in opposition to each other.

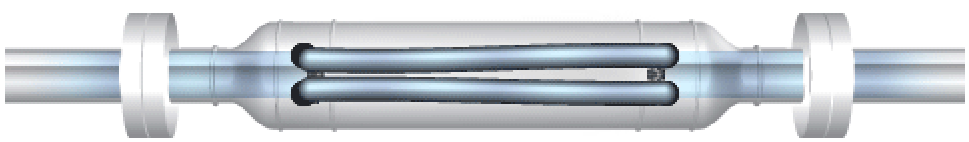
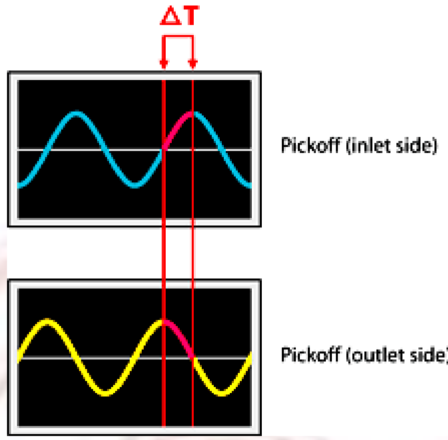
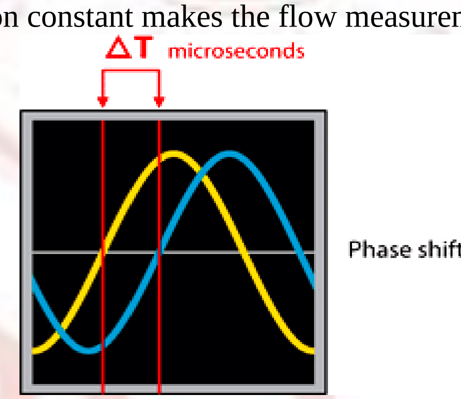


***Figure 4: Flow in curved tube***

The mass flow moving through the inlet legs of the flow tubes generate a Coriolis force that resists the vibration of the flow tubes. As the mass flow moves through the outlet legs, the Coriolis force adds to the vibration of the flow tubes. It is the opposite direction of the Coriolis force between the inlet and outlet legs that result in the twisting motion that is used to measure mass flow rate. As a result of the twist in the flow tubes, the sine waves generated by the pickoffs are now out of phase with each other because the inlet legs are lagging behind the outlet legs.



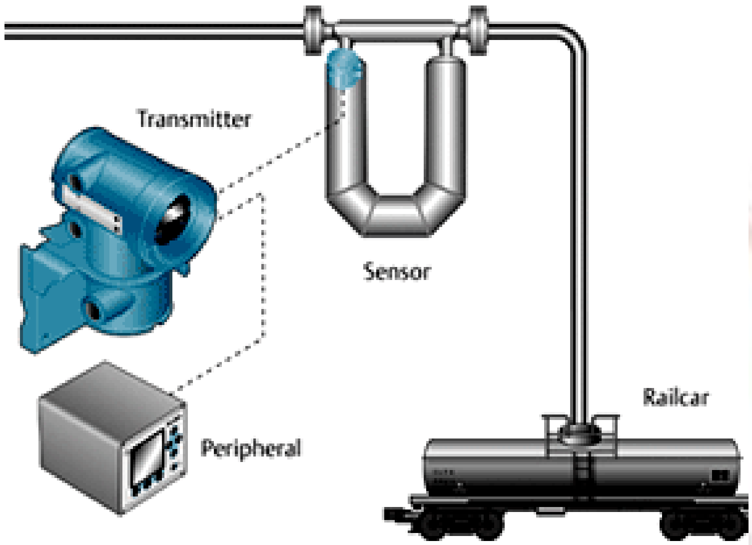

The time delay between the two sine waves is measured in microseconds, and is called Delta-T. Delta-T is always directly proportional to the mass flow rate – the greater the Delta-T created by the Coriolis force, the greater the mass flow rate. (Delta-T is a function of both the phase difference and the frequency of the sine wave signals).The flow calibration factor contains two main components. The first component is the proportionality constant between mass flow rate and measured Delta-T. The second component is a constant used to automatically compensate for changes in the temperature of the flow tubes. Because the flow tube temperature affects the stiffness of the tube material, this compensation constant makes the flow measurement more accurate.



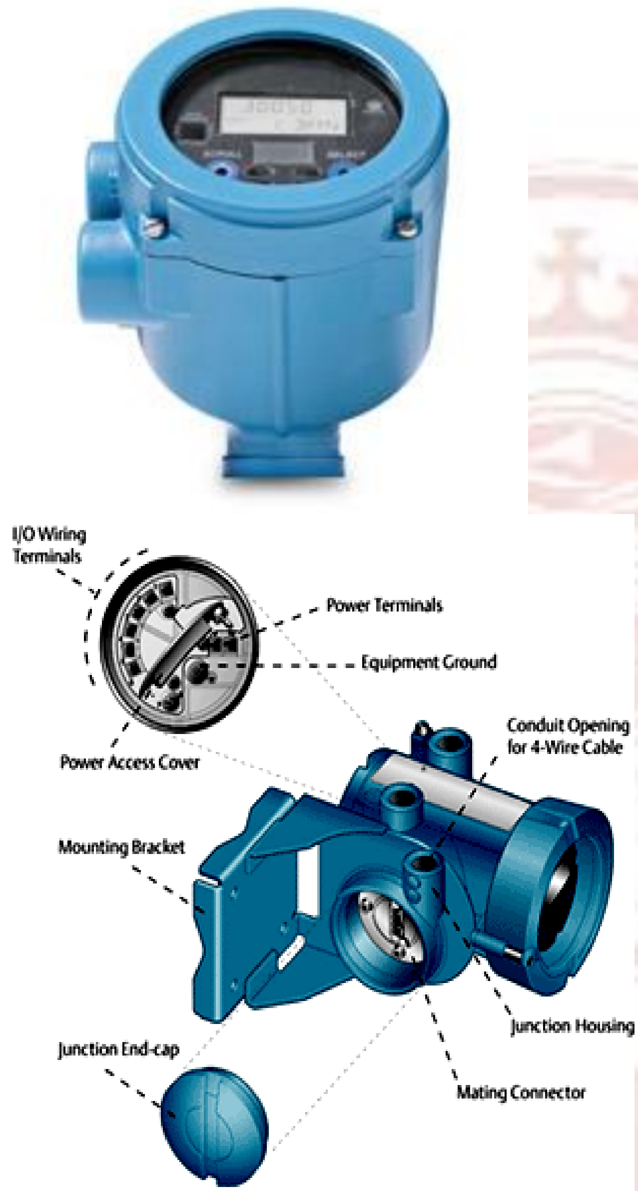

**DESIGN AND CONSTRUCTION**

A Micro Motion Coriolis flow meter consists of a sensor, a transmitter and, in many cases, peripheral devices.

- **Sensors** detect flow rate, density and temperature.
- **Transmitters** provide sensor information as outputs, acting like the brain of the system to provide a display, basic menu access, and outputs to interface with other systems.
- **Peripherals** provide monitoring, alarm or additional functionality, such as batch control and enhanced density functions.




*Micro Motion ELITE® Coriolis flow meter* ***Micro MotionCoriolis Sensor***

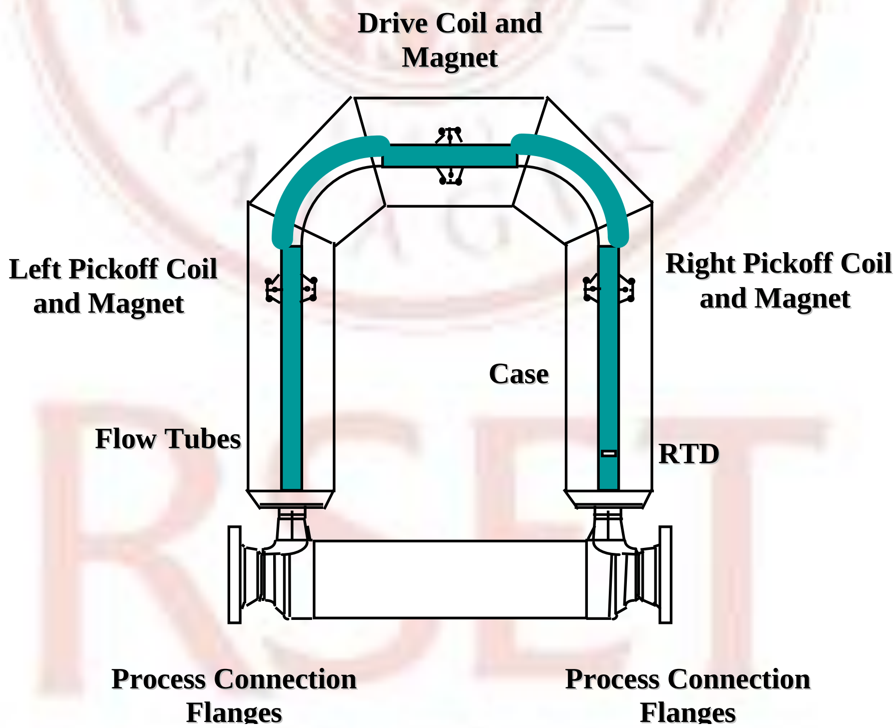



***Micro Motion ELITE® Coriolis flow transmitters (Field mount model)***

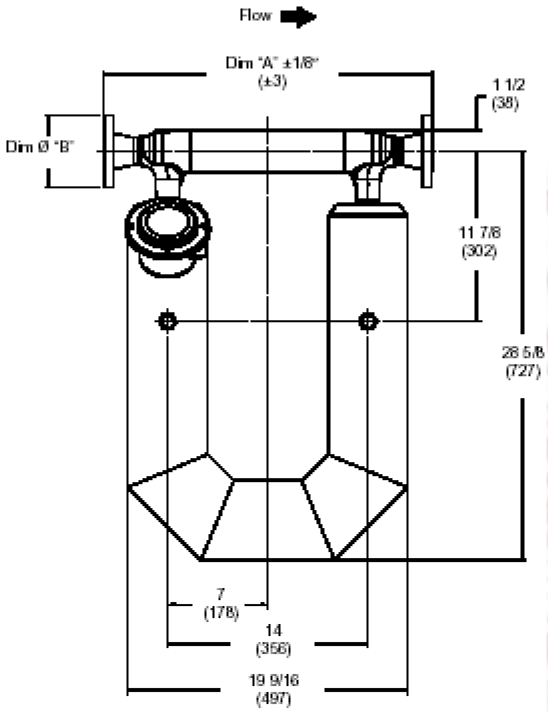
**A Coriolis curved tube sensor design includes:**

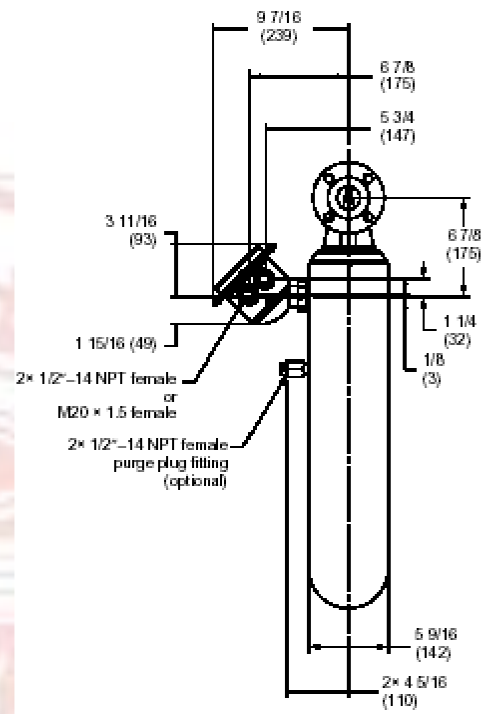
- Flow Tubes: Coriolis flow tubes are wetted parts constructed of 316L stainless steel or nickel alloy depending on the material compatibility of the process fluid
- Drive Coil and Magnet: The drive coil is used with a magnet to produce the oscillation of the Micro Motion Coriolis sensor flow tubes. The coil is energized to keep the tubes vibrating at their natural frequency.
- Pickoff Coil and Magnet: Pickoff coils and their magnets are electromagnetic detectors located on each side of the flow tube. By producing a signal that represents the velocity and position at that point on the vibrating tube, mass flow is determined by measuring the phase difference between these signals.

- RTD: The Resistance Thermal Device (RTD) is a 100 ohm platinum element that provides an output signal of the temperature of the flow tubes.
- Process Connection: Process connections are sometimes called an end connection or fitting. There are two identical process connections that must be mated to a process line for successful installation.
- Flow Splitter: Between the end fitting process connection and the flow tubes is a section call the flow splitter. The flow splitter divides process flow evenly between the two flow tubes.
- Core Processor: The wiring for the Coriolis drive coil, pickoff coils, and RTD element is routed to the core processor. The core processor is a sophisticated set of electronics that controls the sensor, primary signal measurement and processing. The core processor executes all necessary calculations to arrive at the measured process variable values and communicates these to the transmitter for interfacing with operators and control systems.
- Case: Protects the electronics and wiring from external corrosion while providing a redundant (or secondary) containment of the process fluid. Some cases may have purge fittings that can accommodate the requirements of specific applications.




**Model 2400S coriolis flow transmitter dimensions, (painted aluminum housing)**

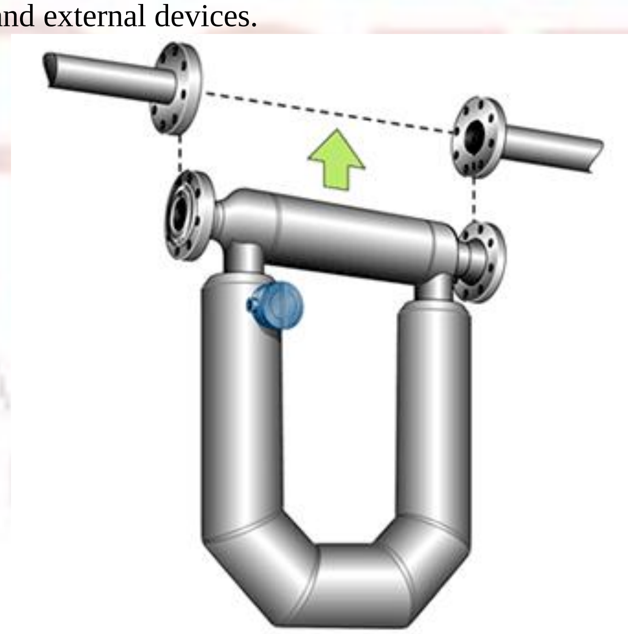



## INSTALLATION

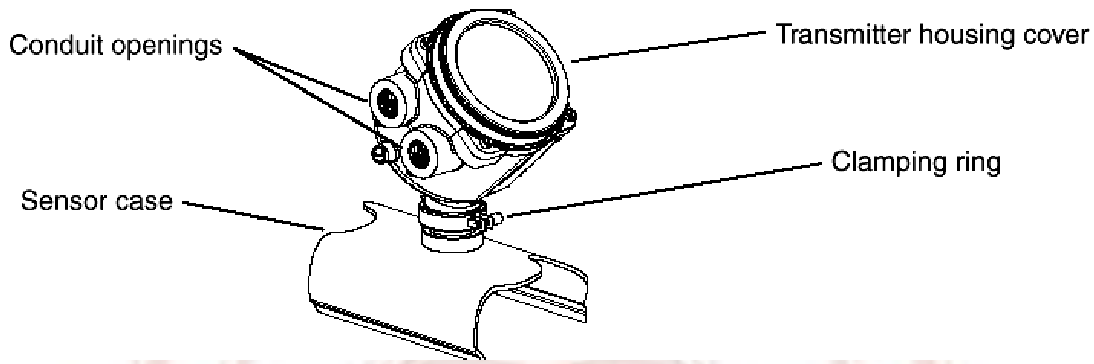
A Model 2200S installation includes the following components:

- Transmitter
- Sensor
- Micro Motion adapter-barrier or third-party barrier (optional). If the flow meter is in a safe area, no barrier is required between the flow meter and external devices. If the flow meter is in a hazardous area, a barrier may be required between the flow meter and external devices.

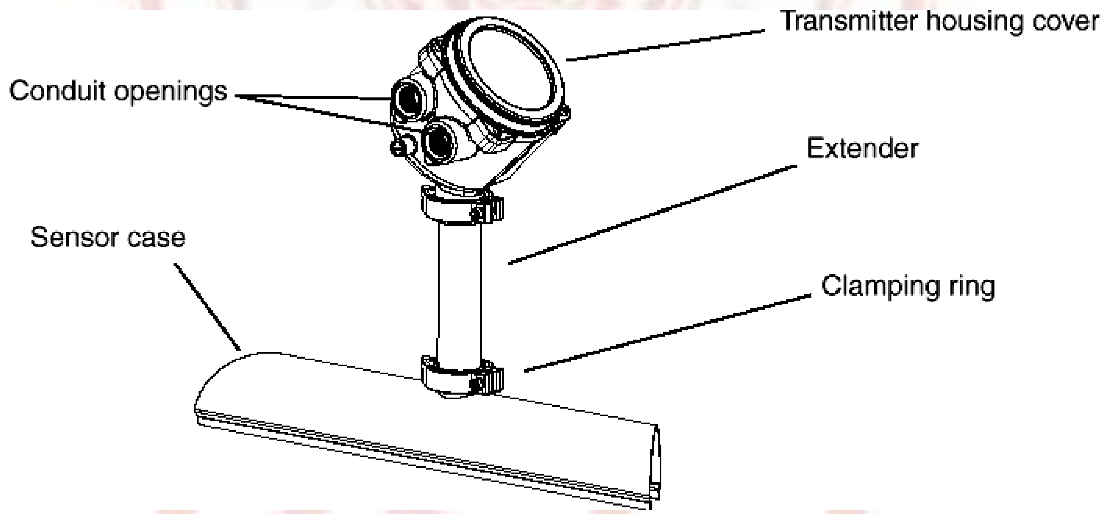


***Process pipe connection***

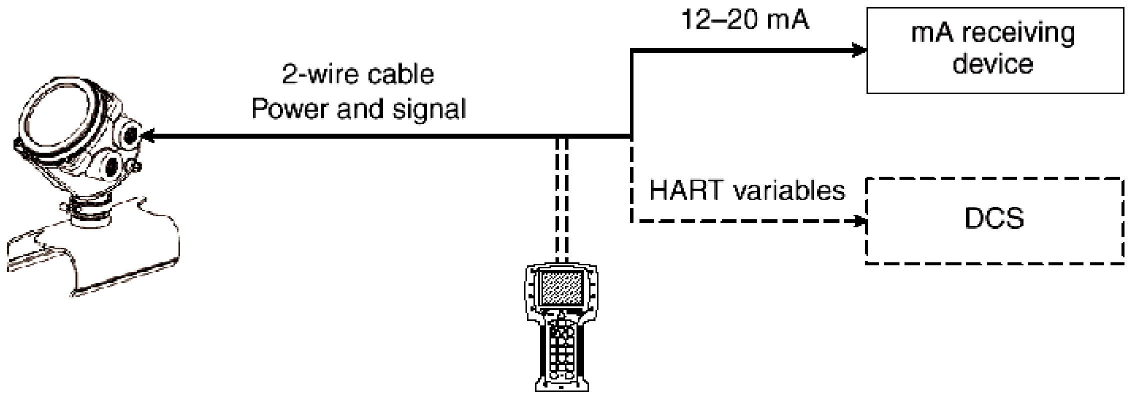
The transmitter is mounted on a Micro Motion sensor, in one of two mounting options: Integral-mount or extended-mount.



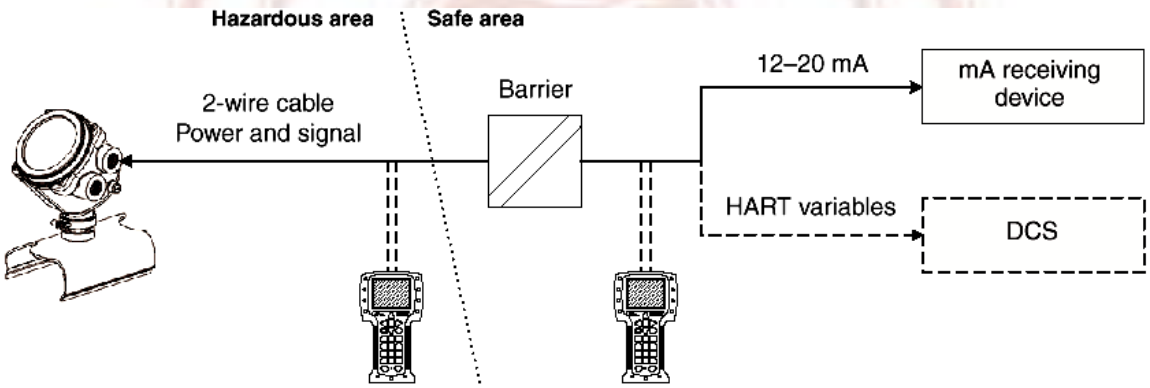

**Transmitter – Integral-mount on to the sensor**




**Transmitter – Extended-mount on to the sensor**




**Type 1 installation – Safe area installation**




**Type 2 installation – Hazardous area installation with third-party barrier**

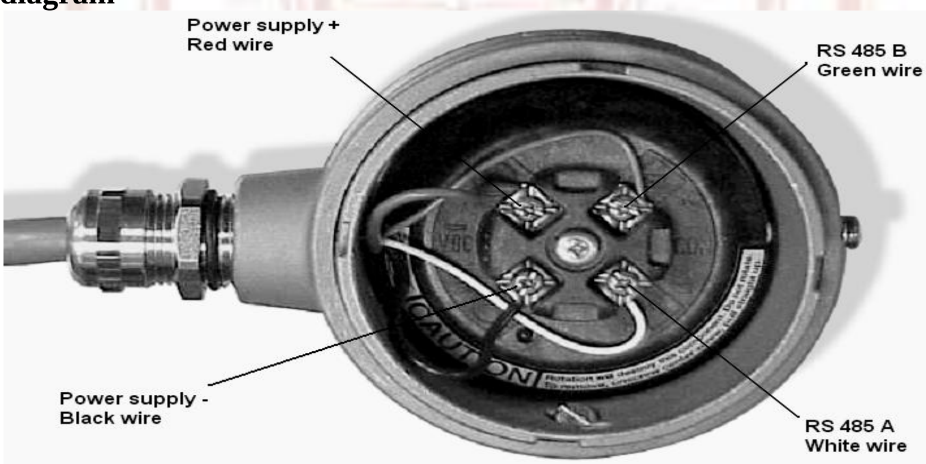
## Installation Recommendations

- The meter should be installed so that it will remain full of liquid and so air cannot get trapped inside the tubes. In sanitary installations, the meter must also drain completely. The most desirable installation is in vertical upward flow pipes Installations where the flow is downward in a vertical pipe are not recommended.
- In newer Coriolis designs, normal pipe vibration should not affect the performance of the Coriolis meter if it is properly supported by the process piping .If the installation instructions require special hardware or supports, the particular meter design is likely to be sensitive to vibration, and the pulsation dampeners, flexible connectors, and mounting/clamping attachments recommended by the manufacturer should be carefully installed.
- If air bubbles are likely to be present in the process fluid, it is recommended to install an air release upstream of the meter.
- It is recommended to install (upstream of the meter) strainers, filters or air/vapor eliminators as required to remove all undesirable secondary phases
- Prior to zeroing the meter, all air should be removed. This can be accomplished by circulating the process fluid through the meter for several minutes at a velocity of approximately 2-6 ft/sec. On batching or other intermittent flow applications, the meter should stay flooded so that it does

not need to be repurged. All meters should be so installed so they can be zeroed while filled with liquid.

- In less critical installations (where weigh tanks are not used), volumetric provers or master meters (typically another Coriolis or a turbine meter calibrated at a flow laboratory) are used. When a volumetric reference is used in calibrating a mass flow meter, the fluid density must be very precisely determined.
- When the process fluid must be held at higher temperatures, some Coriolis meters can be supplied with steam jackets. As an alternative, electrical heating tape can be added to the housing. Jackets or heating tapes must be installed by the manufacturer.
- When flow metering is not required, the Coriolis meter can be used solely as a densitometer. In that case, to minimize cost, usually a small (1/2 in.) meter is installed in a by-pass line. Such a configuration is acceptable only in clean services that will not clog the small bore of the meter. In addition, a restriction must be placed in the main piping (between the by-pass taps) to ensure a flow through the meter.

**Wiring diagram**




**Wiring for installations without a barrier or adapter-barrier:**

In these installations, the transmitter is wired directly to the host. To wire the transmitter to the host:

- Use standard twisted-pair shielded wire. Ensure that all wire lengths are within the maximum wire length as determined by the loop resistance.
- Remove the transmitter housing cover and user interface module as described
- Unscrew the Warning flap screw and raise the Warning flap.
- Connect the wires to terminals 1 and 2. Terminals 1 and 2 are polarity-insensitive.
- Lower the Warning flap and tighten the Warning flap screw.
- Replace the user interface module and transmitter housing cover.
- At the host, connect the wires to the mA terminals.
- Supply power to the loop and add resistance as required.

**TESTING AND INSPECTION**

**1. Zeroing the flow meter**

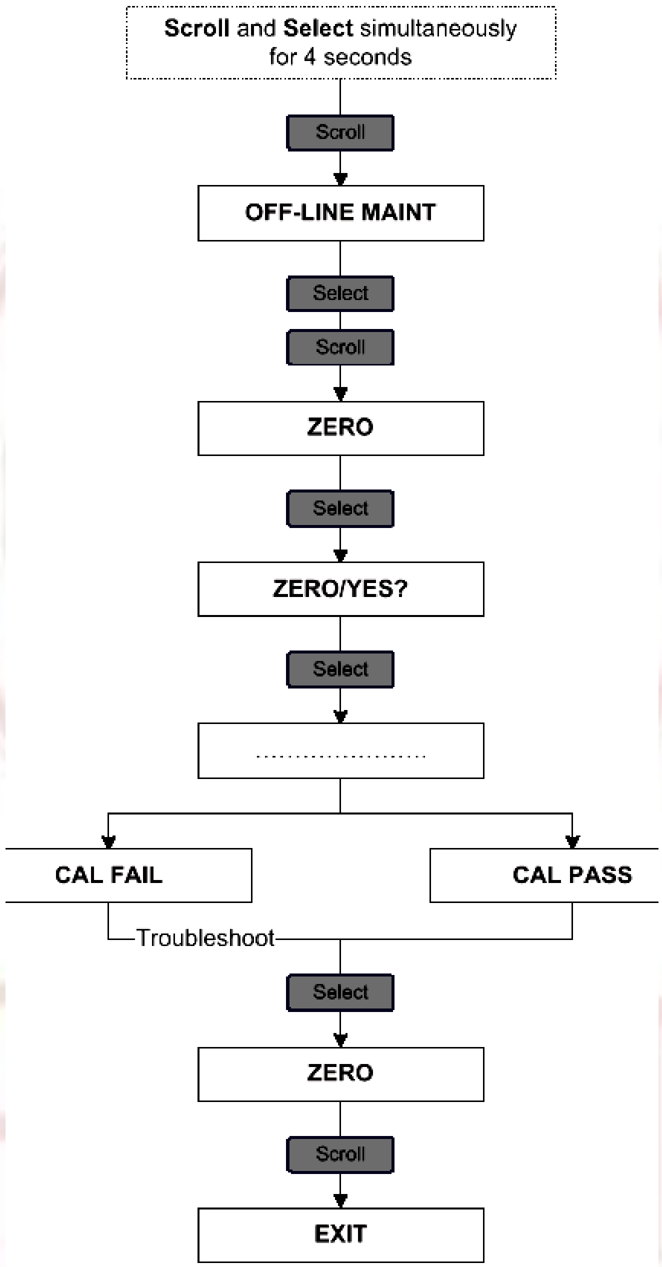
Zeroing the flow meter establishes the flow meter's point of reference when there is no flow. The meter was zeroed at the factory, and should not require a field zero. However, when you zero the flow meter, you may need to adjust the zero time parameter. Zero time is the amount of time the transmitter takes to determine its zero-flow reference point. The default zero time is 20 seconds.

- A long zero time may produce a more accurate zero reference but is more likely to result in a zero failure. This is due to the increased possibility of noisy flow, which causes incorrect calibration.
- A short zero time is less likely to result in a zero failure but may produce a less accurate zero reference.

**Preparing for zero:** To prepare for the zero procedure:

1. Apply power to the flow meter. Allow the flow meter to warm up for approximately 20 minutes.
2. Run the process fluid through the sensor until the sensor temperature reaches the normal process operating temperature.
3. Close the shutoff valve downstream from the sensor.
4. Ensure that the sensor is completely filled with fluid.
5. Ensure that the process flow has completely stopped. CAUTION! Ensure that there is no fluid flowing through the sensor while zero calibration is in process.

**Procedure to perform flow meter zeroing using the display:**

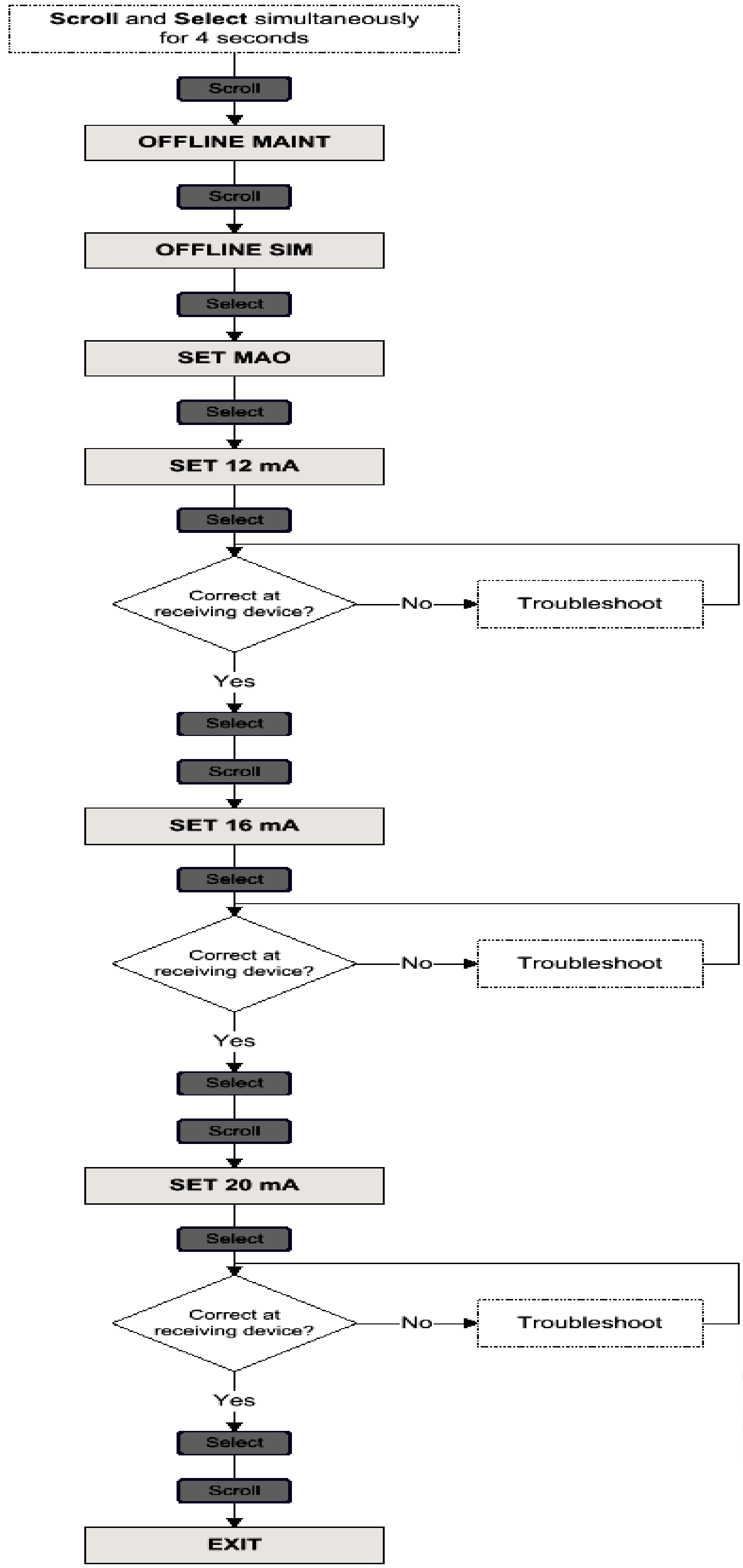



**2. Loop testing**

A loop test is a means to:

- Verify that the mA output is being sent by the transmitter and received accurately by the receiving devices
- Determine whether or not you need to trim the mA output
- Note the following: During the loop test, the transmitter's mA output will not report process data. CAUTION! Do not use the mA output for process control while you are performing the loop test.

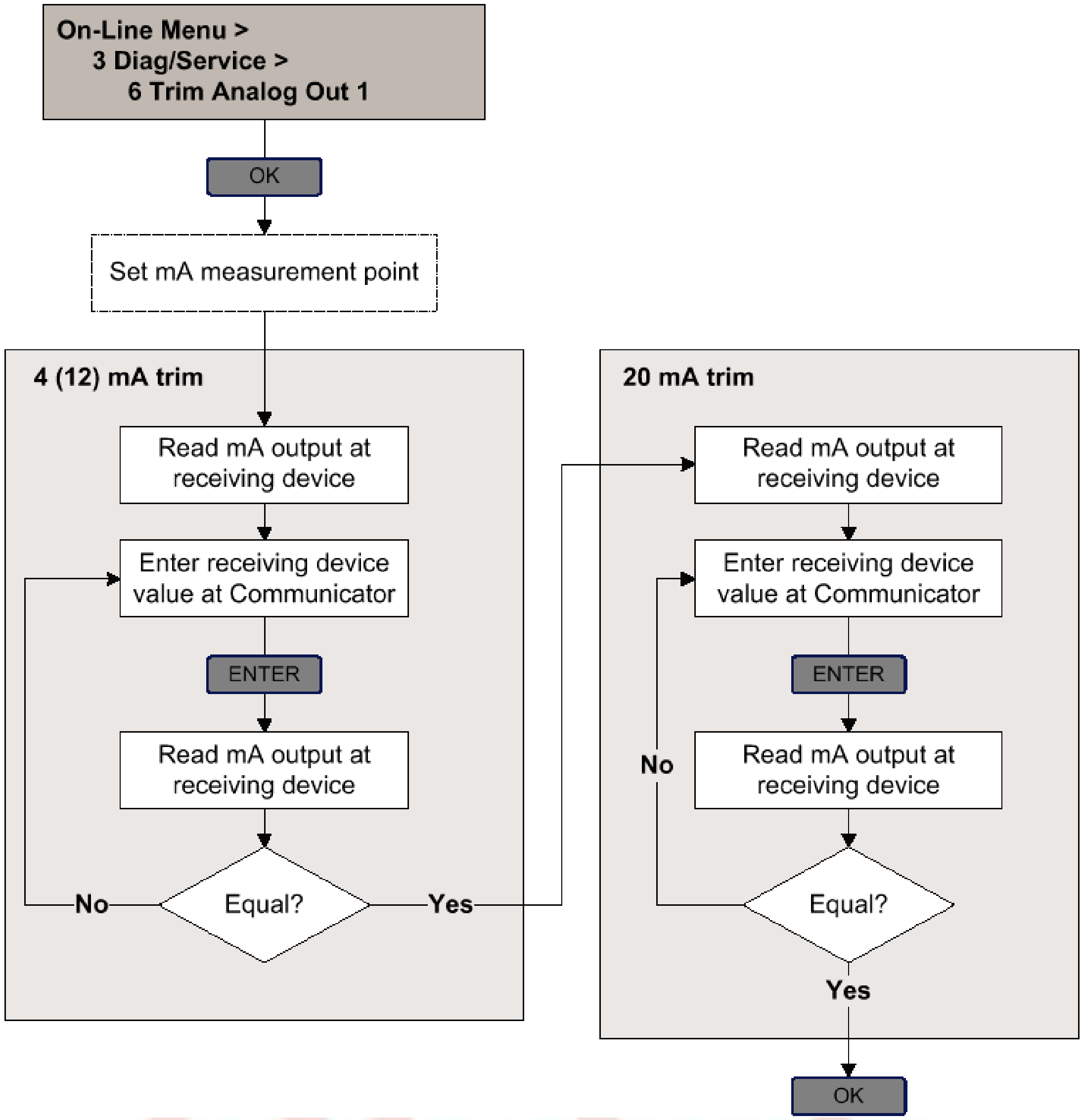
**Procedure to perform loop test using the display:**



**3. Trimming the milliamp output**

Trimming the mA output creates a common measurement range between the transmitter and the device that receives the mA output. For example, a transmitter might send a 12 mA signal that the receiving device reports incorrectly as 12.2 mA. If the transmitter output is trimmed correctly, it will send a signal appropriately compensated to ensure that the receiving device actually indicates a 12 mA signal.
To trim the output: Using the Communicator,

- During the trim, the transmitter's mA output will not report process data. CAUTION! Do not use the mA output for process control while you are performing the trim.
- If you are using the Communicator, you must specify the mA measurement point before you can continue.
- Any trimming performed on the output should not exceed ± 200 micro amps. If more trimming is required, contact Micro Motion customer support.
- If you are using the Communicator, the receiving device value can contain up to two decimal places.




**4. Using sensor simulations to test, tune, and troubleshoot the system**

Sensor simulation allows you to tell the transmitter to behave as if it were receiving specific values for mass flow, temperature, and density from the sensor. We can use sensor simulation for a variety of purposes:

- Testing and verifying the flow meter's response to a variety of process conditions without having to create those conditions in the real world.
- Analyzing the system's response to various process conditions.
- Tuning the loop.
- Locating problems. For example, signal oscillation or noise is a common occurrence. The source could be the PLC, the meter, improper grounding, or a number of other factors. By setting up simulation to output a flat signal, then checking the signal at various points between the transmitter and the receiving device, you can determine the point at which the noise is introduced.

To set up sensor simulation using the Communicator, follow the steps below:

2. Enable sensor simulation mode.
3. for mass flow:
a. Specify the type of simulation you want: fixed value, triangular wave, or sine wave.
b. Enter the required values.

- If you specified fixed value simulation, enter a fixed value.
- If you specified triangular wave or sine wave simulation, enter a minimum amplitude, maximum amplitude, and period.

4. Repeat Step 3 for temperature and density. Disable simulation mode when the tests are complete.

**CALIBRATION: Meter validation and calibration.**

**Meter validation** – confirming performance by comparing the sensor's measurements to a primary standard. Meter validation compares a measurement value reported by the transmitter with an external measurement standard. Meter validation requires one data point. For meter validation to be useful, the external measurement standard must be more accurate than the sensor. If the transmitter's mass flow, volume flow, or density measurement is significantly different from the external measurement standard, you may want to adjust the corresponding meter factor. A meter factor is the value by which the transmitter multiplies the process variable value. The default meter factors are 1.0, resulting in no difference between the data retrieved from the sensor and the data reported externally. Meter factors are typically used for proving the flow meter against a Weights & Measures standard.

**Calibration** – establishing the relationship between a process variable (flow, density, or temperature) and the signal produced by the sensor. The flow meter measures process variables based on fixed points of reference. Calibration adjusts those points of reference. Three types of calibration can be performed:

- Zero or no flow (discussed above in Testing and Inspection)
- Density calibration
- Temperature calibration

Calibration produces a change in the offset and/or the slope of the line that represents the relationship between process density and the reported density value, or the relationship between process temperature and the reported temperature value. For density or temperature calibration to be useful, the external measurements must be accurate.

Coriolis flow meters with the Model 2200S transmitter are calibrated at the factory, and normally do not need to be calibrated in the field. Calibrate the flow meter only if you must do so to meet regulatory requirements. Meters that are expected to be calibrated in-line must be provided with block and bypass valves so that the reference standard (master) meter can be installed and disconnected without interrupting the process. The requirements for in-line calibration (for ISO 9000 verification) consist of comparing the output of the meter against a reference standard of higher accuracy, such as a dead-weight calibrated weigh tank.

## SELECTION CRITERIA

Simple Steps to Sizing and selection

- Determine the maximum acceptable pressure drop at the high flow conditions
- Determine the acceptable flow accuracy at the low flow condition.
- Use sizing program to enter fluid type, operating pressure and temperature.
- Select sensor that produces highest pressure drop below the maximum acceptable value.
- Confirm accuracy at low flow condition. If several sensors are still available for consideration select the sensor based on other criteria such as total installed cost or best accuracy.

## CONFORMATION TO STANDARDS

- ISO 5167, ASME MFC-3M.
- DIN or ANSI standards
- Stainless steel AISI 316
- Intrinsically safe EEx ia IIC T6, Explosion proof EEx d IIC T6
- IP 67

## APPLICATIONS

Coriolis meters will provide optimal flow measurements in these typical applications:

- Custody Transfer
- Batch Control
- Critical Process Control
- Mass Balance
- Loading and Unloading
- Gases
- Concentration and Density Measurements
- Filling & Dosing
- Multi-meter Product transfer skids
- Natural Gas Check Metering
- Pipeline Proving
- Reactor Charging
- Engine Testing
- Blending
- Hot

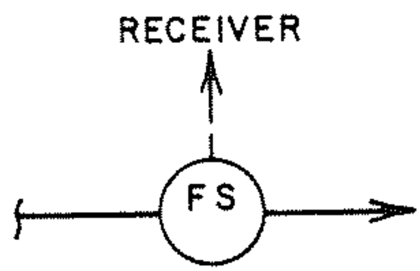
## PARTIAL LIST OF SUPPLIERS

- Micro motion
- Alltru Mass Flow meter & Equipment. Co.
- Contrec Inc.
- Yokogawa Corp,
- Omega Engineering Inc.
- Punj Lloyd Ltd
- Sunflow Instruments Ltd. (India)
-

# FLOW SWITCHES

**Description**
Flow switches are used for visual and/or electrical checking of liquid flow. The units are of rugged, glandless construction, and are available in several versions to suit a wide variety of industrial flow monitoring applications.

**Symbol**



*Flow Sheet Symbol*

**Figure**


*Krohne flow switch with indicator - version DW181/DW182*

**VERSIONS**

**DW 181 (standard)**

- for horizontal or vertical pipelines
- with screw connection G 3/4” to 2”
- indicator G or A
- 1 or 2 electrical limit switches
- measuring system C or E

**DW 182 (standard)**

- for horizontal or vertical pipelines
- with flanged connections DN 15 to DN 50 (DN 65),1/2” to 2”, 150 lbs
- indicator G or A
- 1 or 2 electrical limit switches
- measuring system C or E

**DW 183 (standard)**

- for horizontal or vertical pipelines
- with flanged connections (DN 65) DN 80 to DN 200, 3” to 8”, 150 lbs
- indicator G or A
- 1 or 2 electrical limit switches
- measuring system P

**DW 184 (standard)**

- mounting type for horizontal pipelines (DN ³ 250, 10”)
- mounting flange DN 150 / PN 16, 6”, 150 lbs
- indicator G
- 1 or 2 electrical limit switches
- measuring system P

## SPECIFICATIONS

### Technical data for DW181

| | |
|---|---|
| **Full-scale range (100% values)** | |
| Flow rate $m^3/h$ (US GPM) | 0.16 to 30 (0.7 to 132) |
| Flow velocity m/s (ft/s) | – |
| **Connection** | |
| ... Pipe thread G | 3/4" to 2" |
| ... Flanges to DIN 2501 (NFE 29203) | – |
| ... Flanges to ANSI B 16.5, Class 150lbs/RF | – |
| Information on other standards and pressure ratings supplied on request | |
| **Measuring system** | |
| Measuring disc with tapered tube | C |
| Nozzle with baffle | E |
| Baffle | – |
| **Indicator** | |
| Scale division 1 to 10 | G |
| in flow units | A |
| **Pipe run/flow direction** | |
| Vertical/upwards | VU |
| Vertical/downwards | VO |
| Horizontal/either way | H |
| **Max. allowable operating pressure** | 40 bar (580 psig) |
| Information on higher pressure levels supplied on request | |
| **Product temperature** | |
| Standard | ≤ 120°C (248°F) |
| Housing with ventilation | ≤ 150°C (302°F) |
| High-temperature w/o indicator: H2 | ≤ 200°C (392°F) |
| H3 | ≤ 300°C (572°F) |
| **Viscosity (mPa · s)** | |
| Standard | ≤ 30 |
| Special version | > 30 |
| **Repeatability (switching point)** | ± 3% |
| **Measuring accuracy (Indicator A)** | ± 15% |
| **Protection category** | |
| to EN 60529 /IEC 529 | IP 55 |

## Flow table for DW 181

| Meter size DW 181 Screw | DW 182 Flange DIN DN | ANSI inches | Code | Flow range Indicator G and A l/h | | | US GPM | | | Pressure loss $p_{max.}$ $Q_{min.}$ mbar | psig | $p_{max.}$ mbar | psig |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| 3/4" | 15 | 1/2" | C 011 | 20 | to | 160 | 0.09 | to | 0.70 | 16 | 0.23 | 80 | 1.16 |
| | | | C 012 | 50 | to | 400 | 0.22 | to | 1.76 | 67 | 0.97 | 176 | 2.55 |
| | | | C 013 | 150 | to | 1000 | 0.66 | to | 4.40 | 140 | 2.03 | 440 | 6.38 |
| | | | C 014 | 300 | to | 2500 | 1.32 | to | 11.01 | 150 | 2.18 | 490 | 7.11 |
| | | | E 015* | 64 | to | 160 | 0.28 | to | 0.70 | 65 | 0.94 | 370 | 5.37 |
| | | | E 016* | 100 | to | 250 | 0.44 | to | 1.10 | 150 | 2.18 | 870 | 12.62 |
| | | | E 017* | 160 | to | 400 | 0.70 | to | 1.76 | 18 | 0.26 | 110 | 1.60 |
| | | | E 018* | 250 | to | 630 | 1.10 | to | 2.77 | 40 | 0.58 | 270 | 3.92 |
| | | | E 019* | 400 | to | 1000 | 1.76 | to | 4.40 | 18 | 0.26 | 110 | 1.60 |
| 1" | 25 | 1" | C 021 | 200 | to | 1600 | 0.88 | to | 7.04 | 18 | 0.26 | 80 | 1.16 |
| | | | C 022 | 300 | to | 2500 | 1.32 | to | 11.01 | 26 | 0.38 | 180 | 2.61 |
| | | | C 023 | 500 | to | 4000 | 2.20 | to | 17.61 | 85 | 1.23 | 400 | 5.80 |
| | | | E 025 | 640 | to | 1600 | 2.82 | to | 7.04 | 15 | 0.22 | 110 | 1.60 |
| | | | E 026 | 1000 | to | 2500 | 4.40 | to | 11.01 | 45 | 0.65 | 240 | 3.48 |
| | | | E 027 | 1600 | to | 4000 | 7.04 | to | 17.61 | 25 | 0.36 | 140 | 2.03 |
| 11/2" | 40 | 11/2" | C 041 | 500 | to | 4000 | 2.20 | to | 17.61 | 14 | 0.20 | 68 | 0.99 |
| | | | C 042 | 800 | to | 6300 | 3.52 | to | 27.74 | 32 | 0.46 | 110 | 1.60 |
| | | | C 043 | 1200 | to | 10000 | 5.28 | to | 44.03 | 60 | 0.87 | 160 | 2.32 |
| | | | E 045 | 2500 | to | 6300 | 11.01 | to | 27.74 | 15 | 0.22 | 100 | 1.45 |
| | | | E 046 | 4000 | to | 10000 | 17.61 | to | 44.03 | 50 | 0.73 | 260 | 3.77 |
| 2" | 50 | 2" | C 051 | 1200 | to | 10000 | 5.28 | to | 44.03 | 30 | 0.44 | 80 | 1.16 |
| | or 65 | or 21/2" | C 052 | 2000 | to | 16000 | 8.81 | to | 70.45 | 65 | 0.94 | 260 | 3.77 |
| | | | C 053 | 2500 | to | 20000 | 11.01 | to | 88.06 | 72 | 1.04 | 350 | 5.08 |
| | | | C 054 | 7500 | to | 30000 | 33.02 | to | 132.09 | 47 | 0.68 | 360 | 5.22 |
| | | | E 055 | 6400 | to | 16000 | 28.18 | to | 70.45 | 20 | 0.29 | 110 | 1.60 |
| | | | E 056 | 8000 | to | 20000 | 35.22 | to | 88.06 | 30 | 0.44 | 140 | 2.03 |

*only with indicator G

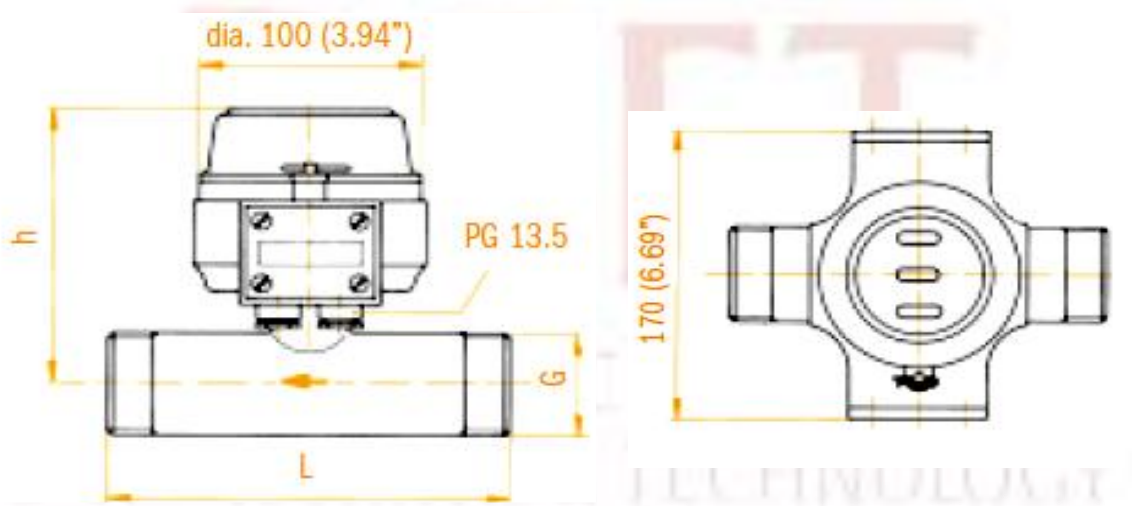
**Instrument versions**

| Version | Cap | Gaskets* | Measuring system | Measuring tube |
|---|---|---|---|---|
| DW 181/B | Stainless Steel 316 L | Buna | Stainless Steel 316 L | Bronze |
| DW 181/RR | Stainless Steel 316 L | Buna | Stainless Steel 316 L | Stainless Steel 316 L |
| DW 182/RR | Stainless Steel 316 L | Buna | Stainless Steel 316 L | Stainless Steel 316 L |
| DW 183/N | Stainless Steel 316 L | Buna | Stainless Steel 316 L | Steel |
| DW 183/R | Stainless Steel 316 L | Buna | Stainless Steel 316 L | Stainless Steel 316 L |
| DW 183/RR | Stainless Steel 316 L | Buna | Stainless Steel 316 L | Stainless Steel 316 L |
| DW 184/N | Stainless Steel 316 L | Buna | Stainless Steel 316 L | Steel |
| DW 184/R | Stainless Steel 316 L | Buna | Stainless Steel 316 L | Stainless Steel 316 L |
| DW 184/RR | Stainless Steel 316 L | Buna | Stainless Steel 316 L | Stainless Steel 316 L |

* Gaskets of Viton, silicone or Klingerit on request
DW 184/R: steel-clad flanges used throughout

| Version | Connection | Housing |
|---|---|---|
| DW 181/B | Bronze | Polycarbonate |
| DW 181/RR | Stainless Steel 316 L | Polycarbonate |
| DW 182/RR | Stainless Steel 316 L | Polycarbonate |
| DW 183/N | Steel | Polycarbonate |
| DW 183/R | Steel** | Polycarbonate |
| DW 183/RR | Stainless Steel 316 L | Polycarbonate |
| DW 184/N | Steel | Polycarbonate |
| DW 184/R | Steel** | Polycarbonate |
| DW 184/RR | Stainless Steel 316 L | Polycarbonate |

**DW 181- Dimensions**



## PRINCIPLE OF OPERATION

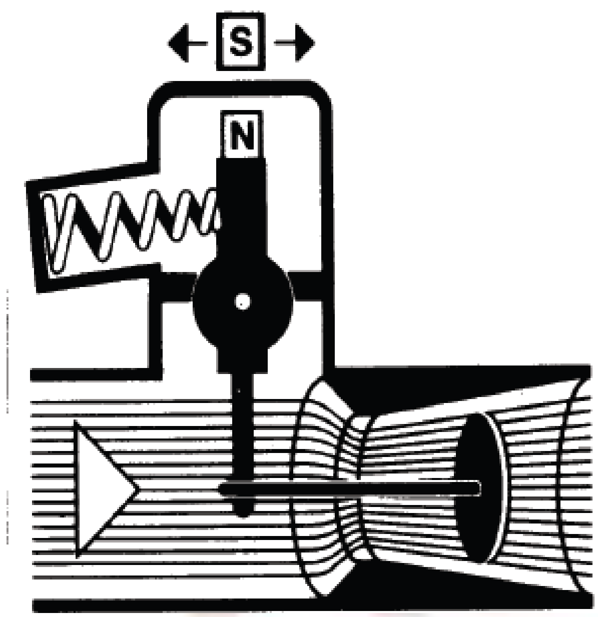
### Measuring systems

- Measuring system C: A hinged measuring disc moves freely in the axis of a tapered tube (DW 181, DW 182 only). At flowing conditions, the system adjusts so that the force acting on the disc is in equilibrium with the spring force. Each flow rate thus corresponds to a particular position of the indicator and simultaneously actuates the limit switches.

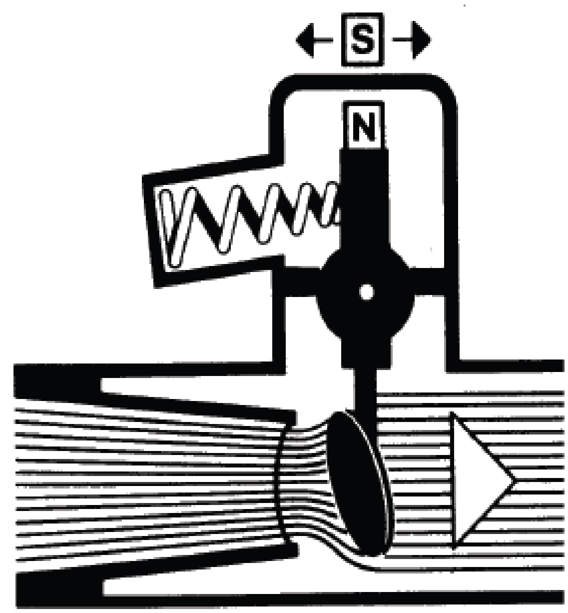
- Measuring system E: Instead of being located in a tapered tube, this system incorporates a nozzle (DW 181, DW 182 only) to increase the flow velocity. This version is particularly suitable for liquids with solids content.

- Measuring system P: (DW 183 and 184 flow switches only).This is used for large nominal pipe diameters (DW 183, DW 184). It is similar to system E but does not require a nozzle.

Measuring system C



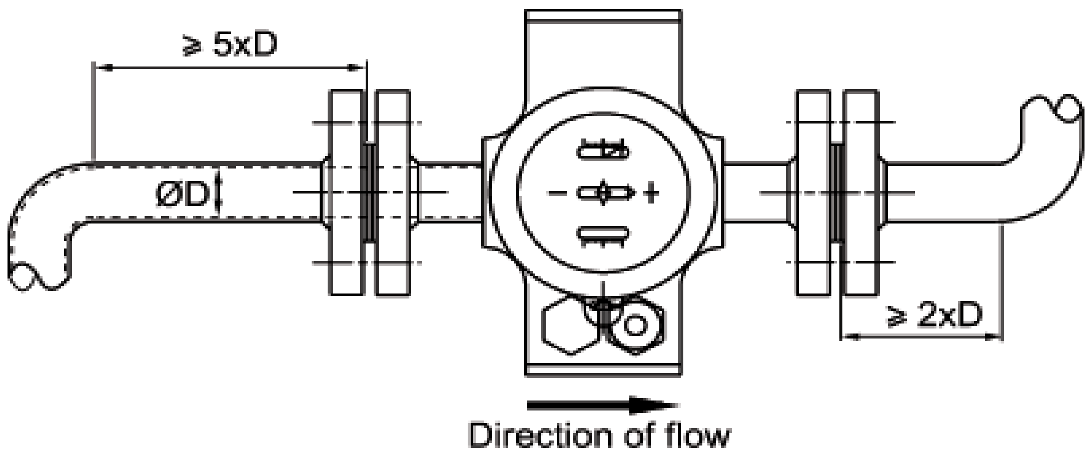

Measuring system E (P)



## INSTALLATION

**Positioning the flow switch**

No obstacles along the pipe within five diameters (D) upstream and two diameters downstream of the instrument.




**Installation in hazardous areas (Ex applications):**

Read all instructions referring to flow switches in hazardous locations before installation. Check that the flange, gasket and other materials in contact with the product are compatible. Refer to the information given on the converter nameplate, the flange markings and specifications given in the ATEX approval certificate.

**Connecting the DW 18 to the pipe:**

Before installation, clean the piping to remove any dust or weld debris.
Fit the instrument on the pipe with the arrow on the housing pointing in the direction of flow.

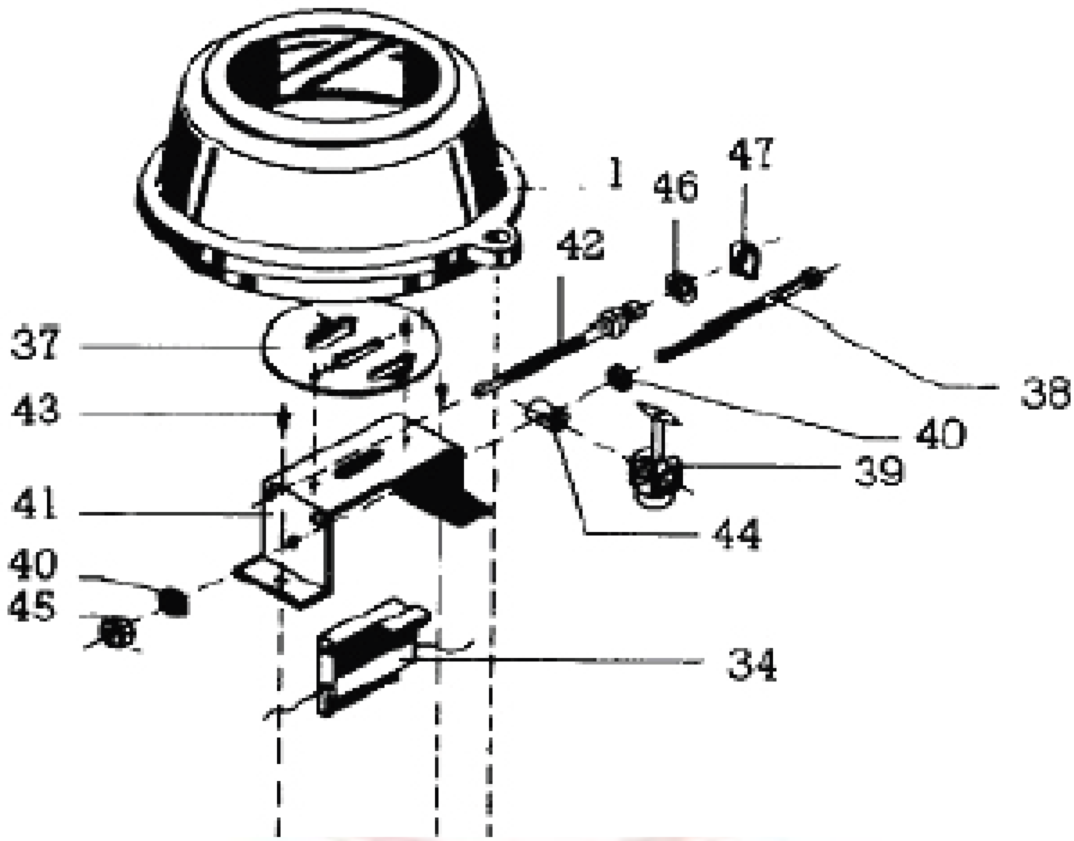
**Flange connections:**

Ensure that the gaskets are in place, flange facings are aligned and parallel and that the bolts have been tightened with the amount of torque specified in European or local (if outside the E.U.) standards.

**Flow Direction**

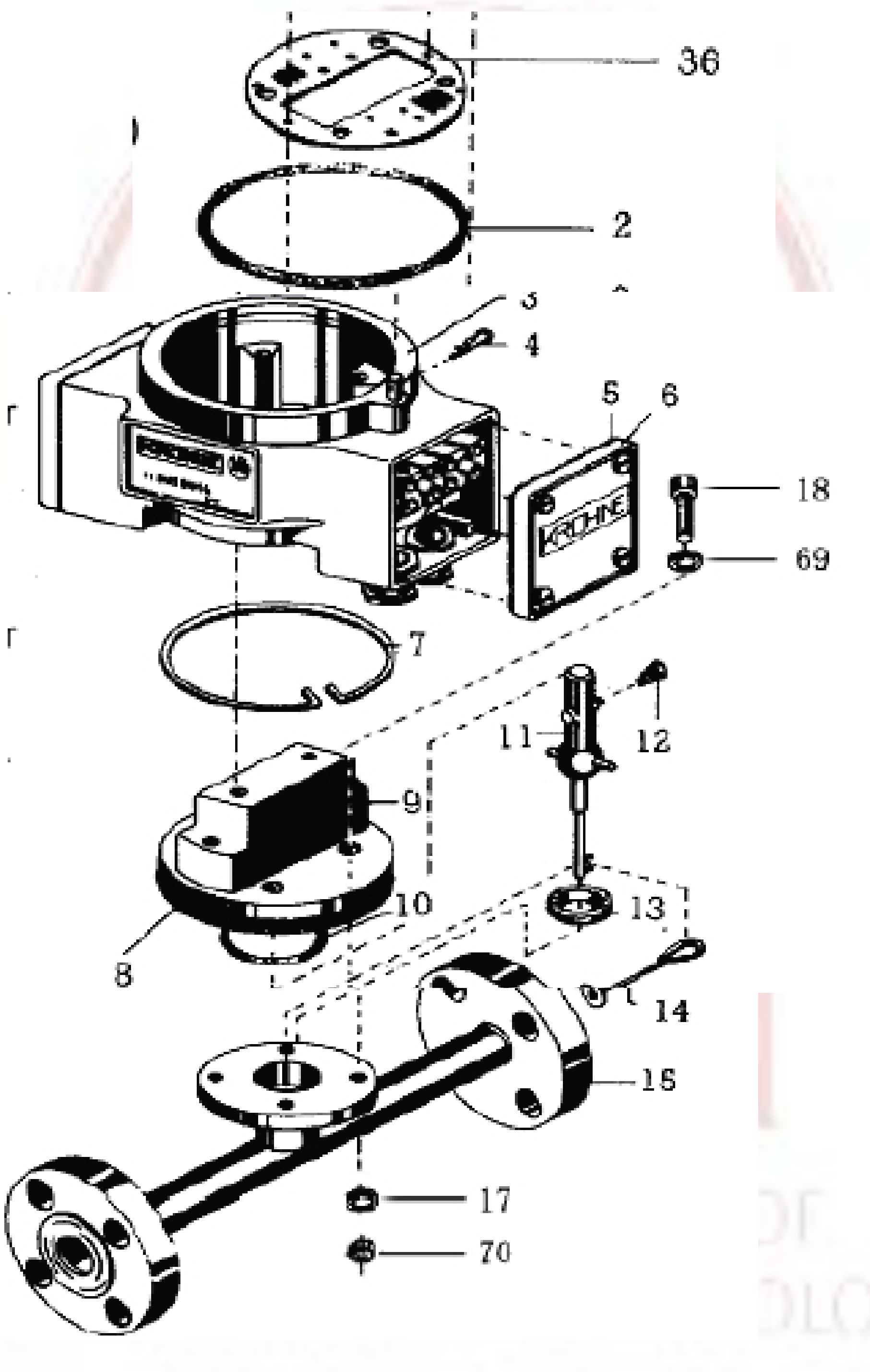
The DW 183 and DW 184 can be installed in any position on the piping. However, the position of installation and the flow direction must be indicated in the customer order (i.e. up, down, left to right and right to left) as the weight of the baffle disc is taken into account when calibrating the instrument. Flow direction must be indicated for DW 181 and DW 182 instruments equipped with type A indicators.

**CONSTRUCTION AND INSTALLATION - exploded view**




1 Cap
2 O-ring
3 Housing
4 Locking pin
5 Gasket
6 Cover
7 Snap ring
8 O-ring
9 Pressure housing
10 O-ring
11 Magnet lever
12 Measuring spring, complete
13 PTFE ring
14 Measuring disc (type C)
15 Tubular body (DW 182 with flanged connection)
17 Spring washer
18 Screw
34 Reed contact G/K1

**Installation - Exploded view**



## CALIBRATION

### Inspection procedure

***Measuring assembly**:*
Check the condition of the measuring system, cone-disc or nozzle-disc. Check the condition of the spring. In the event of leaks between the body and the cap, tighten the four bolts securing the cap. Change the O-ring if necessary. Carefully follow the maintenance procedures.

***Housing** (DW181 & DW182 models):*
Check switches operation using an ohmmeter. Check the operation of the indicating mechanism. By removing the lock ring holding the housing onto the assembly, it is possible to remove the housing from the measuring body without removing the flow switch from the pipe, or stopping the flow. Carefully follow the maintenance procedures.

## SELECTION CRITERIA

| Series | FSW-20 | FSW-25 | FSW-40/50 | FSW-30A | FSW301 | FSW302 | FSW307 |
|---|---|---|---|---|---|---|---|
| Starting Price | $183 | $250 | $180 | $214 | $141 | $160 | $100 |
| Page No. | B-77 | B-78 | B-79 | B-80 | B-75 | B-76 | B-76 |
| Maximum Temperature °C (°F) | 149 (300) | 149 (300) | 93 (200) | 82 (180) | 80 (176) | 80 (176) | 80 (176) |
| Maximum Pressure (psi) | 2000 | 355 | 300 | 400 | 365 | 362 | 145 |
| Pipe Sizes | 1 to 4" | 1 to 3" | 1 to 10" | ½ to 1" | ¾ to 8" | ½ to 1" | ½ to 1" |
| Connection | 1 MNPT | 1 MNPT | 1 MNPT | ½ to 1 FNPT | ½ MNPT | ½ to 1" | ½ to 1" |
| Technology | Paddle | Paddle | Paddle | Paddle | Paddle | Paddle | Paddle |
| Special Features | Bi-Directional | NEMA4X | SPDT 15A | Flow through design | Adjustable paddle length | Brass Body | PVC Body |

## APPLICATIONS

- Chemical
- Mining & materials
- Food & beverage
- Nuclear
- Oil & Gas
- Pharmaceuticals
- Power & Energy
- Wastewater Treatment
- Steel
- Pulp & Paper

## CONFORMATION TO STANDARDS

- Low tension : NF EN 61010-1
- EMC : EN 50081-1
  : EN 50082-2
- ATEX : EN 50014+A1+A2
  : EN 50018
  : EN 50020
  : EN 50281-1-1+A1
  : EN 50284
  : EN 13463-1

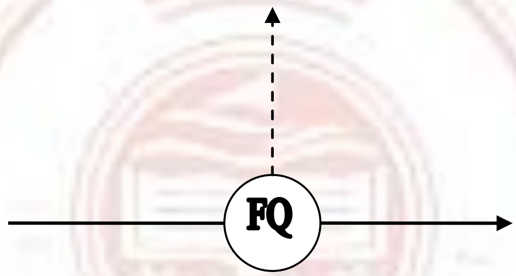
## PARTIAL LIST OF SUPPLIERS

- Krohne
- Honeywell
- Fluid components international
- Zaward
- Sunfull water
- Poway hydraulic industrial
- Asia vital components

# FLOW TOTALISER

**Description**
The flow rate / totalizer model F012-P is a microprocessor driven instrument designed to display flow rate, total and accumulated total. This product has been designed with a focus on ultra-low power consumption to allow long-life battery powered applications (type PB / PC), intrinsic safety for use in hazardous applications (type XI), several mounting possibilities with GRP or aluminum enclosures for industrial surroundings, ability to process all types of flow meter signals.

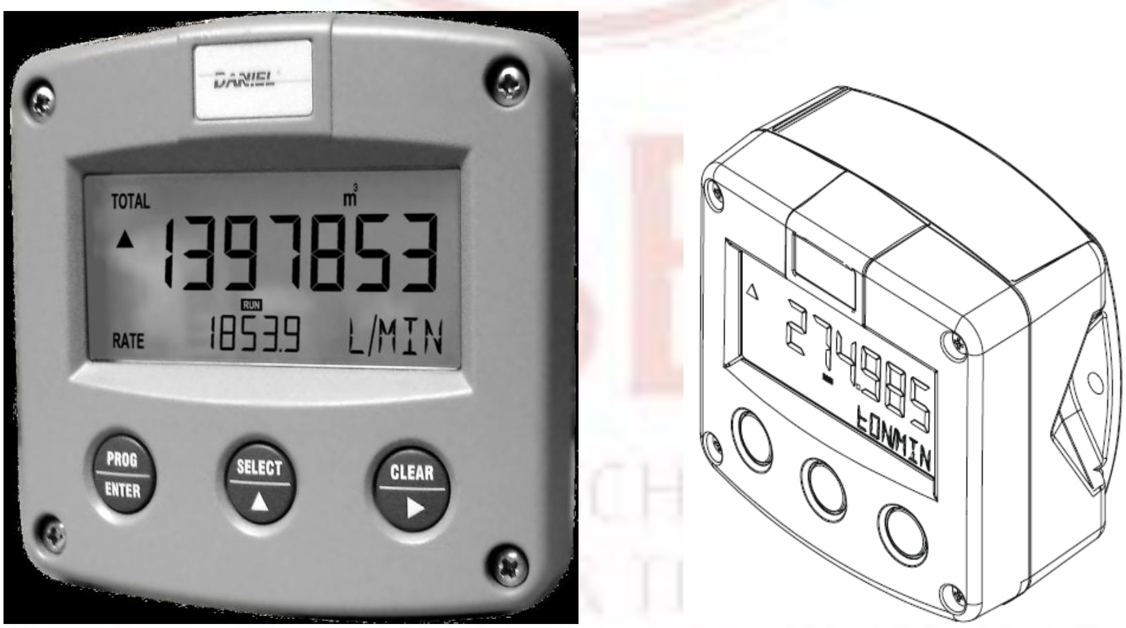
**Symbols**




Flow sheet symbol

**Instrument identification letters**
**FQI** - flow totaliser indicator
**FQIS** - flow totaliser indicator with switch
**FQR** - flow totaliser recorder

**Figure**




***Daniel® Series 500 Liquid Turbine Flow Meter Totalizer***

**SPECIFICATIONS**

- Display-Digits : 7 digit 17mm (0.67”) high intensity LCD
  : 11 digit 8mm (0.31”) high intensity LCD
- K-Factor Range : The pulses per unit of measure (e.g., pulses / gallon) are programmable in the range 0.000010 to 9,999,999.
- Decimal Points : Fully programmable for rate and total
- Time Base : Rates can be displayed in units per second, minute, hour or day
- Resolution : 16 bit. Error < 0.01mA / ±0.05% FS
- Update Time : Four times per second
- Connections : 2 wire
- Voltage Drop : 2.6V DC @ 20mA
- Memory Backup: Lithium battery
- Hazardous Area : II 1 GD EEx ia IIC T4 T100°C
- Frequency Range : 0.01Hz to 7kHz
- Operating Temp. : -40°C to 70°C (-40°F to 158°F)
- Max.Ambient Temp. : 70°C (158°F)
- Battery Powered
  →Battery Type : Lithium battery
  →Battery Life : 5 years
- Signal Type : Coil / sine wave (minimum 20mVpp or 80mVpp - sensitivity selectable), NPN/PNP, open collector, reed switch, Namur, active pulse signals 8 -12 and 24V DC
- Environment Electromagnetic Compatibility: Compliant ref: EN 61326 (1997), EN 61010-1 (1993)

**PRINCIPLE OF OPERATION**

**Flow meter input**
This unit has a pulse type input from the flow meter "-P version". Other versions are available to process (0)4-20mA or 0-10V flow meter signals. One flow meter with a passive or active pulse, Namur or coil signal output can be connected to the F012-P. To power the sensor, several options are available.

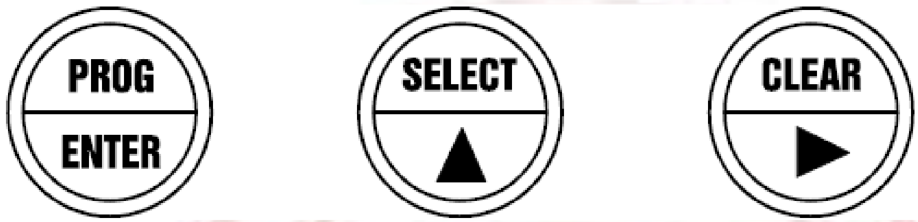
**Configuration of the unit**
The F012-P has been designed to be implemented in many types of applications. For that reason, a SETUP-level is available to configure your F012-P according to your specific requirements. It includes several important features, such as K-factors, measurement units, signal selection etc. All setting are stored in EEPROM memory and will not be lost in the event of power failure.

**Display information**
The unit has a large transflective LCD with all kinds of symbols and digits to display measuring units, status information, and trend-indication and key-word messages. Flow rate and totals can be displayed either with the small 8mm digits or with the 17mm digits. A backup of the total and accumulated total in EEPROM memory is made every minute.

**Options**

The following options are available: intrinsic safety, power- and sensor-supply options, panel-mount, wall-mount and weather-proof enclosures, flame proof enclosure and LED backlight

**Control panel:** The following keys are available:




**Functions of the keys:**

This key is used to program and save new values or settings. It is also used to gain access to SETUP-level.

This key is used to SELECT accumulated total. The arrow-key t is used to increase a value after PROG has been pressed or to configure the unit.

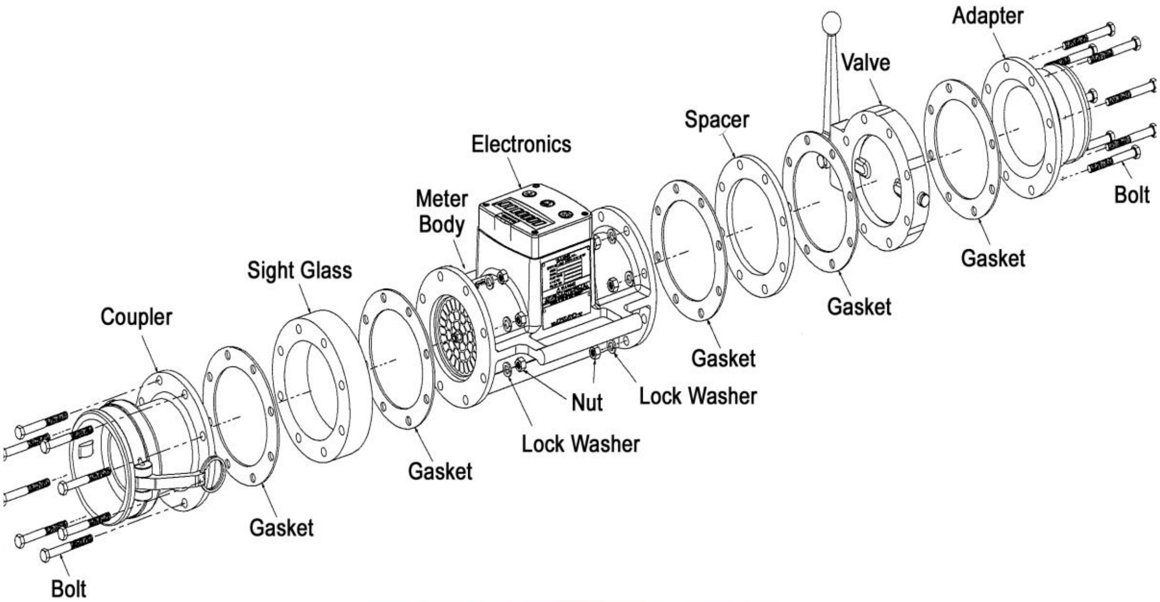
Press this key twice to CLEAR the value for total. The arrow-key 4is used to select a digit after PROG has been pressed or to configure the unit.

**Operator information and functions:**

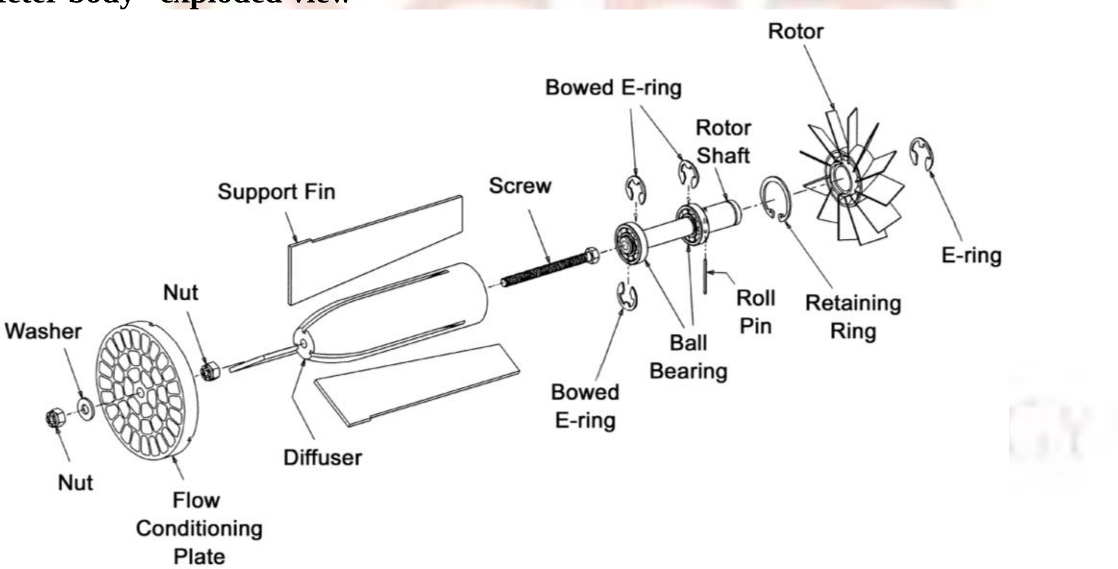
In general, this will always function at Operator level. The information displayed is dependant upon the SETUP-settings. The signal from the connected sensor is processed by the F012-P in the background, whichever screen refresh rate setting is chosen. After pressing a key, the display will be updated very quickly during a 30 second period, after which it will slow-down again**.**

*Example of display information during process*

**CONSTRUCTION- Exploded view**




**Meter body –exploded view**



**Instrumentation Design Criteria.**

Material: The material requirements for Flow totalizer shall in general be according to the instrument design criteria

Accuracy : The accuracy shall be ±0.25%. Repeatability shall be ±0.25%

Reading Scales : Units for Flow totalizer shall be in M3/HR for liquids and NM3for gases.

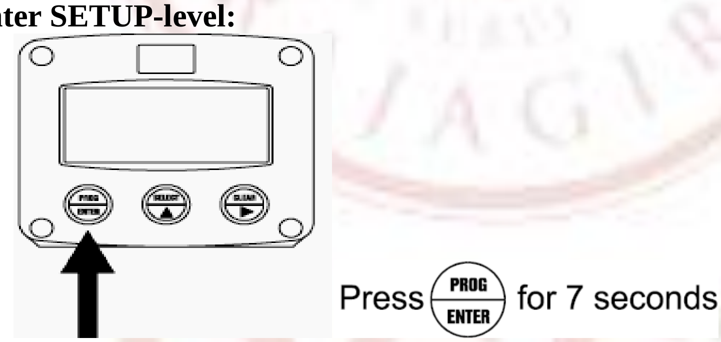
Enclosure Class : In addition to weatherproof of class IP-66and flame proof to EExdIIC, T6, the Flow totalizer enclosure shall be explosion-proof to NEMA-7 and shall be certified by statutory body like UL/FM/BASEEFA or equal for use in hazardous area.

**CALIBRATION**

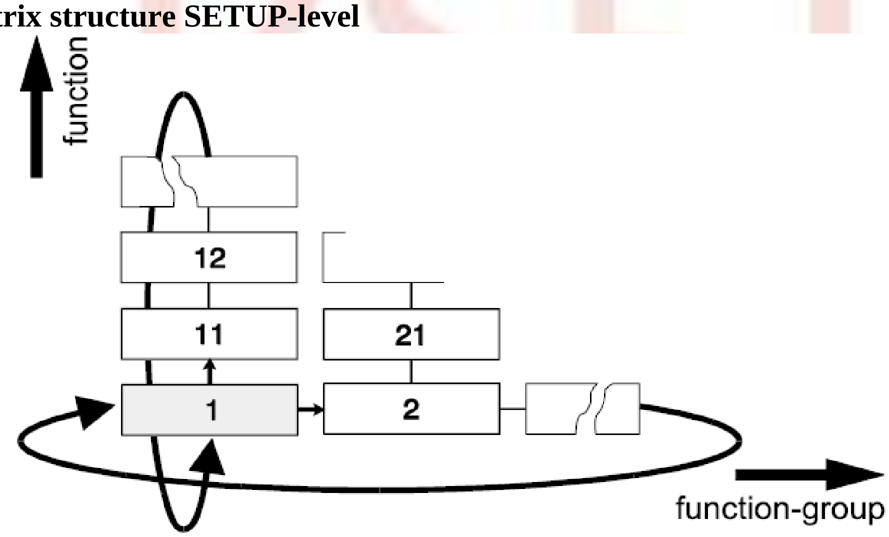
**Programming setup-level: General**

Configuration of the F012-P is done at SETUP-level. SETUP-level is reached by pressing the PROG/ENTER key for 7 seconds; at which time, both arrows will be displayed. In order to return to the operator level, PROG will have to be pressed for three seconds. Alternatively, if no keys are pressed for 2 minutes, the unit will exit SETUP automatically. SETUP can be reached at all times while the F012-P remains fully operational.

**To enter SETUP-level:**

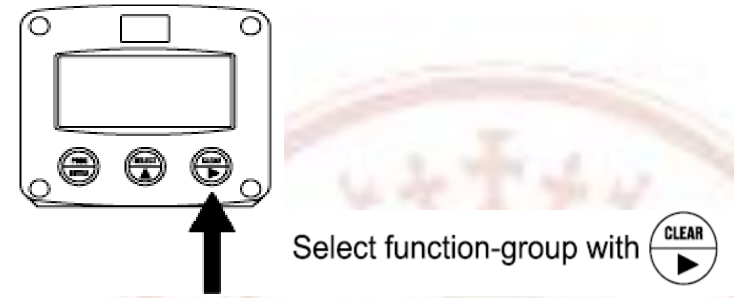



**Matrix structure SETUP-level**



**Scrolling through setup-level**

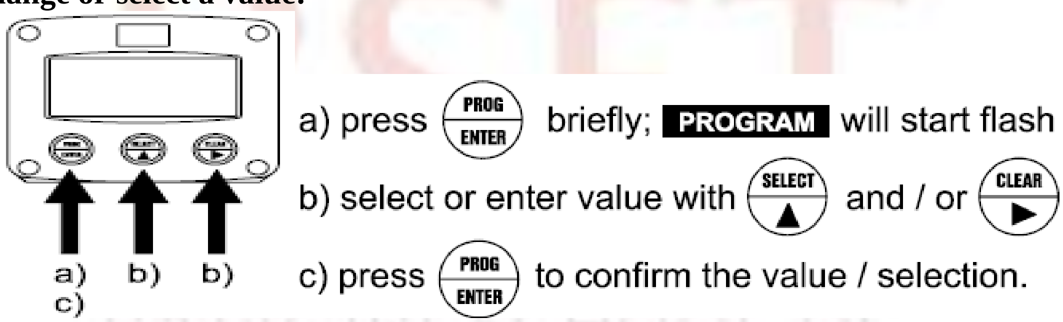
Selection of function-group and function: SETUP is divided into several function groups and functions.





Each function has a unique number, which is displayed below the word "SETUP" at the bottom of the display. The number is a combination of two figures. The first figure indicates the function-group and the second figure the sub-function. Additionally, each function is expressed with a keyword. After selecting a sub-function, the next main function is selected by scrolling through all "active" sub functions (e.g. 1t, 11t, 12t, 13t, 14t, 14, 24, 3t, 31 etc.). The “CLEAR” button can be used to jump a step back if you missed the desired function.

**To change or select a value:**




To change a value, use to select the digits and to increase that value. If the new value is invalid, the increase sign or decrease-sign will be displayed while you are programming. To select a setting, is used to select in one direction and can be used to select in the other direction. When data is altered but ENTER is not pressed, then the alteration can still be cancelled by waiting for 20 seconds or by pressing ENTER for three seconds: the PROG-procedure will be left automatically and the former value reinstated.

**To return to operator-level:**


In order to return to the operator level, PROG will have to be pressed for three seconds. Also, when no keys are pressed for 2 minutes, SETUP will be left automatically.

**SELECTION CRITERIA**

**General:**

- The Flow totalizer shall be microprocessor based.
- The Flow totalizer shall display both flow rate and totalized value. LCD type display shall be provided in the Flow totalizer.
- Flow totalizer shall provide an output of 4-20 mA sq.root signal (for flow rate).The input power supply to the Flow totalizer shall be 24vdc.
- All programming and total values are stored in non-volatile memory and can be retrieved even if the power is removed from the unit.
- The totalizer should have provision to save accumulated total flow even if the power is lost.

[ONGC: functional specification for flow totalizer/format no (ods/sof/004)/vol no iii/rev no 1/ fs no: 3201]

**CONFORMATION TO STANDARDS**

- ATEX + CENELEC
- BP RP 30-1(Instrumentation & Control-Design & Practice)
- BP RP 32-1( Inspection & Testing of new equipment in manufacture)
- BASEEFA (British Approval Services For Electrical Equipment in Flammable Atmosphere)
- IEC60534 Part 4
- BS 5501-Electrical apparatus for potentially explosive atmospheres)
- IEC60529(degrees of protection provided by enclosures (IP Code)) viz EEx ia IIC T4, IP65
- ISO 9001

**APPLICATIONS**

- Flow of chemicals, fertilizers, oil and gas, transfer ship loading metering stations, final product transfer lines of various industries

**PARTIAL LIST OF SUPPLIERS**

- Daniel
- Kep
- Trumeter
- Danaher
- Durant
- Simpson
- Kubler
- Dwyer
- Sbem