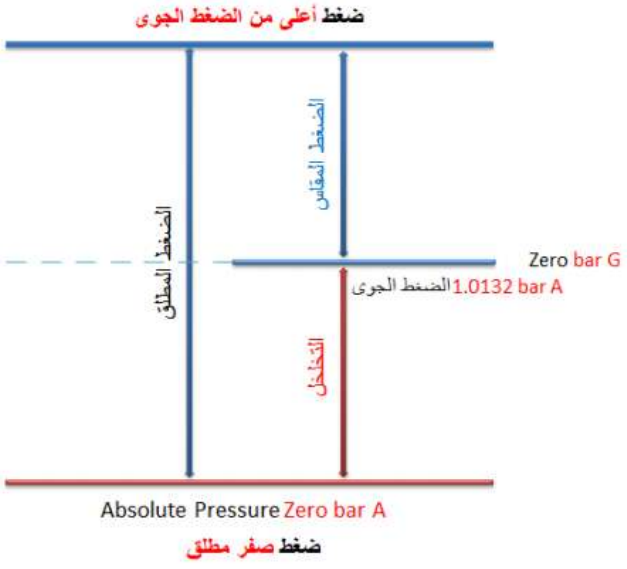
③ Pressure Measurements

- $P = \frac{F}{A} = \rho gh$

To ▶ From ▼	psi	mbar	bar	atm	Pa	kPa	MPa	mmH_2O	$in.H_2O$	mmHg	in.Hg	kg/cm^2
psi	1	68.95	0.0689	0.0681	6895	6.895	0.006895	703.8	27.71	51.715	2.036	0.0704
mbar	0.0145	1	0.001	0.000967	100	0.100	0.0001	10.21	0.402	0.75	0.0295	0.00102
bar	14.504	1000	1	0.987	100000	100	0.1	10210	401.9	750.1	29.53	1.02
atm	14.7	1013.25	1.01325	1	101325	101.325	0.1013	10343	407.2	760.0	29.92	1.033
Pa	0.000145	0.01	0.00001	0.00001	1	0.001	0.000001	0.102	0.00402	0.0075	0.000295	0.00001
kPa	0.14504	10.0	0.01	0.00987	1000	1	0.001	102.07	4.019	7.5	0.295	0.0102
MPa	145.04	10000	10	9.87	1000000	1000	1	101971.6	4014.6	7500.6	295.3	10.2
mmH2O	0.001421	0.098	0.000098	0.000097	9.8	0.0098	0.0000098	1	0.0394	0.0735	0.00289	0.0001
in.H2O	0.0361	2.488	0.002488	0.00246	248.8	0.2488	0.00025	25.4	1	1.866	0.0735	0.00254
mmHg	0.01934	1.333	0.001333	0.001316	133.3	0.1333	0.00013	13.61	0.536	1	0.0394	0.00136
in.Hg	0.4912	33.86	0.03386	0.03342	3386	3.386	0.00386	345.7	13.61	25.4	1	0.0345
kg/cm^2	14.22	980.7	0.9807	0.968	98067	98.067	0.0981	10010	394.1	735.6	28.96	1

- $1\ Bar = 10^5\ Pa = 14.7\ PSI = 10200\ mmH_2o = 1.0193\ Kg/cm^2$
- P (abs) = P(gauge) + P(atm)
- P(vacuum) = P(atm) – P(abs)



- PSI : Pound / $inch^2$
- ρ : Density in (kg/m^3)
- g:acceleration due to gravity (9.8 m/s^2)
- h : depth in liquid in (m)
- $1\ Bar\ = 29.53$ in.Hg
- $PSI\ \mathbf{A} = PSI\ \mathbf{G} + 14.7$

Pressure Measurements

Gauges

- Digital
- Mechanical
  - Diaphragm
  - Bellow
  - Capsule
  - Piston
  - Bourdon Tube
    - C-Shaped
    - Spiral
    - Helical

Switches

- Mechanical
- Contact gauge
- Electronic
- Diff Pressure

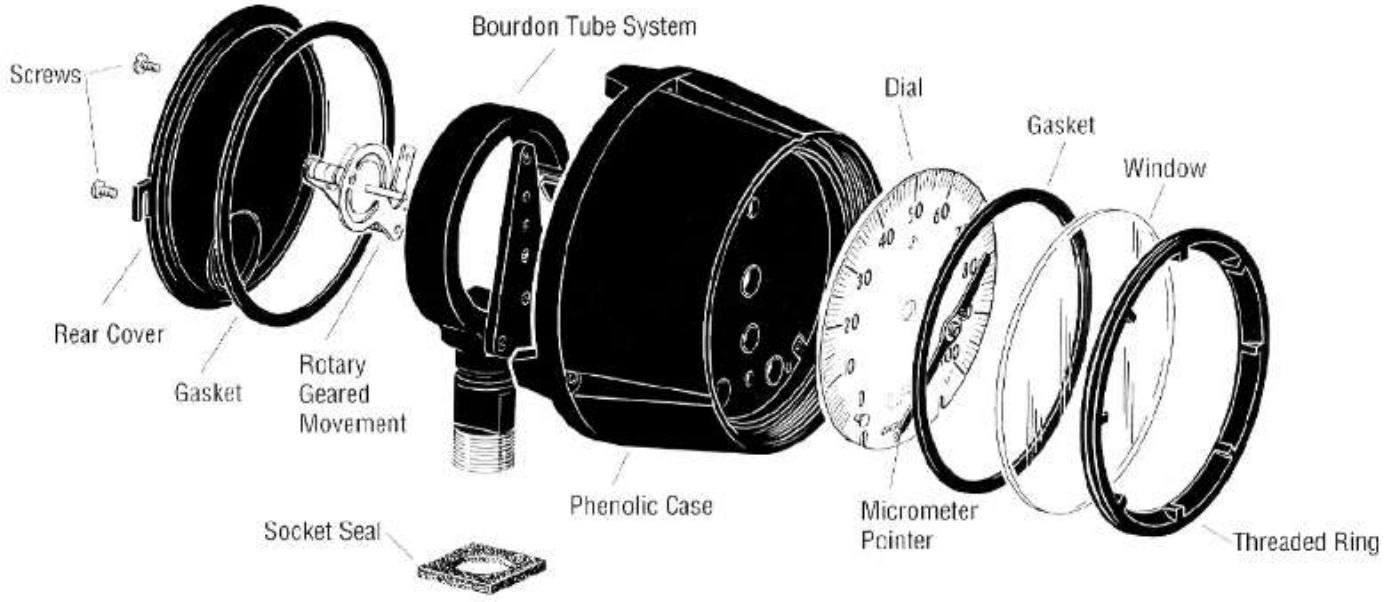
Manometer

- U Tube
- Well Type
- Barometer
- Inclined Tube
- Micro

Transmitters

Transducer

- Strain Gauge
- Capacitance
- Potentiometer
- LVDT
- Piezoelectric



Typical pressure gauge assembly

Pressure Gauge

❖ Digital Pressure Gauge:

- With an accuracy up to 0.025% of span, it can be used for calibration.
- They are expensive.

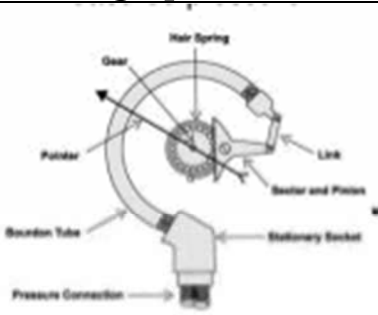
❖ Mechanical (Analog) Pressure Gauge:

Based on pressure sensing(primary) element.

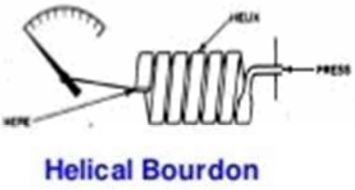
➢ Bourdon Tube:

- Used for medium & high pressures.
- Range: (0.6: 7000) Bar.

Advantages	Disadvantages
Accurate results at high pressure	Not suitable with low pressure
Low cost	Not suitable with overload protection
Simple construction	Not suitable with critical media
Safe even for high pressure	



"C" Type Bourdon



Helical Bourdon

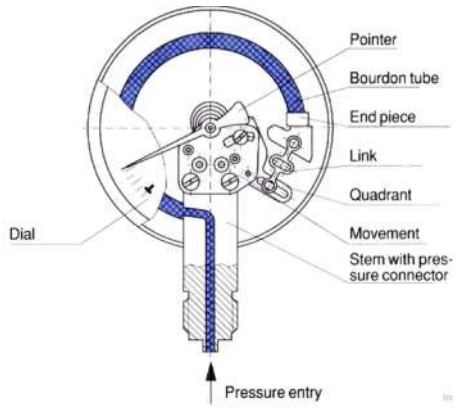
Coiled Bourdon

Pressure Gauges Brands :

- WIKA
- ASHCROFT
- WISE
- WINTERS

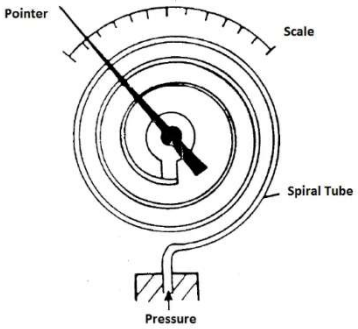
✓ <u>C-Shaped Bourdon Tube</u>:

- Cover the majority of applications.
- Pressure is measured by Bourdon Tube converted motion that transmitted directly to the pointer.
- Can be used for positive, negative pressure.
- Range: [(0:1) Bar – (0:1360) Bar].



✓ <u>Spiral Bourdon Tube</u>:

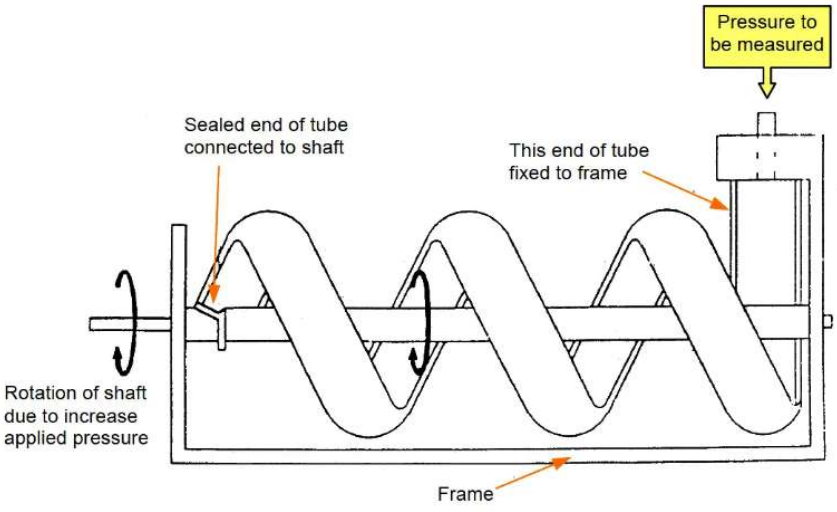
- Can be used for positive, negative pressure.
- More sensitive & accurate.
- Used for Low pressure range (< 0.7 Bar).



✓ <u>Helical Bourdon Tube</u>:

- Helical is a bourdon tube wound in the form of helix. It allows the tip movement to be converted to a circular motion.
- By installing a central shaft inside the helix along its axis and connecting it to the tip, the tip movement become a circular motion of the shaft.

- Higher over range protection.
- More sensitive & accurate.
- Range: [(0:2) Bar – (0:5000) Bar].
- Very expensive.



➢ Diaphragm Pressure Gauge:

- The pressure is transmitted wave shape diaphragm to a link this then transfer the pressure to the movement of pointer.
- More accurate .
- Insensitive to vibration.
- Low pressure range:(0:16 mBar & (0:40 Bar).
- Overload protection (5X,10X).
- Critical media (Chemicals&Viscous).

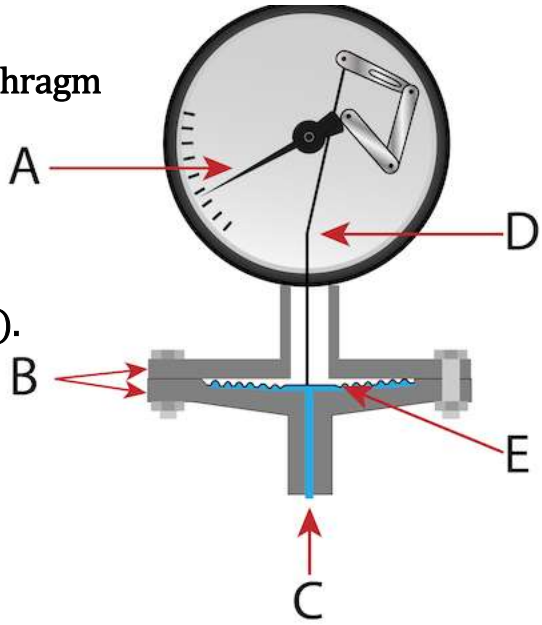
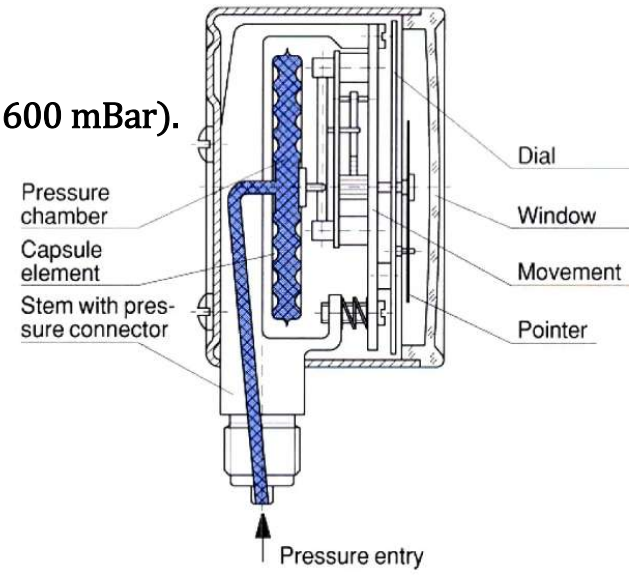


Figure 2: Operating principle of a diaphragm pressure gauge: pointer (A), upper and lower housing (B), pressure inlet (C), pressure element (D), and diaphragm (E).

➢ Capsule Pressure Gauge:

- Diaphragm is a single sheet , joining Two diaphragm to form a capsule.
- Very Low pressure range:(0:2.5 mBar & (0:600 mBar).
- High accuracy (0.1 % : 2.5 %).



Pressure Gauges failure & safety risk :

- Temperature
- Corrosion
- Vibration
- Overpressure

How to select Pressure Gauges :

1. Accuracy (±1%) .
2. Dial size (1.5 " : 10 ").
3. Mounting (Bottom – Back) Connection.
4. Environment (Water – Chemical – Vibration – Oil - Gas).
5. Process connection size (0.25 " NPT – 0.5 " NPT) . #National Pipe Thread
6. Pressure range [max range in between(25%:75%)].
7. Accessories (fill media-Siphons-Diaphragm seals).



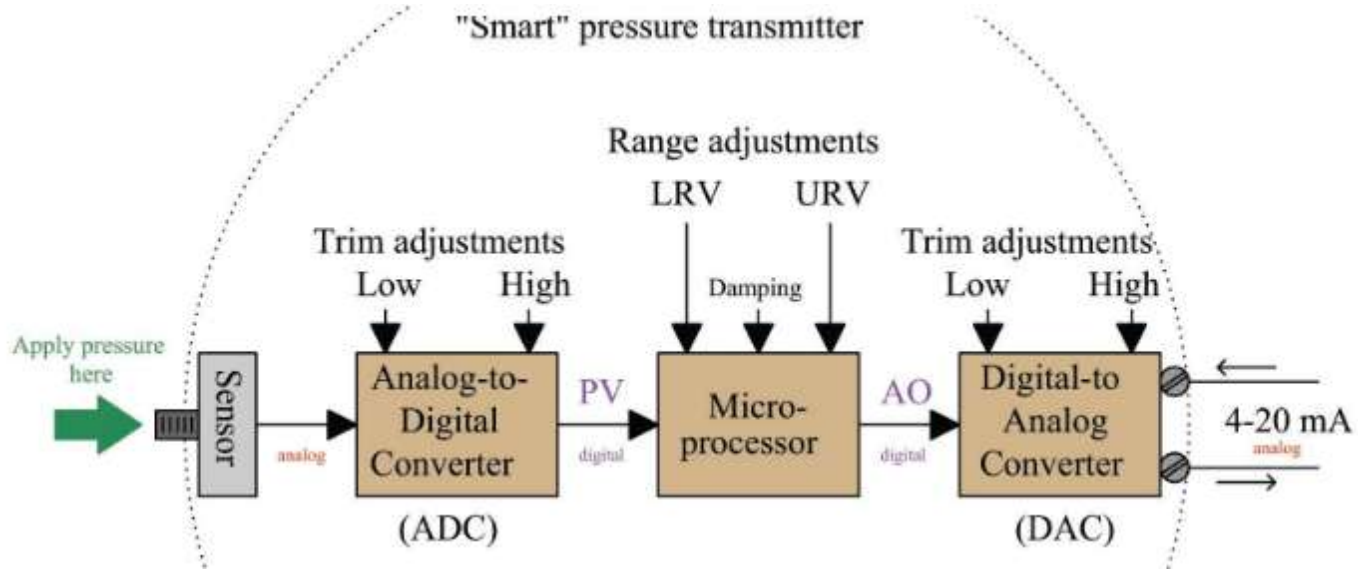
How to calibrate Pressure Gauges :

1. Gauge comparator (Pump).
2. Reference gauge (Digital).
3. Gauge under calibration.

➢ Basic procedure of pressure gauge calibration:

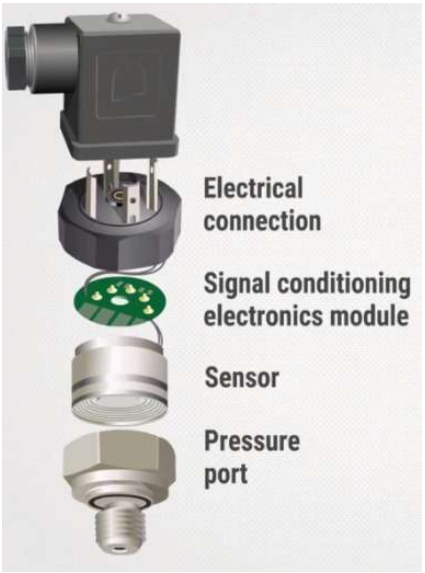
- Connect the equipment's as shown .
- Apply pressure 0%(zero adjust).
- Adjust the zero screw or put the pointer on 0%.
- Apply pressure 100%(span adjustment).
- To correct the indication increase or decrease the sector arm.
- Apply pressure 50%(linear adjust).
- Adjust the length of link or pull the pointer using puller and place at correct spot.
- Check points 0%,25%,50%,70% and 100%.
- Repeat these steps to get correct values.

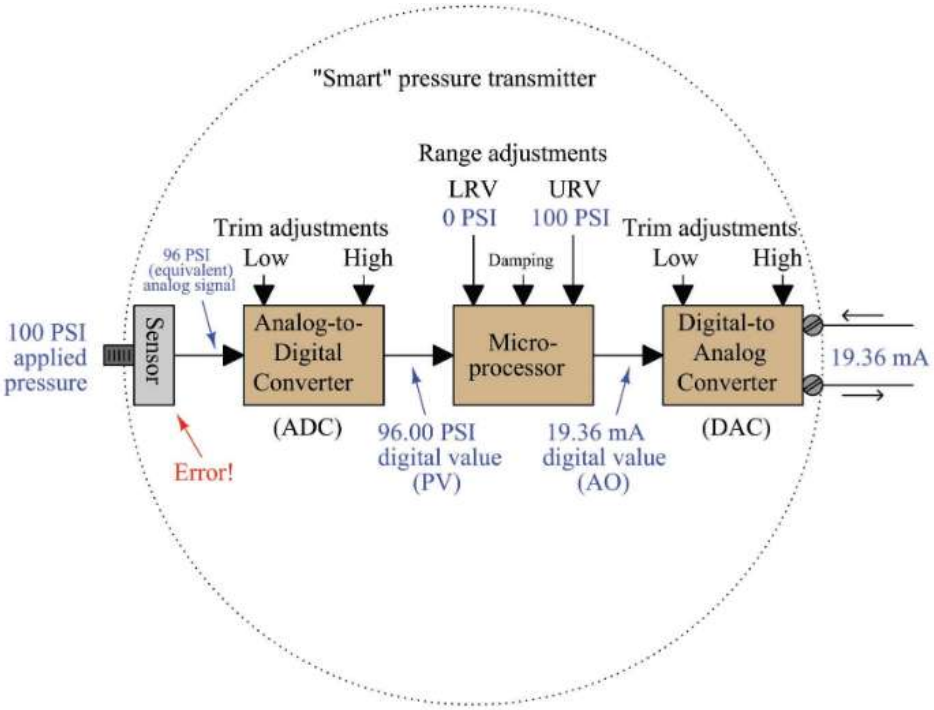
Pressure Transmitter



What's inside of a pressure transmitter?

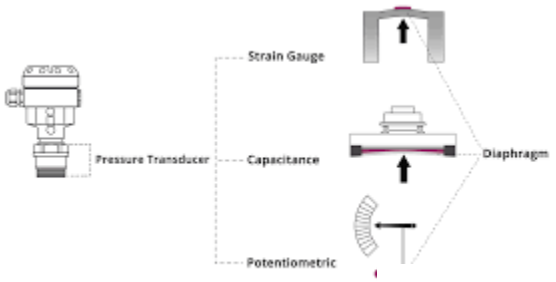
- Pressure Port
- Sensor (Transducer)
- Signal conditioning electronics module
- Electrical connection





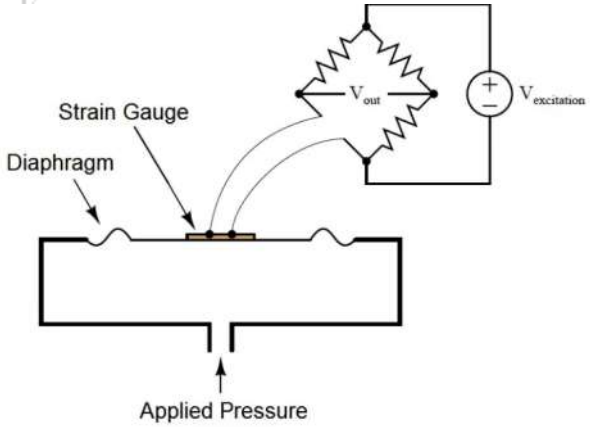
➢ Transducer:

1) Strain Gauge
2) Capacitance
3) Potentiometer
4) LVDT



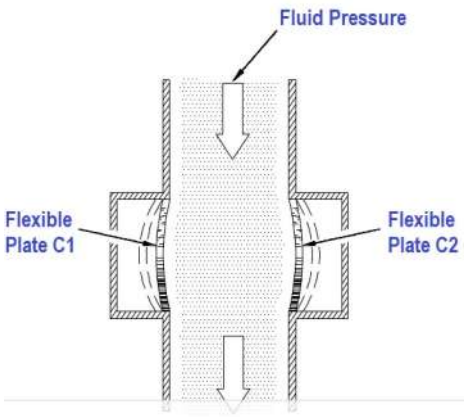
1) Strain gauge:

The strain gauge is a classic example of a piezoresistive element, Piezoresistive means "pressure-sensitive resistance," or a resistance that changes value with applied pressure.



2) Capacitance:

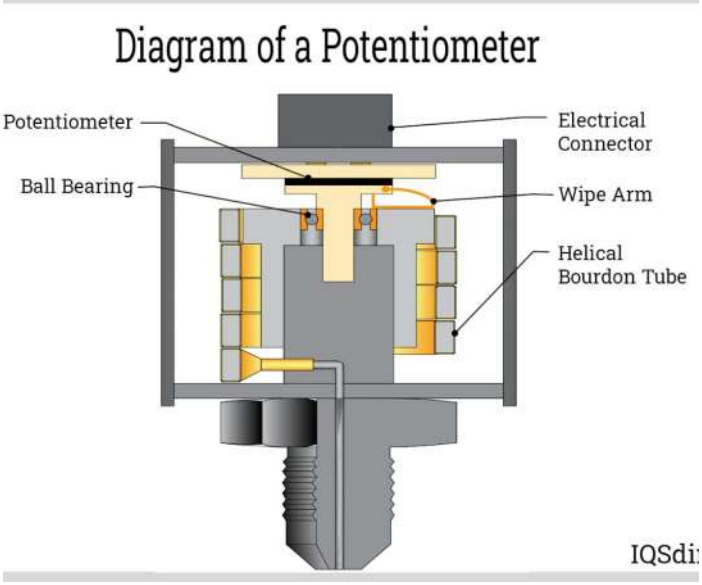
Capacitive-type transducers, illustrated in Figure, consist of two flexible conductive plates and a dielectric.
In this case, the dielectric is the fluid.
As pressure increases, the flexible conductive plates will move farther apart, changing the capacitance of the transducer.
This change in capacitance is measurable and is proportional to the change in pressure.



3) Potentiometer:

A potentiometric pressure transducer is composed of three major parts:

- Capsule
- sliding contact wiper
- resistance wire winding.

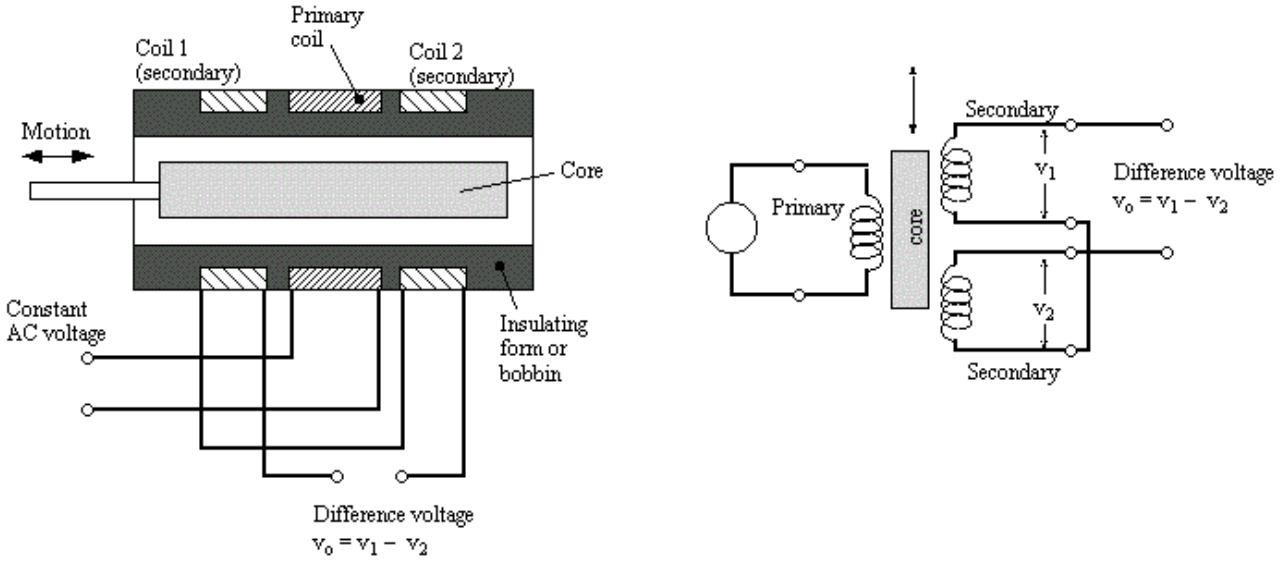


The capsule is connected to the wiper through a linkage rod. When pressure is applied to the capsule, it changes the position of the wiper across the potentiometer. As a result, there is also a change in resistance between the wiper and the potentiometer. Therefore, the mechanical deflection is converted into a resistance measurement.

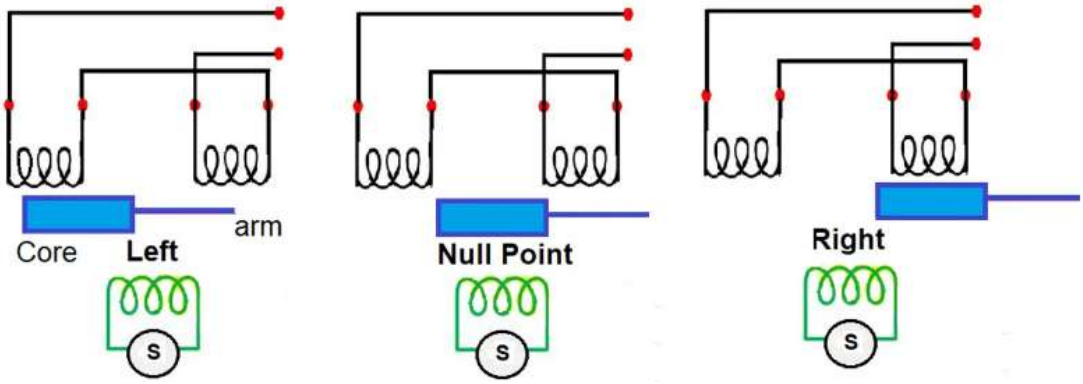
4) Linear Variable Displacement Transducer (LVDT):

LVDT works under the principle of mutual induction, and the displacement which is a non-electrical energy is converted into an electrical energy.

And the way how the energy is getting converted is described in working of LVDT in a detailed manner.

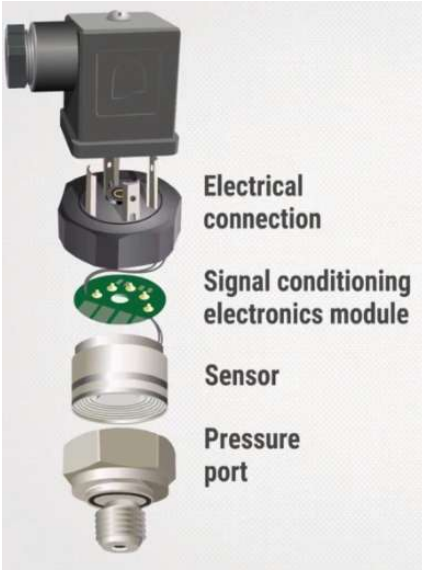


IT converts linear displacement into an electrical signal. It comprises one primary and two secondary coil windings. Both windings are an equal number of turns and they are connected in series to each other. The primary winding is placed as opposed to the two secondary windings as shown in the below figure.



The primary winding is excited by the alternating current; the core is placed inside of it. The alternating current induces flux in primary and by mutual induction, the flux is induced in secondary.

➢ Signal conditioning electronics module:



It converts sensor signal into standard normalized electric output such as :

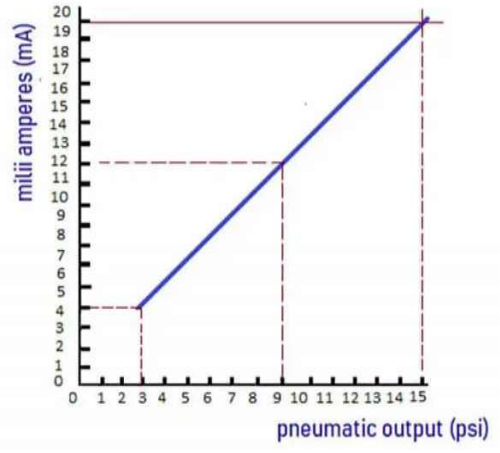
- 4:20 mA
- 0:20 mA
- 0:5 V
- 0:10 V

➢ Electrical Connection:

It's used to wire a pressure transmitter to a measuring system.

Why 4:20 mA is the best ?

- (0:10 V) : Current signals can extend much further than voltage signals, allowing robust signal wire lengths of up to 1,000 meters (Voltage drop).
- (0:20 mA) : In this case, it would be extremely difficult to identify that either 0mA current is due to open circuit of the transmitter or it is due to no pressure of the fluid. (Live Zero)
- Current signals are less susceptible to noise than voltage signals. Therefore, the 4-20mA output is inherently noise-resistant.(and it's possible to use unshielded cable when installing them)
- The electronic chips required to function proper 3 mA as the minimum current .
- Dangerous current threshold for the heart is over 30 mA.
- Induced eddy current (result fault at reading) has affect at less than 4 mA.
- Easy conversion from 4:20 mA to 1:5 VDC using 250 ohm .
- For easy calculation (20% bias) 4-20 mA (analog devices)like 3-15 PSI (pneumatic devices).

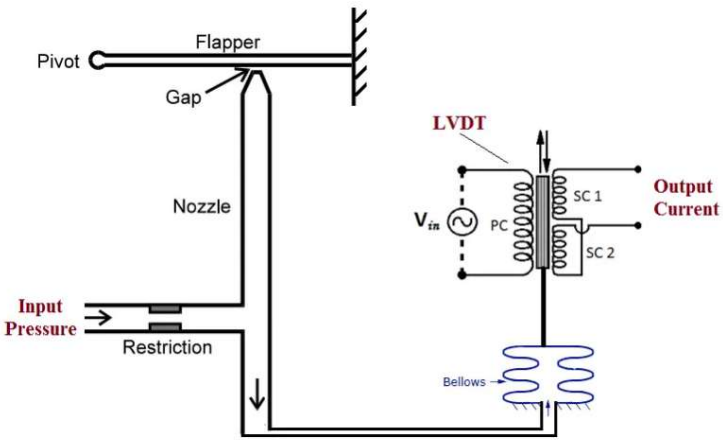


Why I need to convert 4:20 mA to 1:5 VDC ?

- Pressure transmitter send 4:20 mA to Analog input module.
- AI module need to convert analog signal to equivalent binary signal (010101) that PLC or DCS processor can deal with.
- AI module consist of A/D converter (ADC).
- A/D converter need voltage as input signal to convert them to equivalent binary signal (0,1) so we had to convert 4:20 mA to 1:5 VDC using 250 ohm as a standard resistance.

What is an P/I converter?

- We can construct a pressure to current converter using a Flapper- Nozzle arrangement , Bellows and a Linear Variable Differential Transformer (LVDT) circuit.
- Input pressure is given to Flapper-Nozzle arrangement and the output current will come through the LVDT.

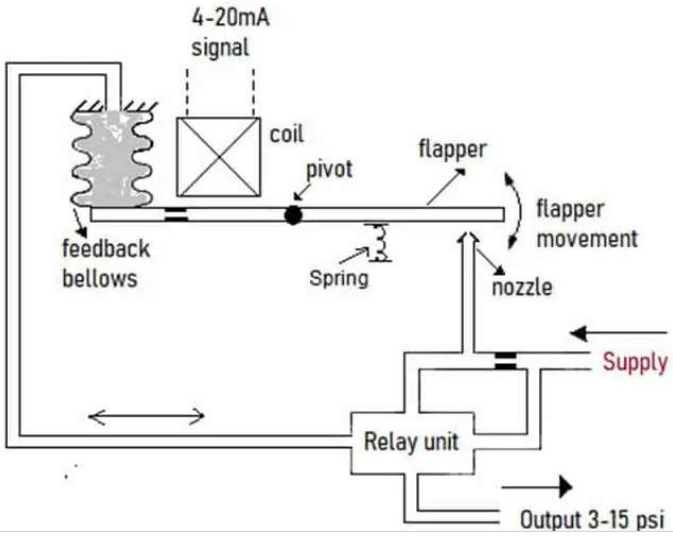


What is an I/P converter? Working Principle, Applications

- I/P converter is a current to pressure transducer that works on the flapper nozzle method. I/P converter translates the input 4 to 20mA current signal into equivalent output of 3 to 15 PSI pressure.

Working principle

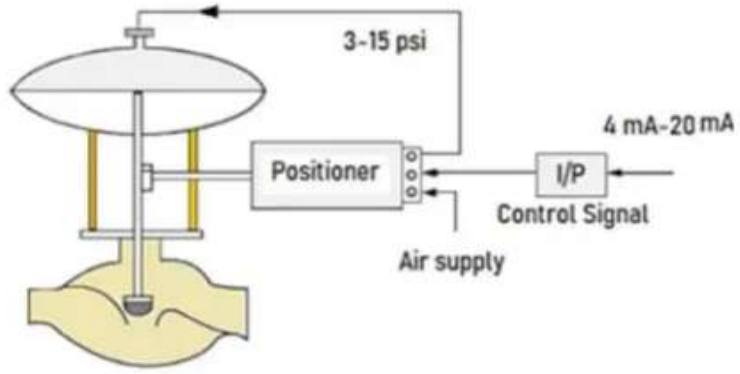
- Pneumatically operated control valves require a converter or transducer to change the proportional electrical signal to a proportional pneumatic signal. Generally, the converter comes as part of the valve.
- Its purpose is to convert the analog signal output

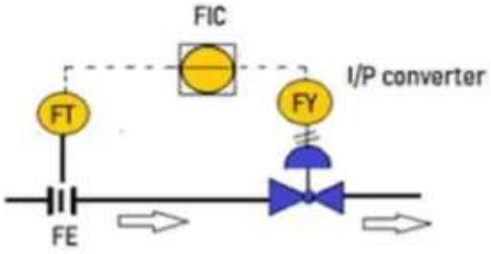


of a control system into an accurate repeatable value of pressure to control pneumatic actuators/operators, pneumatic valves, dampers, vanes, etc.

- The controller output sends an electronic signal to the current-to-pressure (I/P) transducer, which in turn sends a pneumatic signal to the control valve. The control valve changes position in response to the signal to adjust the flow rate to the set point. As the flow changes. It is detected by the flow transmitter. As long as the detected flow is equal to the set value, the valve position will remain the same. Whenever there is a system disturbance or set-point change, the flow control automatically responds to reach the programmed set point.

Application of I/P converter





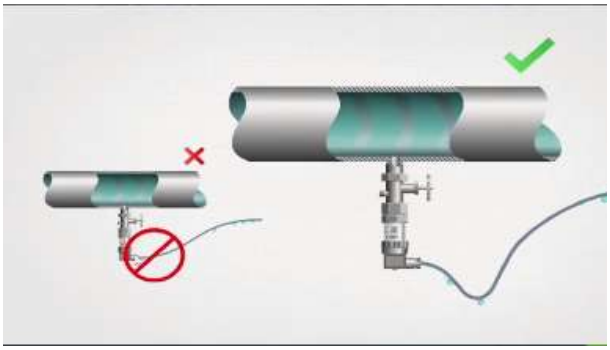
How to select pressure transmitter?

1. Type of pressure measured [Gauge – Absolute – Differential].
2. Pressure range [actual measurement is as 80% of range].

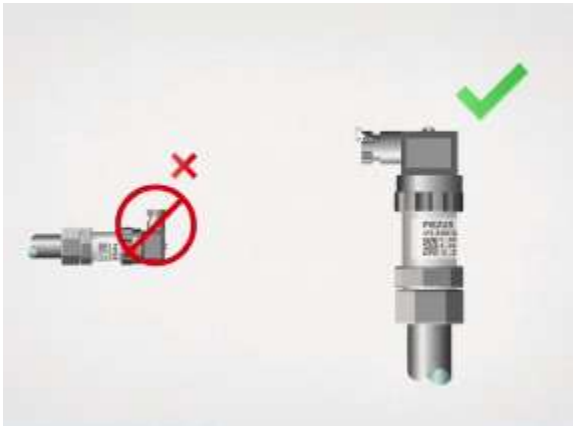
3. Measured media [gas – viscous-sea water].
   # sea water : high nickel content alloys { INCONEL alloy718}.
4. System maximum overload.
5. Accuracy level [0.05%: 0.5%].
6. Operating temperature range.
   # at high temp you can install condensing , radiator or siphon .
7. Power supply & output signal.
8. Working environment [vibration – electromagnetic interference].
   #IP : Ingress Protection {first digit : Solid & 2nd digit : Liquid}
9. Pressure interface connection [M20x1.5].

Transmitters mounting rules?

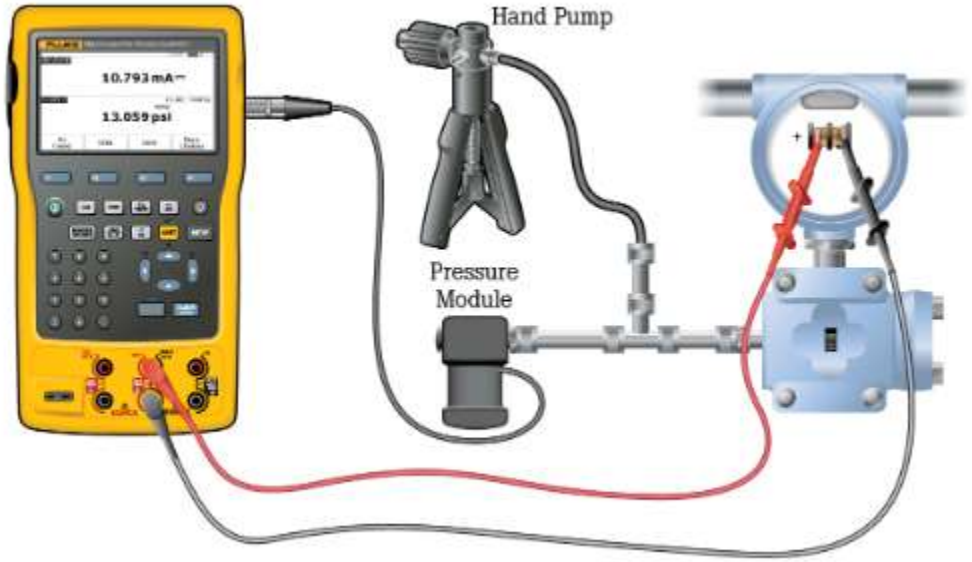
- Prevent moisture to reach transmitter cable connection.



- Used shielded cables if theirs is close power equipment.
- Cable shield must be completely undamaged.
- Avoid to mount the transmitters cable upwards.

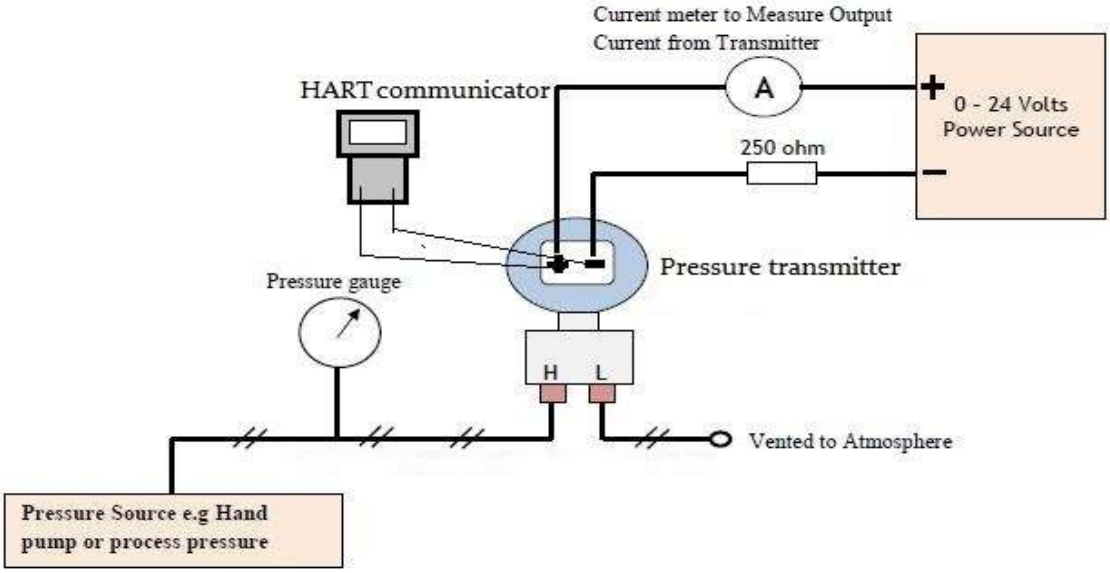


How to calibrate Pressure Transmitters :



- ✓ First isolate the main process isolation valve.
- ✓ De-pressurize the pressure transmitter by opening the vent valve
- ✓ Isolate the manifold valve and open the vent plug.
- ✓ Fix proper instrument fitting (for eg:1/4”npt fitting)
- ✓ Connect the calibrator fitting in to the vent plug entry of manifold valve.
- ✓ The vent valve should be opened.
- ✓ The HART communicator cable should be placed as per transmitter wiring diagram.
- ✓ Apply pressure as per the range given in the transmitter or check with the HART communicator.
- ✓ Check the transmitter reading by applying pressure for 25%, 50%, 75%, and span range.
- ✓ If the transmitter needs to be calibrated use the HART communicator for calibration purpose.
- ✓ Zero & span trims can be done by using HART communicator.
- ✓ After calibration checking remove the pressure calibrator from the transmitter and flush the line.
- ✓ So that hydraulic oil or water will not be inside the transmitter.
- ✓ Close the vent plug.
- ✓ Isolate the vent valve and open the main isolation valve.
- ✓ Open the manifold isolation valve slowly, if u open fast sudden pressure may damage the transmitter diaphragm.
- ✓ After completion of the calibration ensure the transmitter is reading showing properly.
- ✓ Then enter the reading in calibration report format.

How to connect HART communication?



Highway Addressable Remote Transducer Protocol

Figure 1-3 and Figure 1-4 illustrate typical wiring connections between the HART Communicator and any compatible device.

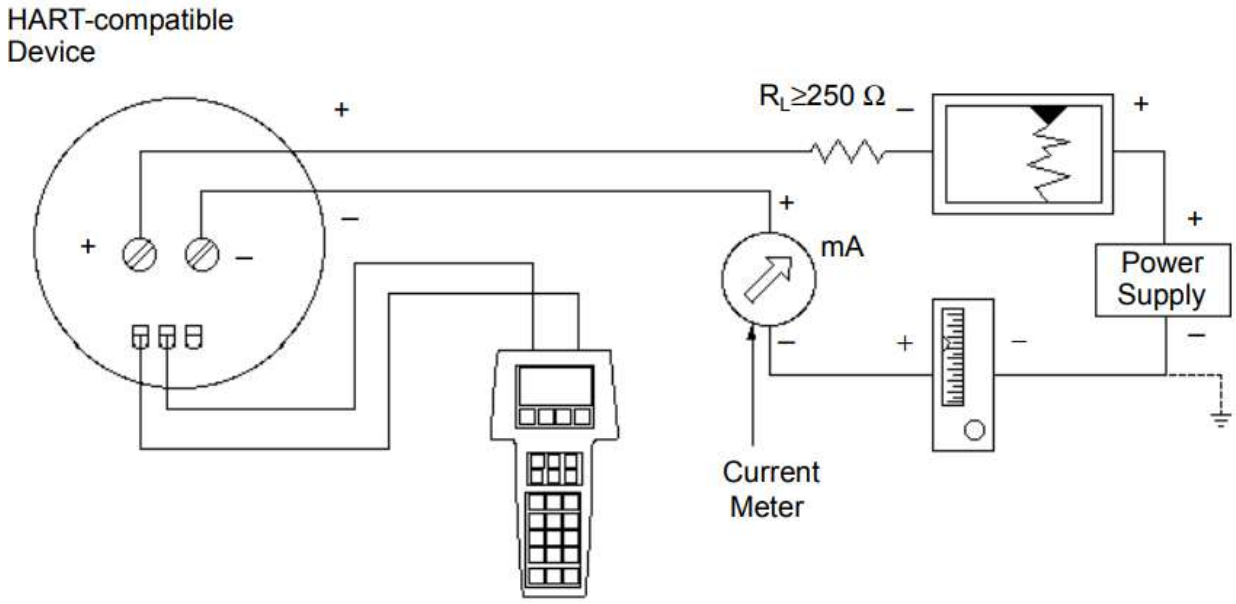


FIGURE 1-3. Connecting to the Transmitter Comm Terminals.

Resistance value:

The HART specification defines the loop resistor value to be in the range of 230 ohms to 600 ohms. Typically, 250 ohms is used. This value provides an easy conversion from a current value to a voltage value used in some control systems. In this case 4mA through a 250 ohm resistor is 1Vdc and 20mA is 5 Vdc.

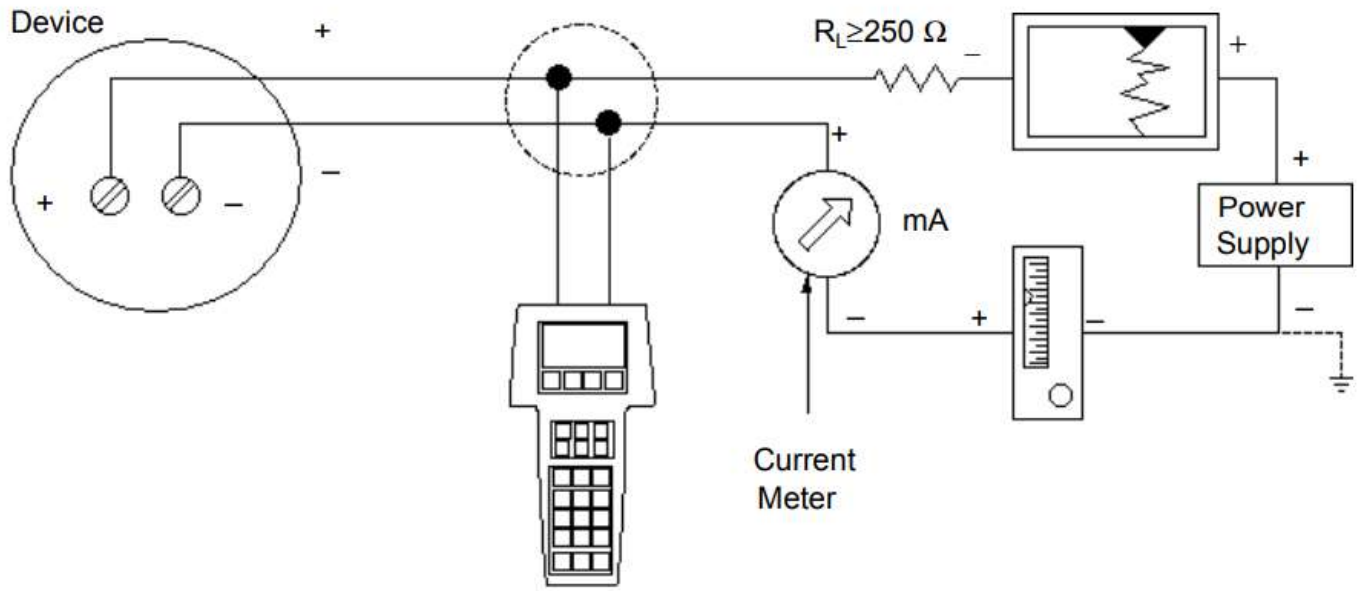


FIGURE 1-4. Connecting the HART Communicator to the Loop.

Figure 1-5 shows how to connect the optional 250 ohm load resistor.

NOTE: To temporarily install the optional 250 ohm Load Resistor:

1. Insert the load resistor into the lead set jacks.
2. Open the loop to allow connection of the resistor in series in the loop.
3. Close the loop using the lead set connectors.

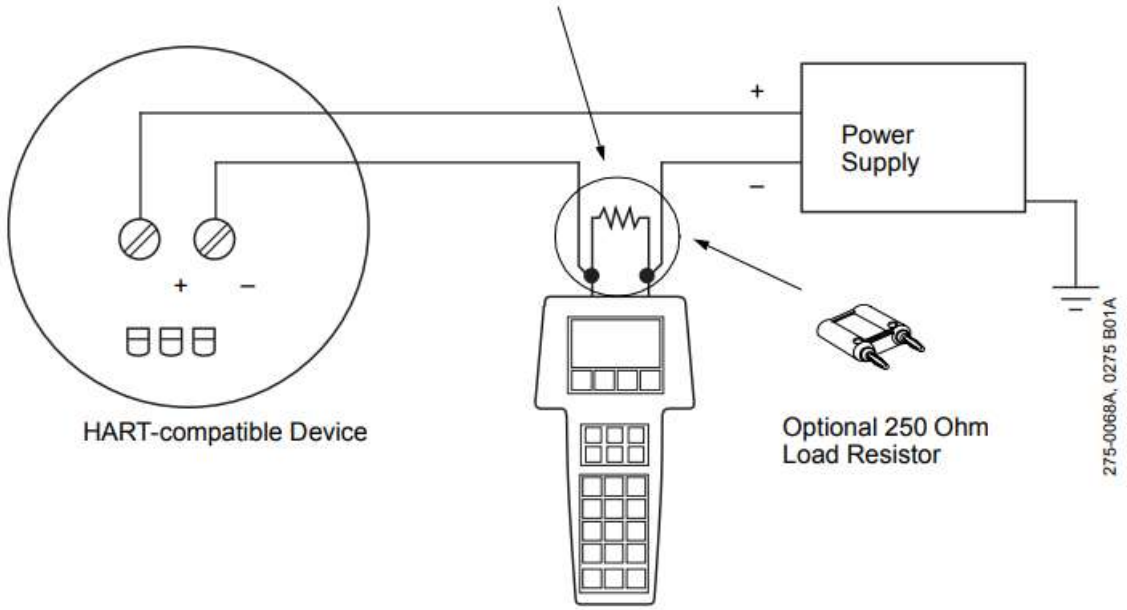


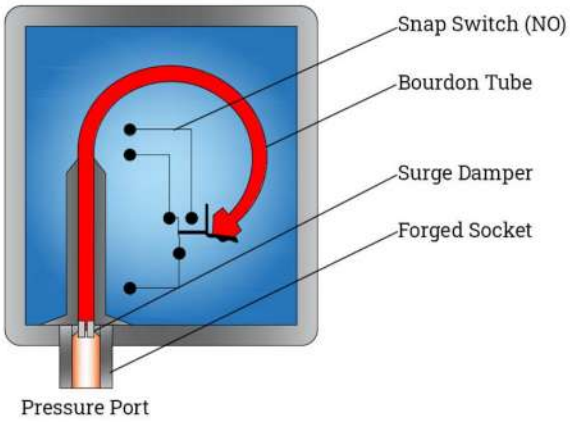
FIGURE 1-5. Connecting the HART Communicator with the Load Resistor.

Pressure Switch

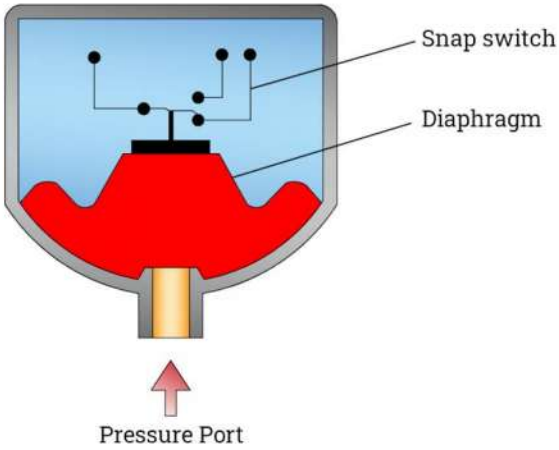
➢ Mechanical Pressure Switch:

- Measure or maintain Pressure , Level of liquid or gas.
- It has spring to return switch.
- Can be used in exponential area.
- Micro switch is used.
- High level electrical power process[250 V–20 A].
- Digital Signal.

Bourdon Tube Pressure Switch

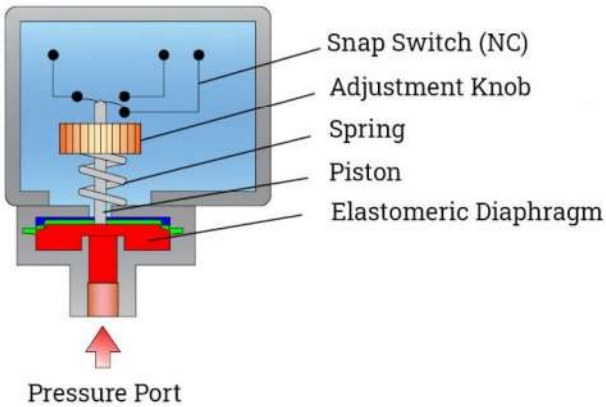


Diaphragm Pressure Switch

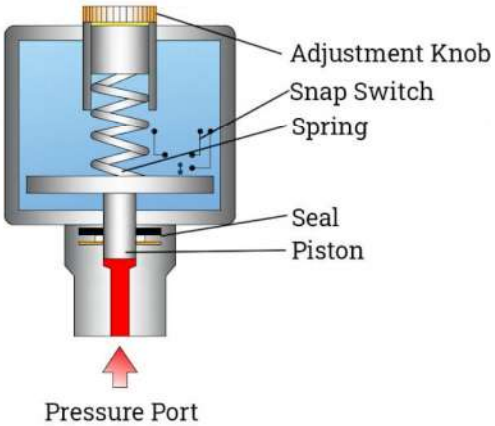


Piston Pressure Switches

With Diaphragm Sealing

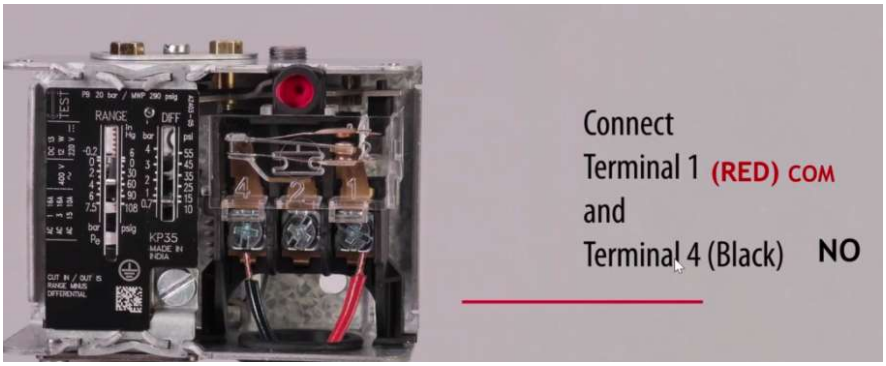


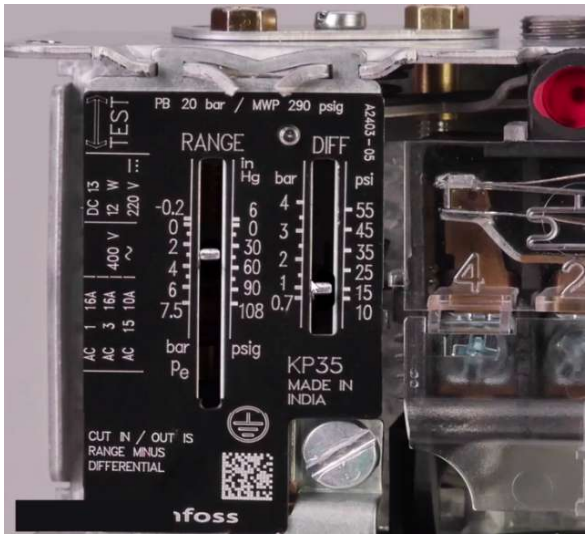
Without Diaphragm Sealing



System start at 3 bar , Stop at 2 bar (Diff=1).

you can rotate the RANGE/DIFF screw to adjust RANGE/DIFF setting.





➢ Contact Pressure Gauge:

- Gauges with switch contacts.
- Can be read on site.
- The switch limits can easily be set.
- Used in indication, Protection &control.

Types :

➢ Electronic Pressure Switch:

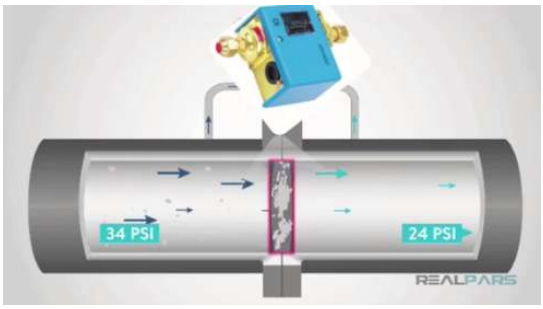
- More accurate & reliable.
- Easy programming of the operation logic.

Consist of :

- ➢ Pressure sensor element.
- ➢ Electronic board.
- ➢ Solid state relay.

➢ Differential Pressure Switch:

- Filter clogged check by applying differential pressure before and after the filter



How to select pressure Switch?

1. For low pressure ⇛ [Diaphragm & Bellow].
   For medium pressure ⇛ [Bourdon & Piston].
2. High service life (operate more than 1 Million) ⇛ [Piston].
   Less than 1 Million ⇛ [Diaphragm & Bourdon].
3. Fast cycling ⇛ [Piston].
4. High accuracy ⇛ [Diaphragm & Bourdon].
5. Adjustable range . [the set point should be in middle of 30% : 65%].
6. Types of switch action :
   - Standard pressure
   - Differential pressure
   - Dual switch sense
7. Fluid media.
8. Proof pressure (is the highest pressure that the switch will stand without permanent deformation), usually defined as 1.5 times max working range.

How to calibrate Pressure Switch?

There are several terms that describe the function of a switch which need to be understood when testing a pressure switch:

Set point: The pressure which the switch will change state.

Normal State: The state of the switch when at barometric pressure or ideal state.

Depends on Pressure switch type.(typically it would be either OPEN or CLOSED).

Reset: The pressure at which the switch resets back to the normal state.

Tolerance: The allowable variation from the set point pressure.

Repeatability: The closeness of agreement between the results of consecutive measurements.

Dead Band: The pressure difference between the change-of-states. (i.e. OPEN to CLOSE or CLOSE to OPEN)

Trip Type: This is the direction to which the change-of state should happen

If the trip type is low, this means the change-of-state happens when the pressure is falling.

If the trip type is high, this means the change-of-state happens when the pressure is rising.

➢ Calibration Procedure :

1. First we connect the pressure gauge and Pressure switch to the hand pump as shown in above figure.
2. Then we need to measure the present status (NO/NC) of electrical output of the switch with the multimeter. Put multimeter in Continuity mode.
3. Note: Here in this example our pressure switch considered is Normally open type. So when you connect the multimeter before calibration we have default Normally Open (NO) signal as output.
4. With our connections complete, we are ready to perform the calibration. We do this by increasing pressure until we detect a change in the switch.
5. Now increase the pressure with the help of hand pump.
6. When we see the switch change state from open to close, we record the result.
7. Next, we decrease the pressure till we see the switch reset (change from close to open) and record the results.
8. Also record the dead band.
9. Lastly, we would repeat this test at least once to determine repeatability. The difference between set point and rest pressures is the dead band.The dead band must be within the range. The deadband & setpoint of pressure switch available on nameplate of pressure switch.
10. For Normally closed Pressure switch calibration also follows the same above mentioned procedure. But the default status of Normally closed type Pressure switch will have N.C. signal as output. When testing with increasing pressure the output state changes from N.C. to N.O and while on decreasing pressure the output state changes from N.O. to N.C. Remaining all steps are same.