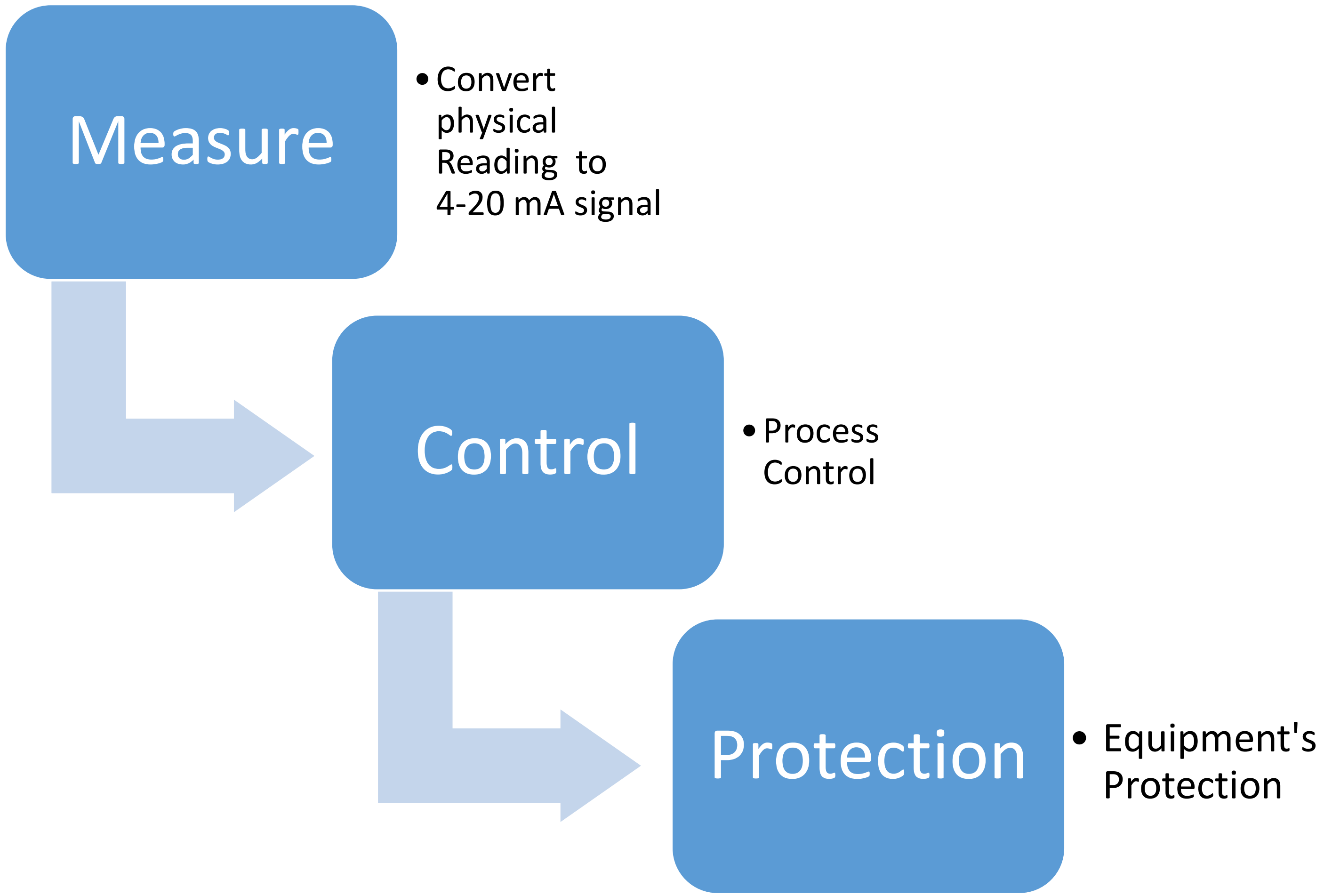
Instrumentation

Training

Mohamed Emad Elshamy

01017155330

Instrumentation Science Depend On:-



Very important Questions to be an Instrumentation Engineer

- Why should We Calibrate?

- What is calibration?

- Risk Involved in Not Calibrating an Instrument !

Why should We Calibrate?

- Testing a new instrument.
- Testing an instrument after it has been repaired or modified.
- Periodic testing of instruments.
- Periodic testing of instruments.
- Testing after the specific usage has elapsed.
- After events such as:

1- An instrument has had a shock, vibration, or exposure to adverse conditions, which can put it out of calibration or damage it.

2-Sudden weather changes.

What is calibration?

1- **a calibration** is a comparison of measuring equipment against a standard instrument of higher accuracy to detect, correlate, adjust, rectify and document the accuracy of the instrument being compared.

2- calibration of an instrument is checked at several points throughout the calibration range of the instrument. The calibration range is defined as “the region between the limits within which a quantity is measured, received or transmitted, expressed by stating the lower and upper range values.” The limits are defined by the zero and span values.

Risk Involved in Not Calibrating an Instrument !

1. Safety procedure: In case of instruments involving perishable products such as food or thermometers with area of sensitive nature, un-calibrated instruments may cause potential safety hazards.
2. If the instrument is improperly calibrated, the chances of faulty or questionable quality of finished goods arises. Calibration helps maintain the quality in production at different stages, which gets compromised if any discrepancy arises.

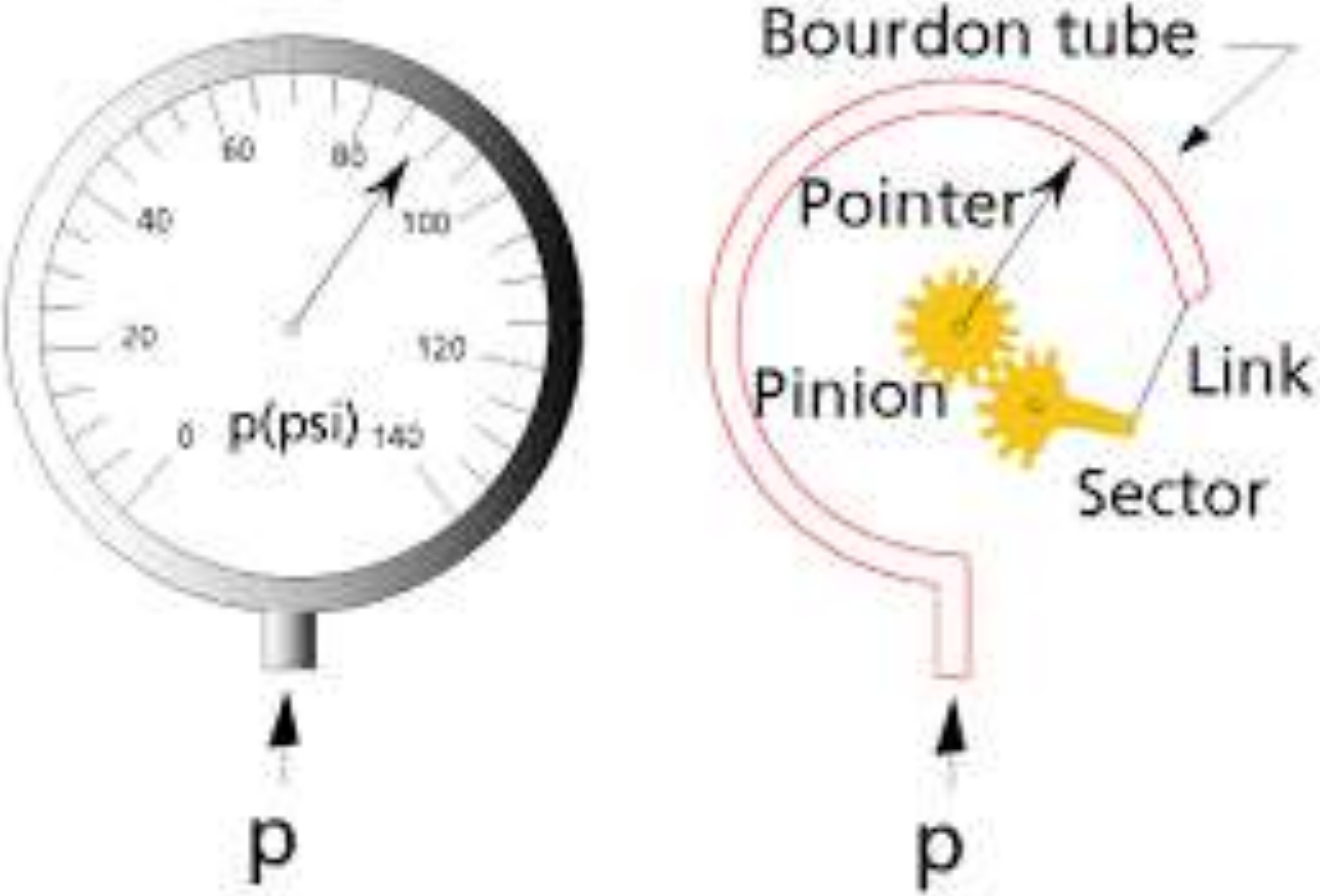
Type Of Field Instruments .

1. Pressure , (Indicators, switch, Transmitters, differential).
2. Level , (Indicators, Switch, transmitters).
3. Flow , (Indicators, Switch, transmitters).
4. Temperature , RTD+TC (Indicator, Switch, transmitters).
5. Valves , MOV,ON/OFF valves,& Manual Valves.
6. PH, Conductivity , PH analyzer & Conductivity transmitter.

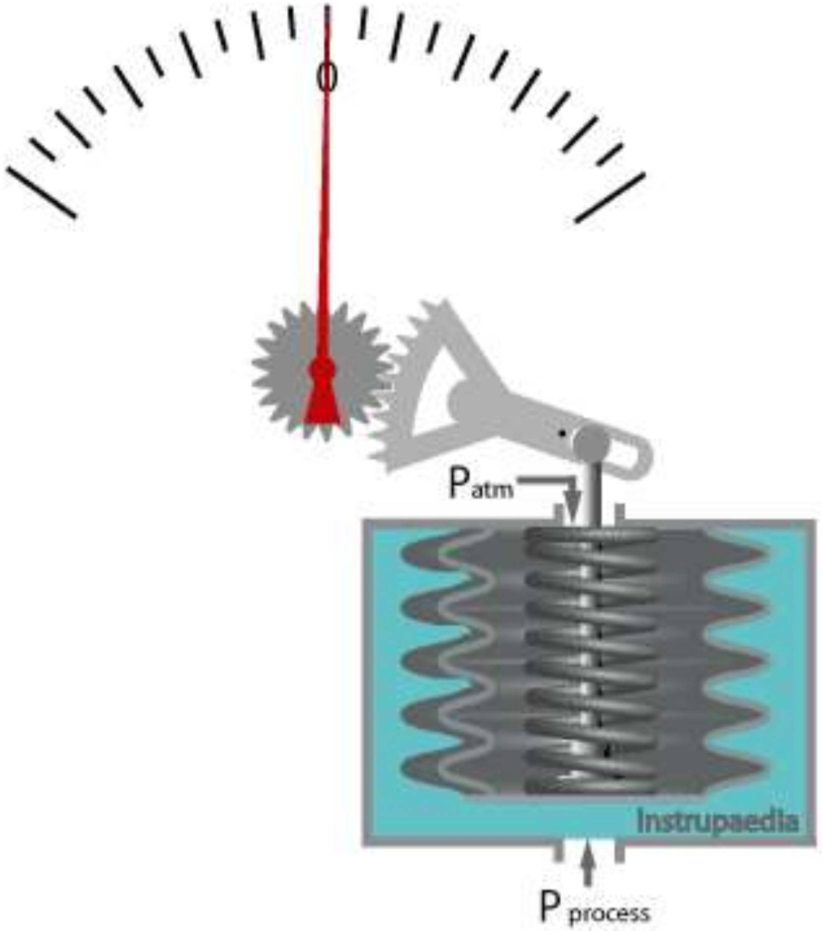
Type Of Pressure detector

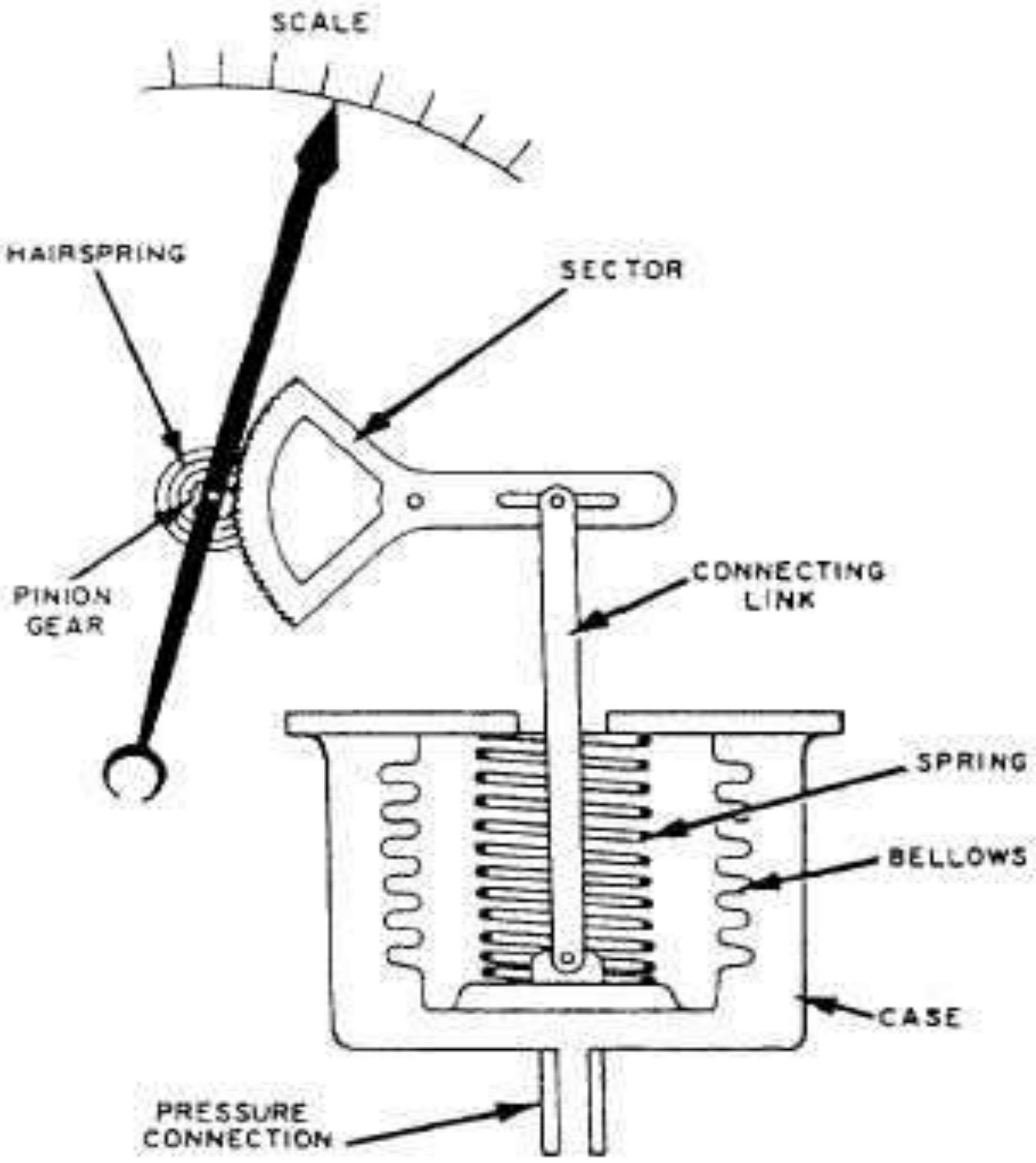
1. Barometer
2. U-Tube Manometer
3. Bourdon Tube.
4. Bellows.
5. Diaphragm.
6. Capsule.
7. DP Capsule.

Bourdon Tube

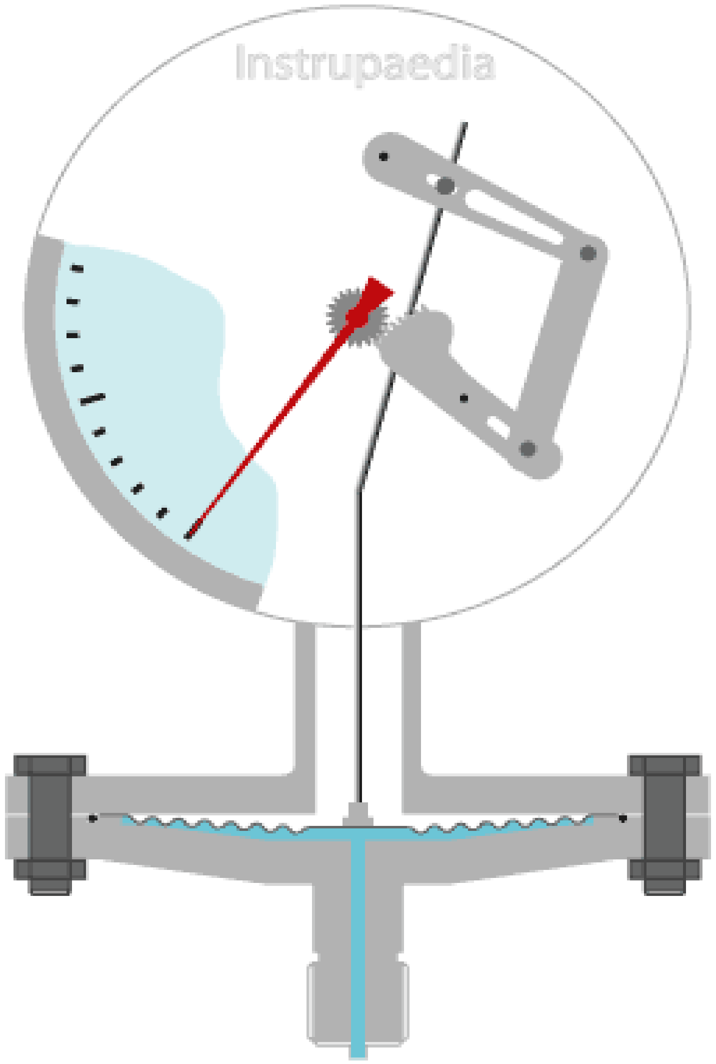

60
80
40
100
20
120
0
p(psi)
140
p
Bourdon tube
Pointer
Link
Pinion
Sector
p

Bellows


0
Patm
Instrupaedia
P process


SCALE
HAIRSPRING
SECTOR
PINION GEAR
CONNECTING LINK
SPRING
BELLOWS
CASE
PRESSURE CONNECTION

Diaphragm



Capsule Gauge

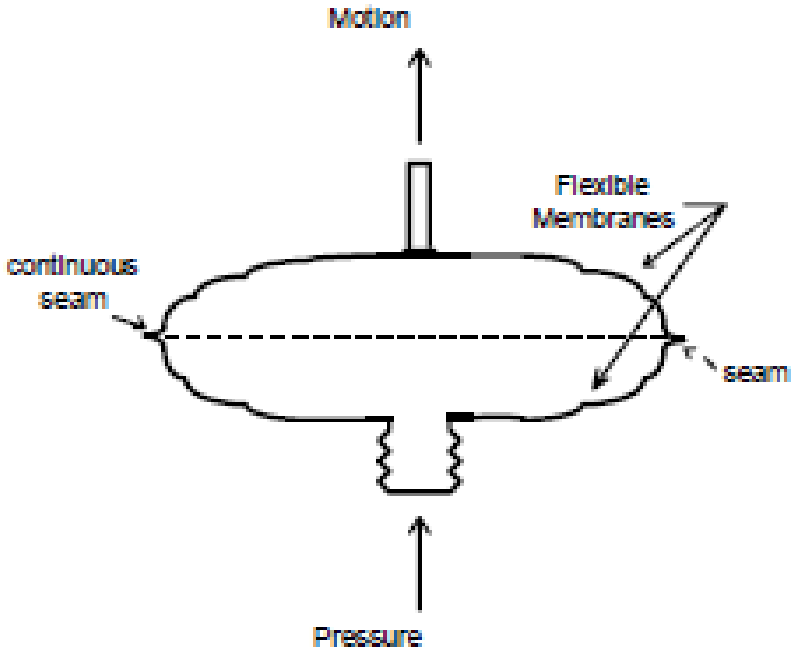
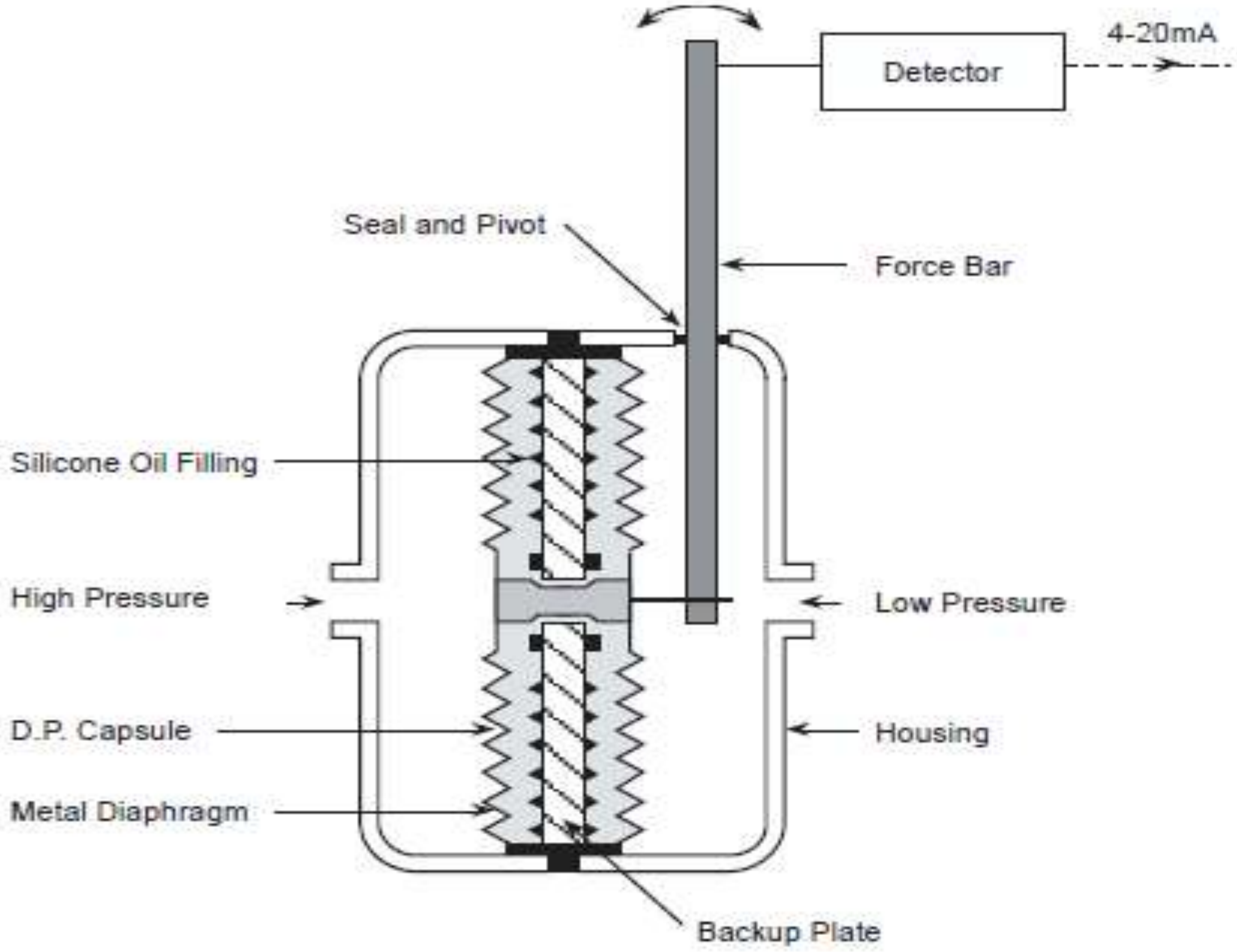
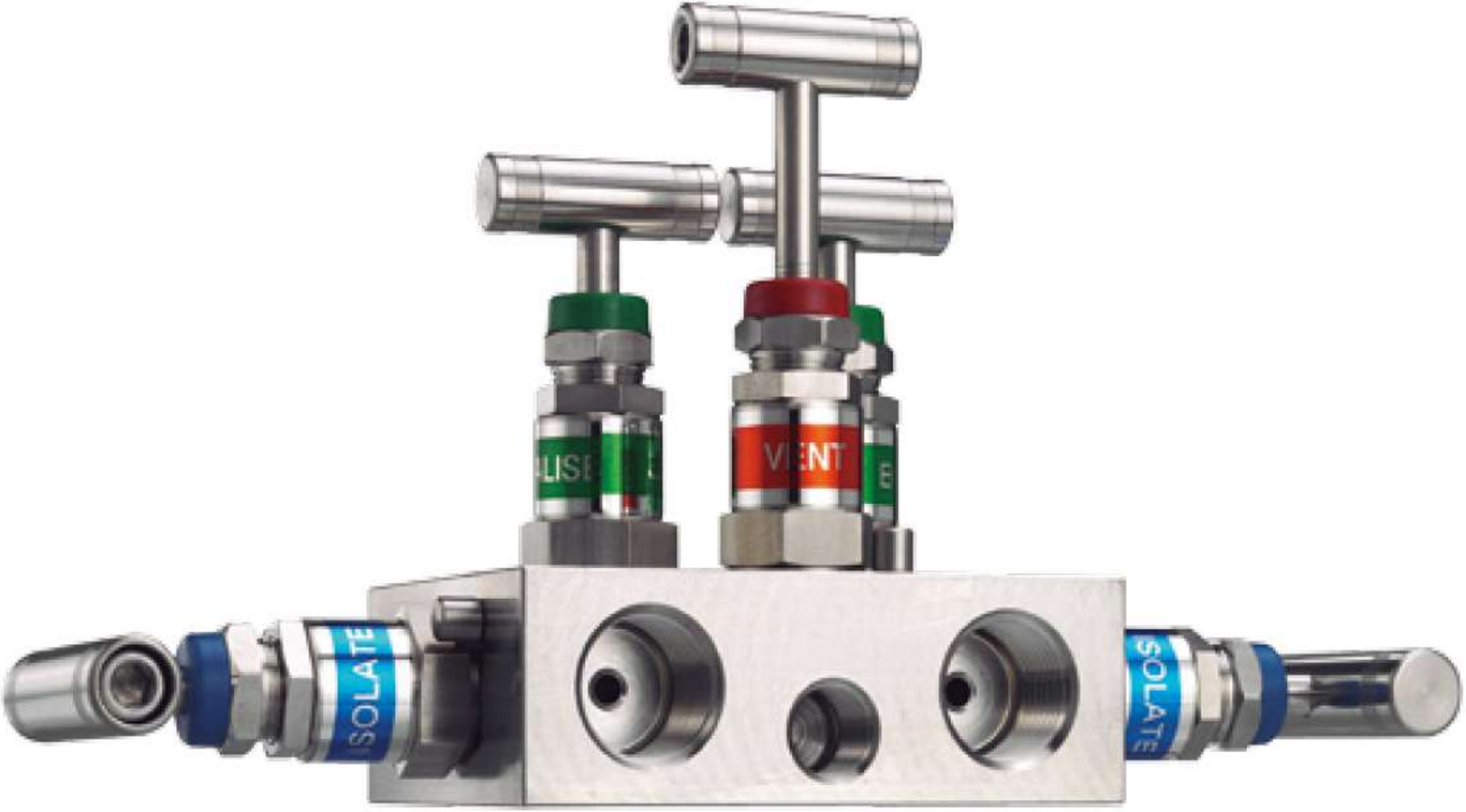


Figure 5
Capsule

Differential Pressure Transmitters (DP capsules)



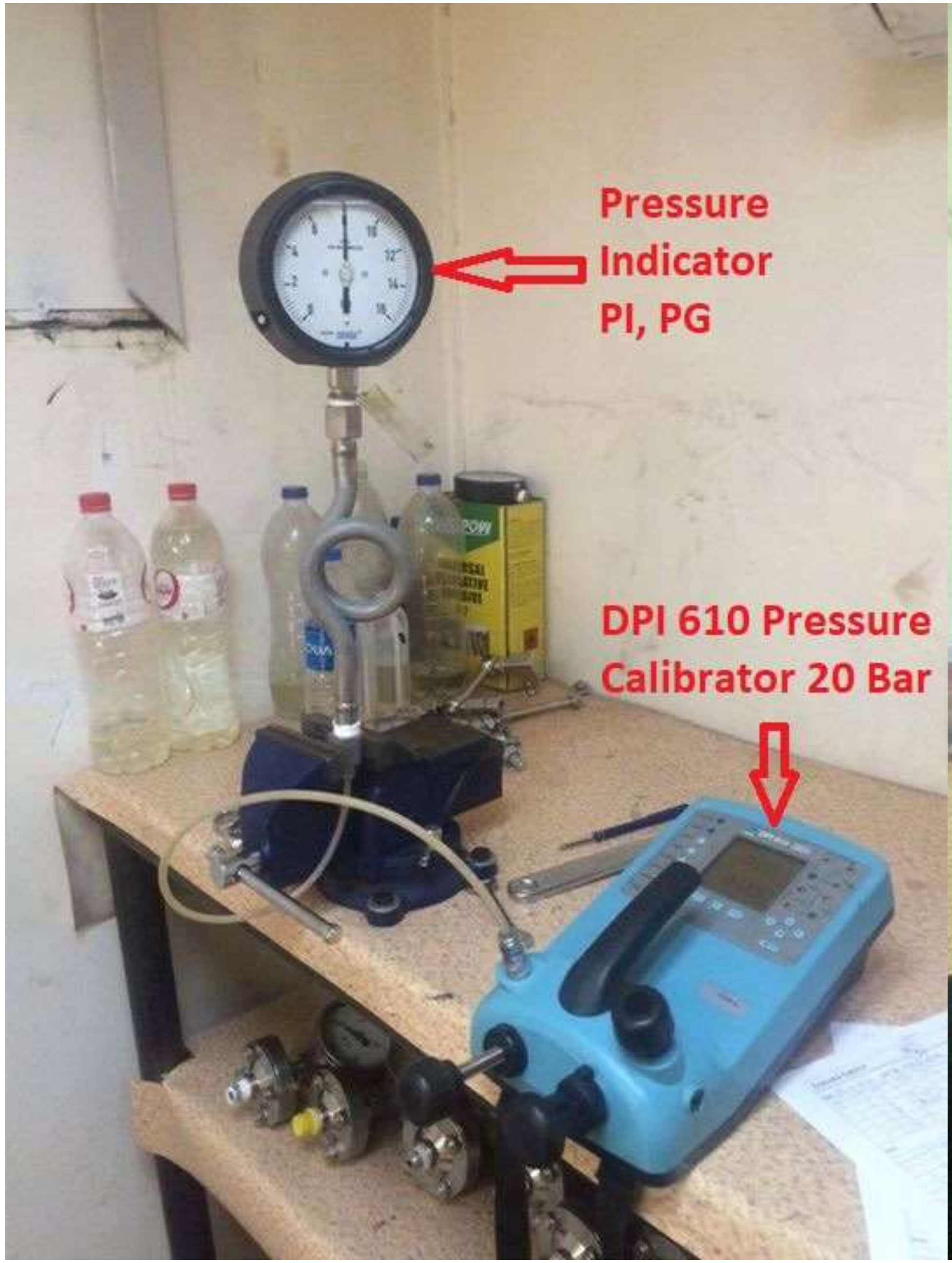
Type Of Valve Manifold

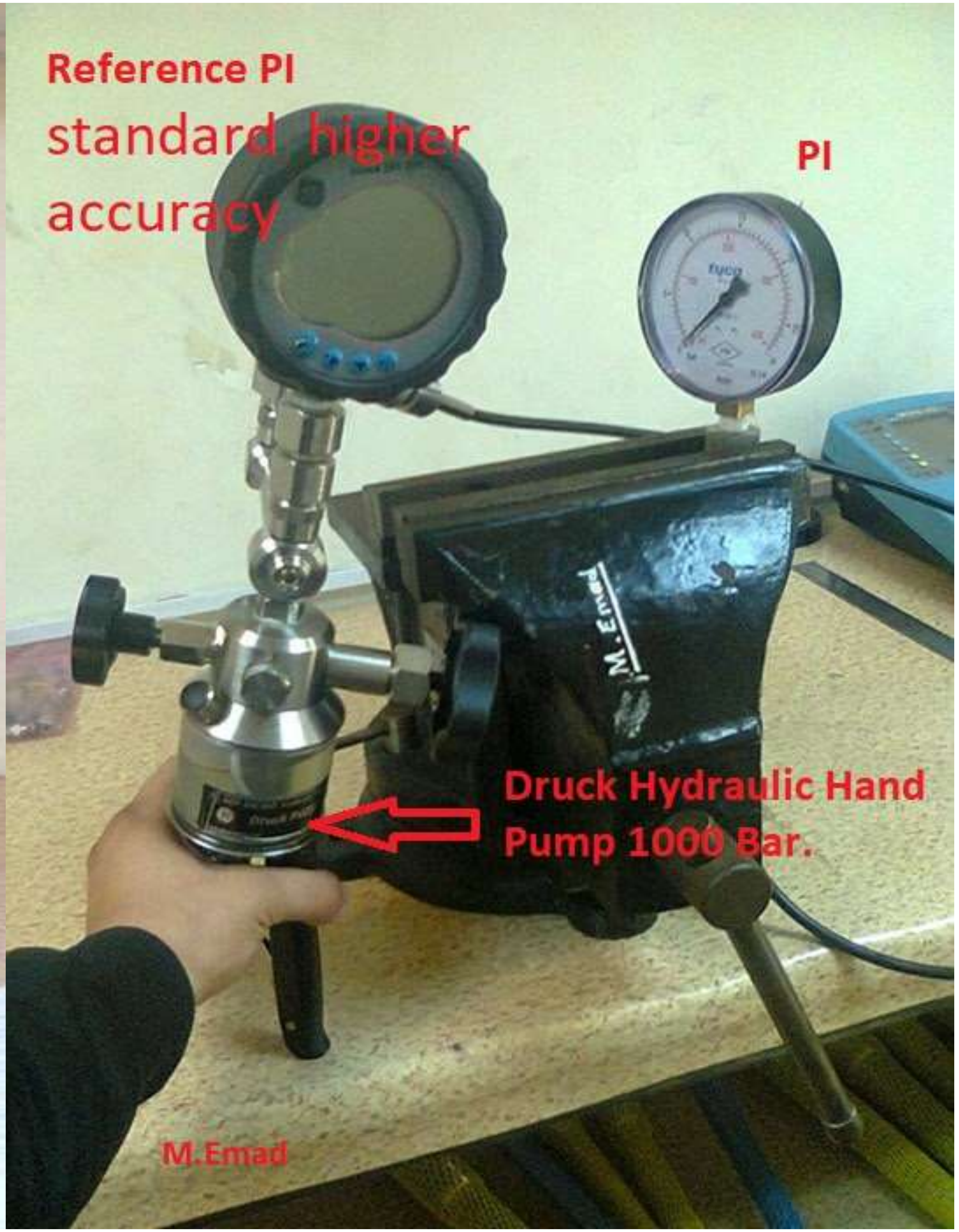

VENT
SOLATE
SOLATE

Pressure

1- Pressure Indicator, Gauge PI. PG

1. Apply pressure from any pressure source or Dead weight tester.
2. Increase the pressure source in steps of 25 % (0 ~ 100%) of gauge full scale.
3. Decrease the pressure source in steps of 25 % (100 ~ 0%) of gauge full scale.
4. All calibration procedure shall be recorded in a certificate.

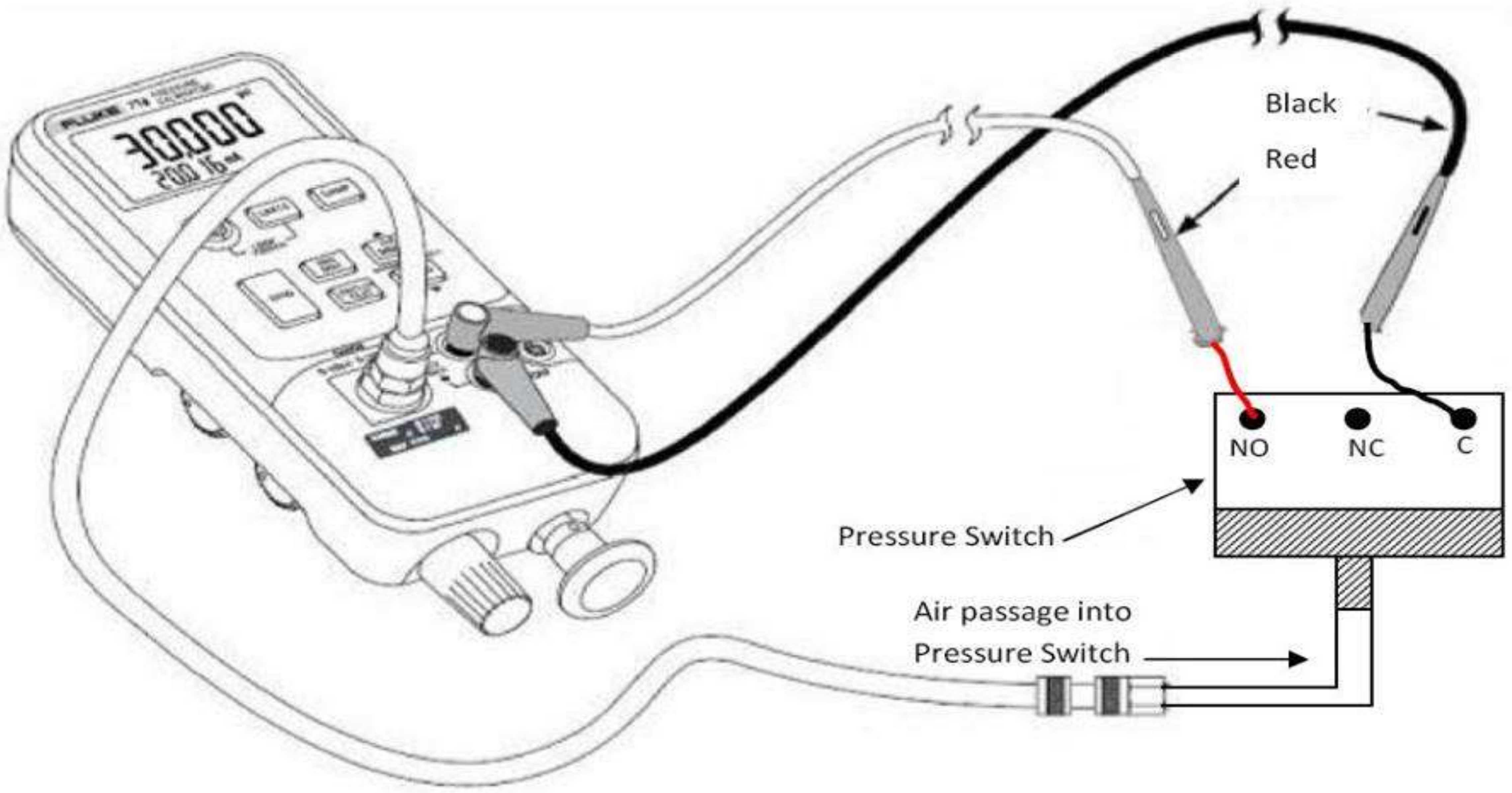

Pressure
Indicator
PI, PG
DPI 610 Pressure
Calibrator 20 Bar


Reference PI
standard higher
accuracy
PI
M.Emad
Druck Hydraulic Hand
Pump 1000 Bar.
M.Emad


DPI 620 Druck Multi-Function Calibrator
Druck Pressure Station
20 Bar , 1000 Bar

2- Pressure Switch , PSH

1. Apply pressure from any pressure source or Dead weight tester.
2. Use digital multi-meter in Ohms mode.
3. Connect digital multi-meter leads to common and Normal close contact NC (NO contact may also use but care should be taken while connecting to the live circuit wiring details should followed).
4. Start increasing the pressure value from the injector until reaching the required actuated set point of the switch; at this point the multi-meter should indicate that the switch NC contact opened.
5. Decreasing the value of the injector with watching the multi-meter value to check the reset point of the switch.
6. In case of mismatch set point trimmer should be adjusted.
7. All calibration procedure shall be recorded in a certificate



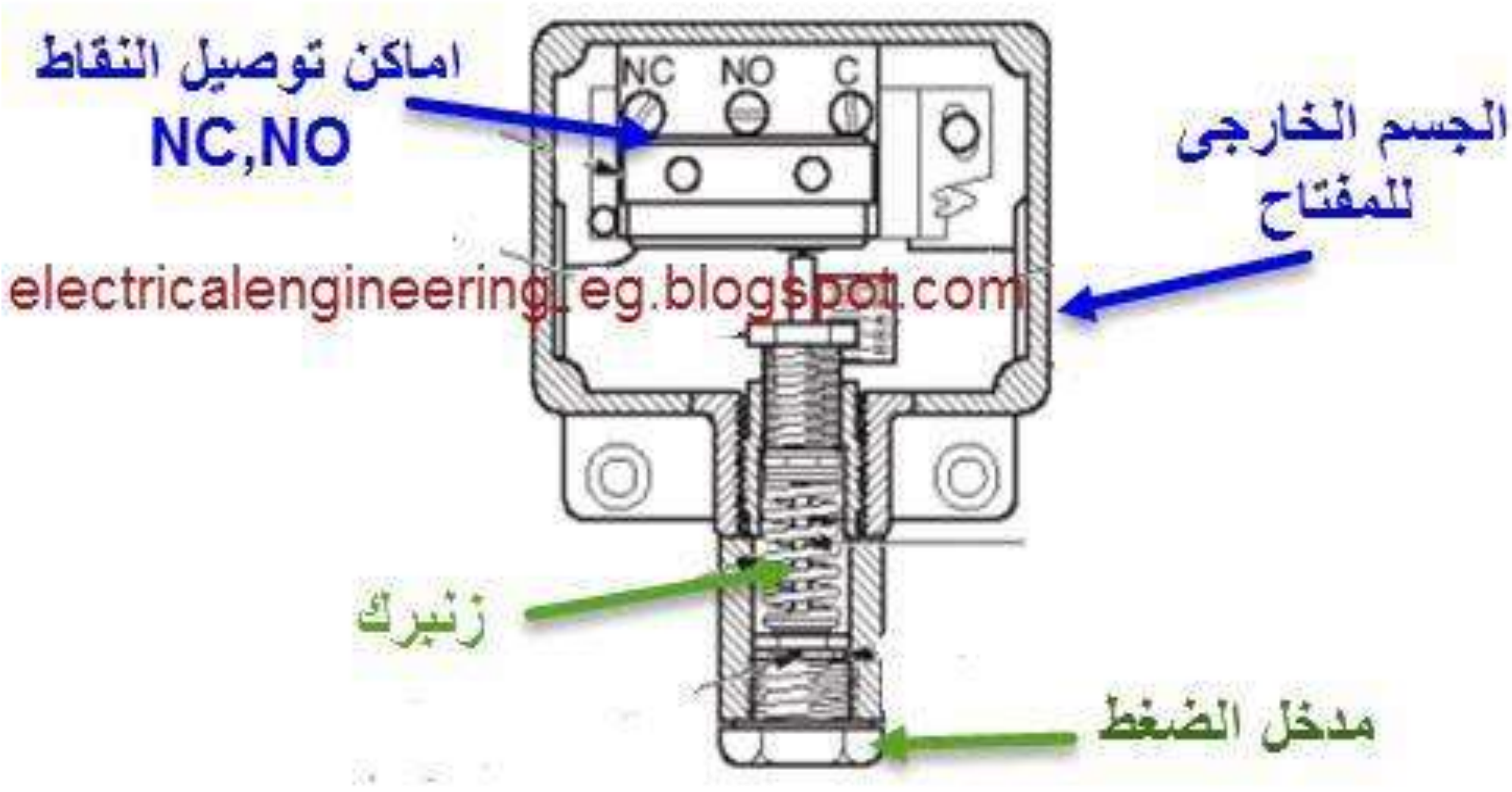
Black
Red
NO
NC
C
Pressure Switch
Air passage into
Pressure Switch


NC NO
ON
E-TT-902-B
P SEAL WATER
TEMPE. (NDE SIDE)


Druck
DPI 610
Pressure Calibrator
max 50V
SET UP
ZERO
INPUT
TASK
OUTPUT
STORE
RECALL
I/O
TASK: P-SWITCH 24V OFF
SNAPSHOT MODE
CONTACT STATE
OPENED AT 0.503 bar
CLOSED AT 0.486 bar
HYSTERESIS 0.017 bar
0.468 bar
RUN
F1
EXIT
F2
55 mA max
mA Sink
24V out
mA out
Xmtr
10V out
20 bar g

3- Pressure Switch , PSL

1. Apply pressure from any pressure source or Dead weight tester.
2. Use digital multi-meter in Ohms mode.
3. Connect digital multi-meter leads to common and Normal close contact NC (NO contact may also use but care should be taken while connecting to the live circuit wiring details should followed).
4. Start increasing the value of the pressure source above the required set point value.
5. Start decreasing slowly the switch should actuated bellow the set point value; watching the multi-meter to check whether the contact changed or not.
6. Increasing one more time above the set point to check the reset point.
7. All calibration procedure shall be recorded in a certificate.

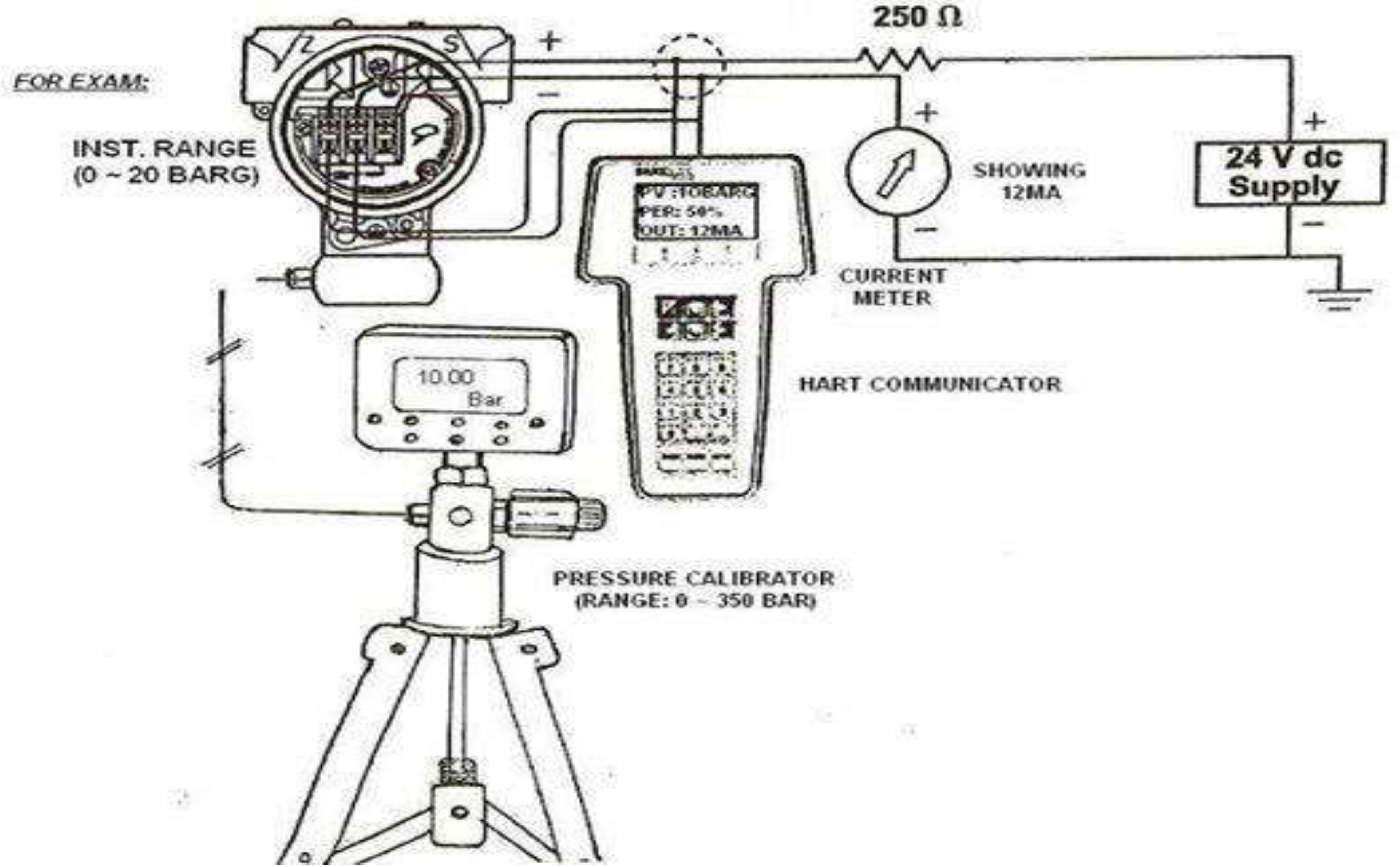


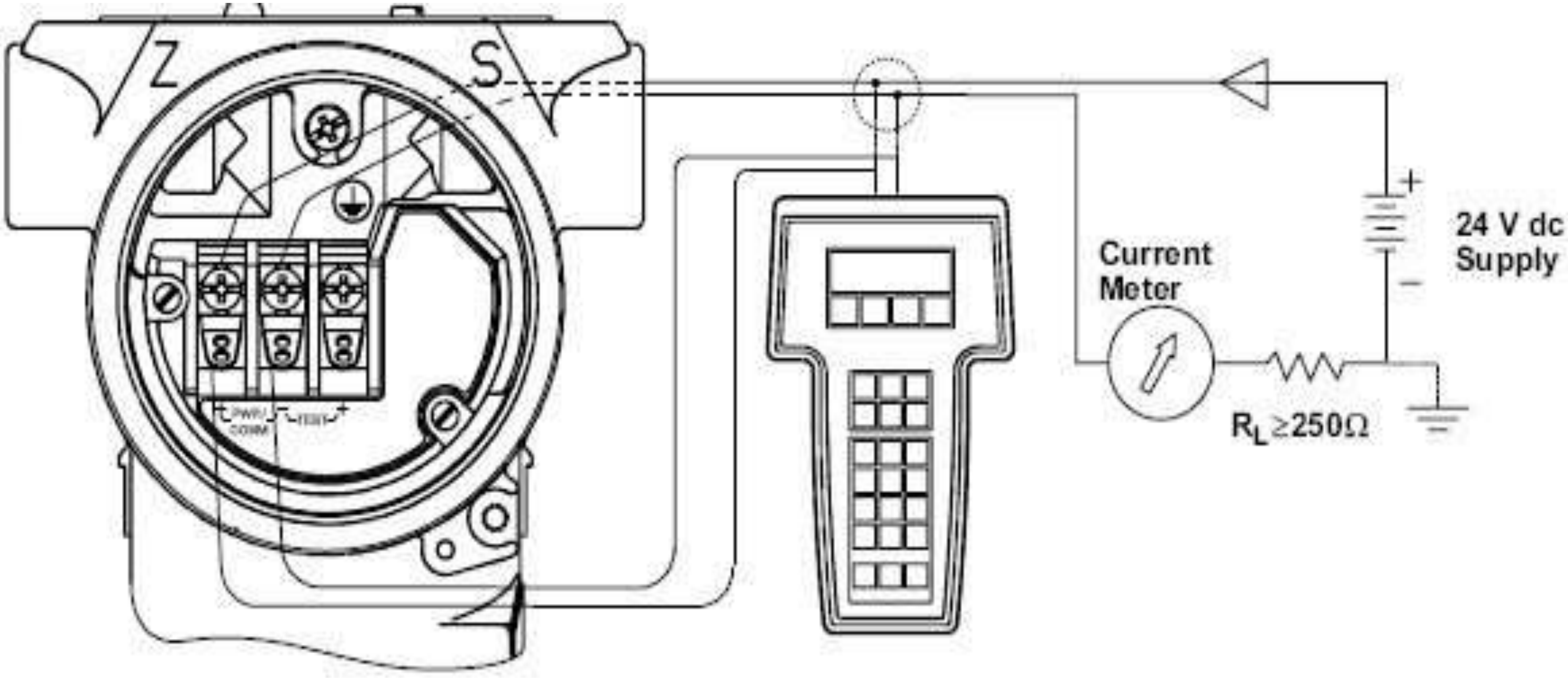
التركيب الداخلى لمفتاح الضغط
pressure switch

4- Pressure Transmitter

1. Connect a pressure source (Druck device), HART communicator, and a digital readout device to the pressure transmitter (Multi-meter).
2. Establish communication between the transmitter and the HART communicator; 250 Ohms resistor may use.
3. Apply pressure from the pressure source device from 0 ~ 100 % of measuring range of the given loop; approved calibration values should be used.
4. Decrease the pressure from 100 ~ 0 % in steps of 25% of the given calibration values.
5. In case of any mismatch of the calibration values then sensor trimming is required.
6. All calibration procedure shall be recorded in a certificate.

PRESSURE TRANSMITTER CAL. BENCH HOOK UP



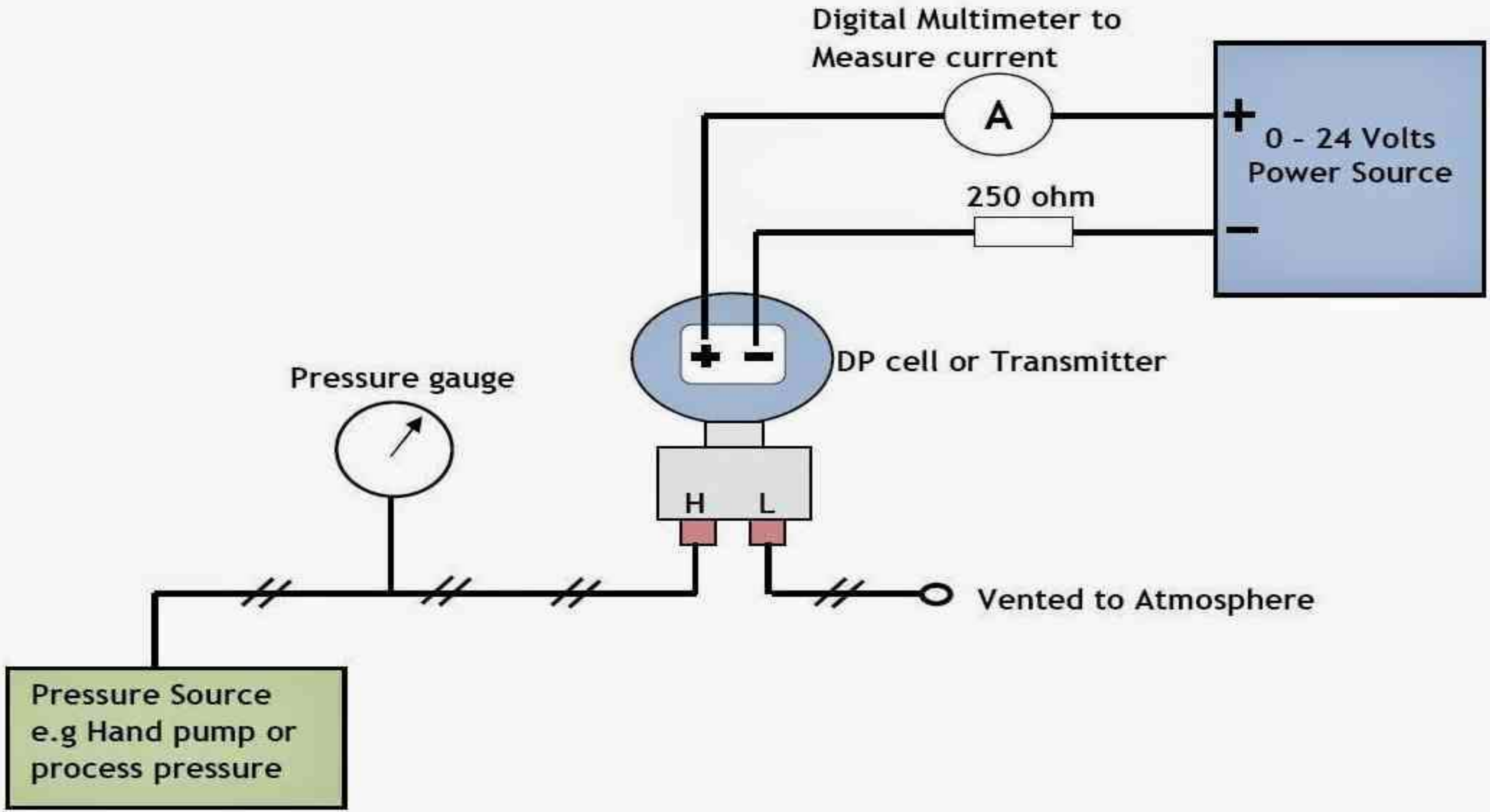


Z
S
Current Meter
24 V dc Supply
R_L ≥250Ω

5- Differential Pressure Transmitter

1. Connect a pressure source (Druck device), HART communicator, and a digital readout device to the pressure transmitter (Multi-meter).
2. Establish communication between the transmitter and the HART communicator; 250 Ohms resistor may use.
3. Apply pressure from the pressure source device to HP side from 0 ~ 100 % of measuring range of the given loop in steps of 25 %; approved calibration values should be used.
4. Decrease the pressure from 100 ~ 0 % in steps of 25% of the given calibration values.
5. While injecting the pressure from source device keep LP side vented.
6. In case of any mismatch of the calibration values then sensor trimming is required; in case of installation the transmitter in lower place so suppression values should be taken to compensate the level difference between the transmitter port and process tapping point.
7. All calibration procedure shall be recorded in a certificate

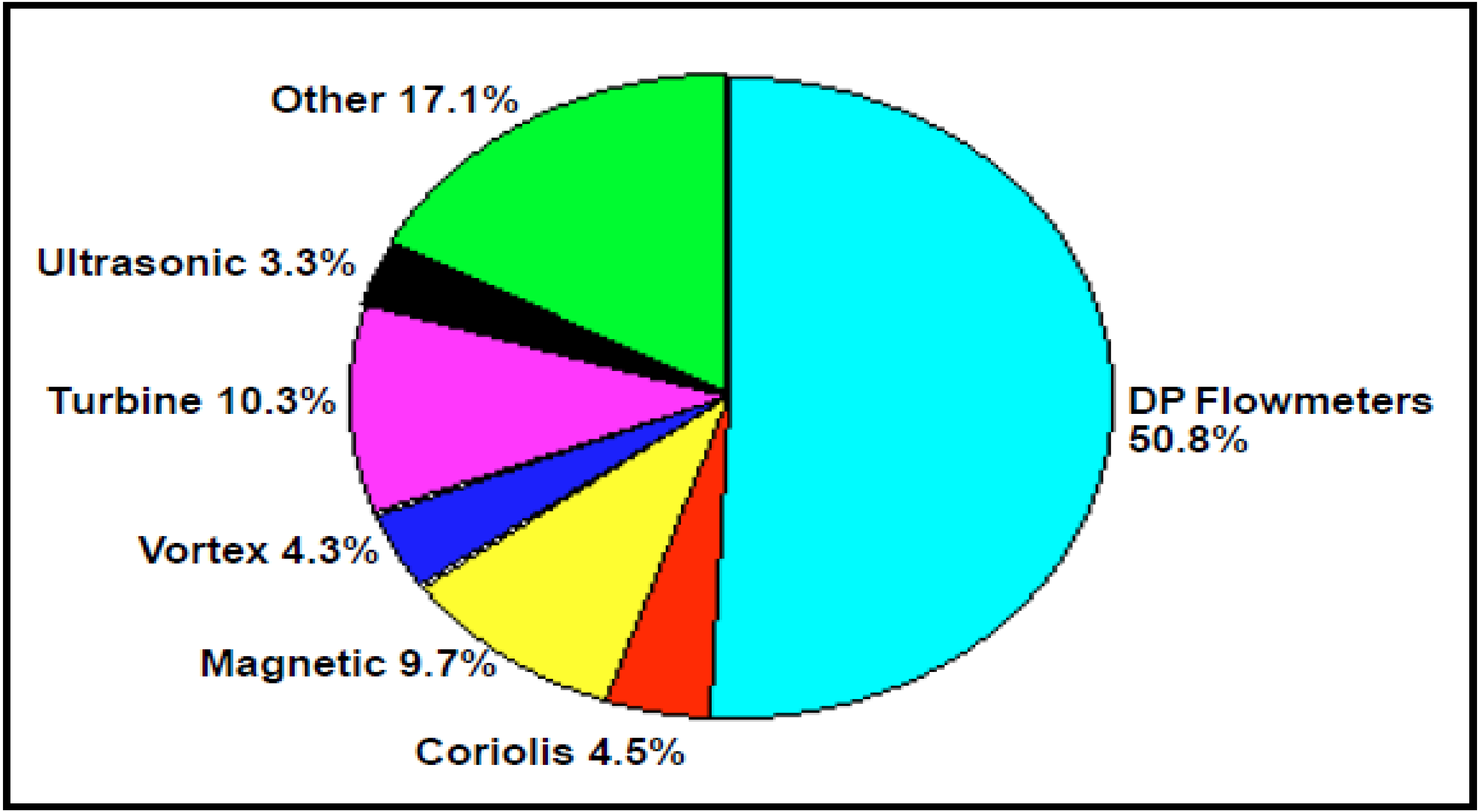

Additel 920 Pneumatic High Pressure
Test Pump 200 BAR
HART COMMUNICATOR 475
Additel 223A
Multifunction, Use as
Power Supply 24VDC
DP Transmitter, PDIT
LP
HP +
+


Digital Multimeter to
Measure current
A
0 - 24 Volts
Power Source
250 ohm
DP cell or Transmitter
Pressure gauge
H
L
Vented to Atmosphere
Pressure Source
e.g Hand pump or
process pressure

Flow Measurements

Flowmeters are grouped into four classes:

1. DP flowmeters
2. Velocity flowmeters
3. Mass flowmeters
4. Positive displacement flowmeters (also called *volumetric flowmeters*)


Other 17.1%
Ultrasonic 3.3%
Turbine 10.3%
Vortex 4.3%
Magnetic 9.7%
Coriolis 4.5%
DP Flowmeters
50.8%

DP Flowmeters

- Most common type of flowmeter.
- Flowmeters in this class measure the differential pressure (DP) caused by an obstruction in the flow stream
- DP flowmeters work because of the equation of continuity and Bernoulli's principle.

$$V1\ A1 = V2\ A2$$

- The flow equation used for DP flowmeters is based on Bernoulli's equation,

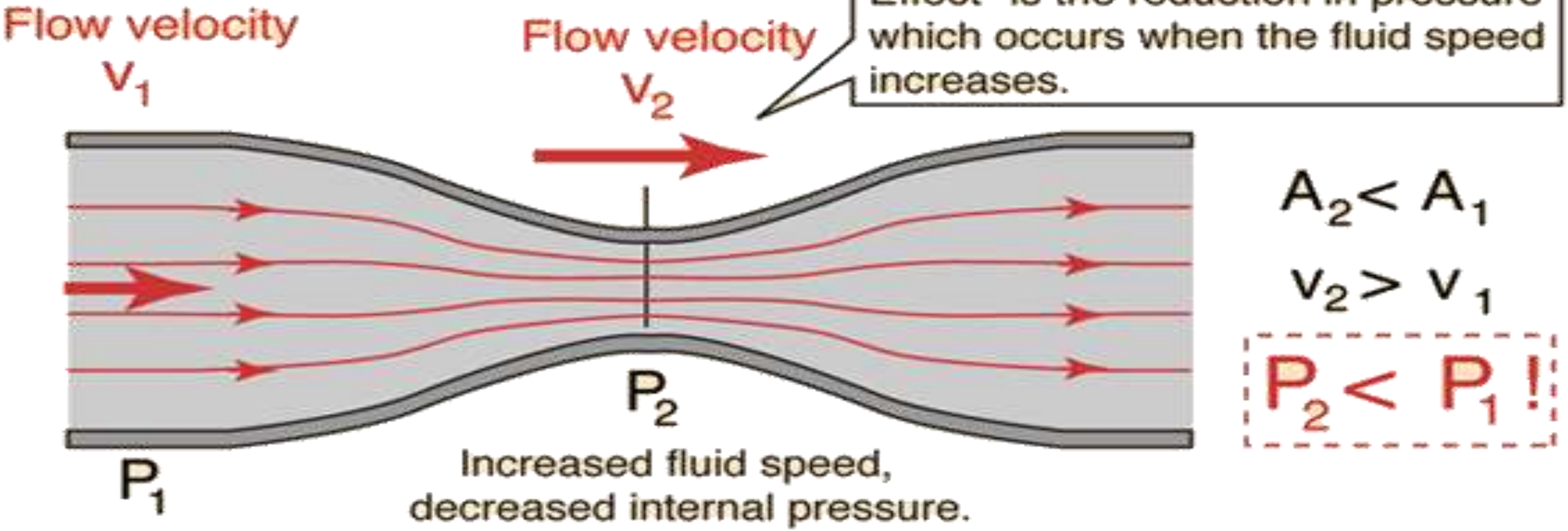
which shows that flow rate (Q) is proportional to the square root of differential pressure

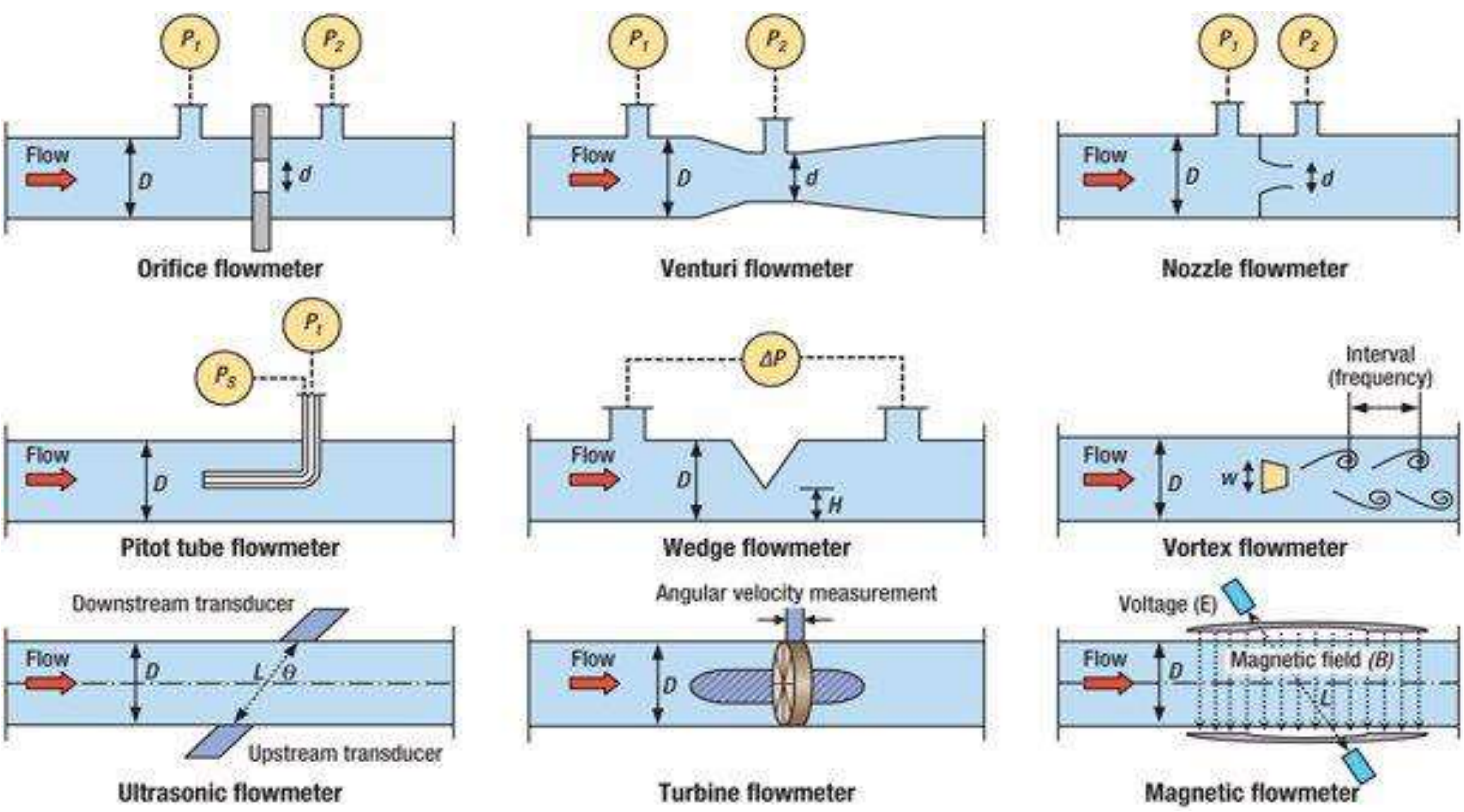
$$Q \alpha \sqrt{\Delta P}$$

Energy per unit volume before = Energy per unit volume after

$$\underbrace{P_1}_{\text{Pressure Energy}} + \underbrace{\tfrac{1}{2}\rho v_1^2}_{\text{Kinetic Energy per unit volume}} + \underbrace{\rho g h_1}_{\text{Potential Energy per unit volume}} = P_2 + \tfrac{1}{2}\rho v_2^2 + \rho g h_2$$

The often cited example of the Bernoulli Equation or "Bernoulli Effect" is the reduction in pressure which occurs when the fluid speed increases.

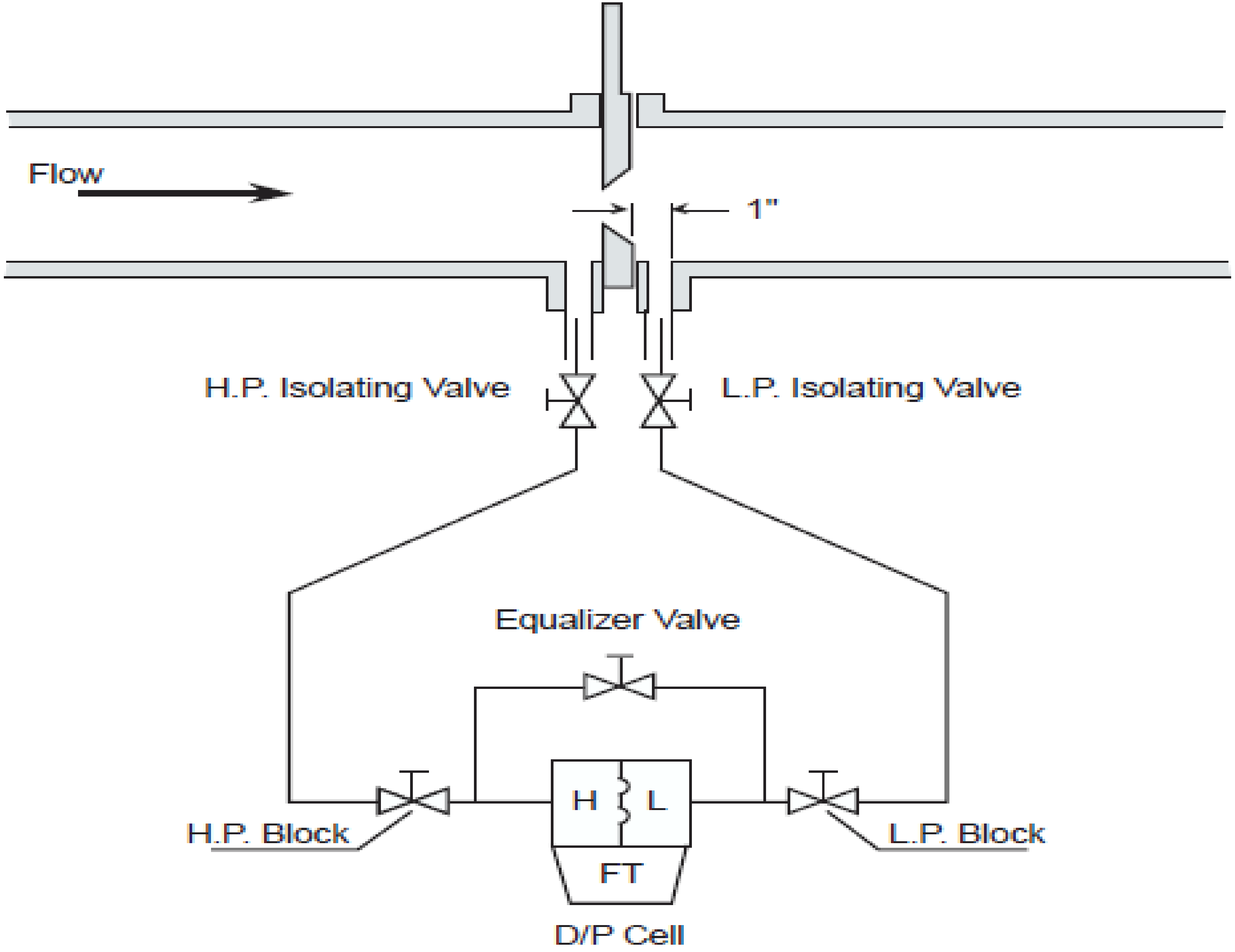




P1
P2
Flow
D
d
Orifice flowmeter
P1
P2
Flow
D
d
Venturi flowmeter
P1
P2
Flow
D
d
Nozzle flowmeter
P1
PS
Flow
D
Pitot tube flowmeter
ΔP
Flow
D
H
Wedge flowmeter
Interval (frequency)
Flow
D
w
Vortex flowmeter
Downstream transducer
Flow
D
L
θ
Upstream transducer
Ultrasonic flowmeter
Angular velocity measurement
Flow
D
Turbine flowmeter
Voltage (E)
Flow
D
Magnetic field (B)
L
Magnetic flowmeter

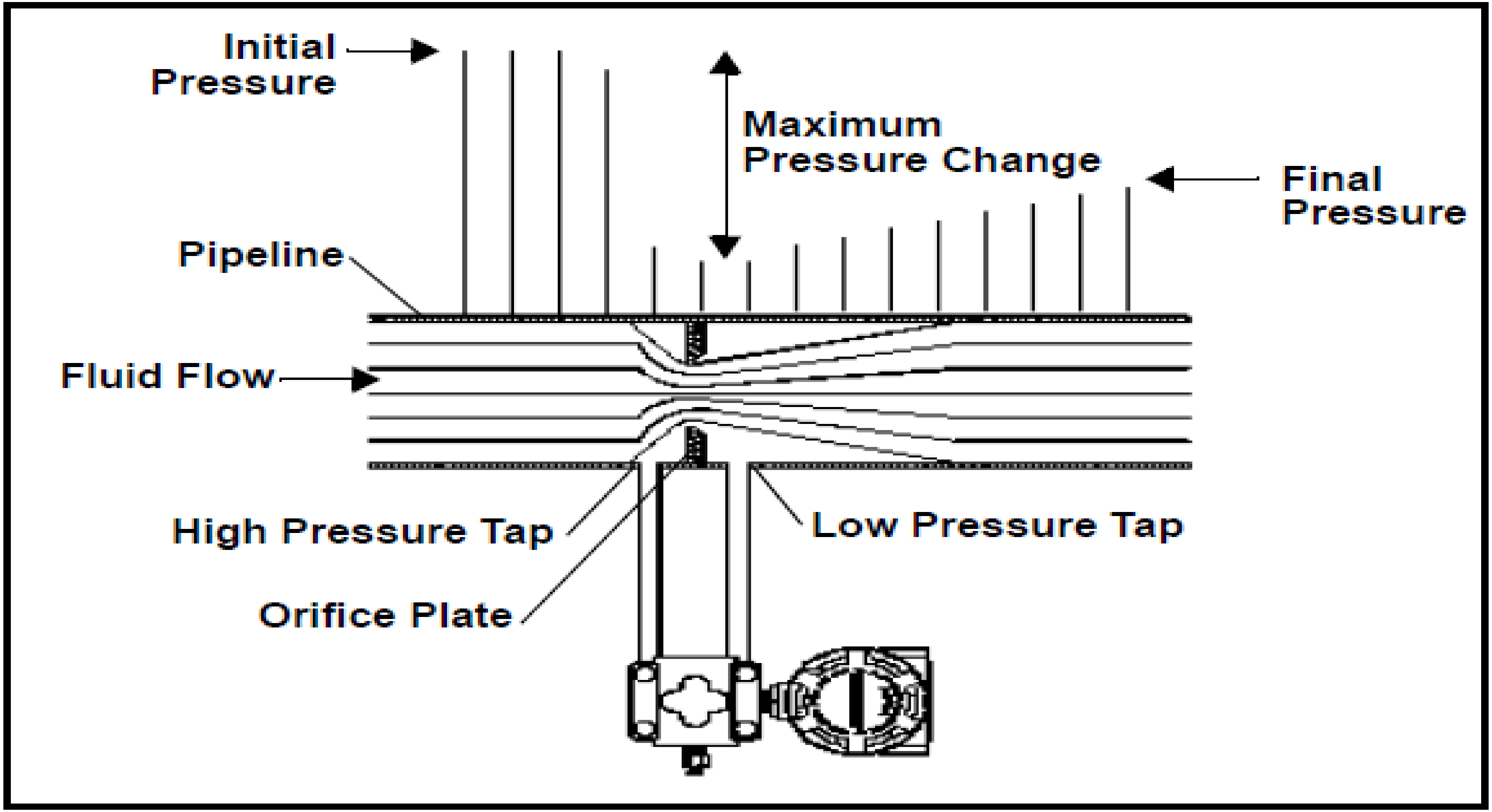
Type of DP flowmeters Detector

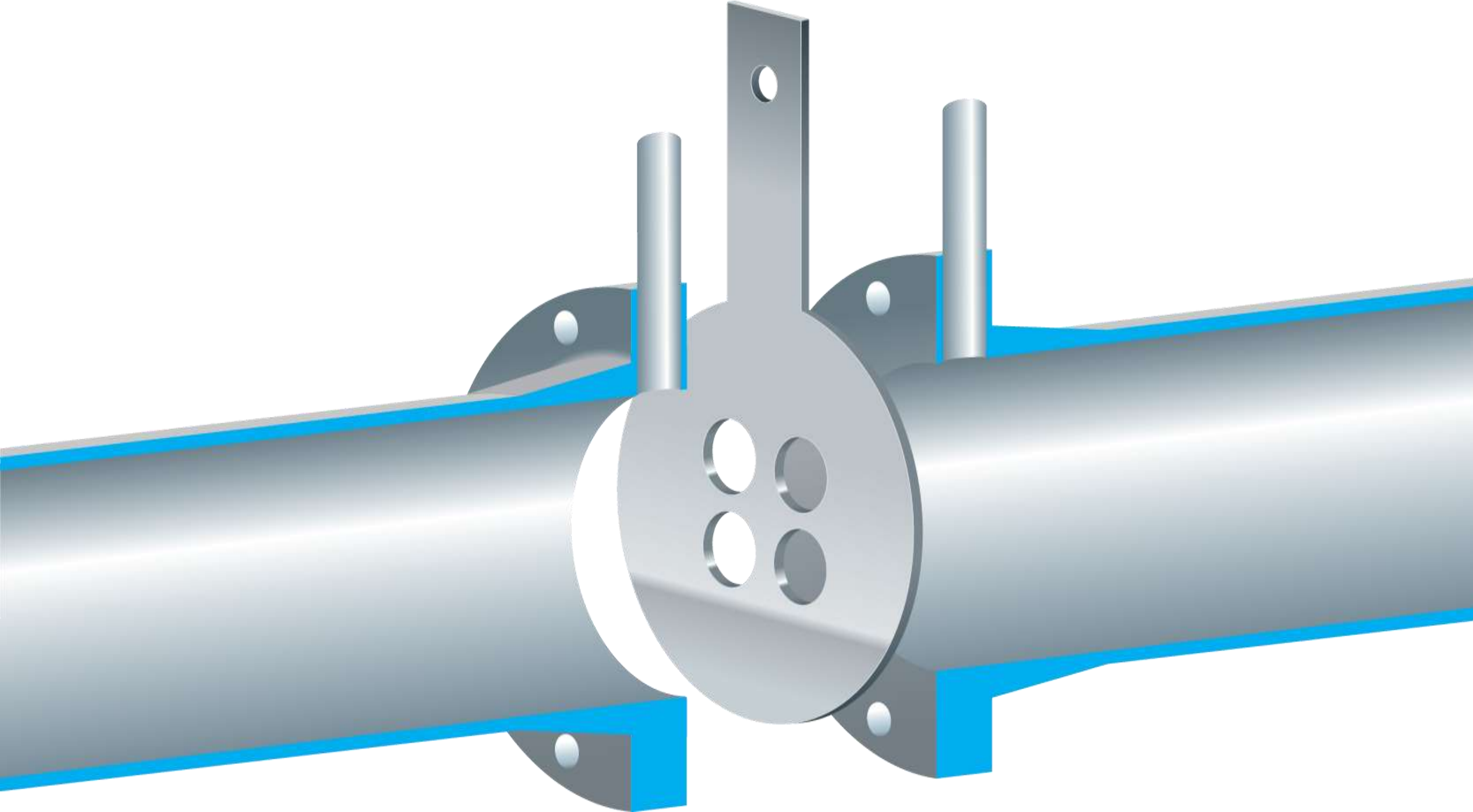
1. Orifice plate
2. Pitot tube
3. Wedge flow element
4. V-cone
5. Venturi tube
6. Flow nozzle
7. Elbow



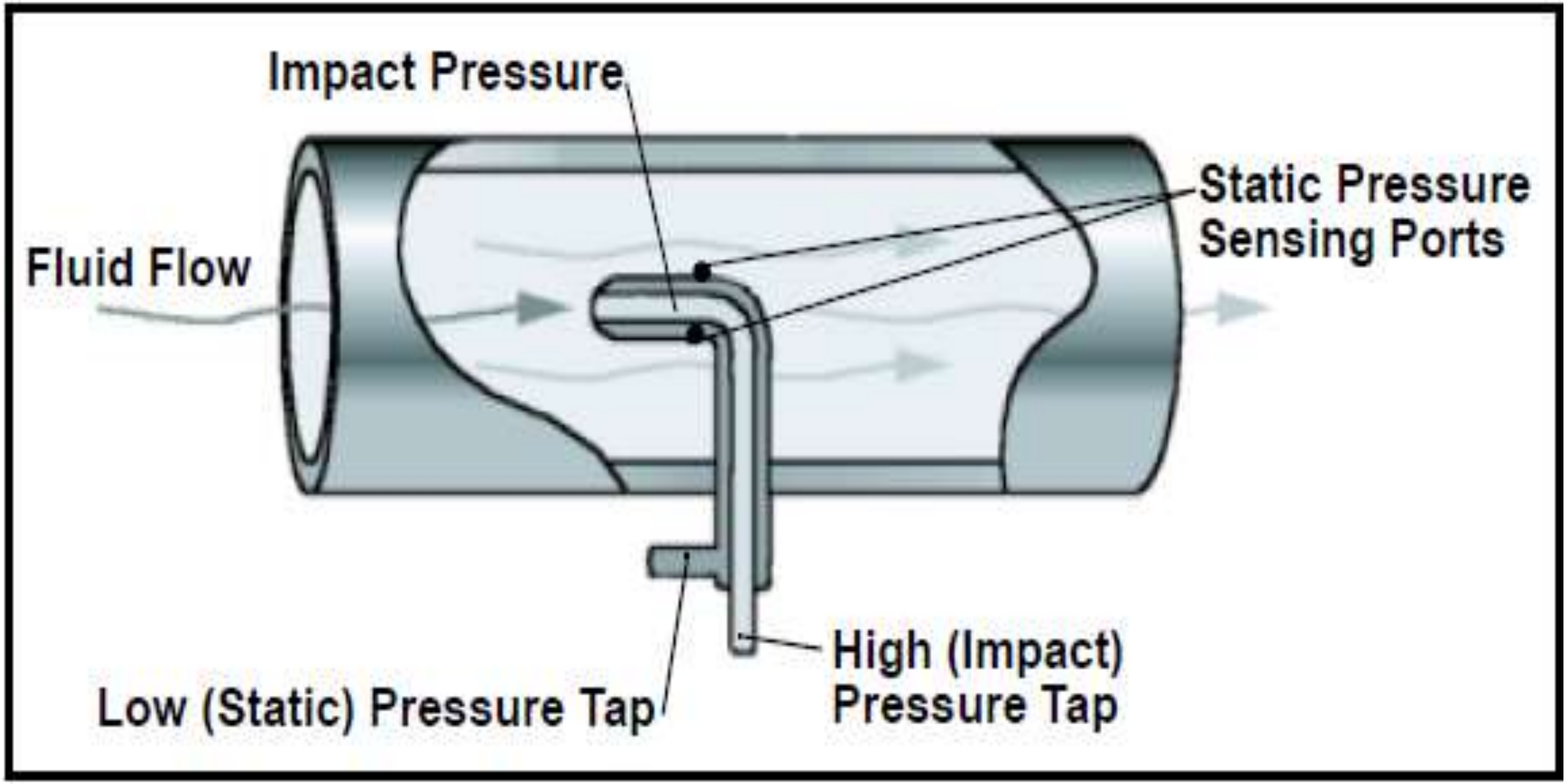
Flow
1"
H.P. Isolating Valve
L.P. Isolating Valve
Equalizer Valve
H
L
H.P. Block
L.P. Block
FT
D/P Cell

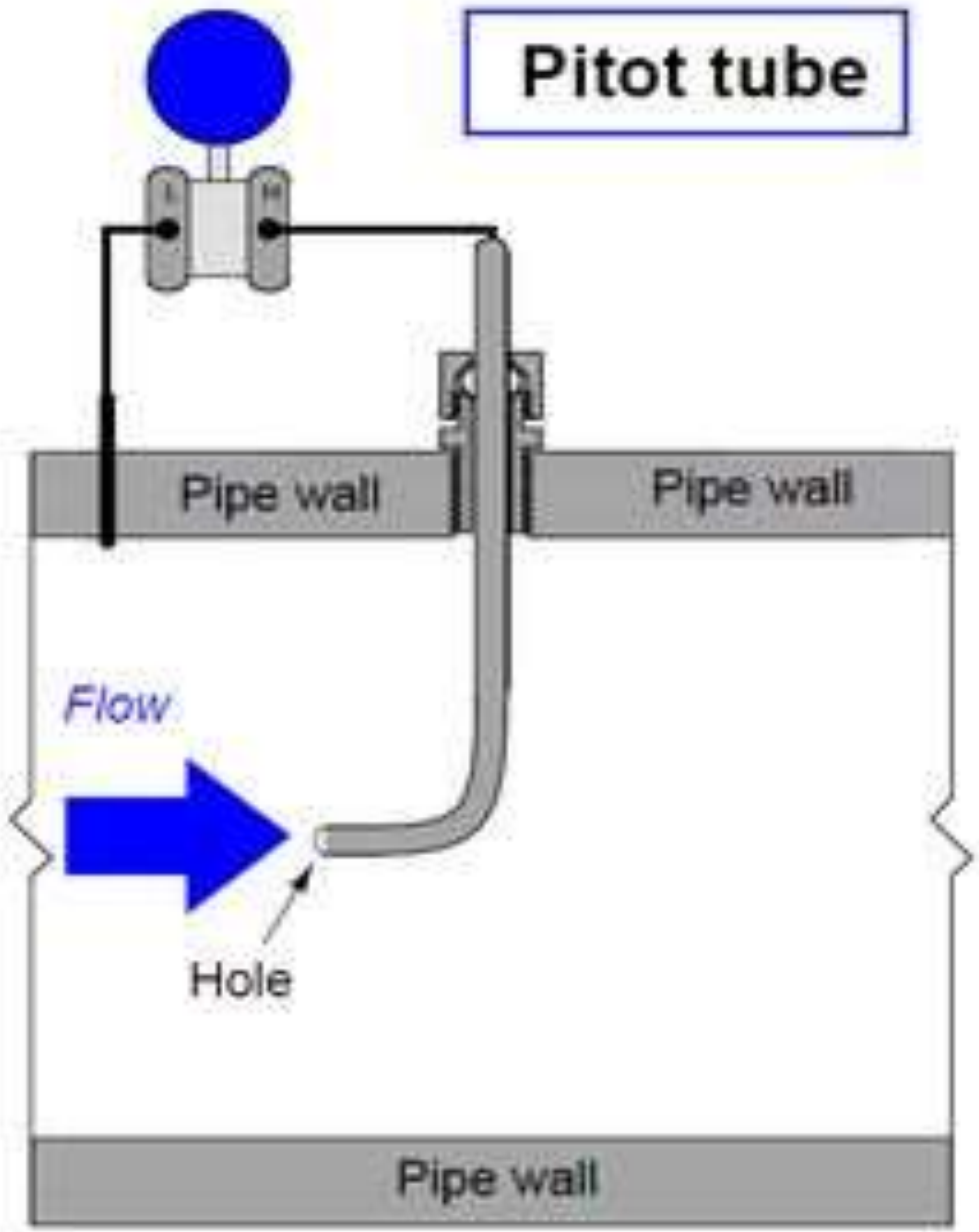
Orifice Plate

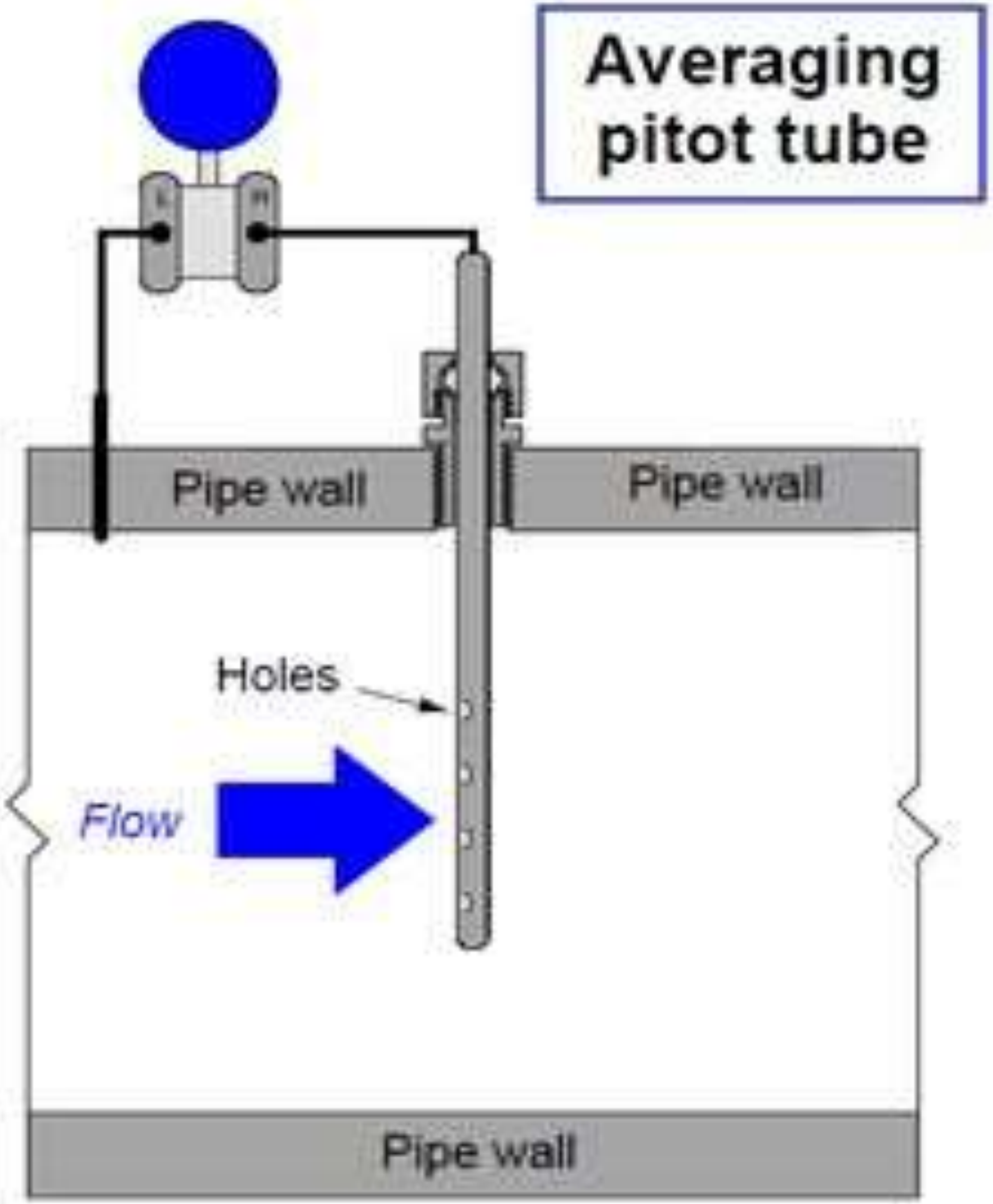




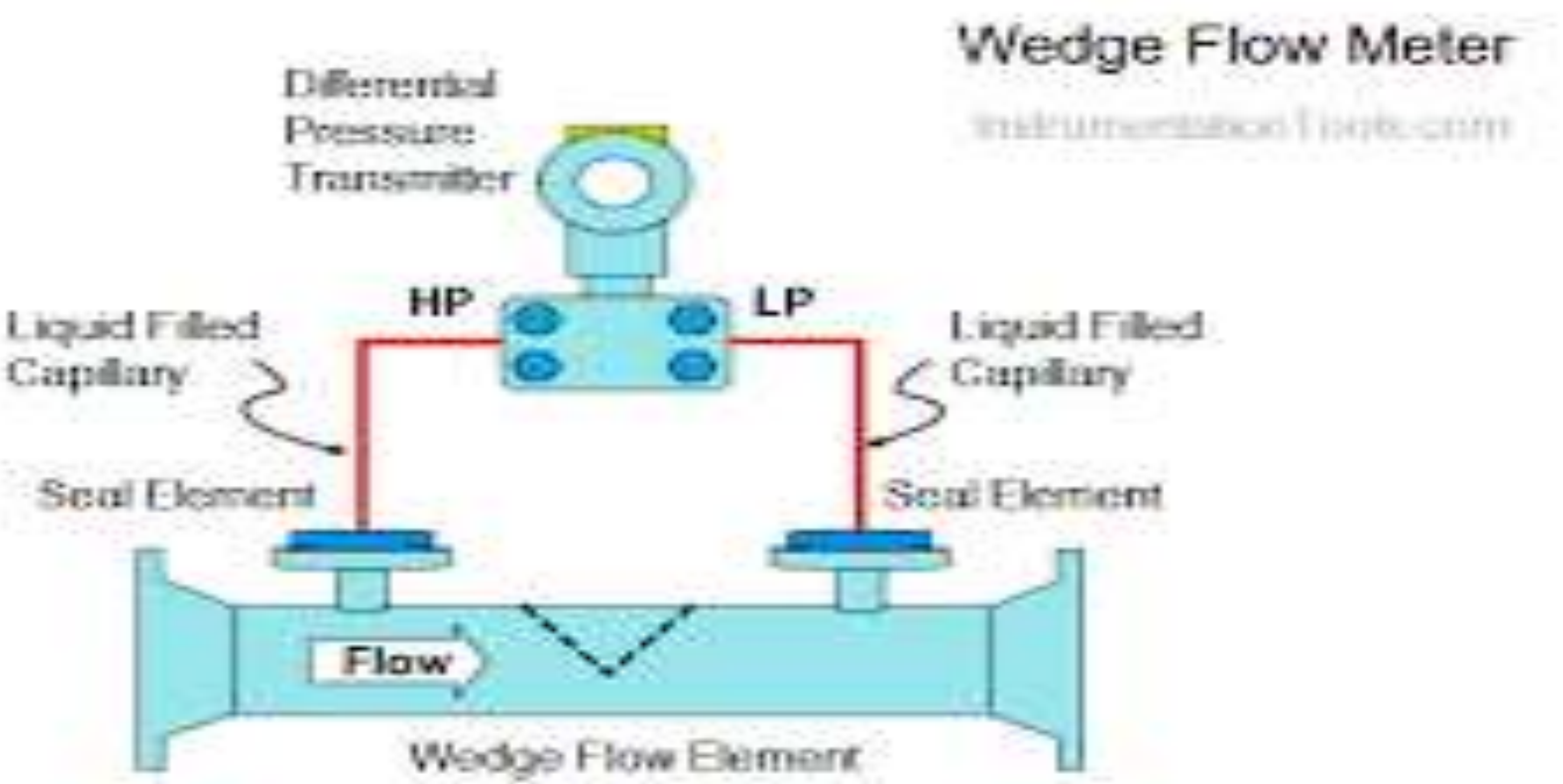
Pitot Tube

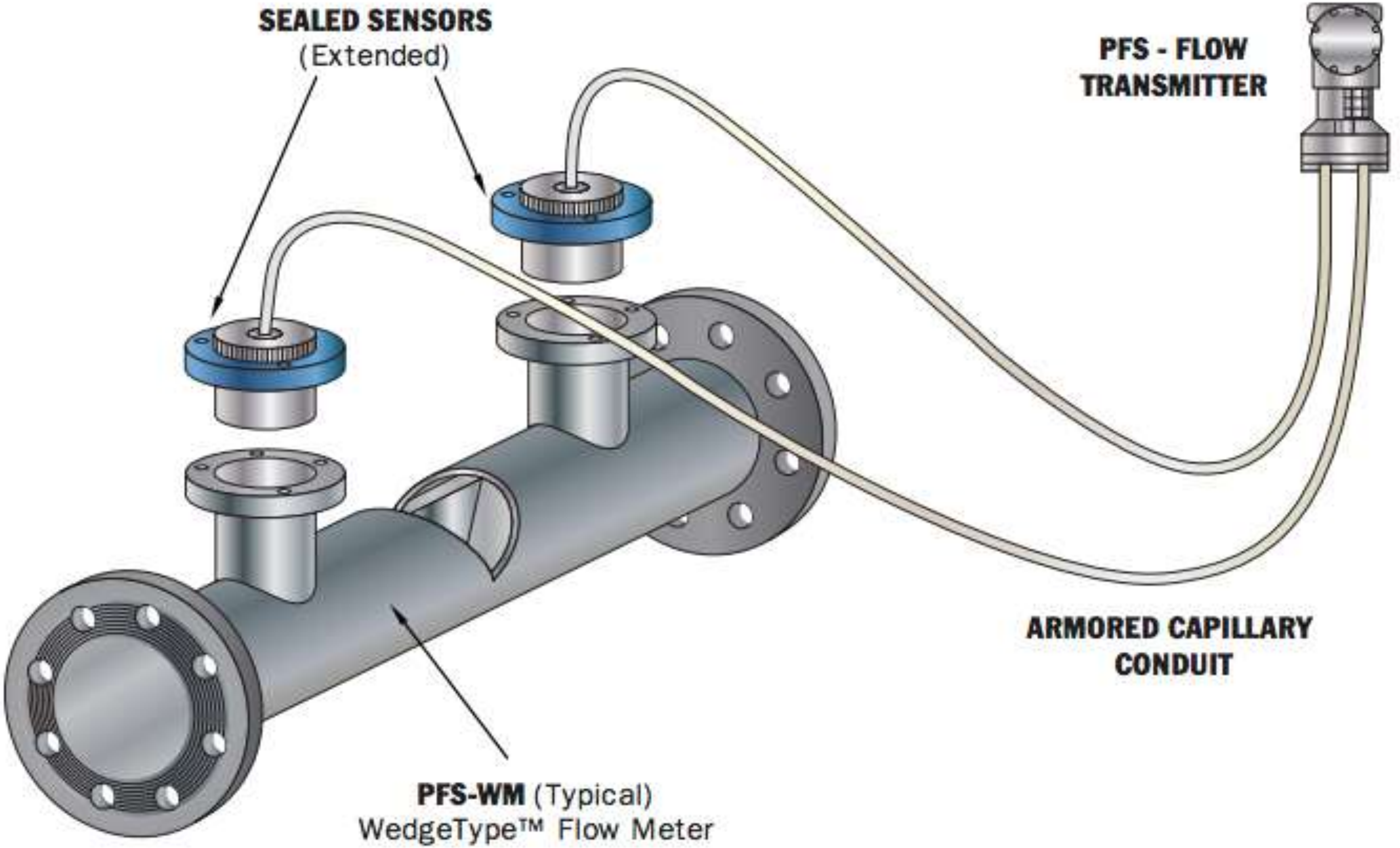

Impact Pressure
Static Pressure
Sensing Ports
Fluid Flow
Low (Static) Pressure Tap
High (Impact)
Pressure Tap


Pitot tube
L
H
Pipe wall
Pipe wall
Flow
Hole
Pipe wall


Averaging pitot tube
L
H
Pipe wall
Pipe wall
Holes
Flow
Pipe wall

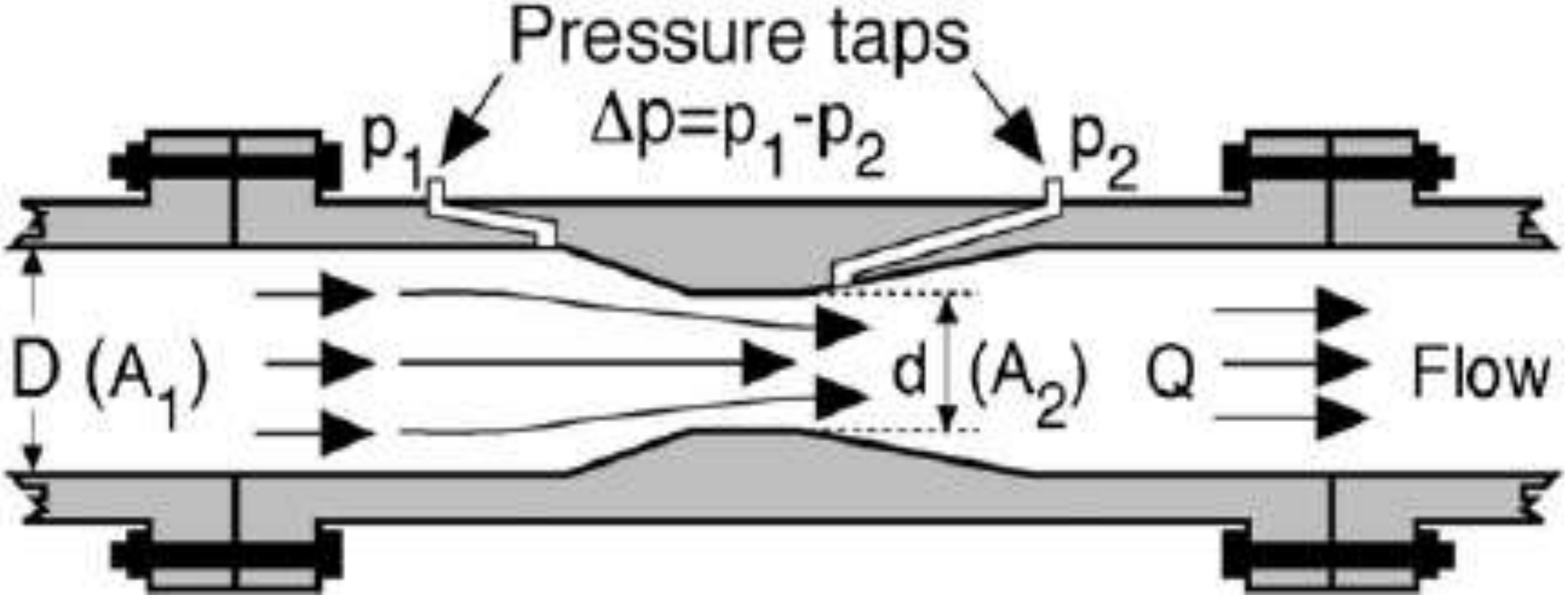
Wedge Flow Element



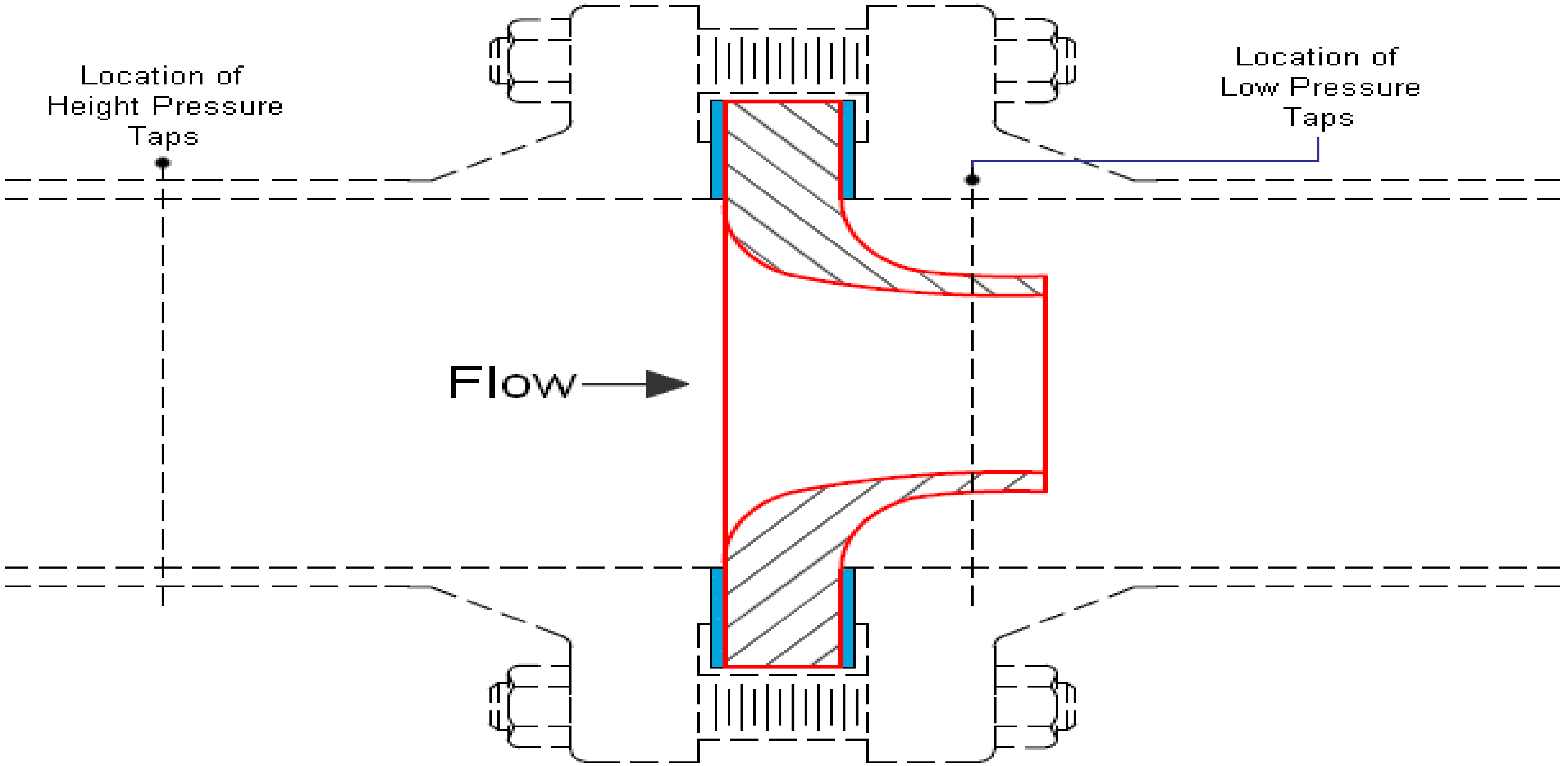

SEALED SENSORS
(Extended)
PFS - FLOW
TRANSMITTER
ARMORED CAPILLARY
CONDUIT
PFS-WM (Typical)
WedgeType™ Flow Meter

V-Cone

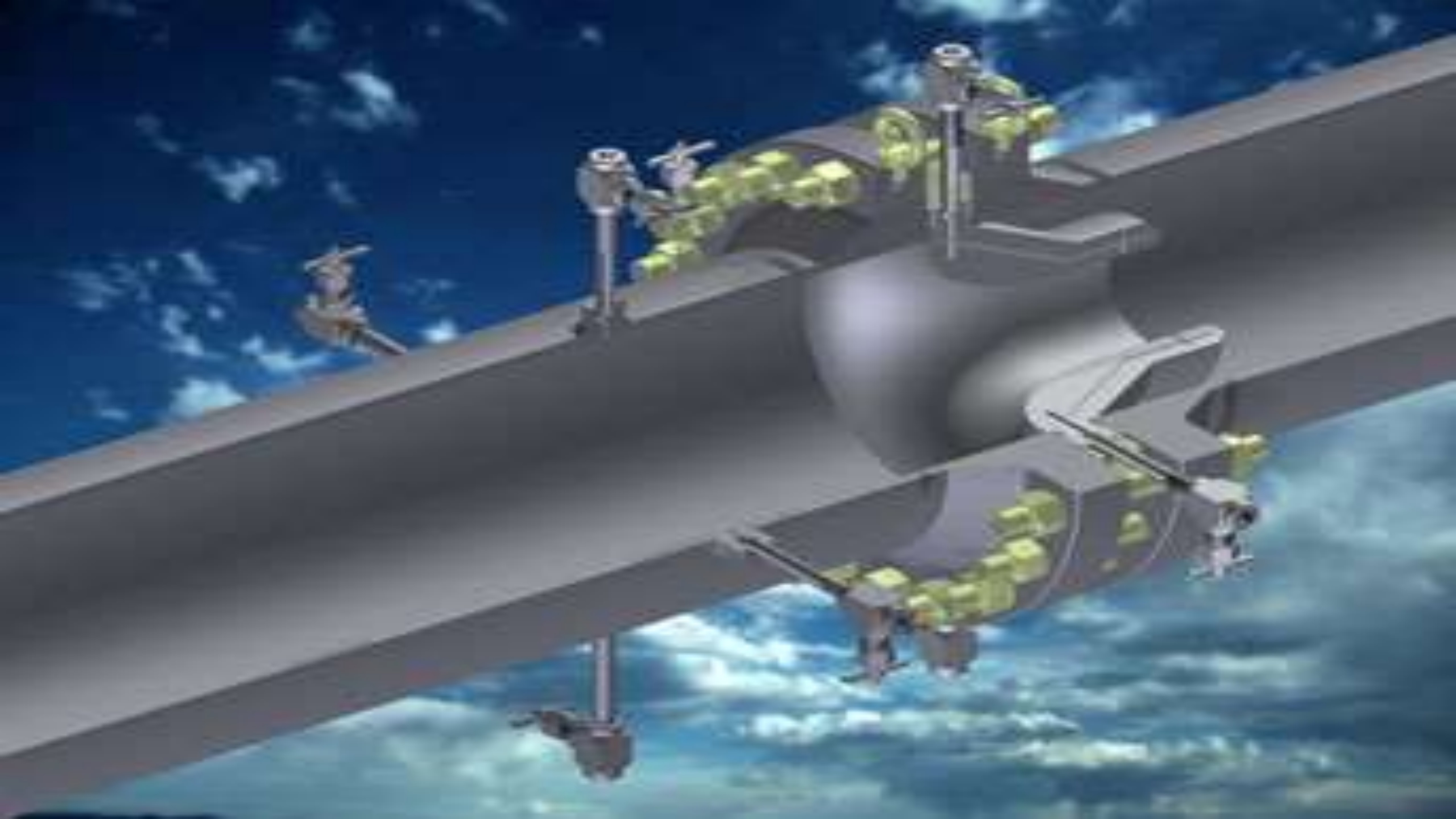
Venturi tube


Pressure taps
$\Delta p = p_1 - p_2$
p_1
p_2
D (A_1)
d (A_2)
Q
Flow

Flow nozzle



Location of
Height Pressure
Taps
Location of
Low Pressure
Taps
Flow



Rotameter

Velocity Flowmeters

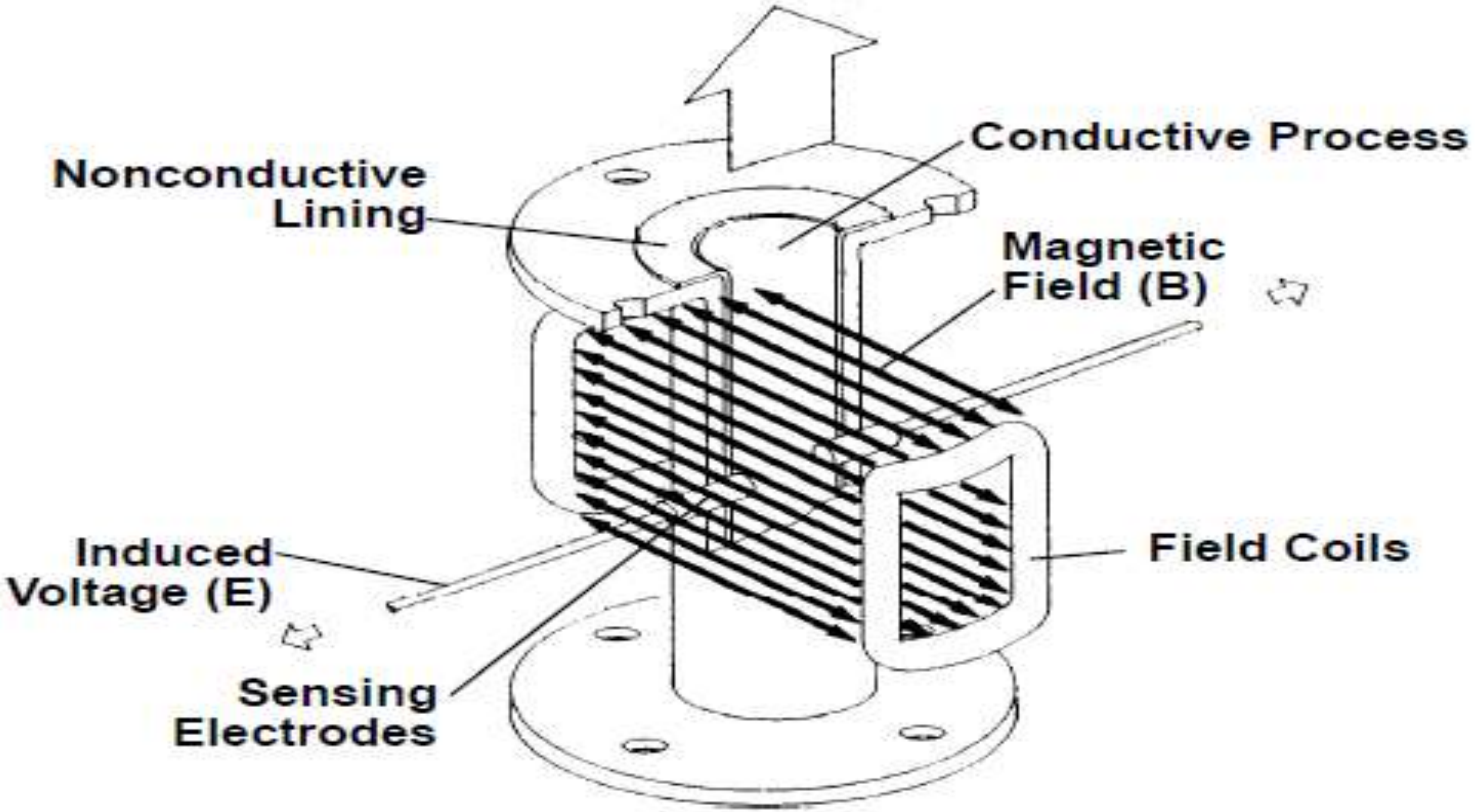
1. Magnetic flowmeter

2. Vortex flowmeter

3. Turbine flowmeter

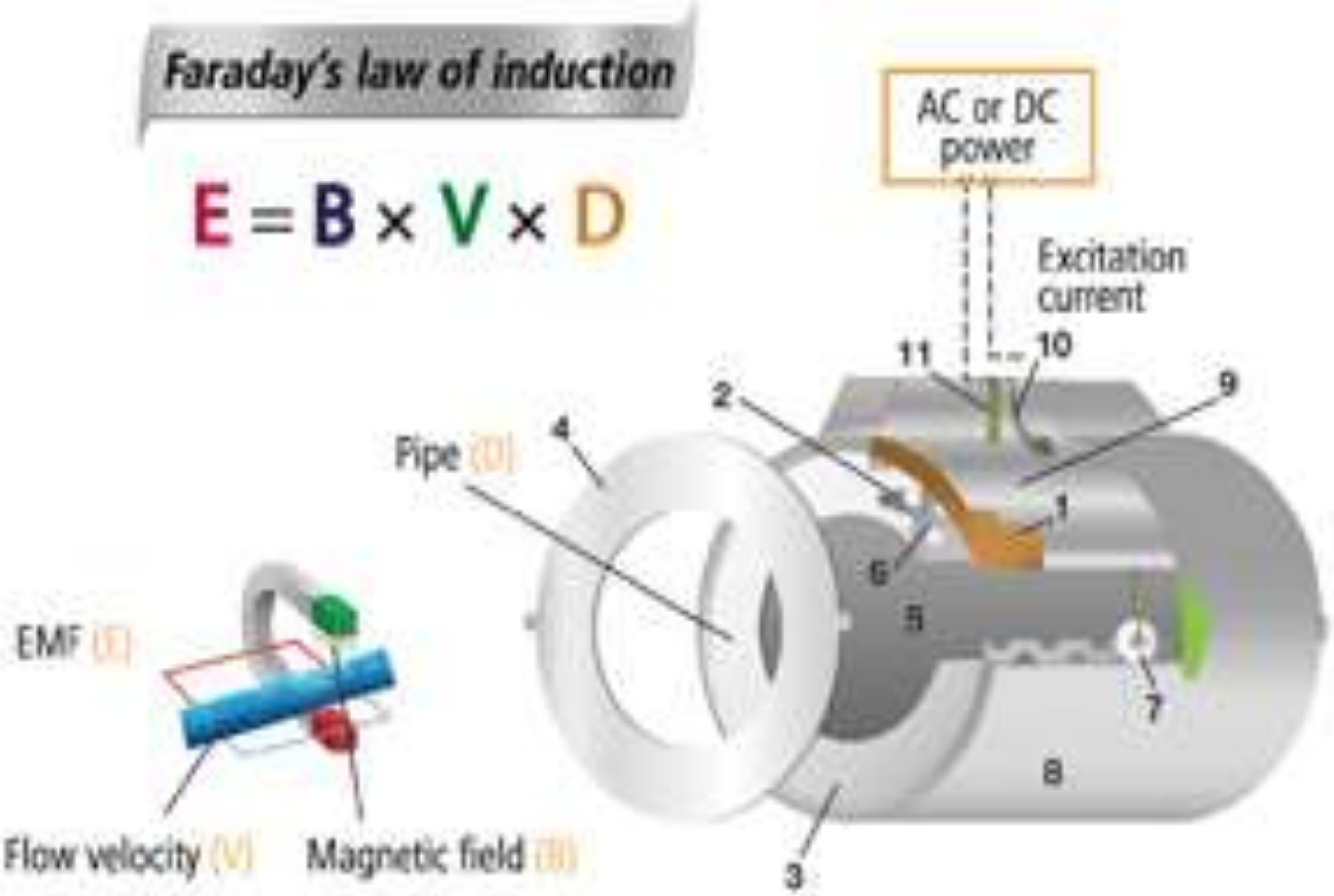
4. Ultrasonic flowmeter

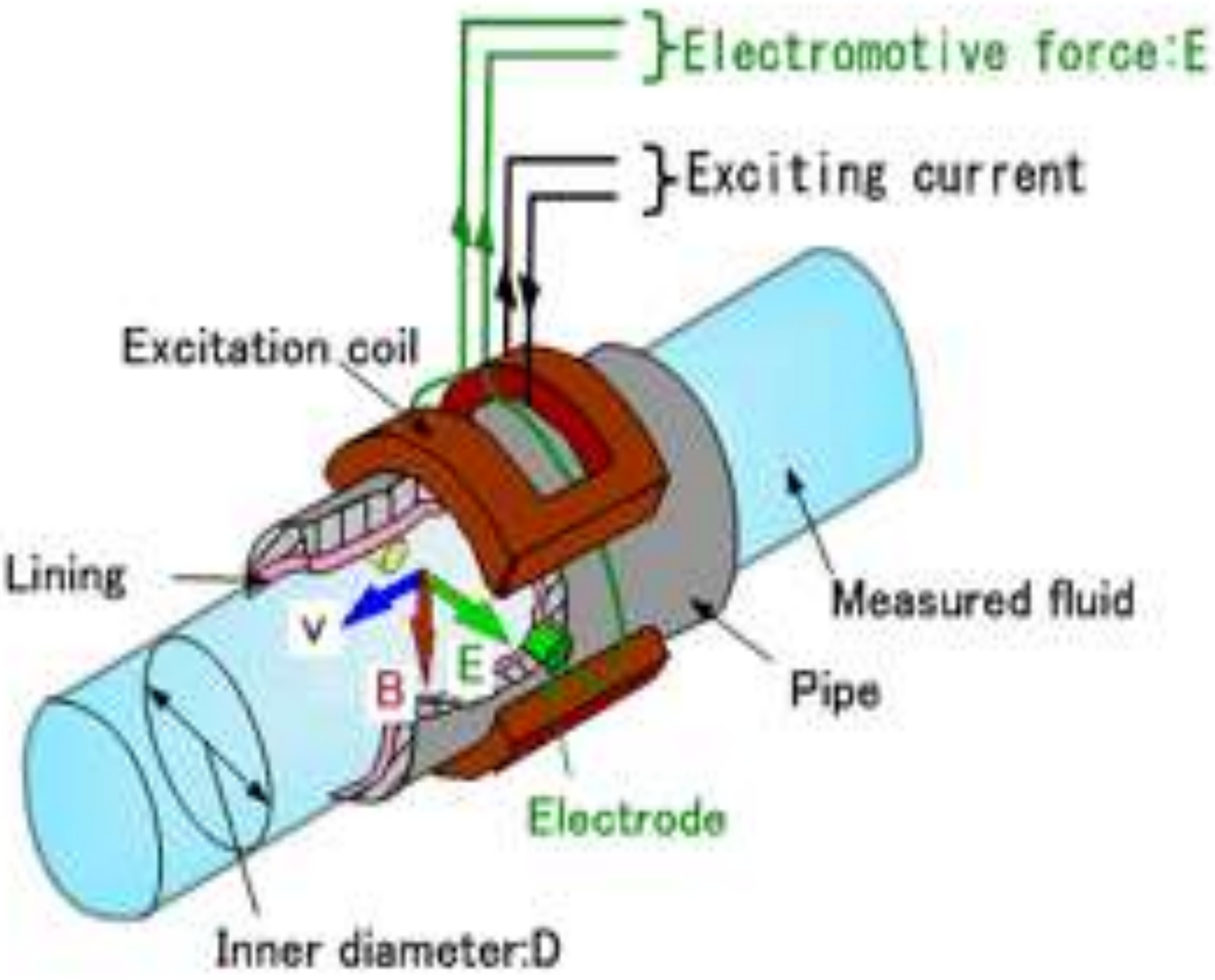
Magnetic flowmeter

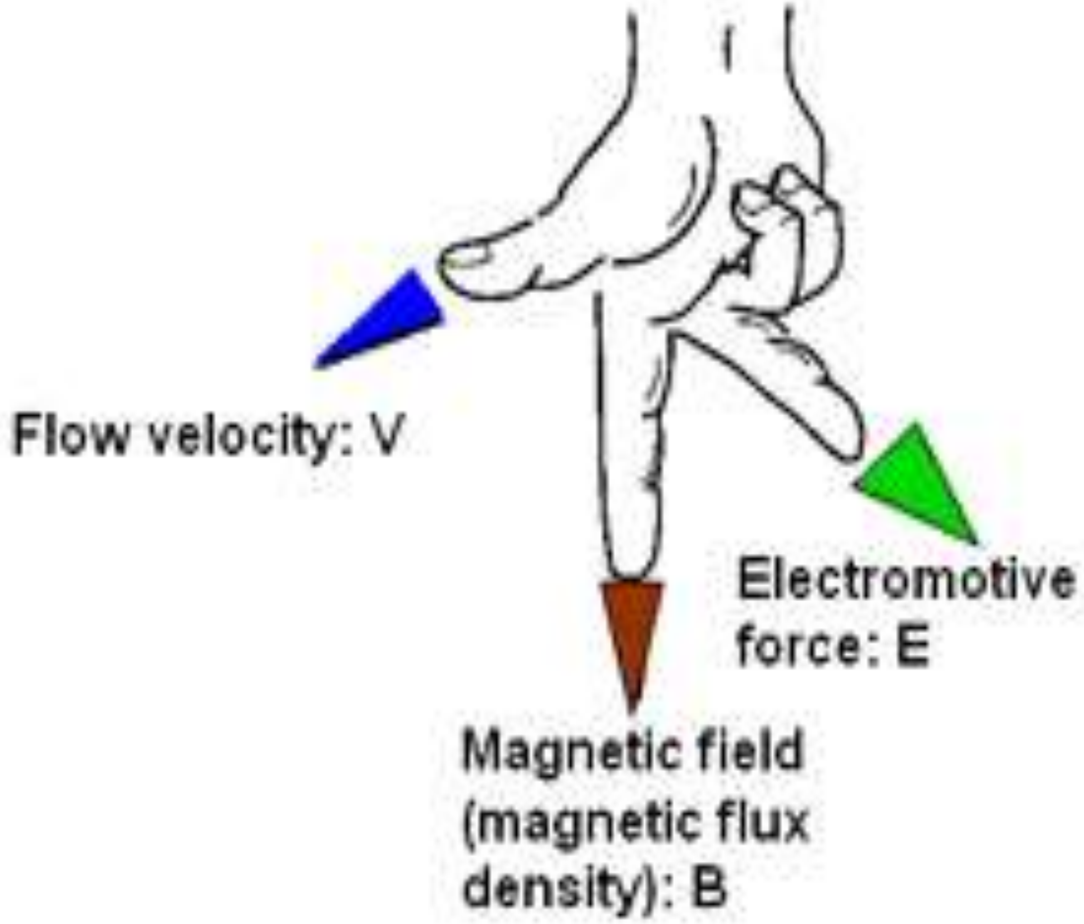


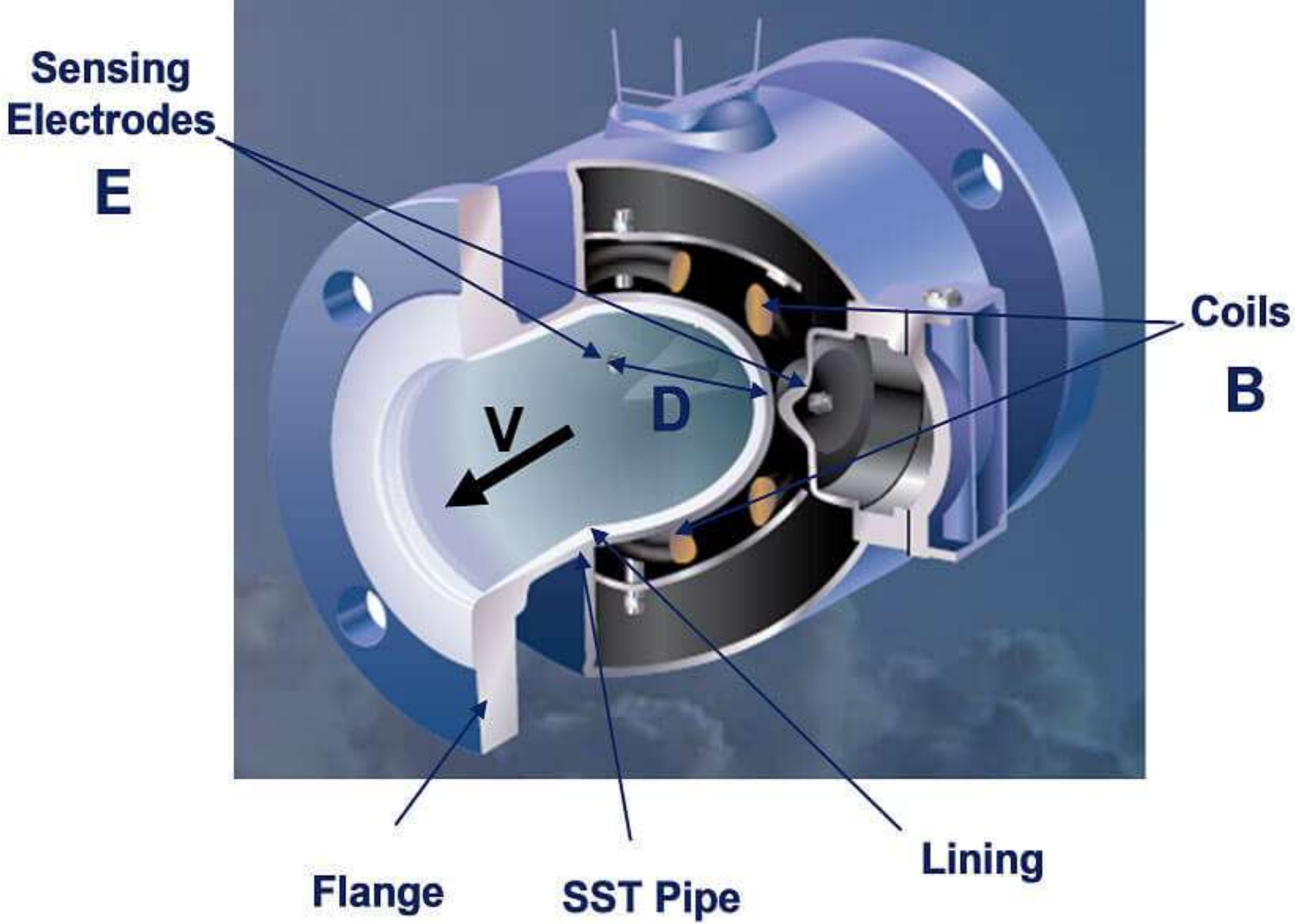
Magnetic flowmeter sensor construction

Item	Description
01	Coils
02	Tube
03	Process connection
04	Earthing ring
05	Liner
06	Punch plate
07	Electrode
08	Body
09	Isolation plate
10	Excitation cable
11	Signal cable

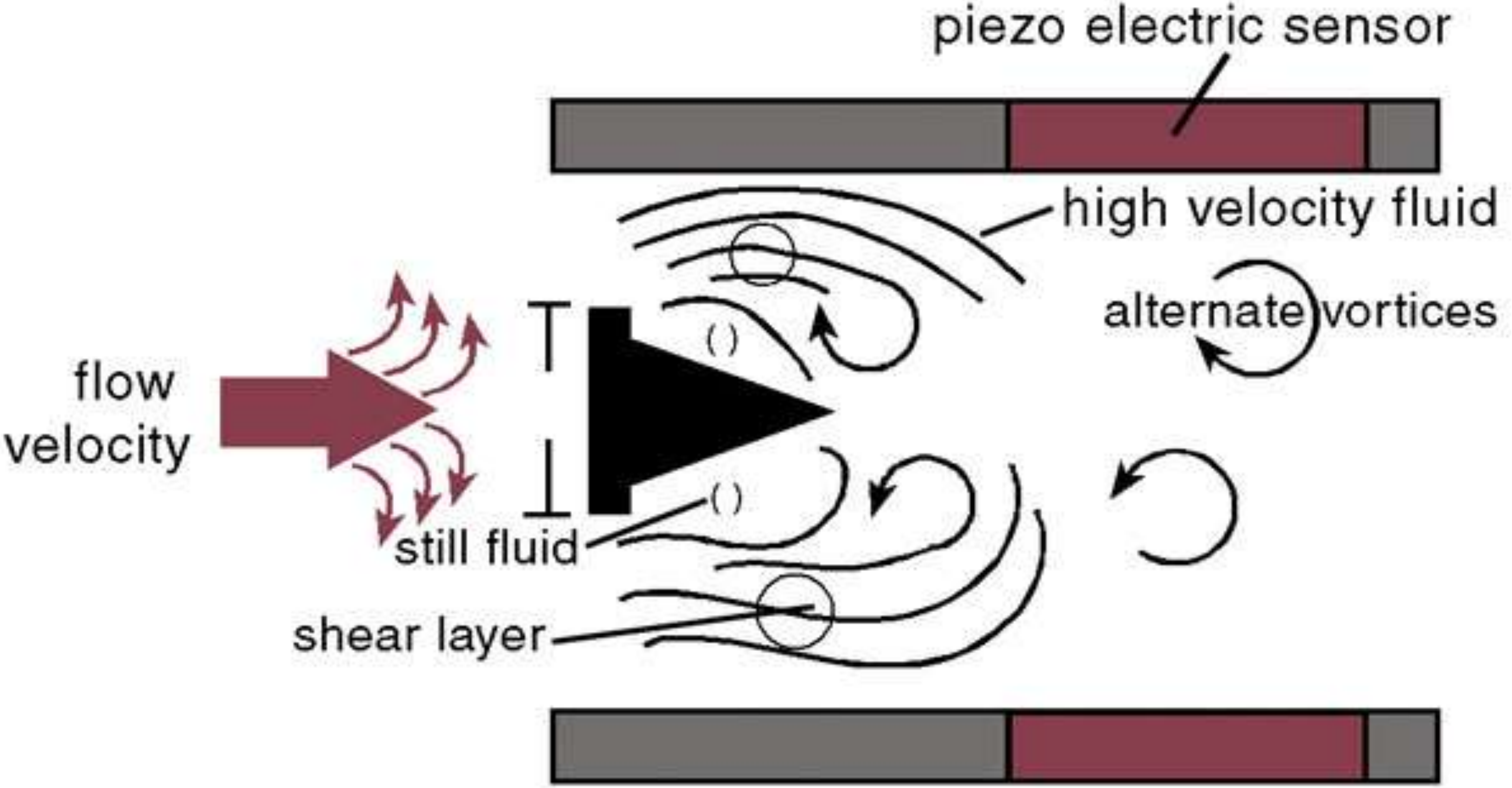



Electromotive force:E
Exciting current
Excitation coil
Lining
V
E
B
Measured fluid
Pipe
Electrode
Inner diameter:D


Flow velocity: V
Electromotive force: E
Magnetic field (magnetic flux density): B

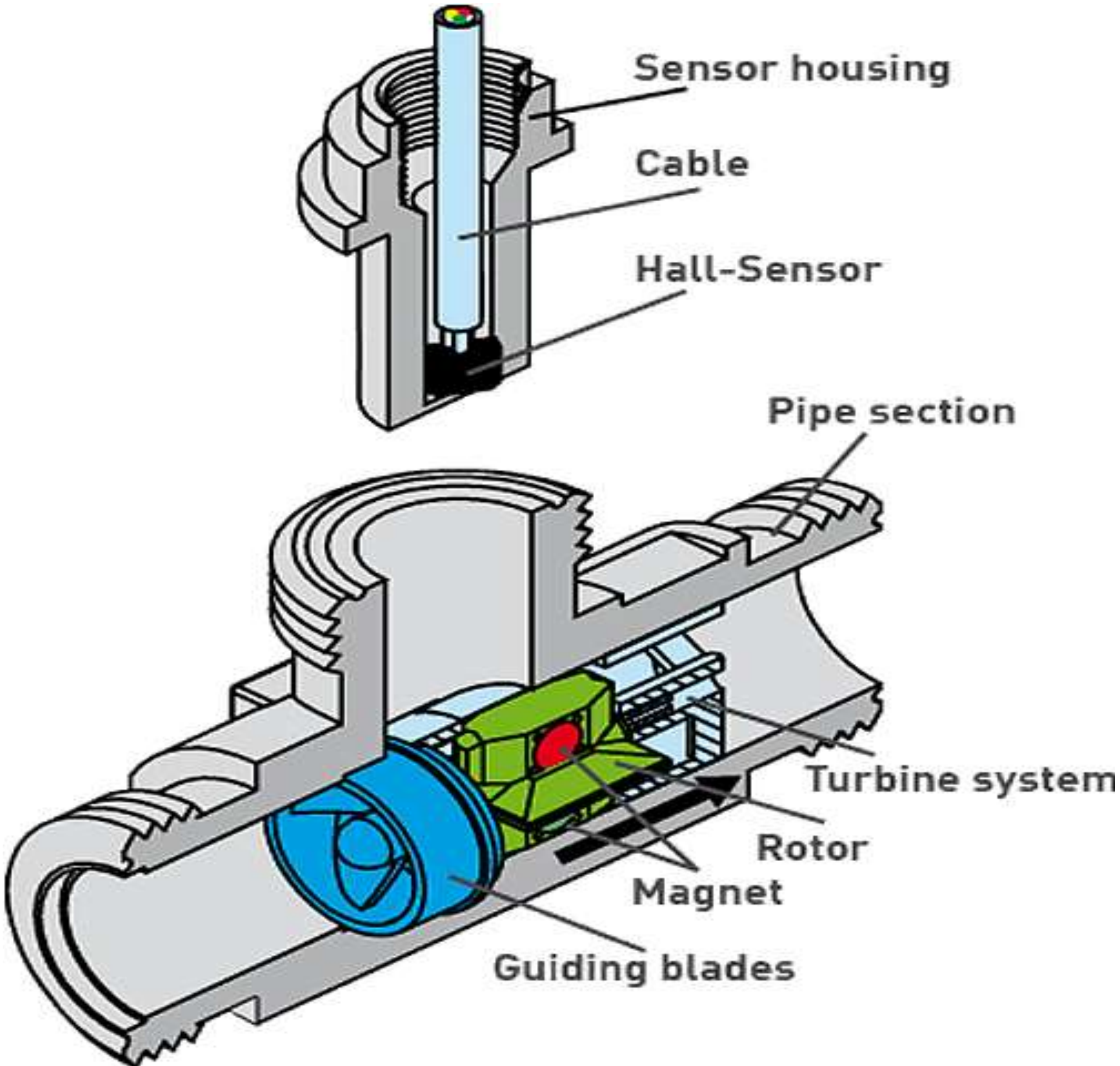

Sensing
Electrodes
E
V
D
Coils
B
Flange
SST Pipe
Lining

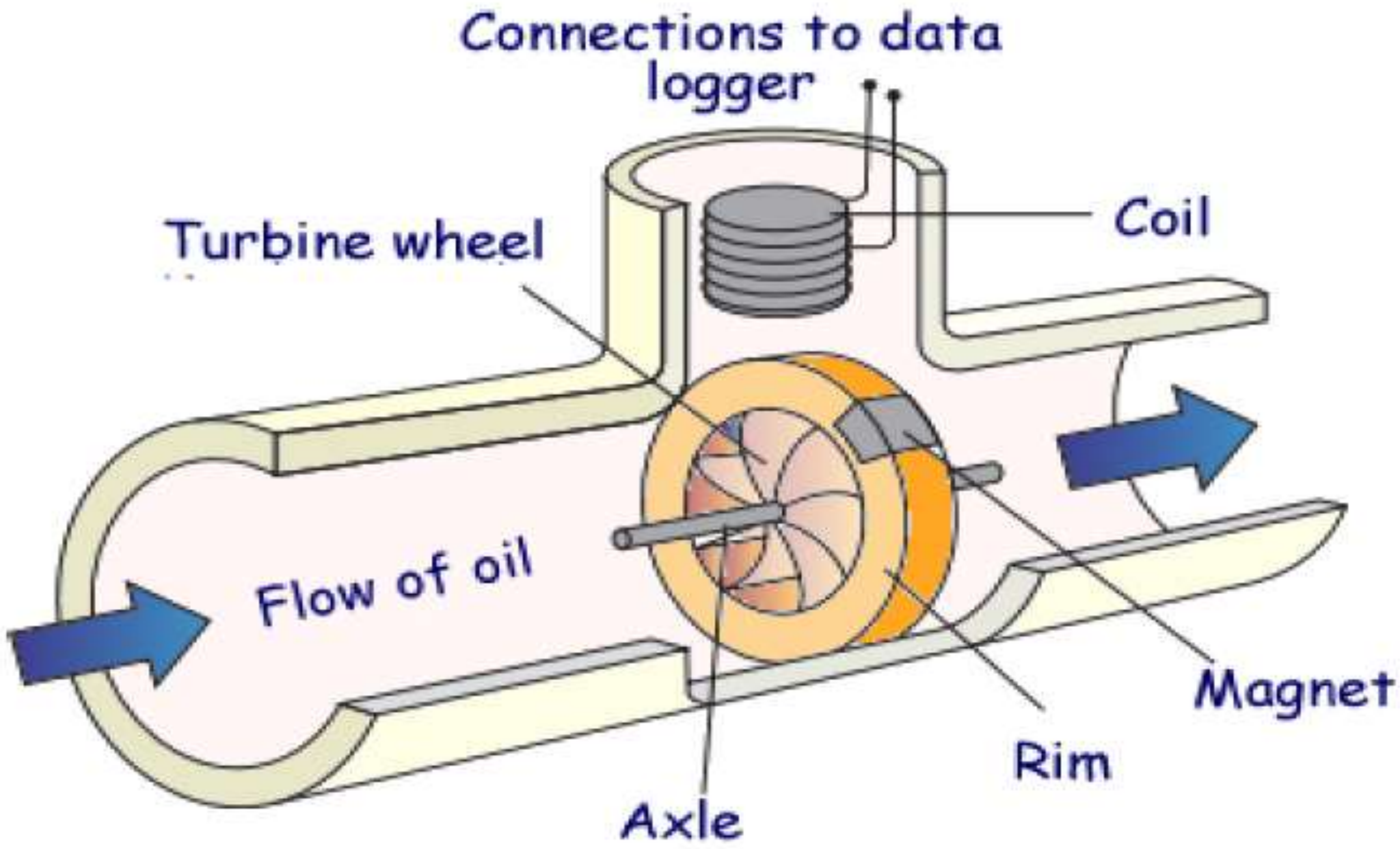
Vortex flowmeter



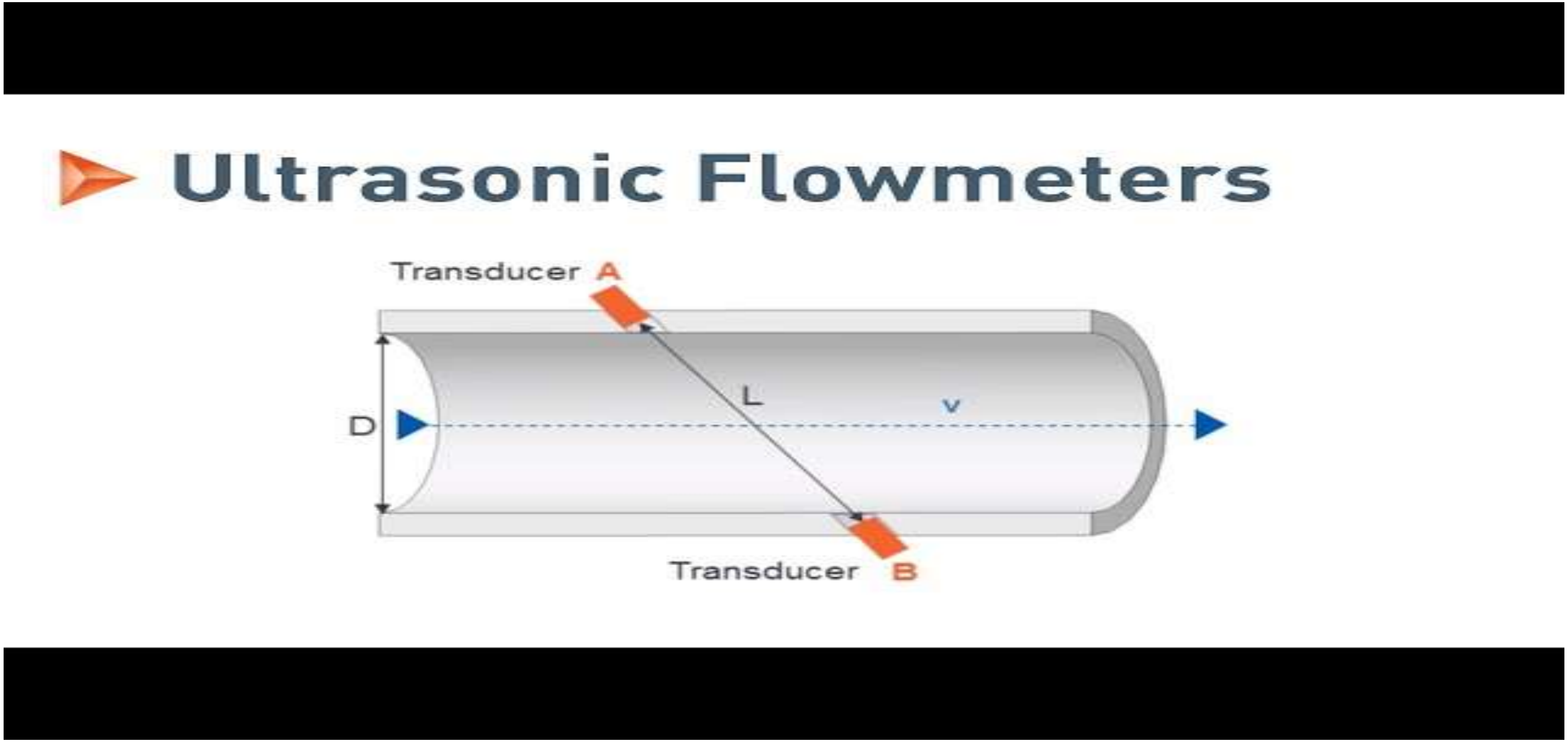

ow Meter
0.000

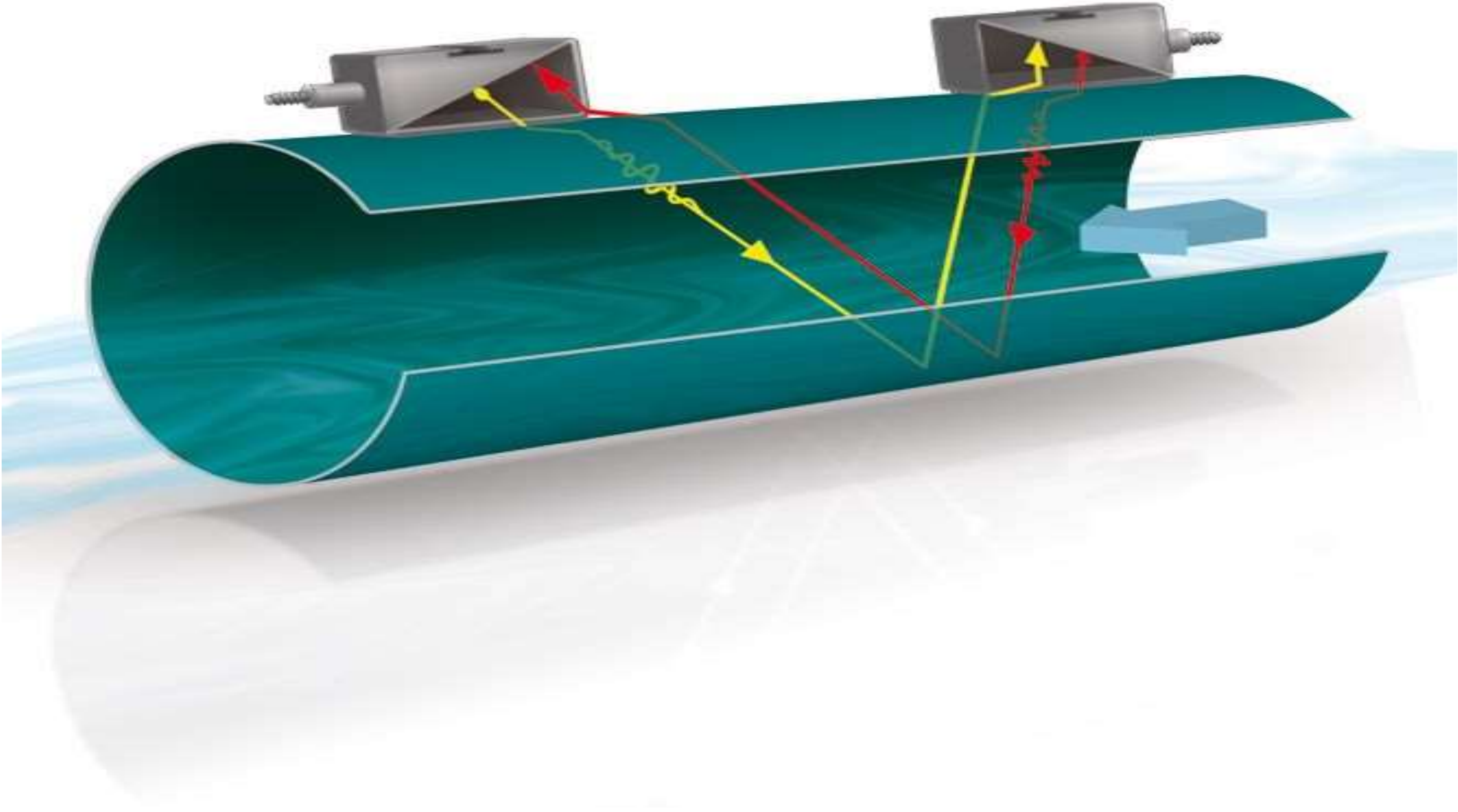
Turbine flowmeter




Connections to data logger
Coil
Turbine wheel
Flow of oil
Magnet
Rim
Axle

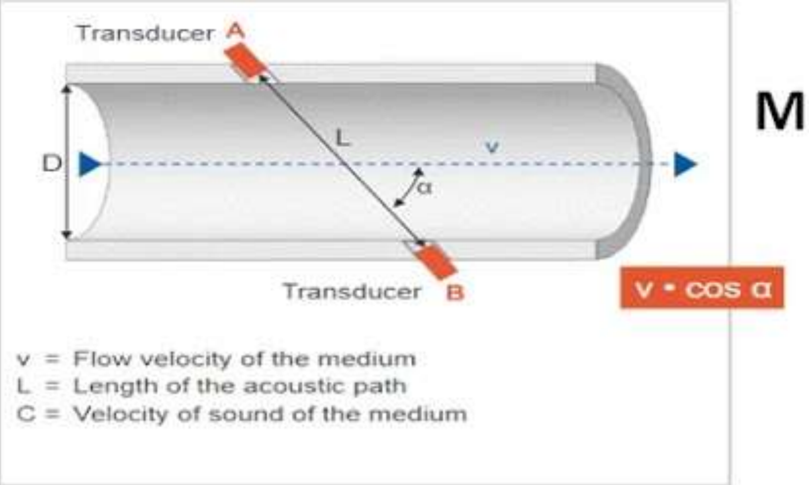
Ultrasonic flowmeter





$$t_d = \frac{L}{c + v\cos(\alpha)}$$

$$t_u = \frac{L}{c - v\cos(\alpha)}$$



Multiplying t_d and t_u ,

$$t_d * t_u = \frac{L}{c + v\cos(\alpha)} * \frac{L}{c - v\cos(\alpha)}$$

$$= \frac{L^2}{c^2 - v^2\cos^2\alpha}$$

$$c^2 - v^2\cos^2\alpha = \frac{L^2}{t_d * t_u} ------(2)$$

$$\Delta t = t_u - t_d = \frac{L}{c - v\cos(\alpha)} - \frac{L}{c + v\cos(\alpha)}$$

$$\Delta t = \frac{L[c + v\cos(\alpha)] - L[c - v\cos(\alpha)]}{[c - v\cos(\alpha)]*[c + v\cos(\alpha)]} = \frac{2vL\cos(\alpha)}{c^2 - v^2\cos^2\alpha} ----(1)$$

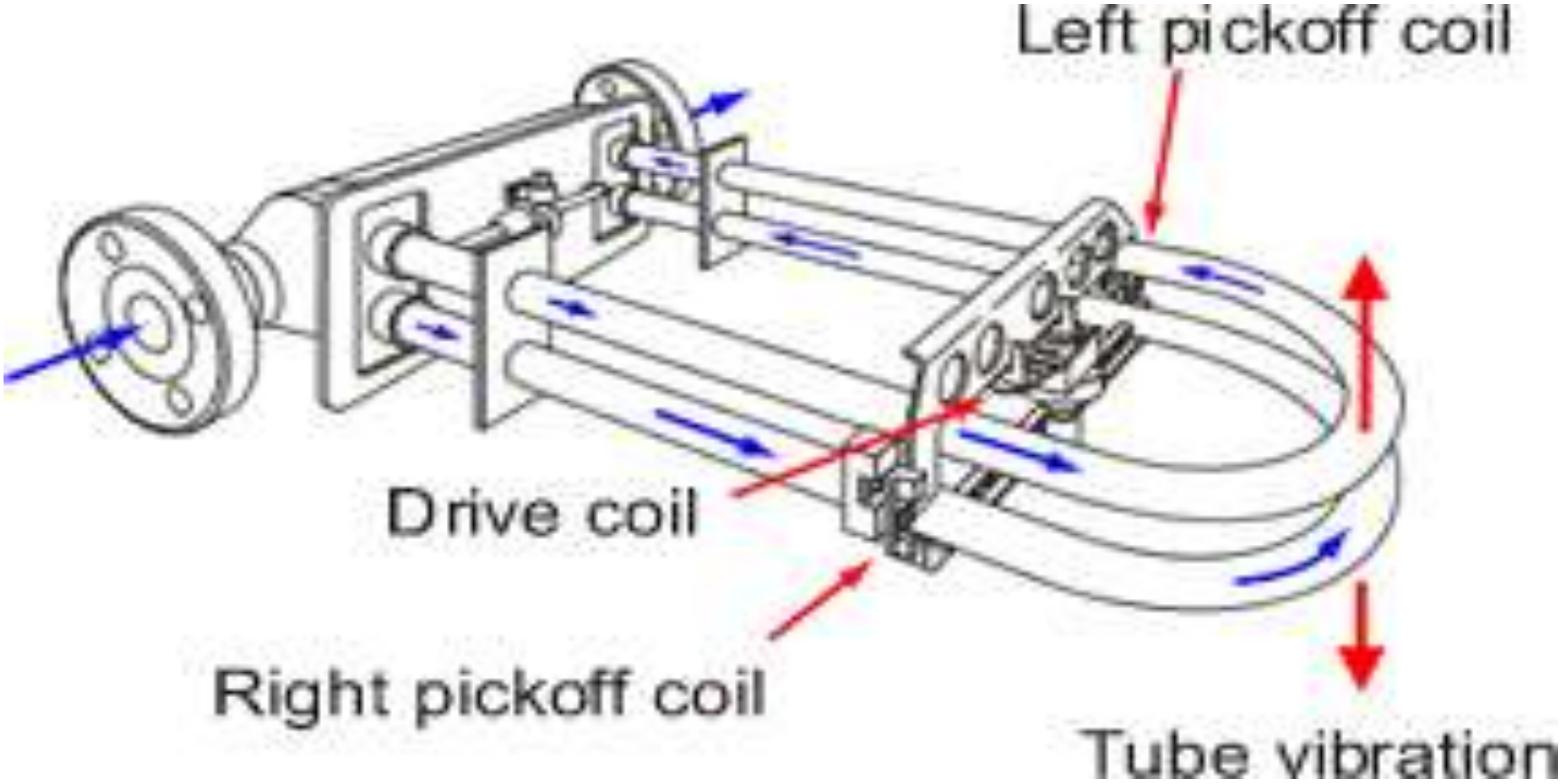
$$\Delta t = \frac{2vL\cos(\alpha)t_d t_u}{L^2}$$

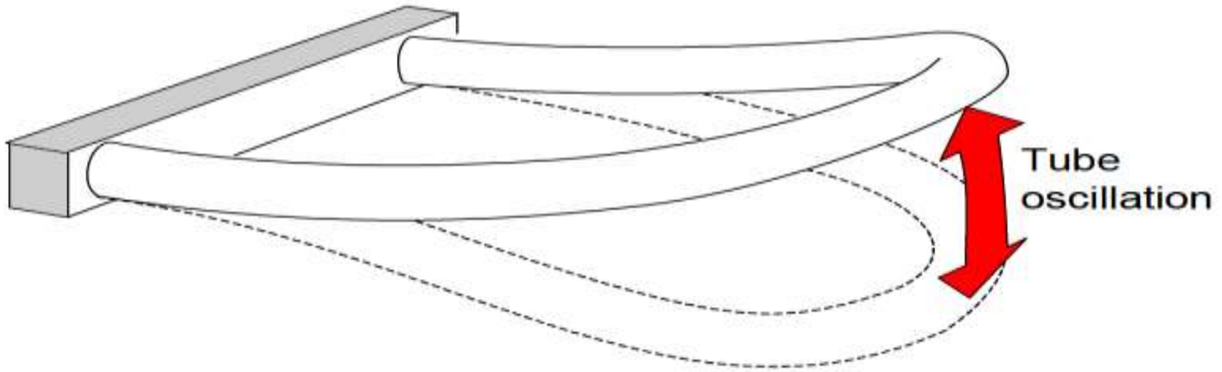
$$v = \frac{L\Delta t}{2\cos(\alpha)t_d t_u}$$

t_d – downstream transmit time,
t_u – upstream transmit time,
Δt - difference in transit time

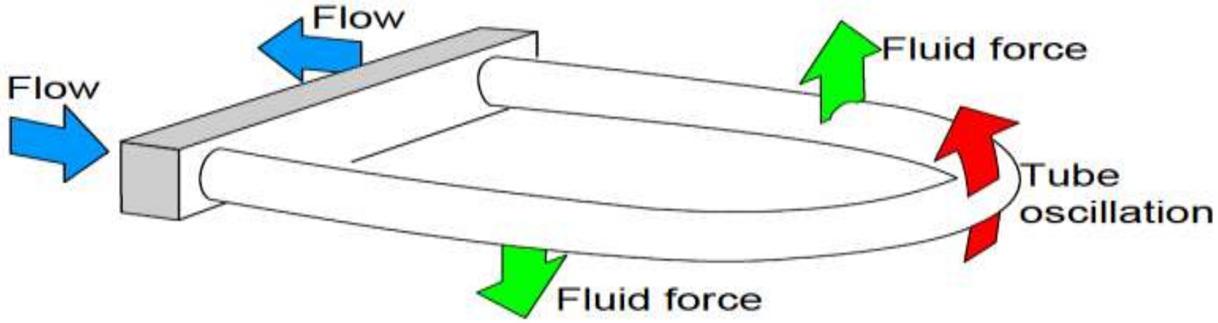
Basic Flow Rate Equation: Q = A * v

Mass flowmeters , Coriolis Mass Flowmeter

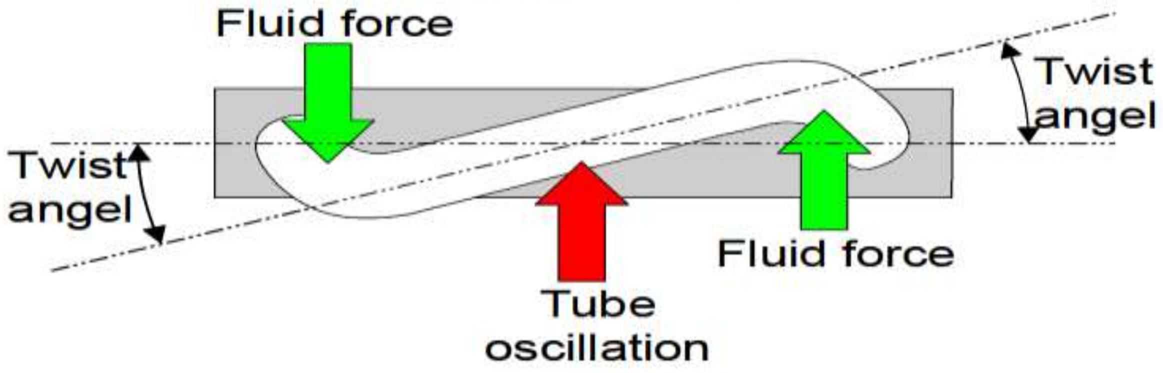




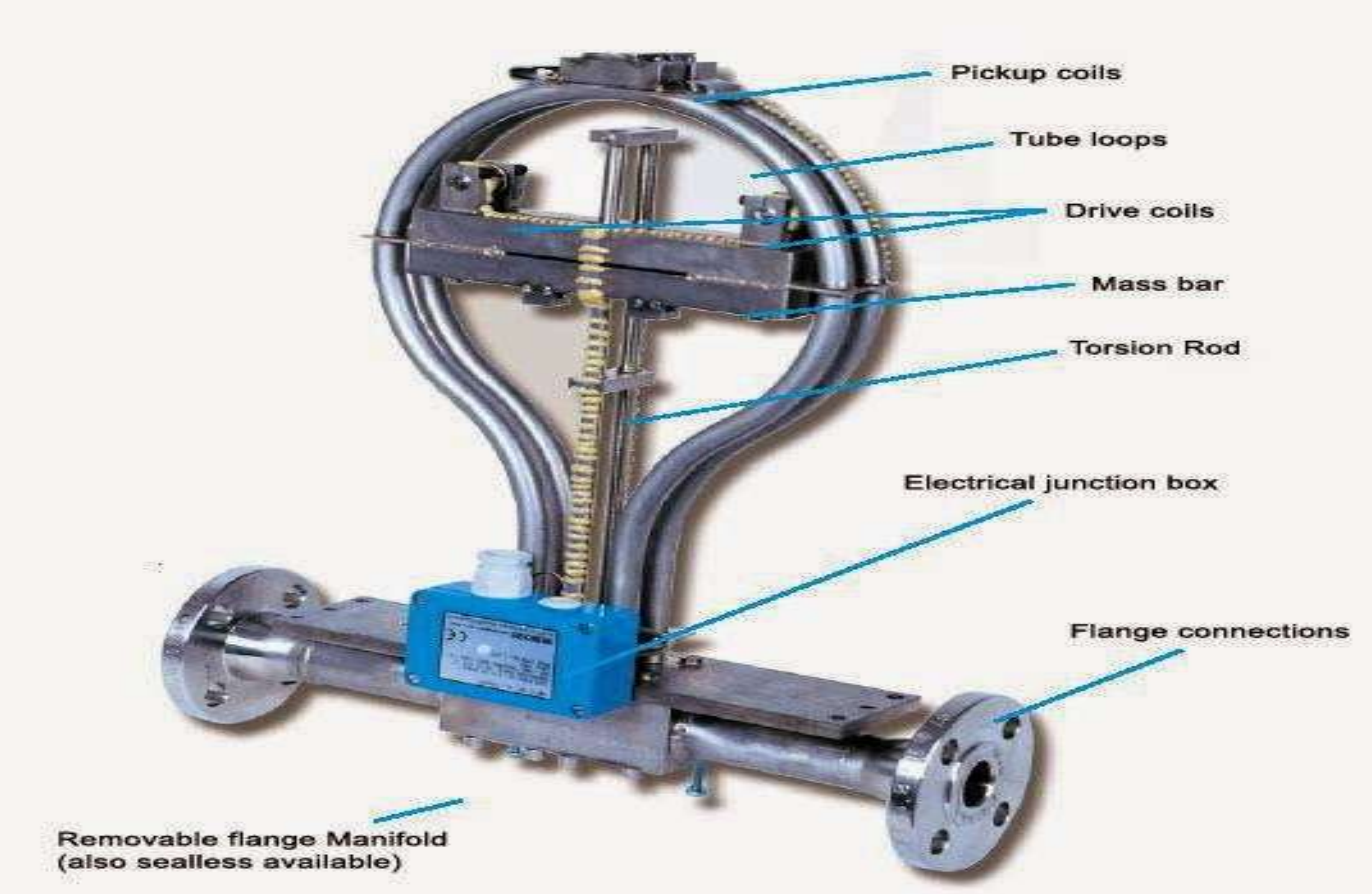
Oscillatory motion applied to a single tube



Forces acting on the tube as a result of fluid flow



The complete loop is twisted by an amount that is directly and linearly to the mass flow rate of the fluid


Pickup coils
Tube loops
Drive coils
Mass bar
Torsion Rod
Electrical junction box
Flange connections
Removable flange Manifold
(also sealless available)

Positive displacement Flowmeter


GALLONS


InstrumentationTools.com

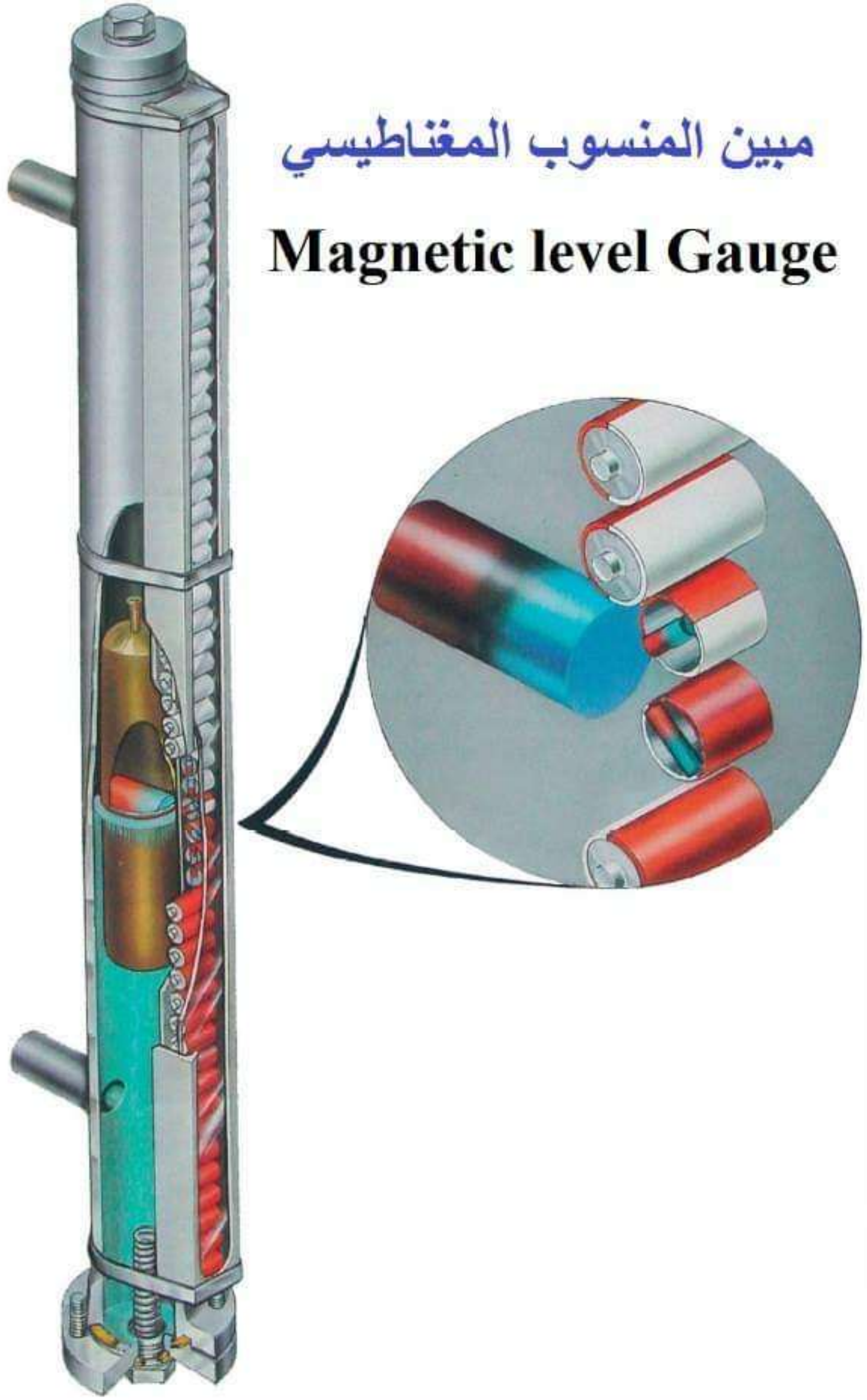
Level Type

1. Level Gauge.
2. Float Level.
3. Hydrostatic Pressure Measurements.
4. Echo Level .
5. Capacitive Level type

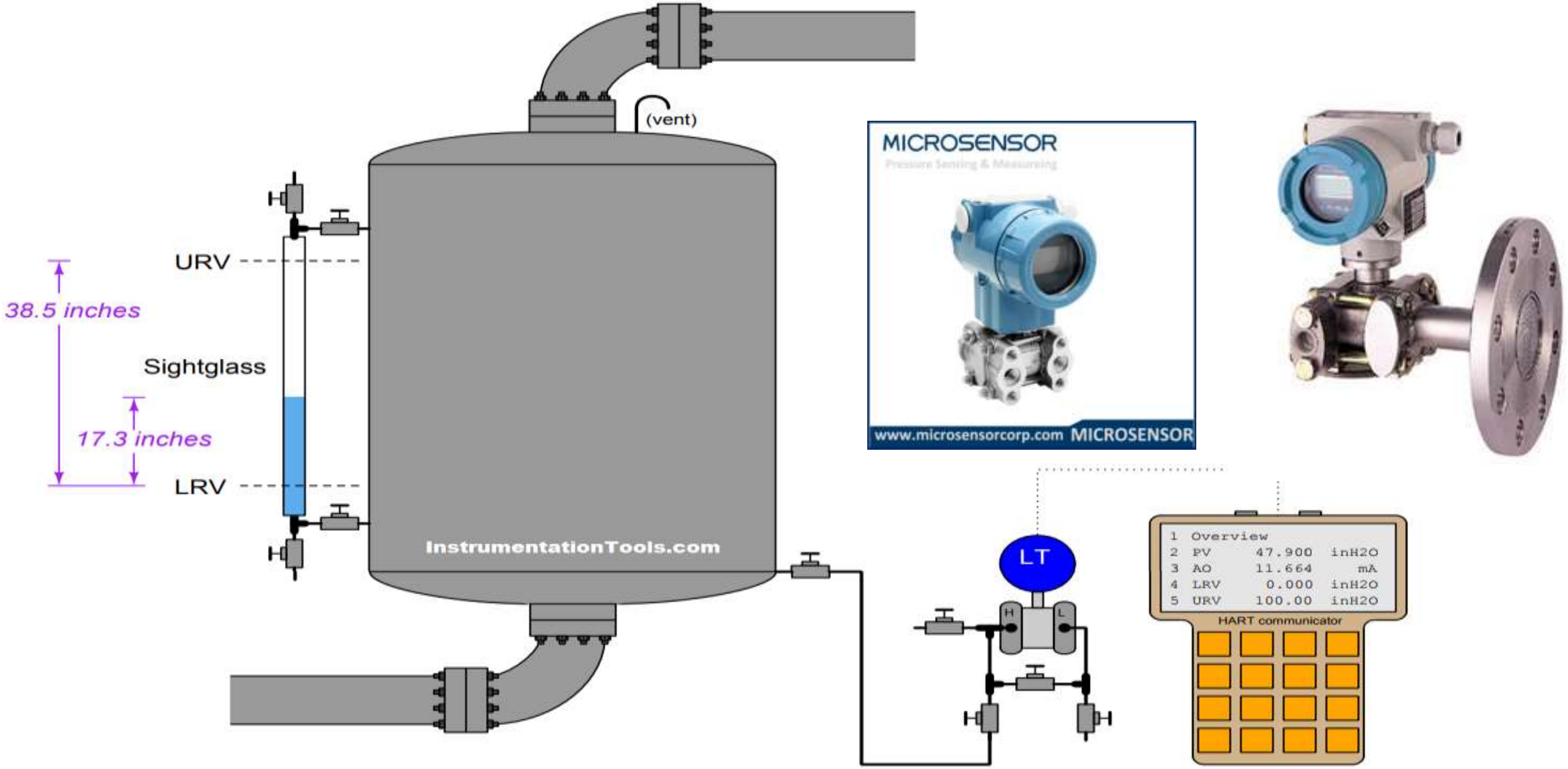
Level , (Indicators, Switch, transmitters).

مبين المنسوب المغناطيسي

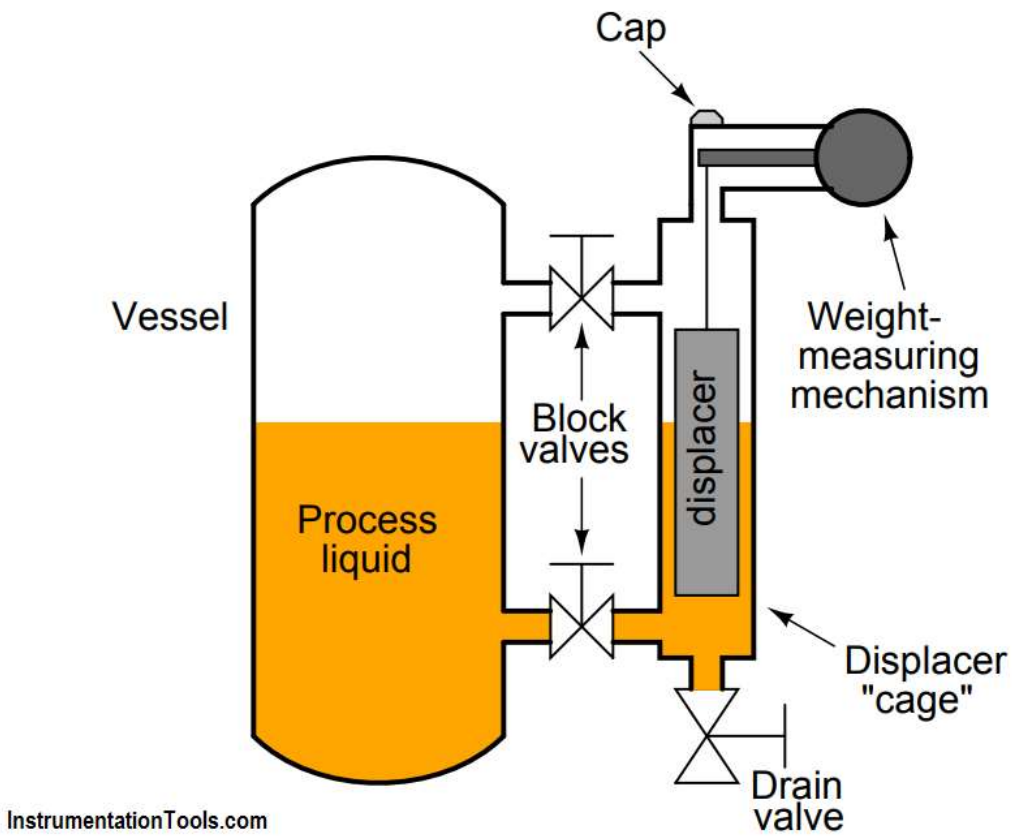
Magnetic level Gauge

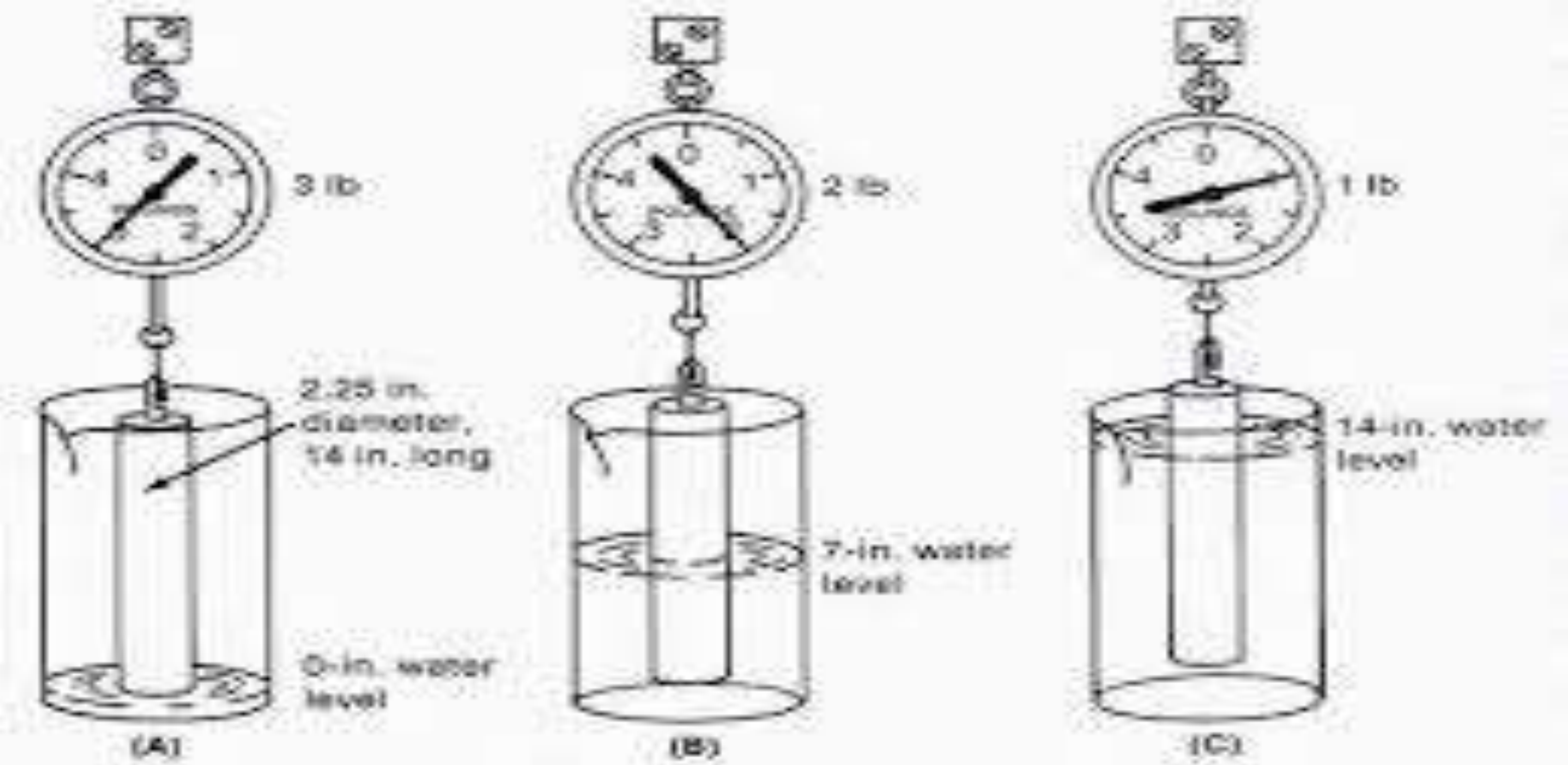


Hydrostatic level Transmitter



Displacer Level Transmitter

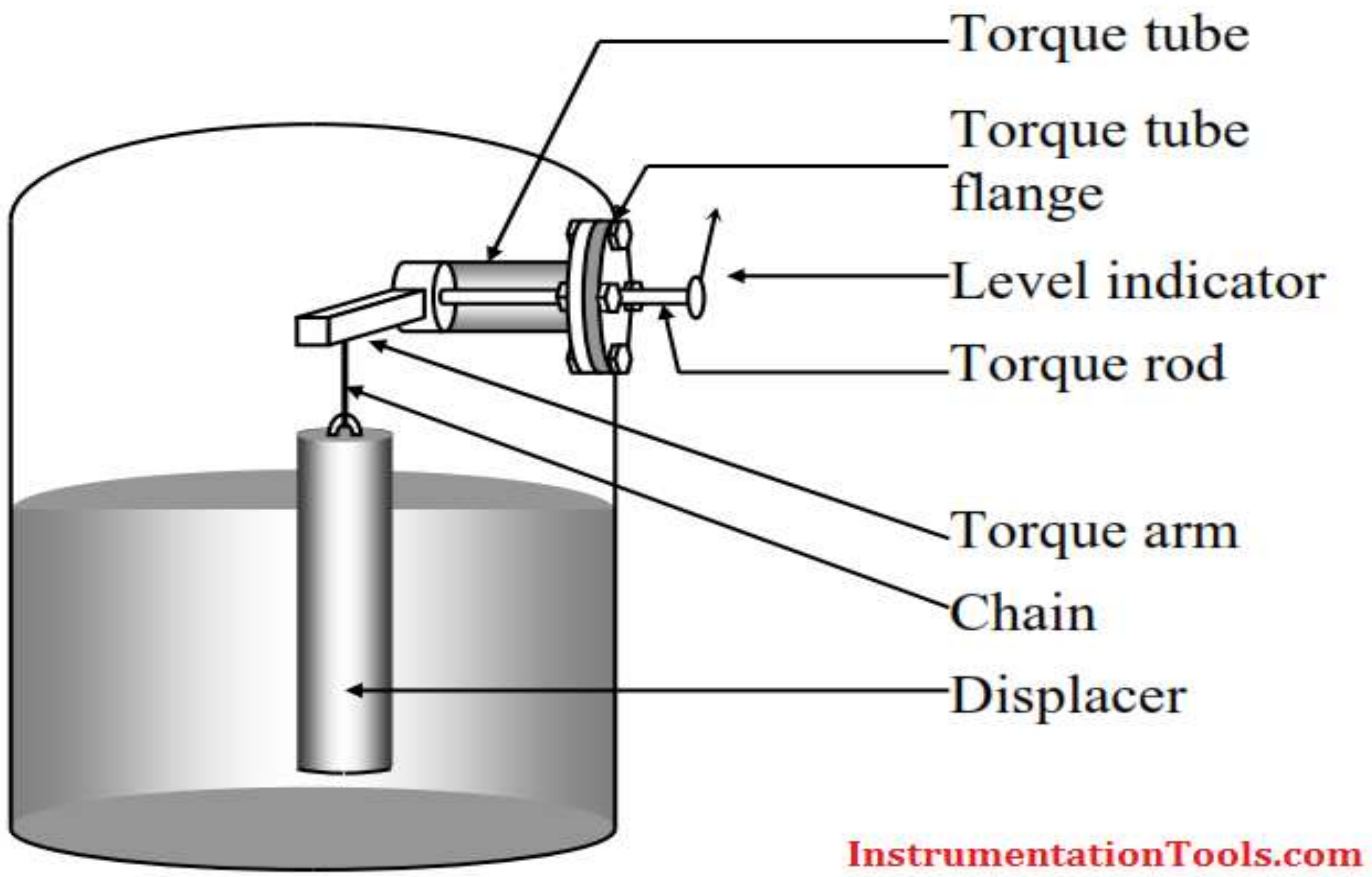




(A)

(B)
Water displaced weights 1 lb

(C)
Water displaced weights 2 lb


Torque tube
Torque tube flange
Level indicator
Torque rod
Torque arm
Chain
Displacer
InstrumentationTools.com

Ultrasonic Level Transmitter

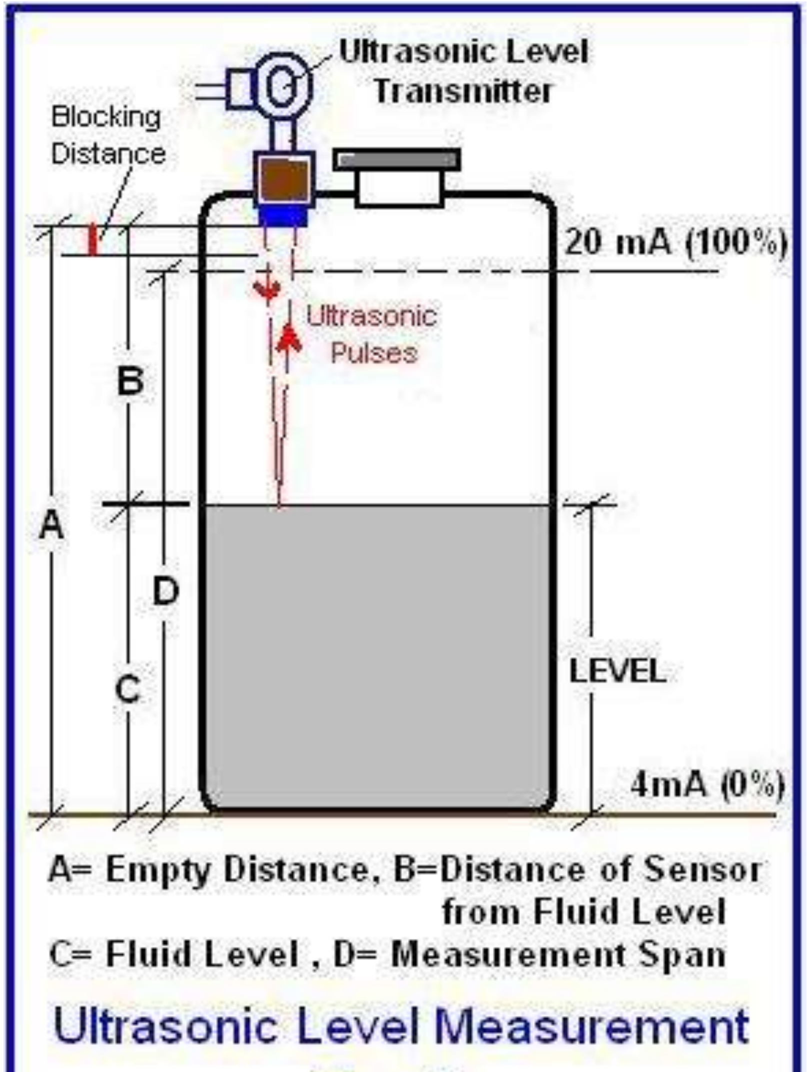
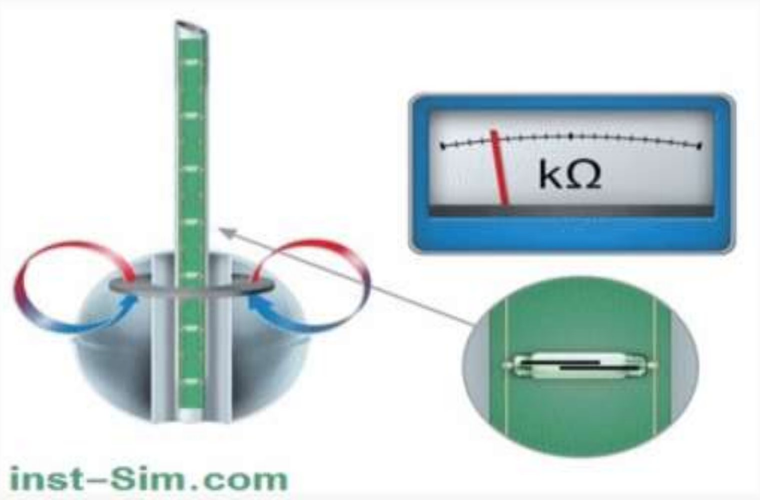
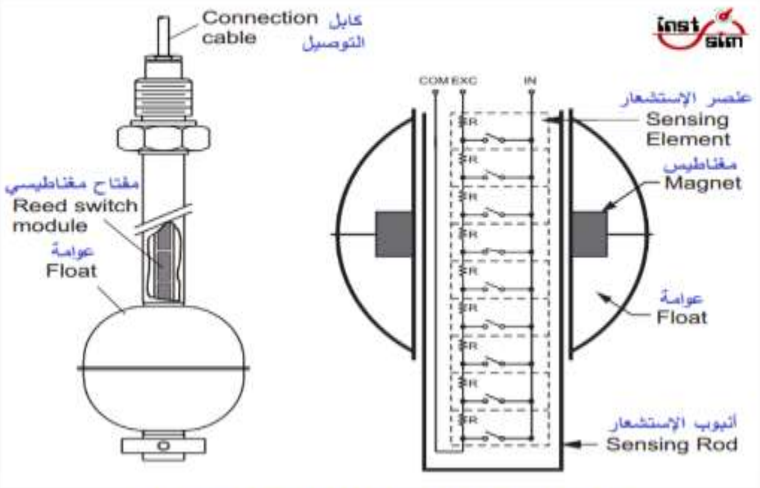


Fig - 1

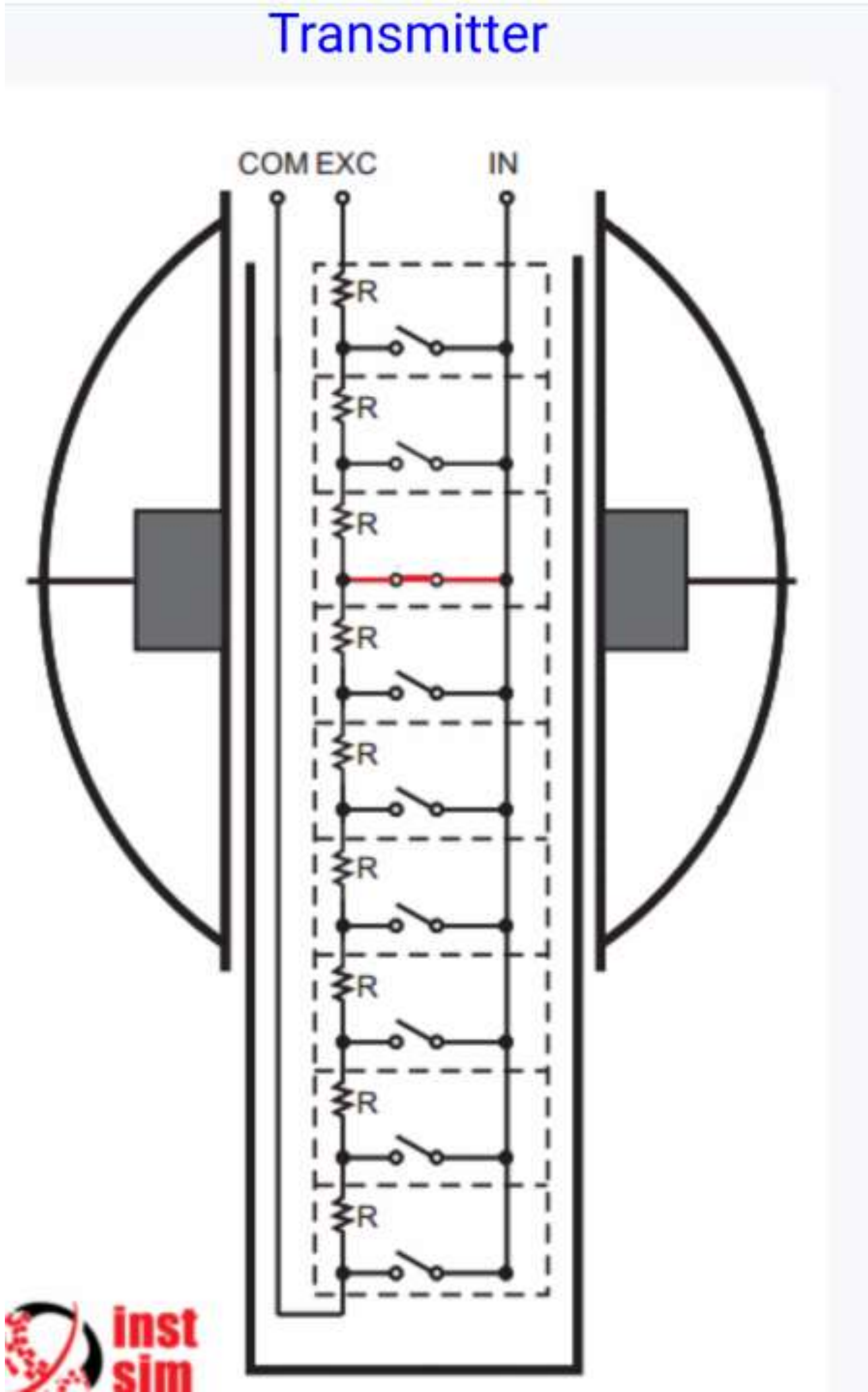
Resistant Level Measurements



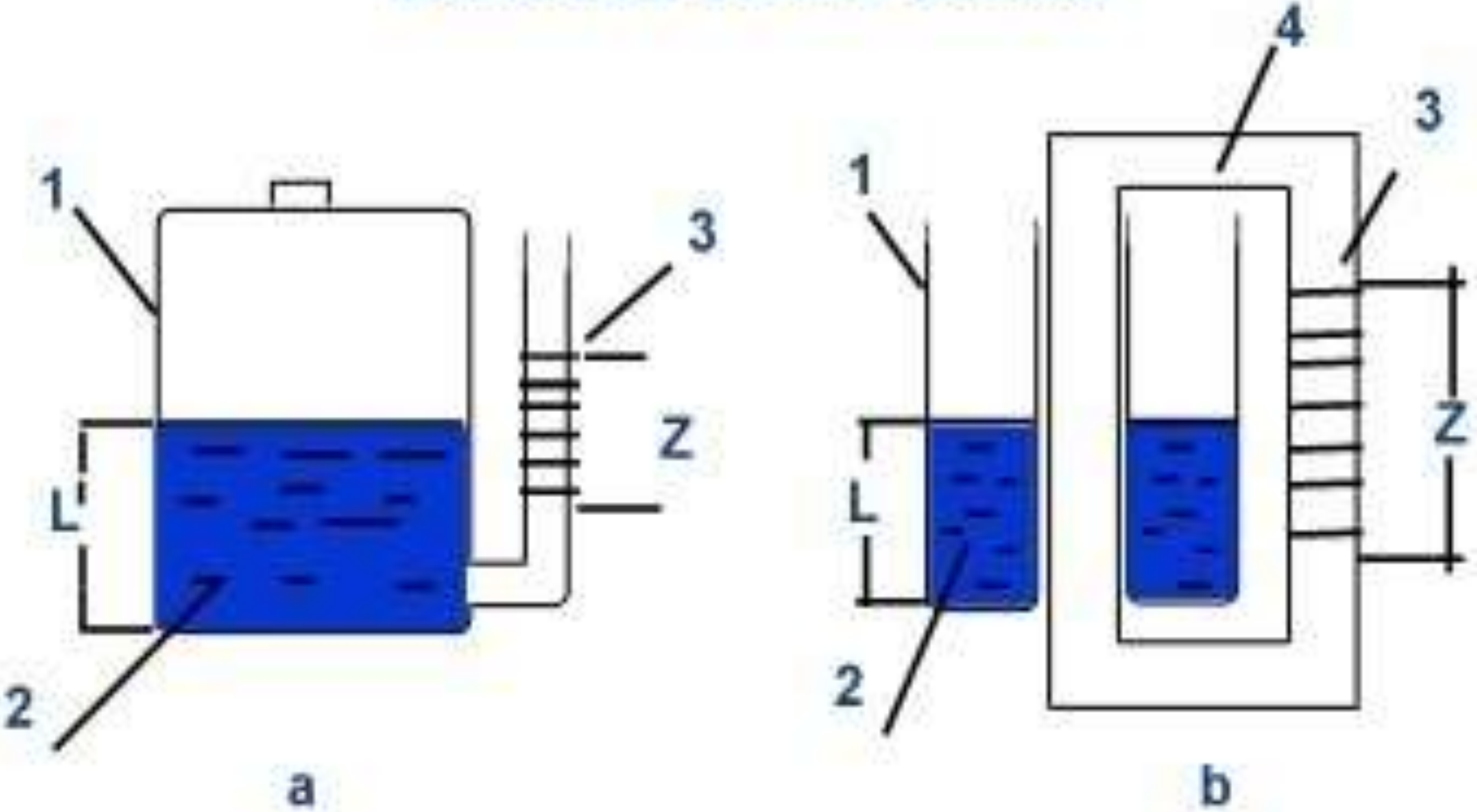


مرسل سلسلة المقاومات

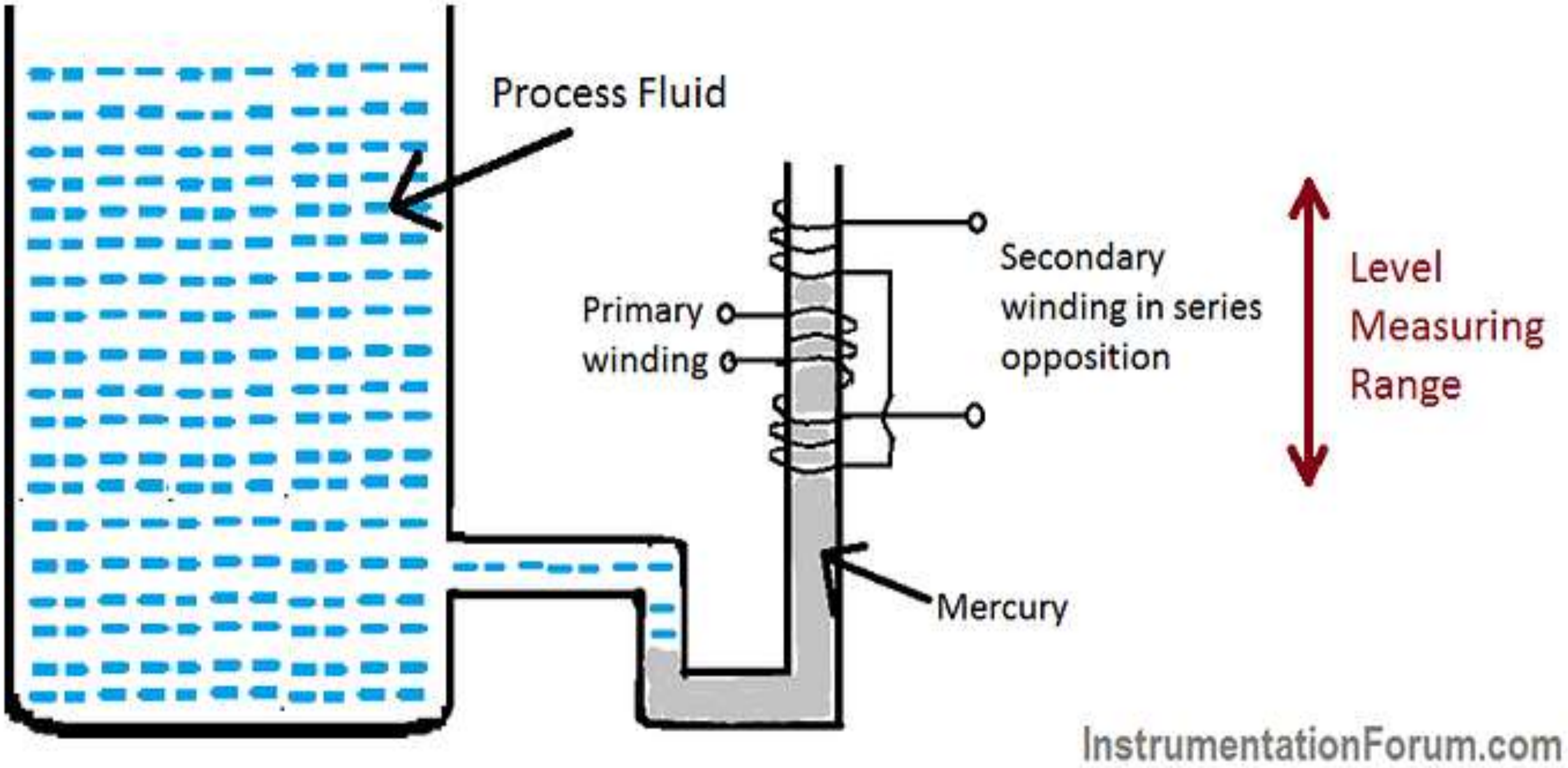
أو Resistance Chain Transmitter



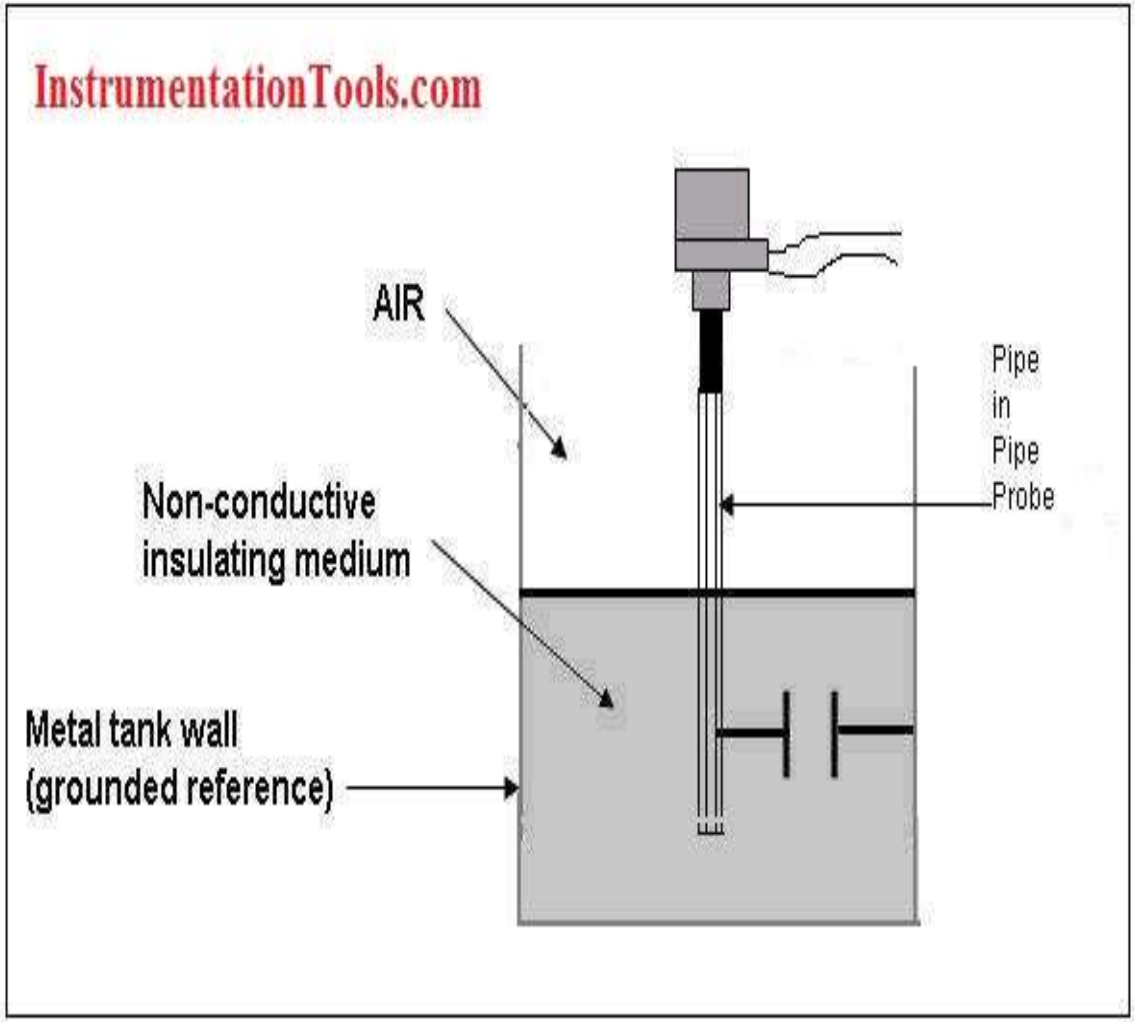
Inductive Level Sensor

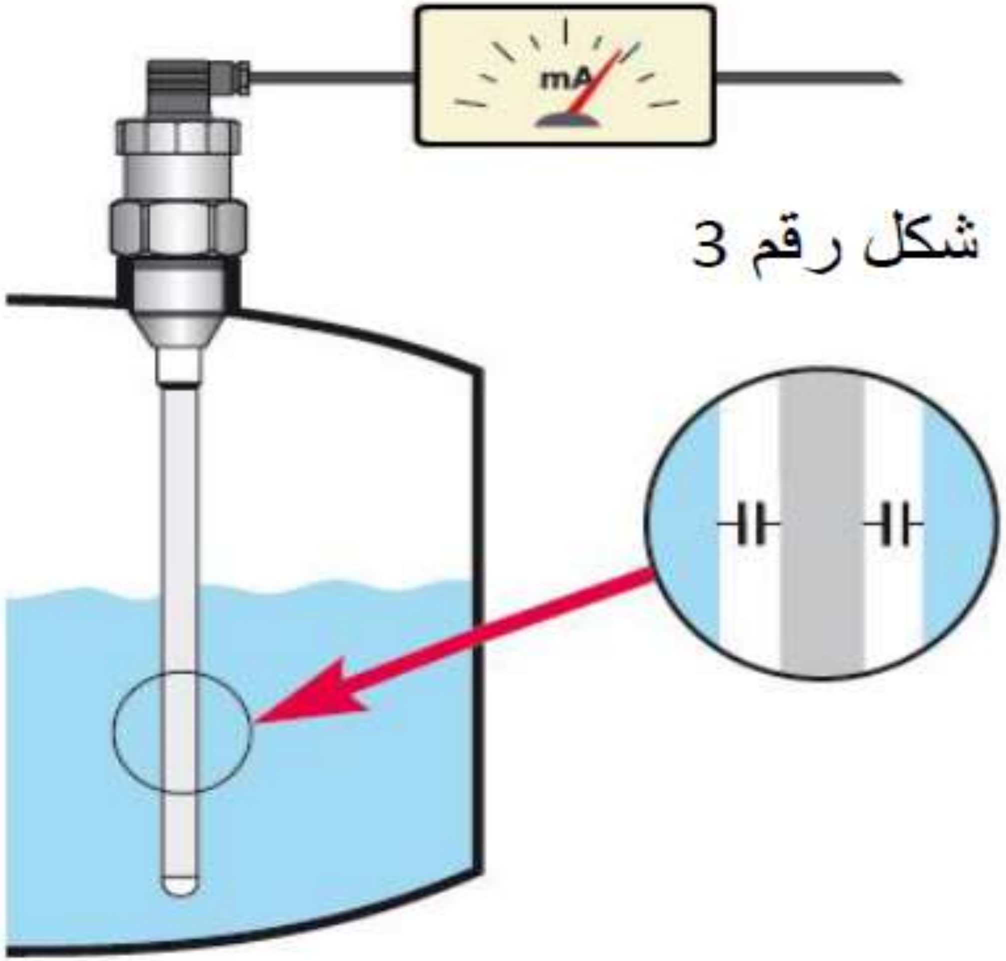


INDUCTIVE LEVEL MEASUREMENT



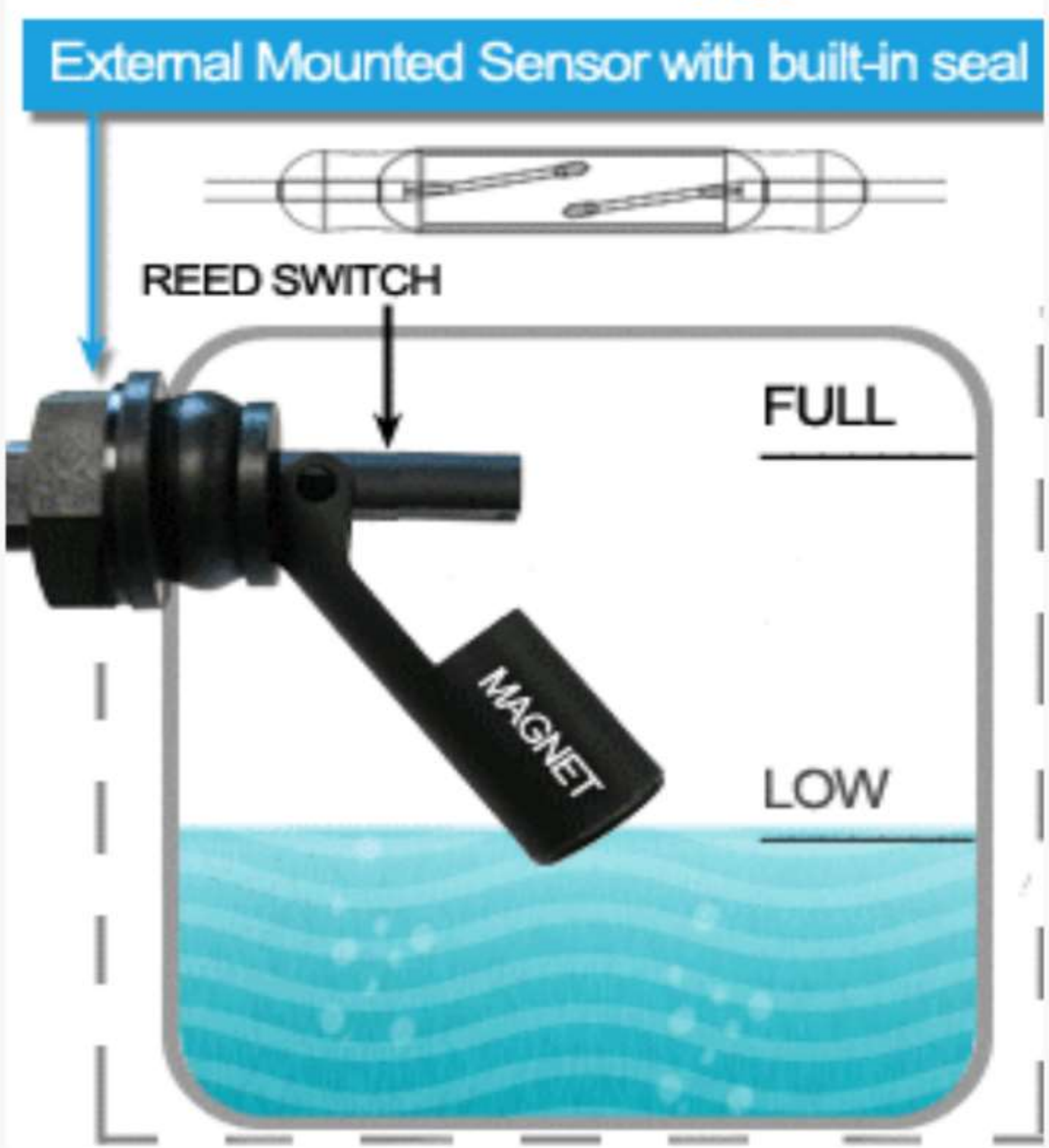
Capacitance Level Measurements.



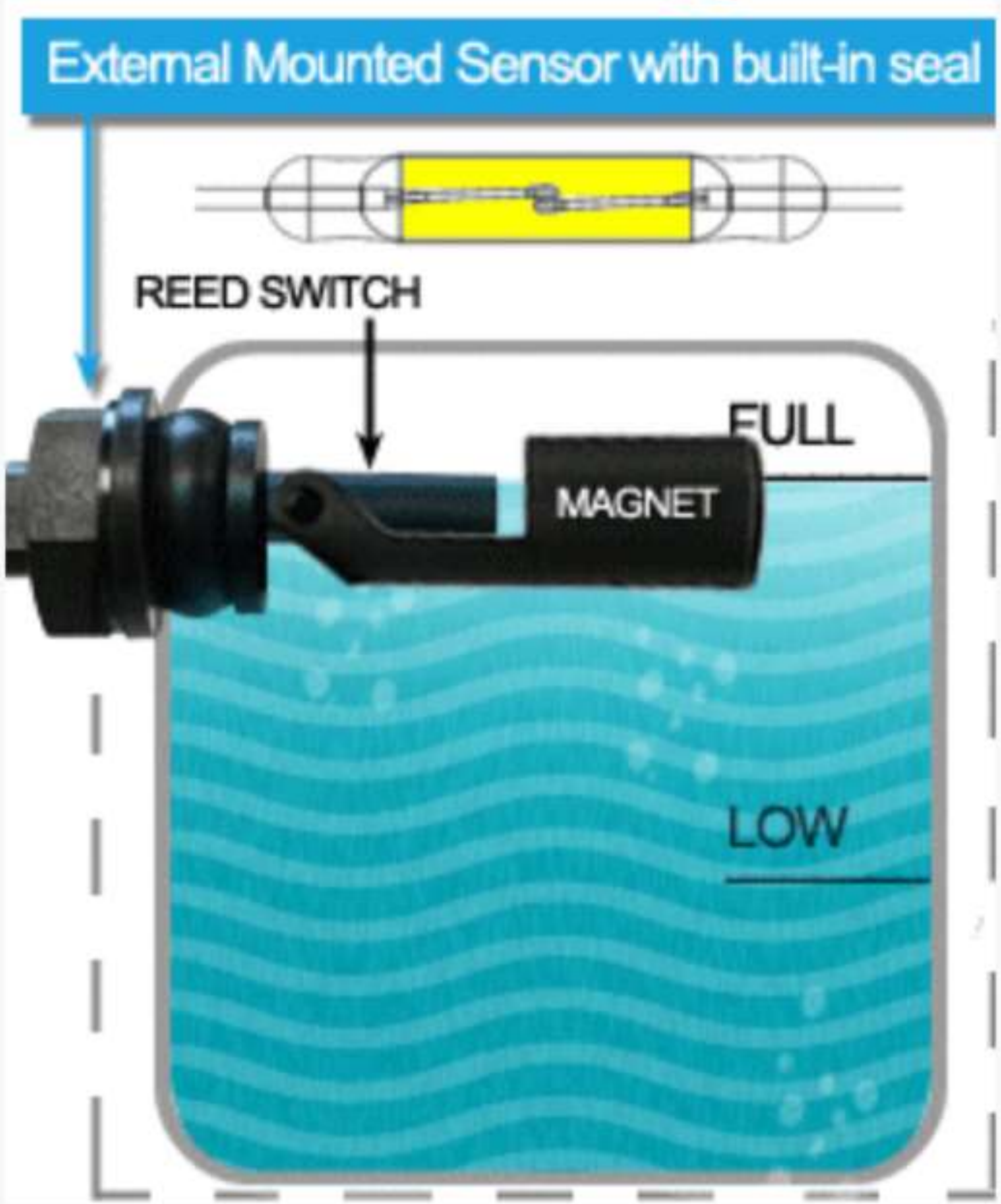


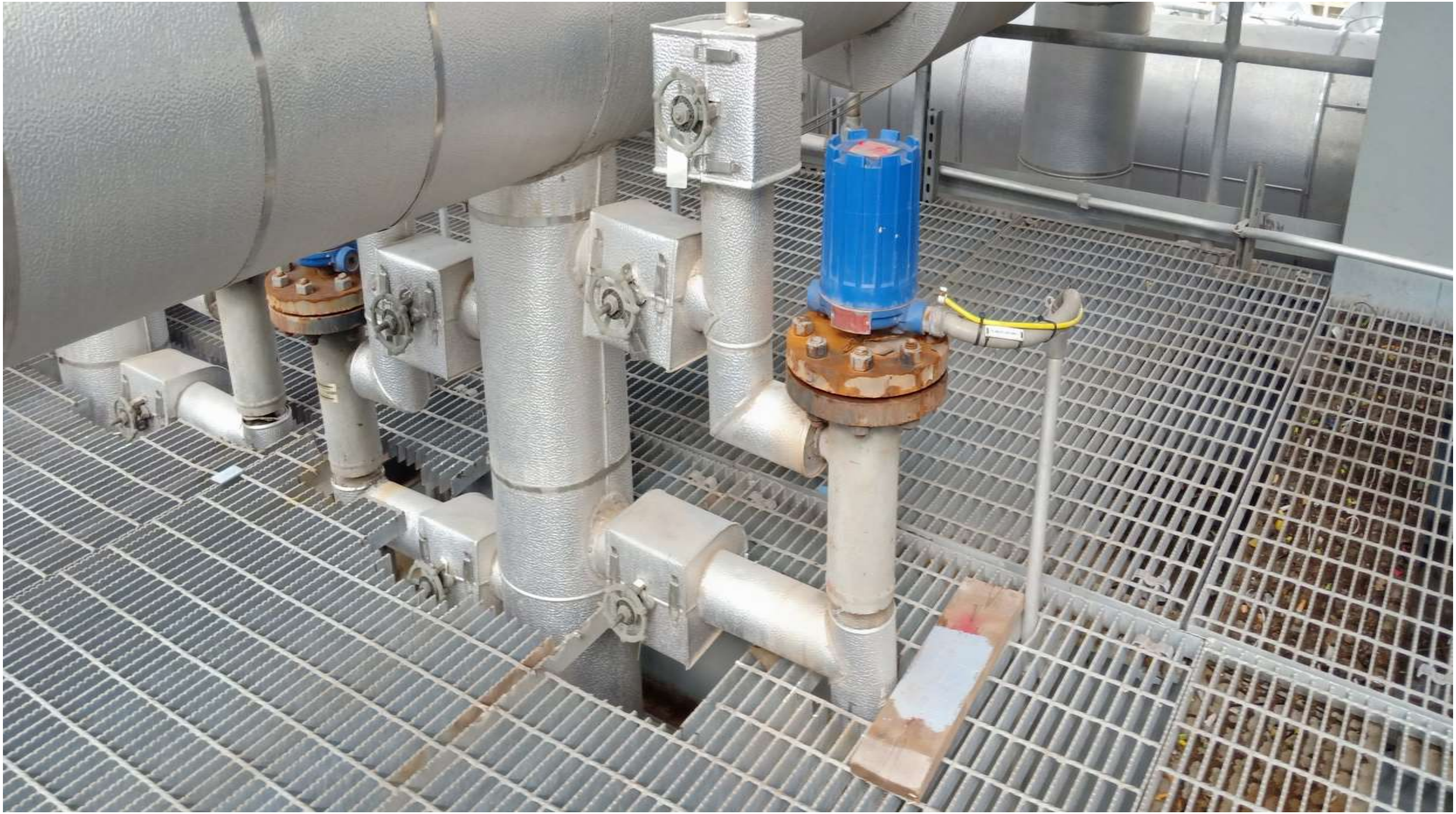
Level Switch

للمنسوب Level Switch



للمنسوب Level Switch





Temperature Measurements.

1. Thermocouples
2. Resistive Temperature Measuring Devices
3. Infrared Sensors
4. Bimetallic Devices
5. Thermometers
6. Change-of-state Sensors
7. Silicon Diode

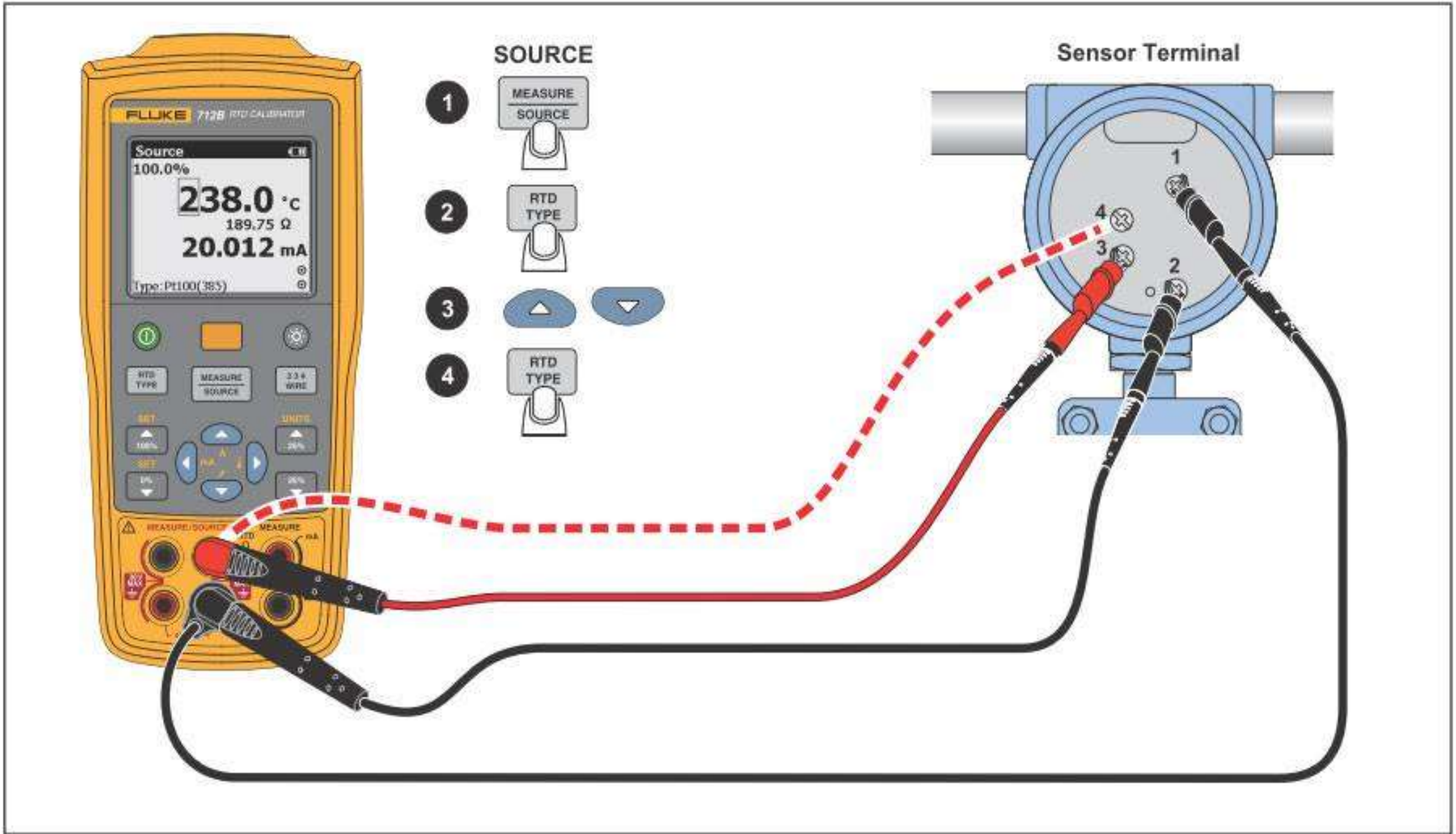

ABB


100,250,400, 550
HEAT
COOL
TEST
T : 14.9 °C
SP: 15.0 °C

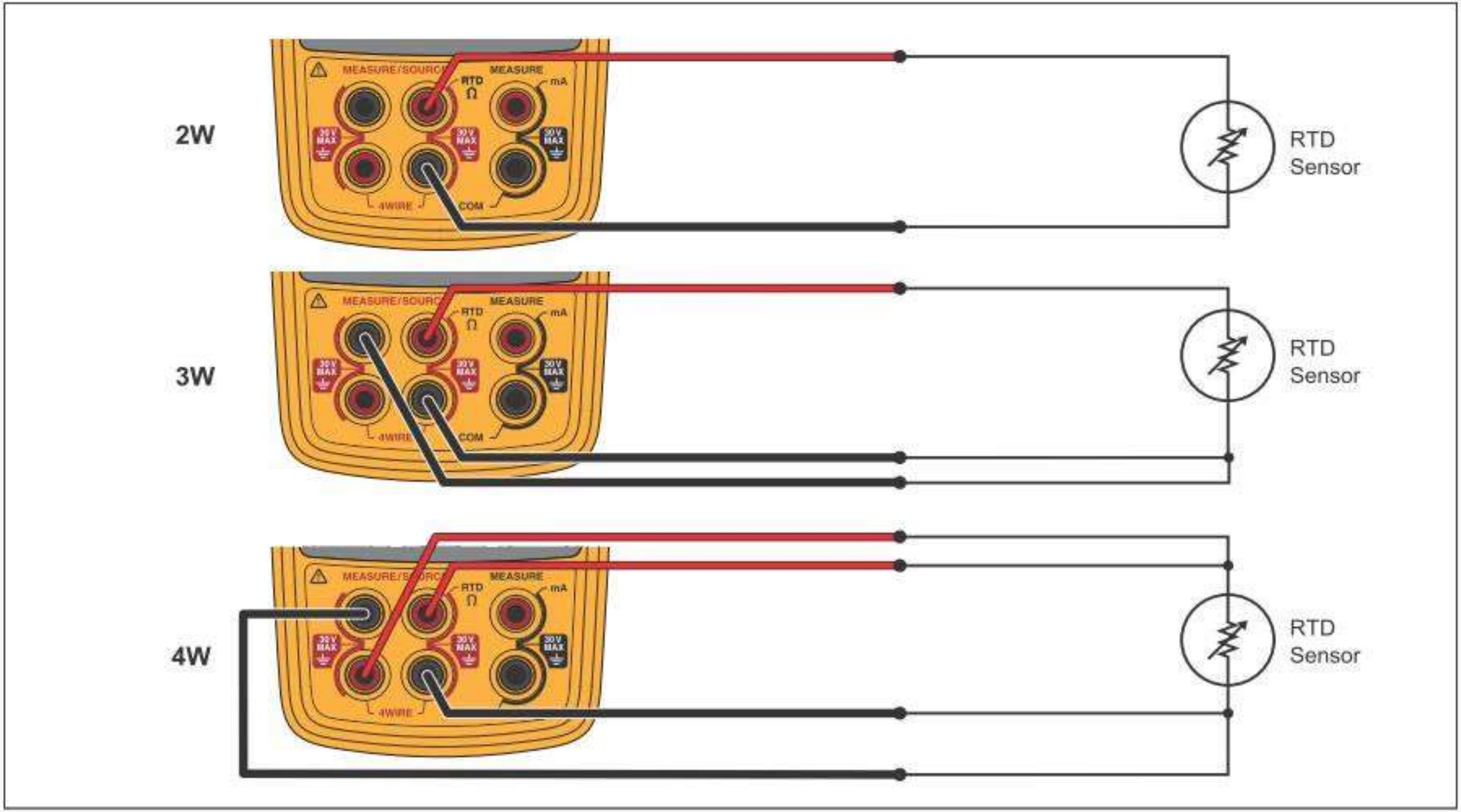
Temperature Calibration.

1. Connect the temperature calibrator to the correct place in the transmitter (RTD /Thermocouple).
2. The calibrator will feed the required power to the transmitter and will measure the current resulting from temperature changes into the transmitter In case of using Thermocouples we have to obtain the correct type from the calibrator.
3. Increase the simulated temperature input in (bases of 25%) 0 ~100% of the required approved calibration range.
4. Decrease the simulated temperature input in (base of 25 %) 100 ~ 0% of the required approved calibration range.
5. All calibration procedure shall be recorded in a certificate.

HART COMMUNICATOR 475
Additel 223A multifunction, Use as
Power Supply 24 VDC,
SIMULATION(source) TC/RTD
Resistance 250 Ohm
TC CABLE
POWER CABLE
Temperature Transmitter. TIT

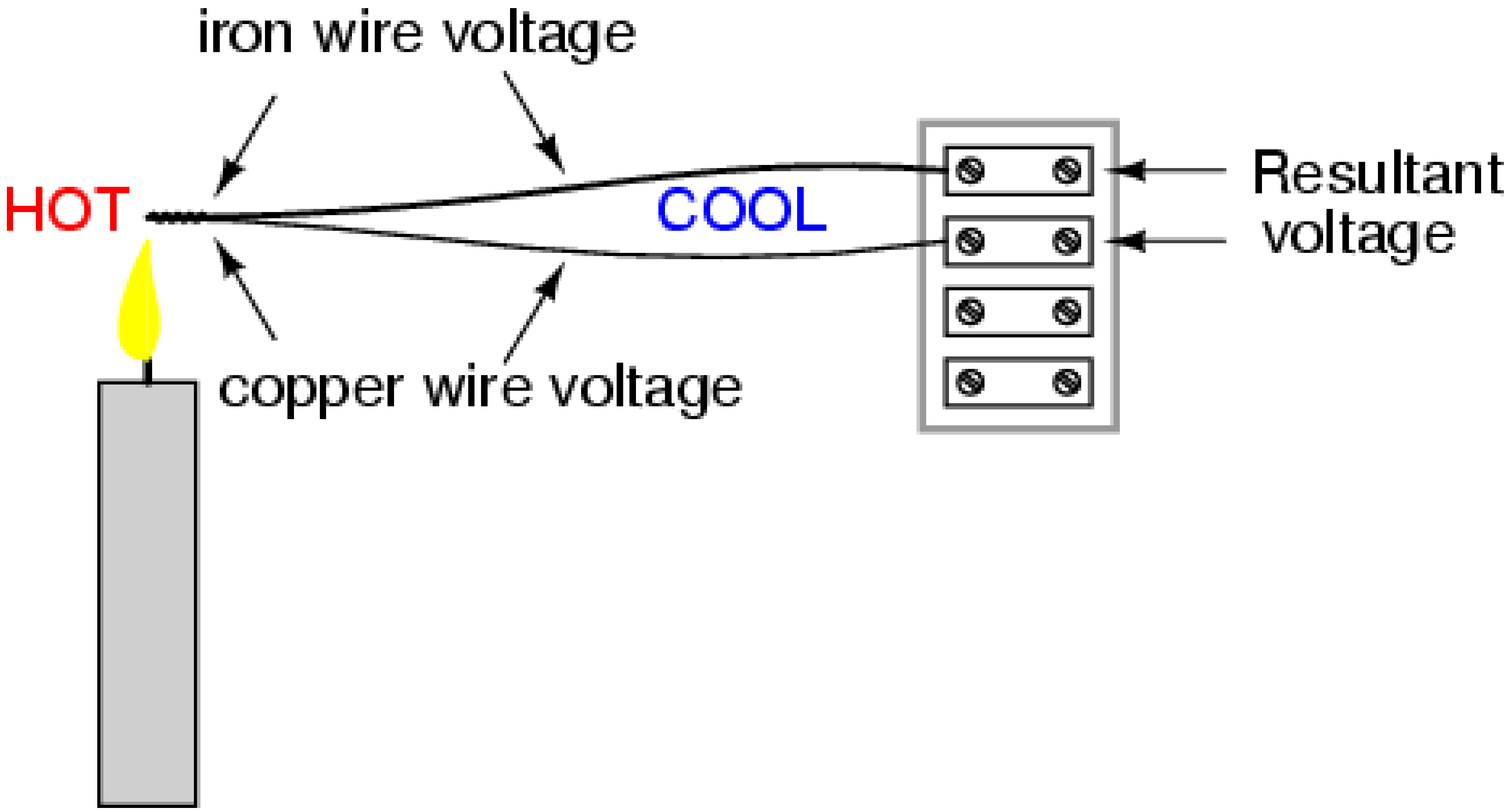


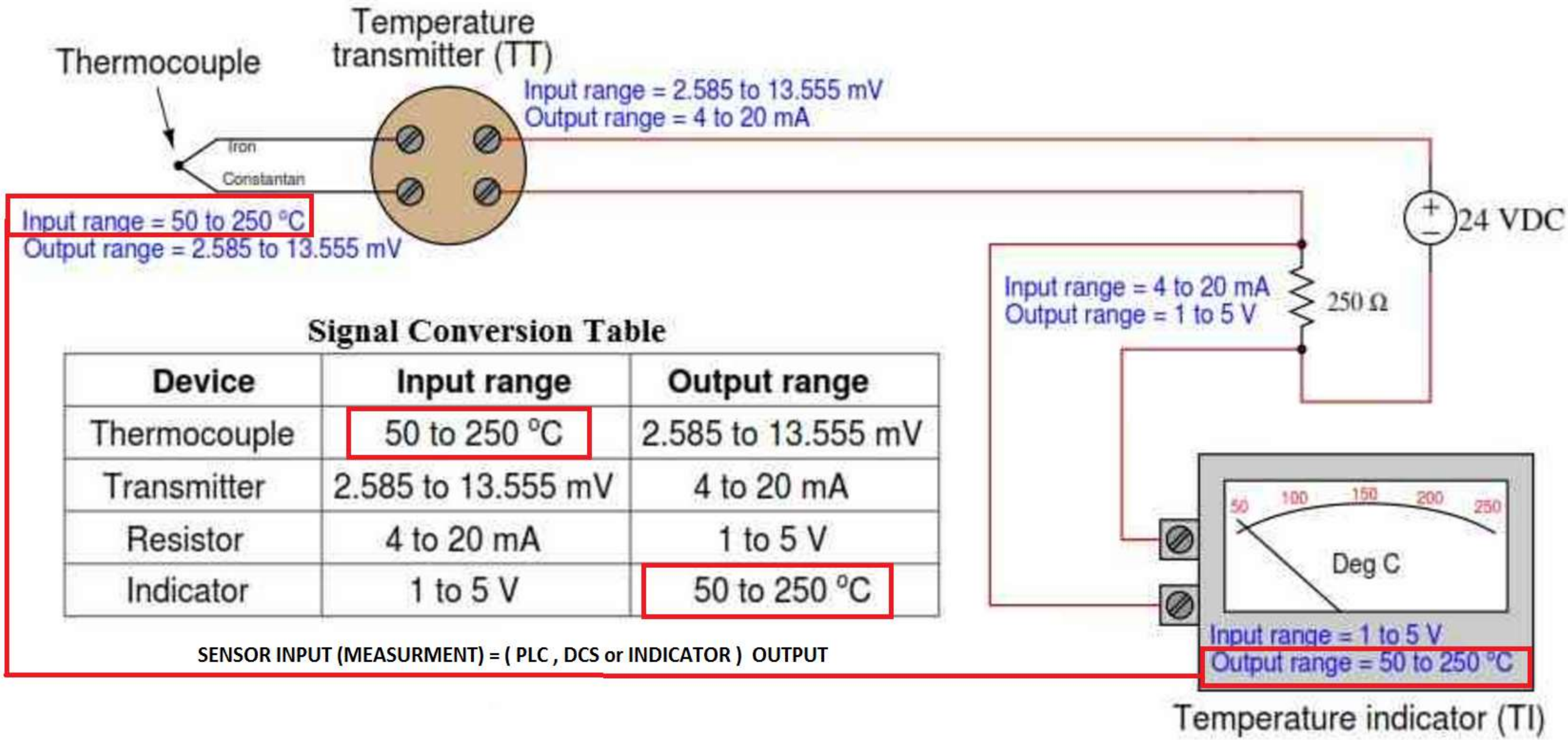
SOURCE
Sensor Terminal
1
2
3
4
MEASURE
SOURCE
RTD
TYPE
RTD
TYPE
FLUKE 712B RTD CALIBRATOR
Source
100.0%
238.0 °C
189.75 Ω
20.012 mA
Type: Pt100(385)



2W
3W
4W
MEASURE/SOURCE
RTD
Ω
MEASURE
mA
30 V MAX
4WIRE
COM
RTD Sensor
RTD Sensor
RTD Sensor


Signal:Pt100 Rank:0.2%FS
Voltage:24VDC Out:4-20mA
Range: 0-50 ℃


iron wire voltage
HOT
COOL
Resultant voltage
copper wire voltage

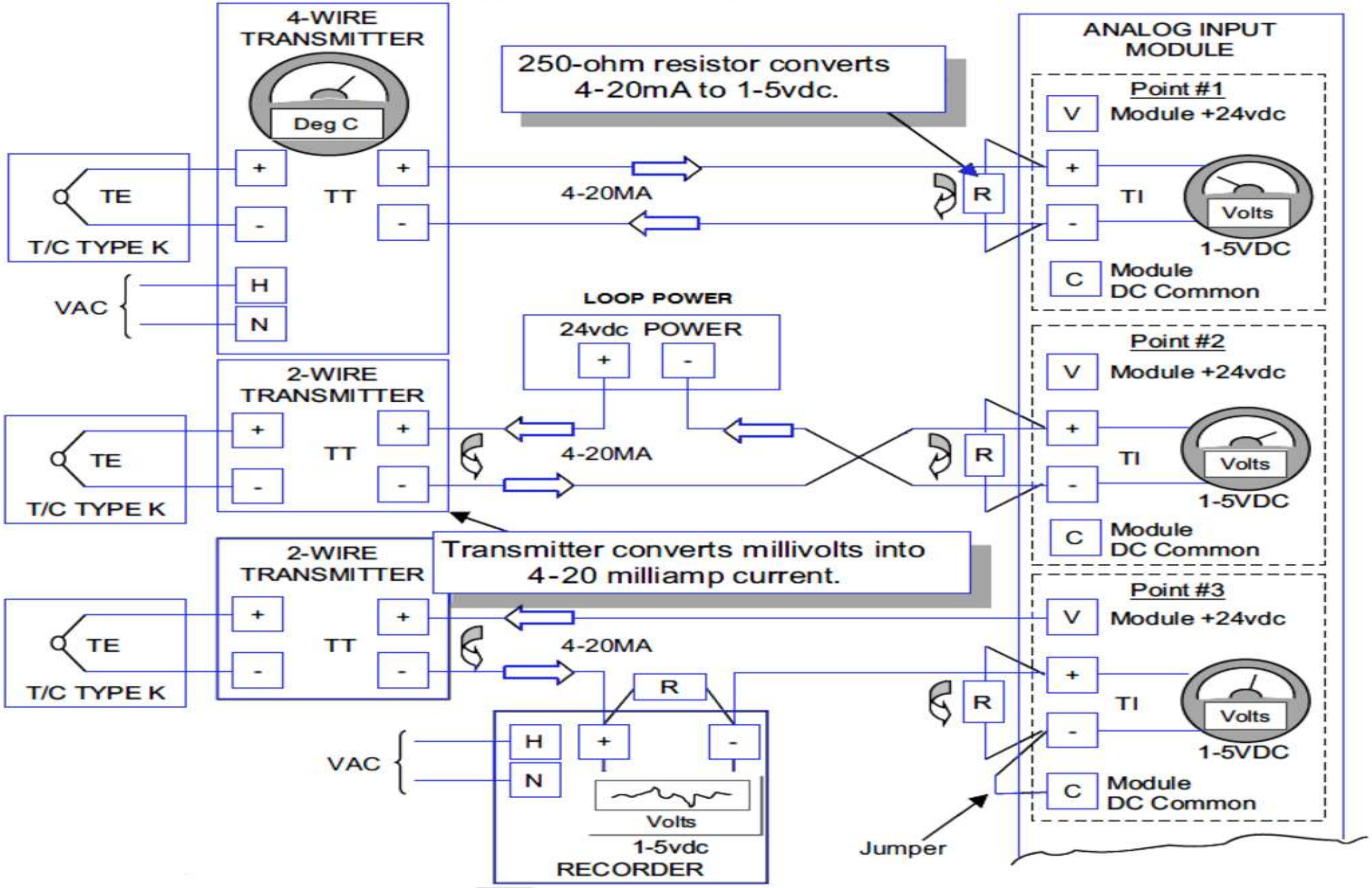


Signal Conversion Table

Device	Input range	Output range
Thermocouple	50 to 250 °C	2.585 to 13.555 mV
Transmitter	2.585 to 13.555 mV	4 to 20 mA
Resistor	4 to 20 mA	1 to 5 V
Indicator	1 to 5 V	50 to 250 °C

SENSOR INPUT (MEASURMENT) = (PLC , DCS or INDICATOR) OUTPUT

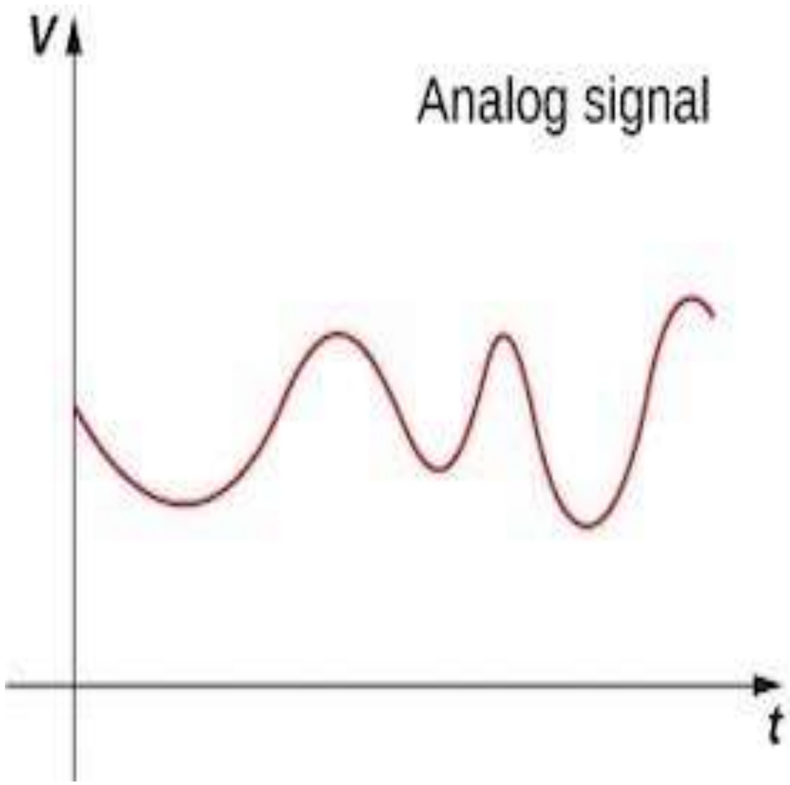
PLC ANALOG SIGNALS WIRING TECHNIQUES

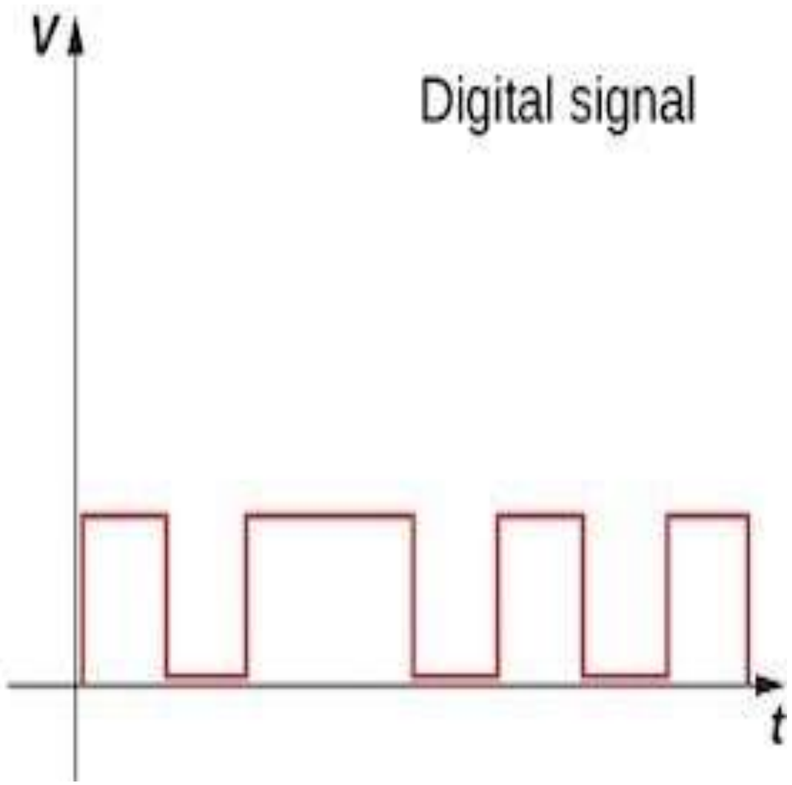


Loop Test.

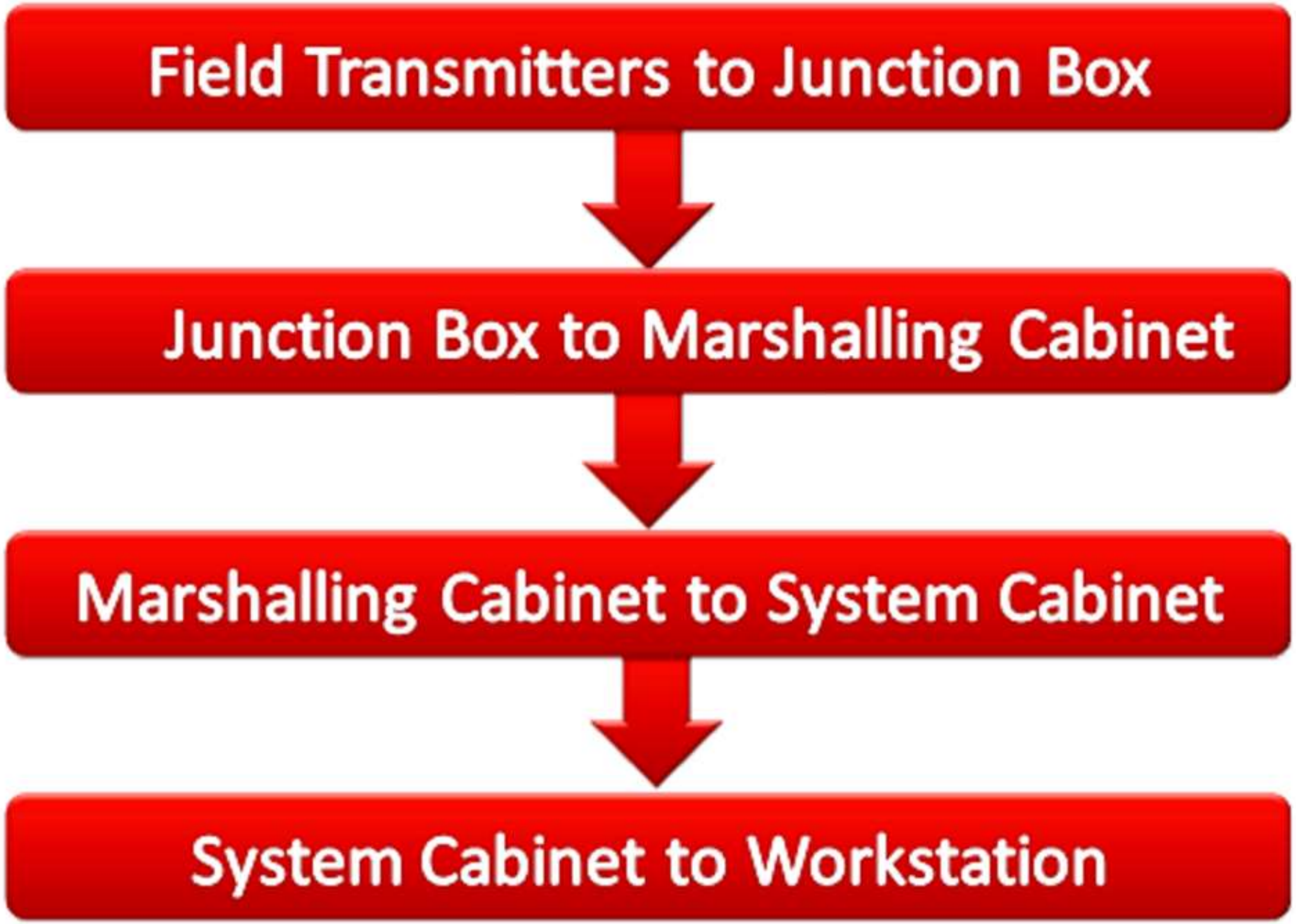
- Type of signal

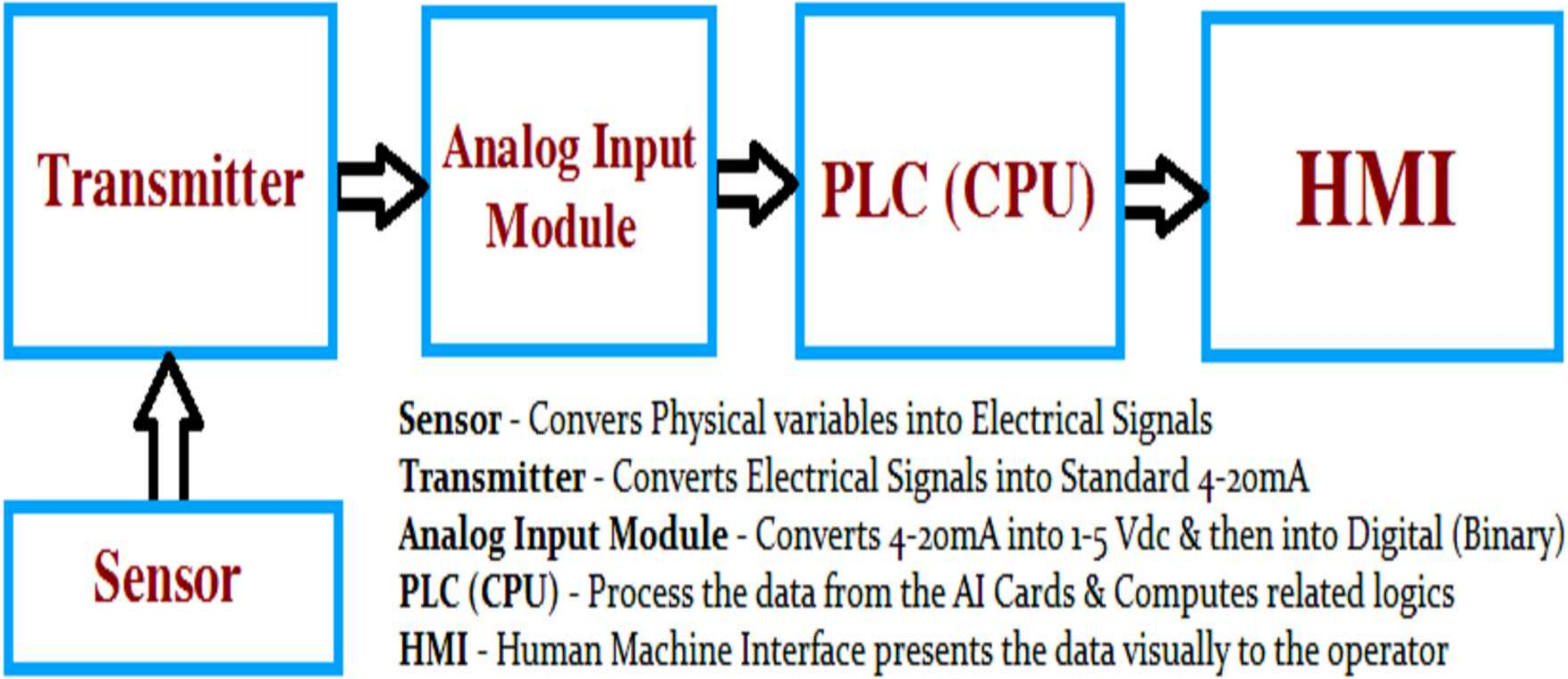
1. Analog signal
2. Digital Signal
3. Pulse Signal





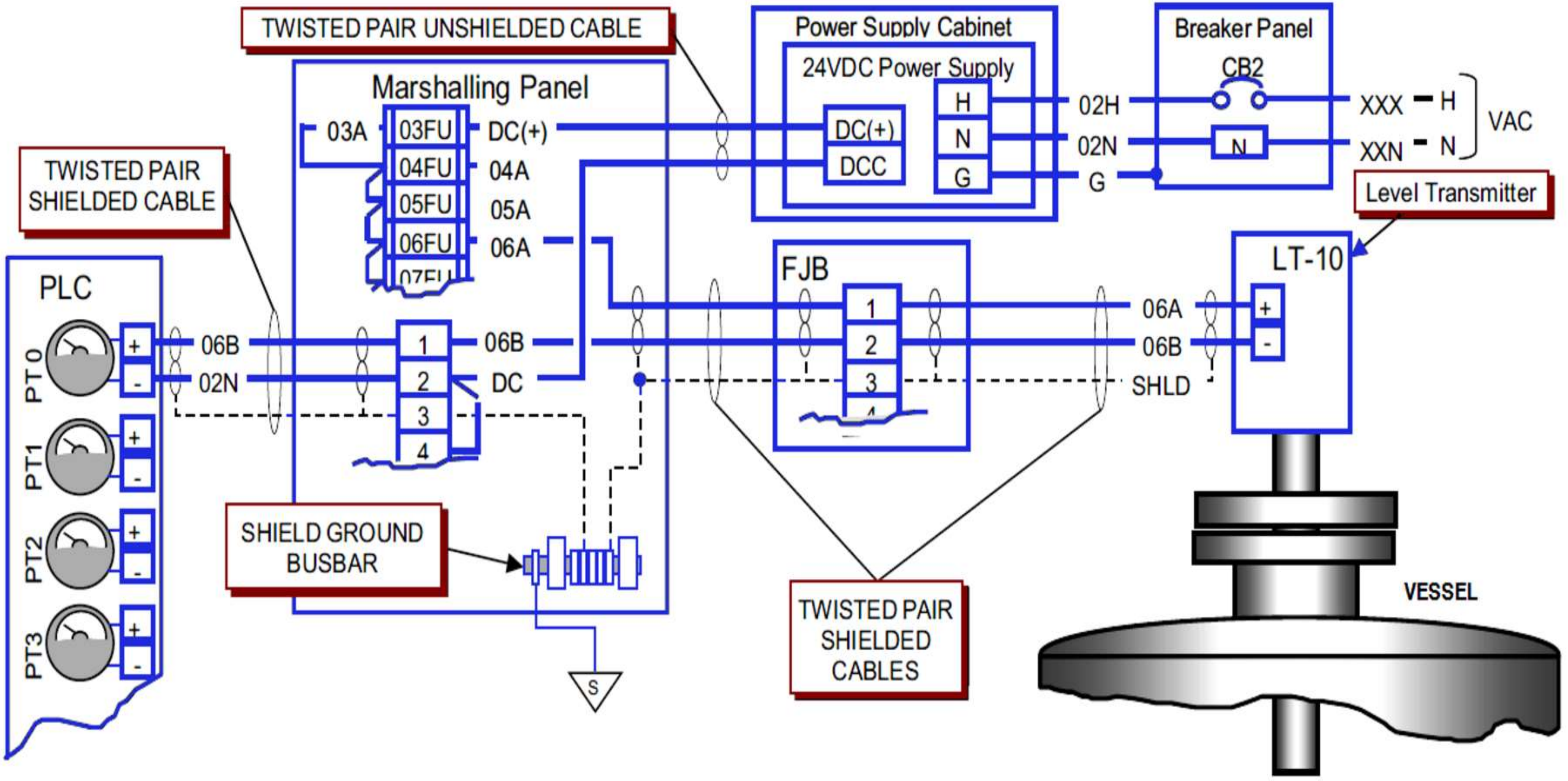
Signal Flow :


Field Transmitters to Junction Box
Junction Box to Marshalling Cabinet
Marshalling Cabinet to System Cabinet
System Cabinet to Workstation

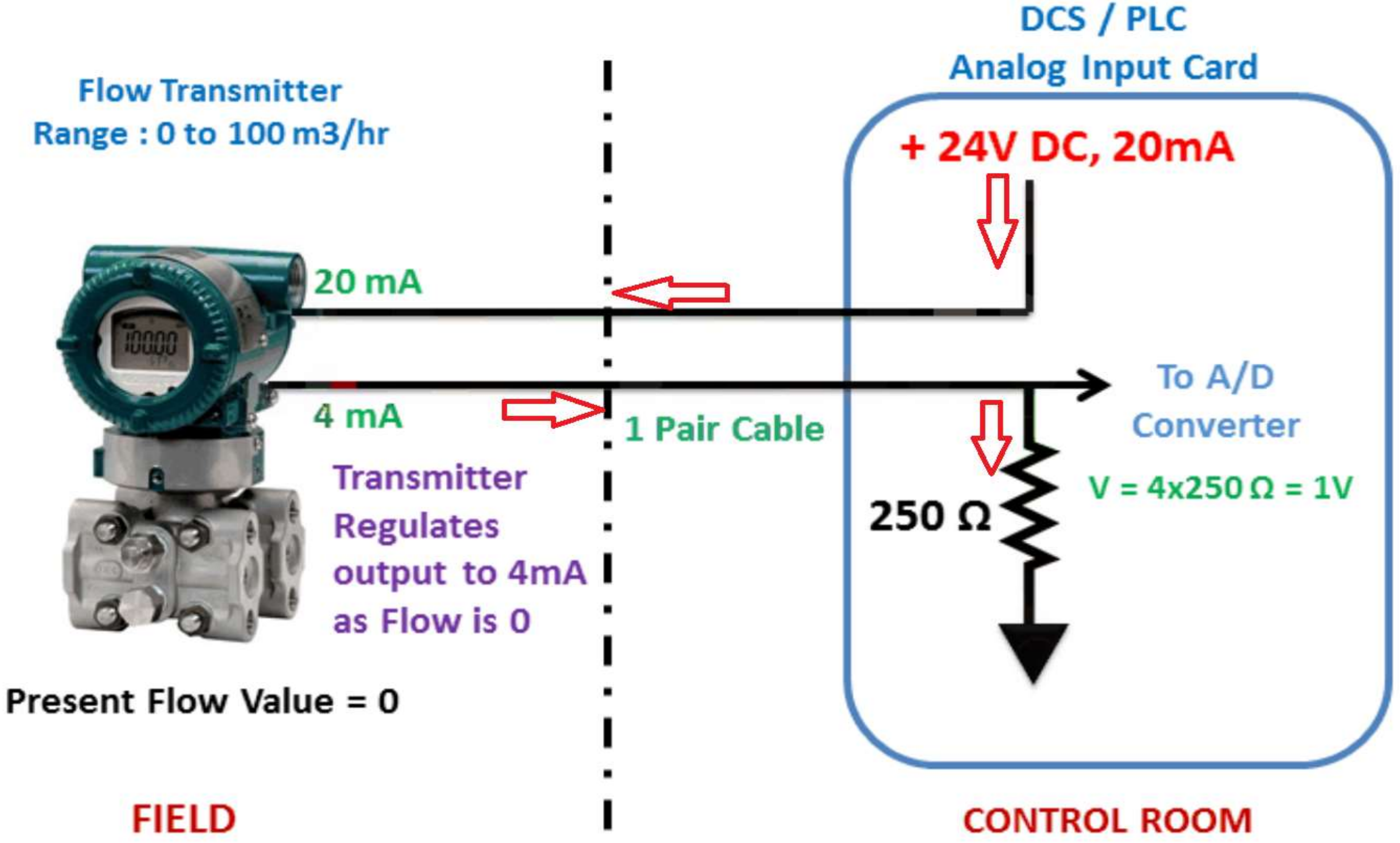


Sensor - Convers Physical variables into Electrical Signals
Transmitter - Converts Electrical Signals into Standard 4-20mA
Analog Input Module - Converts 4-20mA into 1-5 Vdc & then into Digital (Binary)
PLC (CPU) - Process the data from the AI Cards & Computes related logics
HMI - Human Machine Interface presents the data visually to the operator

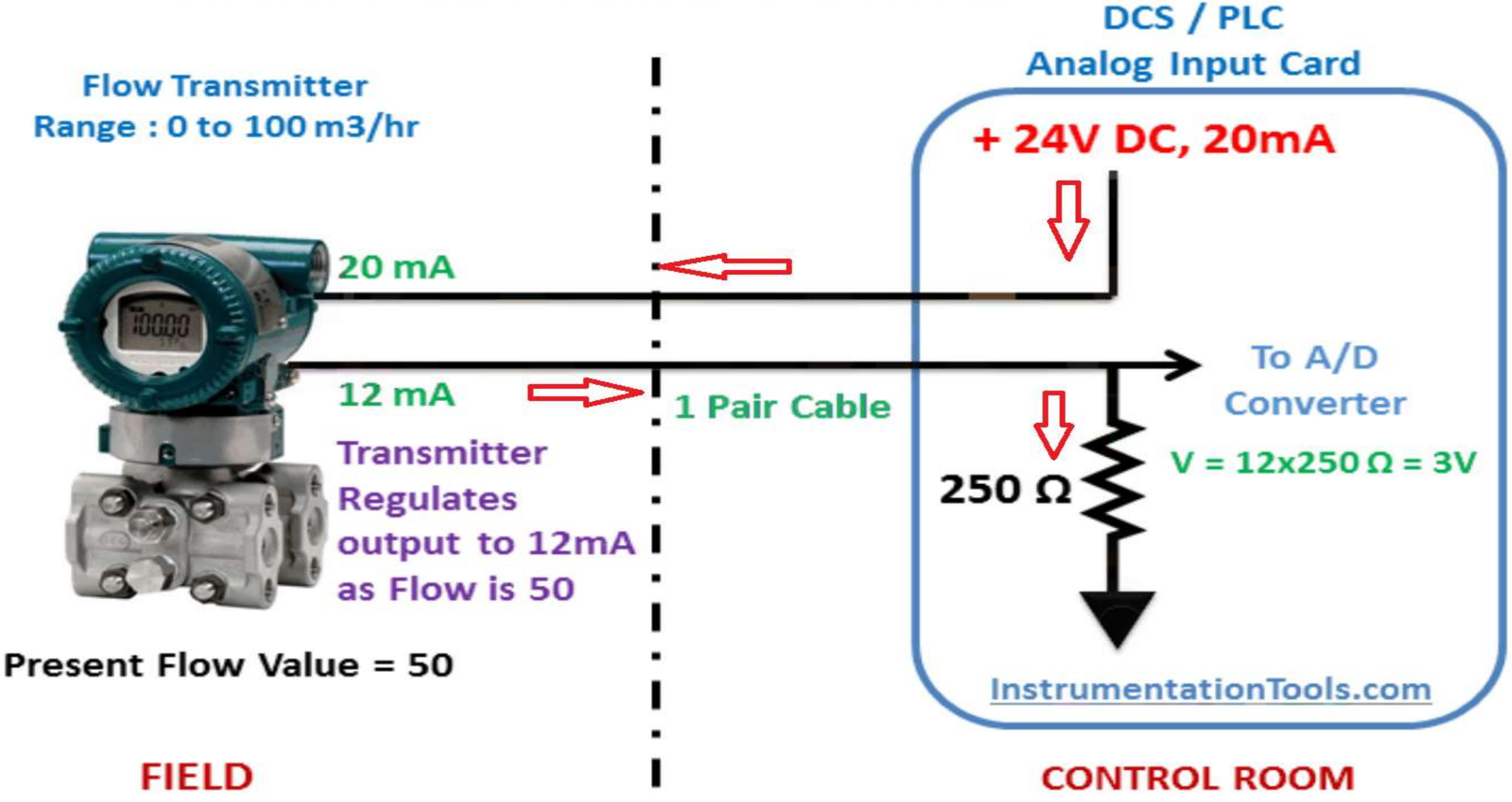
PLC / DCS ANALOG SIGNALS WIRING TECHNIQUES

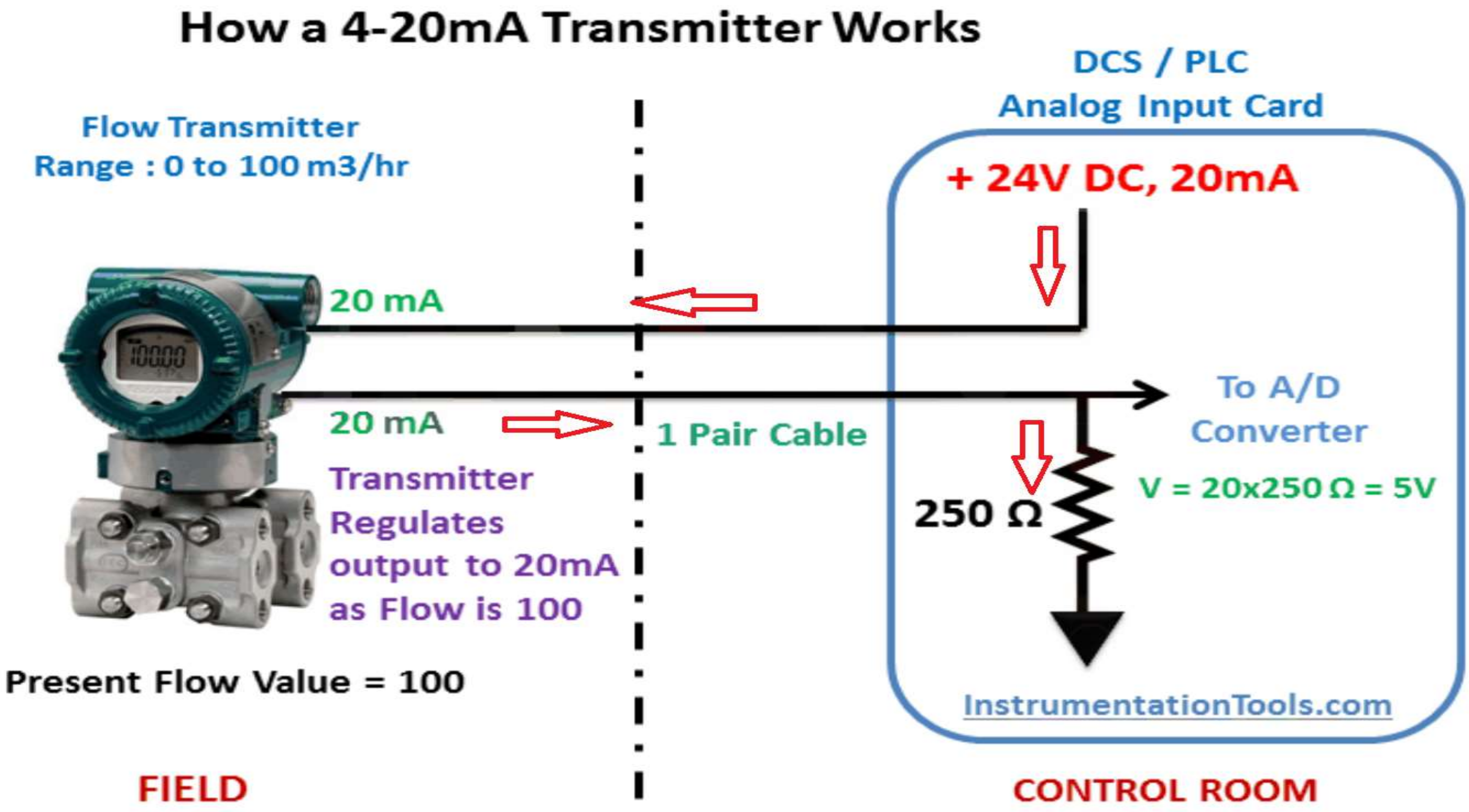


How a 4-20mA Transmitter Works

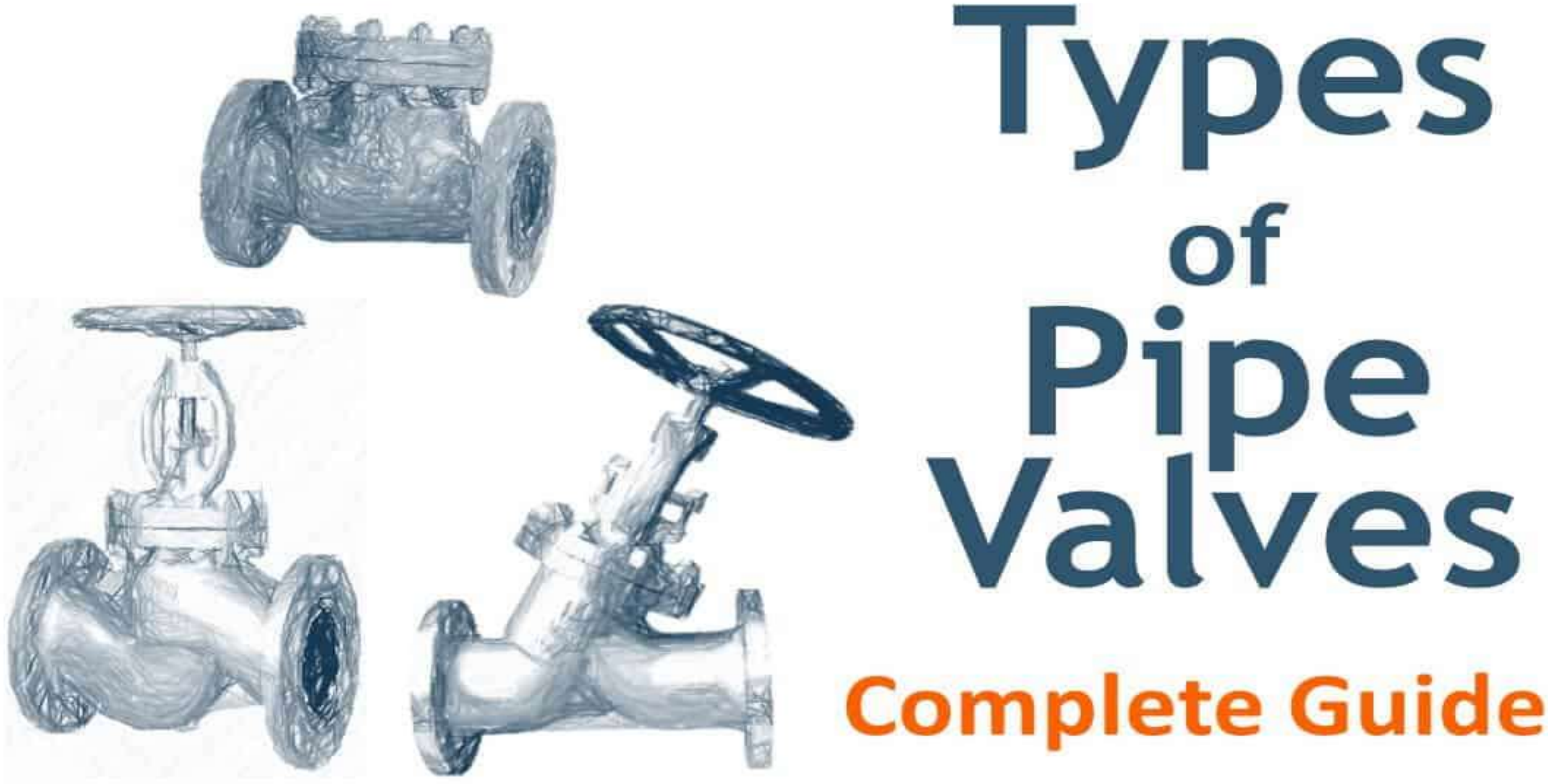


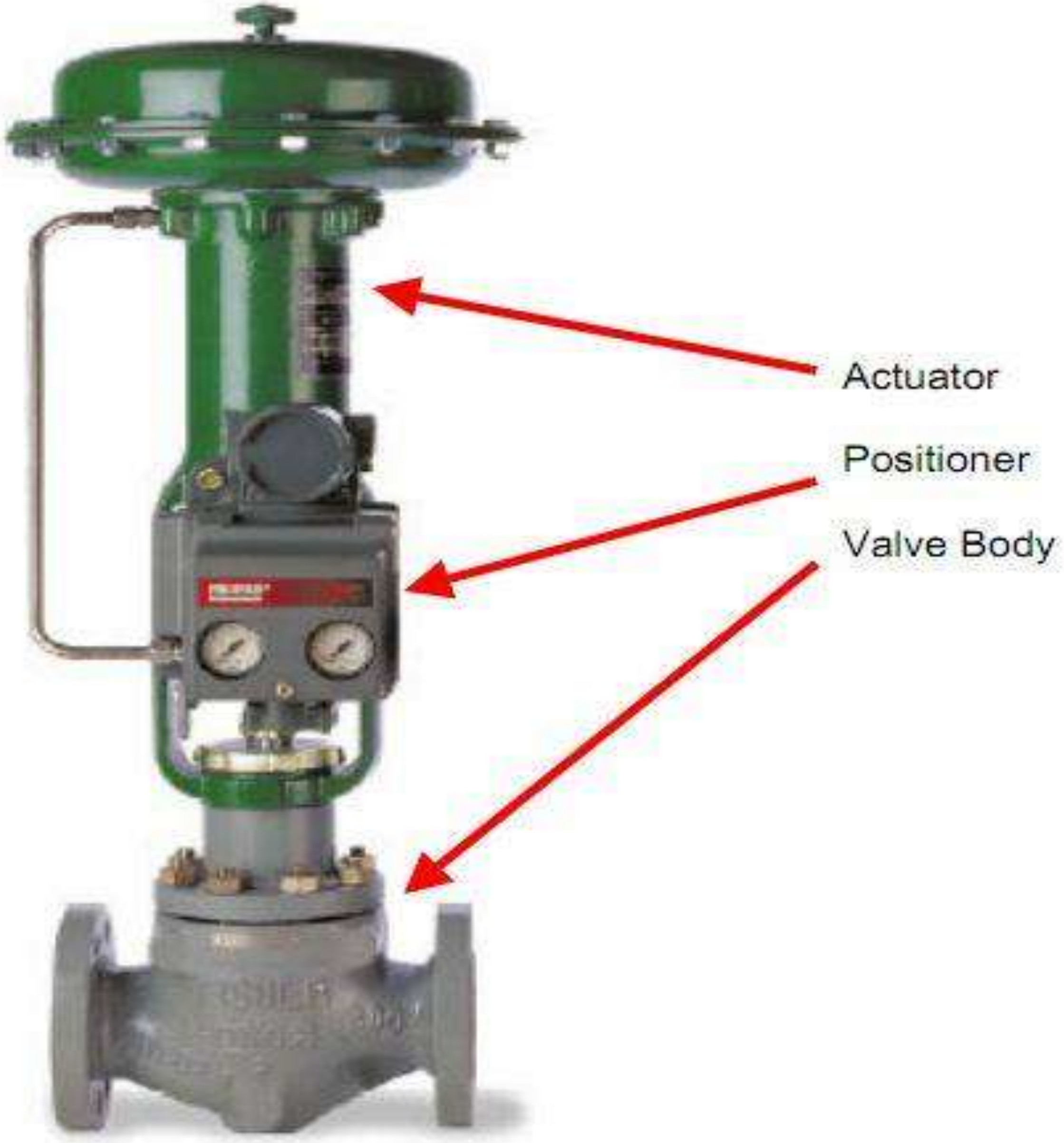
How a 4-20mA Transmitter Works




How a 4-20mA Transmitter Works
DCS / PLC
Analog Input Card
Flow Transmitter
Range : 0 to 100 m3/hr
+ 24V DC, 20mA
20 mA
To A/D
Converter
20 mA
1 Pair Cable
Transmitter
Regulates
output to 20mA
as Flow is 100
V = 20x250 Ω = 5V
250 Ω
Present Flow Value = 100
InstrumentationTools.com
FIELD
CONTROL ROOM

Valves





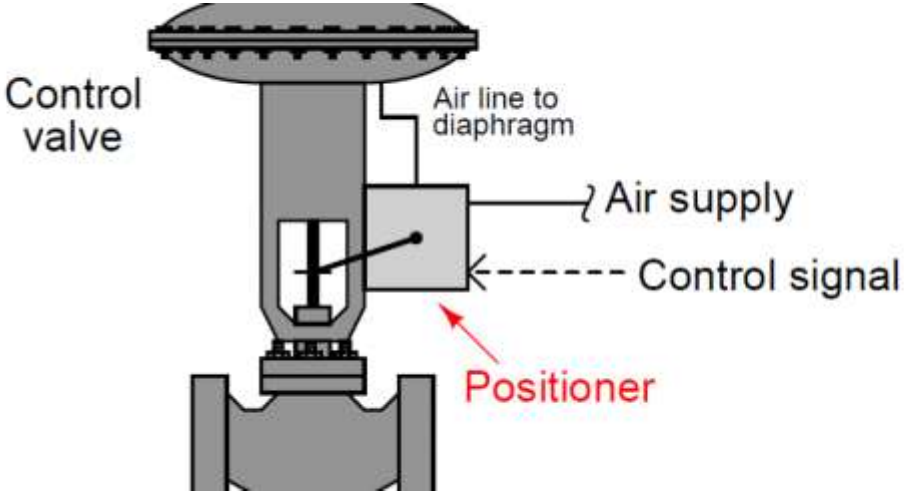
Three Major Control Valve Components

Type of valve actuator

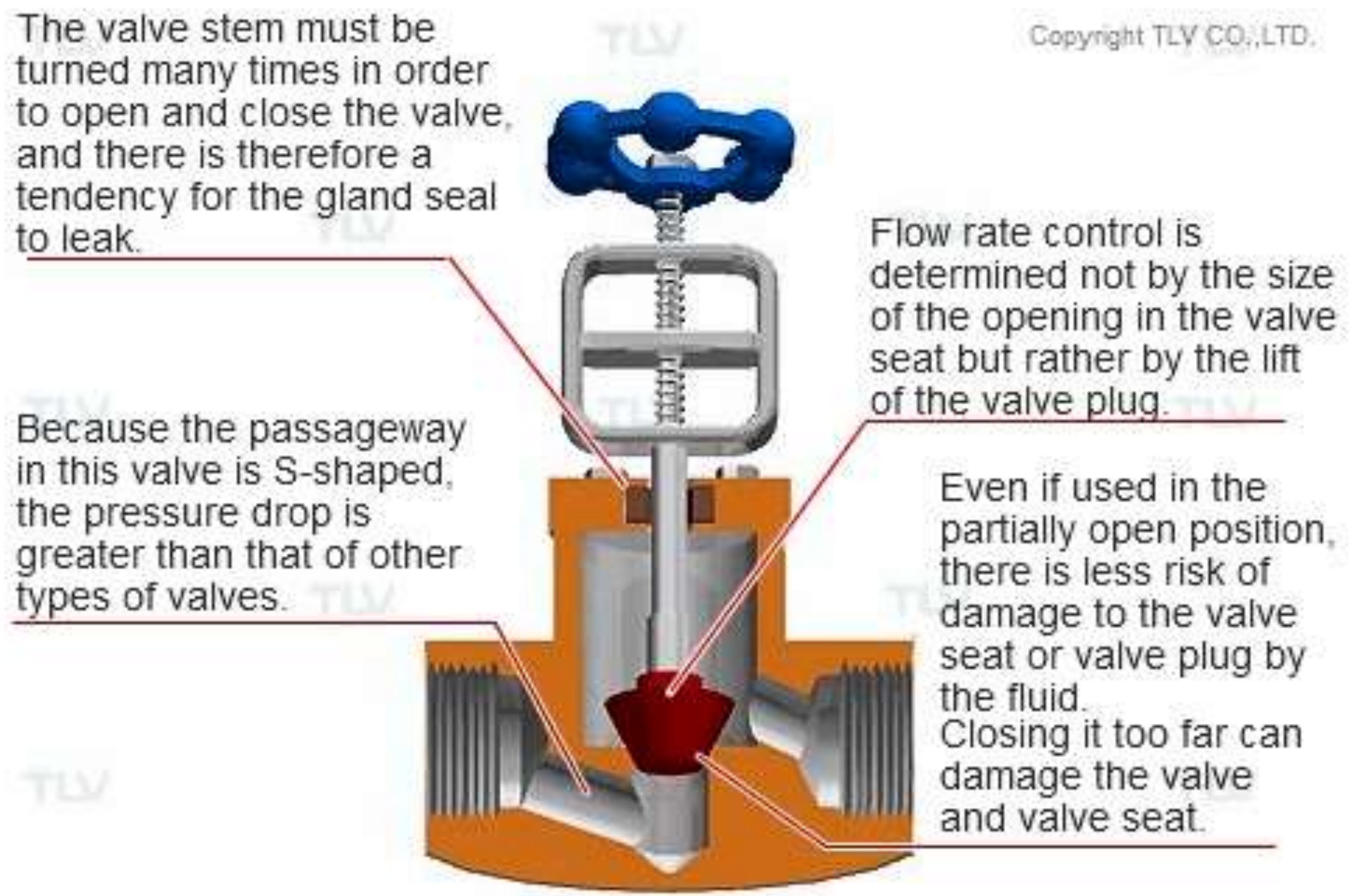
1. Manual
2. Pneumatic
3. Hydraulic
4. Electric
5. Spring

valve Positioner

- **valve Positioner** is a device used to increase or decrease the air load pressure driving the actuator until the **valve's** stem reaches a "POSITION" balanced to the output SIGNAL from the process variable instrument controller

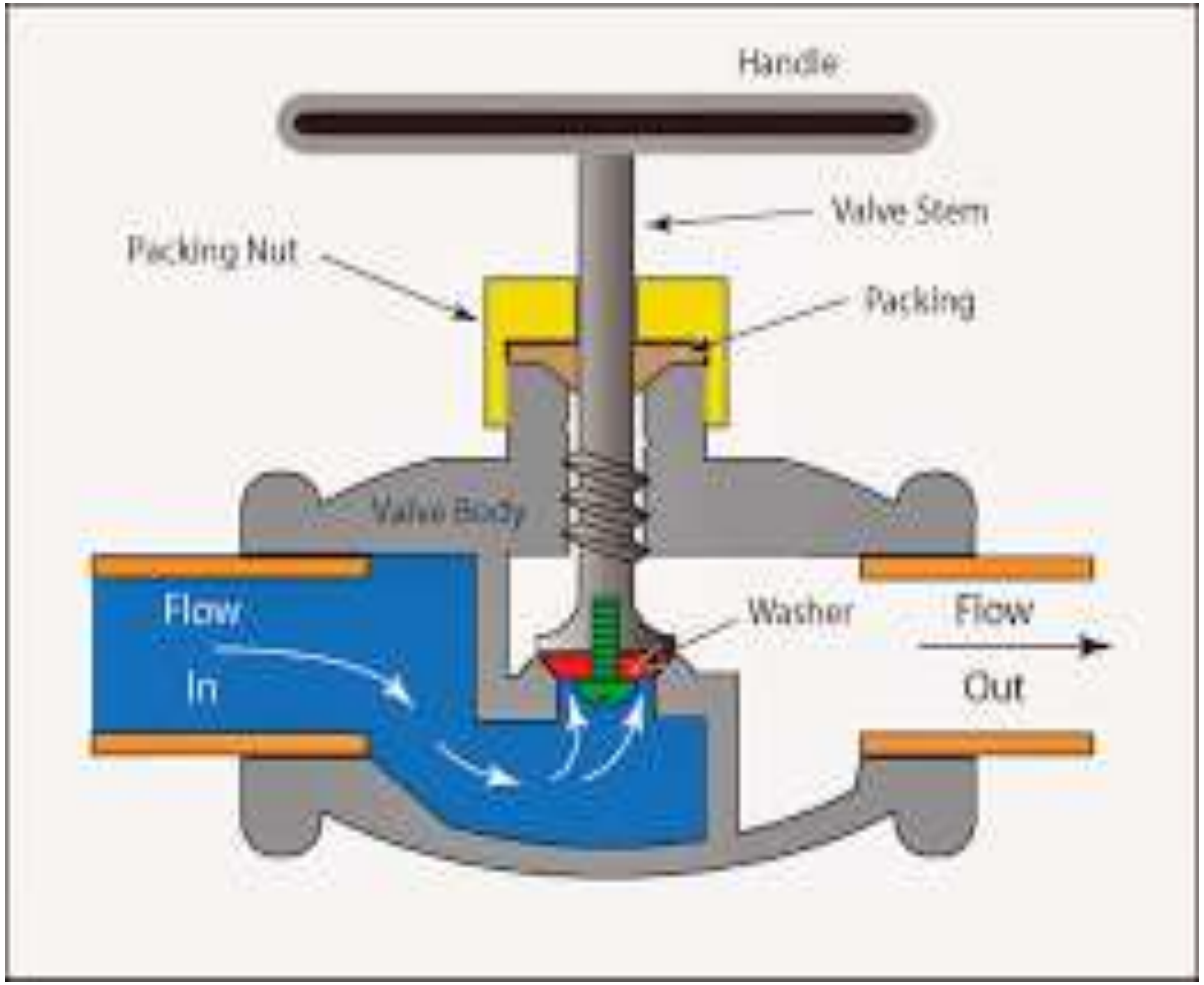


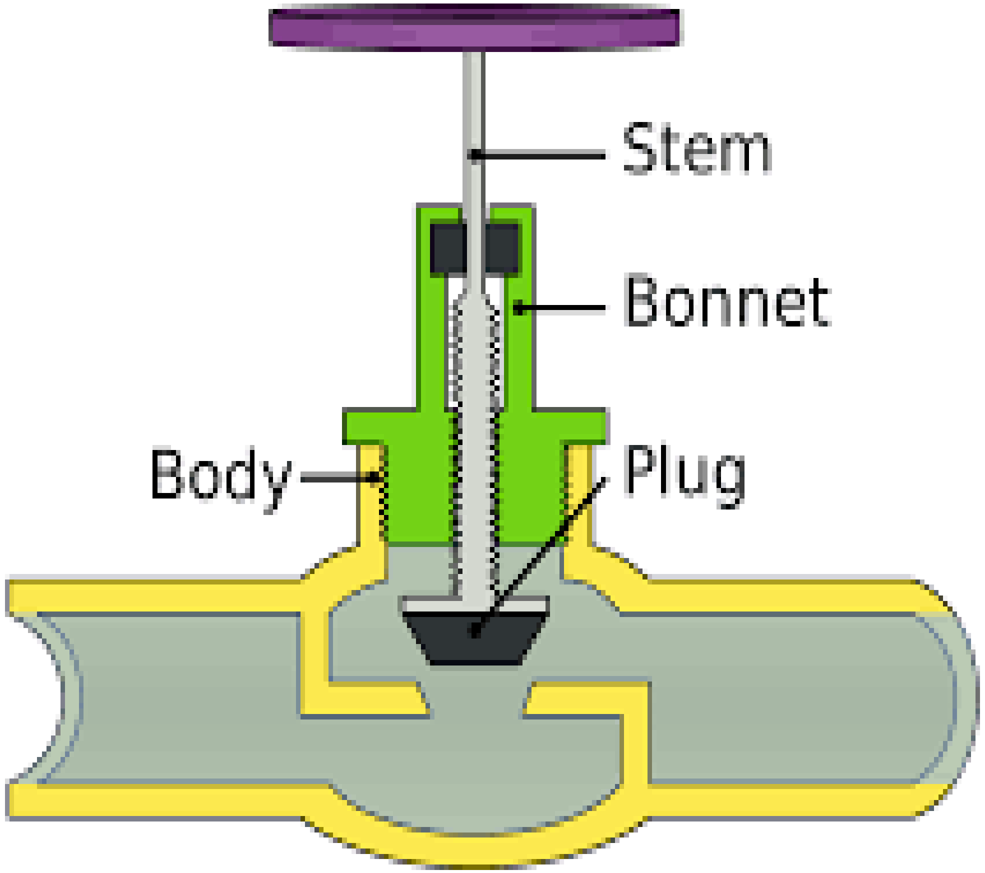
Globe Valve



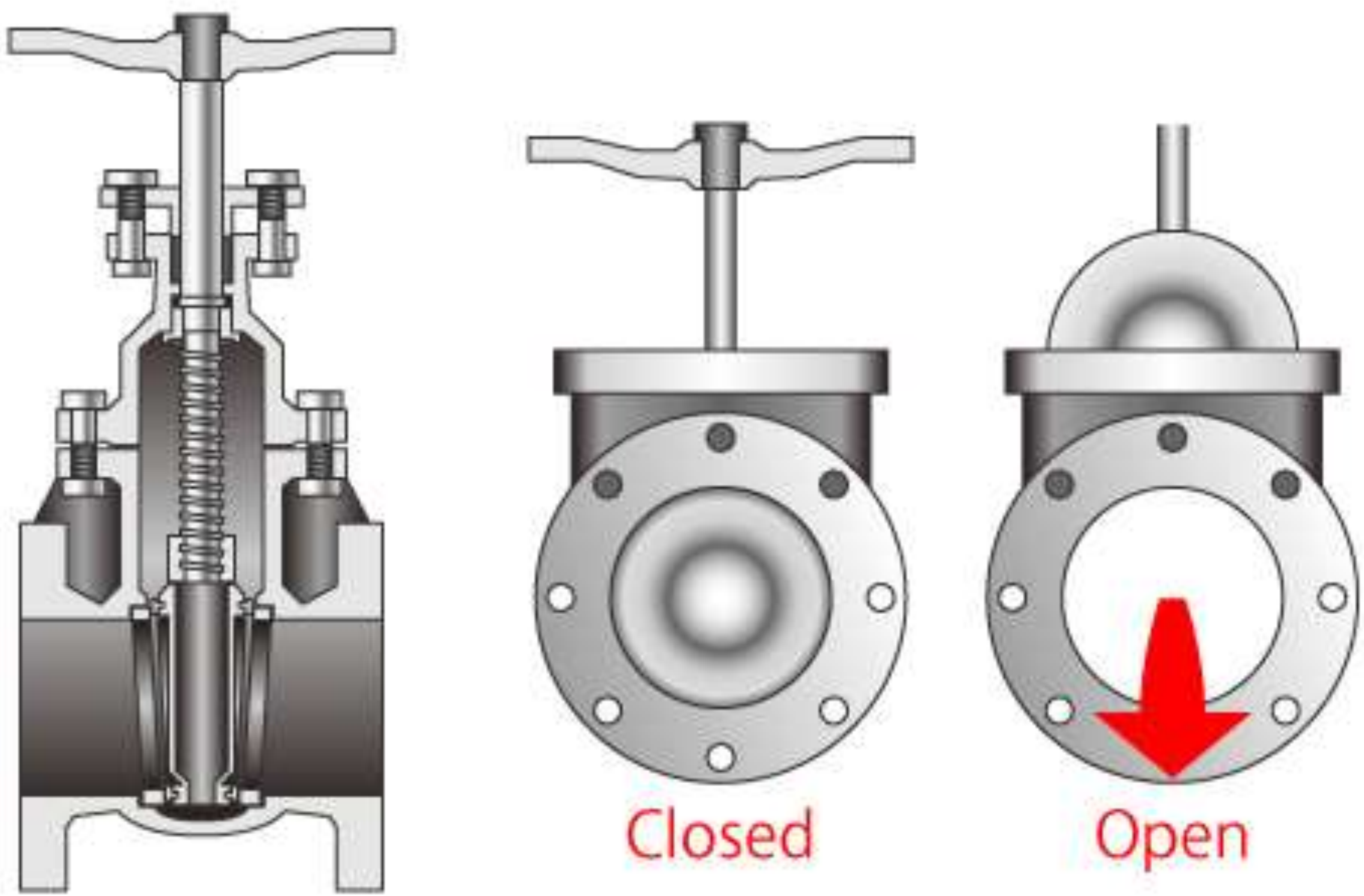
The valve stem must be turned many times in order to open and close the valve, and there is therefore a tendency for the gland seal to leak.
Copyright TLV CO.,LTD.
Flow rate control is determined not by the size of the opening in the valve seat but rather by the lift of the valve plug.
Because the passageway in this valve is S-shaped, the pressure drop is greater than that of other types of valves.
Even if used in the partially open position, there is less risk of damage to the valve seat or valve plug by the fluid.
Closing it too far can damage the valve and valve seat.

Globe Valve

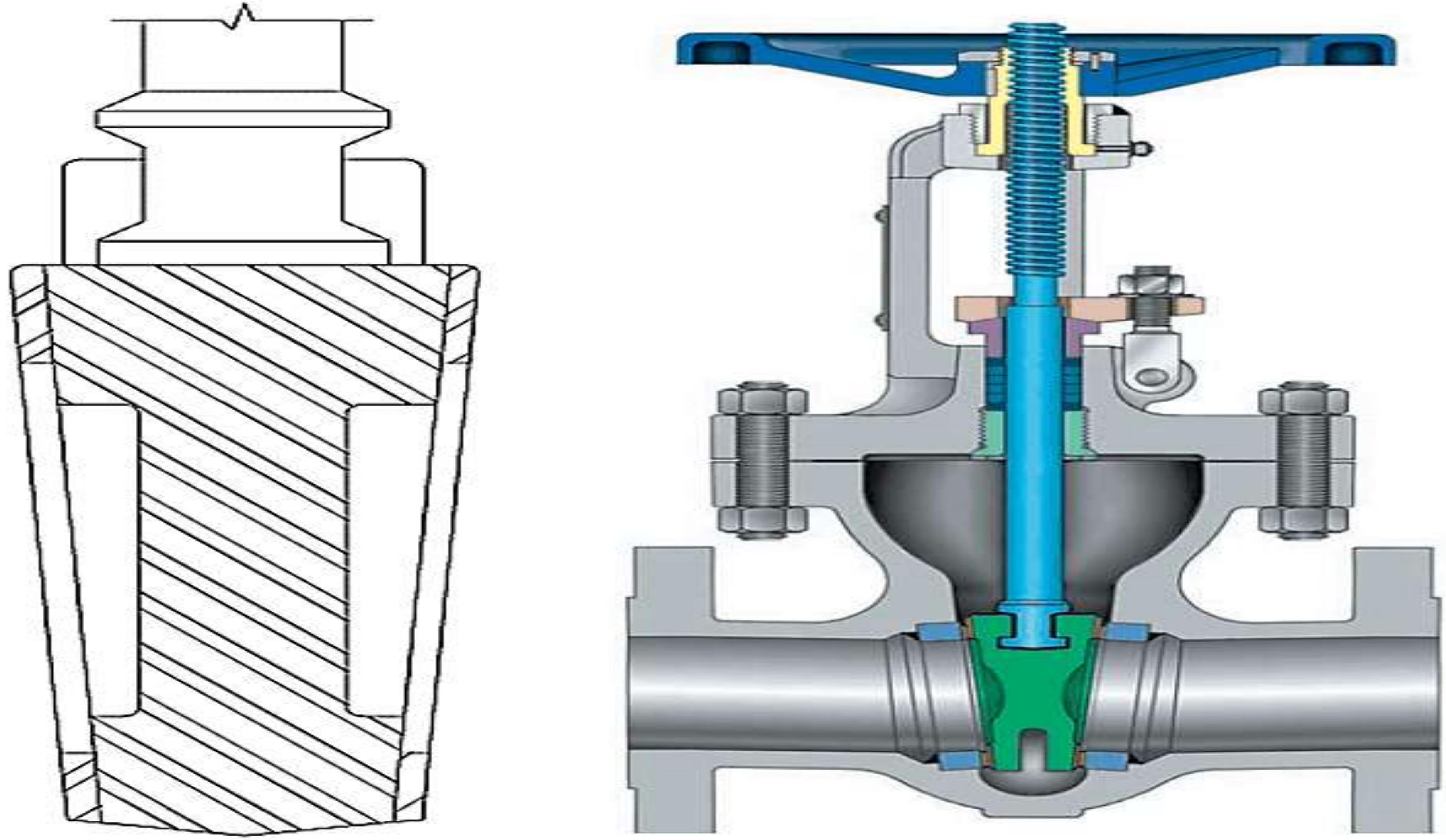

Handle
Valve Stem
Packing Nut
Packing
Valve Body
Washer
Flow
In
Flow
Out


Stem
Bonnet
Body
Plug

Gate Valve

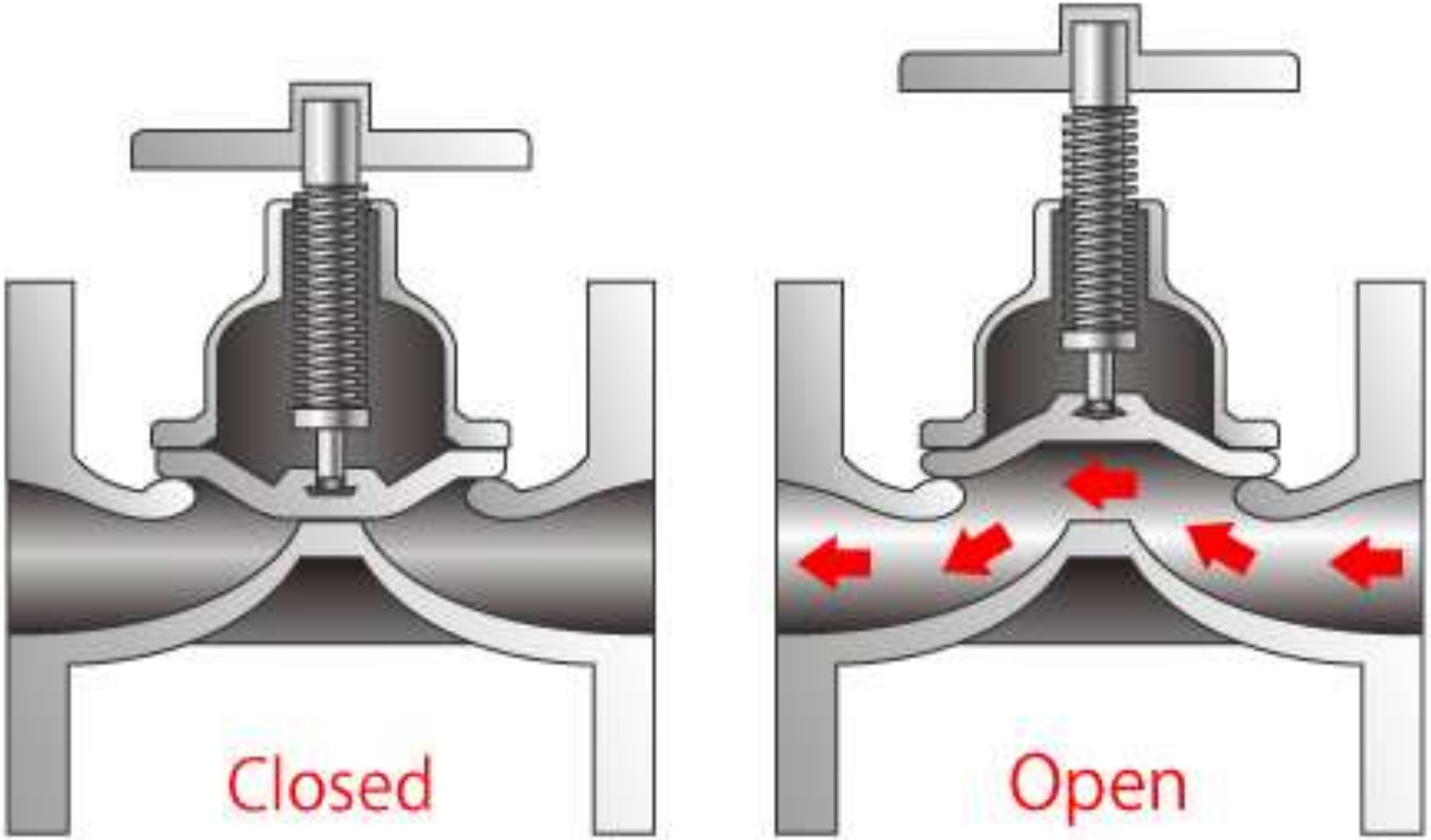


Gate Valve

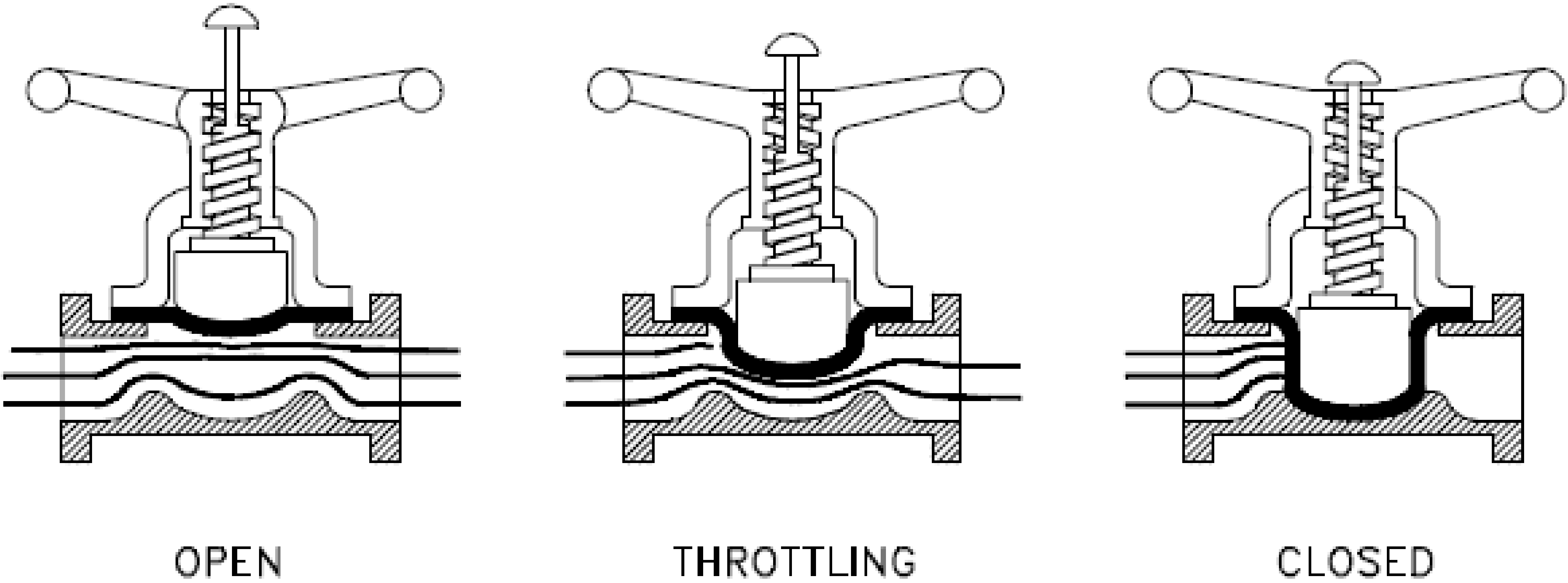


Solid Wedge Gate Valve

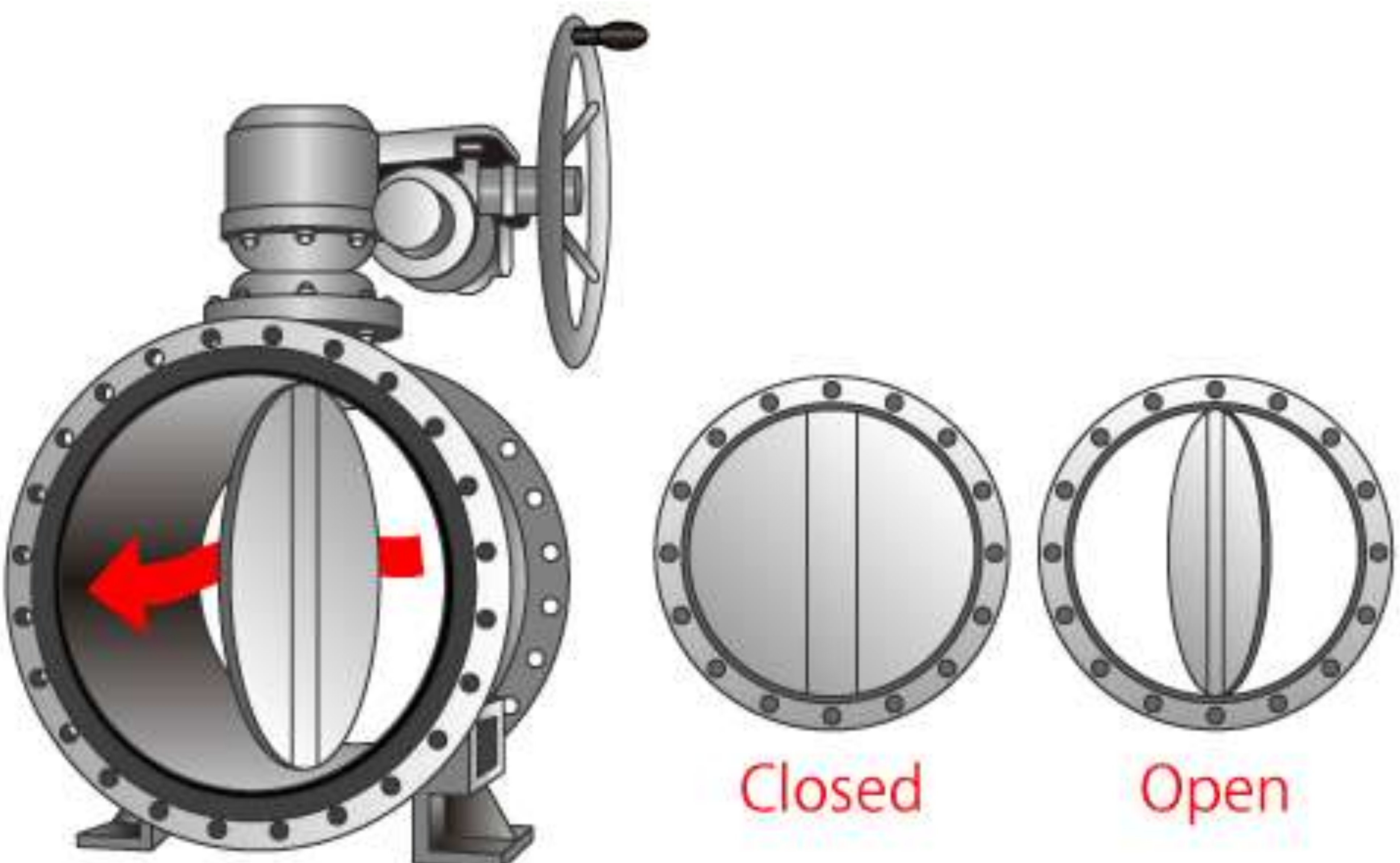
Diaphragm Valve



Diaphragm Valve



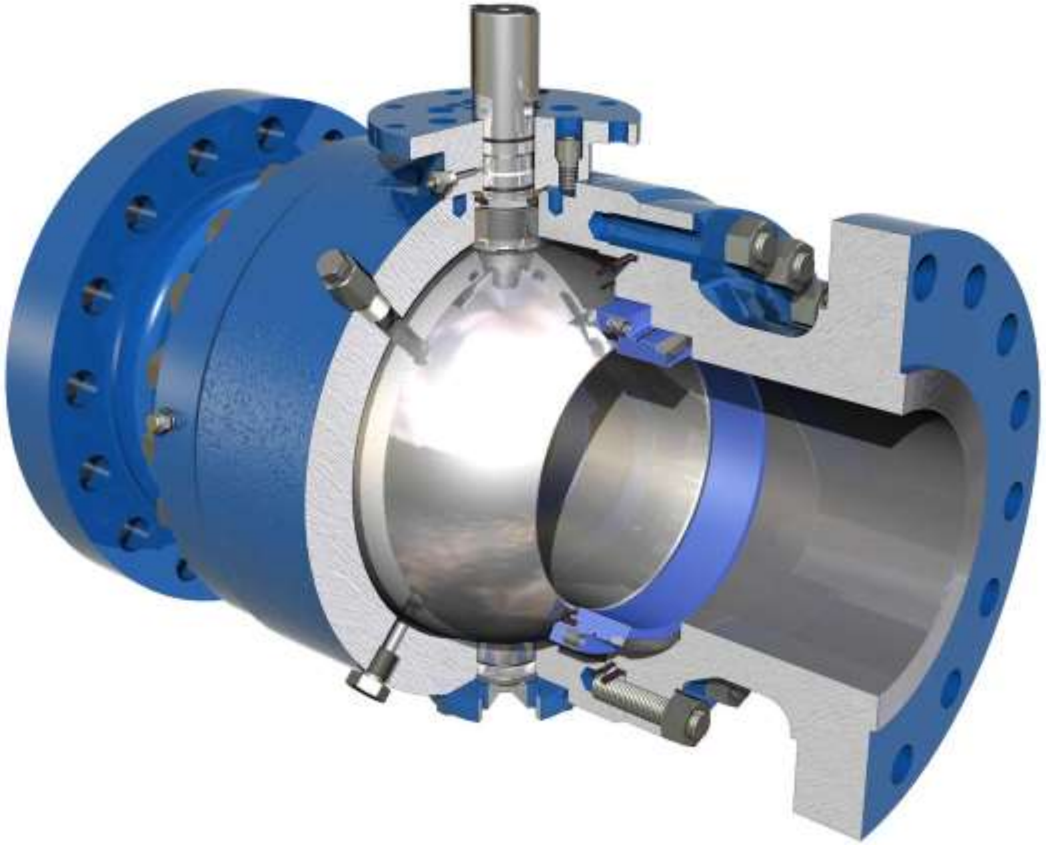
Butterfly Valve



Ball Valve

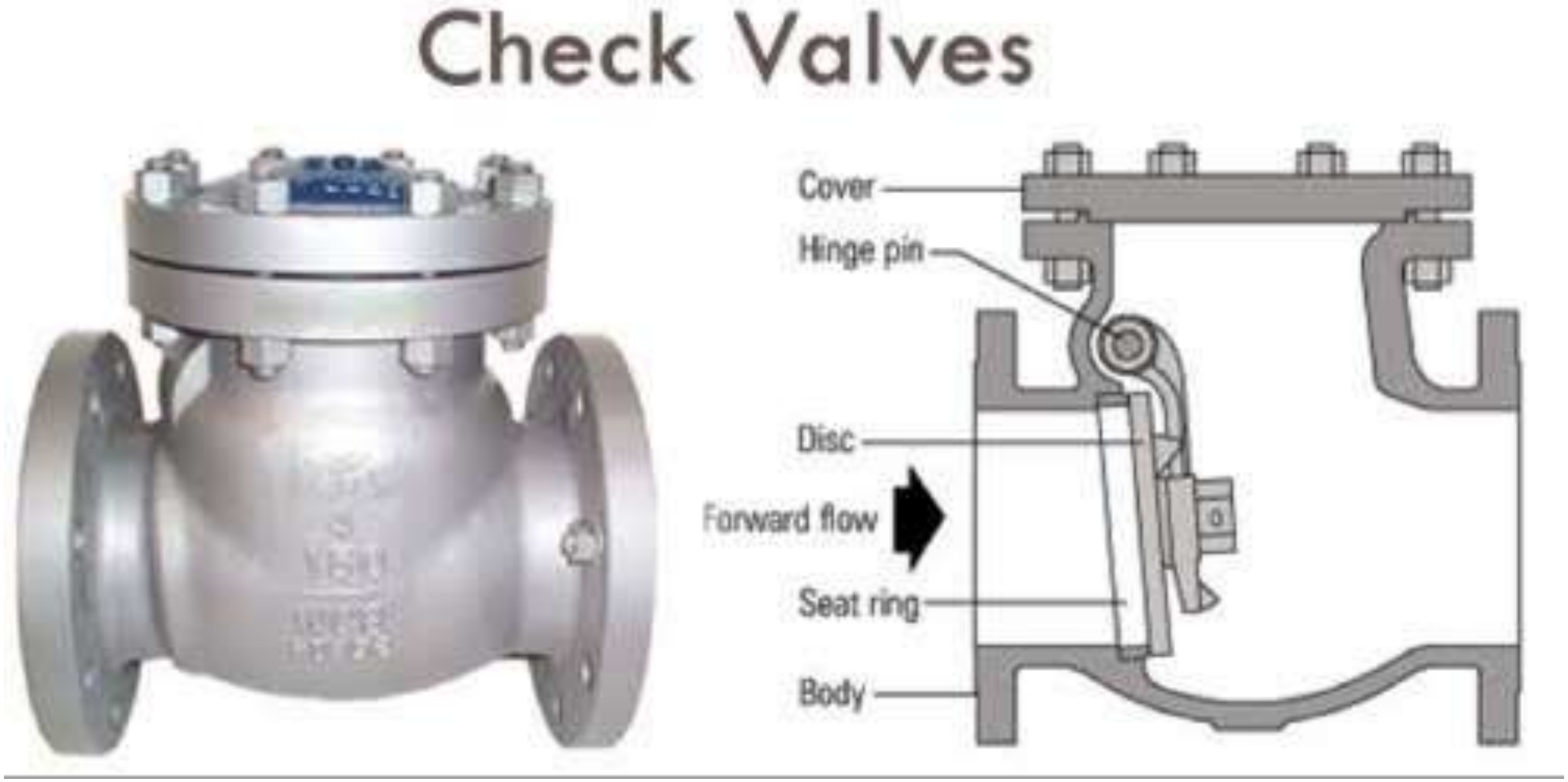
Ball Valve

Ball Valve



Plug Valve

Check Valve (one way)



Check Valve (one way)

Motorized Valve

Motorized Valve