سماد
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Al-Jubail Fert. Company (SAMAD)

Basic Instrumentation

By: Wesam A. Al-Shammasi

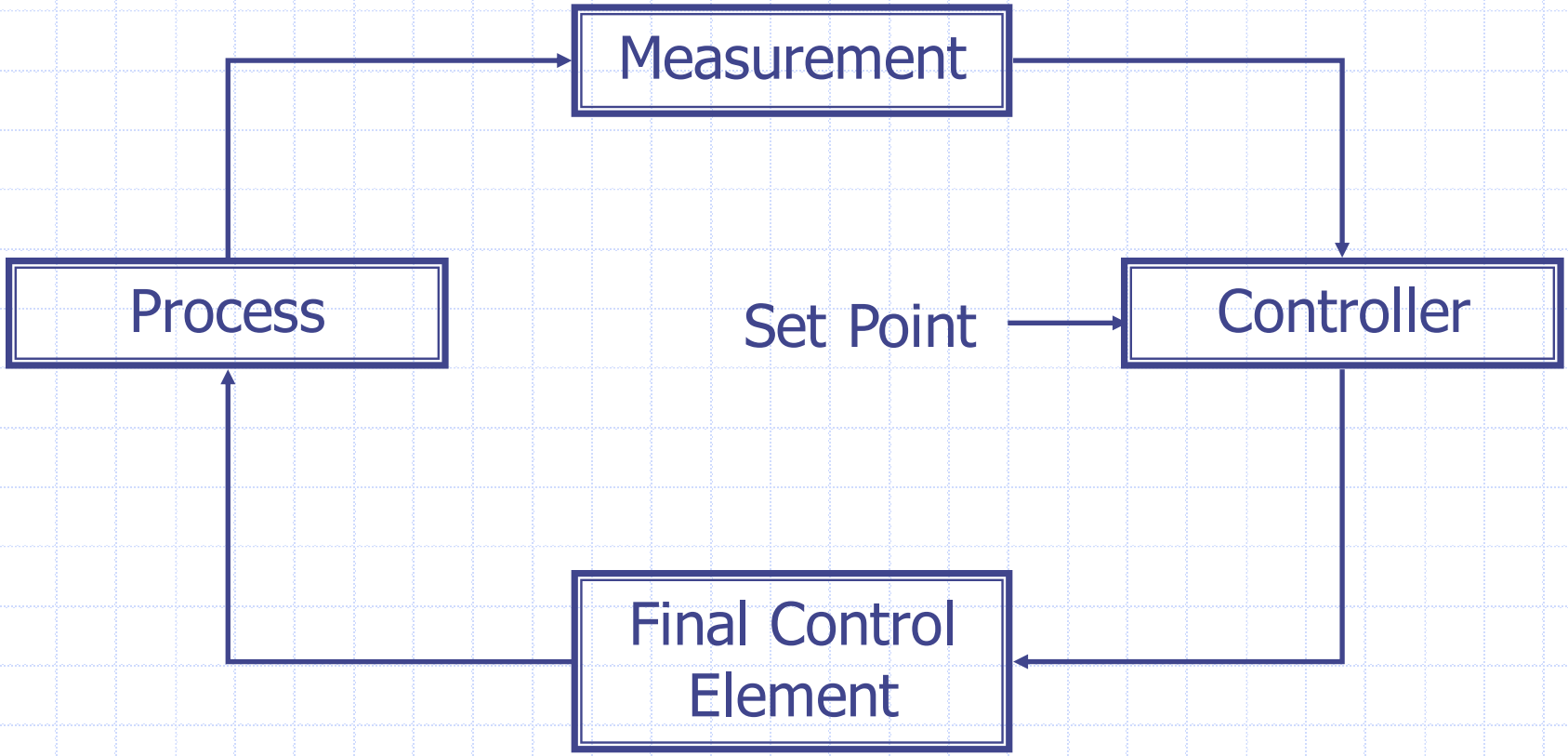
Contents

- Definition of instrumentation & Process Control
- P&IDs & Instrument symbols
- Process Measurement
  - Transducer (Temperature-Pressure-Flow-Level)
  - Transmitting and Switching Elements

Definition of Instrumentation & Process Control System

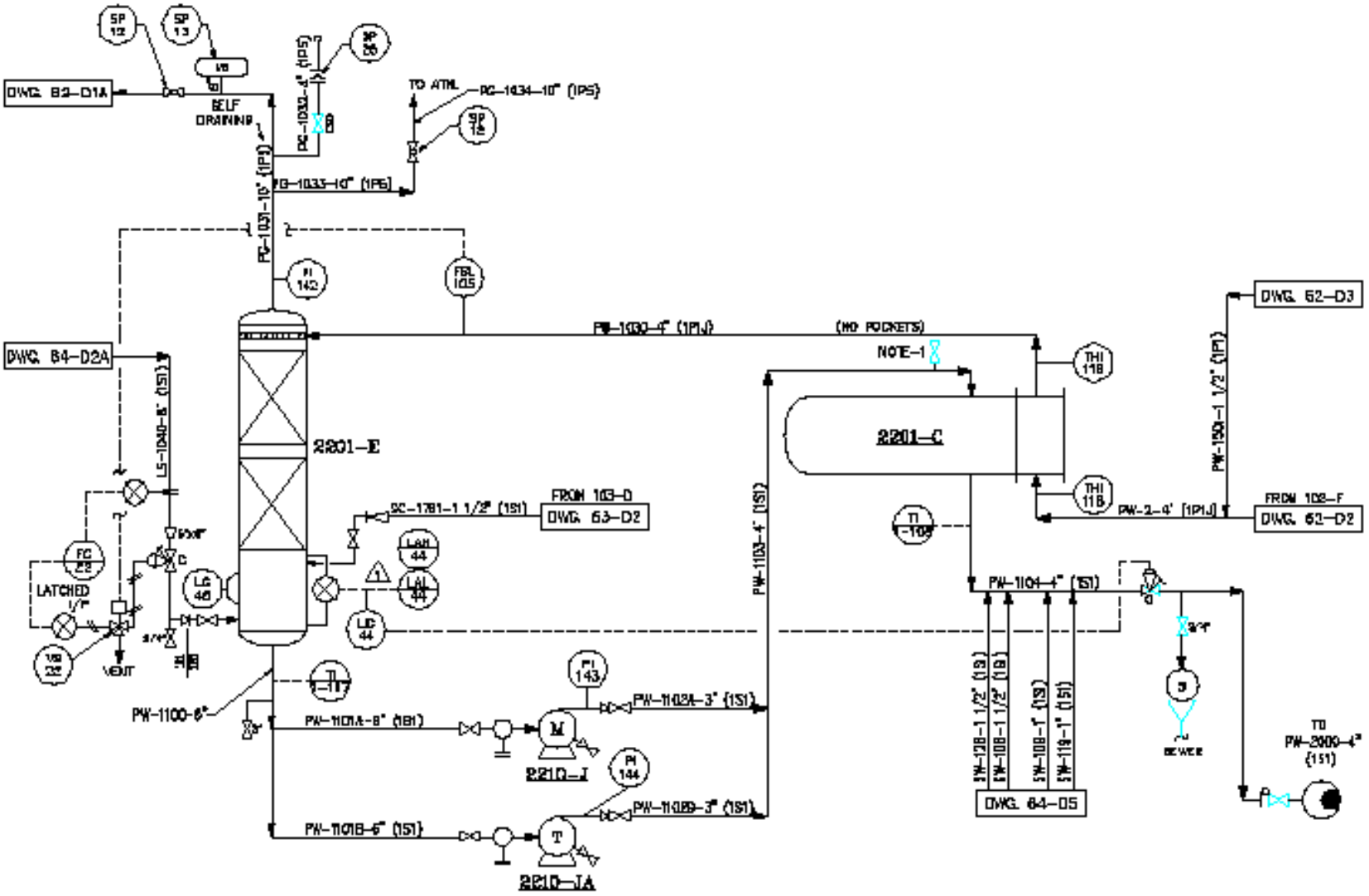
- **Instrumentation:**
  - A collection of instruments for the purpose of observation, measurement, protection or control.
- **Process Control**
  - Regulation or manipulation of variable influencing the process to achieve desire quantity/quality in an efficient manner

Block Diagram of Process Control Loop



P&ID and Instrument Symbols

- **P&ID stands for Piping & Instrumentation Diagram**
  - Definition:diagram where it will show the process piping and instrumentation connections with Process tanks and vessels, reactors, exchangers, …etc. in order to produce particular product or perform specific task.
  - The P&IDs contains detail connections for the instrumentations where defined by graphical symbols and identification letters.

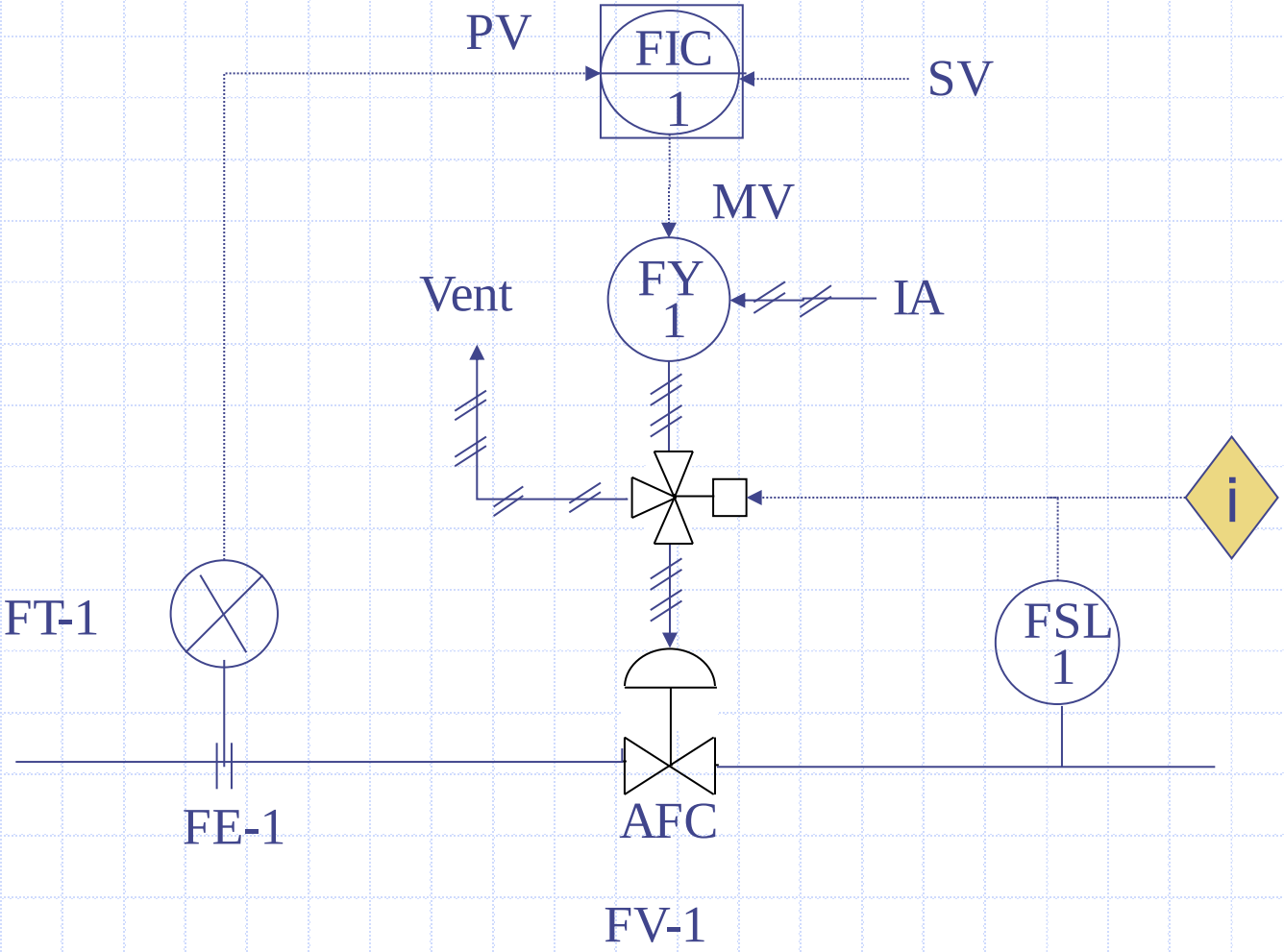

DWG. B2-D1A
SELF DRAINING
PC-1031-10" (1P1)
PC-1033-4" (1P5)
TO ATM.
PC-1034-10" (1P5)
PG-1033-10" (1P5)
DWG. B4-D2A
LS-1040-6" (1S1)
2201-E
PW-1102-4" (1P1J)
(NO POCKETS)
NOTE-1
2201-C
DWG. B2-D3
PW-1104-1 1/2" (1P1)
DWG. B2-D3
PW-2-4" (1P1J)
FROM 102-F
DWG. B2-D2
PC-1781-1 1/2" (1S1)
FROM 103-D
DWG. B3-D2
LATCHED
VENT
PW-1100-6"
PW-1101A-6" (1B1)
2210-J
PW-1102A-3" (1S1)
PW-1101B-6" (1S1)
2210-JA
PW-1103-4" (1S1)
PW-1101-4" (1S1)
PW-128-1 1/2" (1S)
PW-108-1 1/2" (1B)
PW-108-1" (1S)
PW-119-1" (1S1)
DWG. B4-D5
SEWER
TO PW-2000-4" (1S1)

	FIRST LETTER		SUCCEEDING LETTERS		
	MEASURED OR INITIATED VARIABLE	MODIFIER	READOUT OR PASSIVE FUNCTION	OUTPUT FUNCTION	MODIFIER
A	ANALYSIS		ALARM		
B	BURNER FLAME		USERS CHOICE	USERS CHOICE	USERS CHOICE
C	CONDUCTIVITY (ELECTRICAL)			CONTROL	
D	DENSITY OR SPECIFIC GRAVITY	DIFFERENTIAL			
E	VOLTAGE (EMF)		ELEMENT		
F	FLOW	RATIO (FRACTION)			
G	GAUGING		GLASS		
H	HAND (MANUALLY) INITIATED				HIGH
I	CURRENT ELECTRICAL		INDICATE		
J	POWER				
K	TIME OR TIME SCHEDULE			CONTROL STATION	
L	LEVEL		LIGHT (PILOT)		LOW
M	MOISTURE OR HUMIDITY				MIDDLE OR INTERMEDIATE
N	USERS CHOICE		USERS CHOICE	USERS CHOICE	USERS CHOICE
O	USERS CHOICE		ORIFICE (RESTRICTION)		
P	PRESSURE OR VACUUM		POINT (TEST CONNECTION		
Q	QUANTITY OR EVENT	INTEGRATE OR TOTALISE			
R	RADIO-ACTIVITY		RECORD		
S	SPEED OR FREQUENCY	SAFETY		SWITCH	
T	TEMPERATURE			TRANSMIT	
U	MULTIVARIABLE		MULTIFUNCTION	MULTIFUNCTION	MULTIFUNCTION
V	VISCOSITY			VALVE DAMPER OR LOUVRE	
W	WEIGHT OR FORCE		WELL		
X	UNCLASSIFIED		UNCLASSIFIED	UNCLASSIFIED	UNCLASSIFIED
Y	USERS CHOICE			RELAY OR COMPUTE	
Z	POSITION	POSITION		DRIVE ACTUATE OR UNCLASSIFIED FINAL CONTROL ELEMENT	

Instrumentation Identification

- Example of instrument Identification
  - FIC4003 (Flow indication and Control)
  - FI4002 (Flow Indication)
  - FT4003 (Flow Transmitter)
  - FV4003 (Flow Control Valve)
  - PIC4002 (Pressure Indication and Control)
  - PV4002 (Pressure Control Valve)
  - PDSL1234 (Pressure Differential Switch Low)

Control Loops



Process Measurement

- In this lecture we will cover the measurement instruments:
  - Temperature Elements
  - Pressure Elements
  - Flow Elements
  - Level Elements

I. Temperature

- Definition:
  - It is the Degree of Coldness or hotness or in other word related to the kinetic energy of molecules.
  - Temperature generated by heat energy.
  - Heat energy has unit of BTU (Brithish Thermal Unit) or Calorie

Temperature (Cont.)

- Units:
  - Fahrenheit (^{o}F), Centigrade (Celsius) ^{o}C, Kelvin ^{o}K, Ranklin ^{o}R

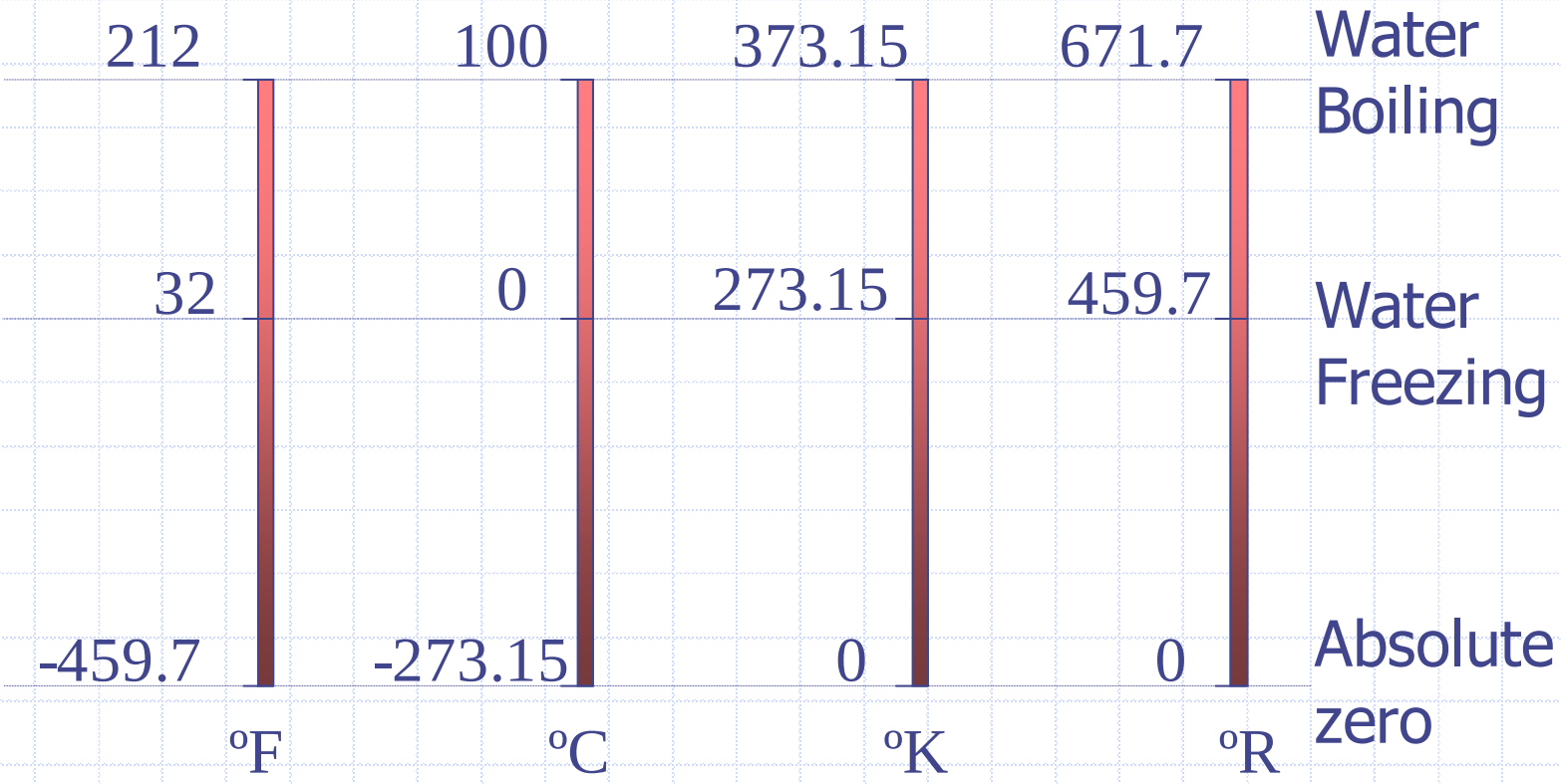
    F= 5/9 x C + 32

    C= 9/5 (F-32)

    K= 273.15 + C

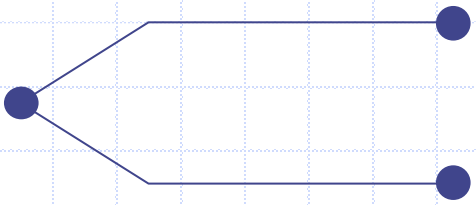
    R= 459.7 +F

Temperature (Cont.)



Temperature (Measurement)

- Thermocouple: Consists of two dissimilar metals joined at one end and other end connected to meter. When joined end (Hot junction) heated, voltage will be produced at the other end (Cold Junction).

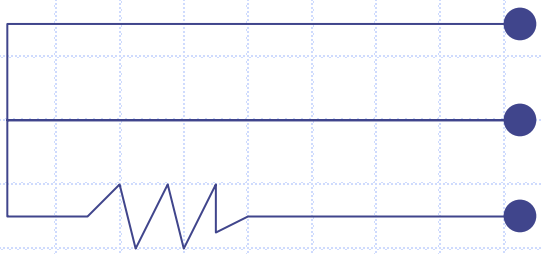


Temperature (Measurement)

T/C Type	Chemical Composition	Range
J-Type	Iron - constantan	-196 to 760 deg C
K- Type	Chromel – Alumel	-190 to 1260 deg C
S- Type	Platinum/Rhodium – platinum	-18 to 1760 deg C
T- Type	Copper – Constantan	-185 to 371 deg C
E- Type	Chromel – Constantan	-196 to 982 deg C
R- Type	Pt87/Rh13 – Platinum	-17.7 to 1704 deg C

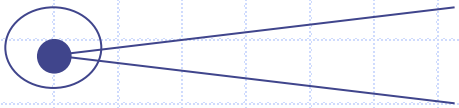
Temperature (Measurement)

- Resistance Temperature Detector (RTD)
  - Heat Sensitive element prepared with carefully made electric resistance.
  - Used material: Platinum, Nickel, Iron, Salver
    - In our plant most of RTDs used are Pt100
      platinum resistance= 100 ohm at 0 degree C
  - As temperature rises, resistance increases.



Temperature (Measurement)

- Thermostor:
  - Very small Solid thermo-electric devise made of solid semiconductor of various metal oxides.
  - The electric resistance of thermostor decrease with an increase in temperature.



II. Pressure

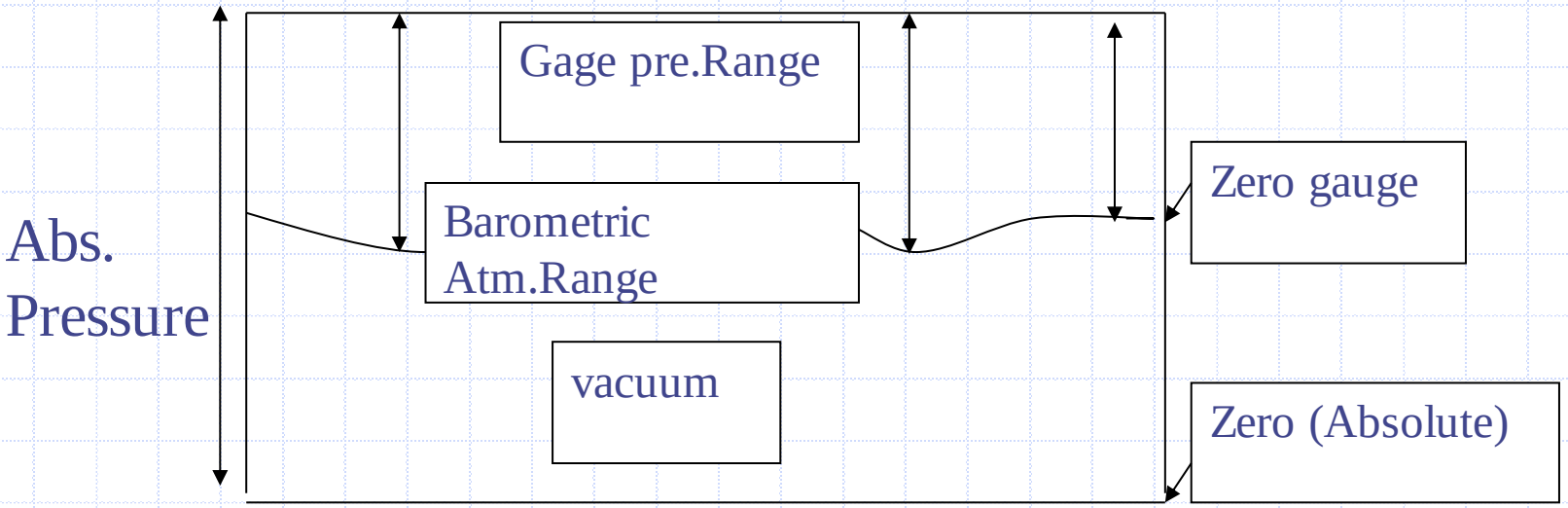
- Definition:
  - Defined as the normal force per unit area acting on surface of an object.
  - P=F/A
- Units:
  - Pa, psi, inches of mercury, inches of water, BAR, atm, Kg/cm2

Pressure (Cont.)

- Scale of measurement:
  - Gauge Pressure Scale
  - Absolute Pressure Scale
  - Vacuum Pressure Scale

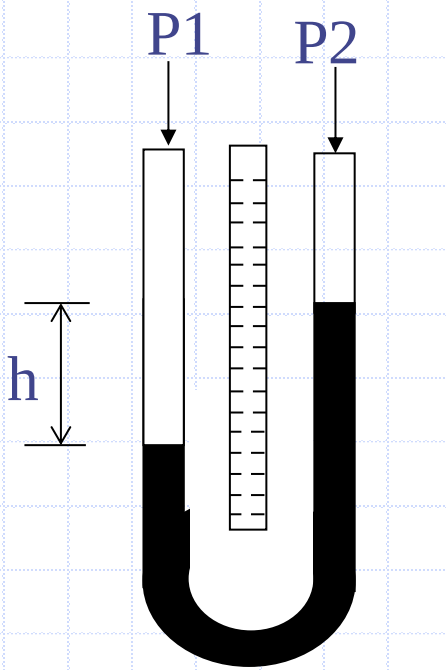
Pg= Pa - Atmospheric Pressure

Pressure (Cont.)



Pressure (Measurement)

- Manometers:
  - Used for the direct measurement of pressure and vacuum.
  - U-Tube Manometer
    - A glass of U- tube shape, partially filled with liquid.
    - The zero is connected to the scale when both ends of the U-glass opened to atmosphere.



U-Tube Manometer

Pressure (Measurement)

- U-Tube Manometer (Cont.)
  - When applied pressure at one end of the tube, difference in level will occur:
  - $P2-P1=\rho . h$

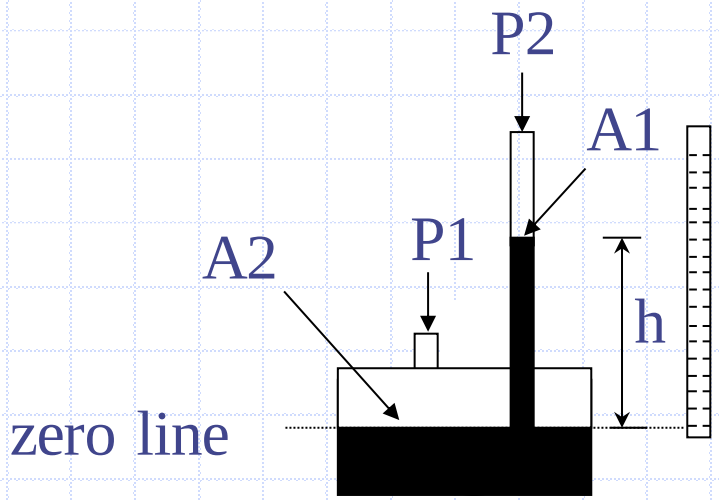
    ρ : Density (lb/in3)

    h : height (in)

    P2-P1: Pressure (psig)

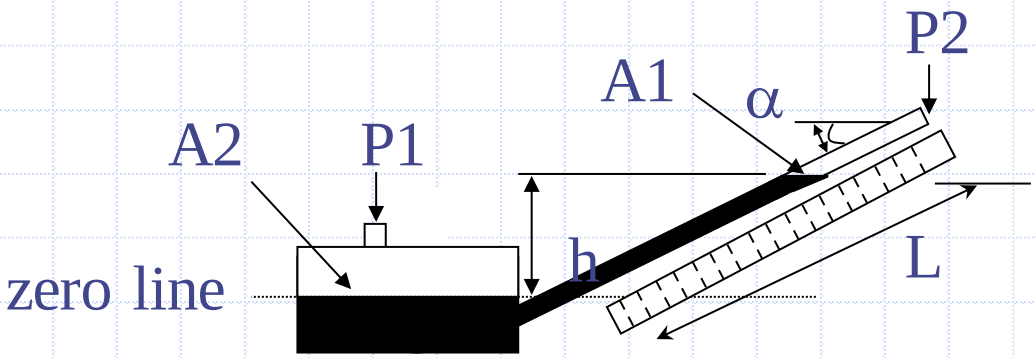
Pressure (Measurement)

- Well Manometer (Single Leg):
  - Used for low pressure application with higher accuracy from the U-Manometer.
  - P2-P1= ρ (1+A1/A2) h



Pressure (Measurement)

- Inclined-Tube Manometer
  - Used for extreme low pressure application
  - P2-P1= ρ (1+A1/A2) L. sin α



Pressure (Measurement)

- Pressure Element
  - Mechanical devices changed its shape when pressure is applied
  - The pressure elements sometimes called elastic deformation pressure element
  - Each type has its range of operation pressure.

Pressure (Measurement)

Pressure elements	Minimum range	Maximum range
i)Diaphragm	0”to 2” water column (WC)	0 to 400 psi
ii).Bellows	0”to 5” water column (WC)	0 to 800 psi
iii)Capsule	0”to 1” water column (WC)	0 to 50psi
iv)Bourdon tube	0 to 12 psi	0 to 100,000 psi
v)Spiral	0 to 115 psi	0 to 4,000 psi
vi)Helix	0 to 50 psi	0 to 10,000psi

Pressure (Measurement)

- Pressure Transducers
  - Elastic deformation element joined to electrical device.
  - Changes in resistance, inductance, or capacitance

Pressure (Measurement)

- Strain Gauge:
  - Fine wire in form of grid.
  - When the grid distorted, resistance of the wire will change according to:

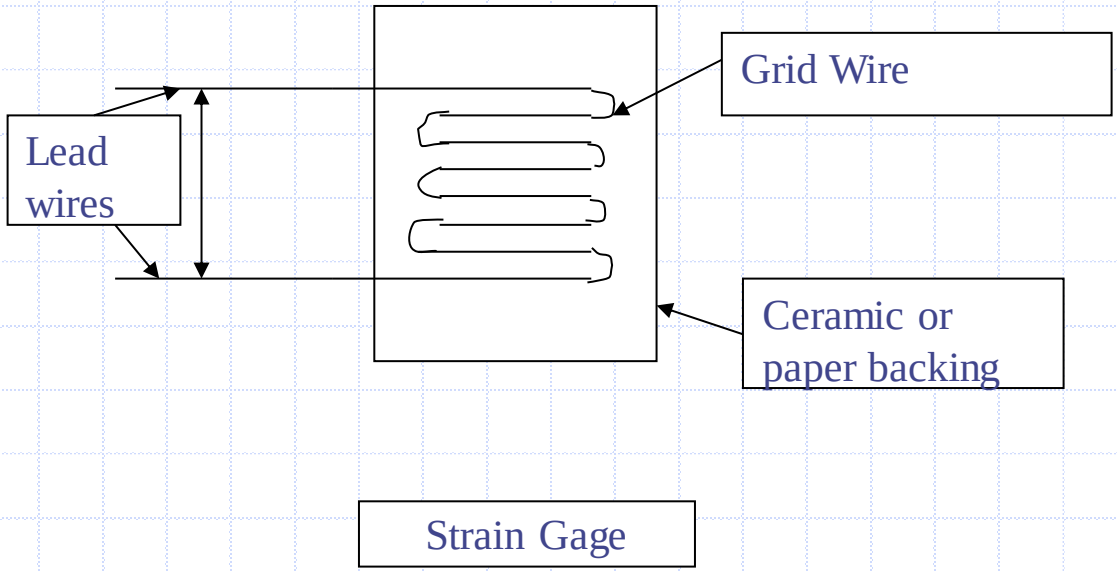
    R=K. L/A

    K : Resistively of the metal

    L : Length of wire

    A : Cross sectional Area

Pressure (Measurement)



Pressure (Measurement)

- Strain Gage (Cont.)
  - As Strain Gage is distorted by the elastic deformation length will increase and area will reduced.
  - Resistance will increase accordingly.

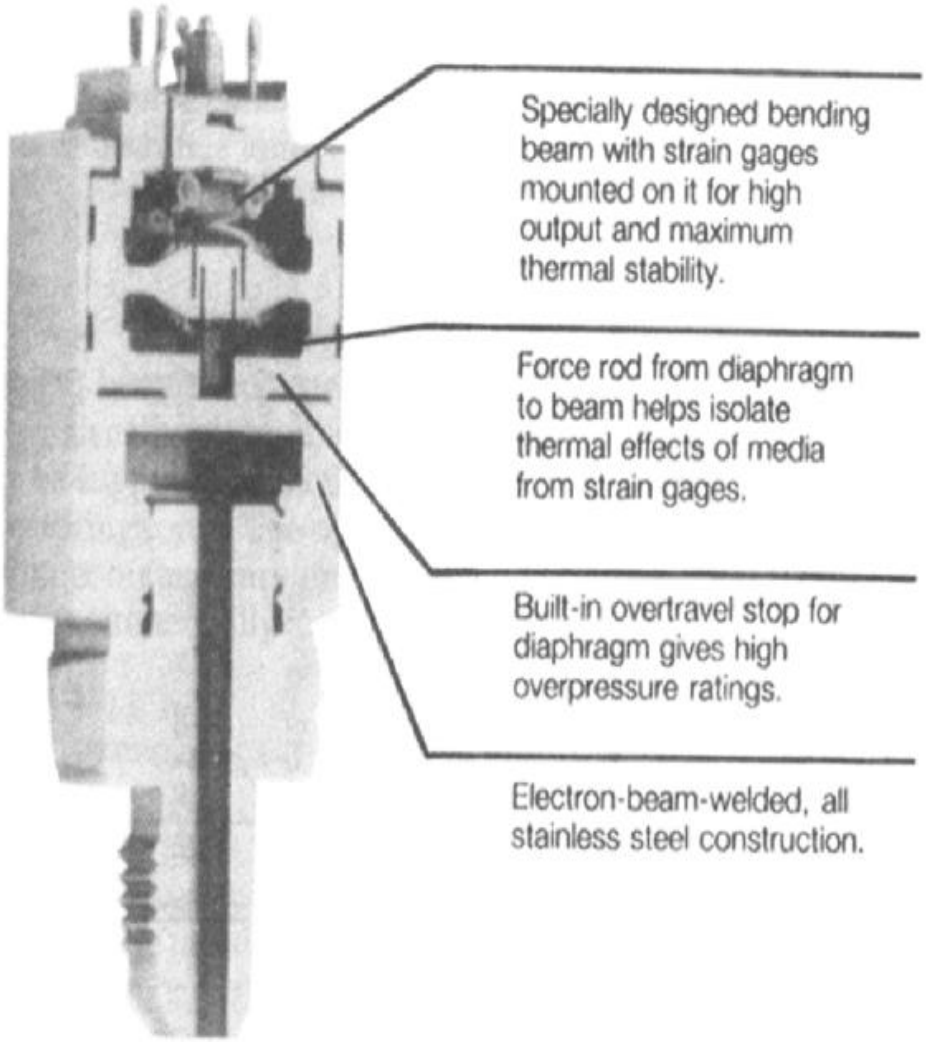
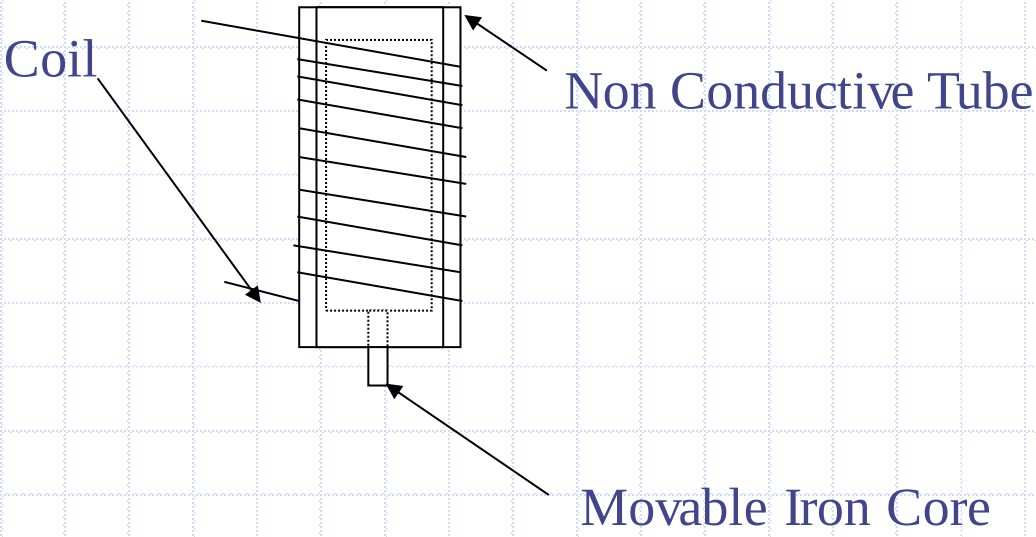


FIGURE 13 Strain-gage pressure transducer incorporating a force transfer rod between diaphragm and double cantilever beam with four foil strain gages on beam. Units are calibrated and temperature-compensated to ensure stability over specified ranges, as well as unit interchangeability. Units are available with required signal conditioning. (*Lucas Schaevitz.*)

Pressure (Measurement)

- Inductance Type
  - Consists of Coil, Movable Magnet core, and elastic deformation element.
  - AC current pass through coil.
  - As the pressure varies the elastic deformation, the magnet core will move through the coil.
  - This will change the inductance.

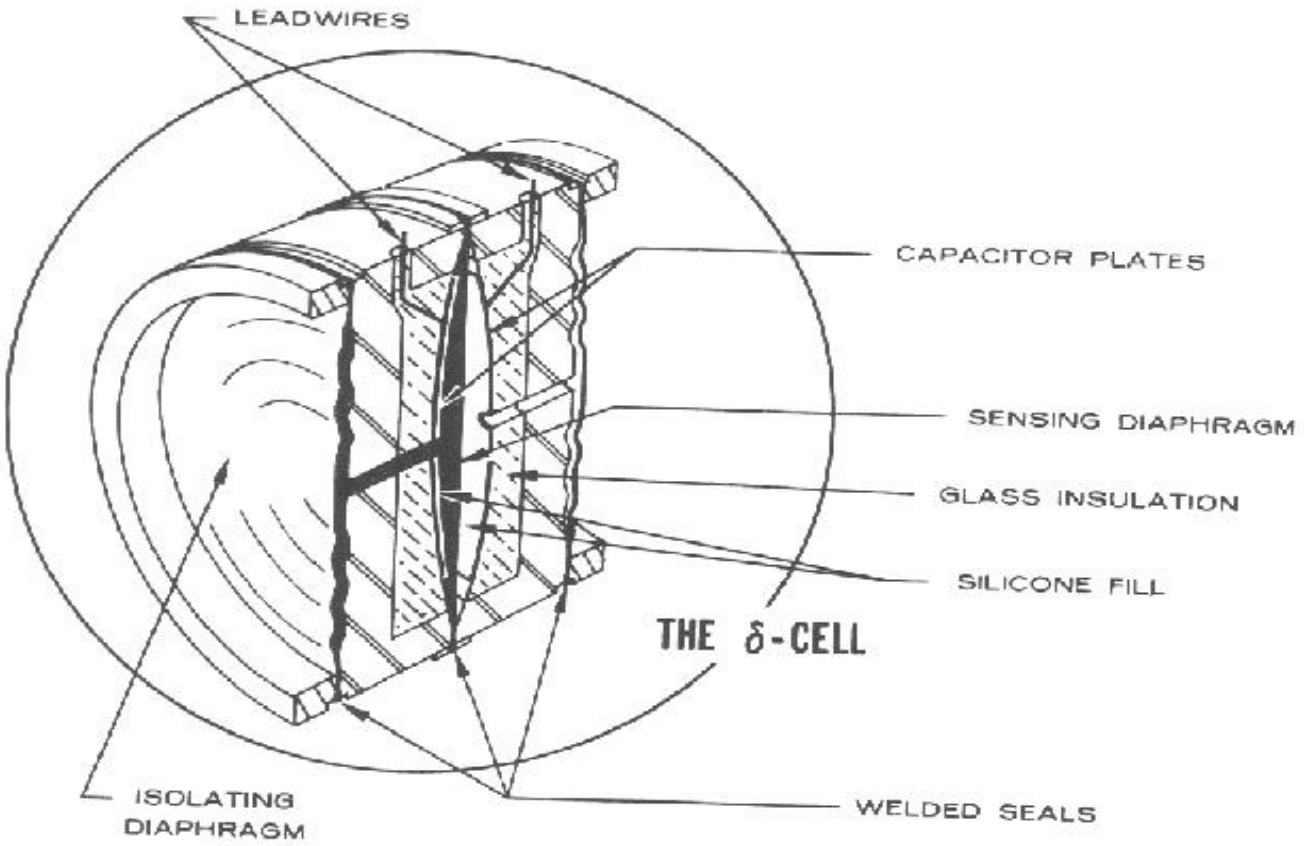
Pressure (Measurement)



Pressure (Measurement)

- Capacitance Type
  - Consists of two conductive plates, dielectric, and diaphragm.
  - As the pressure increases diaphragm will move the plate changing the capacitance.

Pressure (Measurement)



Flow (Measurement)

- Flow rate and flow quantity of materials is made primarily for determining the proportions of materials introduced to the process.
- Method of measurements:
  - Head Elements
  - Area Elements
  - Quantity Velocity Elements

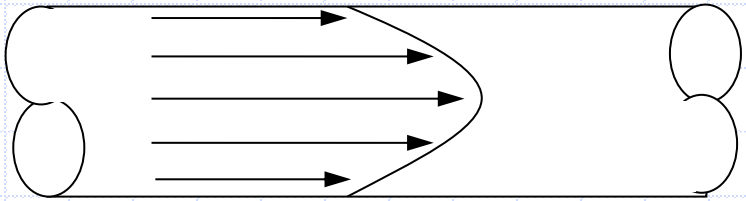
Flow (Measurement)

- The following properties are important for the flow measurement:
  - Pressure: Force applied on Area
  - Density : Weight divided by volume
  - Viscosity : Resistance to flow
  - Velocity : Speed of the fluid. It determine the behavior of the fluid.

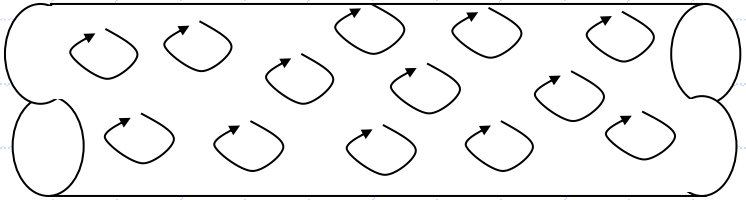
Flow (Measurement)

- Flow Types:
  - When the average velocity is slow, the flow is called laminar, i.e fastest layers at the center and the slowest at the edges
  - When the average velocity increases, the flow is called turbulent.
  - The measurement of laminar, turbulent flow is as per Reynolds number

Flow (Measurement)



Laminar Flow



Turbulent Flow

Flow (Measurement)

- Most Flow are design to work in turbulent flow
- Units of Flow:
  - lb/Hr, Kg/Hr, T/Hr: mass flow
  - cfm, M3/H, KNM3/Hr: Volumetric Flow

Flow Measurement

- Head Flow Elements
  - When the liquid flows through a restriction, the energy converted kinetic energy.
  - The pressure will drop and velocity increases.

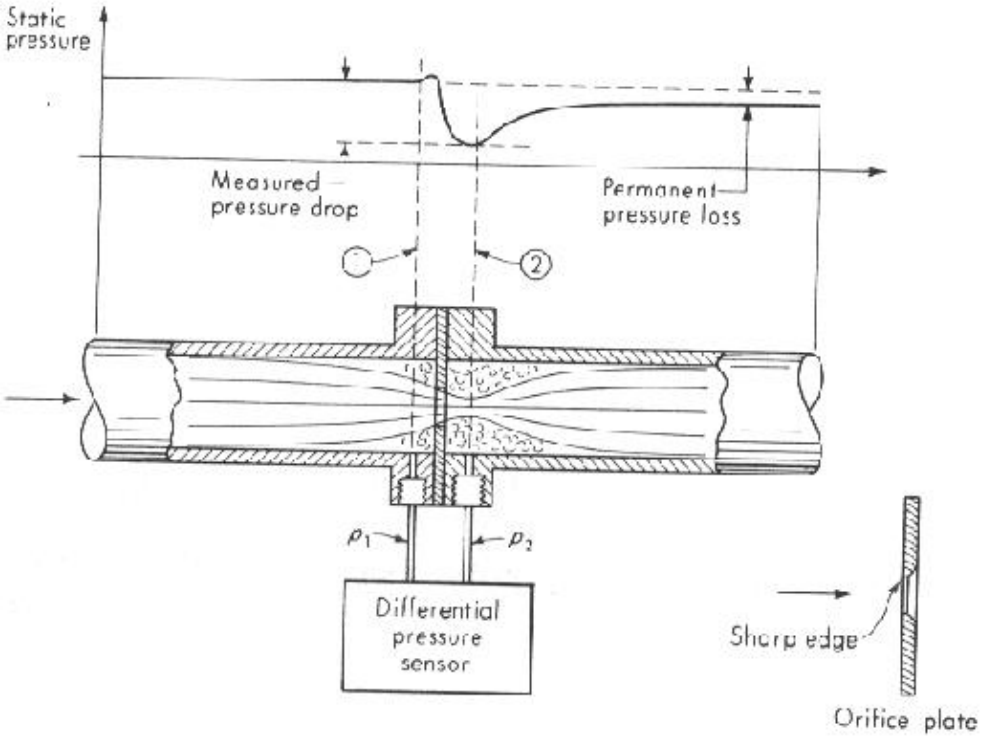
$$Q = C \times \sqrt{\Delta P}$$

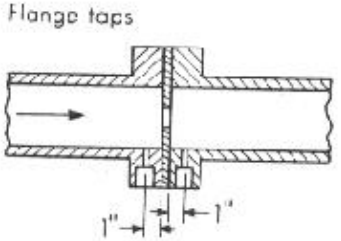
C: constant

ΔP: Differential pressure across restriction

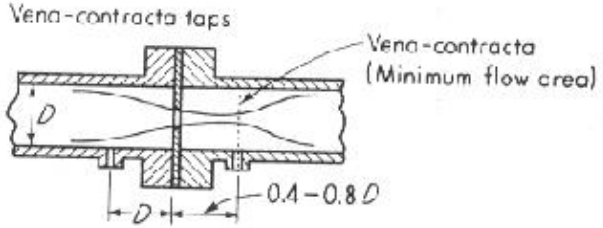
Flow Measurement

- Head Flow Elements
  - Orifice Plate: the loss in the pressure is more that other type of flow measurement.
    - The selection of orifice plate based on ratio of bore diameter to (d) to inside pipe diameter (D). $\beta = d/D$
    - best accuracy is when: $0.2 < \beta < 0.6$
    - Taps used :
      - Flange tap
      - Pipe taps
      - Vena Contracta tap

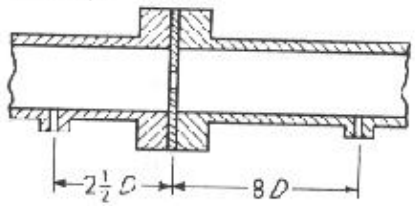




Most widely used



Largest Δp (Slightly greater accuracy)

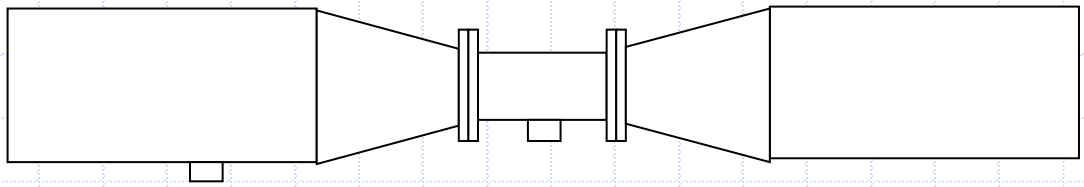


Measures permanent pressure loss

Small Δp reduces compressibility correction for gas-flow measurements

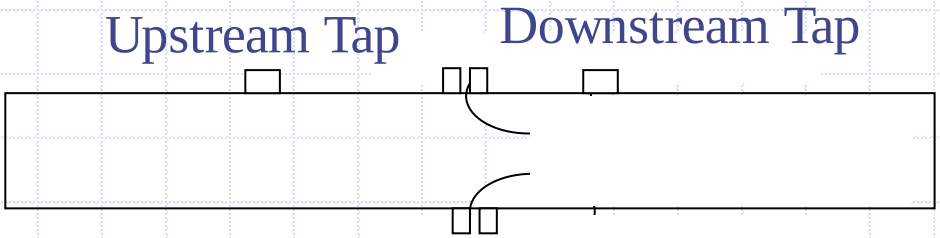
Flow Measurement

- Venturi tube: expensive and the most accurate type β>0.75
  - Pressure recovery is excellent



Flow Measurement

- Flow Nozzle: cheaper than venturi,
  - accuracy less than venturi
  - $\beta > 0.75$
  - pressure recovery is not as good as venturi



Flow Measurement

- Variable Area Flow Meter
  - Rotameter: consists of tapered, vertical glass consists of float.
  - Flow will carry the float from bottom to top through variable area glass.

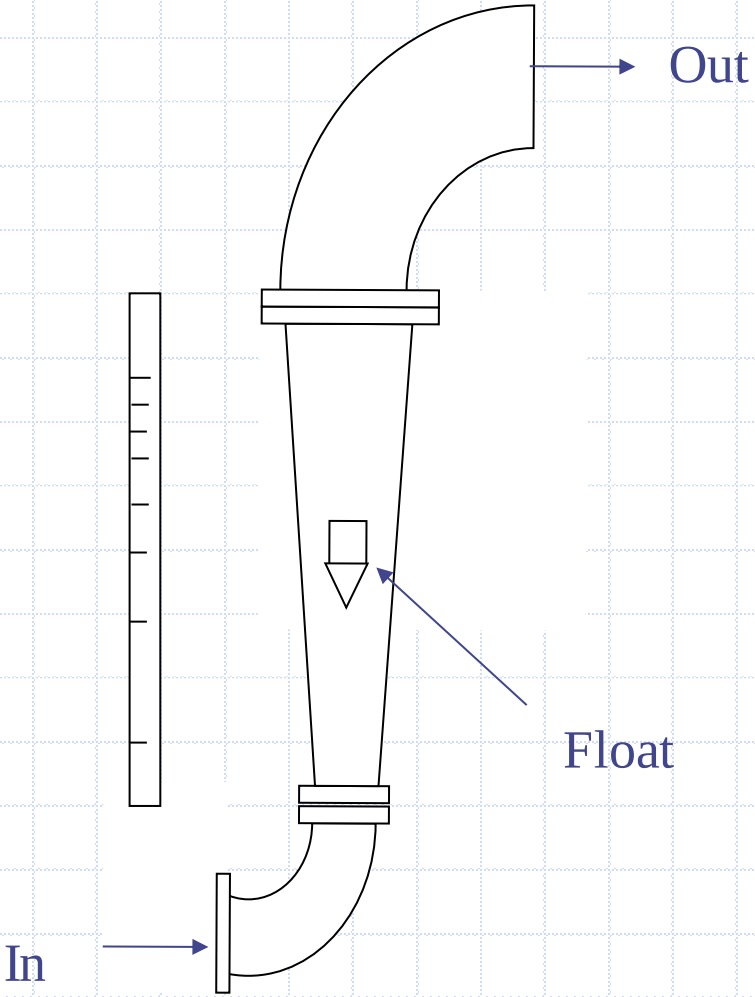
$$Q = A \times \sqrt{2gh}$$

A: cross sectional area of the glass

g: gravitational acceleration constant

h: the height of the float.

Variable Area Flow Meter



Flow Measurement

- Quantity Flow Measurement
  - Positive displacement
    - Measure the total quantity of the flow
    - separate the liquid into discrete volumes
    - Total of these volumes in time period will give the total flow amount
  - Mass Flow meter:
    - measurement of the weight per unit time.
    - Continuous measurement of density

Level

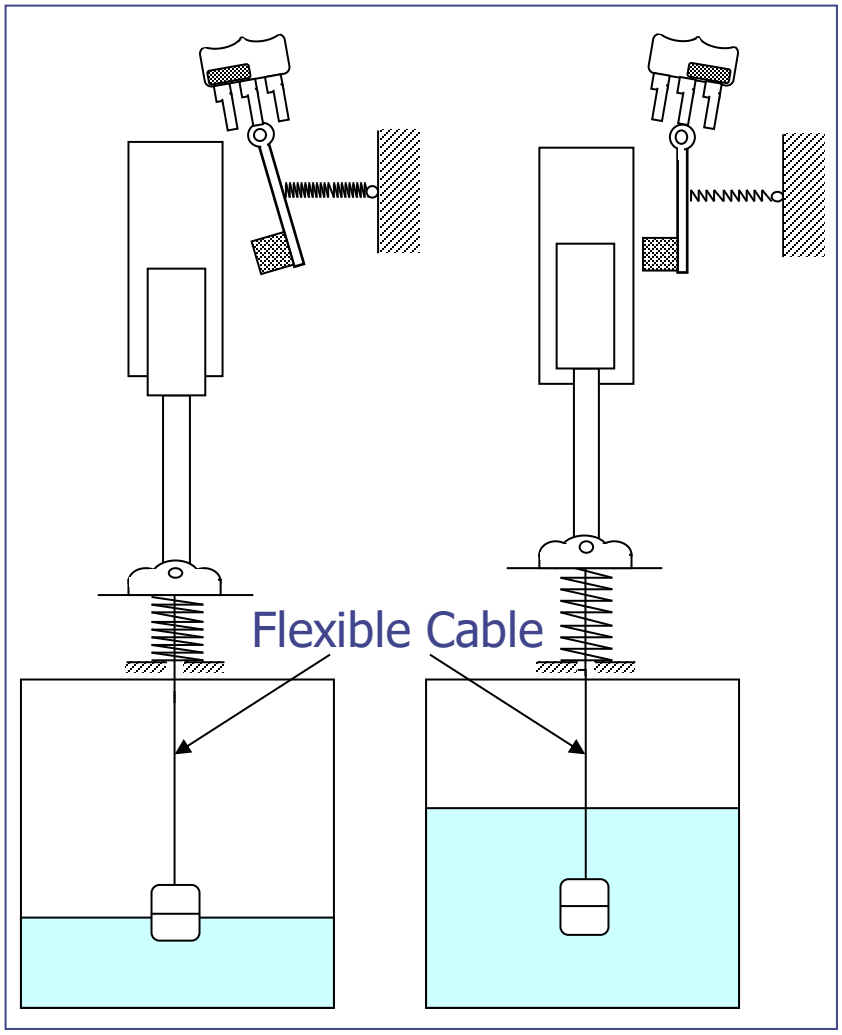
- There is two ways of measuring level
  - Direct level measurement
    - by varying liquid will get the level
  - Indirect level measurement
    - by using a variables which changes with the liquid level changes.

Level Measurement

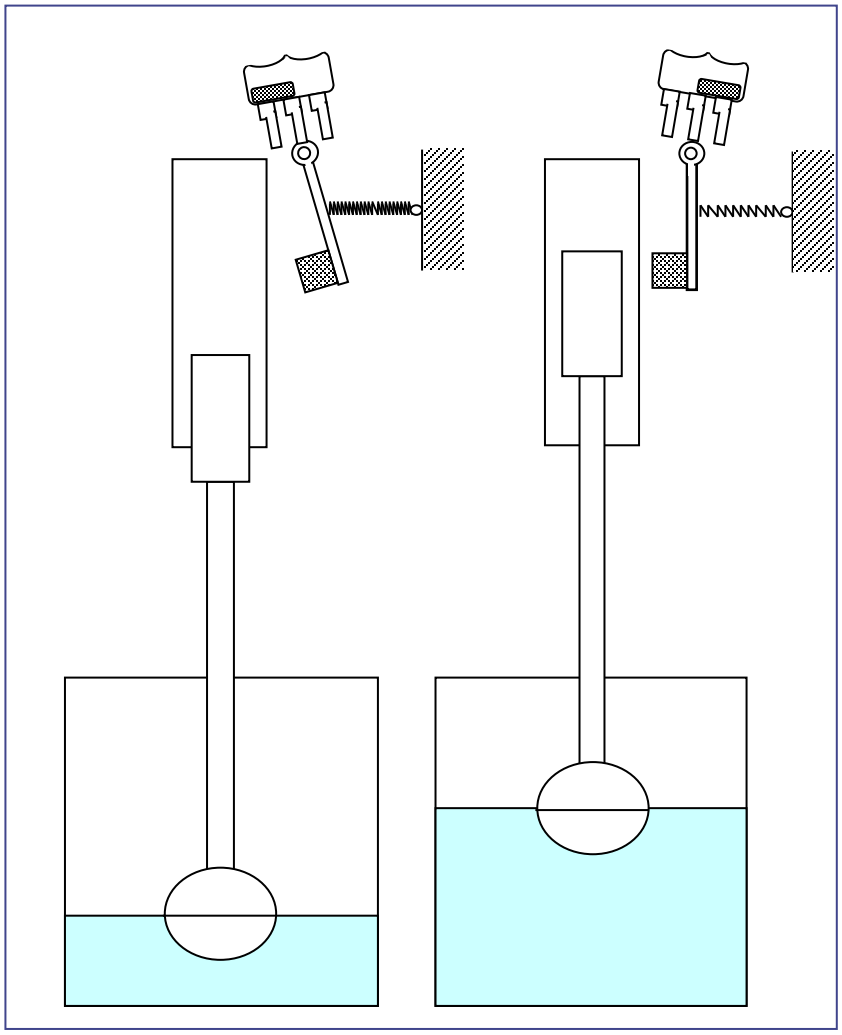
- Float
  - special material designed to follow the level or the interface level of a tank
  - The specialty is the density of the float shall be always touching the desired measurement level.
  - As the level increases/decreases, float will follow and causing a connecting tape to change its length.

Level Measurement

- Displacer
  - Archimede's Principle: a body wholly or partially immersed in a fluid is buoyed up by a force equal to the weight of the fluid displaced.
  - The level is measured by detecting the buoyancy force of an immersed displacer
  - The major difference between float and displacer is that displacer is partially or totally immersed, while float is always floating in the surface of the level.



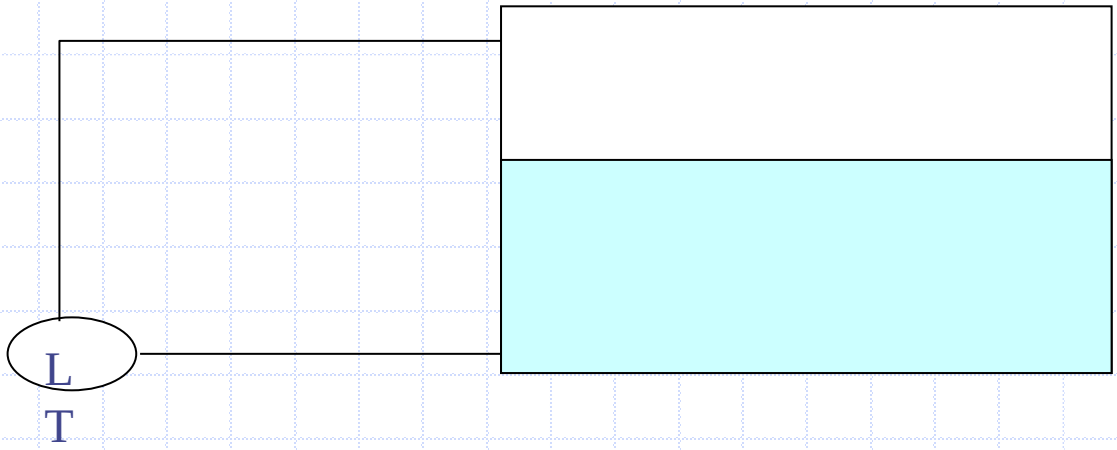
Displacer



Float

Level Measurement

- Differential pressure
  - h = $\Delta P/\rho$ (British unit) inches
  - h= $\Delta P/(g.\rho)$ (SI unit) meters
  - as level changes differential pressure will change accordingly.



Instrument Signal Types

- All measurement elements are sent to DCS/ESD/PLC Either for alarming, interlocking or controlling.
- Measurement Instrumentation consists of two parts
  - Measurement elements (Transducer)- Covered in the previous sections
  - Transmitting elements
  - Switching elements

Instrument Signal Types

- Transmitting Elements
  - Transmitting element will convert the Transducer signals into either electronic or pneumatic signals
  - Transmitting elements are commonly used for indication and control
  - Electronic transmitter will send 4 ~ 20 mA
    - 4mA : min. range
    - 20mA: max. range
  - Pneumatic transmitter will convert the transducer signal into 3~15 psi
    - 3 psi = min. range
    - 15 psi = max range

Instrument Signal Types

- Switching Elements
  - Switching elements will convert the transducer signal into a switching contact
  - The contacts are used commonly in alarming and interlocking processes

Conclusion

- Definition of instrumentation & Process Control
- P&IDs & Instrument symbols
- Process Measurement
  - Transducer (Temperature-Pressure-Flow-Level)
  - Transmitting and Switching Elements

??QUESTIONS??

THANK YOU