PRESSURE CONTROL

BY;

USMAN NASRULLAH

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B-TECH (Pass)
ELECTRONICS

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Introduction

Instrumentation is the art of measuring the value of some plant parameter, pressure, flow, level or temperature to name a few and supplying a signal that is proportional to the measured parameter. The output signals are standard signal and can then be processed by other equipment to provide indication, alarms or automatic control.

The project is going to deal with pressure control. The project includes pressure principles, pressure sensing, measuring and controlling equipments.

Topics of Discussion

-1 Pressure Standards

-2 Pressure Detectors

-3 Pressure Transducers

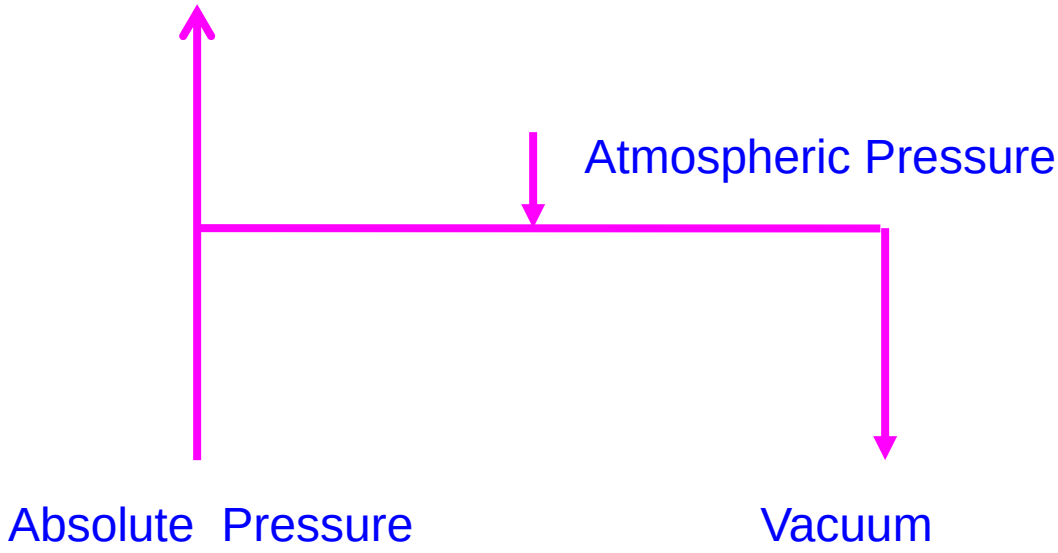
-4 Pressure Measurements

-5 Pressure Control

1 Pressure standards

Pressure

Force per Unit Area $P = F / A$



Pressure Units

- PSI (Pounds Per Square Inch)
- Kg/cm^2
- mm H_2O
- Inches H_2O
- mm Hg
- 1 Atm = 760 mm Hg at 0^oC = 1 Kgf/cm^2
- IDENTIFICATION
  - **PSI G Gauge Pressure**
  - **PSI A Absolute Pressure**

Pressure Conversion Table

	PSI	in.WG	in.Hg	kPa	millibars	Mm.H20	mm.Hg
PSI	1.000	27.68	2.036	6.8974	68.947	703.08	51.715
in.WG	0.0316	1.000	0.0735	0.2491	2.491	25.400	1.8683
in.Hg	0.4912	13.596	1.000	3.3864	33.864	345.32	25.400
KPa	0.1450	4.0147	0.2953	1.000	10.000	101.973	7.5006
Millibar	0.0145	0.4014	0.0295	0.100	1.000	10.197	0.7501
mm.WG	0.14223	0.03937	$2.8958 * 10^{-3}$	$9.806 * 10^{-3}$	0.09806	1.000	0.07355
mm.Hg	0.0193	0.5352	0.0393	0.1333	1.3332	13.595	1.000

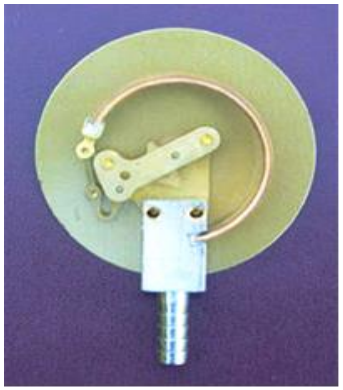
2 Pressure Detectors

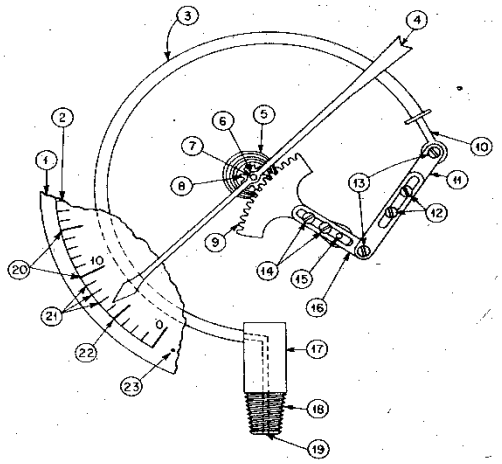
Four most common detectors/sensors are;

- Bourdon tube
- Bellows
- Diaphragms
- Capsules

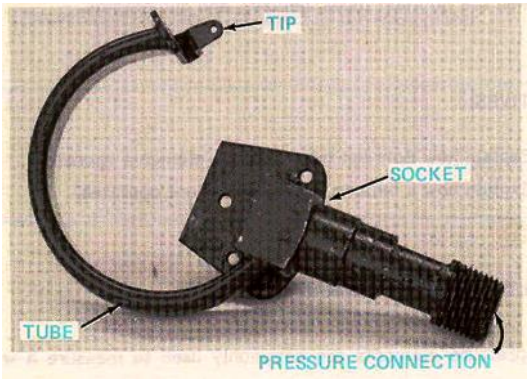
Bourdon Tube

- Pressure applied to the inside of the tube causes distention of the flat sections and tends to restore its original round cross-section. This change in cross-section causes the tube to straighten slightly.
- Since the tube is permanently fastened at one end, the tip of the tube traces a curve that is the result of the change in angular position with respect to the center. Within limits, the movement of the tip of the tube can then be used to position a pointer or to develop an equivalent electrical signal to indicate the value of the applied internal pressure.

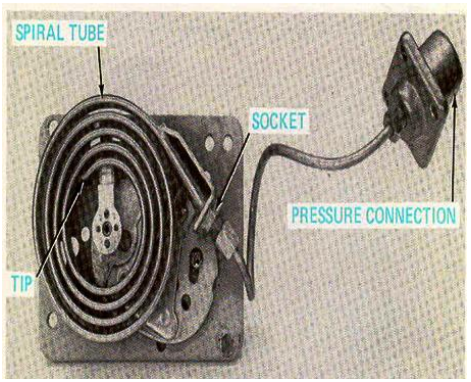




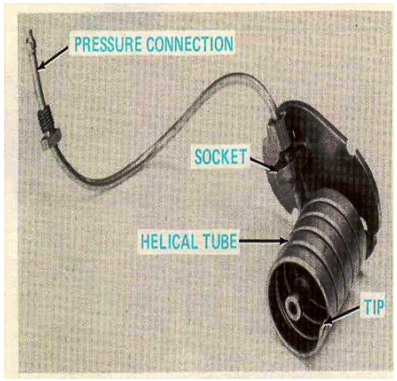
Types of Bourdon Tube



C-TYPE



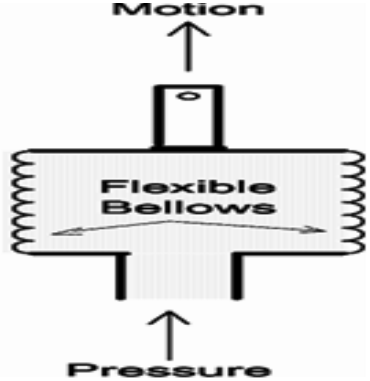
SPIRAL-TYPE

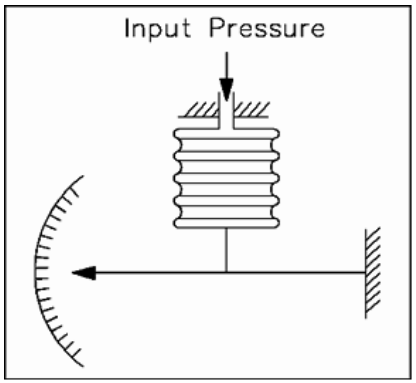


HELICAL-TYPE

The Bellows

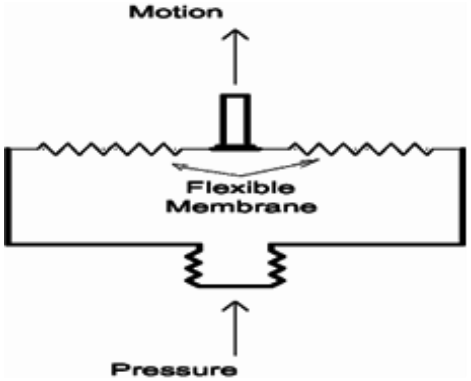
- The need for a pressure sensing element that was extremely sensitive to low pressures and provided power for activating recording and indicating mechanisms resulted in the development of the metallic bellows pressure sensing element. The metallic bellows is most accurate when measuring pressures from 0.5 to 75 psig. However, when used in conjunction with a heavy range spring, some bellows can be used to measure pressures of over 1000 psig. Figure 1 shows a basic metallic bellows pressure sensing element.

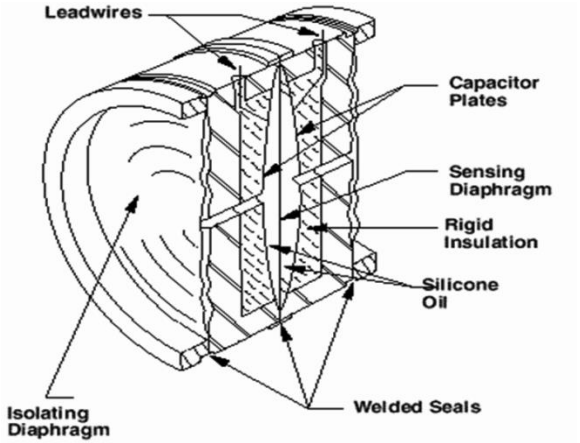




Diaphragms

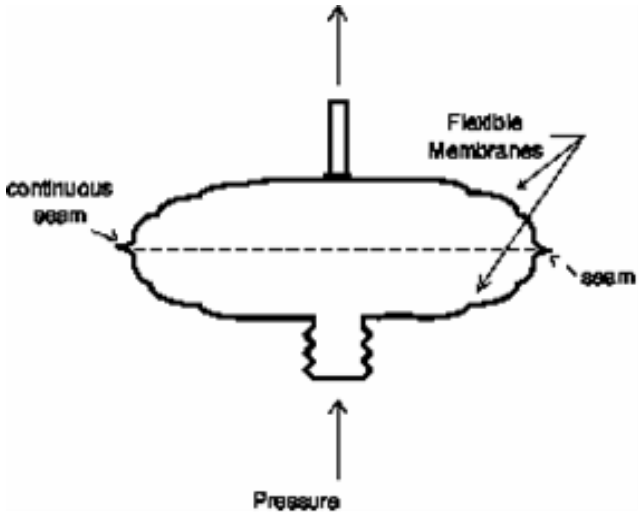
- A diaphragm is a circular-shaped convoluted membrane that is attached to the pressure fixture around the circumference. The pressure medium is on one side and the indication medium is on the other. The deflection that is created by pressure in the vessel would be in the direction of the arrow indicated.
- Diaphragms provide fast acting and accurate pressure indication. However, the movement or stroke is not as large as the bellows.





Capsules

- The pressure is applied to the inside of the capsule and if it is fixed only at the air inlet it can expand like a balloon. This arrangement is not much different from the diaphragm except that it expands both ways.
- The capsule consists of two circular shaped, convoluted membranes (usually stainless steel) sealed tight around the circumference. The pressure acts on the inside of the capsule and the generated stroke movement is shown by the direction of the arrow.



Pressure Elements Ranges

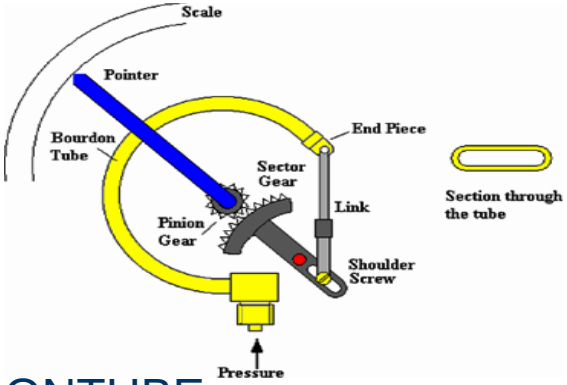
Pressure Elements	Minimum Ranges	Maximum Ranges
Bourdon Tube	0 To 12 psi	0 To 100,000 psi
Spiral	0 To 15 psi	0 To 4,000 psi
Helix	0 To 50 psi	0 To 10,000 psi
Diaphragm	0” To 2” H_2O	0 To 400 psi
Bellows	0” To 5” H_2O	0 To 800 psi
Capsules	0” To 1” H_2O	0 To 50 psi

3 Pressure Transducers

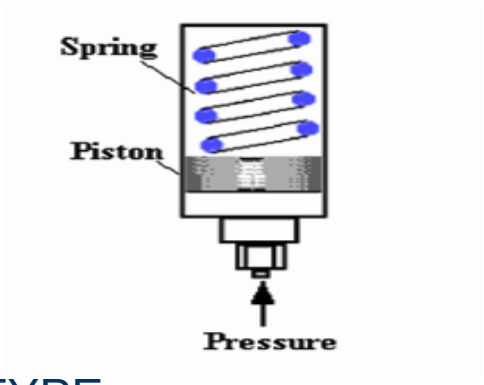
The most common pressure transducers are;

-1 Mechanical Type Transducers
-2 Electrical Pressure Transducers
-3 Resistance Type Transducers
-4 Inductance Type Transducers
-5 Capacitive Type Transducers
-6 Optical Type Transducers
-7 Resonant Wire Type Transducers
-8 Potentiometric Type Transducers

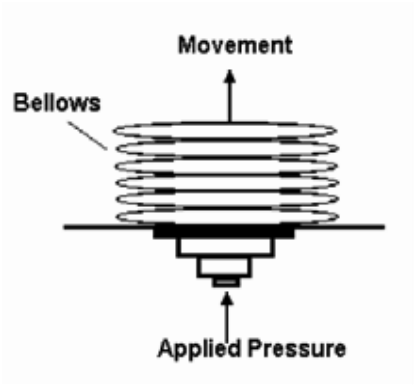
Mechanical Pressure Transducers



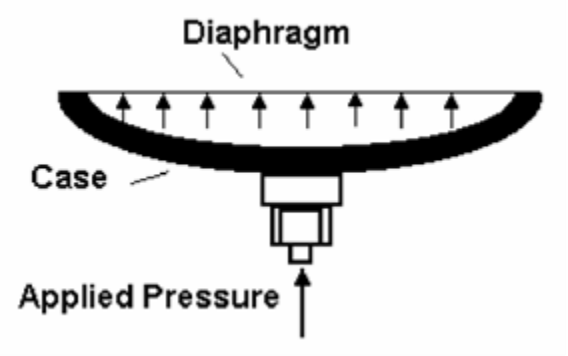
BOURDONTUBE



PISTON-TYPE

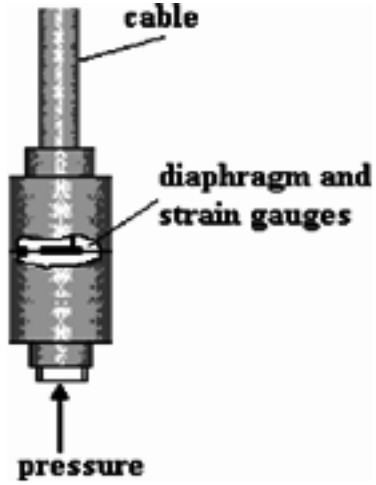


CAPSULES & BELLOWS

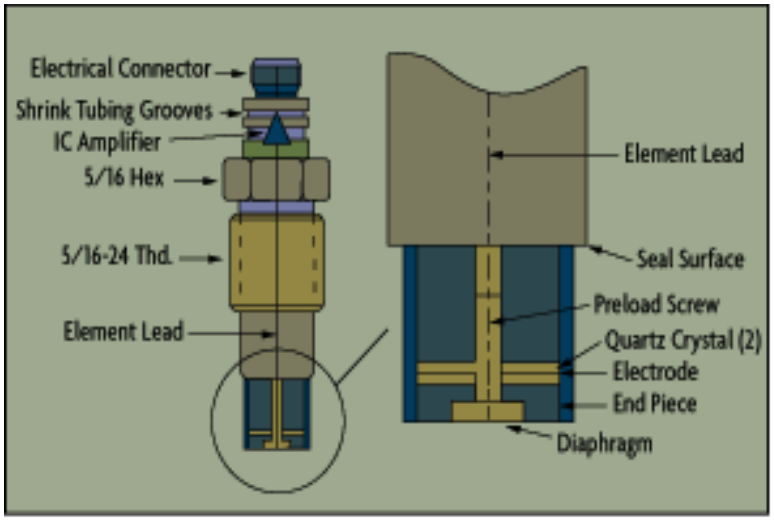


DIAPHRAGMS

Electrical Pressure Transducers

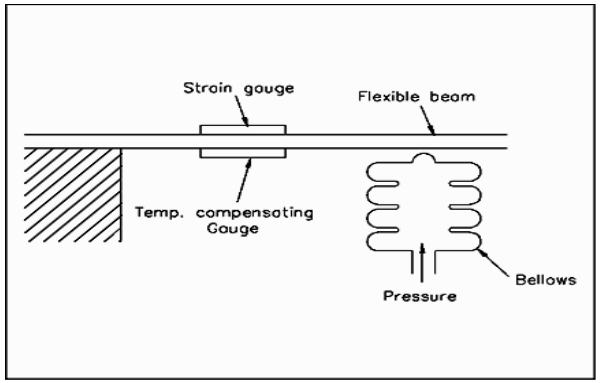


Strain Gauge Type Transducers

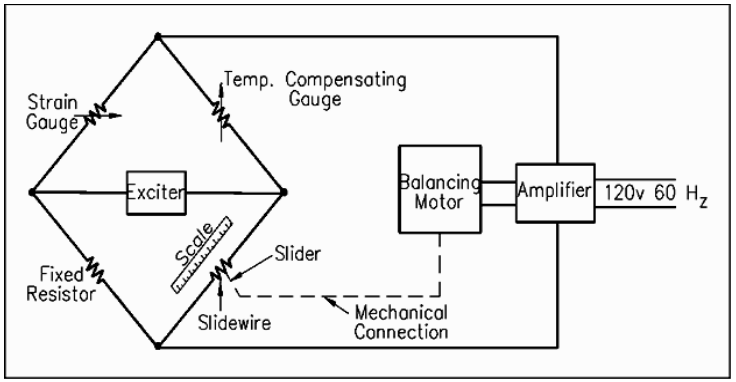


Piezo Electric-Type Transducers

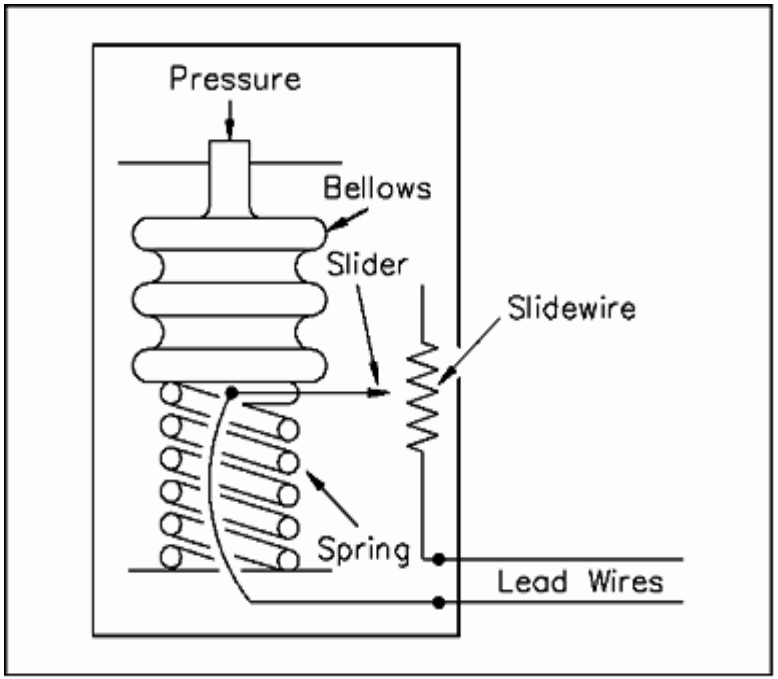
Resistance-Type Transducers



Strain Gauge Pressure Transducer

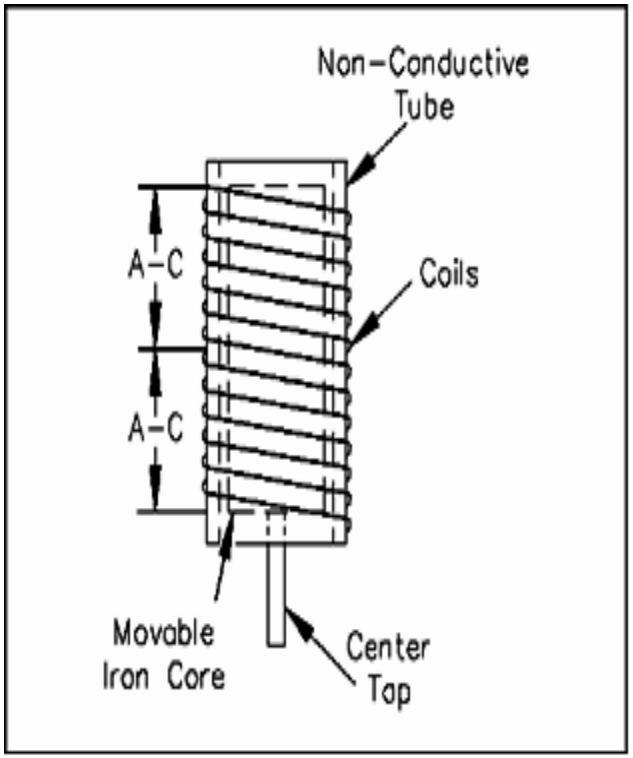


Gauge Used in a Bridge Circuit

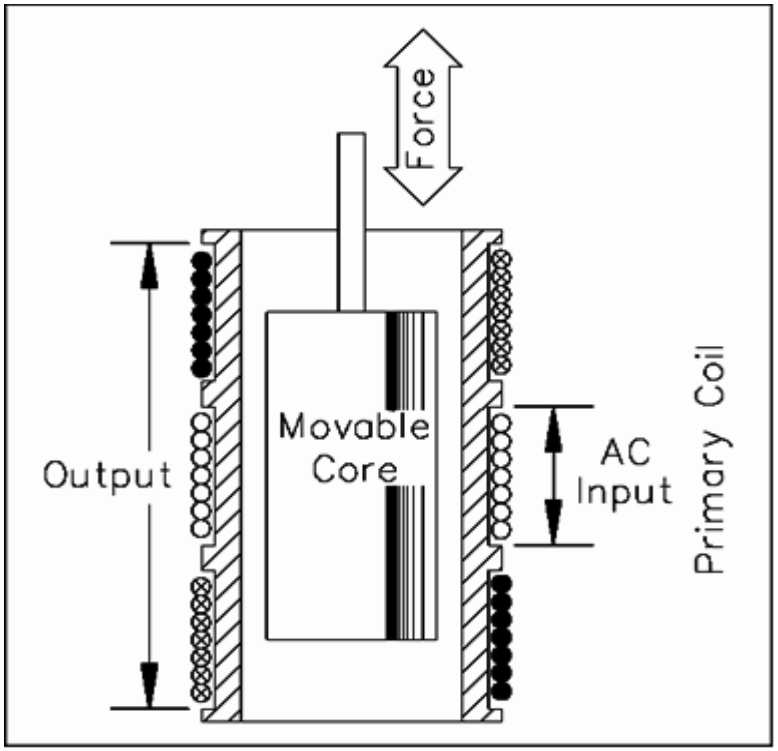


Bellows-Type Resistance Transducer

Inductance-Type Pressure Transducer

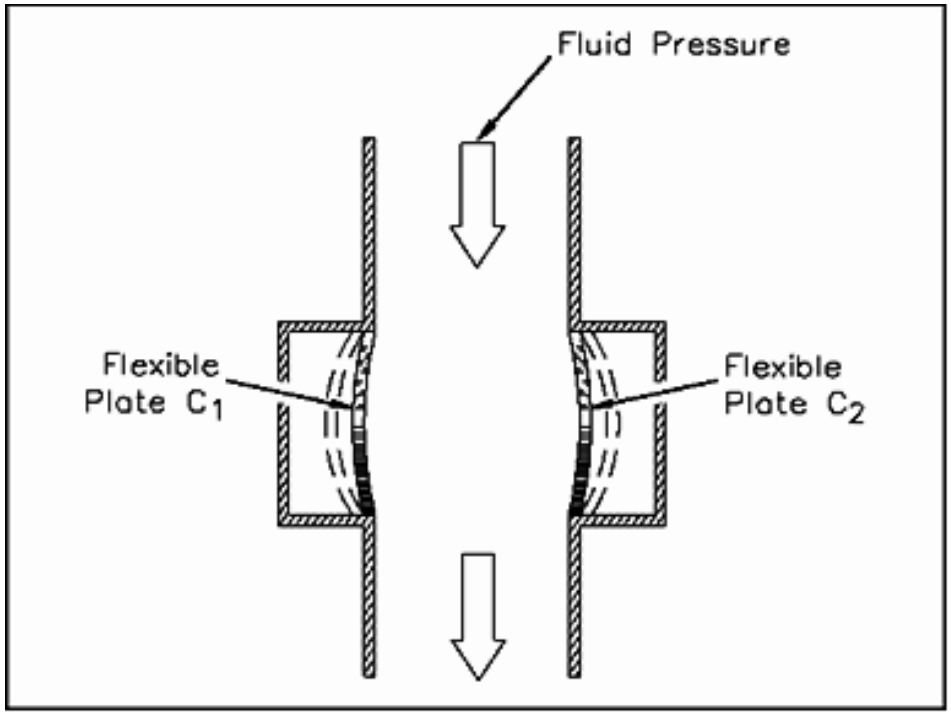


Inductance-Type Transducer coil

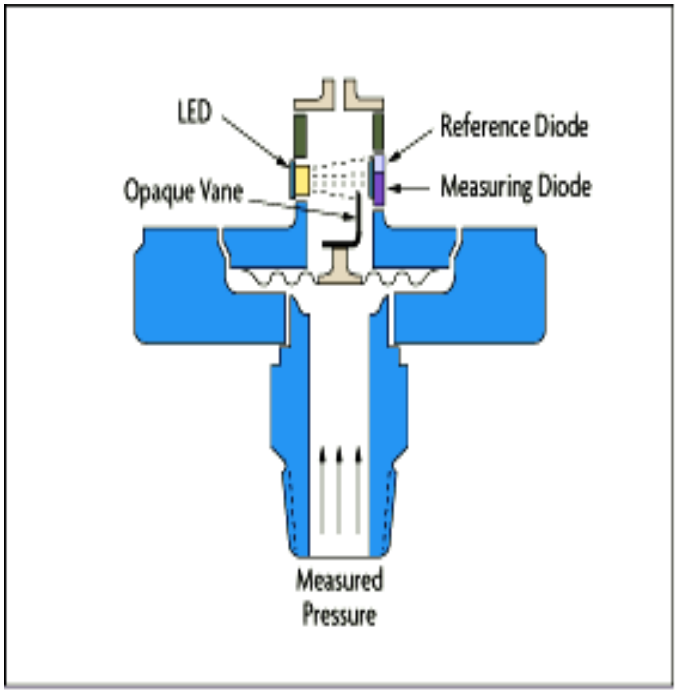


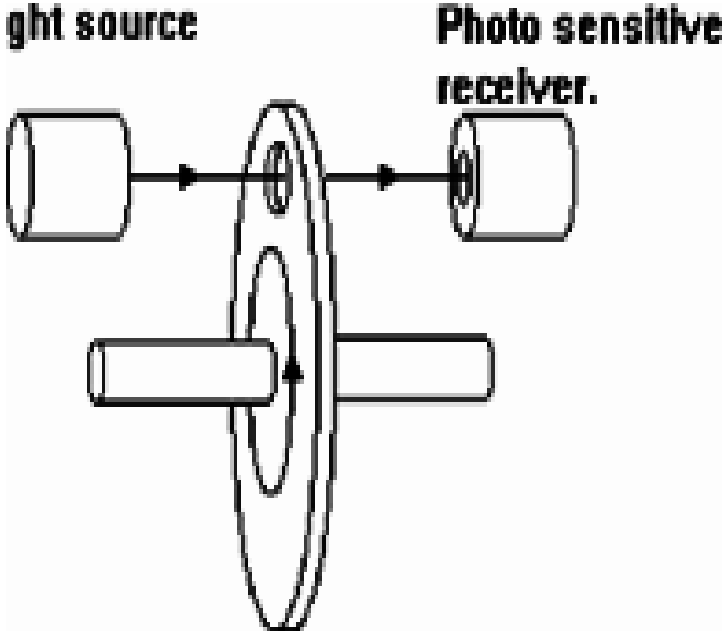
Differential Transformer with Moveable core

Capacitive-Type Transducers

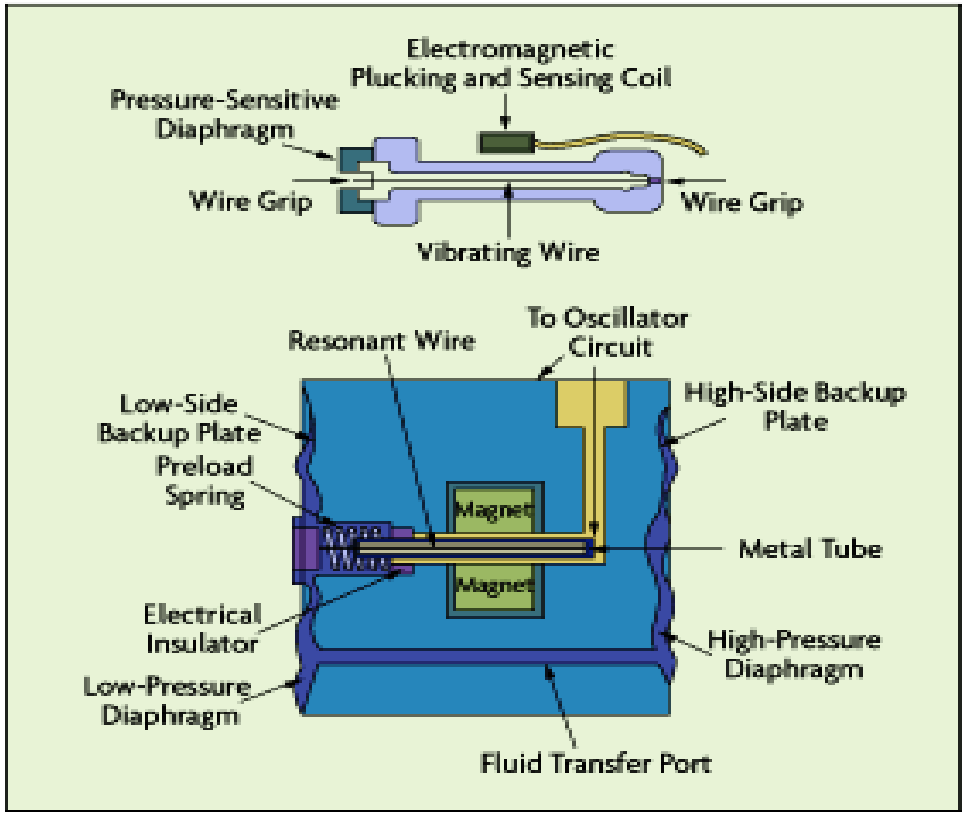


Optical-Type Pressure Transducer

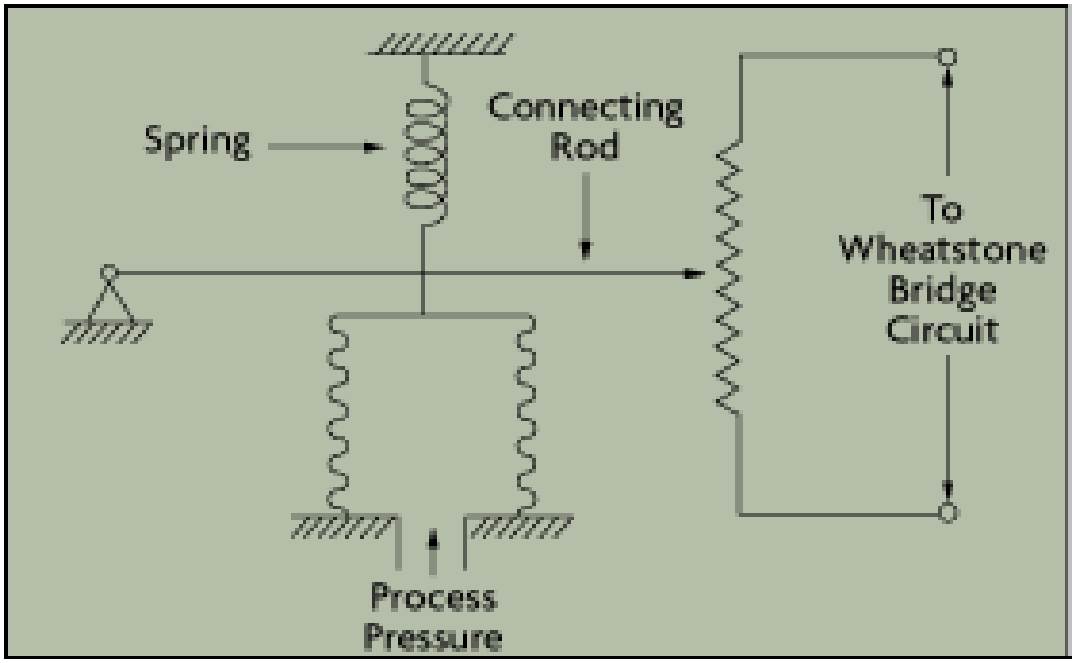




Resonant Wire-Type Transducers

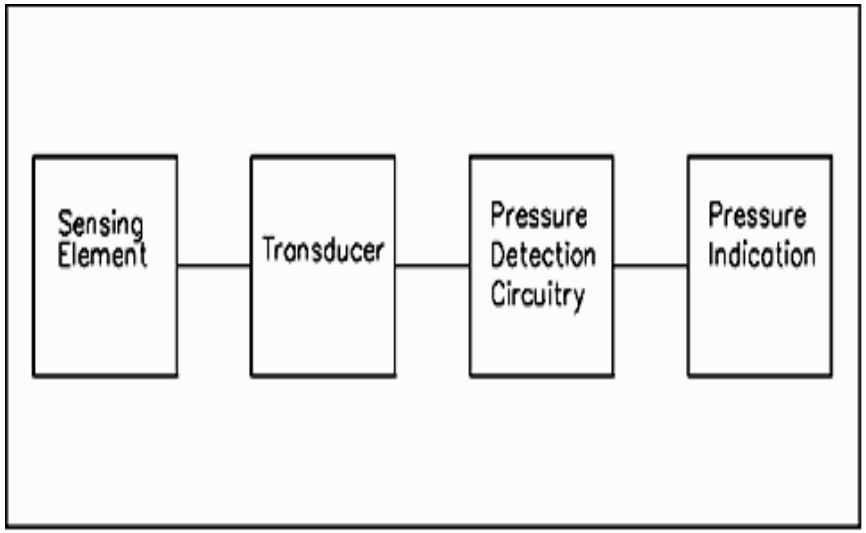


Potentiometric Pressure Transducers



Detection Circuitry

The sensing element senses the pressure of the monitored system and converts the pressure to a mechanical signal. The sensing element supplies the mechanical signal to a transducer. The transducer converts the mechanical signal to an electrical signal that is proportional to system pressure. If the mechanical signal from the sensing element is used directly, a transducer is not required and therefore not used.



The detector circuitry will amplify and/or transmit this signal to the pressure indicator. The electrical signal generated by the detection circuitry is proportional to system pressure. The exact operation of detector circuitry depends upon the type of transducer used. The pressure indicator provides remote indication of the system pressure being measured.

4 Pressure Measurements

Pressure measurements consists of two basic parts;

- Primary Elements

Contact directly or indirectly with fluid.

- Secondary Elements

Translate, Indicate and Recording.

Pressure Measuring Devices

There are two categories;

Wet Meters

Manometers, Barometers, etc.

Dry Meters

Transmitters, Transducers, and Mercury less meters.

Manometers

- **Range Zero PSI to 30 PSI**
- **Liquid Used Mercury or Water**
- **Simple and Accurate**

TYPES OF MANOMETERS

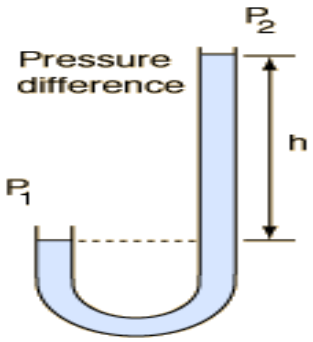
-1 U- Tube Manometers

-2 Well Manometers

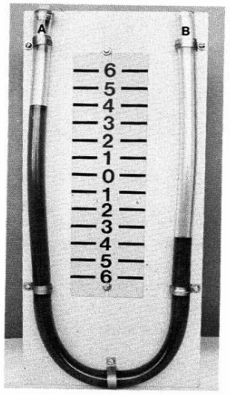
-3 Inclined Manometers

U-Tube Meter

- **Indicating ΔP**
- **Measure difference of liquid travel in both legs.**

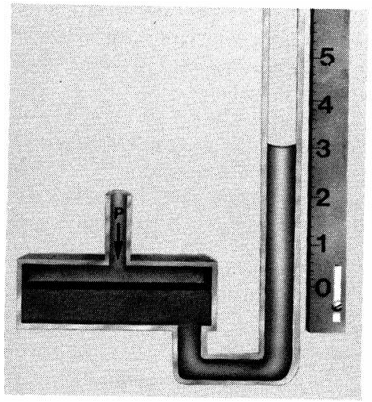


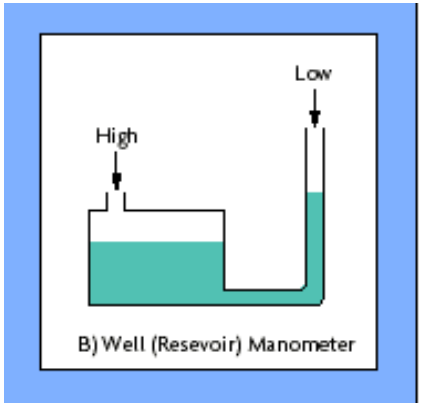
Pressure difference $\Delta P = P_2 - P_1 = \rho g h$



Well-Type Manometer

- Well Filled With Mercury
- Pressure Applied to the Surface of Liquid
- Liquid Will Rise in Column Until Pressure Exerted by the Height of Column Is Equal to Applied Pressure.



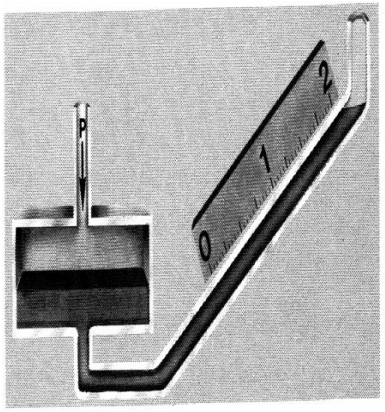


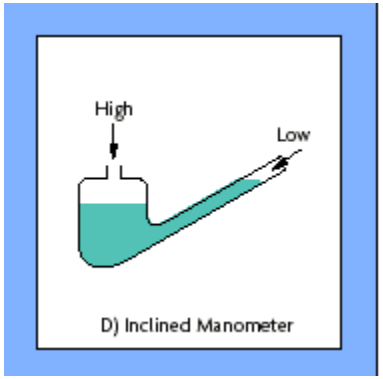
ADVANTAGE

- ✓ Reading of Pressure With Single Observation

Inclined-Type Manometer

- Tube is sloped
- Liquid column rise vertical height
- Travel farther
- Scale has smaller graduation
- Advantage
  Precise Reading

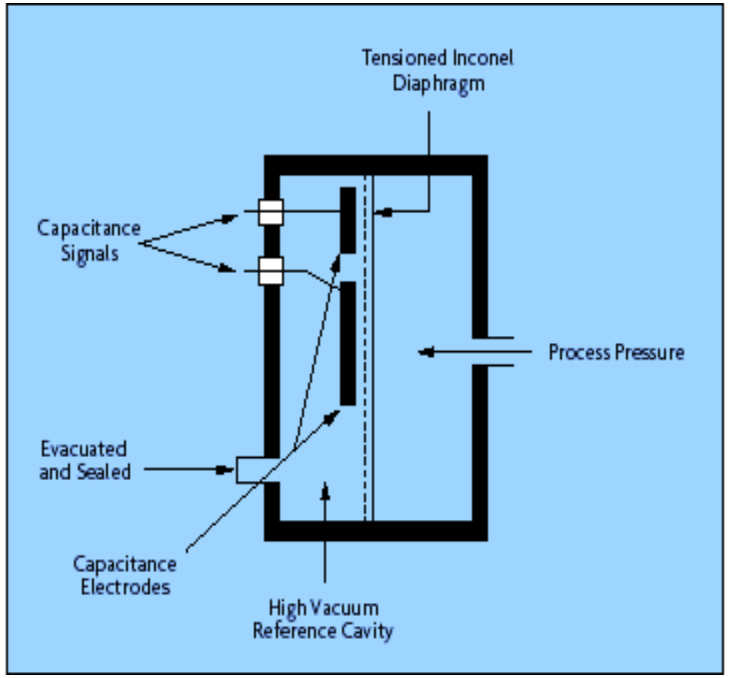




Capacitance Manometer

- A capacitance sensor operates by measuring the change in electrical capacitance that results from the movement of a sensing diaphragm relative to some fixed capacitance electrodes.

- The great advantage of a capacitance gauge is its ability to detect extremely small diaphragm movements.



Barometers

- An instrument used to measure atmospheric pressure.
- It can measure the pressure exerted by the atmosphere by using water, air, or mercury.

Types of Barometer

Three types of Barometer.

-1 Water-Based Barometer

-2 Mercury Barometer

-3 Aneroid Barometer

Water-Based Barometer

- It can also be called a "storm glass" or a "Goethe barometer".
- It consists of a glass container with a sealed body, half filled with water.
- When the air pressure is lower than it was at the time the body was sealed, the water level in the spout will rise above the water level in the body; when the air pressure is higher, the water level in the spout will drop below the water level in the body.

Mercury Barometer

- A standard mercury barometer has a glass column of about 30 inches (about 76 cm) in height, closed at one end, with an open mercury-filled reservoir at the base.
- The mercury barometer's design gives rise to the expression of atmospheric pressure in inches or millimeters (torr): the pressure is quoted as the level of the mercury's height in the vertical column. 1 atmosphere is equivalent to about 29.9 inches, or 760 millimeters, of mercury.

Aneroid Barometer

- The mechanism is made deliberately 'stiff' so that tapping the barometer reveals whether the pressure is rising or falling as the pointer moves.
- A barograph, which records a graph of some atmospheric pressure, uses an aneroid barometer mechanism to move a needle on a smoked foil or to move a pen upon paper, both of which are attached to a drum moved by clockwork.

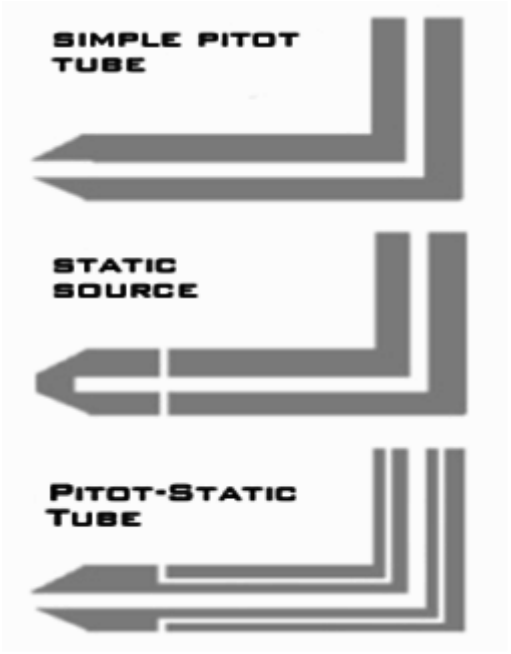
Old Aneroid Barometer

Modern Aneroid Barometer

Other Pressure Measuring Elements

Barograph

Pressure Altimeter



Pitot-Tubes

Pressure Transmitters

- The pressure transmitter is secondary element.
- Both pneumatic and electronic transmitters are used.

Pneumatic Transmitters

- Diff. pressure to be measured is applied across a pair of metal diaphragms welded to opposite sides of a capsule.
- Space between the diaphragms and core member is filled with liquid.

Pressure Transmitters

- The force developed by diff. pressure is brought out of the transmitters by a rigid rod passing through a metal seal diaphragm.
- Force opposed by a balancing force developed by pneumatic bellows
- Imbalance between capsule force and pneumatic bellows force is sensed by a pneumatic nozzle-baffle
- A simple pneumatic servomechanism responsive to nozzle pressure re-establishes the balance.

Pressure Transmitters

- Pneumatic pressure is maintained exactly proportional to differential pressure
- Standardized signals is 3 to 15 pounds per square inch

Electronic Transmitters

- This particular type utilizes a two-wire capacitance technique.
- Process pressure is transmitted through isolating diaphragms and silicone oil fill fluid to a sensing diaphragm in the center of the cell. The sensing diaphragm is a stretched spring element that deflects in response to differential pressure across it.

Pressure Transmitters

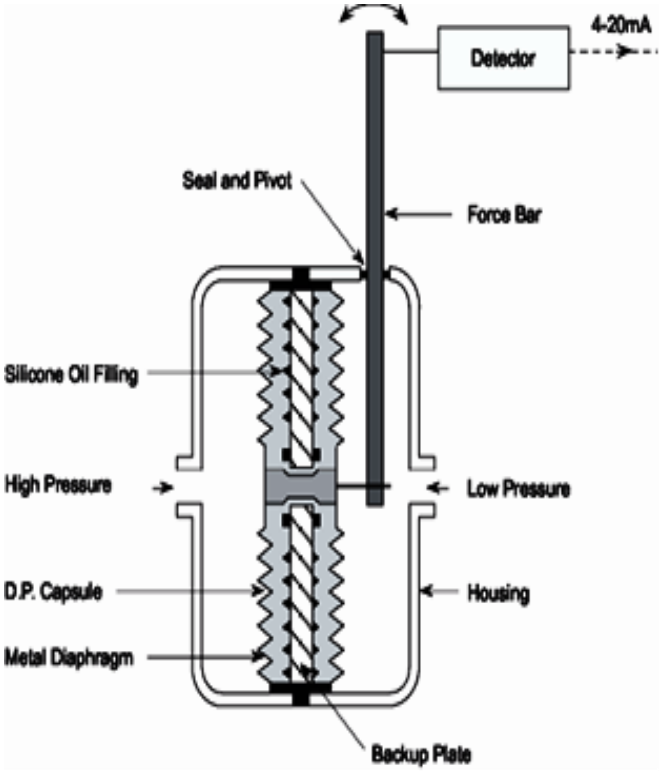
- The displacement of the sensing diaphragm is proportional to the differential pressure.
- The position of the sensing diaphragm is detected by capacitor plates on both sides of the sensing diaphragm.
- The differential capacitance between the sensing diaphragm and the capacitor plates is converted electronically to a 4–20 ma.
- These signals are standard in industry.
- The mechanical element techniques most generally used to convert applied pressures into displacement are diaphragms, bellows, Bourdon tubes, and straight tubes.

Transmitters Special Features

- **Service :** Liquid, Gas and Vapor
- **Ranges :** 0-25 to 0-150 in H_2o , 0-50 to 0-300 psi
- **Output :** 4-20ma
- **Power Supply:** 12 to 45 v dc
- **Temp. Limit:** -29 t 93 C
- **Static Pressure :** 0-4500 psig
- **Damping Time Constant Adjustable 0.2 to 1.5 sec.**
- **Turn on Time :** 2 Second
- **Dead Band :** None

Differential Pressure Transmitters

- Most pressure transmitters are built around the pressure capsule concept. They are usually capable of measuring differential pressure (that is, the difference between a high pressure input and a low pressure input) and therefore, are usually called DP transmitters or DP cells.

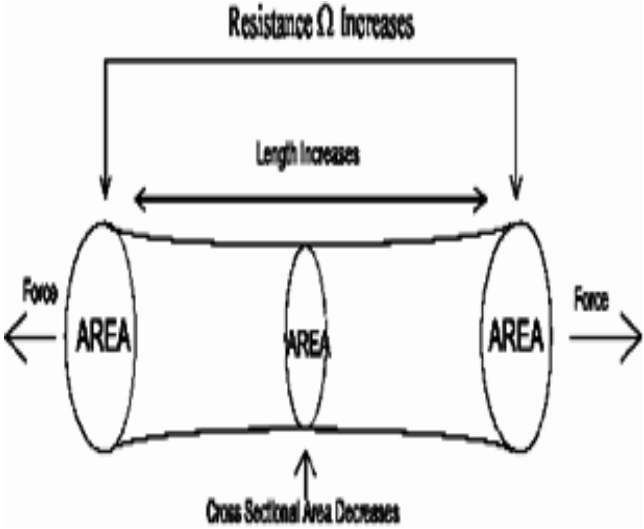


Differential Pressure Transmitters

- 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.

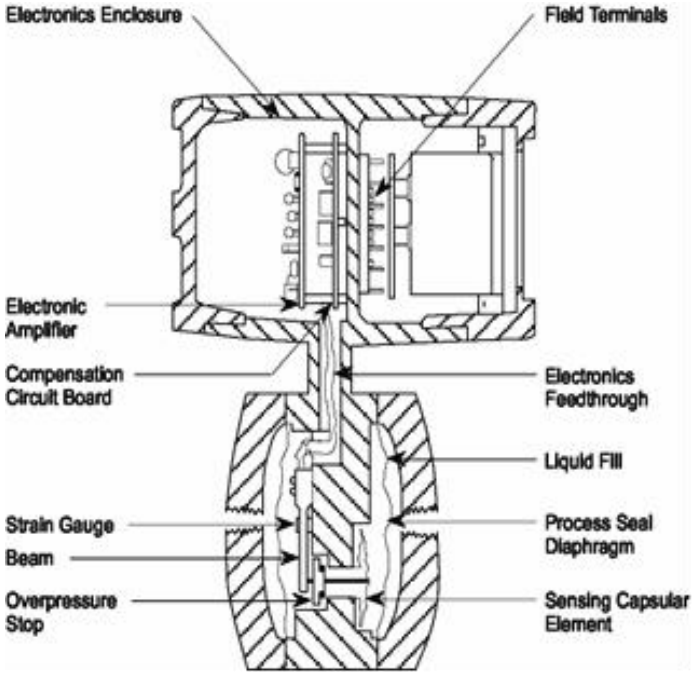
Strain Gauge

- The strain gauge is a device that can be affixed to the surface of an object to detect the force applied to the object. One form of the strain gauge is a metal wire of very small diameter that is attached to the surface of a device being monitored.
- For a metal, the electrical resistance will increase as the length of the metal increases or as the cross sectional diameter decreases. When force is applied as indicated, the overall length of the wire tends to increase while the cross-sectional area decreases. The amount of increase in resistance is proportional to the force that produced the change in length and area. The output of the strain gauge is a change in resistance that can be measured by the input circuit of an amplifier.



Resistive Pressure Transmitter

Strain gauges can be bonded to the surface of a pressure capsule or to a force bar positioned by the measuring element, is a strain gauge that is bonded to a force beam inside the DP capsule. The change in the process pressure will cause a resistive change in the strain gauges, which is then used to produce a 4-20 mA signal.



5 Pressure Control

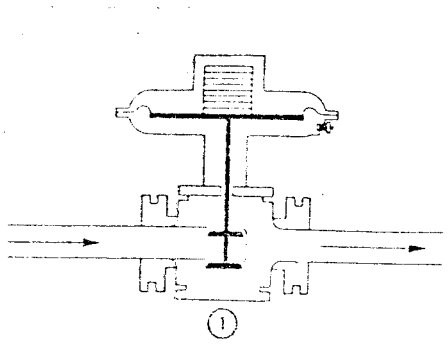
- A frequent problem in pressure control is the regulation of fluid pressure.
- Pressure regulators are commonly used to provide this service.

Classification of Pressure Regulators

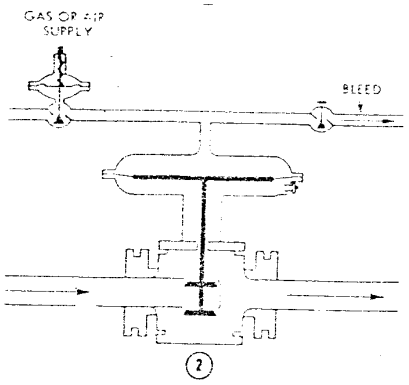
There are three classes of pressure regulators;

- **Direct-operated Regulators**
- **Pilot-operated Regulators**
- **Instrument Pilot-operated Regulators**

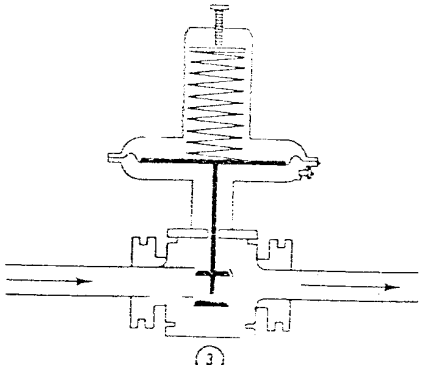
Direct-Operated Regulators



a



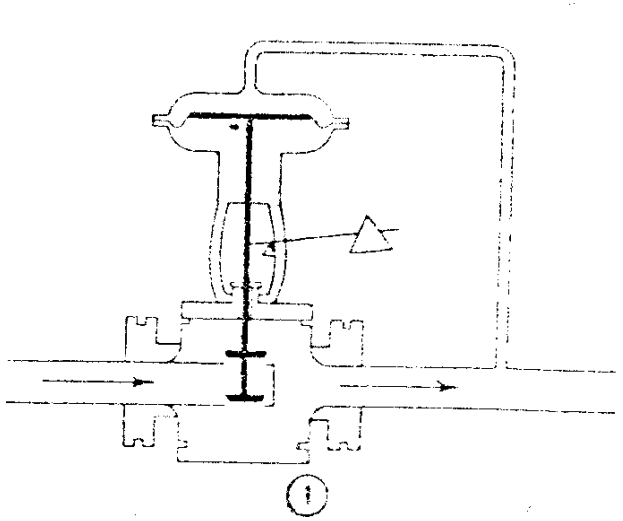
b



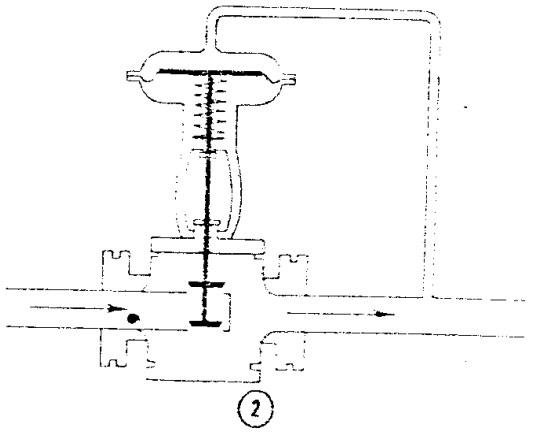
c

Direct-operated Regulators can be a.weigt-loaded, b. pressure-loaded c. spring-loaded

Direct-operated Regulators



a

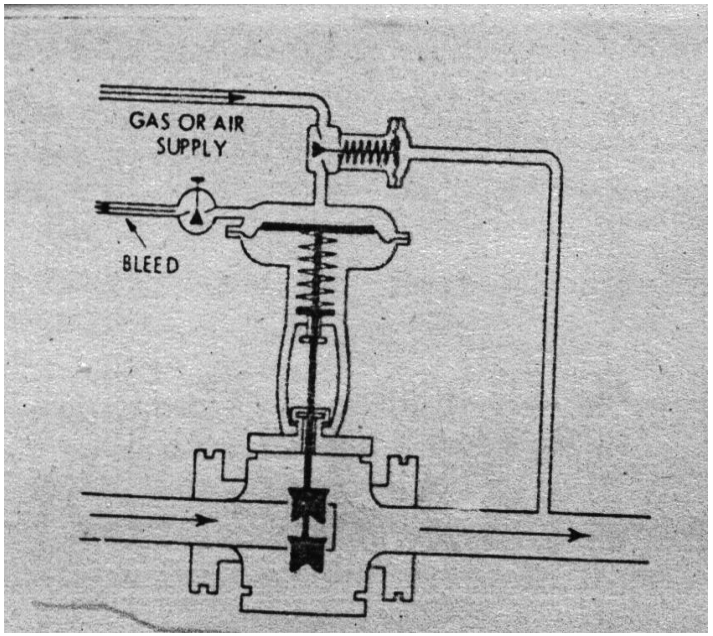


b

Externally connected regulators can be a. Weight load b. spring load

Pilot-operated Regulators

- A pilot is a small regulator positioned between the pressure connection to the regulator, and loading chamber. Controlled pressure is piped to the pilot, which varies the loading on the regulator. The addition of the pilot improves the control. Only a light change in the controlled pressure is required to produce a full range change of the regulator.



Instrument Pilot-operated Regulators

- Instrument pilot-operated regulator, provides more flexible control. In general, the pilot is pneumatic controller with a bellows or pressure spring as the sensing element. The controller usually includes proportional band adjustment for varying the sensitivity. The regulation is actually performed by a control valve.