Instrumentation Fundamental

- Instrumentation: measure the variable

  Variable: T, P, L, F

  Method: Direct and indirect method

Direct method: Physical dimension

Indirect method: Quality of the product

(ex. bacteria in the milk)

Criteria of selection of measuring instrument:

- how accurate
- when the final data required
- cost criteria
- what form of the data displayed
- whether variable is constant or time variant

Static characteristics of an instrument:

- Variable not varying with time

Characteristics

- Accuracy: determined as maximum amount by which the result differ from the true value
- Reproducibility: value repeatedly measure
- Sensitivity: Ratio of output response to change in input
- Static error: Instruments reading

  = true value +static error
- Drift: Insidious quality(spreading gradually or without being noticed, but causing serious harm)
- Dead zone: largest range of the value of measured variable to which the instrument does not respond

Dynamic characteristics of an Instruments

common variations are

- Step change
- Linear
- Sinusoidal change
- Speed of response: quickness of an instrument to read the measured variable
- Fidelity :change in measured variable without dynamic error
- Measuring lag

Transducer: Mechanical signal to voltage or current

- Pressure transducer
- level transducer
- velocity transducer

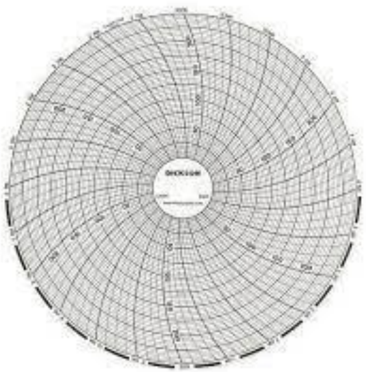
Indicator : Only present value has meaning and past record is of no consequences

- Eccentric scale indicator
- Co-centric scale indicator
- linear scale indicator

Eccentric scale indicator   Co-centric scale indicator   Linear scale indicator

Recorder :

- Circular recording chat



Strip recorder chart

Strip chart recorder

Pressure measurement

- Absolute pressure (p_a)
- Differential pressure: Algebraic difference between two pressure
- Gauge pressure $p_g = p_a - p_{atm}$
- Vacuum pressure $p_v = p_{atm} - p_a$

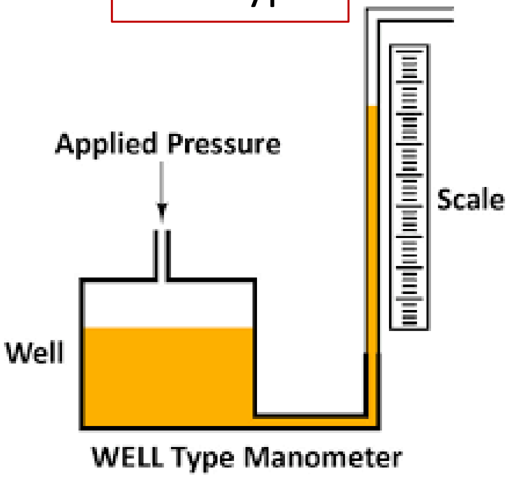
Measuring instrument

- liquid column :manometer
- elastic pressure element
- electrical device
- electronic device

Manometer

- U tube manometer
- Inclined tube manometer: Pressure change is very small
- Well type
- Cistern barometer
- McLeod gauge

Well type



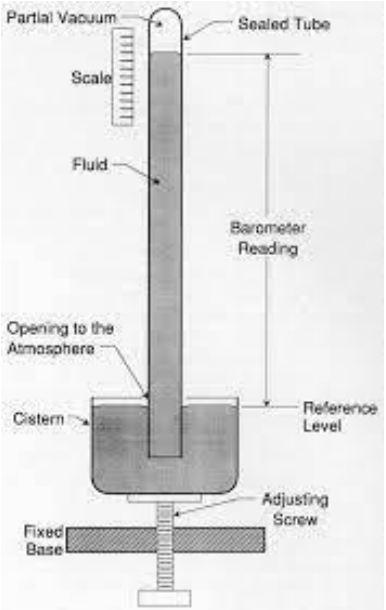
Rise of the liquid level in the Well is very small compared to the narrative so h can be measured directly

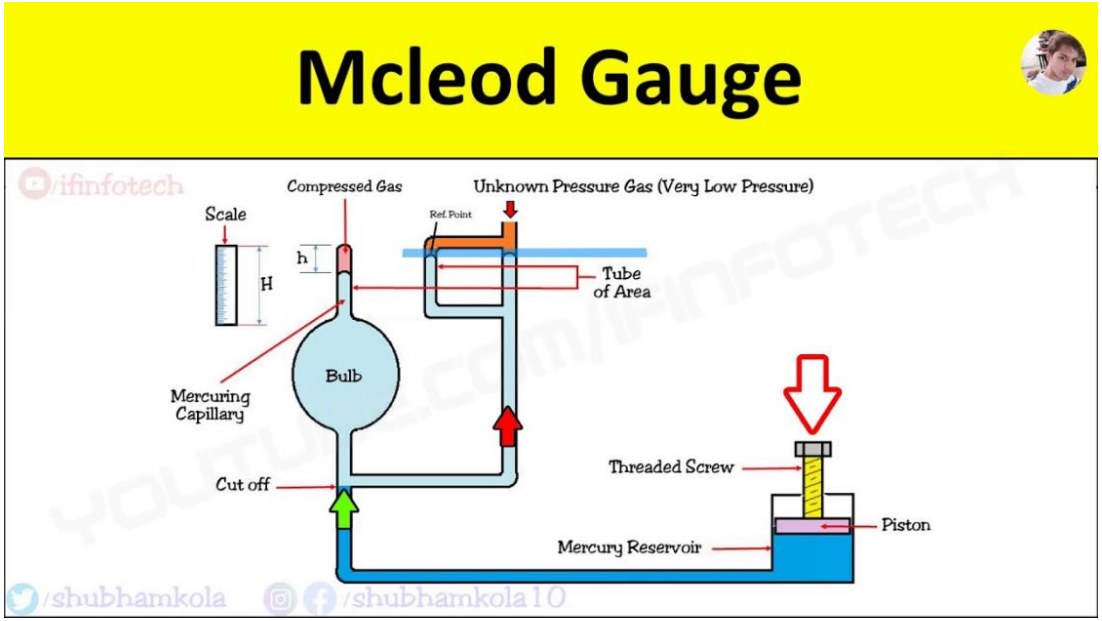
Cistern barometer

Measure the absolute pressure .
Narrow tube is evacuated and sealed.

Fixed Cistern barometer

measure the gas pressure





- Mcleod gauge (Boyle's law, $P_1V_1=P_2V_2$)

  very low pressure

Instruments use Elastic pressure elements

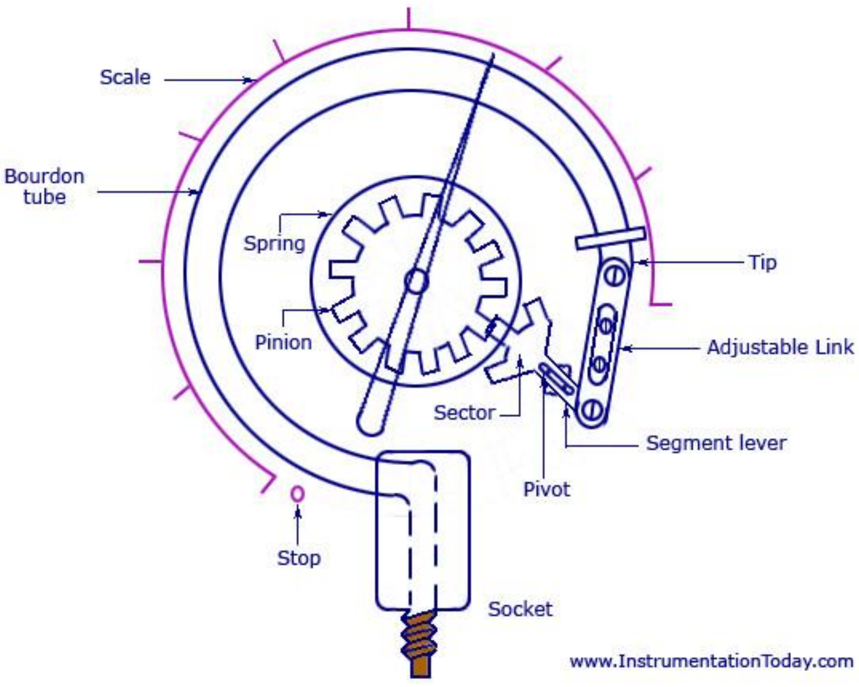
converts pressure signal into proportional mechanical displacement also known as transducer

Type:

- Bourdon pressure gauge
- Diaphragm pressure gauge
- Bellows pressure gauge

Bourdon pressure gauge

Tube can be Helix / Spiral



Bourdon Tube Pressure Gauge

Bourdon pressure gauge

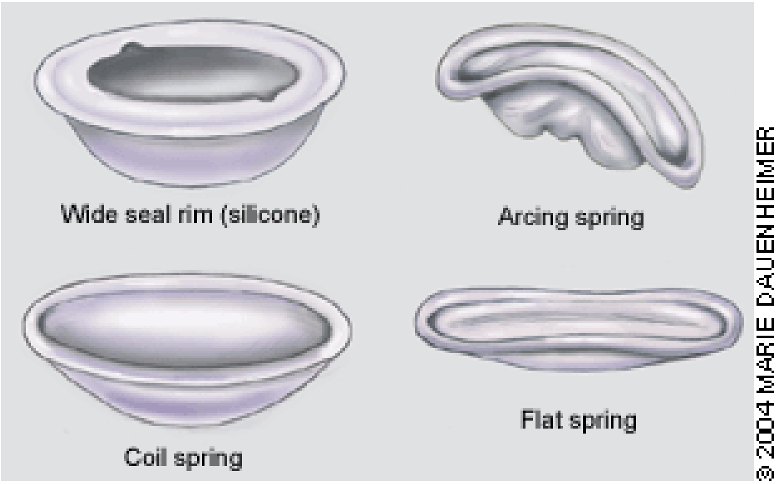
- movement of free end of the tube is transmitted to a section through an adjustable connection link.
- Pointer gives the reading.
- Reference pressure is atmospheric so it measure the gauge pressure.

Diaphragm pressure gauge

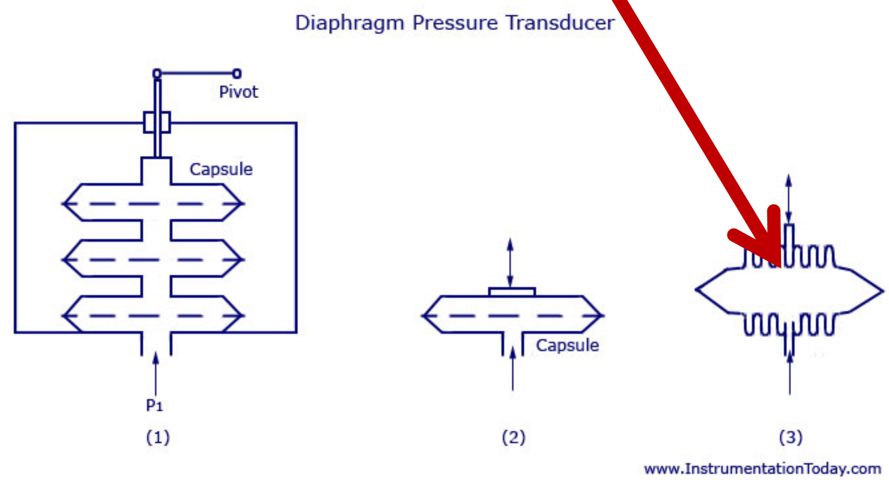
- Thin ductile material
- Depending upon face strength and deflection Desired
  - Dished
  - Flat
  - Corrugated

Dished

Flat



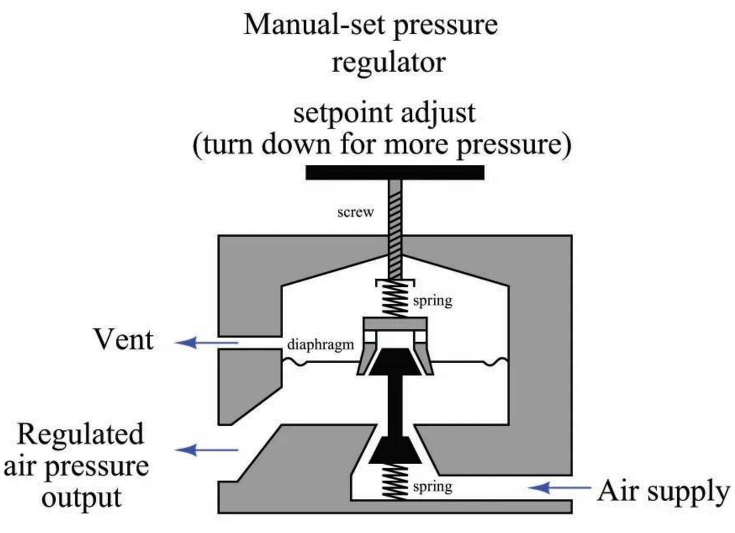
Corrugated

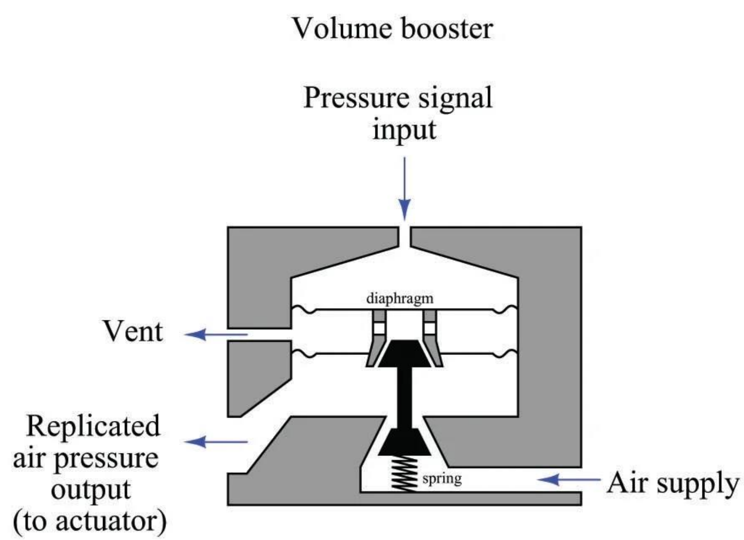


Diaphragm

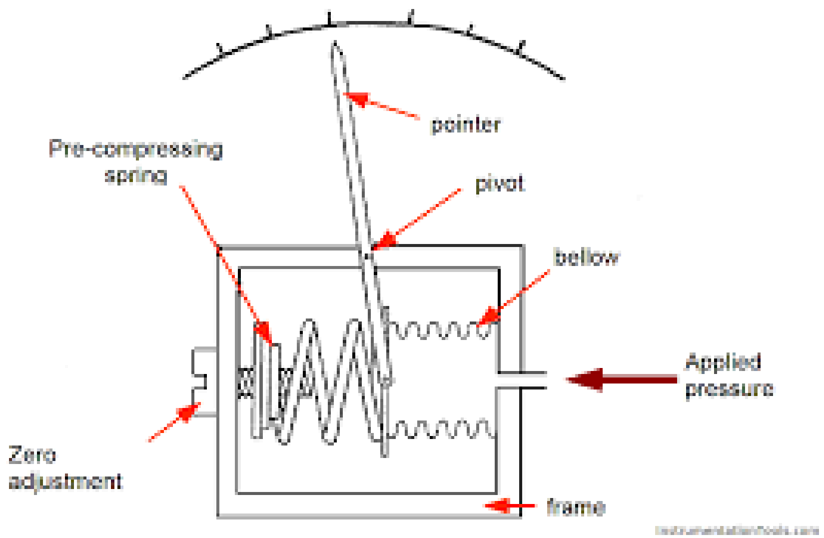
Corrugated diaphragm will have 4 times the deflection of flat type diaphragm Material: brass

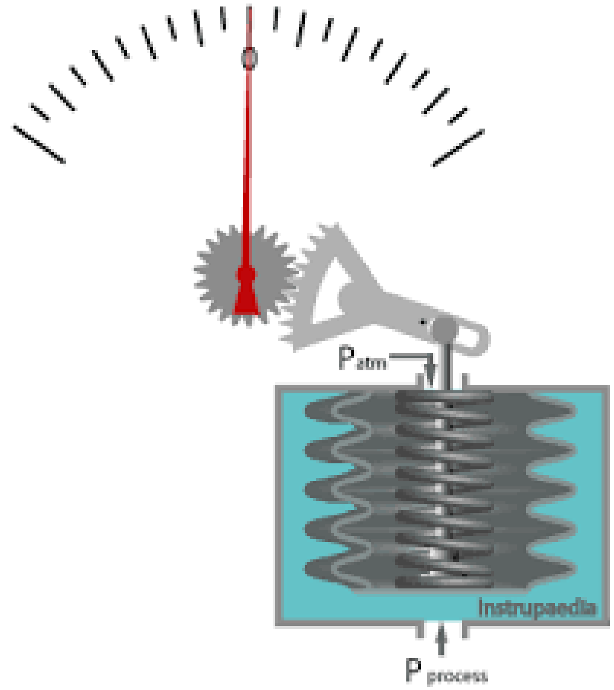
Range: 0.35 to 15 kilogram per centimetre square





- Bellows pressure gauge





It can be expanded or contracted by the application of pressure or vacuum

Instruments which use electrical devices

Properties :

- Magnitude of current
- The rate at which heat is dissipated by conduction Convection and radiation

If current is constant

↓

Then temperature will depend upon the heat dissipation

↓

Conductivity /conduction of media

↓

Density of media

↓

Pressure

If Pressure ↓ (decrease) conductivity ↓ (decrease) wire become hotter for same current.

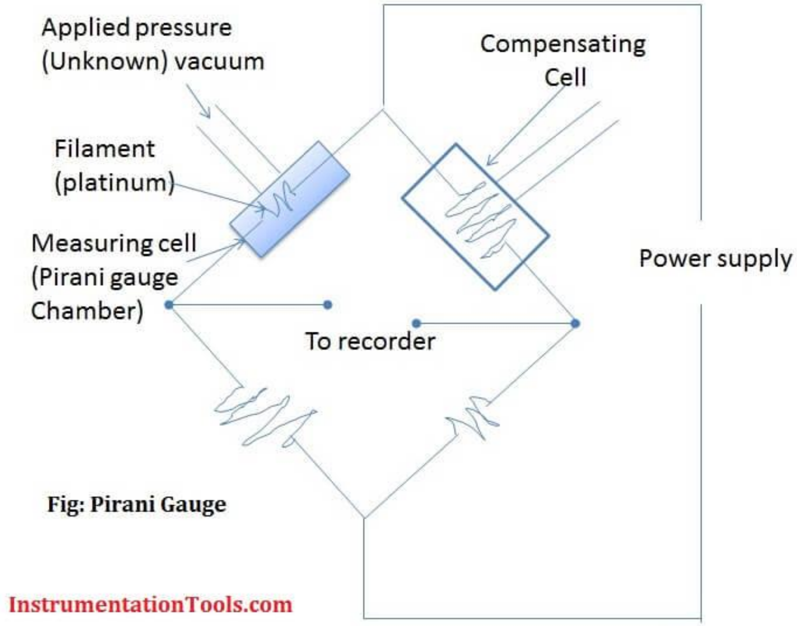
So for a given current temperature of the wires directly depend on the pressure

Two type of instrument

- Pirani gauge
- Thermocouple gauge case

- **Pirani gauge (20-1000 μ Hg)**

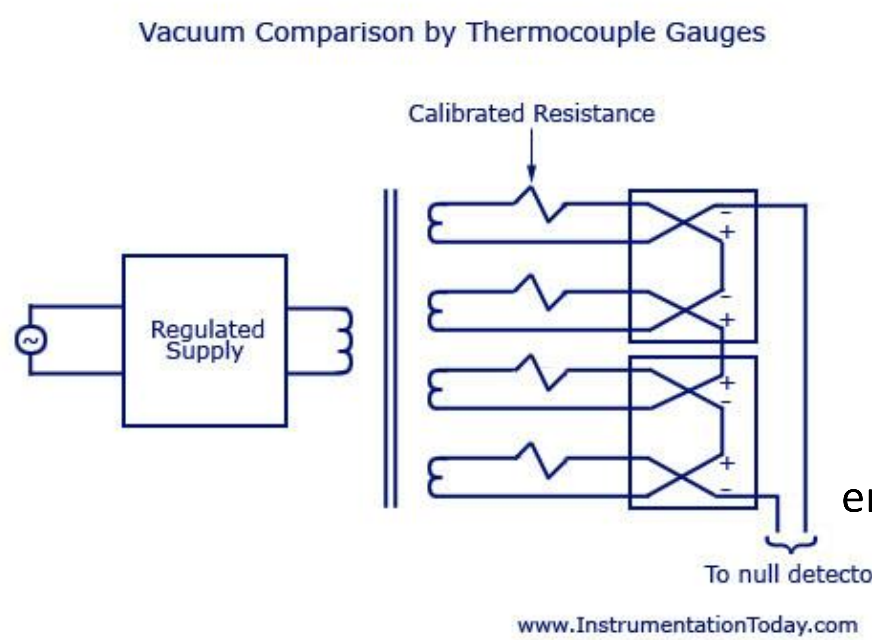
https://www.youtube.com/watch?v=3h_LIJtmCDc



Vacuum to be measured

Filament temperature < 300 ^oC

- **Thermocouple gauge case**



emf

- Thermocouple attach at the middle of the Each resistor will differ develop an emf which is proportional to the temperature difference of the junction
- This emf is proportional to pressure the Potentiometer which is used to measure the emf is calibrated in terms of pressure

Instruments uses electronic device

Property: Electron emitted at the cathode by thermionic emission attracted towards the grid.

- Pass through the grid towards the plate
- Ions are formed by collision of the electron with molecules present in the tube.

Devices

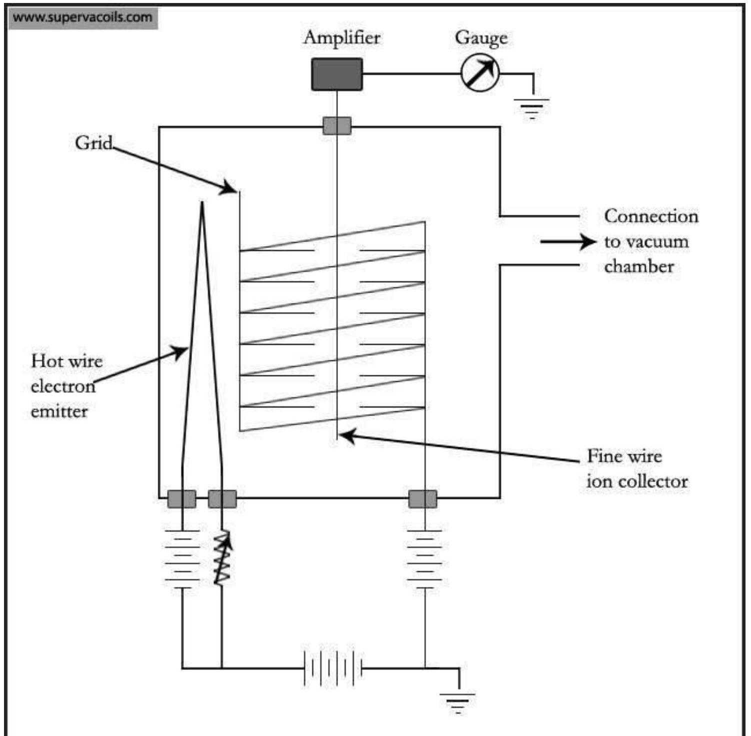
- Hot filament ionization gauge
- Cold cathode ionization gauge
- Radio active ionization gauge

Hot filament ionization gauge

Electron emitted at the cathode by thermionic emission attracted towards the grid.

- IONS are formed by collision of the electron with the molecules of the gas present in the tube.

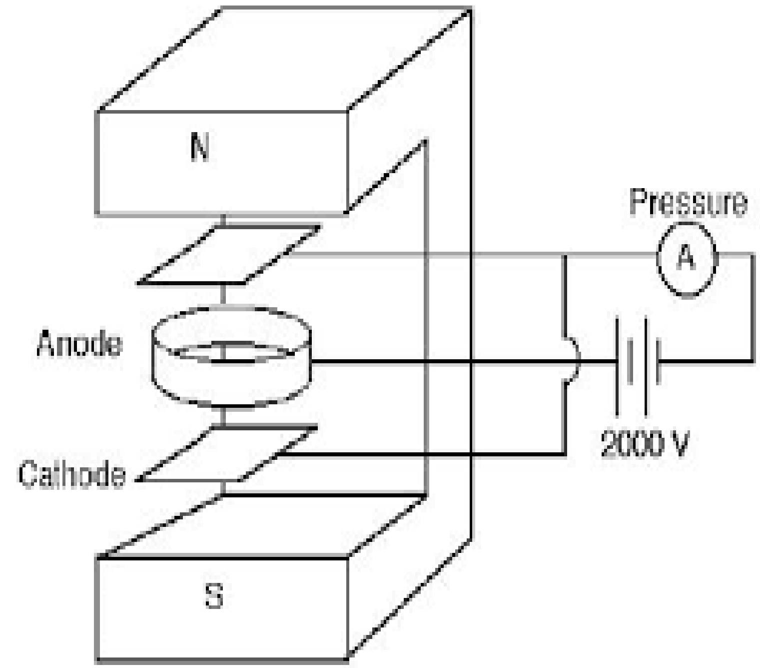
- Positive ions are collected by on the plate and as a current positive ions current exist.
- Amount of ion current is proportional to the amount of gas present Provided the electron current is constant.
- The electron to grid is maintained by the great current.
- Cannot used to measure above 2 **μ Hg** because of the probability of burning out the elements.
- It can be used in conjunction with Pirani guage is used to measure pressure above 2 **μ Hg.**
- Can also measure of absolute pressure of inert gases like O_2, CO_2 and H_2O.



A schematic sketch of Hot Cathode Ionization Gauge

Cold cathode ionization Gauge

- Two parallel flat plate as cathode and cylindrical anode
- High Voltage is maintained between anode or cathode the electrodes will discharge ions.
- At low pressure the probability of these electrode colliding with molecules and ionizing them are very less.
- To overcome this difficulty the gauge is placed in between the poles of the Electromagnet so the magnetic field is at right angle to the plate. ↓
- Electron to make towards the anode cylinder in a helical path ↓
- Ionized molecules of gas even though that are very few in numbers.
- Range → 10^{-3} to 10^{3} mmHg



Radio active ionization gauge

Radio material (source) → Place in a air tight chamber

↓

α Particle

↓

Ionize gas particle

Similar to thermionic gauge

- Range → 10^{-3} to 10 μHg

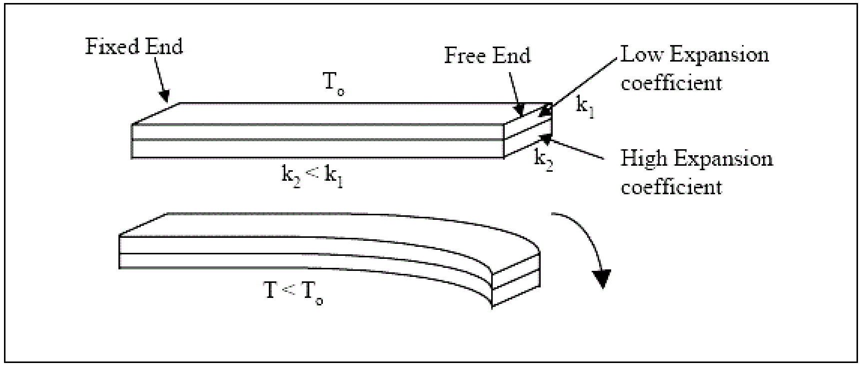
Temperature Measurement

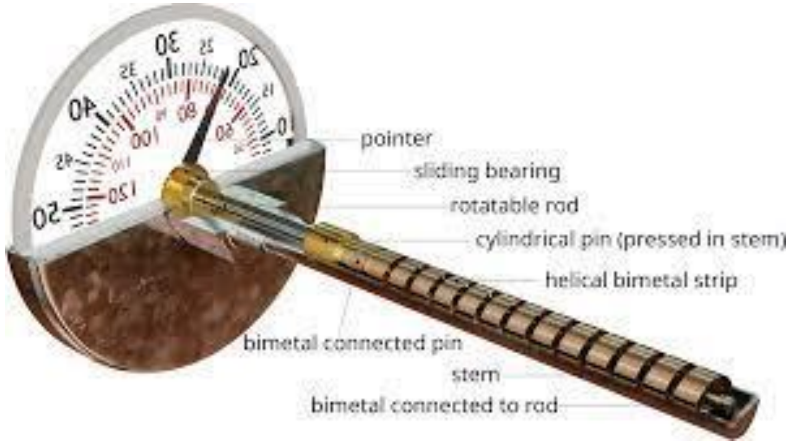
- Thermometer → glass tube
- Bimetallic thermometer
- Bourdon tube thermometer
- Thermocouple
- Thermopiles
- Resistance thermometer
- Pyrometer

Bimetallic thermometer

- Bi-metal having different coefficient of thermal expansion
- When strip is heated or cooled different expansion or contraction occurs causing the strip to bend.
- The angular velocity is proportion to the temperature change.

Bimetallic Thermometer





Example: Invar (Ir 64 %and Ni 36%) low expansion metal alloy

Brass → high expansion metal alloy

Range→ 30 to 550 °C

Dis advantage

- **Spot reading**
- **Stem must deep in fluid**

Bourdon tube thermometer

- Liquid filled thermometer
- Gas filled thermometer
- Vapour Pressure thermometer

Liquid filled thermometer:

- Thermal expansion of liquid
- Pressure spring to unwind
- Movement is converted into circular movement of level which moves on a scale.
- Calibrated in terms of temp.

Gas filled thermometer:

At constant volume (Charles law)

$T_1 / P_1 = T_2 / P_2$

Gas is filled at high pressure.

So that increase in press for each degree temp will be more .

The deflection of bourdon tube is converted to circular movement of a lever.

Vapour pressure Thermometer

- Change in vapour pressure of liquid with temperature.

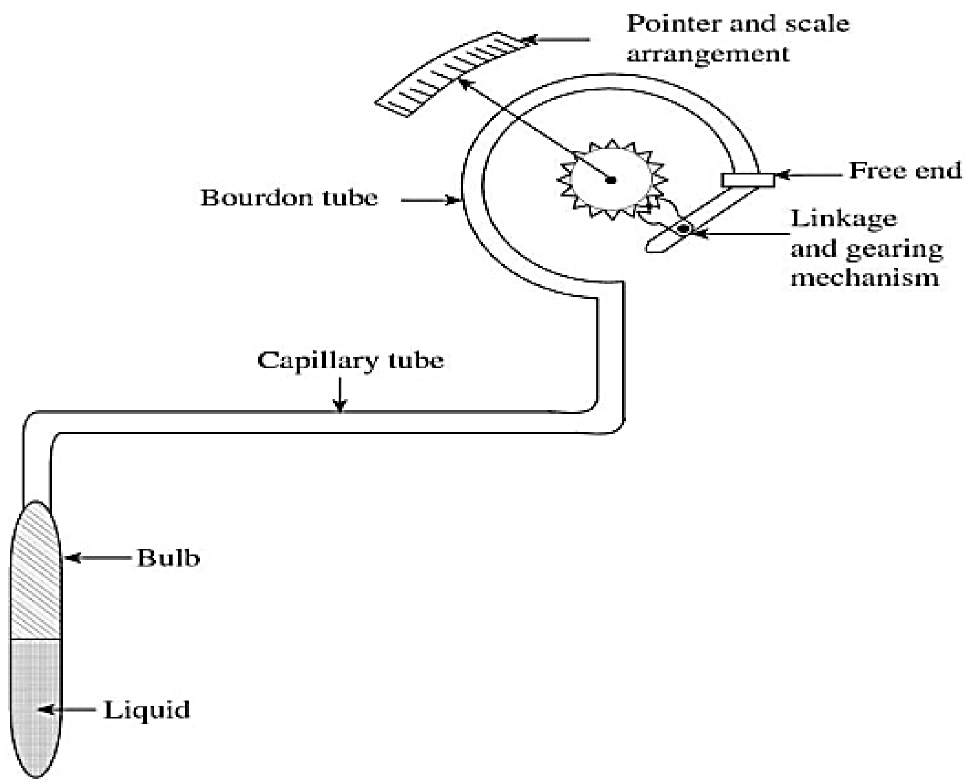


Fig. 15.11 Pressure thermometer

Temperature range : - 40 to 540 ^oC
Hg filled with 150 to 200 ft

Thermocouple

- The change in material resistance as a function of temperature.
- There exists another dependence of electrical behavior of materials on temperature that forms the basis of a large percentage of all temperature measurement.
- This effect is characterized by a voltage-generating sensor in which an electromotive force (emf) is produced that is proportional to temperature.
- Such an emf is found to be almost linear with temperature and very repeatable for constant materials.
- Devices that measure temperature on the basis of this thermoelectric principle are called thermocouples (TCs).

Thermoelectric Effects

- The basic theory of the thermocouple effect is found from a consideration of the electrical and thermal transport properties of different metals.
- In particular, when a temperature differential is maintained across a given metal, the vibration of atoms and motion of electrons is affected so that a difference in potential exists across the material.
- This potential difference is related to the fact that electrons in the hotter end of the material have more thermal energy than those in the cooler end, and thus tend to drift toward the cooler end.
- This drift varies for different metals at the same temperature because of differences in their thermal conductivities.
- If a circuit is closed by connecting the ends through another conductor, a current is found to flow in the closed loop.

- The proper description of such an effect is to say that an emf has been established in the circuit and is causing the current to flow.
- Pictorial representation of this effect, called the Seebeck effect, in which two different metals, A and B, are used to close the loop with the connecting junctions at temperatures.
- We could not close the loop with the same metal because the potential differences across each leg would be the same, and thus no net emf would be present.
- The emf produced is proportional to the difference in temperature between the two junctions.
- Theoretical treatments of this problem involve the thermal activities of the two metals.

Optical Sensors

INSTRUCTIONAL OBJECTIVES

We should be able to

- Describe electromagnetic (EM) radiation in terms of frequency, wavelength, speed of propagation, and spectrum.
- Define the energy of EM radiation in terms of power, intensity, and the effects of divergence.
- Compare photoconductive, photovoltaic, and photo emissive-type photodetectors.
- Describe the principles and structure of both total radiation and optical pyrometers.
- Distinguish incandescent, atomic, and laser light sources by the characteristics of their light.
- Design the application of optical techniques to process-control measurement applications.

- A desirable characteristic of sensors is that they have a negligible effect on the measured environment—that is, the process.
- Thus, if a resistance-temperature detector (RTD) heats up its own temperature environment, there is less confidence that the RTD resistance truly represents the environmental temperature.
- When electromagnetic (EM) radiation is used to perform process-variable measurements, transducers that do not affect the system measured emerge.
- Such systems of measurement are called *nonlocal* or *noncontact* because no physical contact is made with the environment of the variable.
- Noncontact characteristic measurements often can be made from a distance.
- In process control, EM radiation in either the visible or infrared light band is frequently used in measurement applications.
- The techniques of such applications are called *optical* because such radiation is close to visible light.

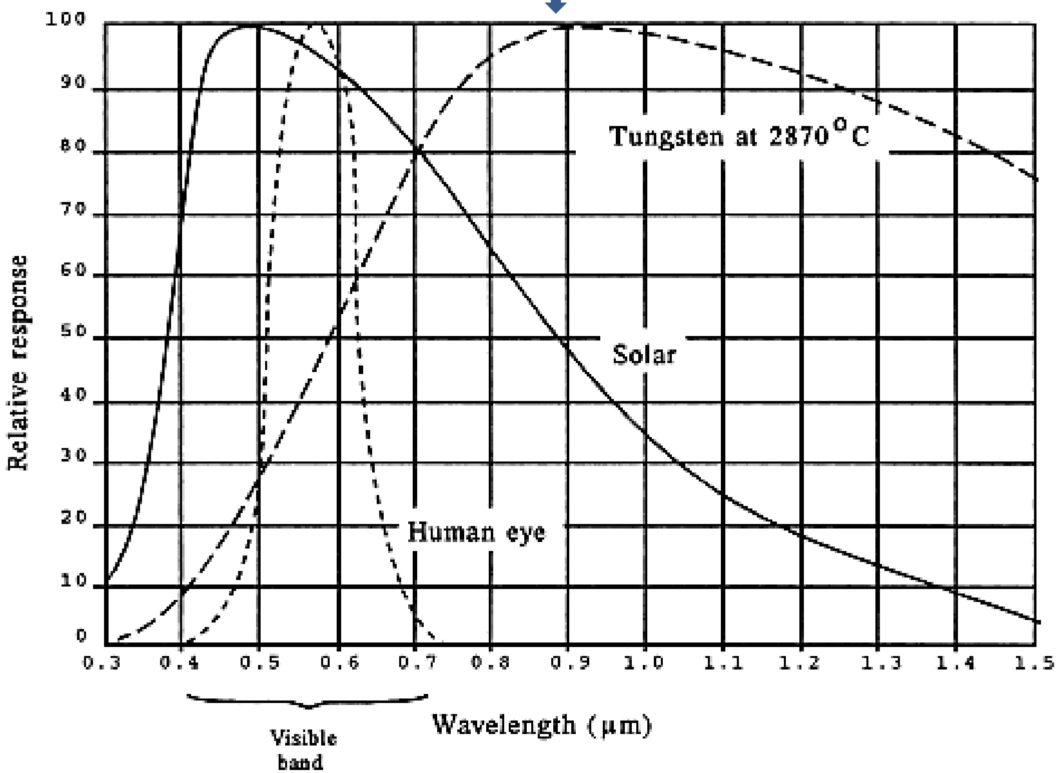
- A common example of optical transduction is measurement of an object's temperature by its emitted EM radiation.
- Another example involves radiation reflected off the surface to yield a level or displacement measurement.

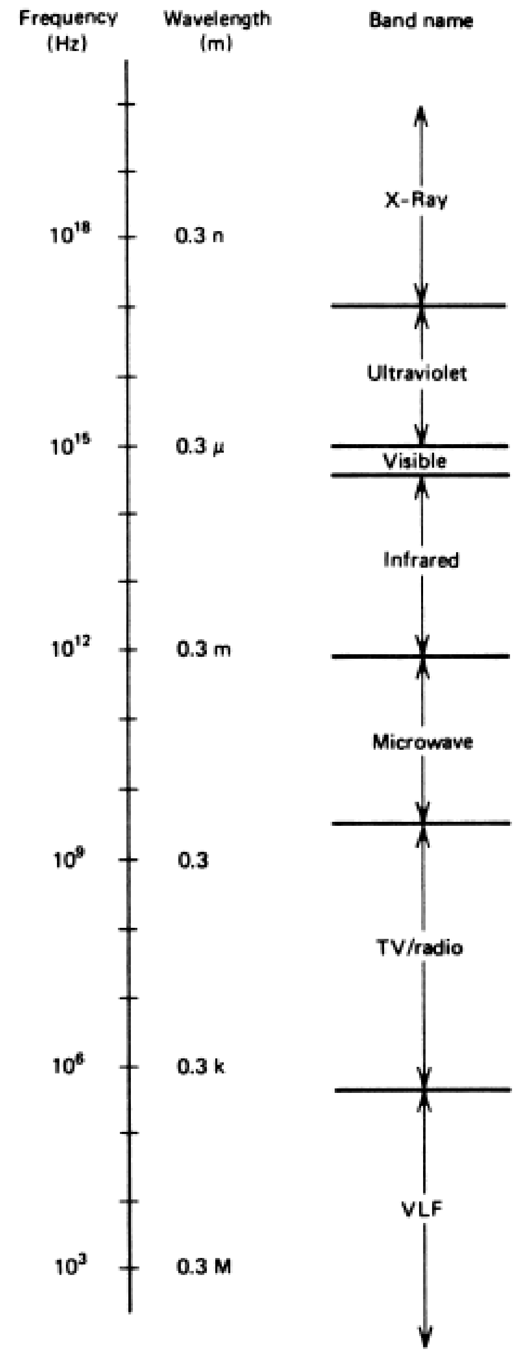
FUNDAMENTALS OF EM RADIATION

- We are all familiar with EM radiation as *visible light.* Visible light is all around us.
- EM radiation is also familiar in other forms, such as radio or TV signals and ultraviolet or infrared light.
- Although much of what follows is valid for the complete range of radiation, particular attention is given to the infrared, visible, and ultraviolet, because most sensor applications are concerned with these ranges.

The electromagnetic radiation spectrum covers everything from very low frequency (VLF) radio to X-rays and beyond.

Comparison of EM radiation emitted by the sun and heated tungsten filament, as well as the spectral sensitivity of the human eye.





Spectroscopy method of composition analysis

- The atom of a substance are excited and thereby their configuration is changed.
- Then they either absorb or radiate energy at unique frequencies.
- Line spectra are caused due to absorption or emission of discrete wavelength of radiation by atoms.

The absorption spectroscopy is based on principle that when x-ray radiation or infrared radiation or ultraviolet radiation is passed through a unknown material, some frequencies of radiations are observed.

In the emission Spectroscopy, the sample of unknown substance is placed in a flame or an arc. This developed emission of radiation with characteristics of each substance.

The fluorescence Spectroscopy can be applied to substances which undergo fluorescence only .

- The substance is excited by absorption of light.
- The excitation of a substance causes emission of light which is related to the composition of substance.

Mass spectroscopy

The sample of the substance (vapour or gas) whose composition is to be determined is bombarded with an electron beam in a evacuated chamber

This bombarded produce ions from the atom present in the substances.

The ions are accelerated into the circular path.

The radius of the path depend on the mass of the ions and Ion beam is formed.

By measuring the strength of the beam the composition of the tube substances can be determined.

The Spectroscopy can be classified as:

Spectrometer						
wavelength of radiation used			production radiation		method used to separate beams	
Infrared	Visible	Ultraviolet	Absorption	Emission	Refracting (Prism)	Diffracting (Grating)

Infrared Spectrometer

- The wavelength of the infrared radiation which is falling on the Thermocouple is determined by the angle of setting of the wavelengths mirror.
- The wavelength spectrum can be scanned by slowly rotating the wavelength mirror.
- The prism to be used is determined by the range of wavelength adaptable to the substance under analysis.
- The effect of temperature is accounted by employing the temperature compensated which position the mirror based on temperature coefficient of refractive index of the prism.
- The Spectroscopy data is recorded by automatic balance Potentiometer.
- The concentration of various component of the sample substance can be determined from the amount of absorption at any wavelength by Beer's law,

$$A = \log_{10} \frac{I_0}{I}$$
$$A = -\log_{10} T$$

- I_0 the intensity of the beam before sample I_x science test of the beam after sample

- Gas is continuously sent through a sample cell.
- The wavelength of infrared radiation is so selected that the analysis is sensitive
- The amount of radiation received by each bolometer depend on the concentration of the absorbing gas.
- A **bolometer** is a device for measuring the power of incident electromagnetic radiation via the heating of a material with a temperature-dependent electrical resistance.
- This method is used for a wide variety of the gas is except hydrogen Nitrogen Oxygen because these do not absorb radiation in the infrared region this type can be employed for liquid also.

Ultraviolet absorption spectrometer

- These are used for all type of analysis and operates in the range of 0.2 to 0.8 Micron.
- The light source is focused by the condensing mirror and buy a flat Mirror on entrance slit.
- From the Slit it proceed to the collimating mirror then through, quartz prizm, back to the collimating mirror and through exit slit.
- The intensity of the beam is measured from the photo-tube using potentiometer instruments.
- The particular wavelength pass through the sample cell is determined by angle of setting of the prism.
- The angle of the parts place determine which part of the refracted themes falls on the exit split
- The sample cell can be arranged for continuous flow of the gas and liquid sample.
- This instrument can be used either for complete analysis of sample by running a complete spectrograph or for continuous analysis by operating at fixed wavelength critical to the analysis being made .
- As source tungsten lamp is used in the visible region from 0.3 to 1 Micron and hydrogen discharge lamp from 0.22 to 0.35 Micron ultraviolet region

X-ray absorption spectrometer

- This is employed for composition of analysis of solid liquid and gases.
- In this two beam of X-Ray wavelength (0.4 to 1.5 A) are passed as:

1) one being is passed through the sample cell to a fluorescent screen

2) another beam is passed through a variable thickness aluminium alternator and then to a second sample cell to the same fluorescent screen

- Using the amplifier the difference in intensity of the two beams is measured .
- The aluminium alternator is adjusted until the two beams have the same intensity .
- Thus the difference in absorption of the two sample is expressed in terms of aluminium thickness.
- The thickness of Aluminium is calibrated to the content of critical component

Emission spectrometer: These are

1)arc type used for analysis of magnesium aluminium and steel. in arc emission type spectrometer, spark of an arc is used for producing radiation emission and a grating for diffraction of the emitted radiation into the spectrum.

The intensity of radiation of at various wavelength in the ultraviolet region of 800 to 2500 A is measured by multiplier phototube to operate a direct reading instrument.

2) flame type used for analysis of inorganic compounds.

the flame type spectrometer operates by atomising an aquaeous solution and introducing into a burner. A lens system concentrates the emitted light on a phototube through the filters. The output from phototube is amplified by an amplifier and is indicated by potentiometer type instrument, corresponding to the concentration.

Mass spectrometer

mass spectrometer employs a principle

a) for a given acceleration force, the acceleration is inversely proportional to the mass

b) since the ions of different material have different weight, so they are accelerated at different rates

c) The ions followed a curved path when they are sent through a magnetic field

d) for a constant voltage and constant magnetic field the radius of the path depend on the mass.

e) The radius of the path is given by r= $144\frac{\sqrt{mV/e}}{B}$

f) the angular velocity of charged particle moving in a magnetic field is dependent upon f= $\frac{1}{2\pi}\frac{eB}{me}$

- Analysis of a spectrum gives the composition of the vapour or gas sample.
- The spectrum is compared with the spectrum of a pure substance and the mole fraction of the components are calculated by direct proportion. One special use of the mass spectrometer is, in analysing isotopes and small samples are enough for analysis

Fuel gas analysis the fuel gas contains mostly CO_2 , Co, H_2 and nitrogen and hydrocarbons.

combustible gases like Co hydrogen and hydrocarbons: heat of combustion method are used to determine the presence of a combustible gases by burning the gas at the filament and measuring the temperature rise of the filament. Thermocouple is used to measure the heat of the combustion.

Hydrogen sulphide: Chemical method is used to determine the amount of H_2S gas in gas sample if paper tape is treated with the lead acetate and is passed to the gas chamber. A light and photocell are arranged to measure the reflectance of the paper before and after tape pass through gas chamber. if hydrogen sulphide is present in the gas sample then it reacts with lead acetate and form lead sulphide the presence of the lead sulphide on a paper reduce the reflectance of light.

Depending on the difference of output photocells the amount of hydrogen sulphide present in the gas sample is determined.

Automatic orsat: This is used as a carbon dioxide metre.

This device is operated on a continuous cycle to extract a given volume of the gas which has been washed, clean and temperature controlled. The gas is then passed through a solution of caustic Potash which absorb carbon dioxide.

The remaining gas pass through the displacement metre.

The volume of the remaining gas is difference between the given volume of the gas and the carbon dioxide present.

Oxygen analysis: This is measured using paramagnetic method.

Carbon dioxide gas: This is measured continuously using thermal conductivity method (CO_2 analyser) and automatic orsat.

Hot wire anemometer In this a small resistance wire is inserted in the fluid stream and the wire is heated by Electric Supply.

The loss of the heat from the wire depends on the mass velocity of the fluid and the specific heat of the fluid.

The current to the wire is maintained constant and the resistance of the wire (varies with temperature) is measured by which wheatstone bridge.

The resistance of a wire is related to the flow rate of the liquid. another way is that the temperature of the wire is kept constant by changing current to the wire then the velocity of it is related to the current.

Colorimetry: Colorimetry refers to the determination of a substance from its ability to absorb visible light.

Visual **Colorimetry** methods are based on the comparison of the coloured solution of unknown concentration with one or more coloured solution of known concentration.

The general terms for chemical analysis through measurements of absorption of radiation is is absorptiometry. The term **Colorimetry** is applied only in relation to the visible spectra region.

Photoelectric pyrometer

These are employed in the range of 800 to 1600 ^{o}C.

The response of photocell to the radiation is very fast. The response of photocell is in visible radiation and near infrared radiation (0.4 to 1.2 microns wavelength).

Photovoltaic cell give e.m.f proportion to the amount of radiation falling on it. The photoemissive tube produces current, proportional to the amount of radiation falling on it.

Photoelectric pyrometer use the principle of matching the radiation from Standard source with the radiation from target surface.

The photoemissive tube generates an electron current which is proportional to the intensity of the radiation.

A lens concentrates radiation from object surface whose temperature is to be measured on a photo tube the response from the measuring cell is amplified through an Bridge type circuit to adjust the current through the standard lamp

This is used to measure the temperature of fast moving object such as n a steel Rolling Mills, open hearth furnace and welding temperature.

This is calculated by comparison with the optical pyrometer.

Moisture content in paper and textiles:

This principle is that the resistance of a material varies with the moisture content.

The complete dry materials are very bad conductors of electricity and their resistance is highly decreased when they are moist.

In practice the electrical conductivity is measured by means of two electrodes of one form the other depends upon the material to be tested.

The specific resistance or conductance of a body depends on

1) Dimensions and shape of the electrodes
2) Distance between the electrode
3) Condition of the measurement like temperature pressure etc.
4) A method of measuring, the paper roll whose resistance is to be measured is sent in between the roller and shaft
5) The resistance between the roller and soft is related to the moisture content of the paper and this resistance is measured to determine the moisture content of paper.
6) the electrical circuit consists of wheatstone bridge in which two arms are of equal resistance and of the other two arms by internal resistance of the double triode.
7) A micrometre is connected across a wheatstone bridge diagonal.

Oxygen analysis: all the gases are influenced by magnetic field.

gases which are paramagnetic are attracted towards strong magnetic field.

oxygen is strongly paramagnetic this paramagnetic principle is used to determine the percentage of oxygen in the gas sample.

A measuring cell and a reference cells are used which contain the platinum heating wire (resistance wire).

A measuring cell is arranged in the field of a permanent magnet.

the gas sample flows from the bottom of the pile cell and get is sent to the cell by aspirator pump or a blower.

if oxygen is present in a gas sample that attracted by the magnetic field and oxygen come into the contact with the heated filament.

As oxygen get heated by the filament it is less attracted by the magnetic field and the hot oxygen is pushed down by the incoming oxygen.

if more oxygen is present in the gas and then there were more circulating gas in the measuring cell. The measuring cell element is cooled by more circulation and thereby reducing the filament resistance.

The resistance of filament is proportional to the amount of oxygen in the gas sample. The two cells are connected to the wheatstone bridge circuit for operation of indicator or recorder

Polaro graph: This instrument is used for analysing substance which undergoes electrolyte oxidation and reduction.

Analysis of Steel alloys and ores is done by this instrument. Mercury is drop into the solution containing the sample

In the beginning potential supply starting from zero volt and then gradually increase by steps to 5 volt is given to the electrode.

Due to the attraction of iron of various constituents to the electrodes the current rise in steps.

The voltage of each step shows the presence of certain elements in the sample and height of the steps (current) is proportional to the consideration of the element the plots of current vs voltage is term as Polarogram.

Thermistors : A thermistor is a non-metallic resistor.

- In this resistance decreases with temperature increases.
- Thermistor are made of mixture of metallic oxides like manganese, Cobalt, copper, iron, Nickel etc. or their salts.
- The electrical characteristics of the thermistor are dependent on the type of the oxides or salt used and their physical size and configuration.
- The variation of resistance with temperature is high in these and so small size elements are used.
- These are useful only up to 300 degree centigrade and good only up to 100 degree centigrade.
- Thermistor follows the relation R= a$e^{b/T}$

List of temperature measuring instrument and their range of operation

- Constant volume Gas thermometer:
  - hydrogen gas 0-100 ^oC
  - Nitrogen gas above 100 ^oC
  - Helium gas below 0 ^oC
- Mercury in glass thermometer -30 to 350 ^oC
- Bimetallic thermometer 0 to 400 ^oC
- vapour pressure thermometer -20 to 300 ^oC
- Thermocouples -20 to 1600^oC
- Resistance thermometer -2000 to 650 ^oC
- Radiation pyrometers 800 to 2000^oC
- Optical pyrometer 800 - 2000 ^oC
- Photoelectric pyrometer 800 to 1800 ^oC

- The commonly used thermocouples and their ranges are:

  Copper- constantan: 100 to 600 ^{o}C

  Iron –constantan: 0 to 600 ^{o}C

  Chromel- Alumel: 300- 1100 ^{o}C

  Platinum- Platinum, 13% rhodium: 600 to 1600 ^{o}C

- **list of various pressure measuring devices and their ranges of operation:**
  - Liquid column manometers: less than 30 psi differential pressure
  - bourdon bellows, diaphragm gauges: 30 to 200 psig
  - ionization gauge: 3- 0.0004 microns
  - McLeoid gauge: 8 to 0.006 microns (large bulb)
  - Knudsen gauge, Philips gauge: 15 to 0.04 microns
  - Pirani Gauge: 2 to 4000 microns
  - Thermocouple gauge: 3 to 700 microns
  - Alphtron: 3 to 40000 microns
  - McLeoid gauge (small bulb) : 90- 20,000 microns
  - Bellows gauge: 4000 to 10^6 microns

- **List of various liquid level measuring measuring instrument and their range of operation**
  - Float and tape method: 4 inch to 60 Feet level
  - float and shaft type: 1000 PSI and less
  - Bellows: less than 20 inch
  - Bubbler type : 5 inch to 400 inch
  - Diaphragm box: 20 inch to 250 feet
  - Air trap: 20 inch to 250 feet
  - Differential manometers: 1 inch - 100 feet
  - Displacement float: 14 inches to 180 inches
  - pneumatic balance displacement float gauge: 2 inches to 60 Feet
  - level by weighing
  - Level by electronic signalling (fixed level)

List of various flow measuring instruments and their range of operation

- orifice metre
- Venturi metre
- pitot tube
- Rotameter
- Rectangular notches, V- notches, trapezoidal notches, Parshall flume: 1 to 10 million gallon per day for liquid and sludges
- velocity metres, propeller metre, Cup anemometer, deflecting vane metre, hot wire anemometer for liquid and gases
- Tilting tap metre, piston metre, rotary vane metre , sealed drum metre, lobed impeller metre, bellows metre
- conveyor weighing for dry solid materials.

Standard symbols and letter used in instrumentation diagram

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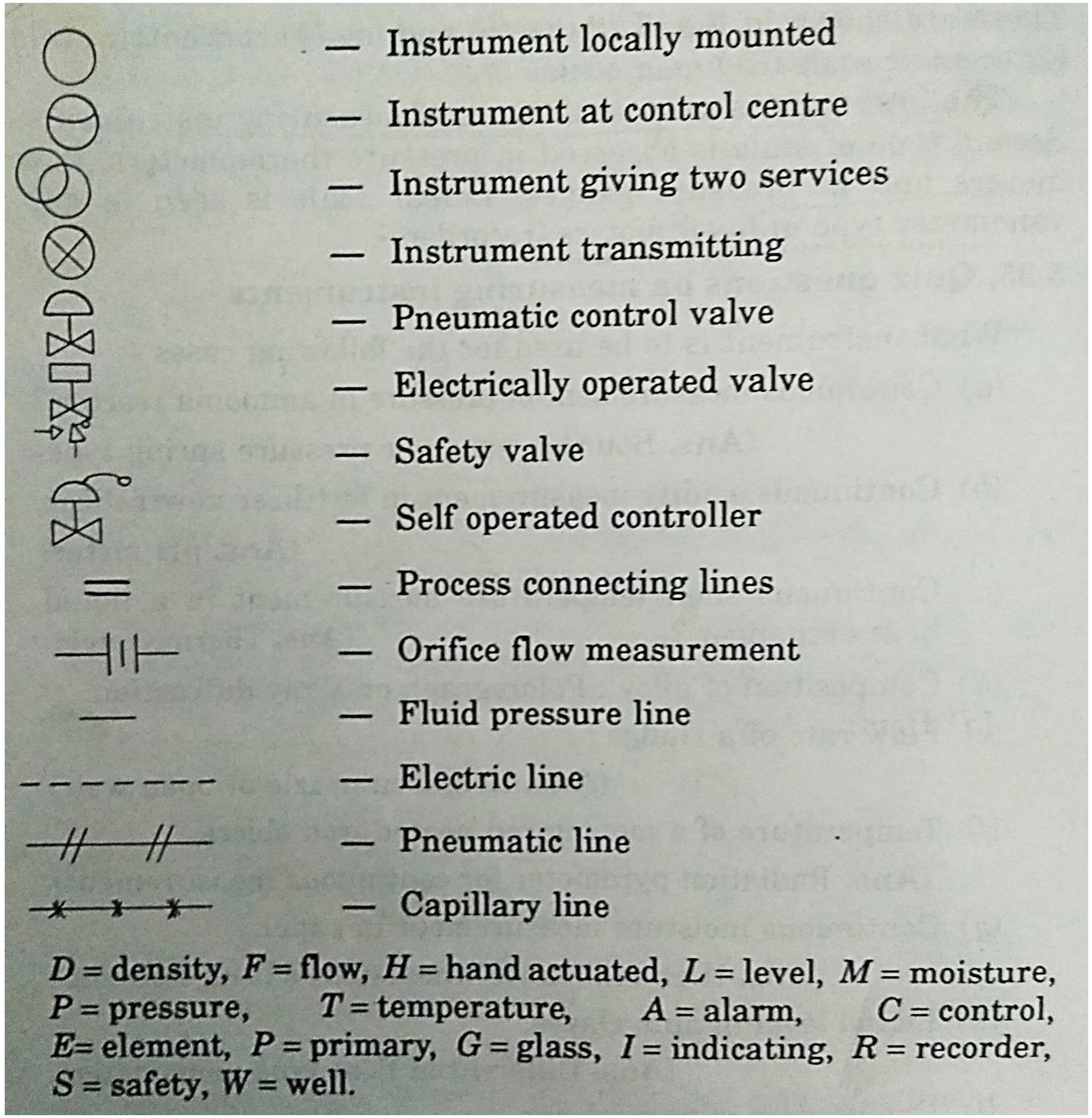


— Instrument locally mounted

— Instrument at control centre

— Instrument giving two services

— Instrument transmitting

— Pneumatic control valve

— Electrically operated valve

— Safety valve

— Self operated controller

— Process connecting lines

— Orifice flow measurement

— Fluid pressure line

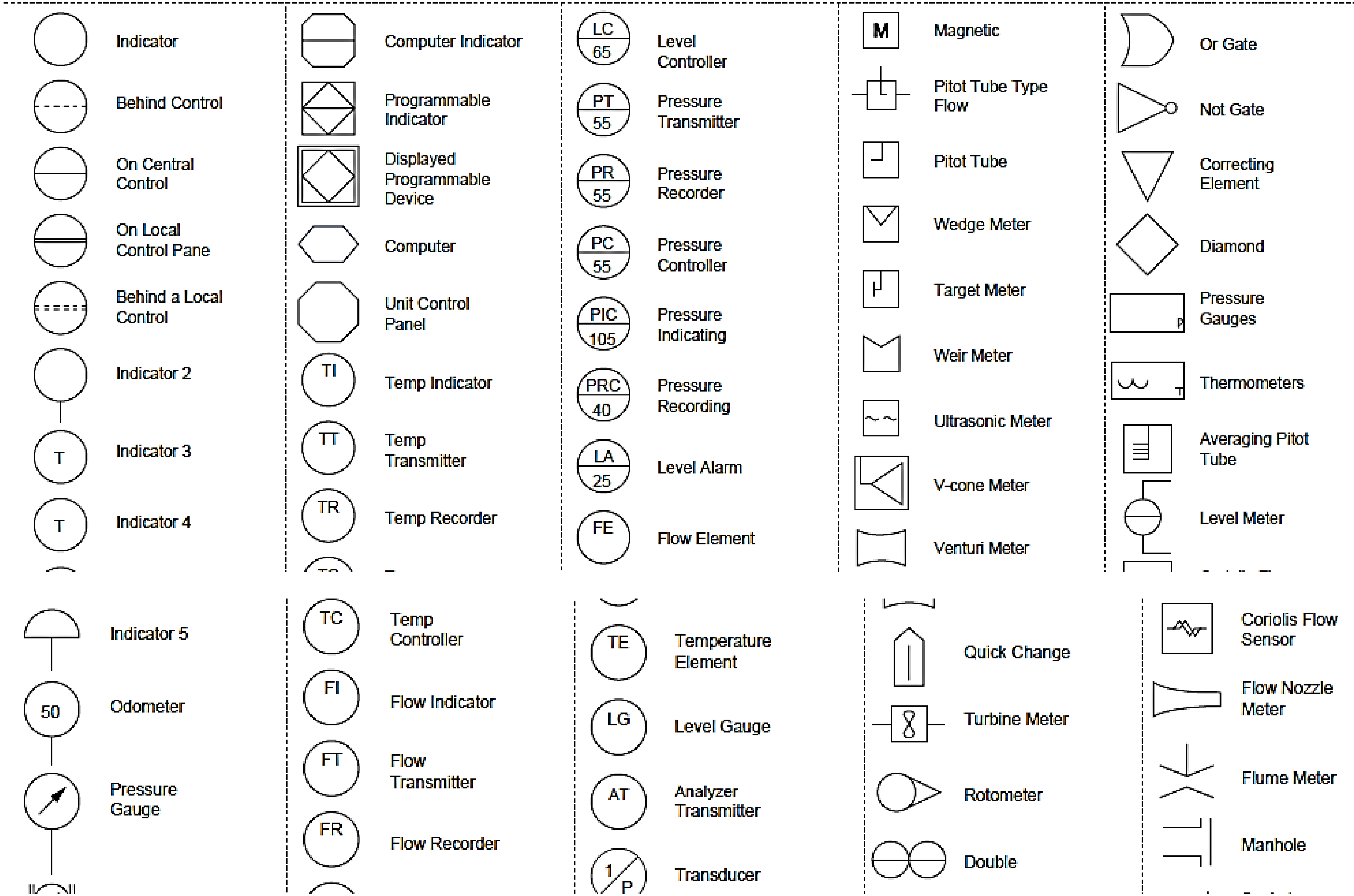
— Electric line

— Pneumatic line

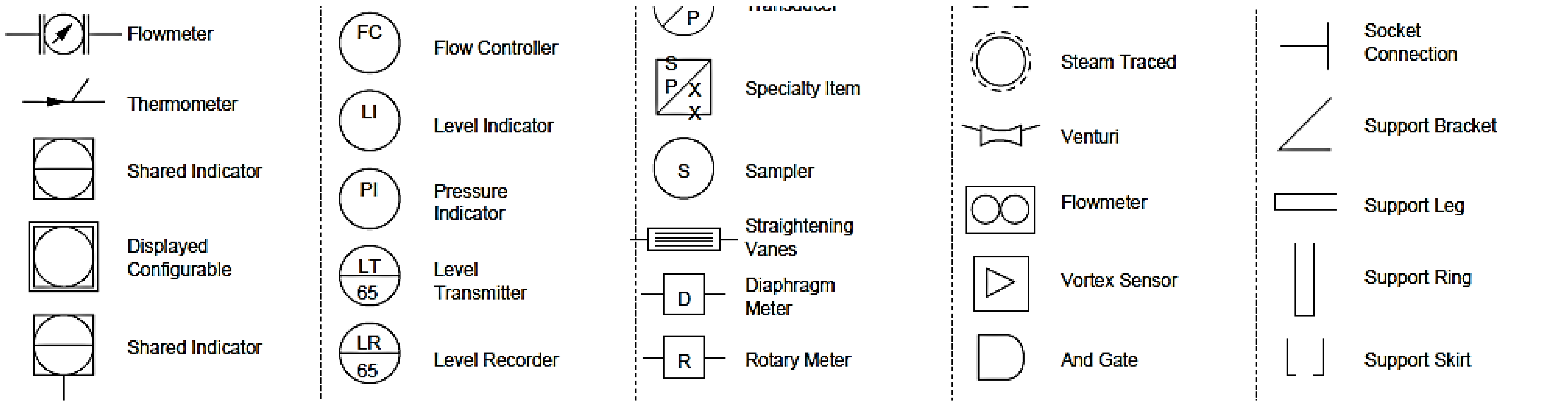
— Capillary line

D = density, *F* = flow, *H* = hand actuated, *L* = level, *M* = moisture, *P* = pressure, *T* = temperature, *A* = alarm, *C* = control, *E* = element, *P* = primary, *G* = glass, *I* = indicating, *R* = recorder, *S* = safety, *W* = well.

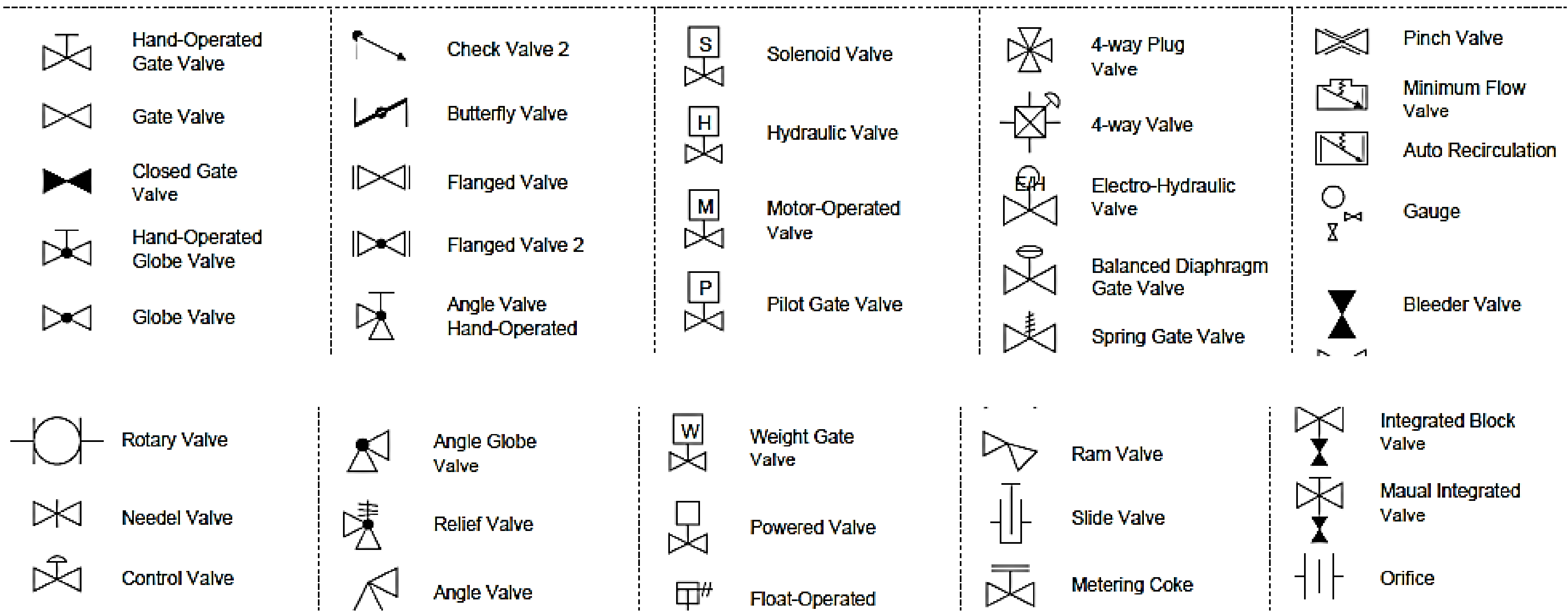
Instrument

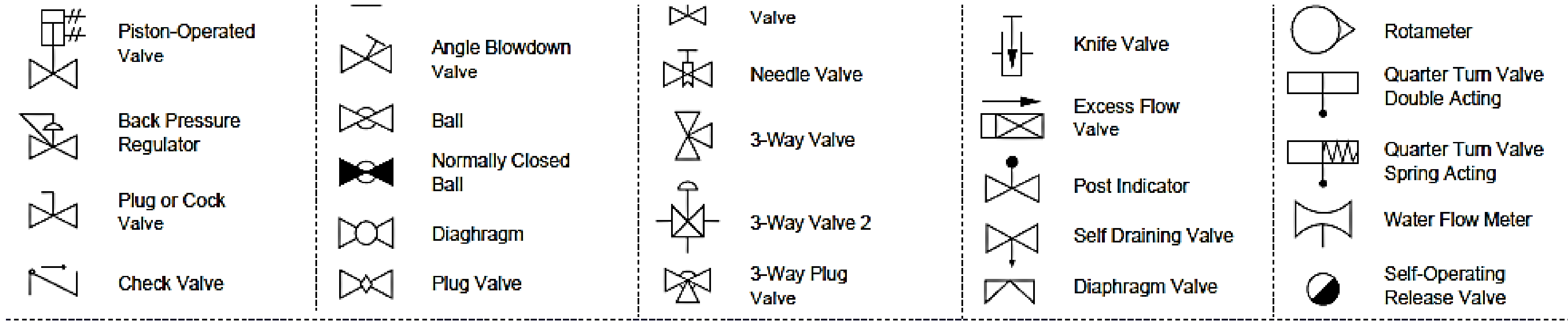


Indicator
Behind Control
On Central Control
On Local Control Pane
Behind a Local Control
Indicator 2
T
Indicator 3
T
Indicator 4
Computer Indicator
Programmable Indicator
Displayed Programmable Device
Computer
Unit Control Panel
TI
Temp Indicator
TT
Temp Transmitter
TR
Temp Recorder
LC 65
Level Controller
PT 55
Pressure Transmitter
PR 55
Pressure Recorder
PC 55
Pressure Controller
PIC 105
Pressure Indicating
PRC 40
Pressure Recording
LA 25
Level Alarm
FE
Flow Element
M
Magnetic
Pitot Tube Type Flow
Pitot Tube
Wedge Meter
Target Meter
Weir Meter
Ultrasonic Meter
V-cone Meter
Venturi Meter
Or Gate
Not Gate
Correcting Element
Diamond
Pressure Gauges
Thermometers
Averaging Pitot Tube
Level Meter
Indicator 5
50
Odometer
Pressure Gauge
TC
Temp Controller
FI
Flow Indicator
FT
Flow Transmitter
FR
Flow Recorder
TE
Temperature Element
LG
Level Gauge
AT
Analyzer Transmitter
1 P
Transducer
Quick Change
Turbine Meter
Rotometer
Double
Coriolis Flow Sensor
Flow Nozzle Meter
Flume Meter
Manhole

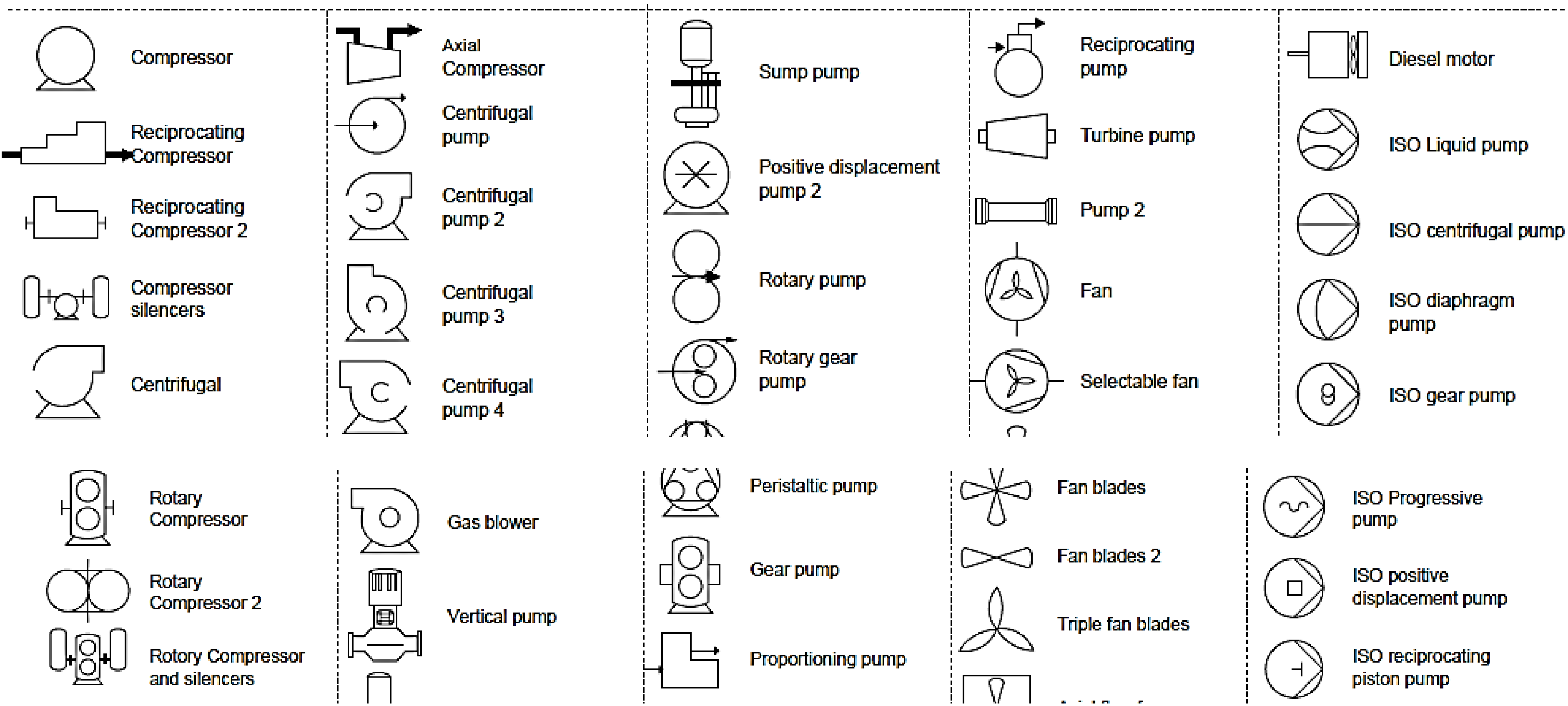

Flowmeter
Thermometer
Shared Indicator
Displayed Configurable
Shared Indicator
FC
Flow Controller
LI
Level Indicator
PI
Pressure Indicator
LT 65
Level Transmitter
LR 65
Level Recorder
Specialty Item
S
Sampler
Straightening Vanes
D
Diaphragm Meter
R
Rotary Meter
Steam Traced
Venturi
Flowmeter
Vortex Sensor
And Gate
Socket Connection
Support Bracket
Support Leg
Support Ring
Support Skirt

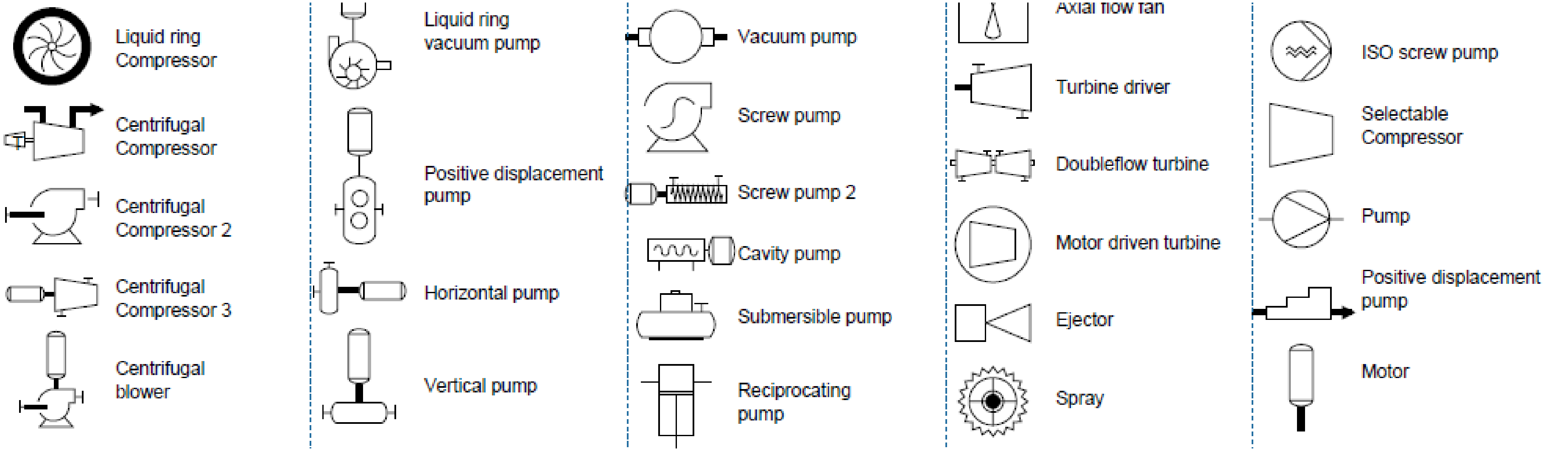
Valves


Hand-Operated Gate Valve
Gate Valve
Closed Gate Valve
Hand-Operated Globe Valve
Globe Valve
Check Valve 2
Butterfly Valve
Flanged Valve
Flanged Valve 2
Angle Valve Hand-Operated
S
Solenoid Valve
H
Hydraulic Valve
M
Motor-Operated Valve
P
Pilot Gate Valve
4-way Plug Valve
4-way Valve
E/H
Electro-Hydraulic Valve
Balanced Diaphragm Gate Valve
Spring Gate Valve
Pinch Valve
Minimum Flow Valve
Auto Recirculation
Gauge
Bleeder Valve
Rotary Valve
Needel Valve
Control Valve
Angle Globe Valve
Relief Valve
Angle Valve
W
Weight Gate Valve
Powered Valve
Float-Operated
Ram Valve
Slide Valve
Metering Coke
Integrated Block Valve
Maual Integrated Valve
Orifice

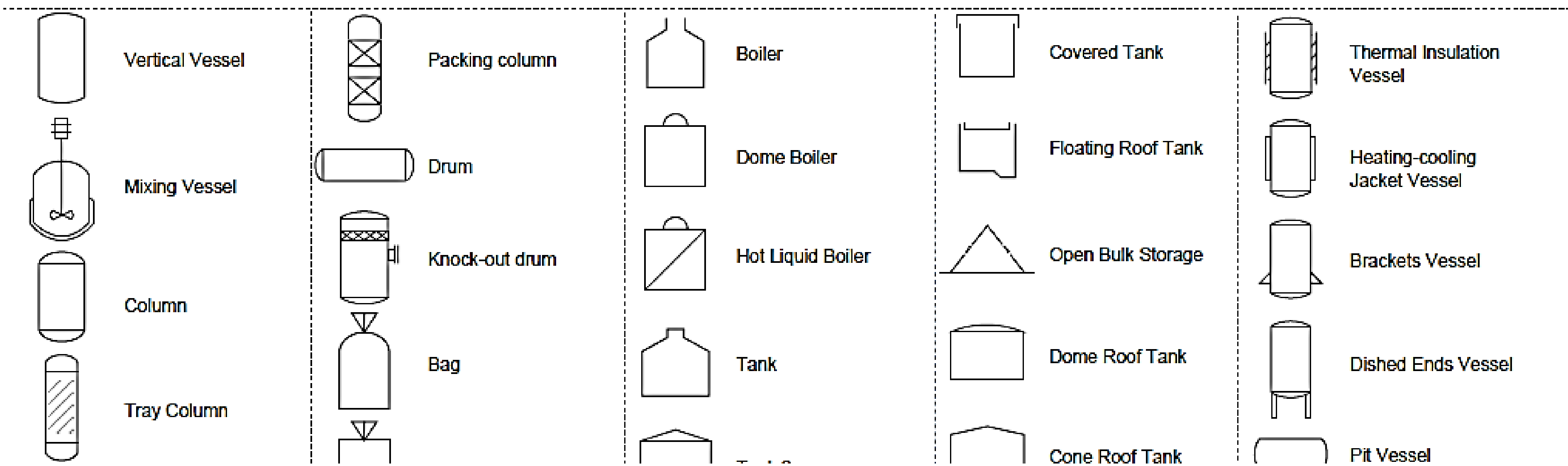

Piston-Operated Valve
Back Pressure Regulator
Plug or Cock Valve
Check Valve
Angle Blowdown Valve
Ball
Normally Closed Ball
Diaghragm
Plug Valve
Valve
Needle Valve
3-Way Valve
3-Way Valve 2
3-Way Plug Valve
Knife Valve
Excess Flow Valve
Post Indicator
Self Draining Valve
Diaphragm Valve
Rotameter
Quarter Turn Valve Double Acting
Quarter Turn Valve Spring Acting
Water Flow Meter
Self-Operating Release Valve

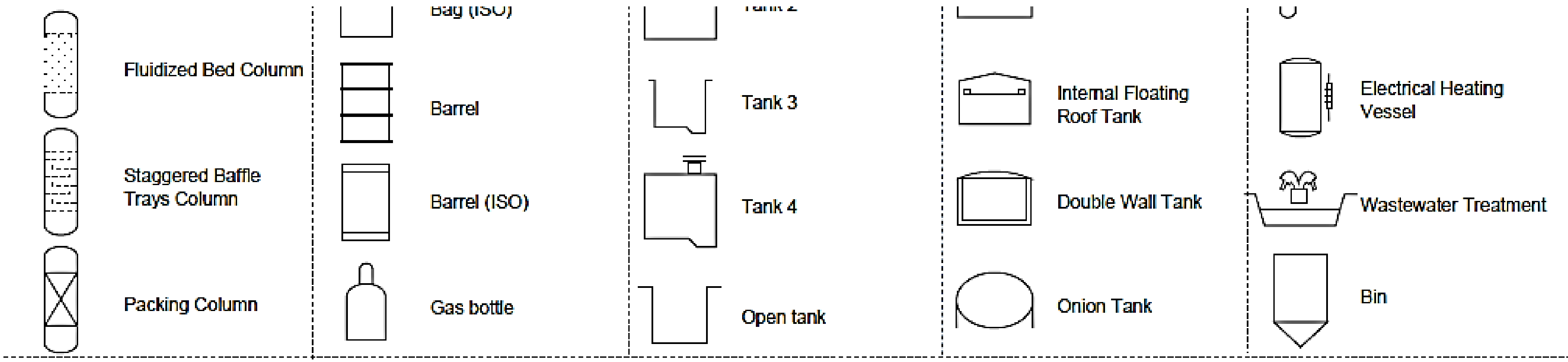
Pumps


Compressor
Reciprocating Compressor
Reciprocating Compressor 2
Compressor silencers
Centrifugal
Axial Compressor
Centrifugal pump
Centrifugal pump 2
Centrifugal pump 3
Centrifugal pump 4
Sump pump
Positive displacement pump 2
Rotary pump
Rotary gear pump
Reciprocating pump
Turbine pump
Pump 2
Fan
Selectable fan
Diesel motor
ISO Liquid pump
ISO centrifugal pump
ISO diaphragm pump
ISO gear pump
Rotary Compressor
Rotary Compressor 2
Rotory Compressor and silencers
Gas blower
Vertical pump
Peristaltic pump
Gear pump
Proportioning pump
Fan blades
Fan blades 2
Triple fan blades
ISO Progressive pump
ISO positive displacement pump
ISO reciprocating piston pump

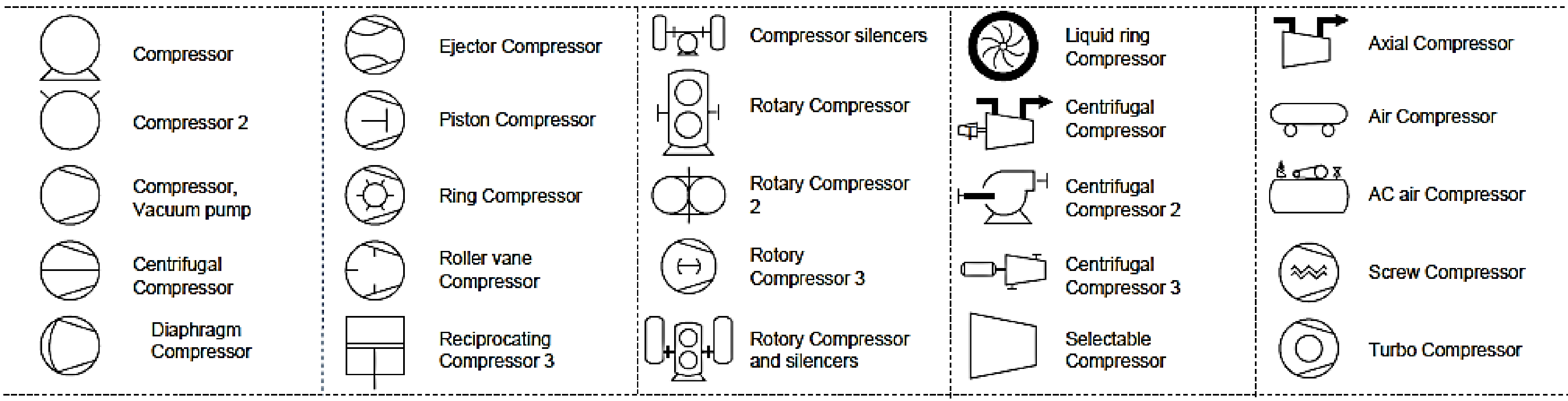

Liquid ring
Compressor
Centrifugal
Compressor
Centrifugal
Compressor 2
Centrifugal
Compressor 3
Centrifugal
blower
Liquid ring
vacuum pump
Positive displacement
pump
Horizontal pump
Vertical pump
Vacuum pump
Screw pump
Screw pump 2
Cavity pump
Submersible pump
Reciprocating
pump
Axial flow fan
Turbine driver
Doubleflow turbine
Motor driven turbine
Ejector
Spray
ISO screw pump
Selectable
Compressor
Pump
Positive displacement
pump
Motor

Vessels


Vertical Vessel
Mixing Vessel
Column
Tray Column
Packing column
Drum
Knock-out drum
Bag
Boiler
Dome Boiler
Hot Liquid Boiler
Tank
Covered Tank
Floating Roof Tank
Open Bulk Storage
Dome Roof Tank
Cone Roof Tank
Thermal Insulation
Vessel
Heating-cooling
Jacket Vessel
Brackets Vessel
Dished Ends Vessel
Pit Vessel



Compressors



Piping and Connecting Shapes