Instrumentation

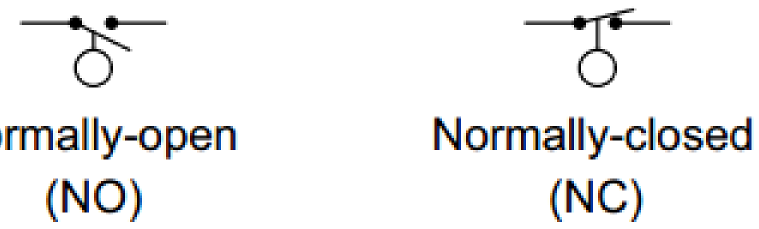
Level Measurement

Course Instructor: Mohammad Reza Nayeri

Spring 2022

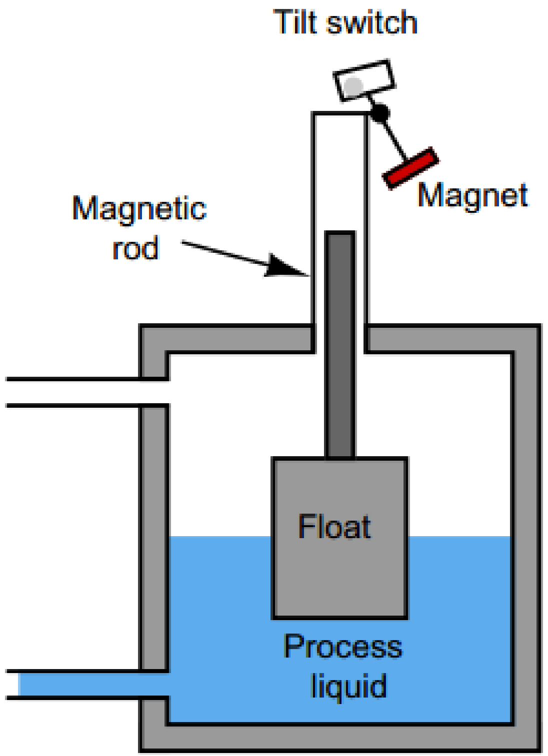
Level Switch

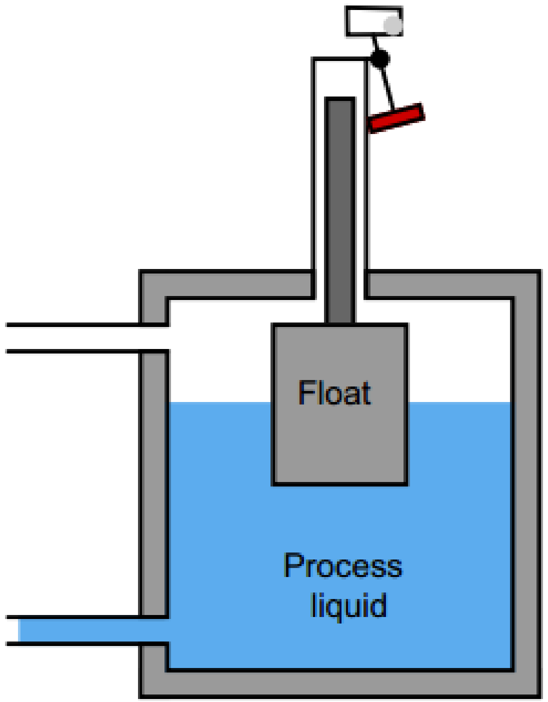
Level switch symbols



Level Switch

Float-type level switches





Level Switch

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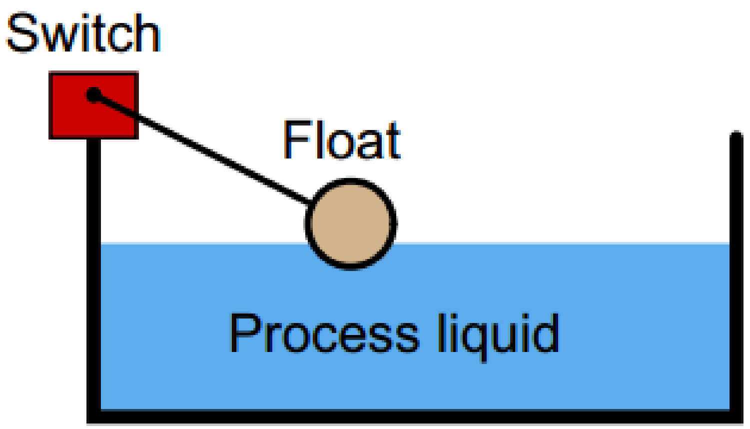
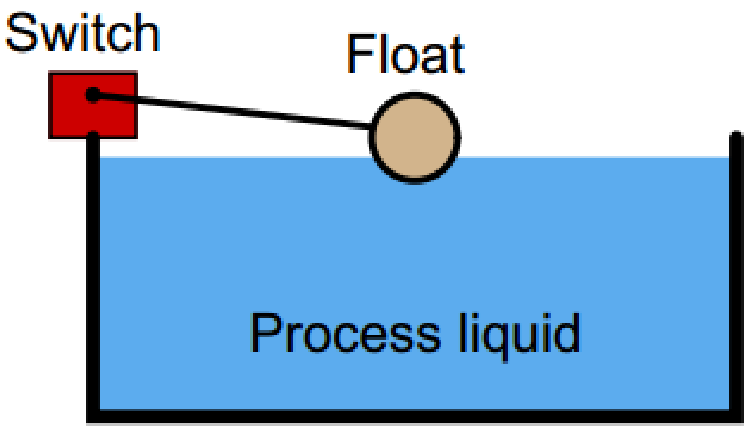
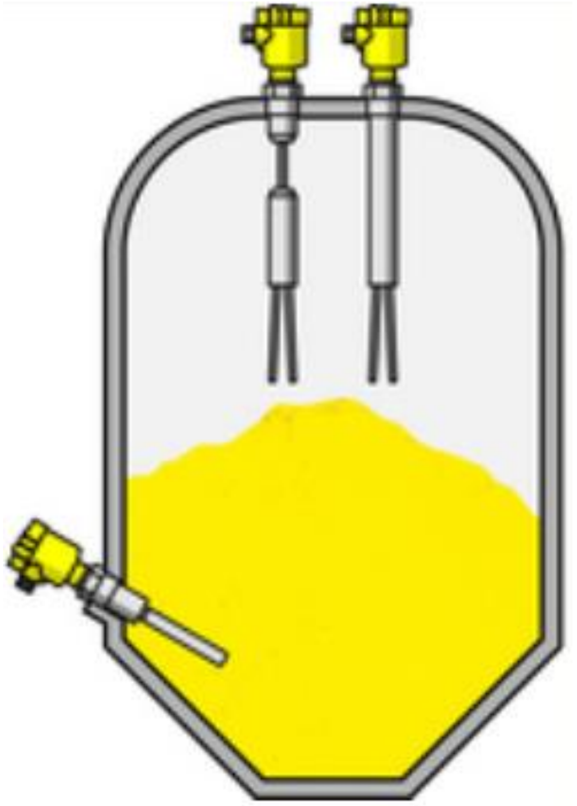




Level Switch

Tuning fork level switches



- An electronic circuit continuously excites the tuning fork, causing it to mechanically vibrate.

- When the prongs of the fork contact anything with substantial mass, the resonant frequency of the fork decreases.

- The circuit detects this frequency change and indicates the presence of mass contacting the fork.

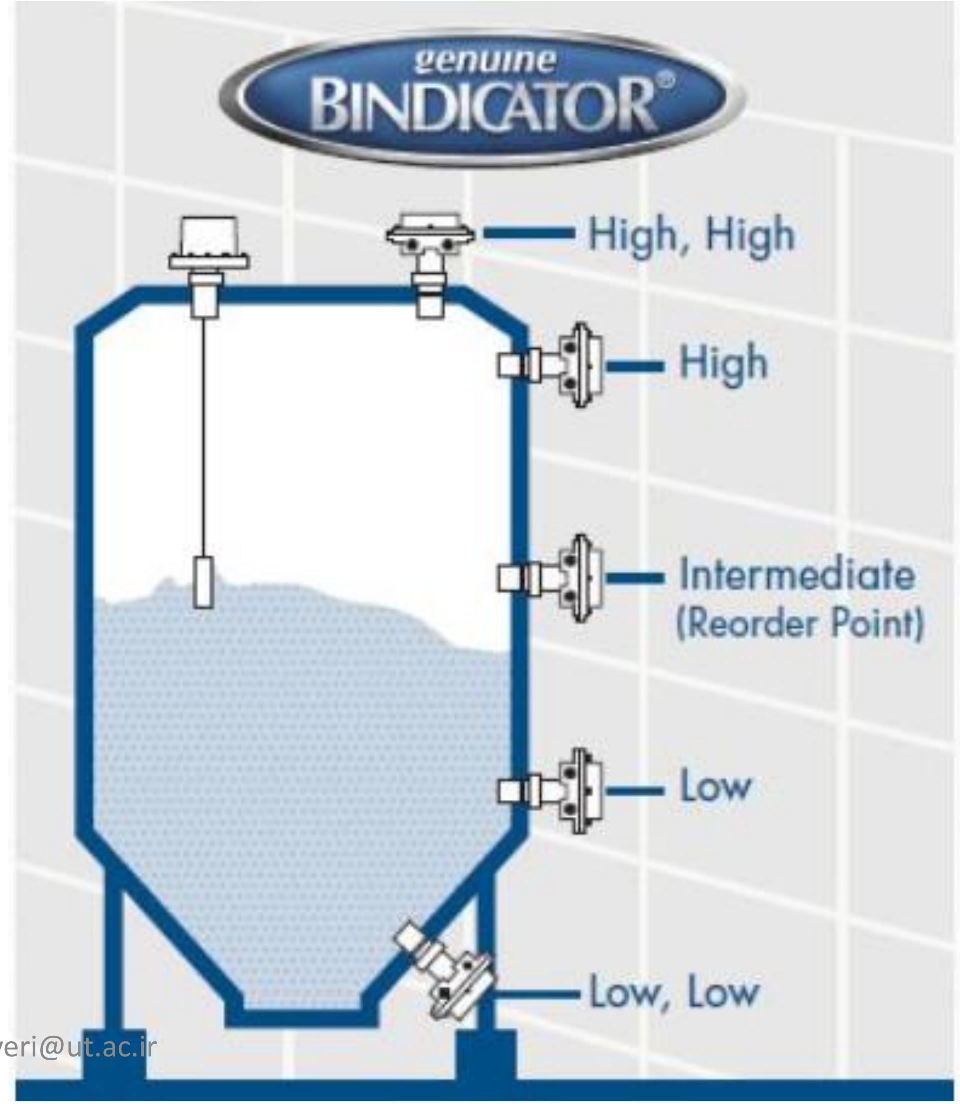
Level Switch

Paddle-wheel level switches

- This level switch uses an electric motor to slowly rotate a metal paddle inside the process vessel.
- A torque-sensitive switch mechanically linked to the motor actuates when enough torsional effort is detected on the part of the motor.

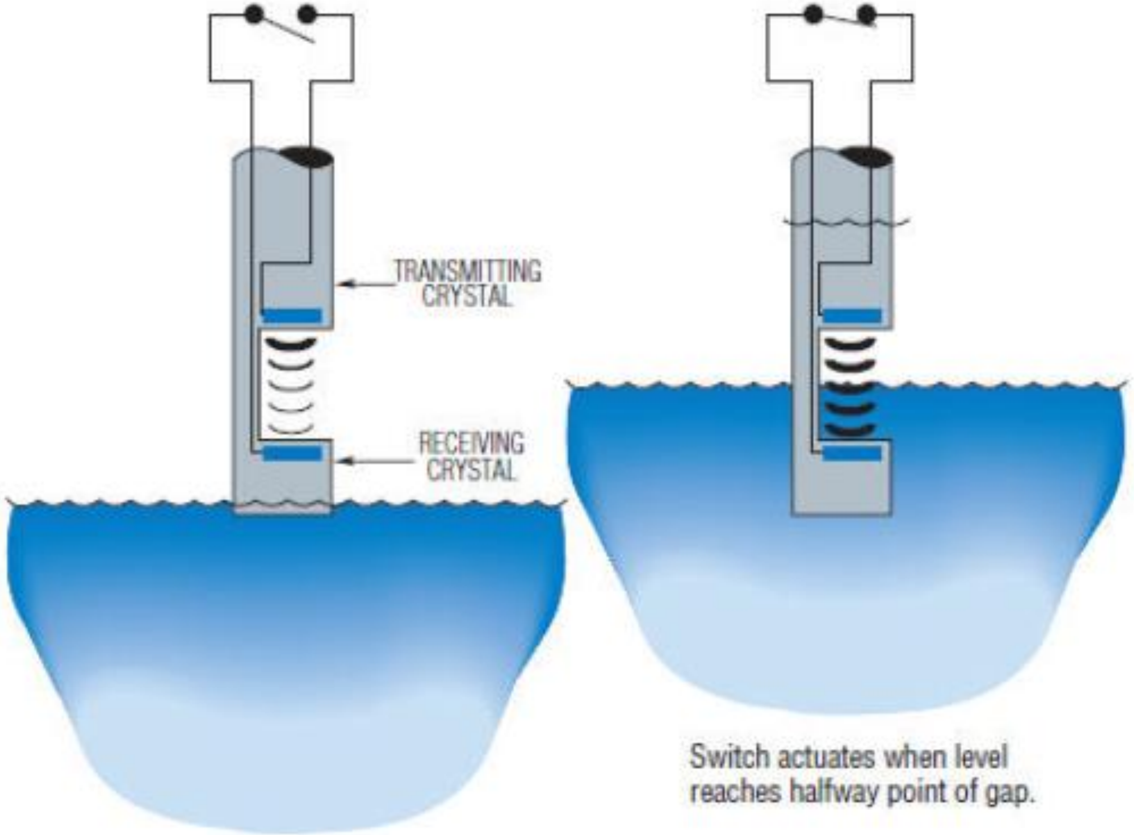
Level Switch

Paddle-wheel level switches



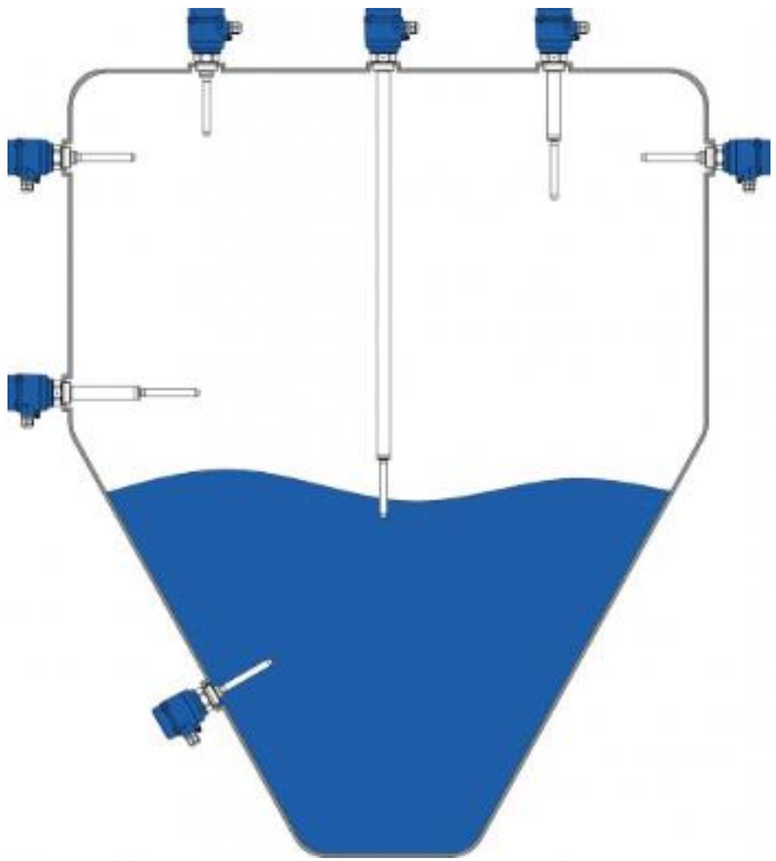
Level Switch

Ultrasonic level switches



Level Switch

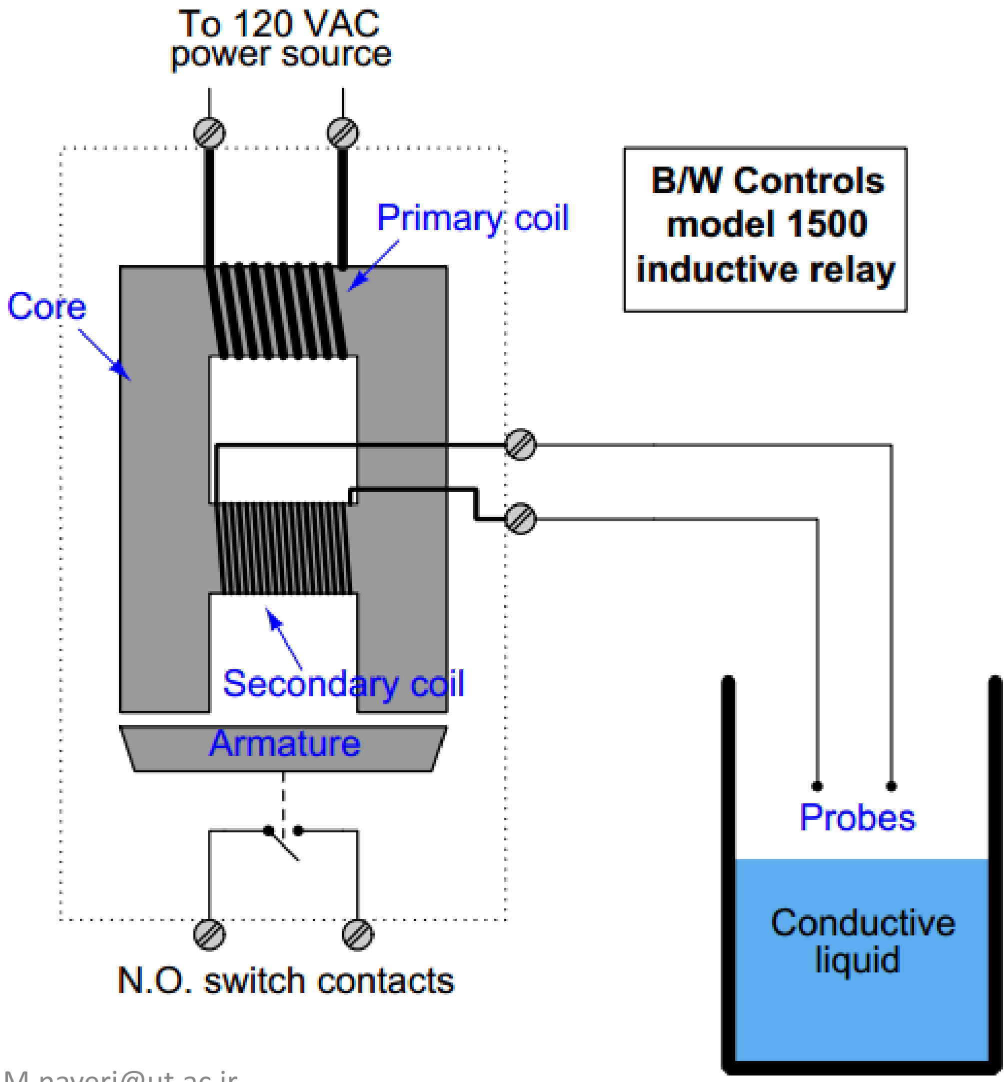
Capacitive level switches



Level Switch

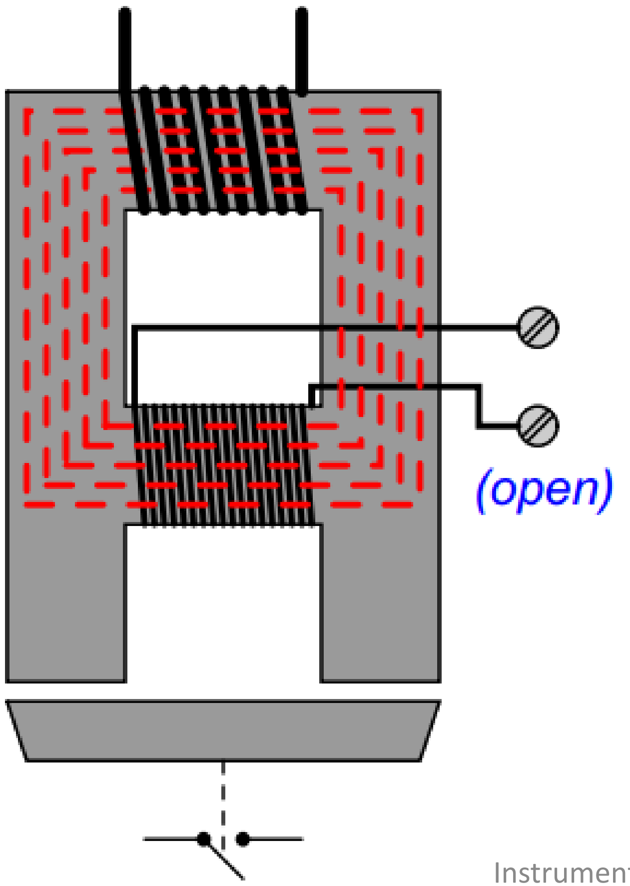
Conductive level switches

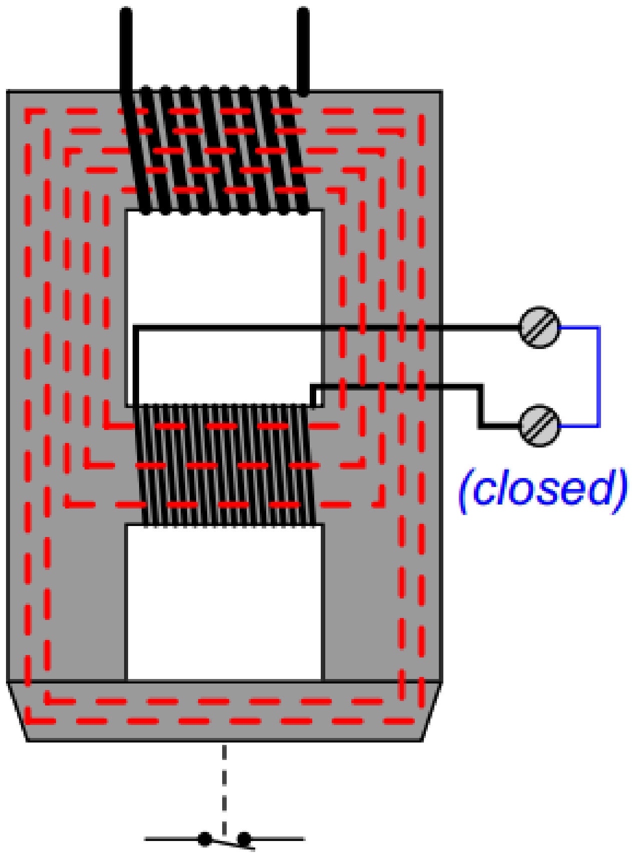
- This type of switch, of course, only works with granular solids and liquids that are electrically conductive



Level Switch

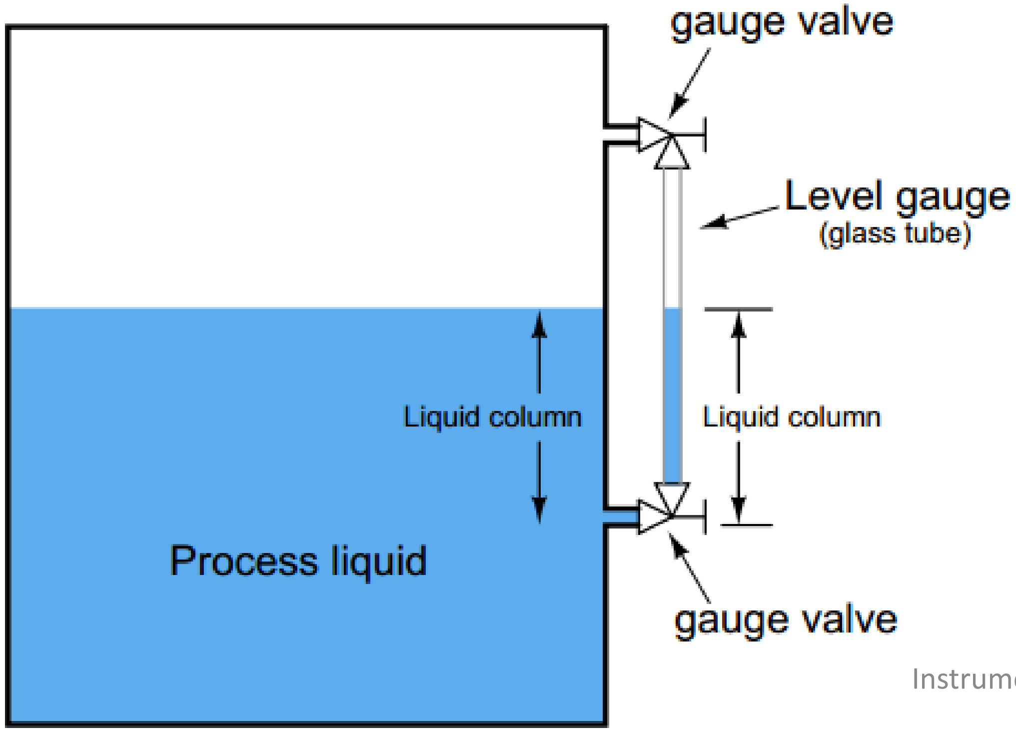
Conductive level switches



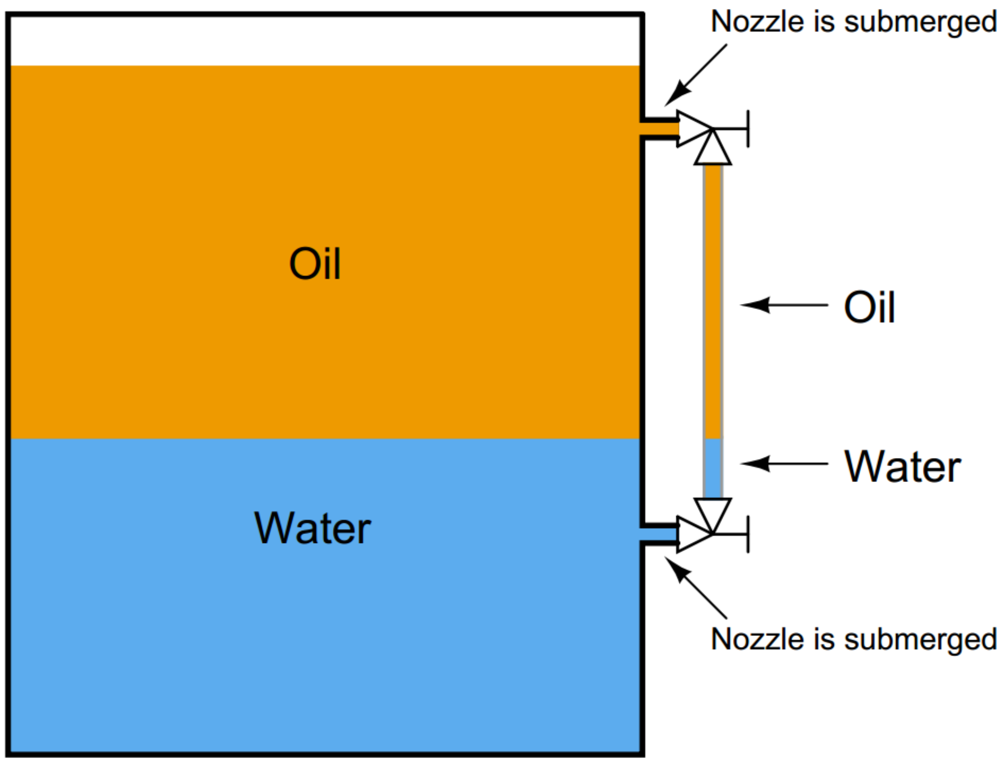


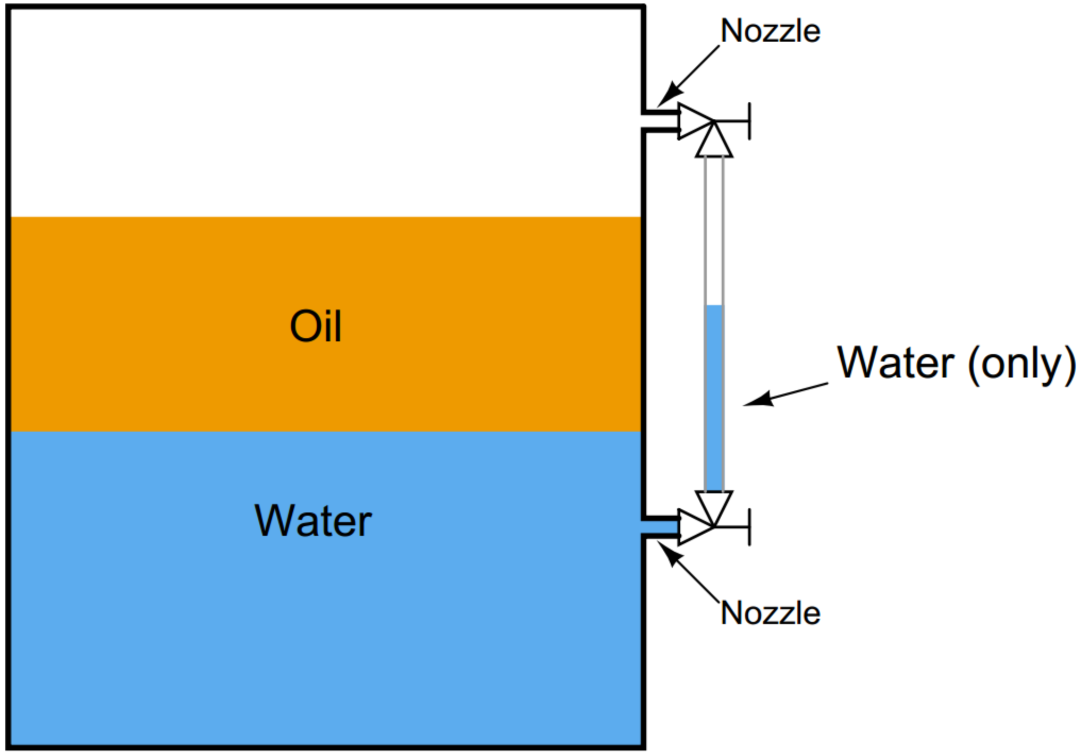
Level gauges (sightglasses)

- The level gauge, or sightglass is to liquid level measurement as manometers are to pressure measurement: a very simple and effective technology for direct visual indication of process level.



Level gauges (sightglasses)

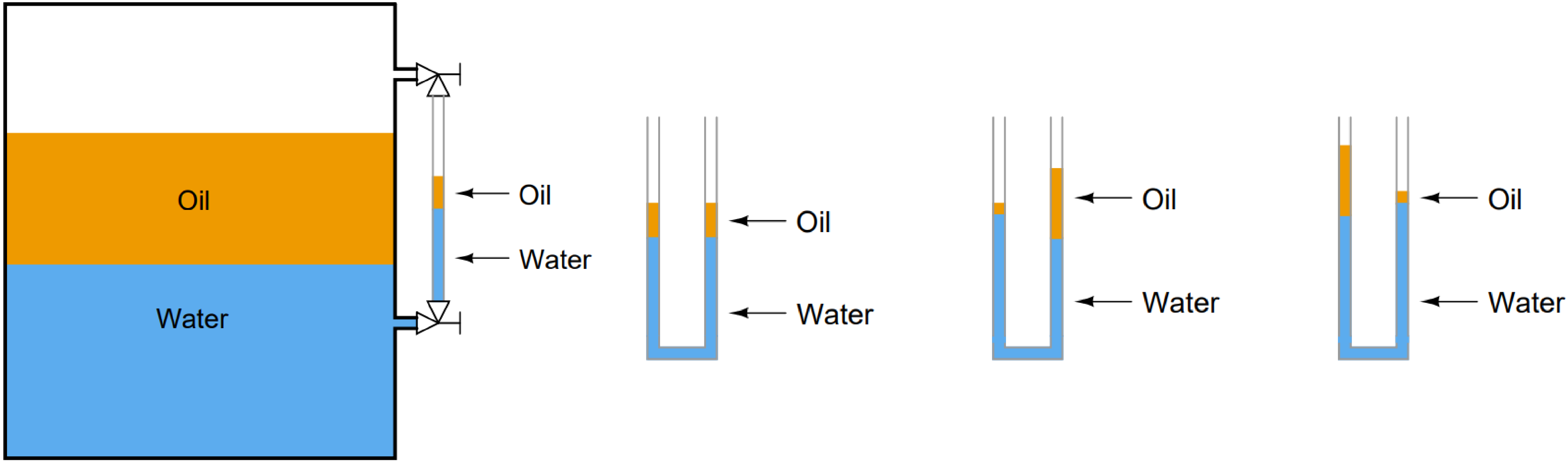




The only way to ensure proper two-part liquid interface level indication in a sightglass is to keep both ports (nozzles) submerged.

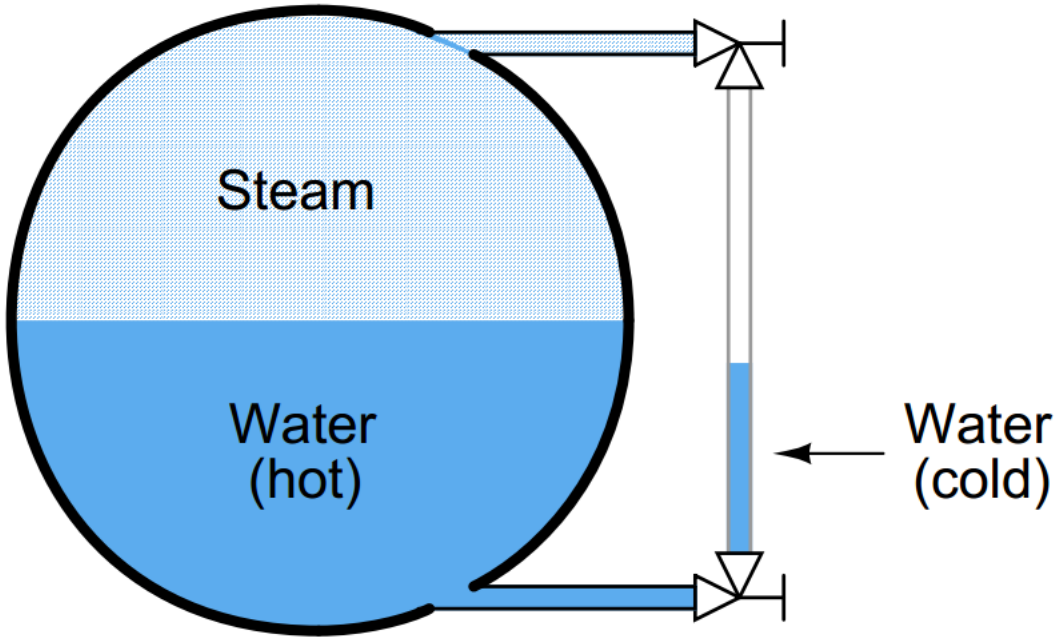
Since the oil lies between the two level gauge ports into the vessel, it cannot enter the sightglass tube, and therefore the level gauge will continue to show just water.

Level gauges (sightglasses)



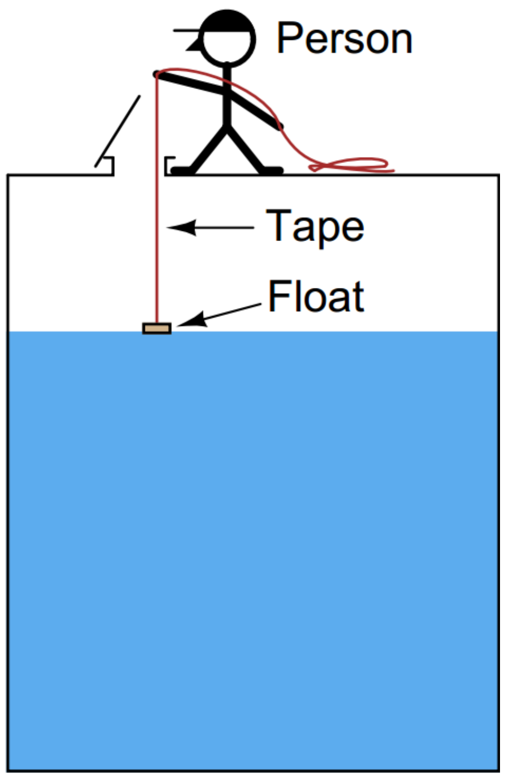
Level gauges (sightglasses)

Temperature problems

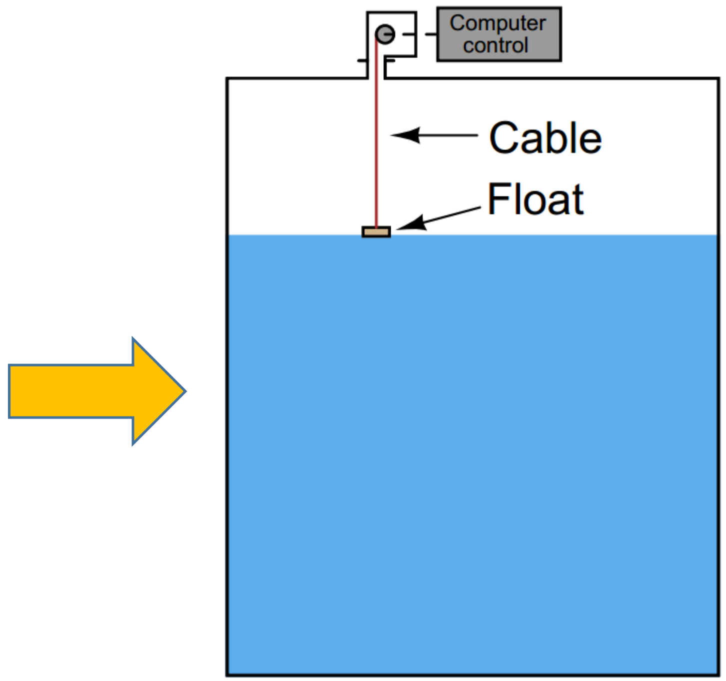


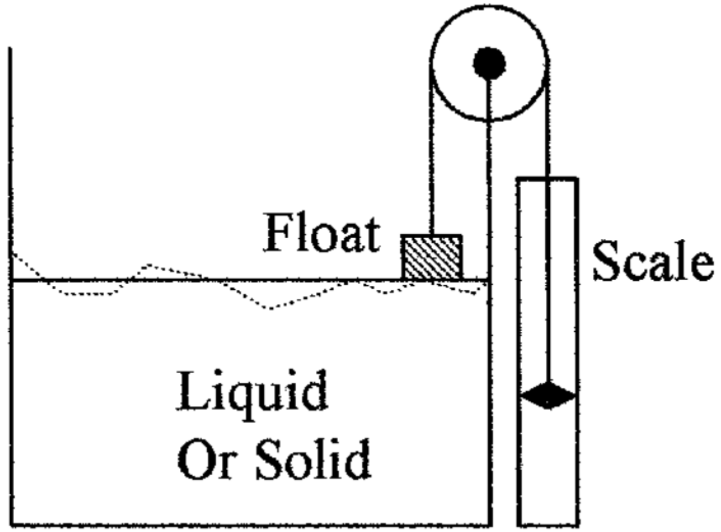
This is commonly seen on boiler level gauges, where the water inside the sightglass cools off substantially from its former temperature inside the boiler drum.

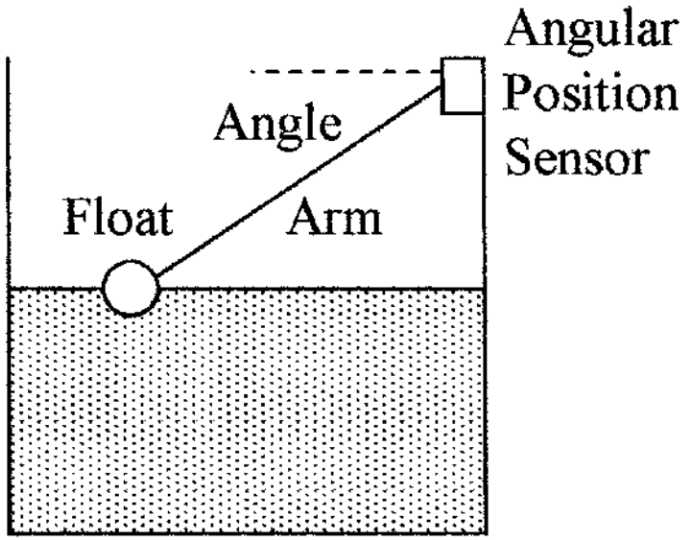
Float



manual “gauging”

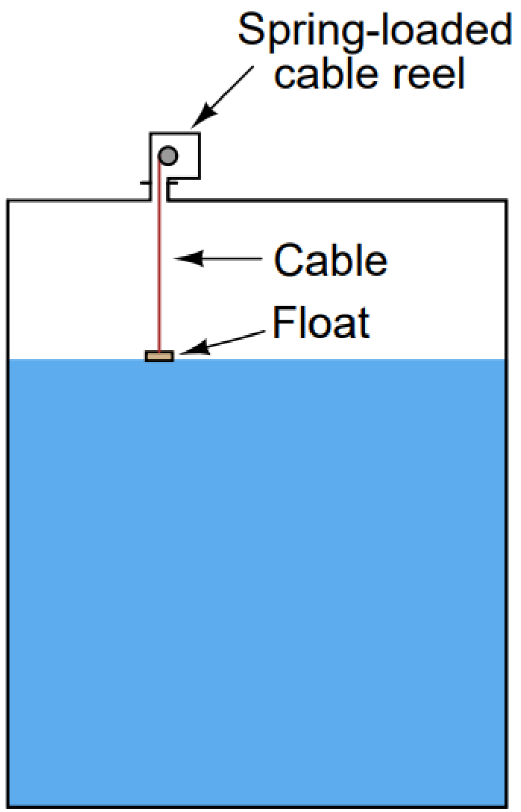


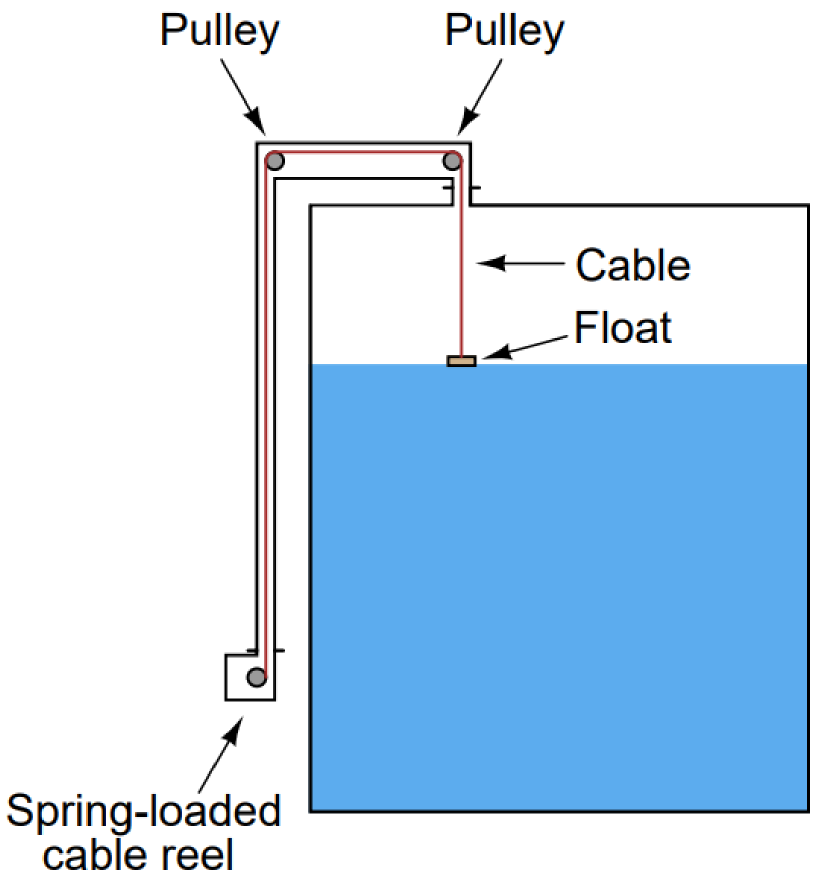




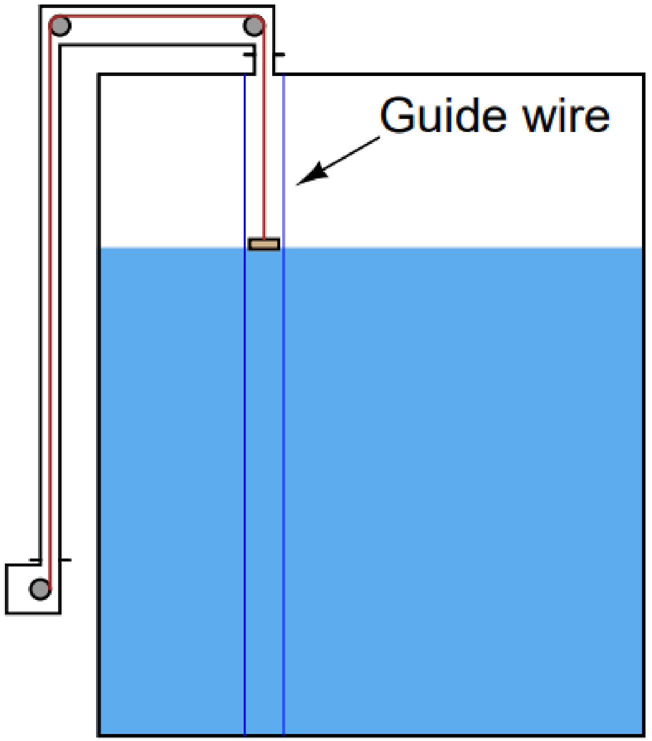
If the vessel is pressurized, this method is simply not applicable.

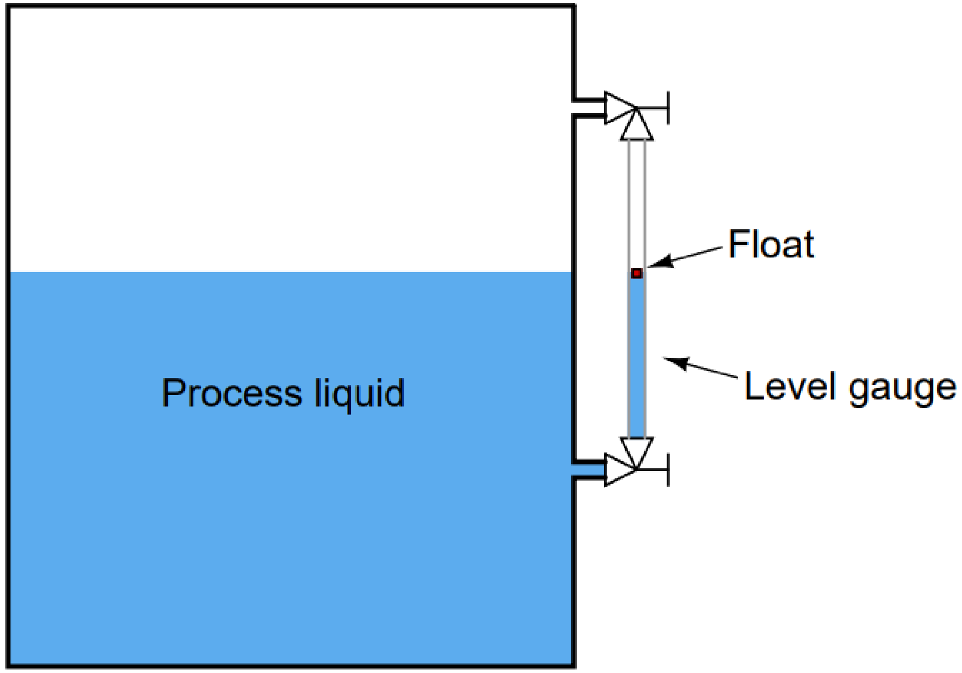
Float


Spring-loaded
cable reel
Cable
Float


Pulley
Pulley
Cable
Float
Spring-loaded
cable reel

Float

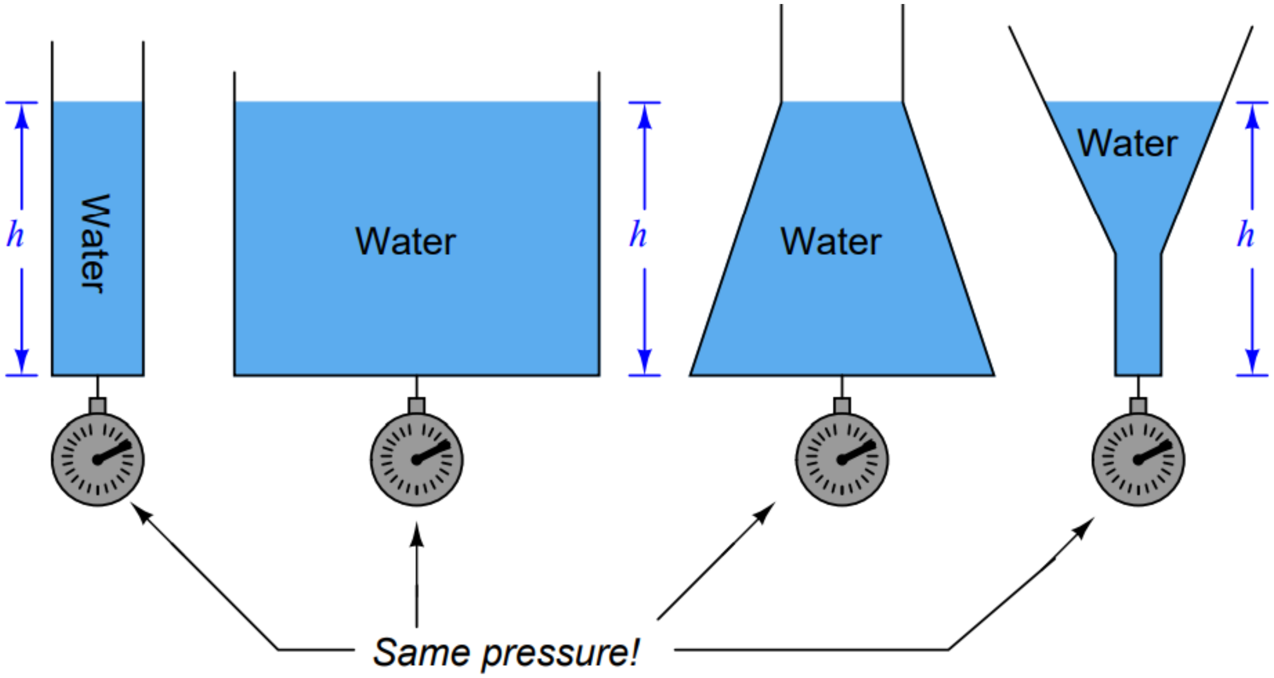


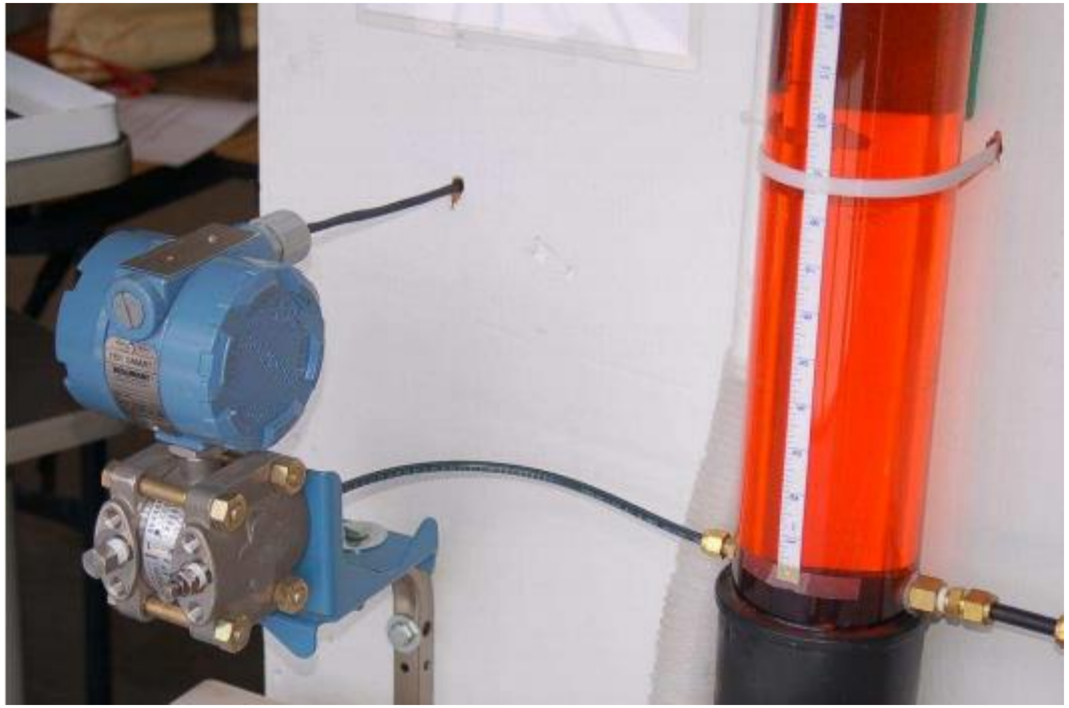


If the liquid inside the vessel is subject to turbulence, guide wires may be necessary to keep the float cable in a vertical orientation

The float's position inside the tube may be readily detected by ultrasonic waves, *magnetic sensors or any other* applicable means.

Hydrostatic pressure

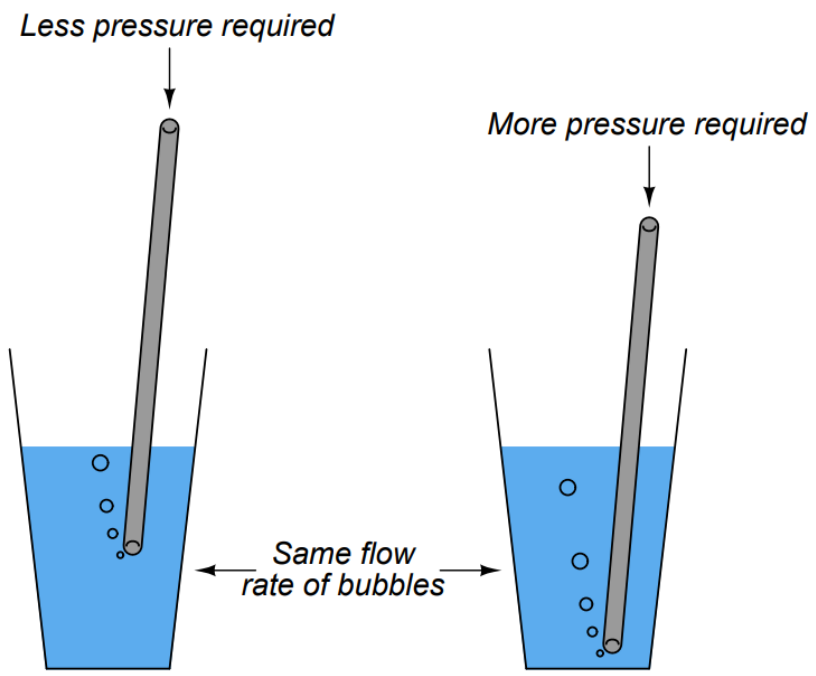


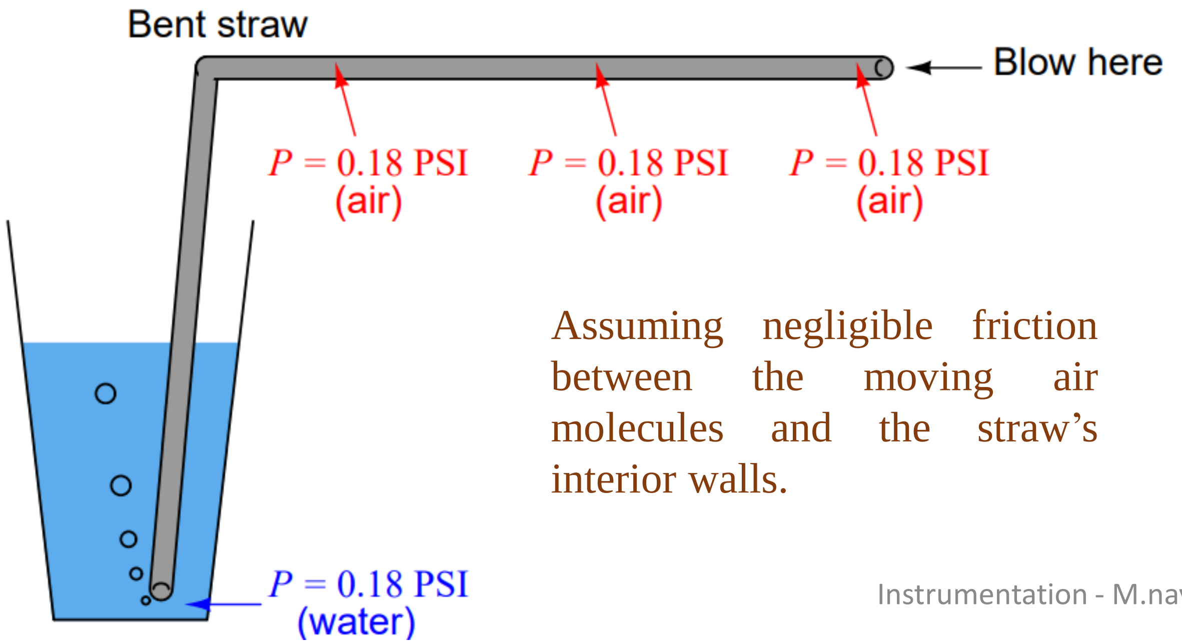


Hydrostatic pressure (Bubbler systems)

- Use of a purge gas to measure hydrostatic pressure in a liquid-containing vessel.

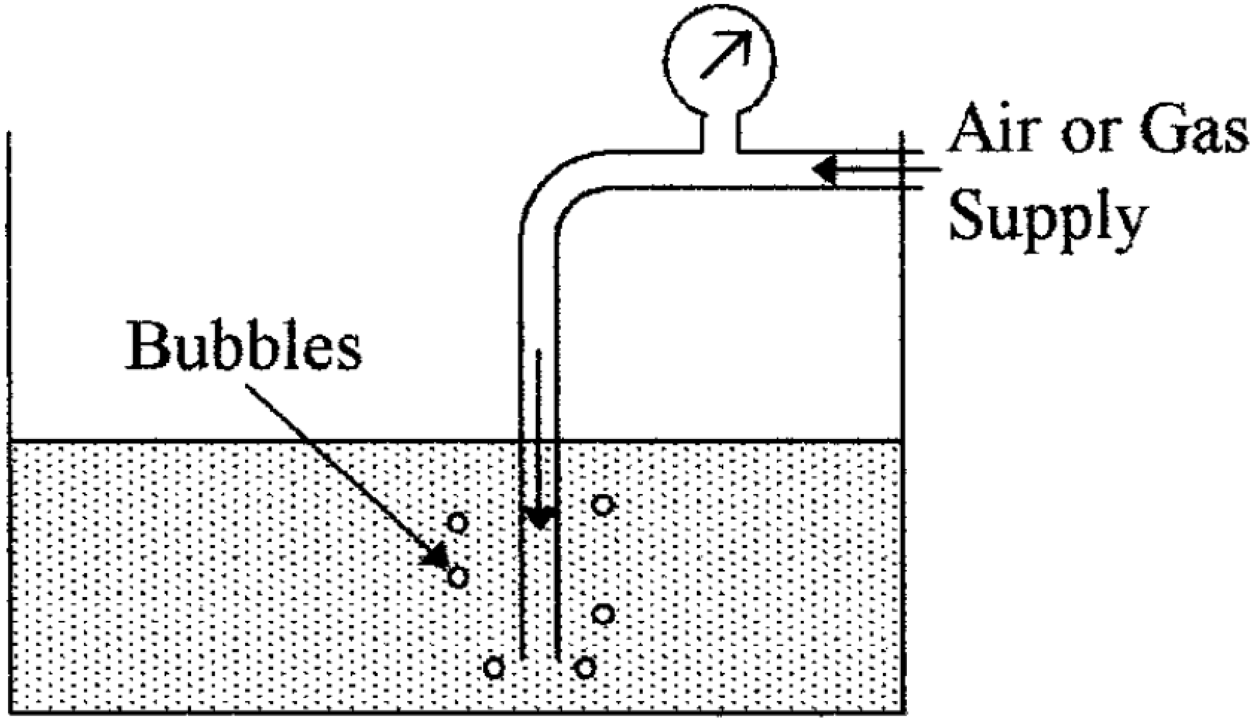
- This eliminates the need for direct contact of the process liquid against the pressure-sensing element, which can be advantageous if the process liquid is corrosive.





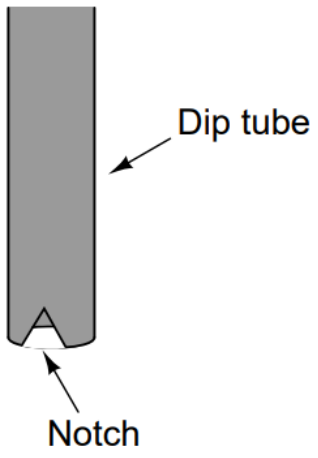
Assuming negligible friction between the moving air molecules and the straw's interior walls.

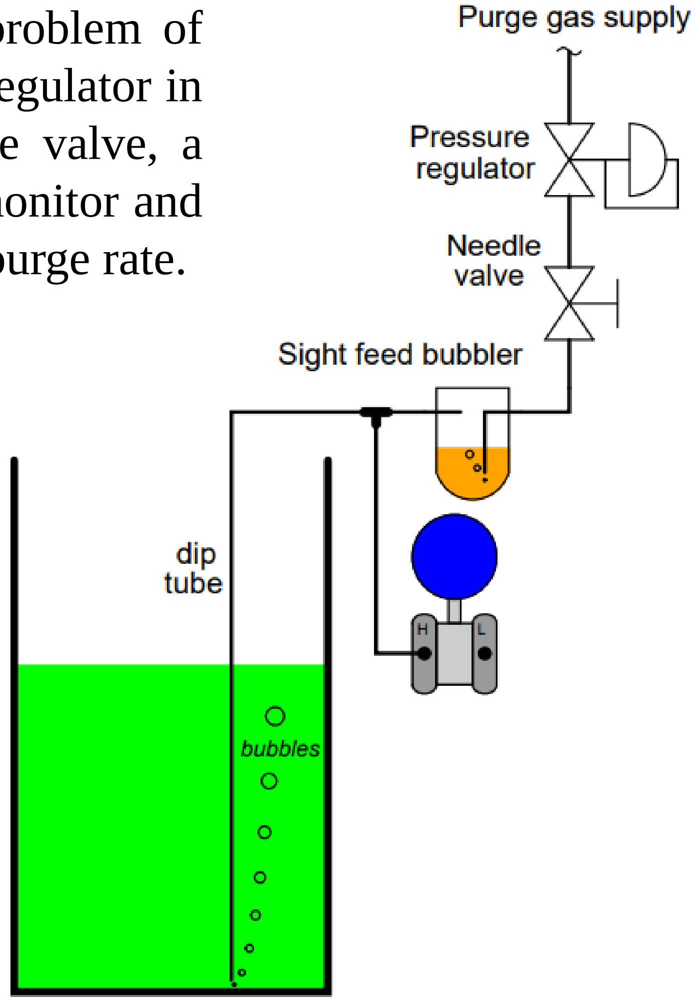
Hydrostatic pressure (Bubbler systems)

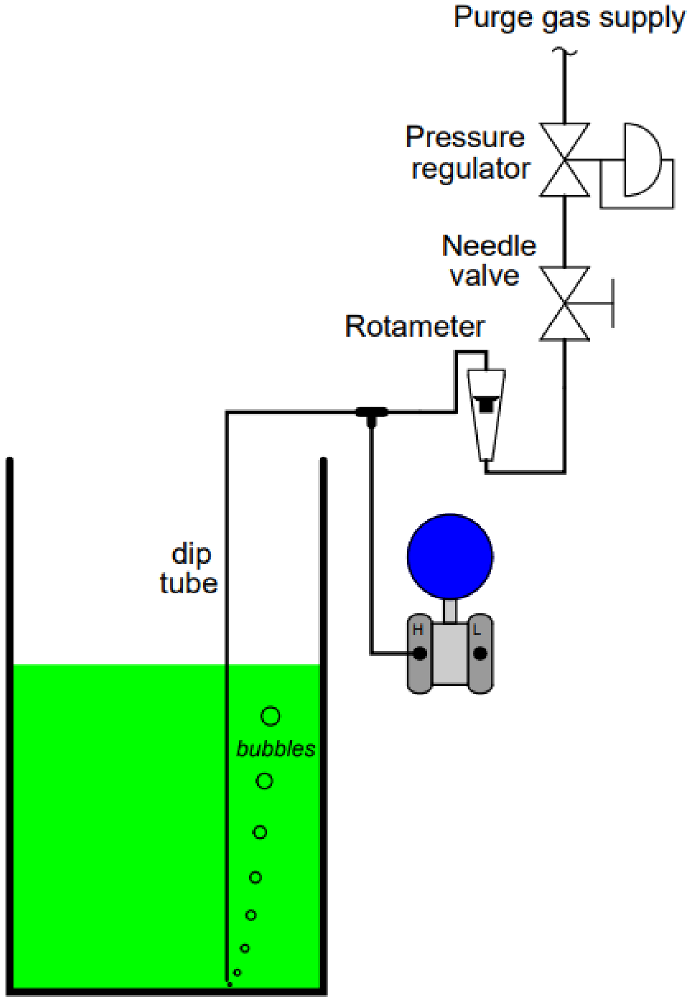


Hydrostatic pressure (Bubbler systems)

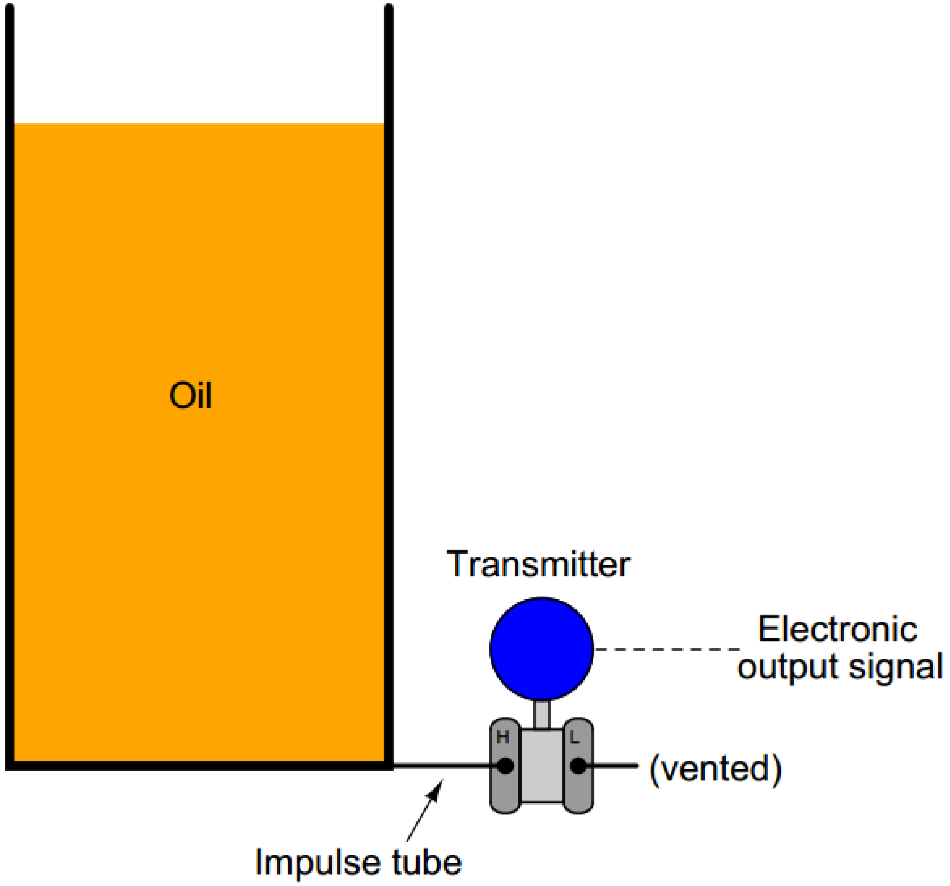
A more sophisticated solution to the problem of purge gas flow rate is to install a flow-regulator in lieu of a pressure regulator and needle valve, a mechanism designed to automatically monitor and throttle gas flow to maintain a constant purge rate.

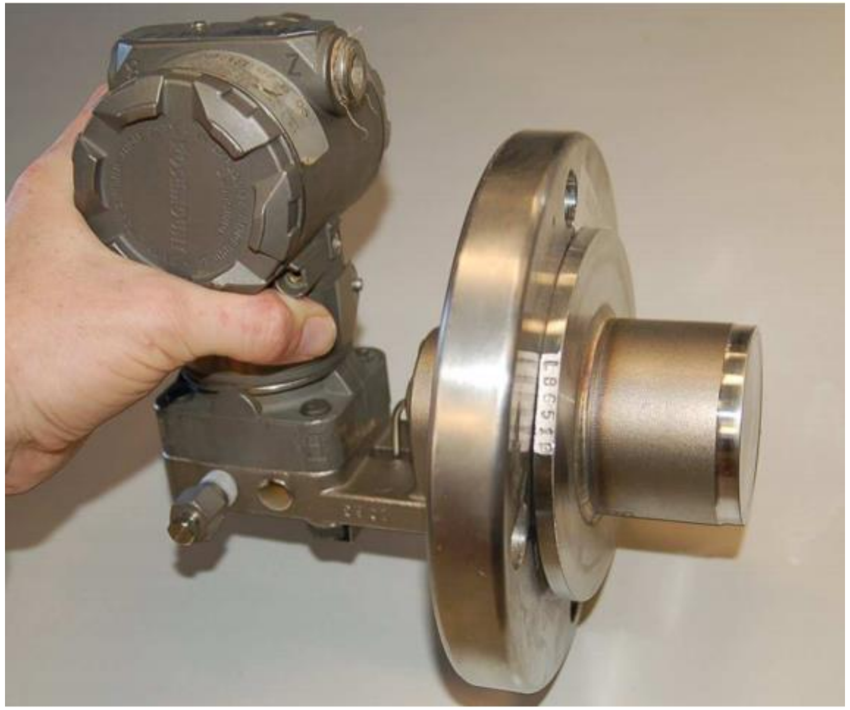




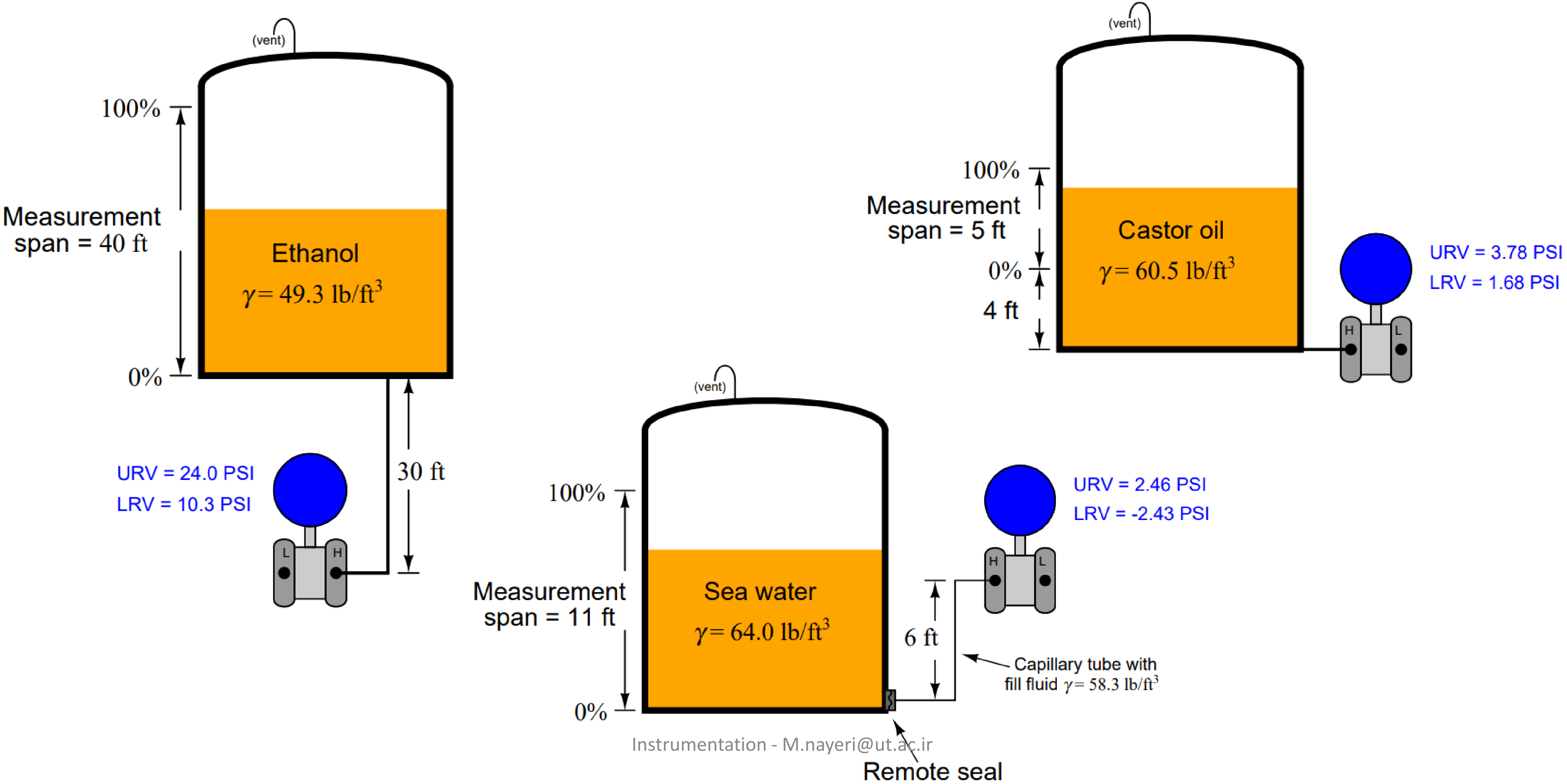


Hydrostatic pressure



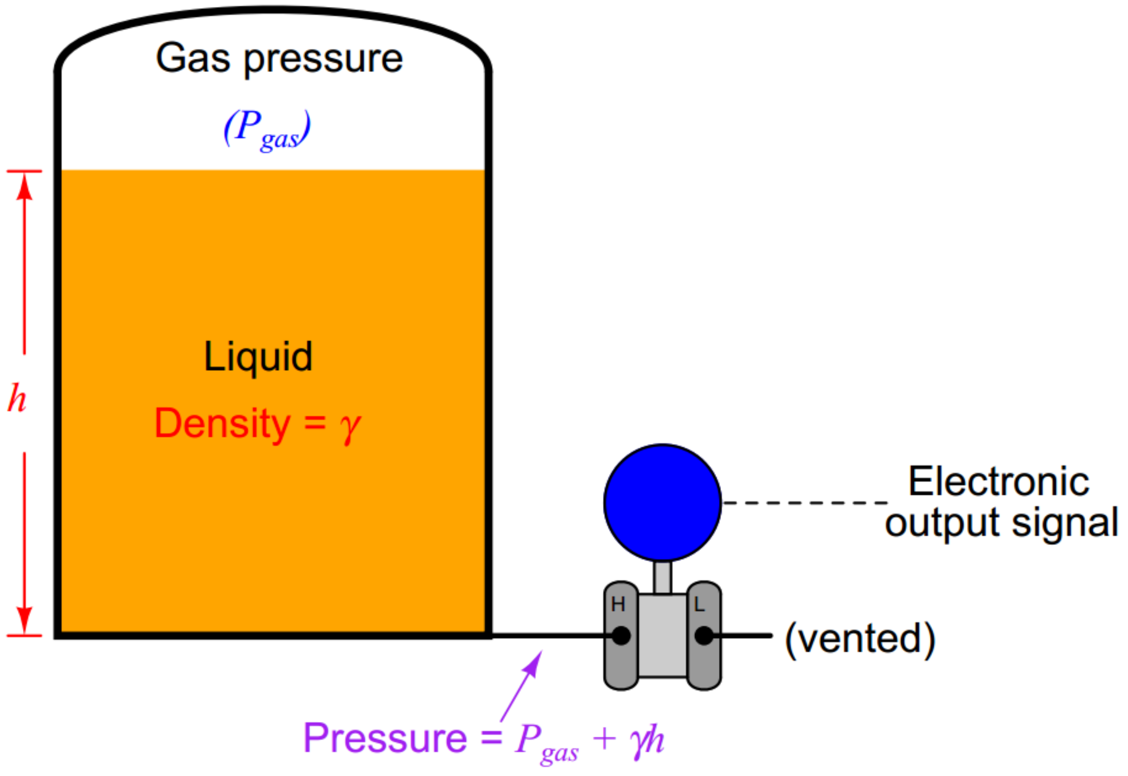


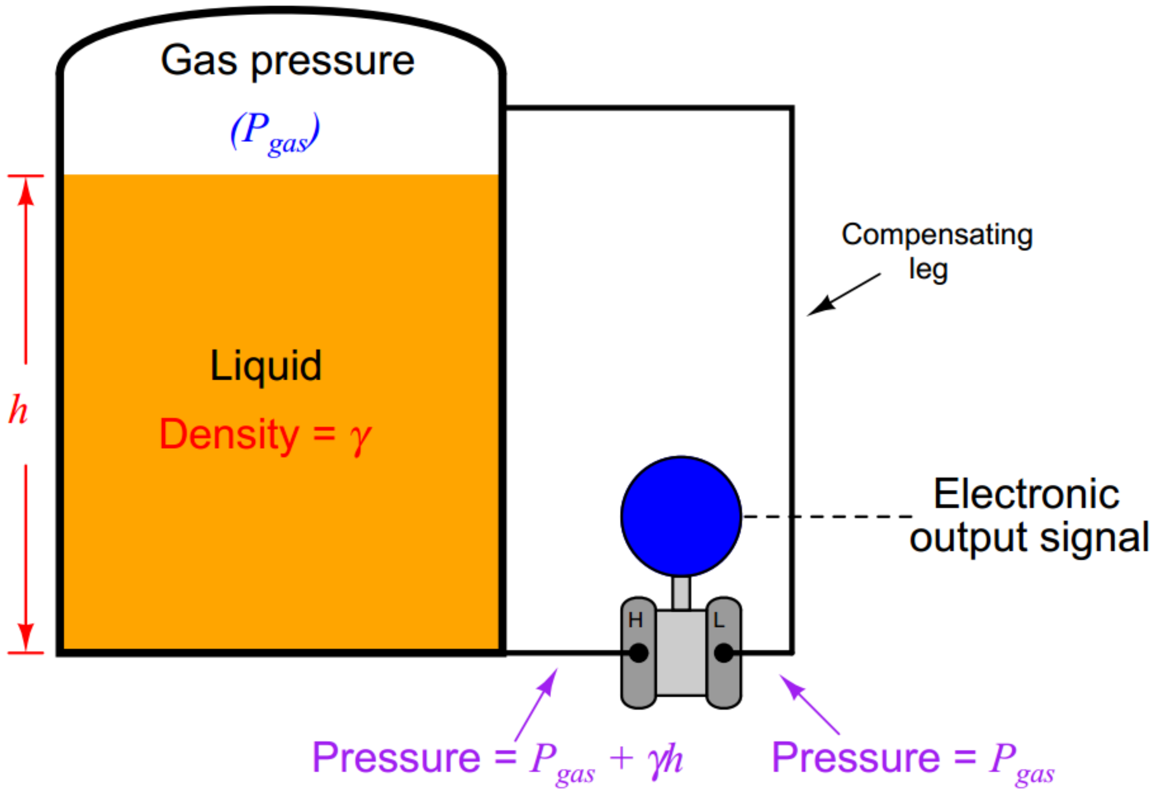
Hydrostatic pressure



Hydrostatic pressure

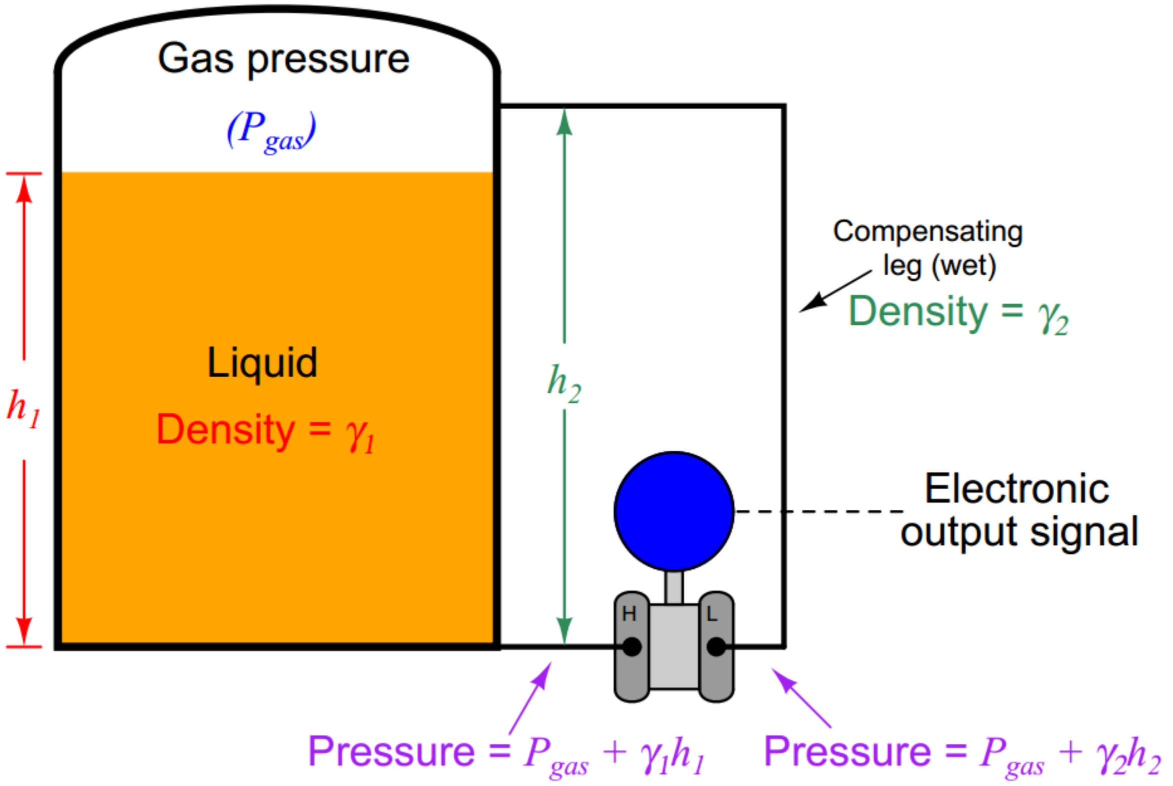
Compensated leg systems

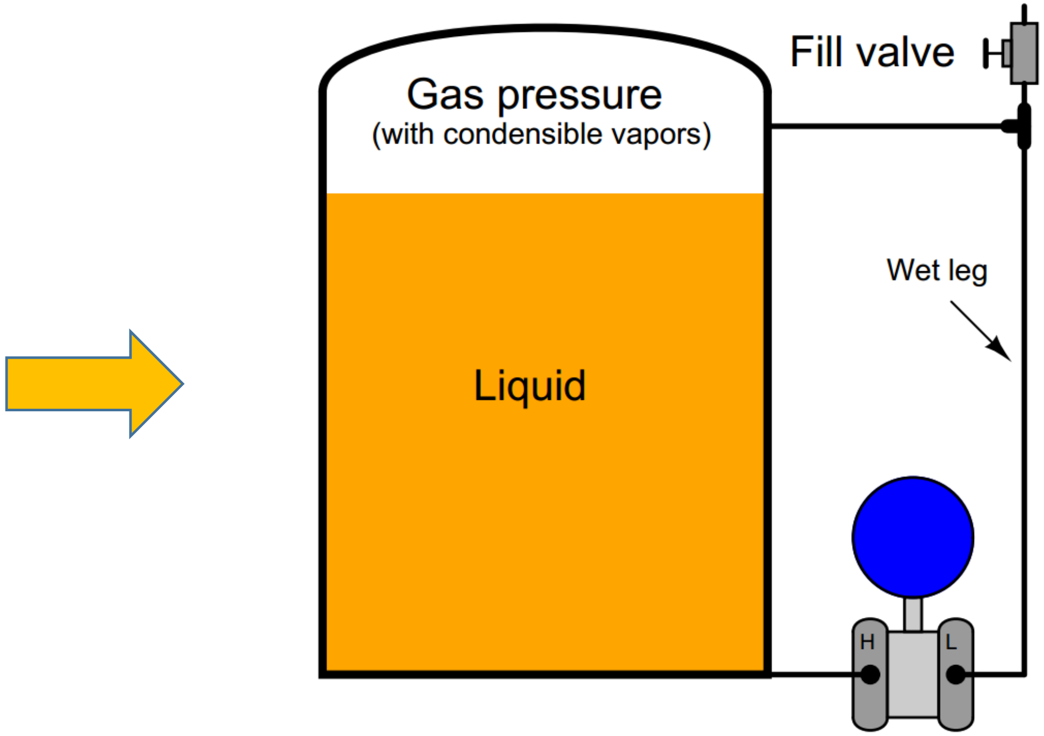




Hydrostatic pressure

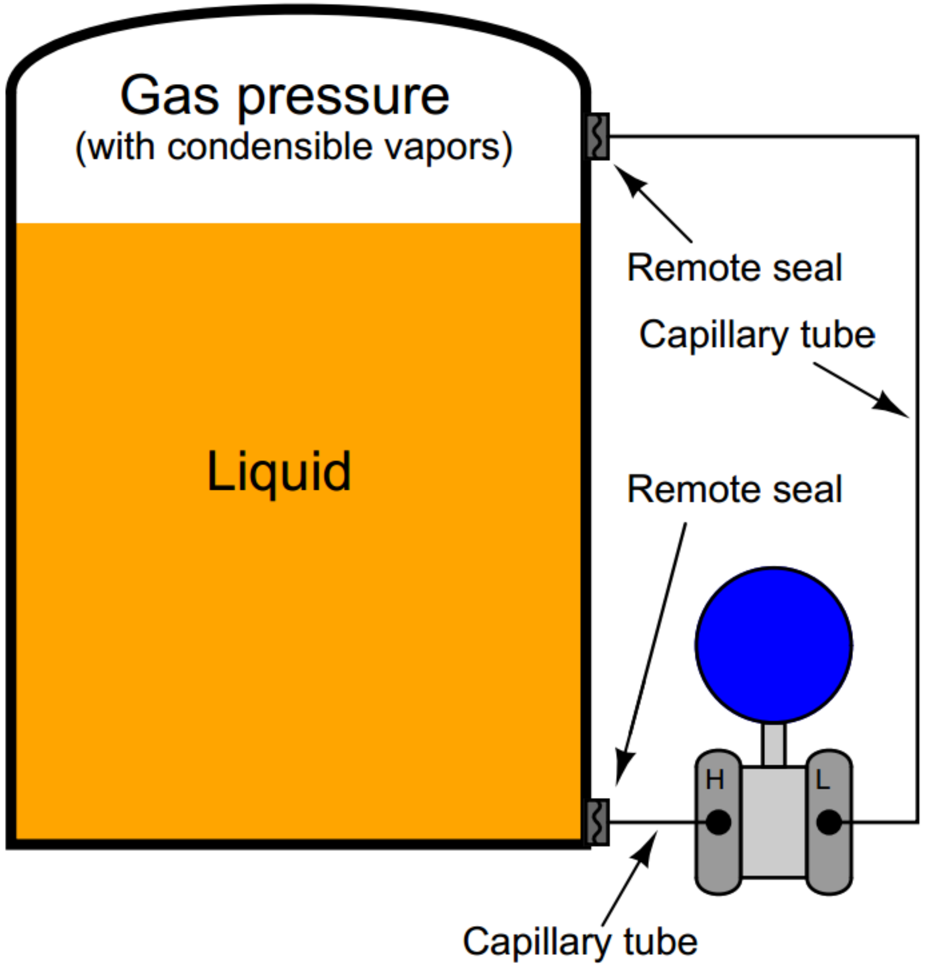
Compensated leg systems





Hydrostatic pressure

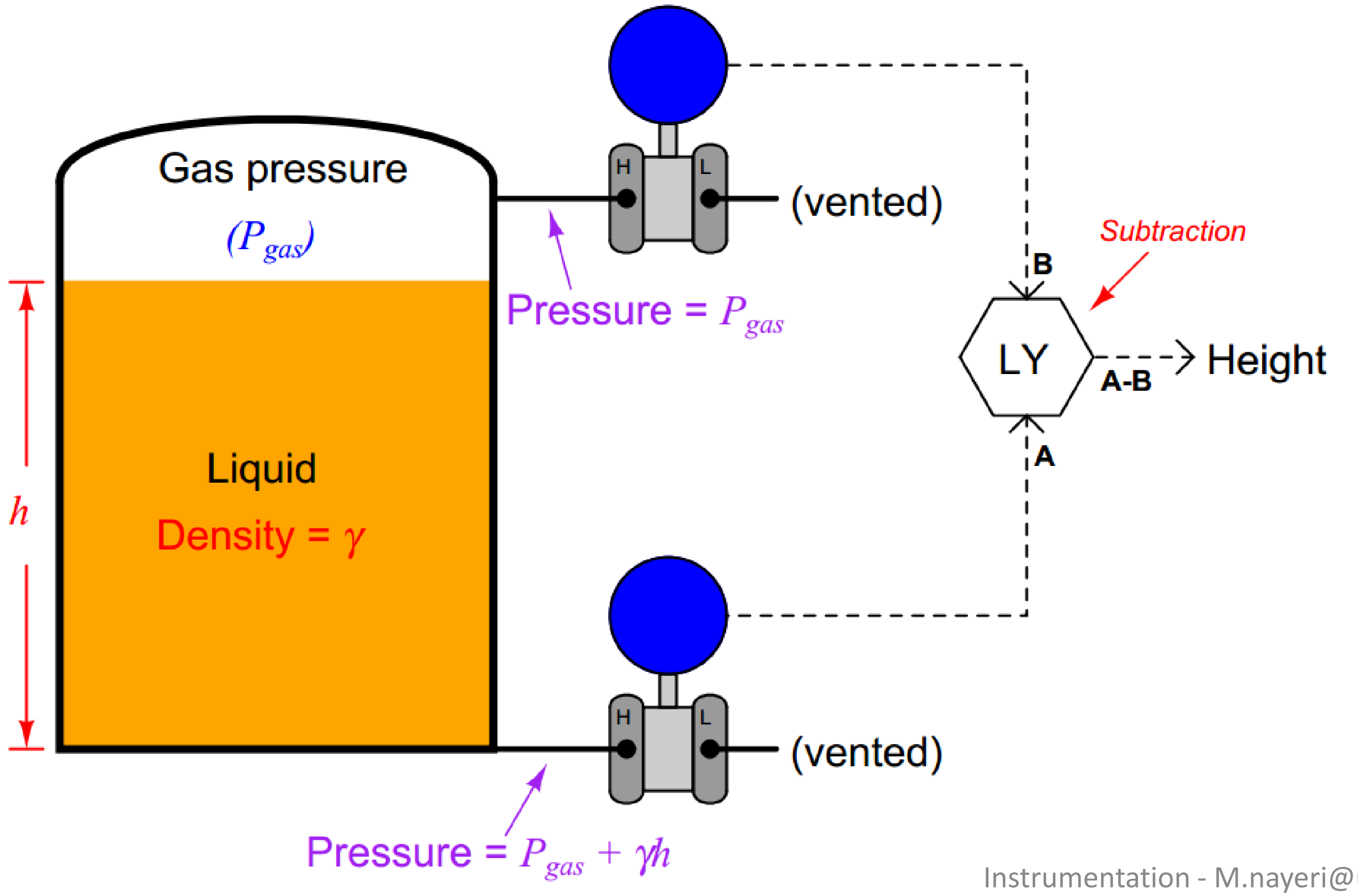
Compensated leg systems



Hydrostatic pressure

Compensated leg systems

Tank expert systems



- This approach enjoys the distinct advantage of avoiding a potentially wet compensating leg.

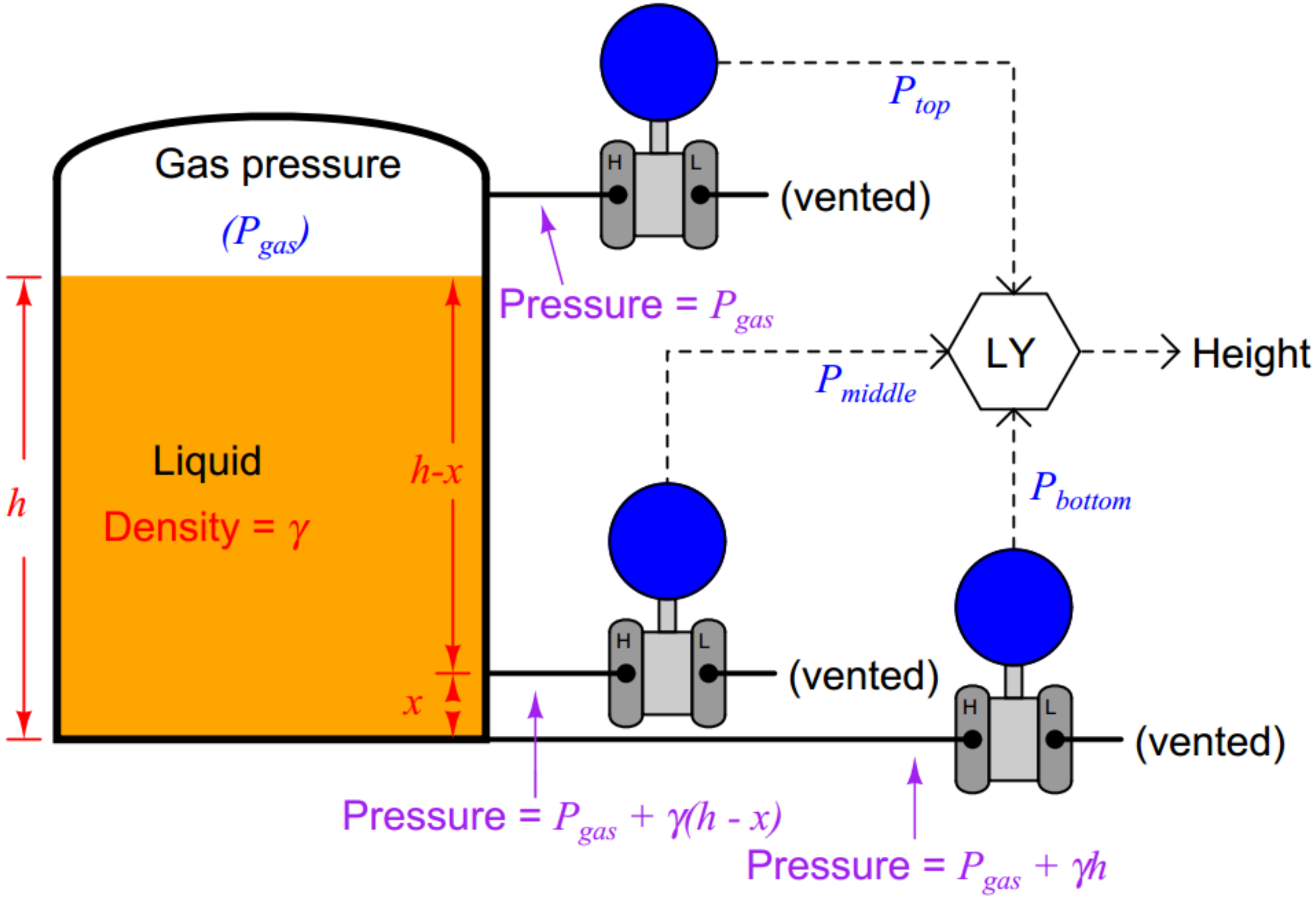
- Suffers the disadvantages of extra cost and greater error due to the potential calibration drift of two transmitters rather than just one.

- Such a system is also impractical in applications where the gas pressure is substantial compared to the hydrostatic pressure.

Hydrostatic pressure

Compensated leg systems

Tank expert systems



- These systems are used on large storage tanks operating at or near atmospheric pressure, and have the ability to measure infer **liquid height**, **liquid density**, **total liquid volume**, and **total liquid mass** stored in the tank

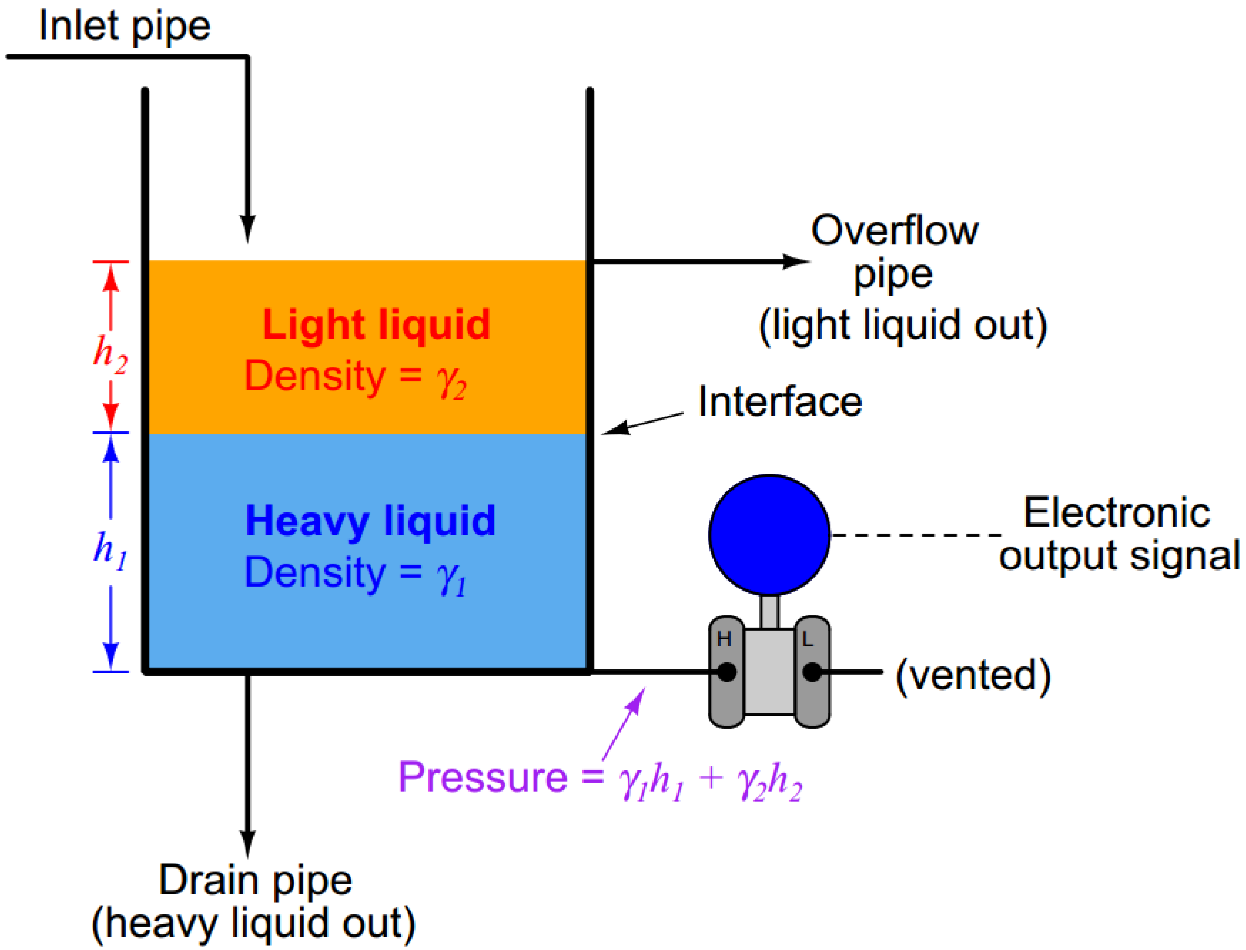
Hydrostatic pressure

Compensated leg systems

Tank expert systems

Hydrostatic pressure

Detect the level of a liquid-liquid interface



Hydrostatic pressure

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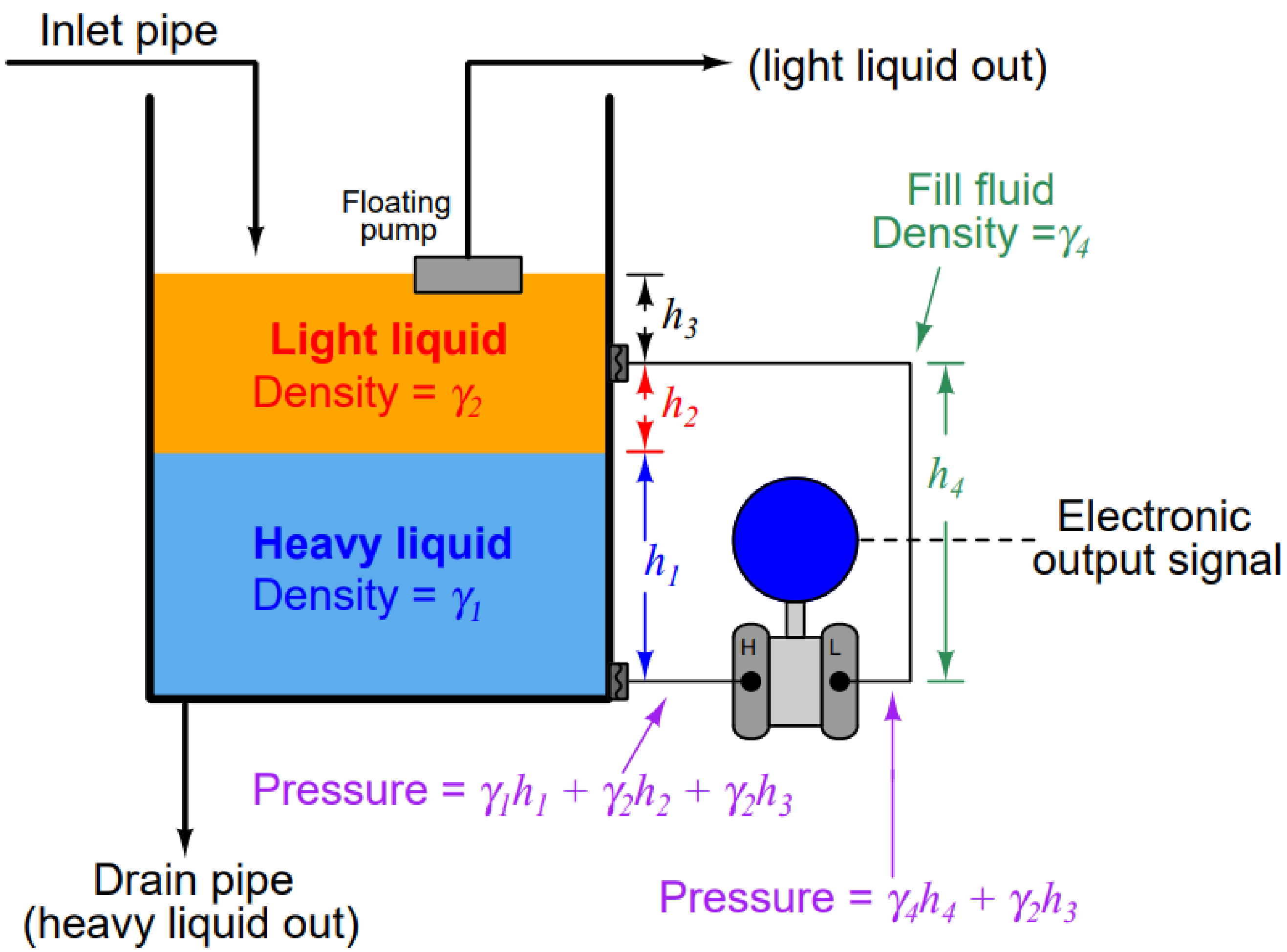
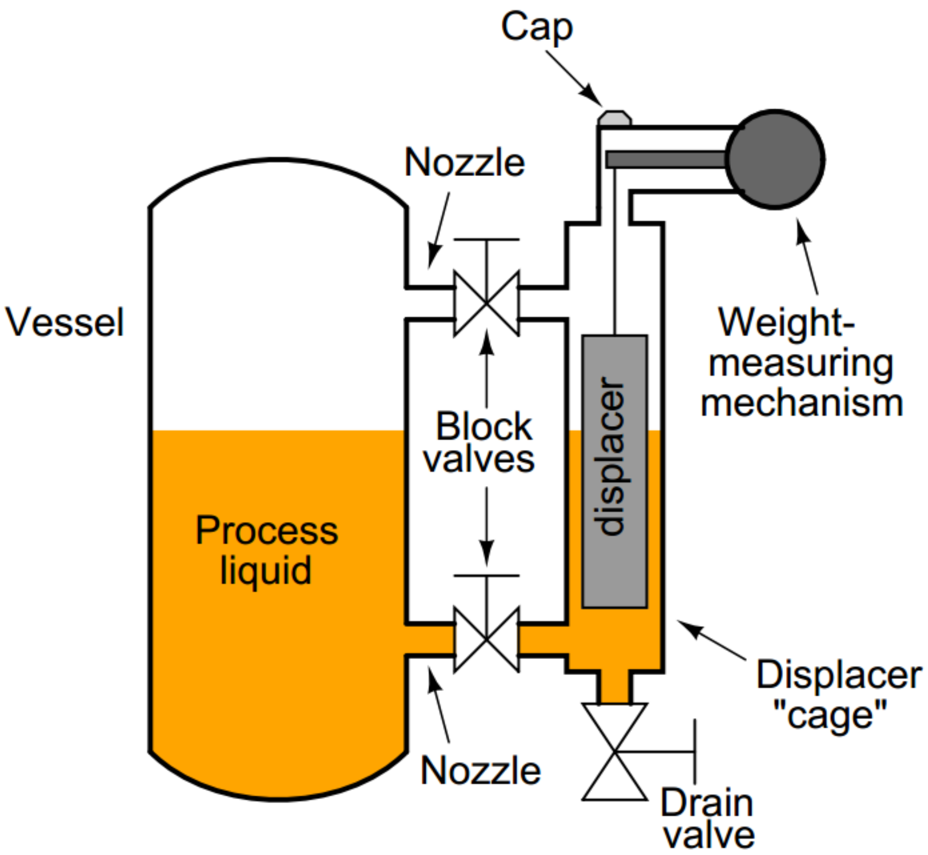
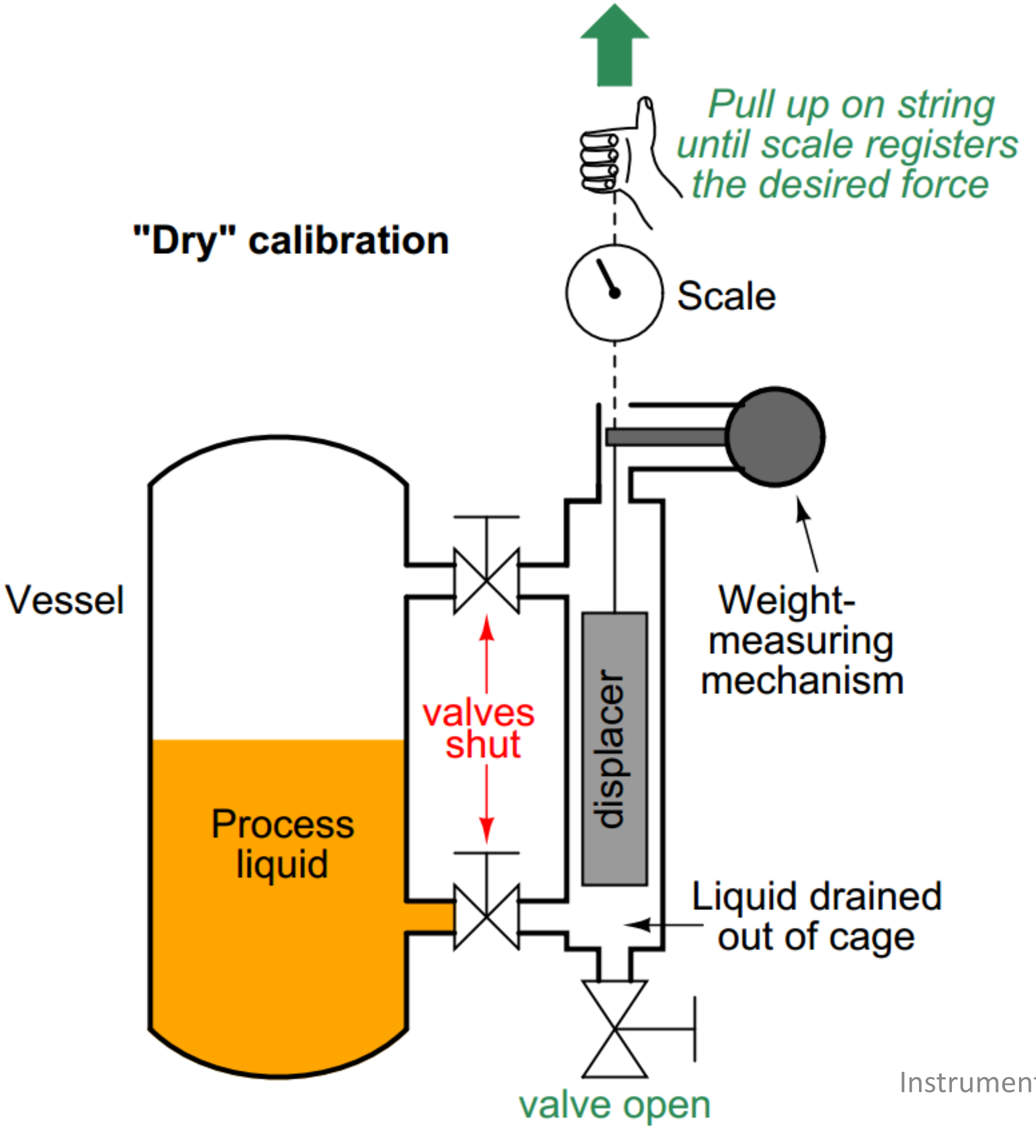


Displacement

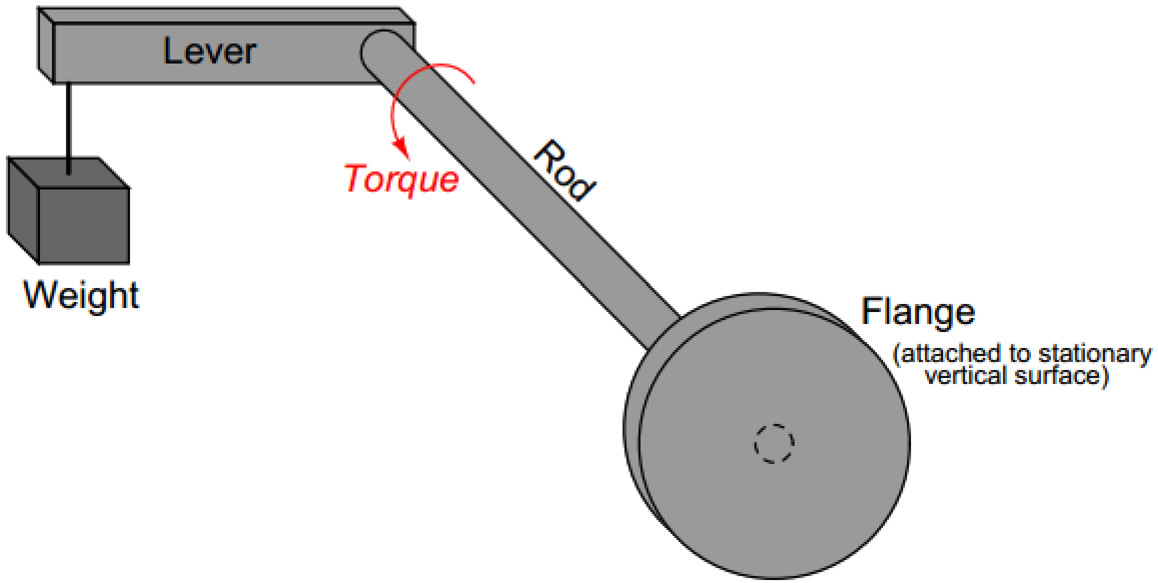


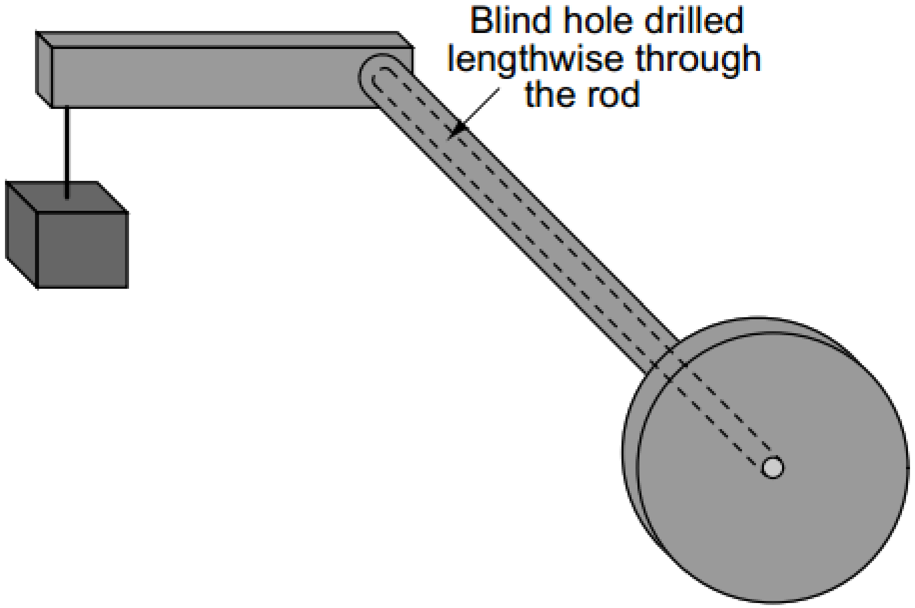
Displacement



Displacement

Torque tubes





Displacement

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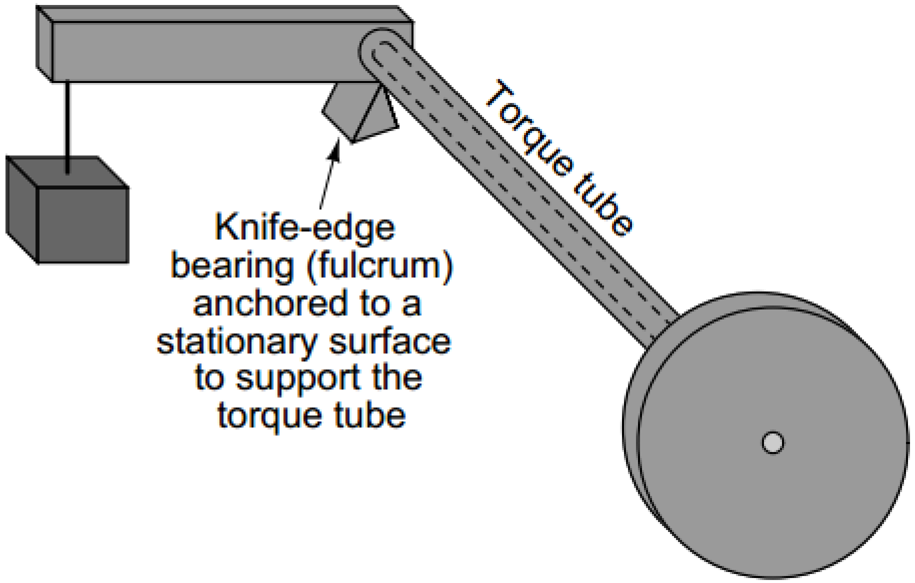
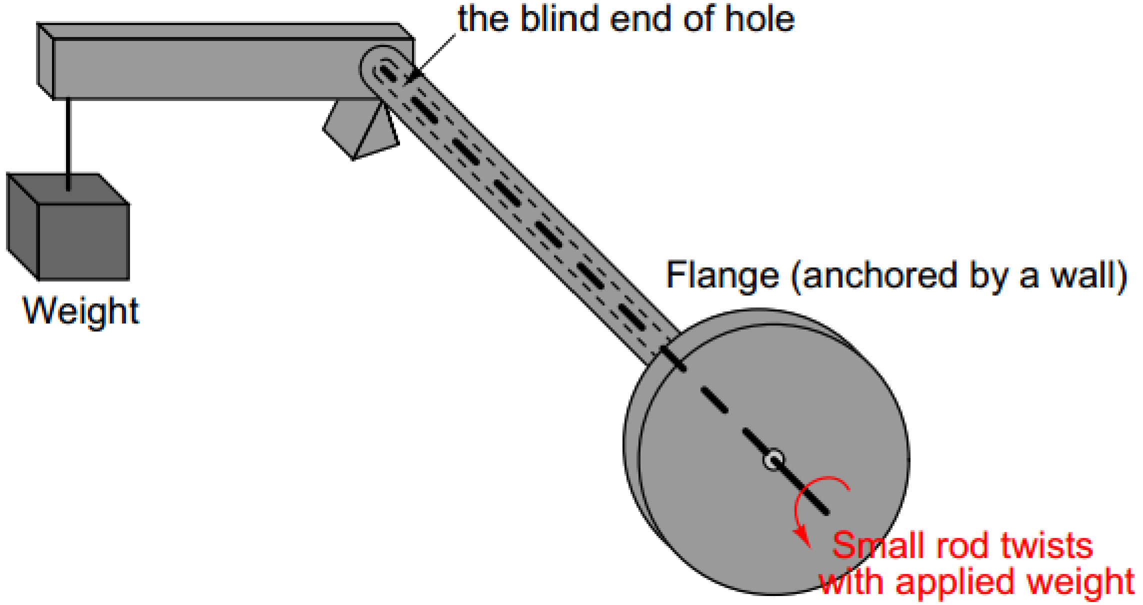
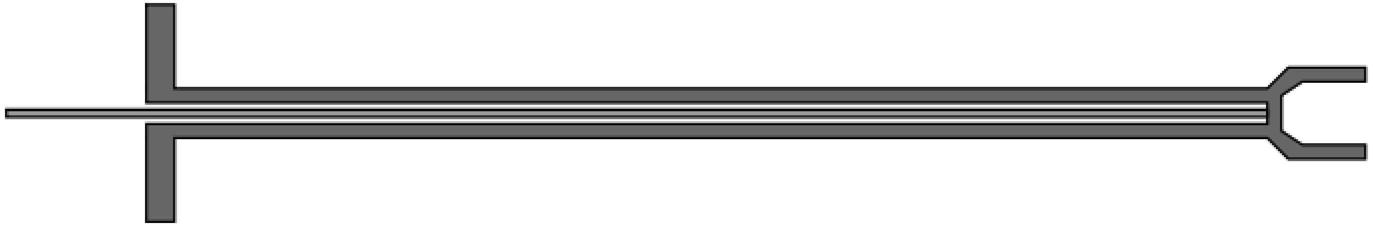




Displacement

Torque tubes



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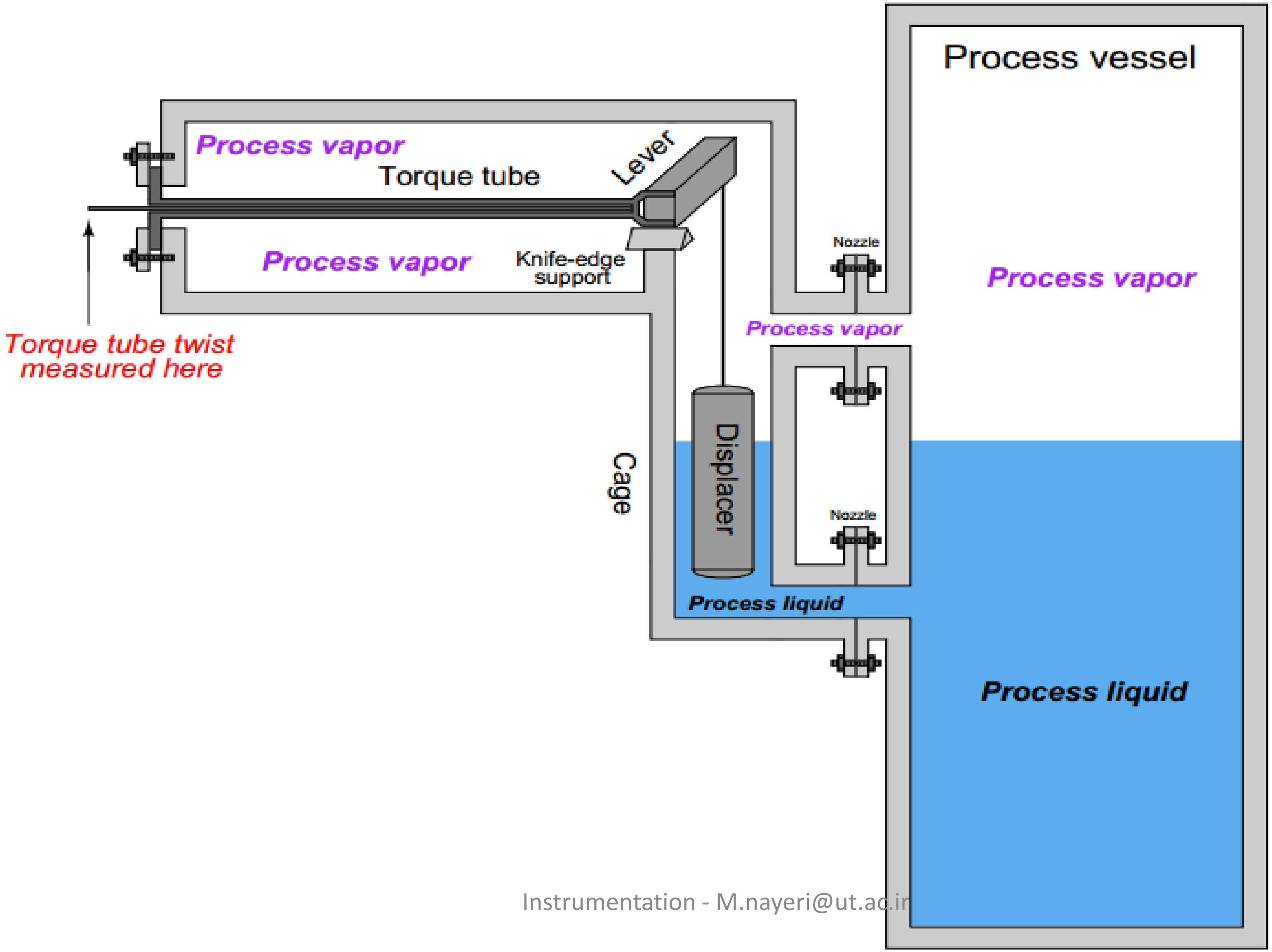
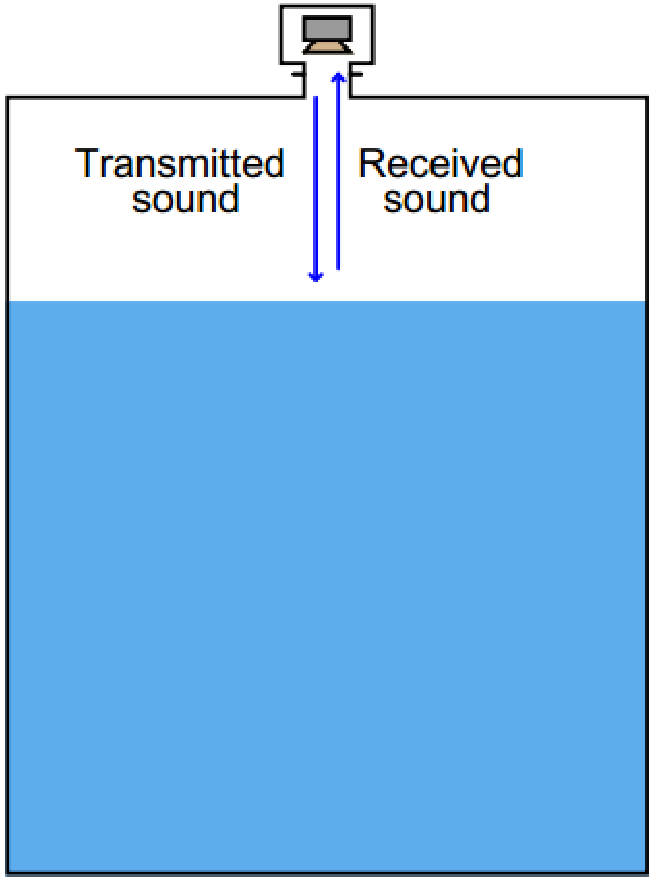
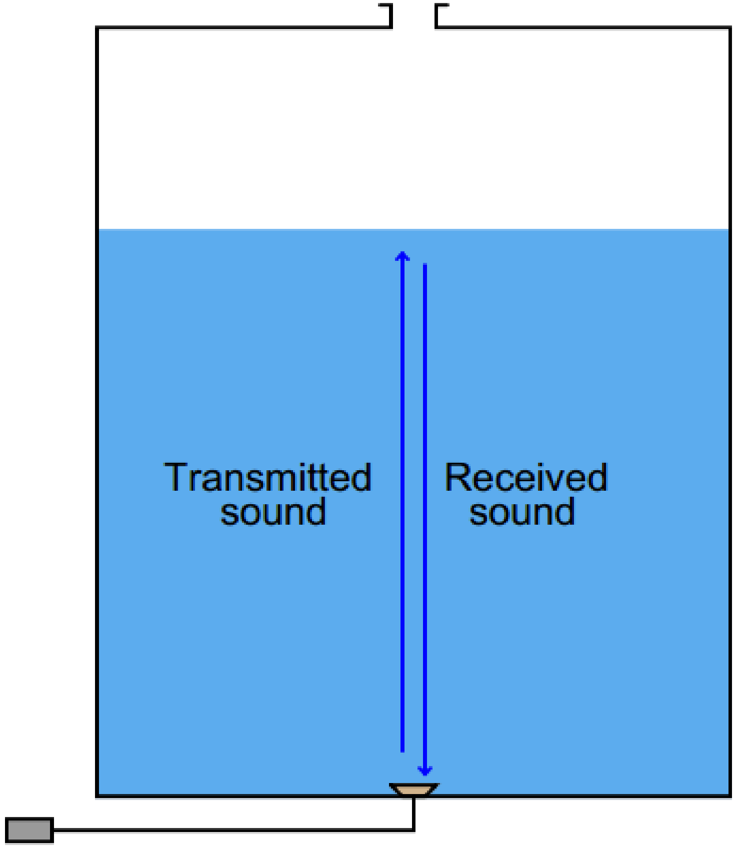
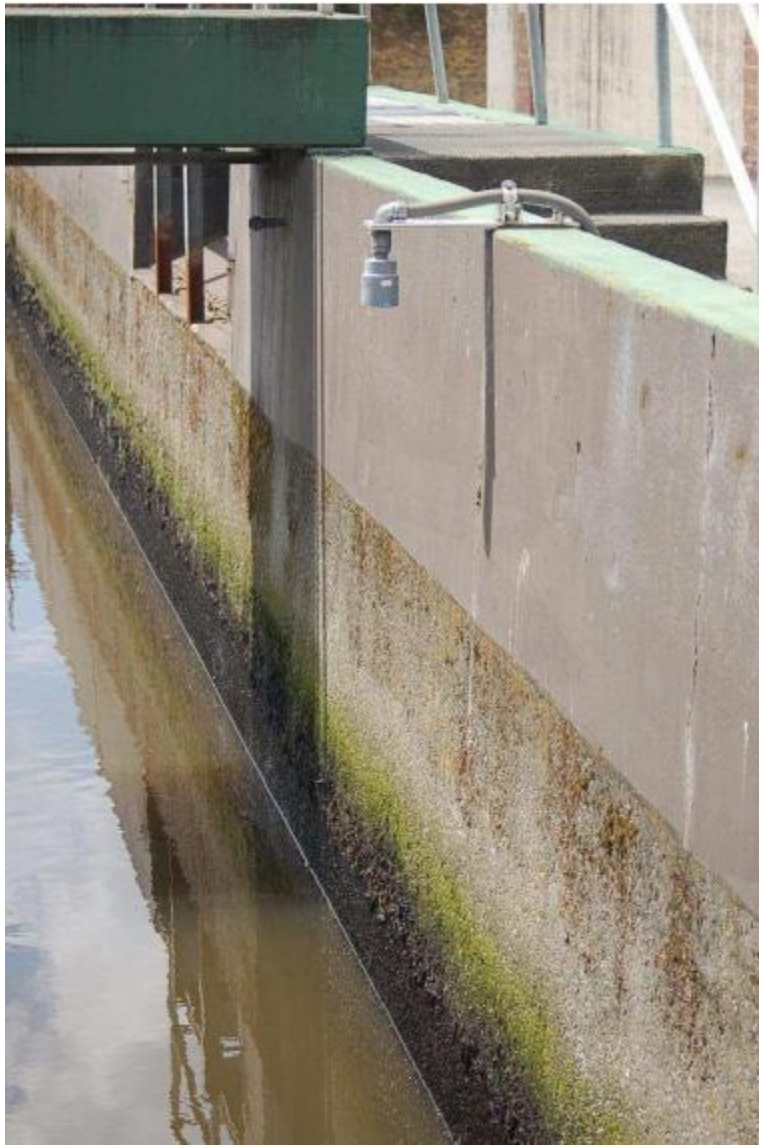


Ultrasonic level measurement

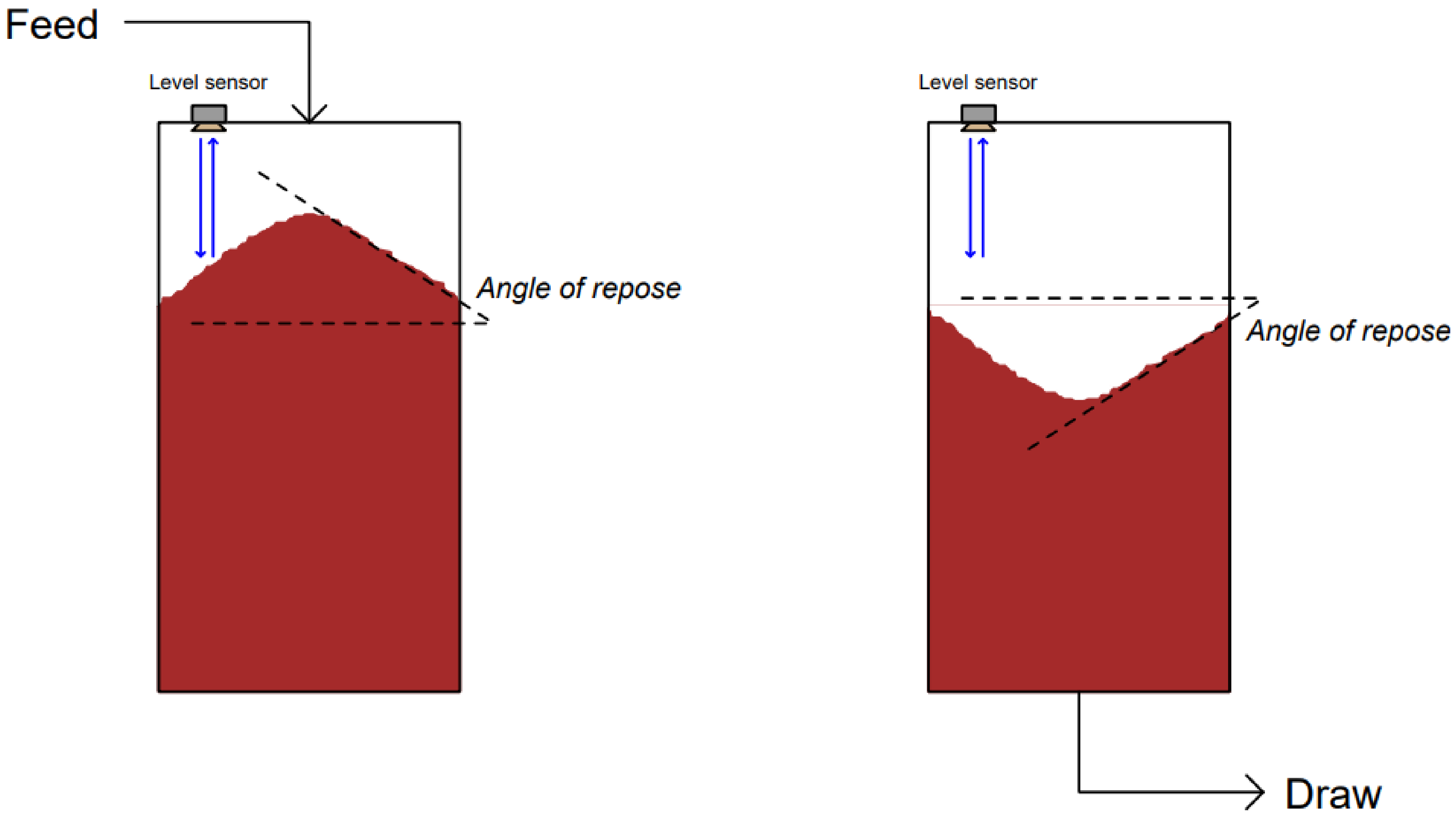




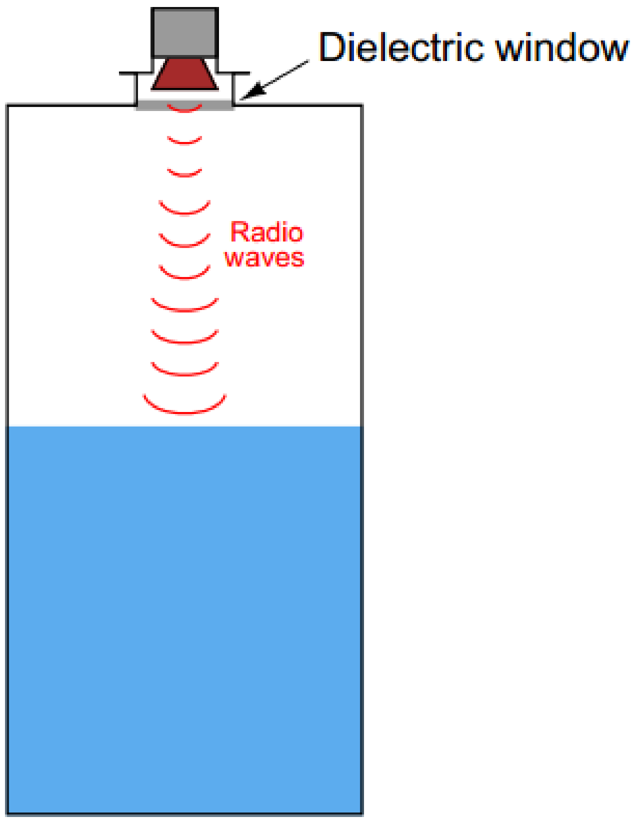
Ultrasonic level measurement



Ultrasonic level measurement



Radar level measurement



- Non-contact radar instruments rely on antennas to direct microwave energy into the vessel, and to receive the echo (return) energy.

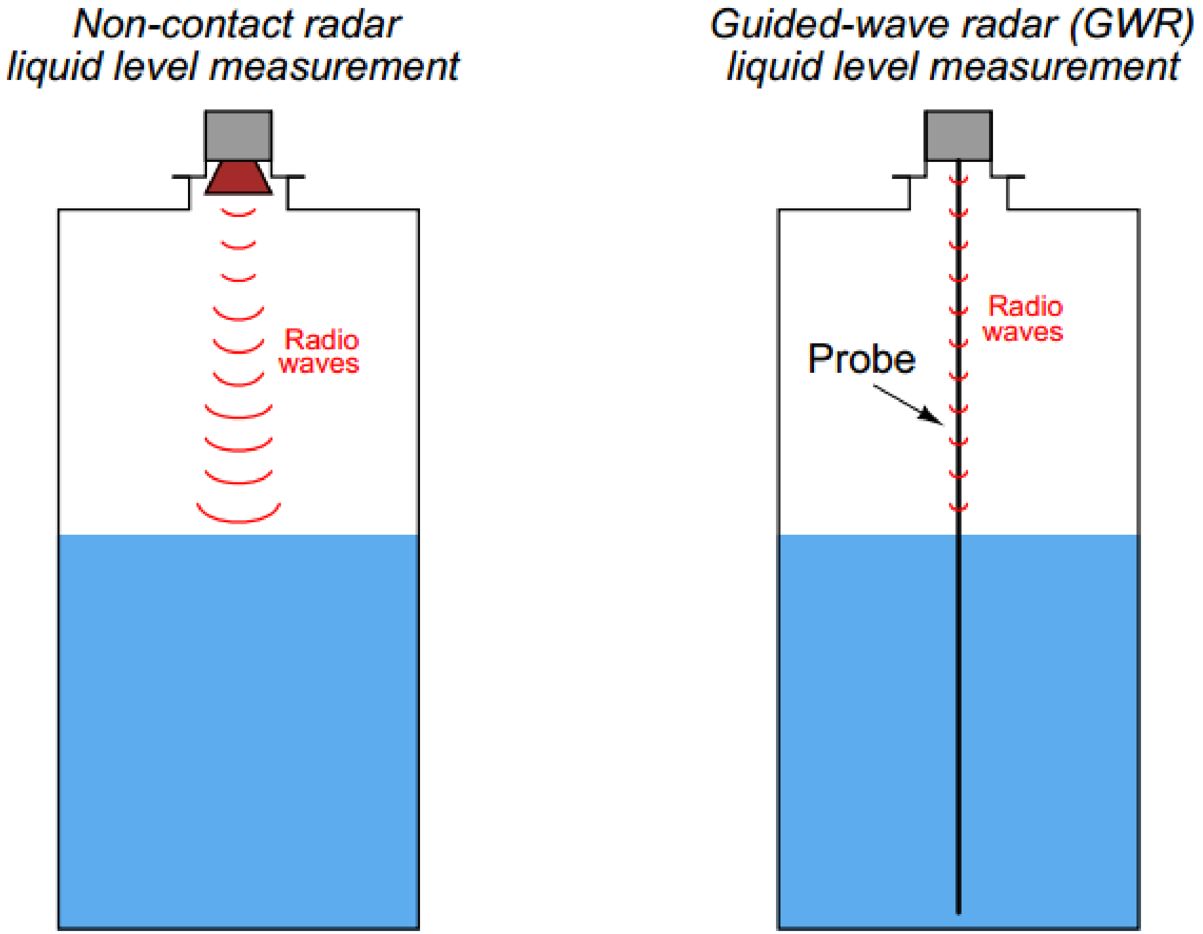
- Electromagnetic waves travel at the speed of light (2.9979×10^8 meters per second in a perfect vacuum) The velocity of an electromagnetic wave through space depends on the dielectric permittivity of that space. The relative permittivity of air at standard pressure and temperature is very nearly unity (1).

$$v = \frac{c}{\sqrt{\epsilon_r}}$$

$$\epsilon_r = 1 + (\epsilon_{ref} - 1)\frac{PT_{ref}}{P_{ref}T}$$

ϵ_r = Relative permittivity of a gas at a given pressure (P) and temperature (T)
ϵ_{ref} = Relative permittivity of the same gas at standard pressure (P_{ref}) and temperature (T_{ref})
P = Absolute pressure of gas (bars)
P_{ref} = Absolute pressure of gas under standard conditions ($\approx$ 1 bar)
T = Absolute temperature of gas (Kelvin)
T_{ref} = Absolute temperature of gas under standard conditions ($\approx$ 273 K)

Radar level measurement



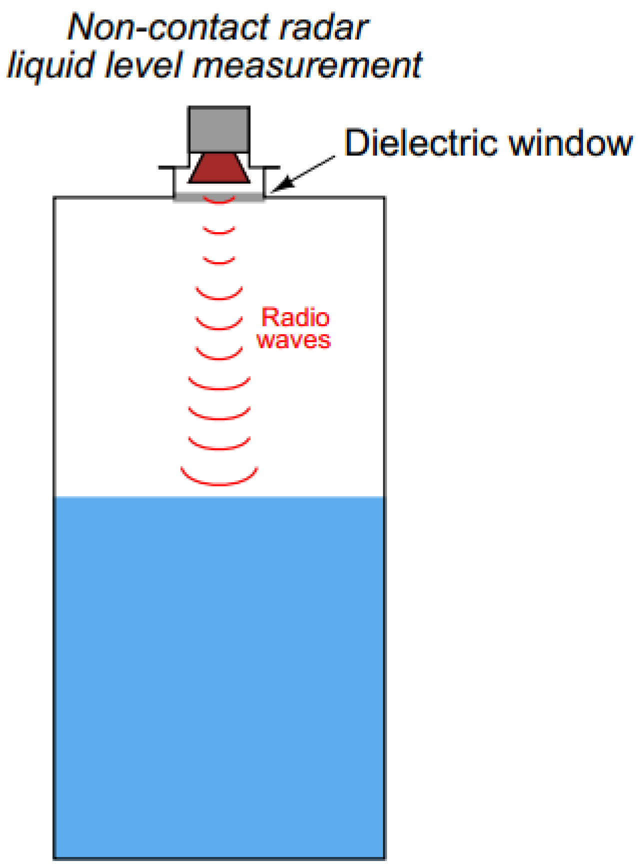
Radar level measurement

Non-contact radar devices suffer much more signal loss than guided-wave radar devices.

Radar level measurement

- Antenna must be kept clean and dry, which may be a problem if the liquid being measured emits condensable vapors.

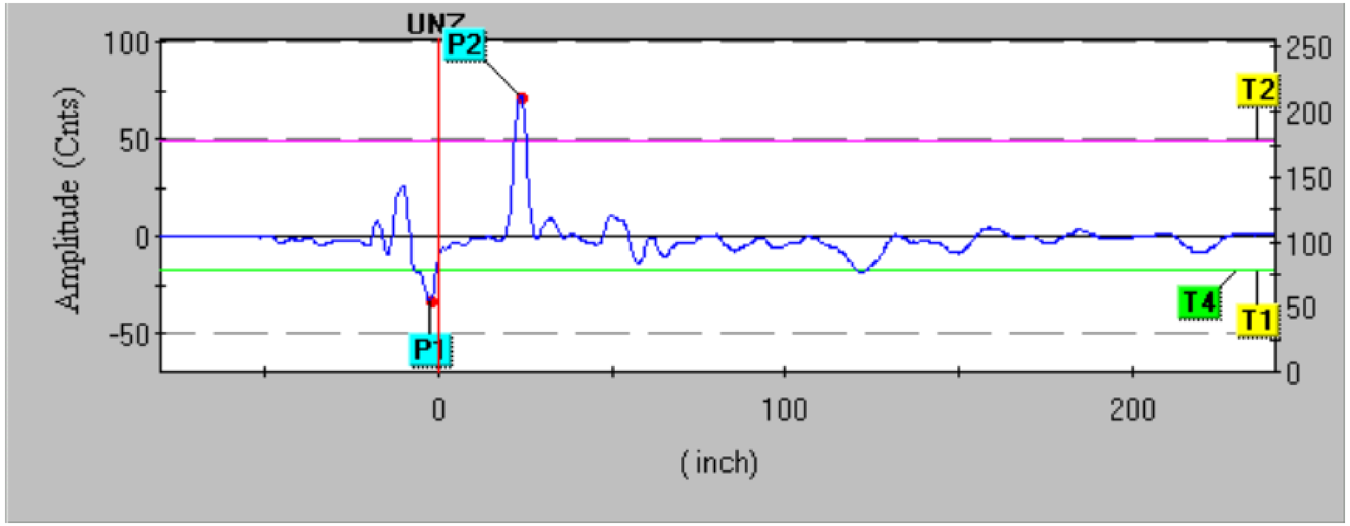
- Non-contact radar instruments are often separated from the vessel interior by means of a dielectric window

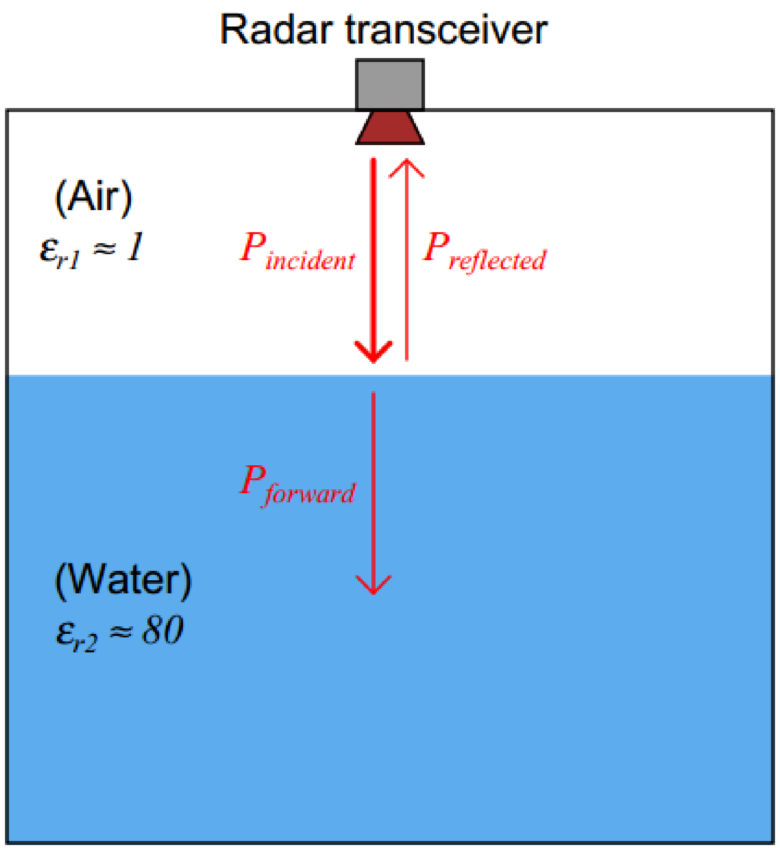


Radar level measurement

$$R = \frac{\left(\sqrt{\epsilon_{r2}} - \sqrt{\epsilon_{r1}}\right)^2}{\left(\sqrt{\epsilon_{r2}} + \sqrt{\epsilon_{r1}}\right)^2}$$

R = Power reflection factor at interface, as a unitless ratio
ϵ_{r1} = Relative permittivity (dielectric constant) of the first medium
ϵ_{r2} = Relative permittivity (dielectric constant) of the second medium

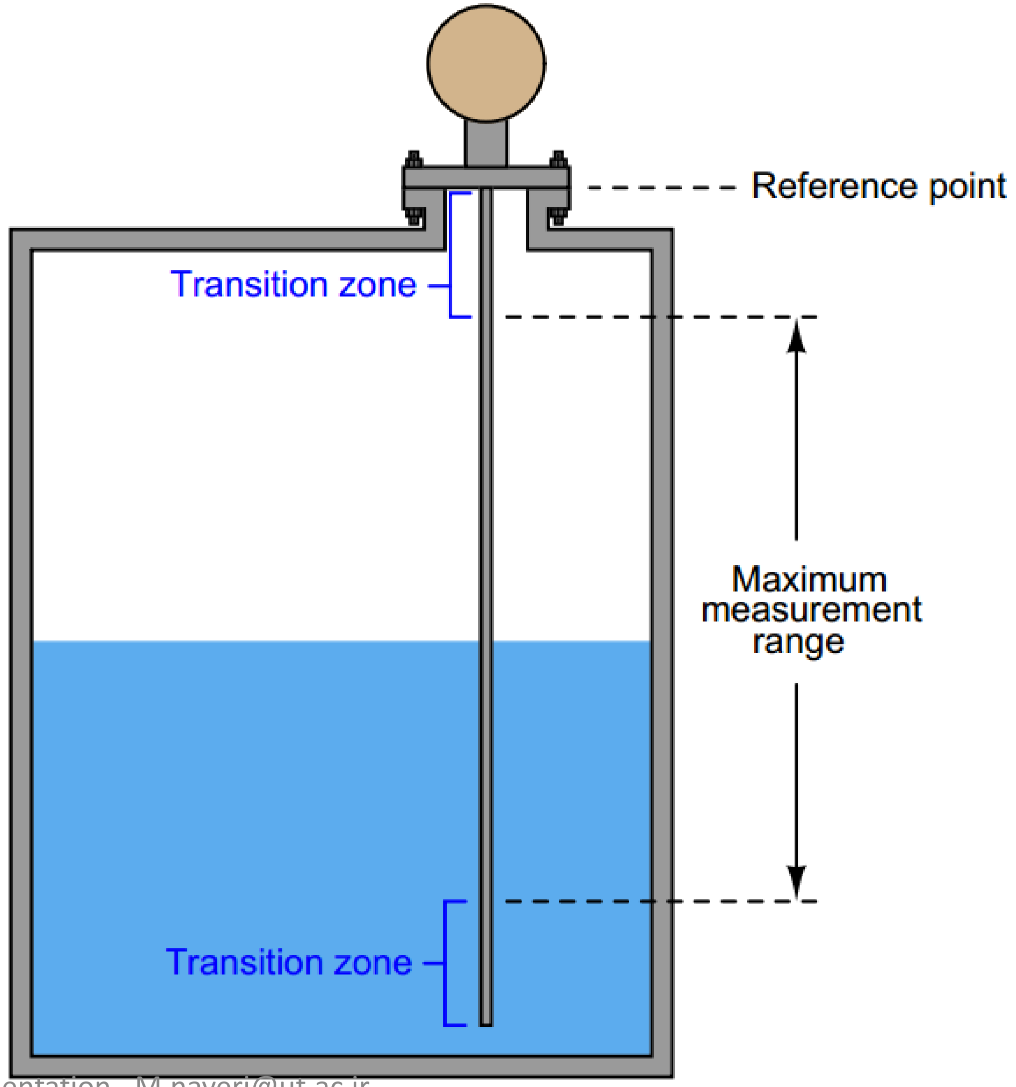




Radar level measurement

- Some radar level instruments allow thresholds to be set as curves themselves rather than straight lines.

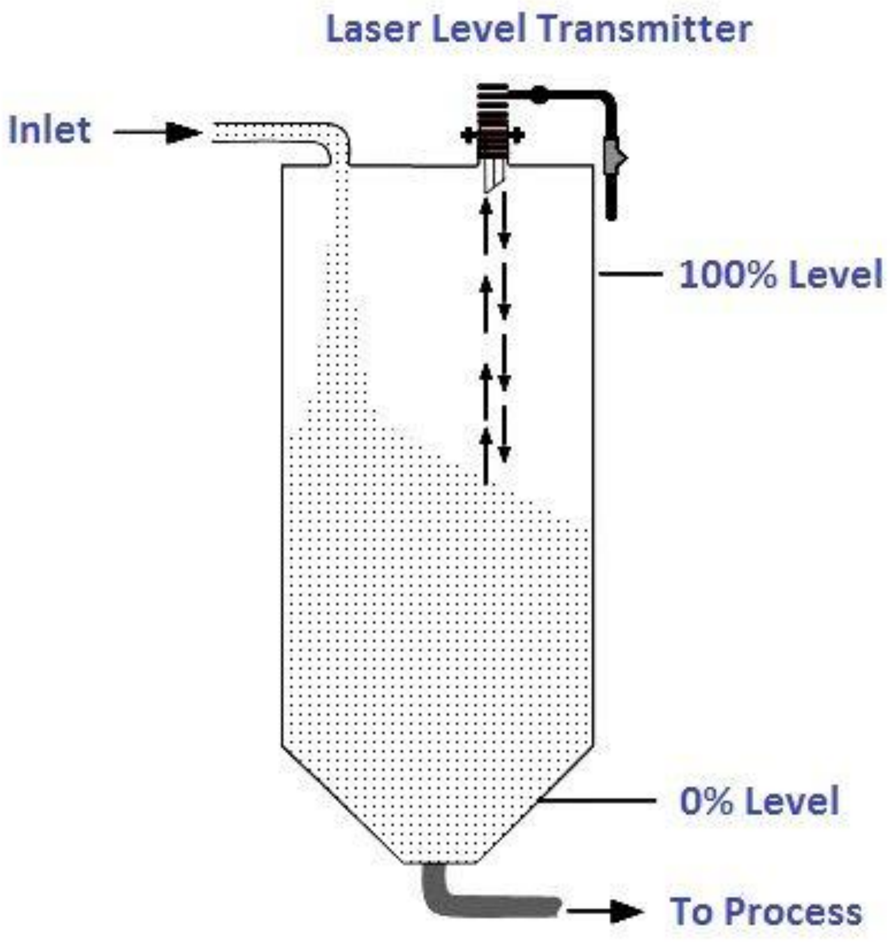
- The size of these transition zones depends on both the process substances and the probe type.



Laser level measurement

- Many liquids are not reflective enough for this to be a practical measurement technique.

- The presence of dust or thick vapors in the space between the laser and the liquid will disperse the light, weakening the light signal and making the level more difficult to detect.



Magnetostrictive level measurement

①Current pulse is applied to one end of magnetostrictive wire.

↓

②Circular magnetic is generated, encompassing the entire wire.

↓

③Magnetic field from the position magnet and the circular magnetic field interact.

↓

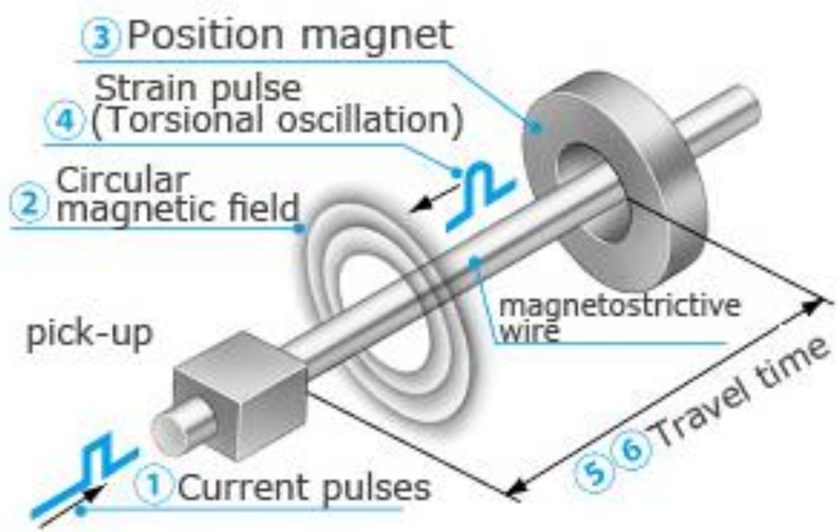
④The interaction produces a strain pulse.

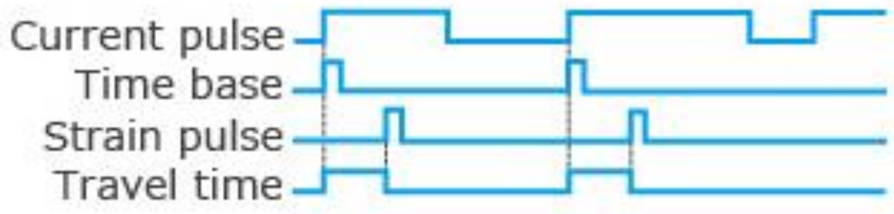
↓

⑤Travel time of the strain pulse to the pick-up is proportional to the distance the pulse travels.

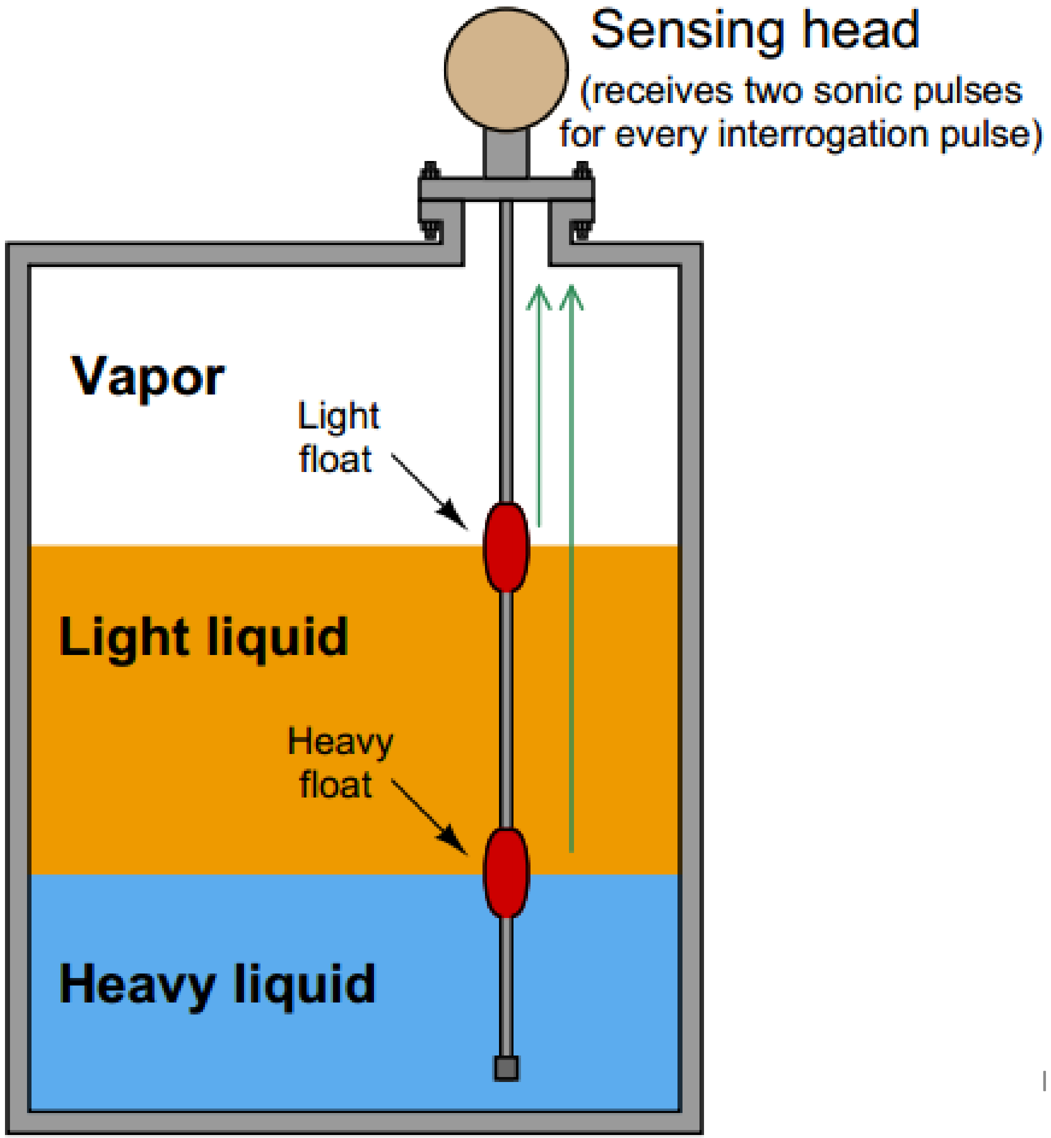
↓

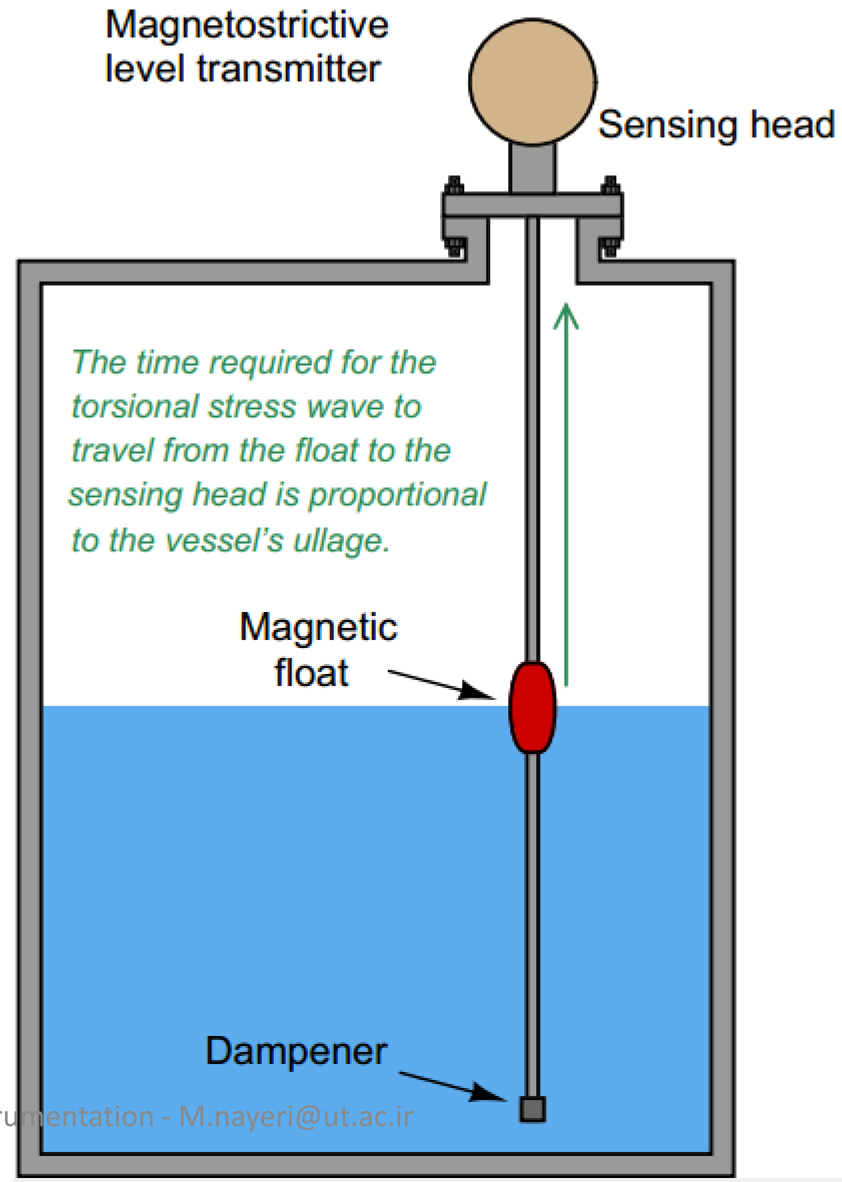
⑥ The time elapsed is measured multiple times. Remarkably accurate measurement is ensured.



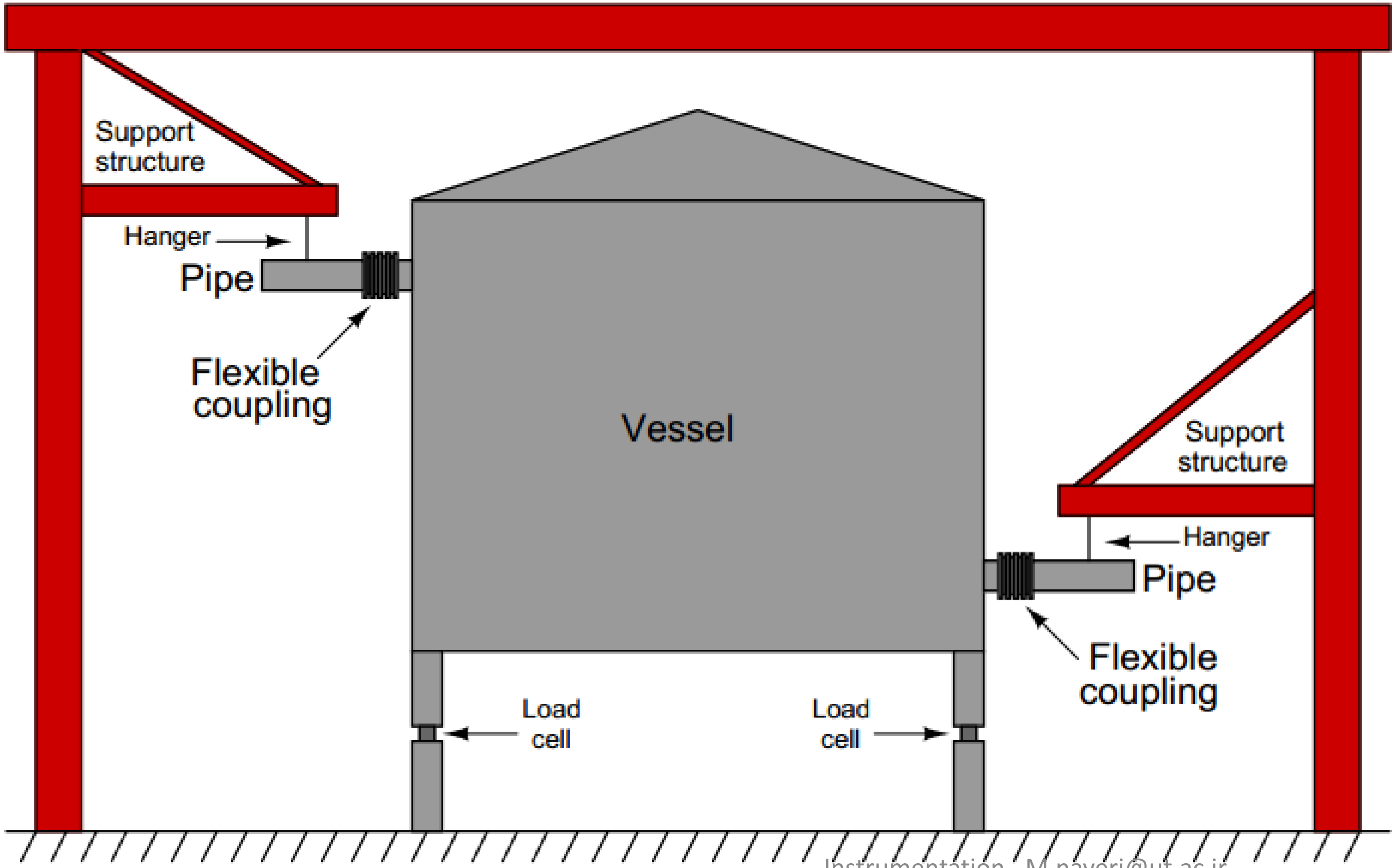


Magnetostrictive level measurement



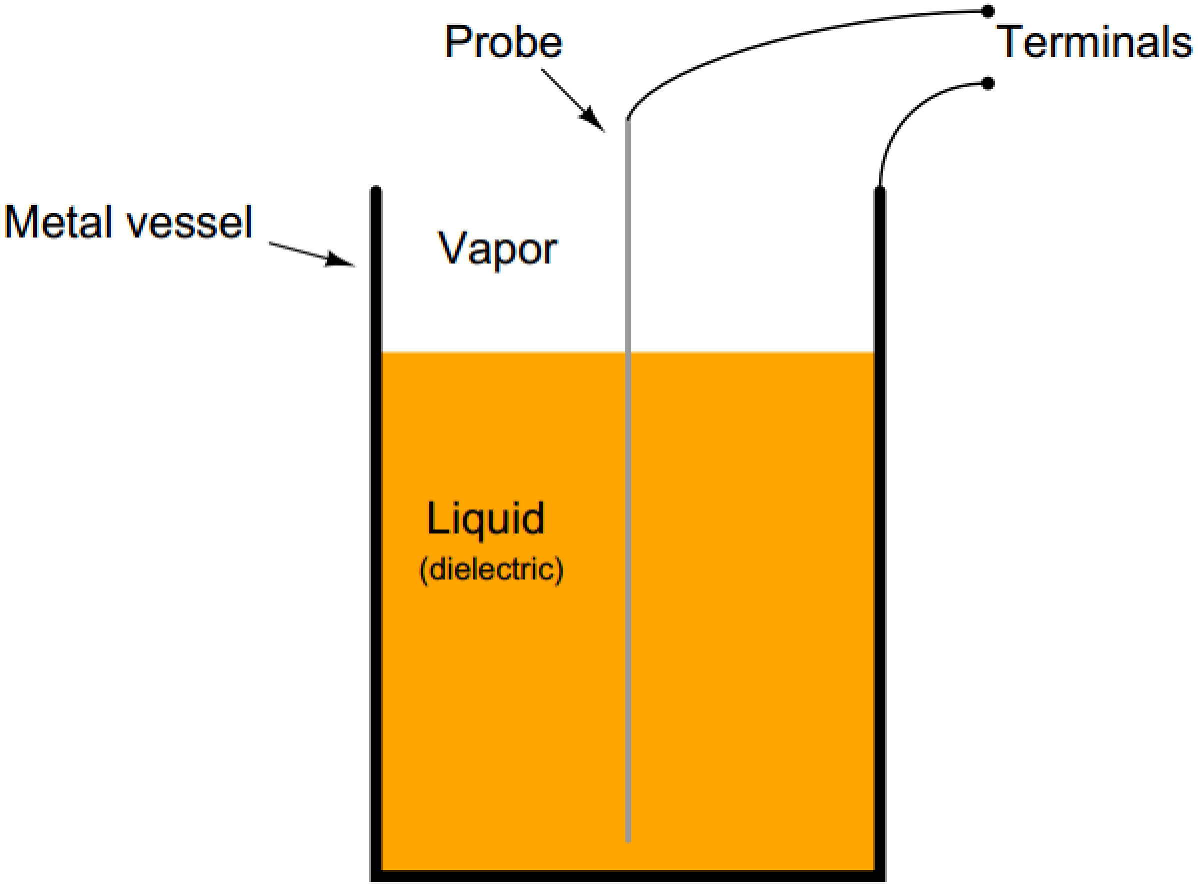


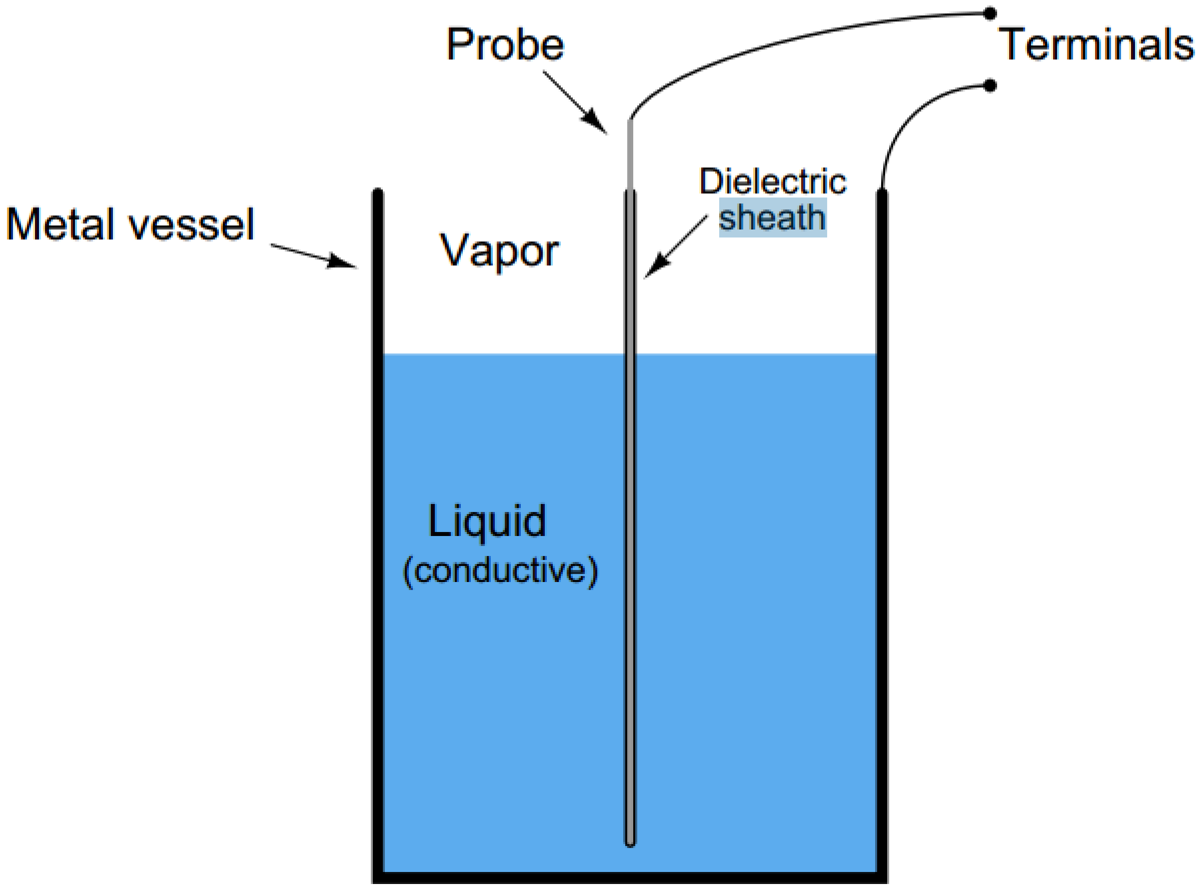
Weight



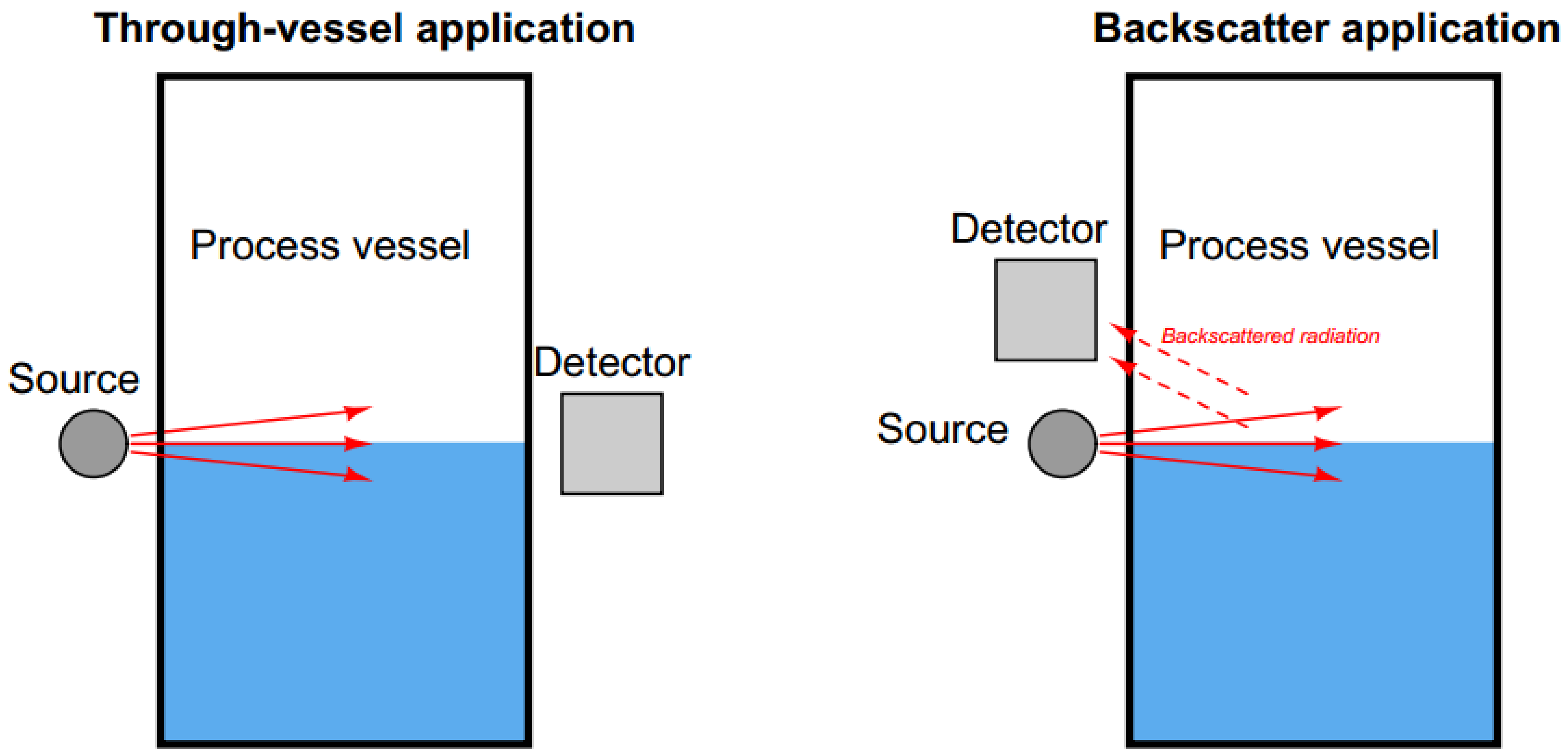
Support structure
Hanger
Pipe
Flexible coupling
Vessel
Support structure
Hanger
Pipe
Flexible coupling
Load cell
Load cell

Capacitive level measurement

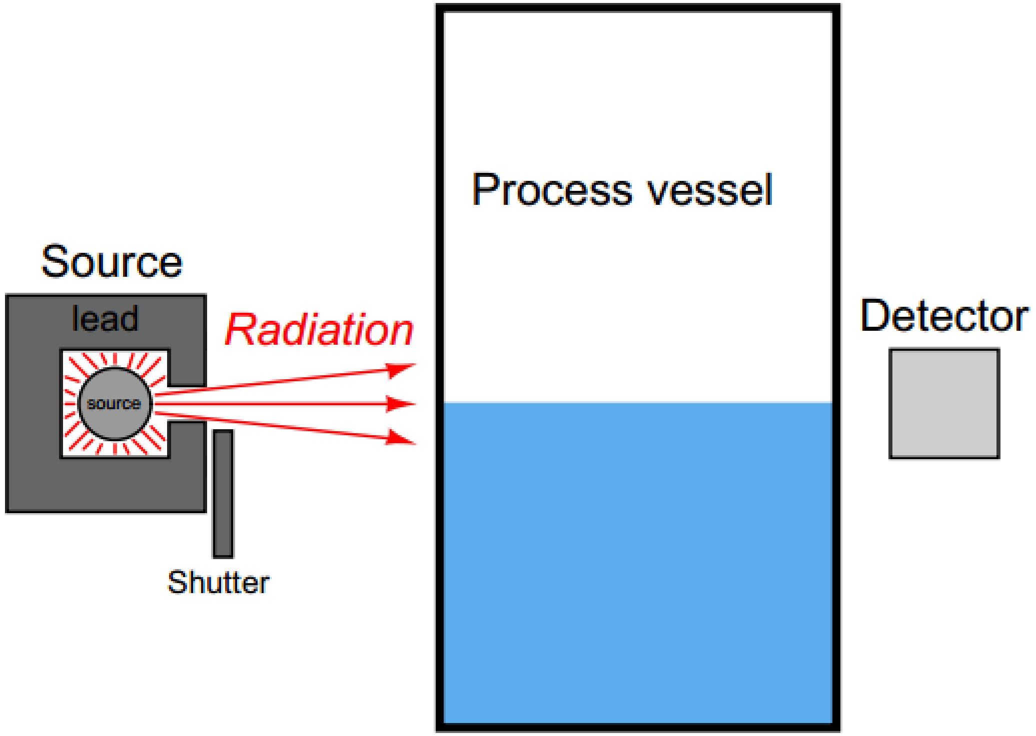




Radiation level measurement



Radiation level measurement



Radiation level measurement