



Enhanced Density

Overview

By Azriel Kutasov

KAMA Ltd

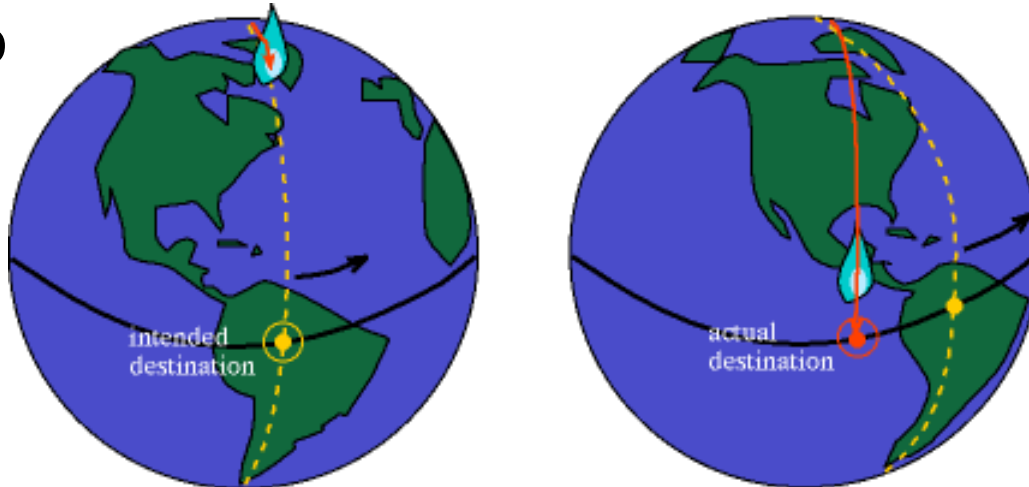


Principle of Operation



Theory of Operation

- | The Coriolis effect is an inertia force.
- | In 1835, Gustave-Gaspard de Coriolis showed that this inertia force must be taken into consideration if the simple Newton's Law of Motion of bodies are to be used in a rotating reference frame.



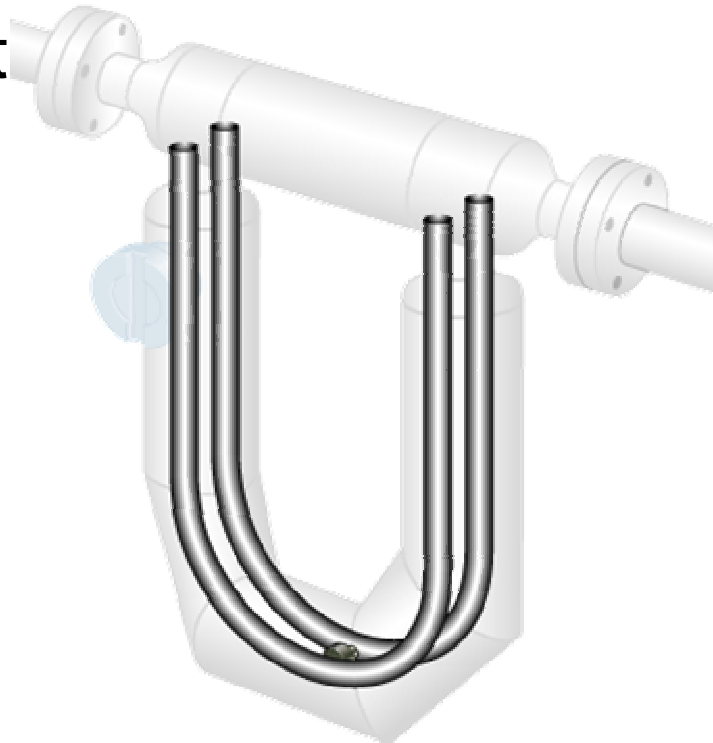
Coriolis Effect: The original path is deflected westward by the rotation of the planet



Gaspard de Coriolis

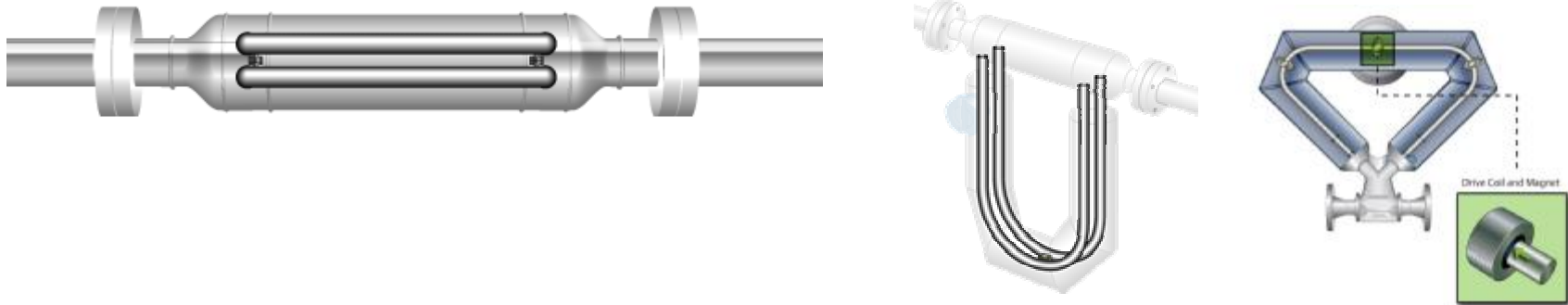
Theory of Operation – Mass Flow

- | In a Coriolis meter, the inertial force is provided by vibrating the flow tubes. The tube twist or angle of deflection from the vibration plane is measured and converted into a mass flow measurement



Theory of Operations – Mass Flow

- Process fluid enters the sensor and flow is split with half the flow through each tube. The sensor flow tubes are vibrated in opposition to each other by energizing a drive coil. Tubes are oscillated at their natural frequency.



- Magnet and coil assemblies, called pick-offs, are mounted on the flow tubes. As each coil moves through the uniform magnetic field of the adjacent magnet it creates a voltage in the form of a sine wave.

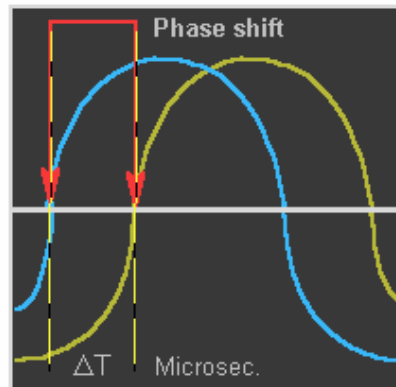
Theory of Operations – Mass Flow

- | During a no flow condition, there is no Coriolis effect and the sine waves are in phase with each other.
- | When fluid is moving through the sensor's tubes, Coriolis forces are induced causing the flow tubes to twist in opposition to each other. The time difference between the sine waves is measured and is called Delta-T which is directly proportional to the mass flow rate.



Theory of Operations – Mass Flow

- | The Flow Calibration Factor consists of 10 characters, including two decimal points.
 - The first five digits are the flow calibration factor. This calibration factor, multiplied by a given Delta-T, yields mass flow rate in grams/sec.
 - The last three digits are a temperature coefficient for the sensor tube material. This coefficient compensates for the effect of temperature on tube rigidity (% change in rigidity per 100°C).



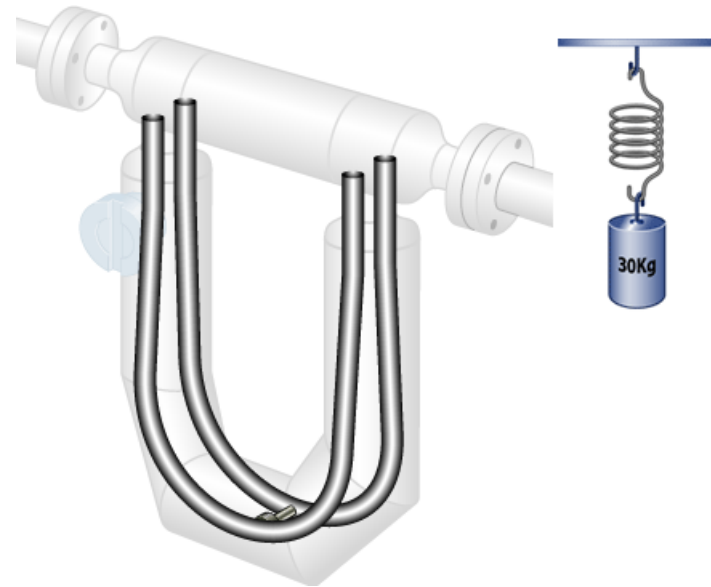
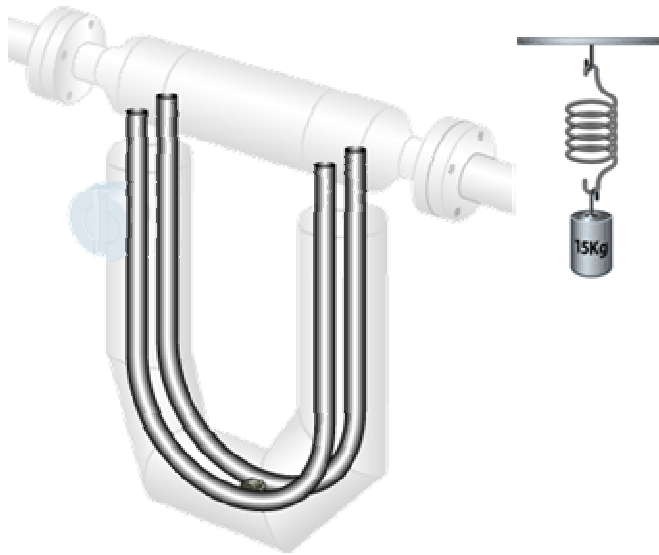
Applies to liquid and gas, and is linear throughout the entire range of the meter

4.2745 4.74
Calibration factor | Temperature Coefficient

- | Three wire platinum RTD measures tube temperature on inlet side of sensor
 - Accurate to +/- 1,0°C
 - Available as additional process variable

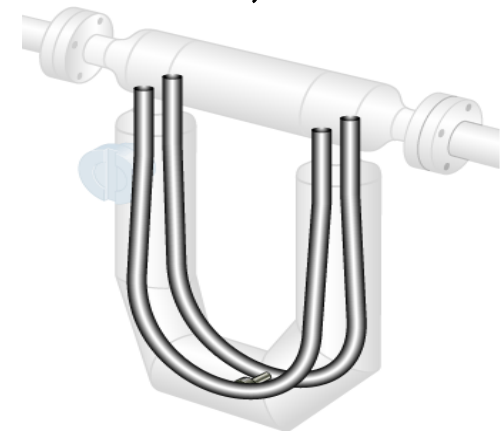
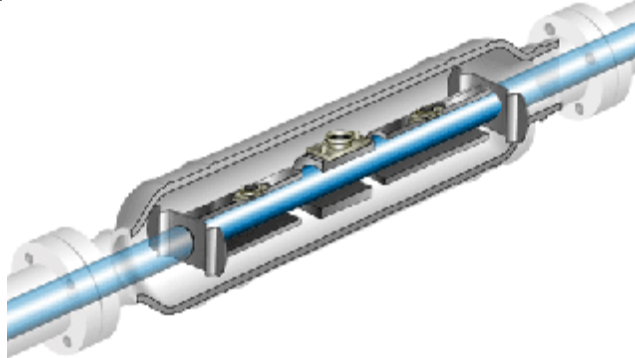
Theory of Operation - Density

- | Density measurement is based on the natural frequency of the system including the flow tubes and the process fluid.
 - As the mass *increases*, the natural frequency of the system *decreases*.
 - As the mass *decreases*, the natural frequency of the system *increases*.

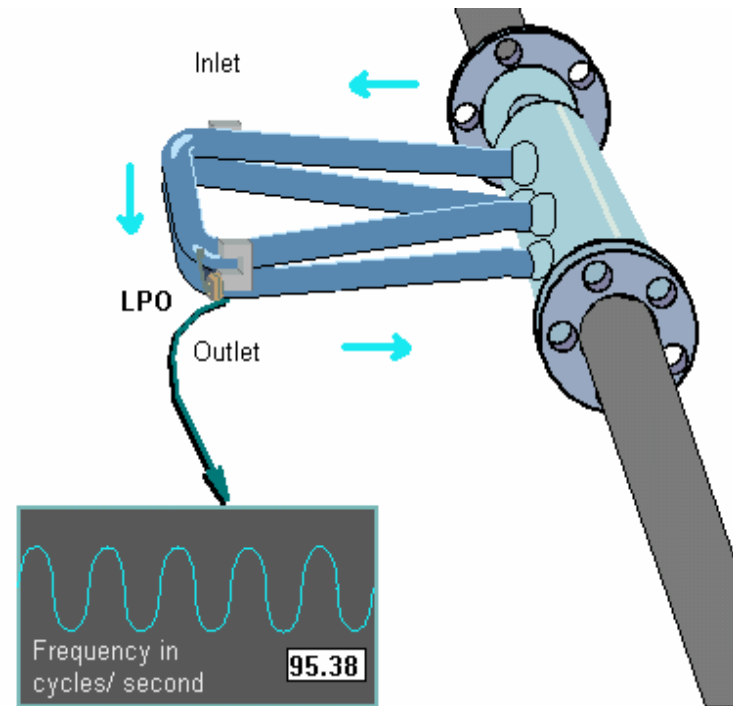
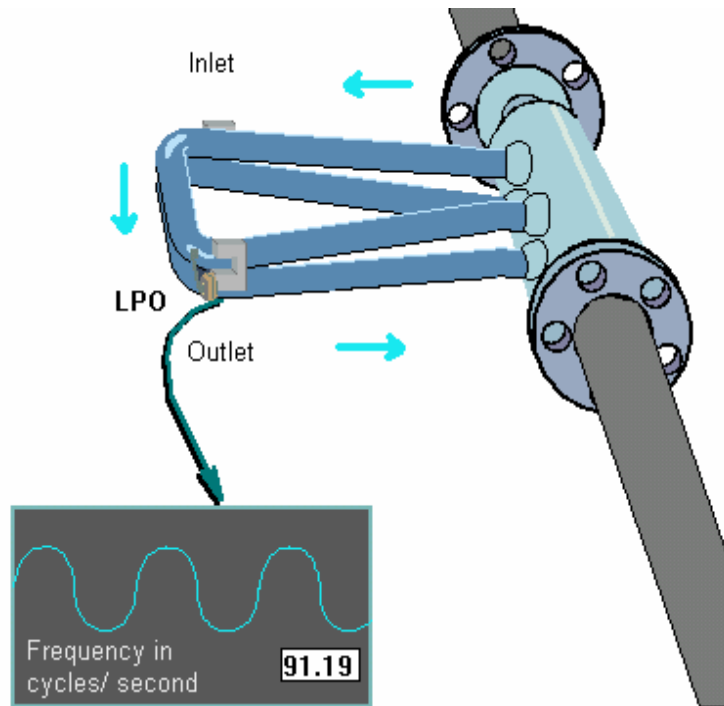


Theory of Operation - Density

- ▮ The density of the process fluid can be derived from the frequency of oscillation of the sensor. This frequency signal is taken from the left pickoff (LPO) coil.
- ▮ The volume of the fluid contained in the flow tubes remains constant, so the only way mass can change is if density changes. Because of this relationship between mass and density, the natural frequency of the flow tubes indicates not only the mass of the fluid contained, but also the density.
- ▮ The more volume of fluid contained in the sensor, the more the mass changes with density.

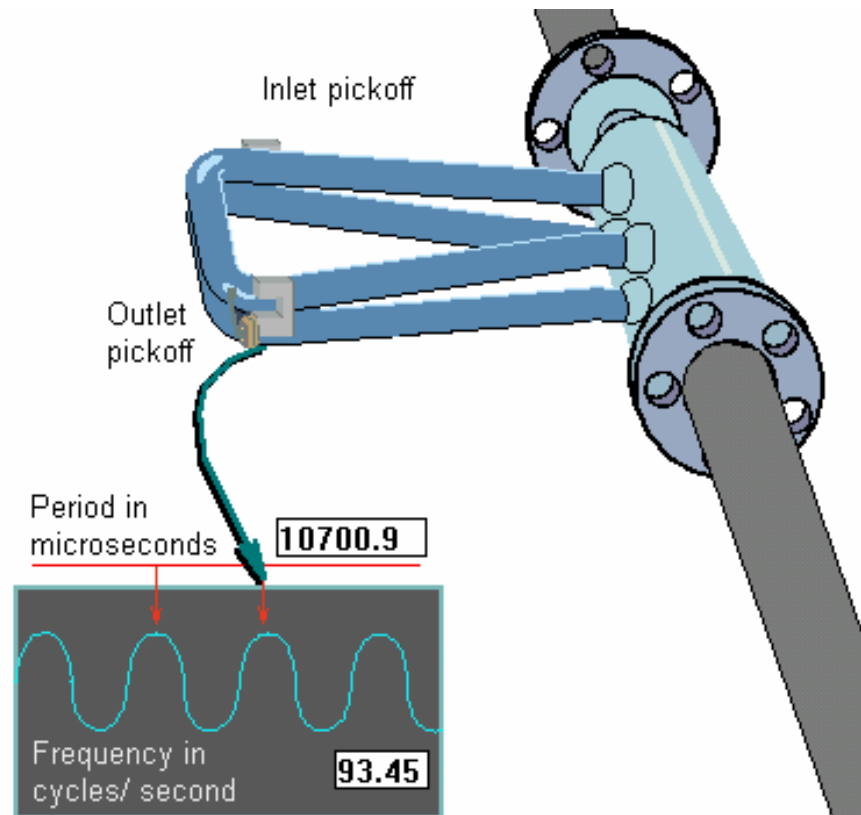


Density Operating Principal



Density Operating Principal

Frequency is measured in cycles per second. Since it is easier to time the cycles than to count them, the Micro Motion transmitter computes density of a process fluid by using tube period, the number of microseconds per cycle. Tube period is inversely related to frequency. Density is directly related to tube period

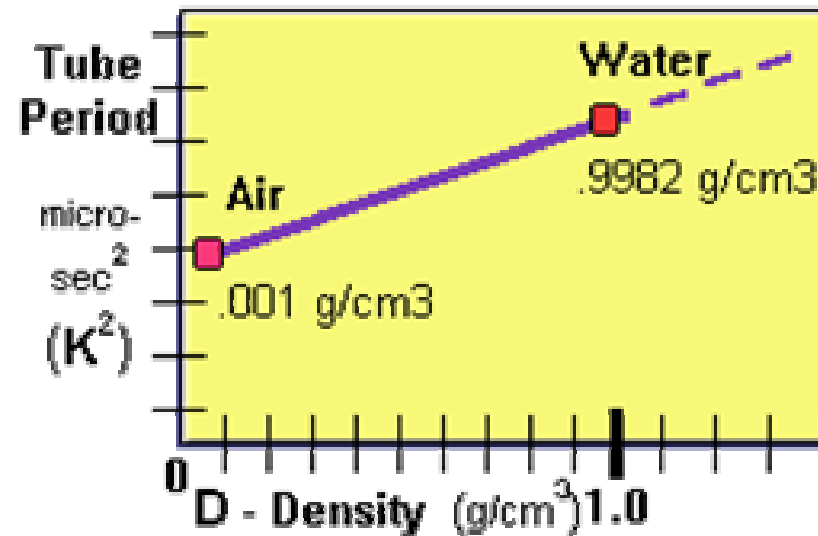


Density Operating Principal

Higher density calibration
fluid (water)

$K_2 = 10966$ microsec.

$D_2 = 0.9982$ g/cm³



Lower density calibration
fluid (air)

$K_1 = 10484$ microsec.

$D_1 = 0.0010$ g/cm³

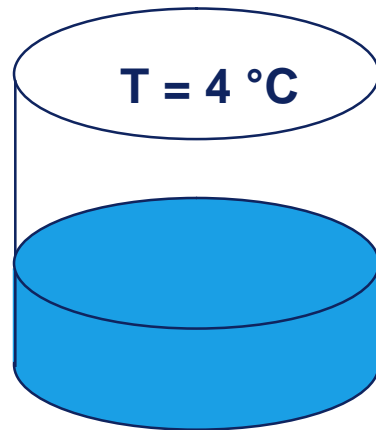
Definitions

Definitions.....Density

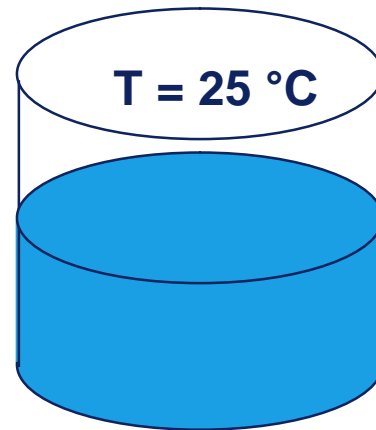
- n Mass per unit volume.
- n Decreases with increasing temperature for most substances.

Definitions.....Density

- n Mass per unit volume
- n Decreases with increasing temperature for most substances.



100 kg
100.0 liter
 $\rho_{4\text{ °C}} = 1000 \text{ kg/m}^3$



100 kg
100.3 liter
 $\rho_{25\text{ °C}} = 997 \text{ kg/m}^3$

Definitions.....Density

n Common Engineering units include:

- kg/m^3
- g/cm^3
- lb (mass)/ft^3
- lb (mass)/gal

Factors which effect density

- a) Temperature
- b) Pressure
- c) Composition
- d) All of the above

What is the right answer?

Factors which effect density

- a) Temperature
- b) Pressure
- c) Composition
- d) All of the above

Other Density Dependent Variables

- | Degrees API: normally used to measure oil products

$$\text{Degrees API} = (141.5/\text{SGU} - 131.5)$$

- | Degrees Baumé

Light (for liquids lighter than water)

$$\text{Degrees Baume Lt.} = (140/\text{SGU} - 130)$$

Heavy (for liquids heavier than water)

$$\text{Degrees Baume hv.} = 145 - (145/\text{SGU})$$

- | % Sugar

Brix, HFCS, Plato, Balling

- | % solids, % mass, % Concentration

Definitions.....Concentration

| Percent by mass:

- Mass of target divided by total mass of mixture or solution, multiplied by 100
- This is the most useful type of concentration measurement

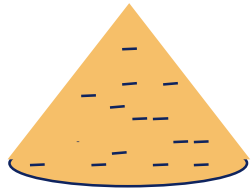
| Percent by volume:

- Volume of target divided by total volume of mixture or solution, multiplied by 100
- Rarely used, except in the distilled spirits industry (proof = 2 x %volume of alcohol)

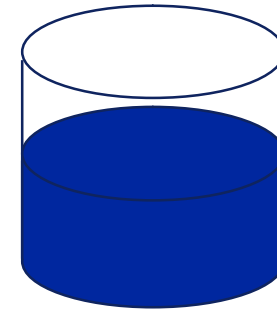
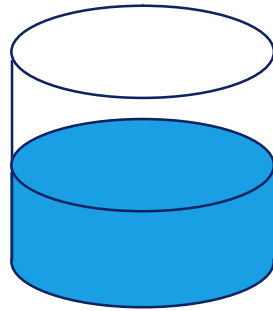
Definitions.....°Brix

- | °Brix is a measure of % concentration of a solution of sucrose and water
- | °Brix does not vary with temperature

Definitions..... °Brix



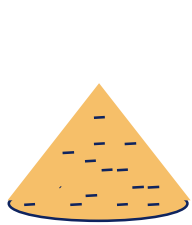
55 kg Sucrose + 45 kg Water =



**100 kg Sucrose
Solution**

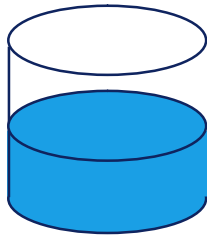
55 °Brix

Definitions.....°Brix



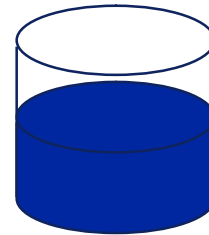
55 kg Sucrose

+



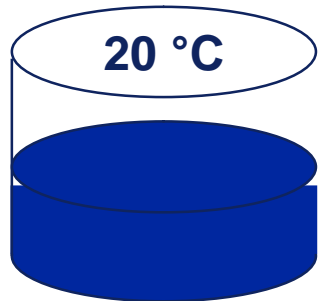
45 kg Water

=



100 kg Sucrose Solution

55 °Brix

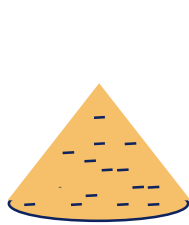


$r = 1.2575 \text{ g/cm}^3$

$\text{SG}^{20/20} = 1.2598$

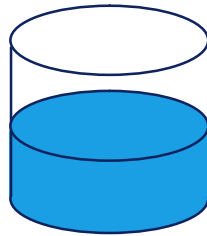
°Brix = 55°

Definitions..... °Brix



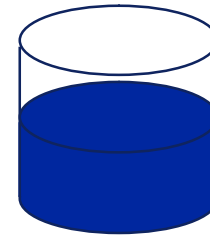
55 kg Sucrose

+



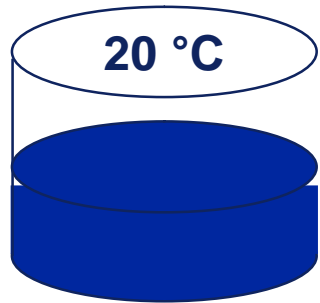
45 kg Water

=



100 kg Sucrose Solution

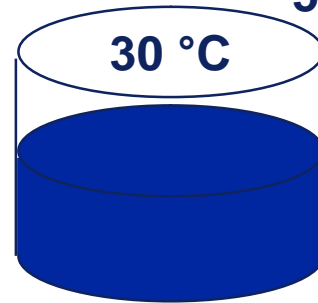
55 °Brix



$\rho = 1.2575 \text{ g/cm}^3$

$\text{SG}^{20/20} = 1.2598$

°Brix = 55°

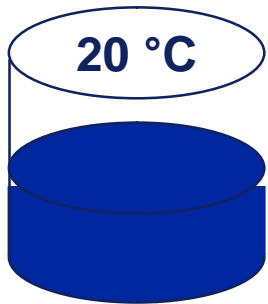


$\rho = 1.2530 \text{ g.cm}^3$

$\text{SG}^{20/20} = 1.2598$

°Brix = 55°

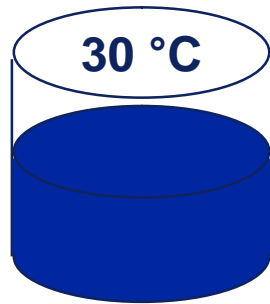
Definitions..... °Brix



$$\rho = 1.2575 \text{ g/cm}^3$$

$$\text{SG}^{20/20} = 1.2598$$

$$\text{°Brix} = 55^\circ$$



$$\rho = 1.2530 \text{ g/cm}^3$$

$$\text{SG}^{20/20} = 1.2598$$

$$\text{°Brix} = 55^\circ$$

When a measurement of density is used to determine the value of °Brix, temperature compensation is very important, since the density changes with temperature but the value of °Brix does not.

Theory of Operation

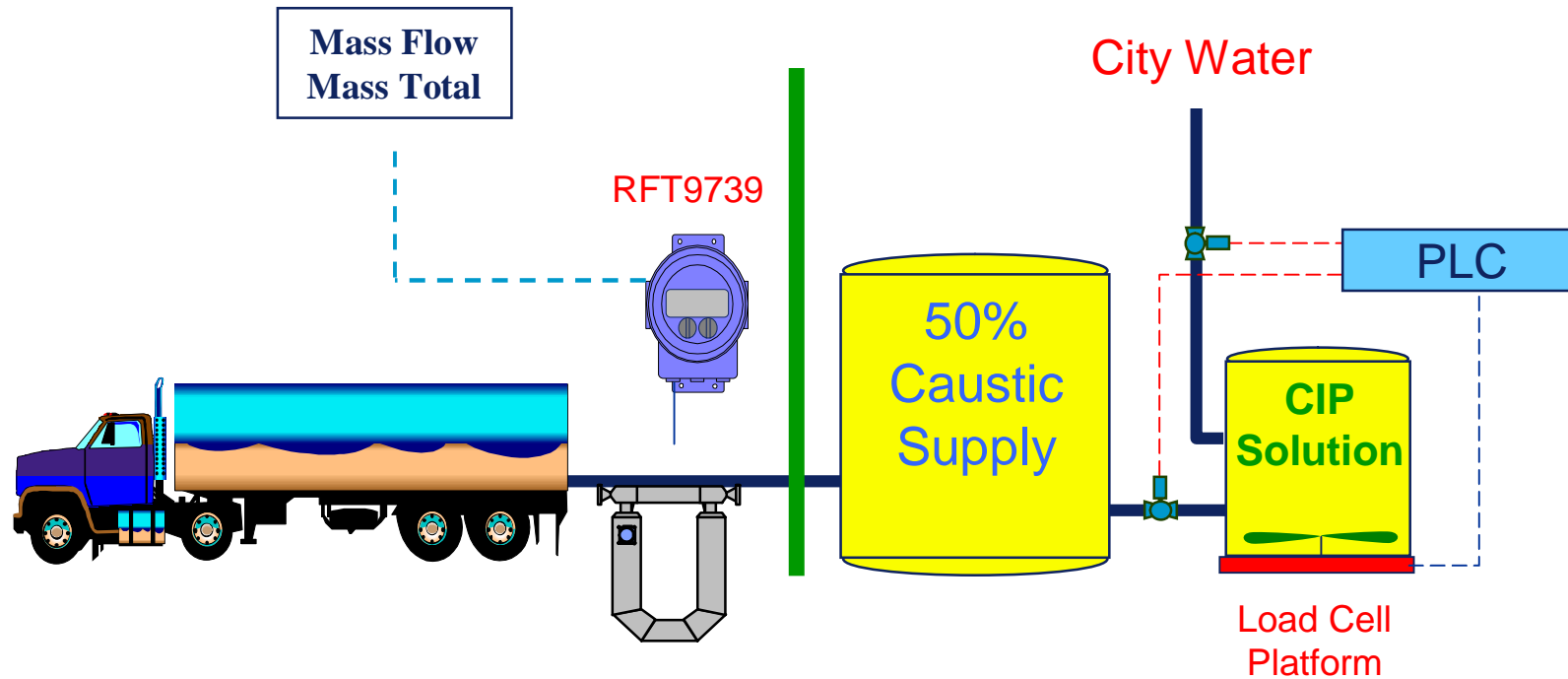


Case Study

Caustic Concentration



Caustic CIP Makeup -The Story Begins....



CIP = Clean In Place

Concentration

What do we mean when we say that the caustic is 50% by concentration?



Concentration - Definition

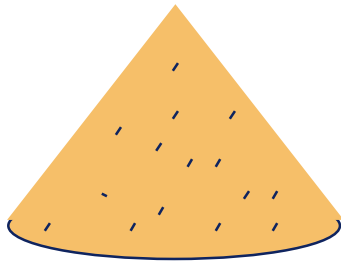
- | The ratio of the quantity of one component of a mixture to the total quantity of the mixture, expressed as a percentage.

Percent Concentration by Mass

- | Mass of caustic divided by total mass of caustic & water, multiplied by 100 (to change to a percent)
- | This is the most useful, and common type of concentration measurement

$$\frac{\text{Mass of Caustic}}{\text{Mass of Total Caustic/Water}} \times 100 = \% \text{ by Mass}$$

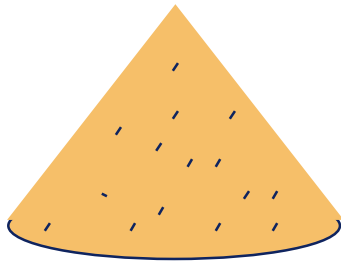
Example 50% Caustic



100 lb

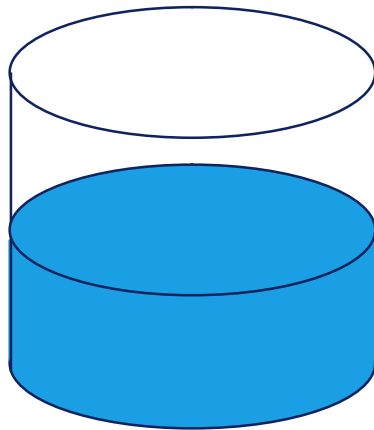
NaOH (100%)

Example 50% Caustic



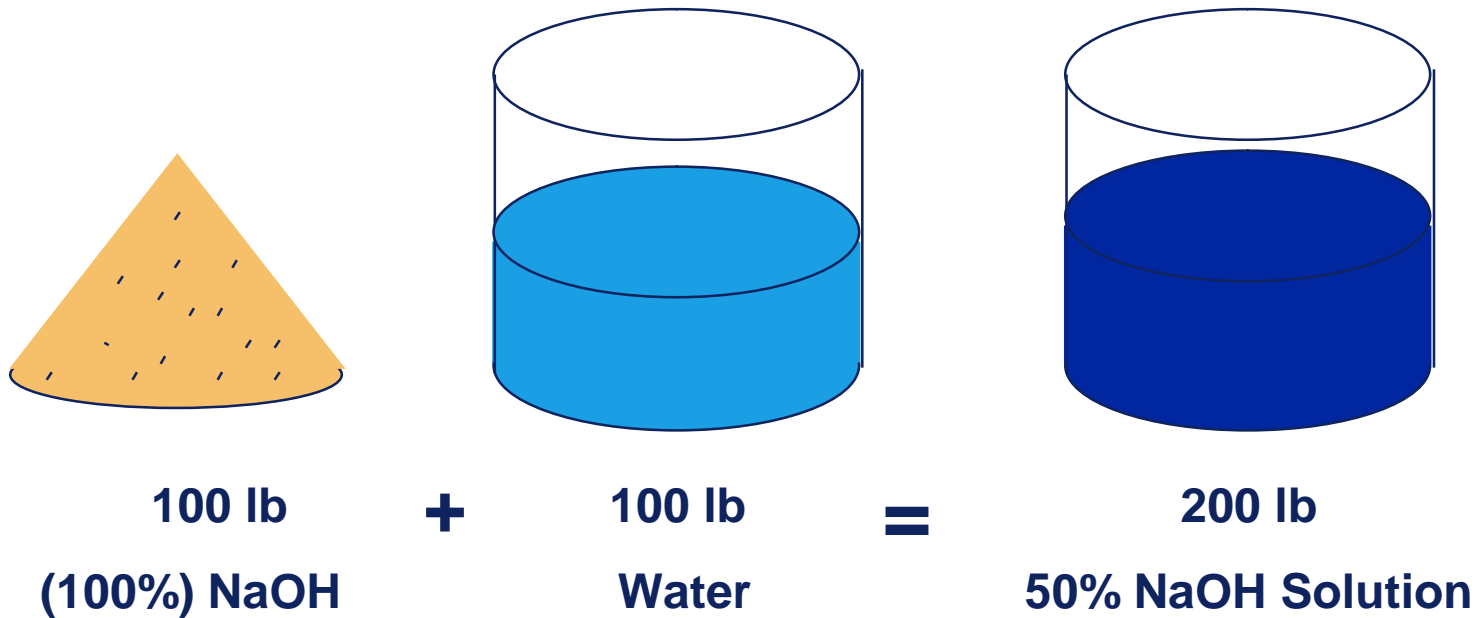
100 lb
NaOH (100%)

+



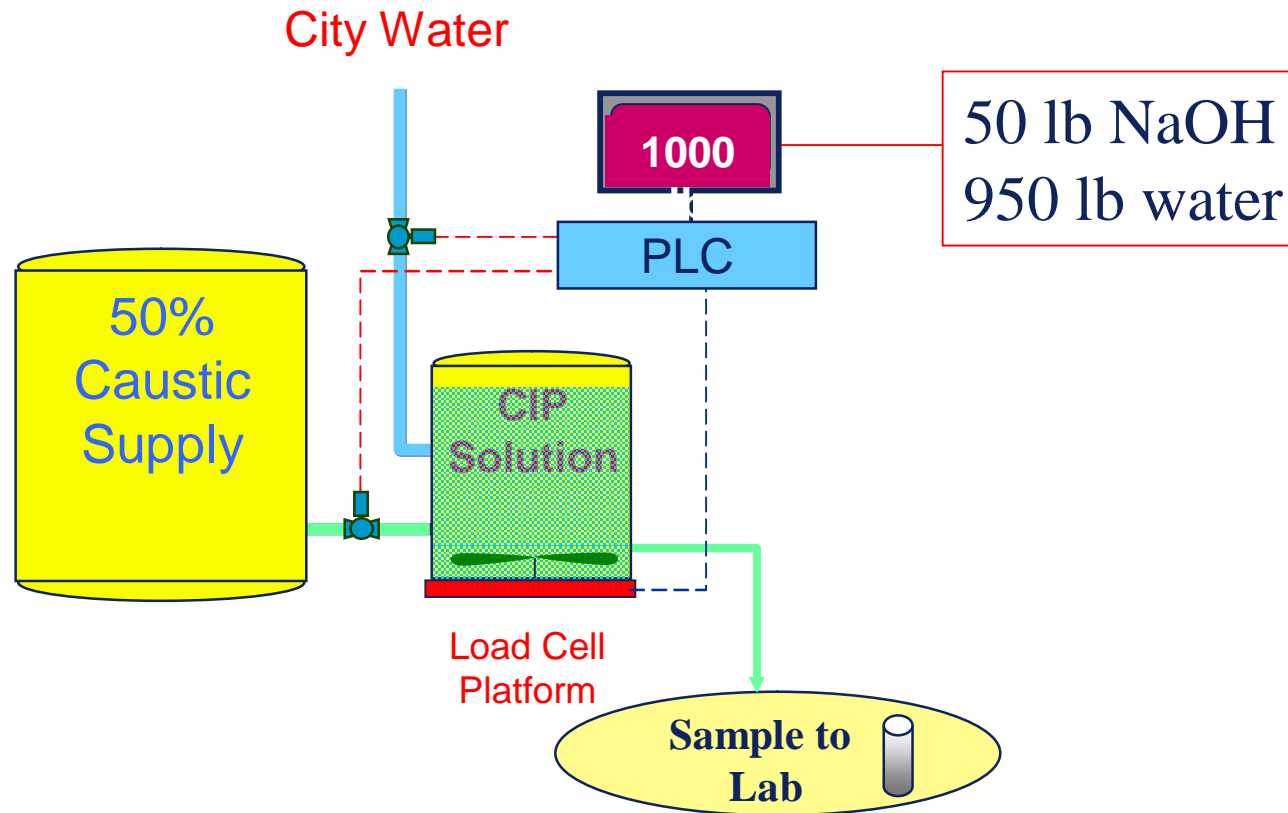
100 lb
Water

Example 50% Caustic

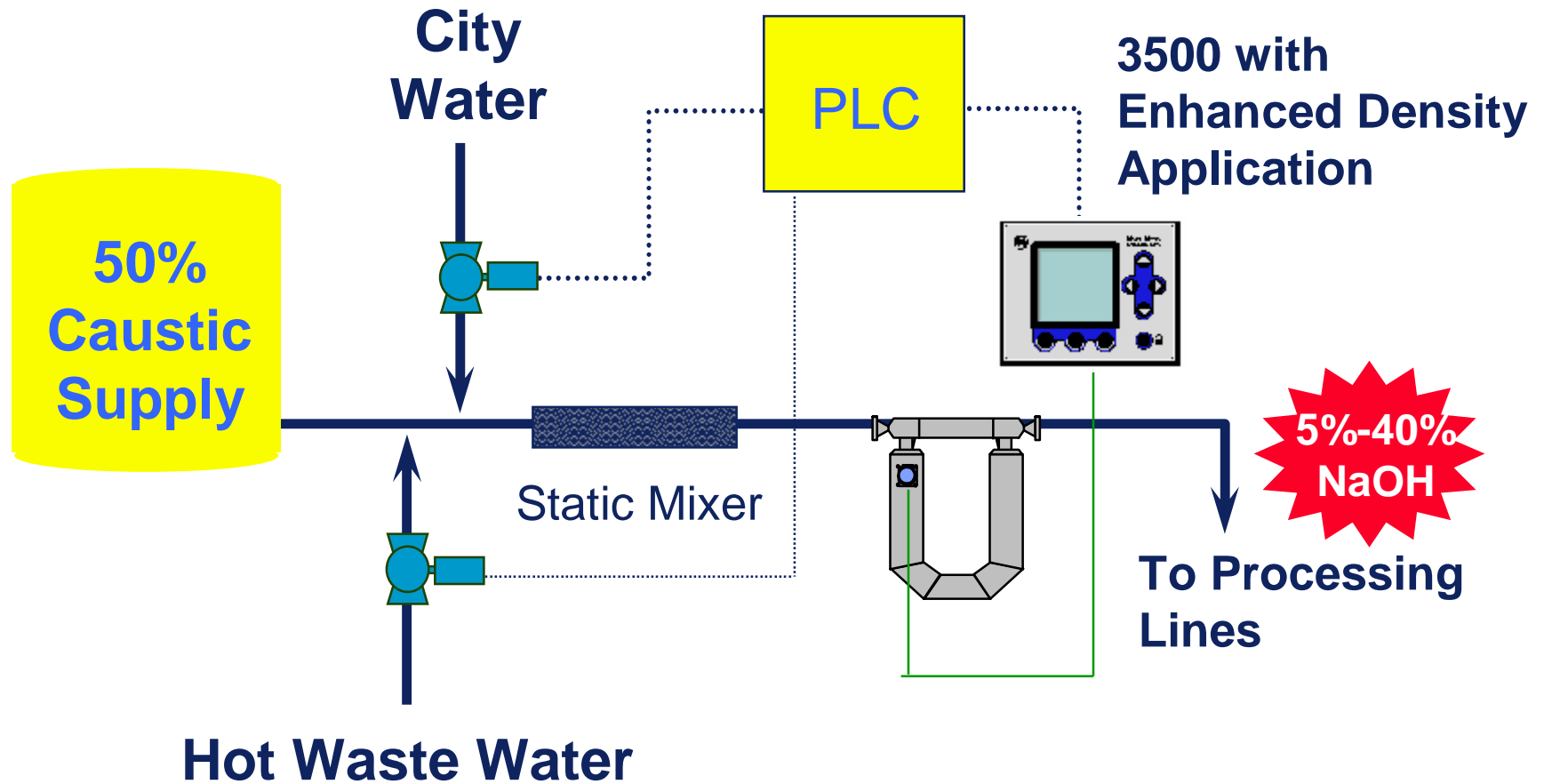


$$\frac{100 \text{ lbs. Caustic}}{200 \text{ lbs. Solution}} = 50\% \text{ NaOH Sol'n}$$

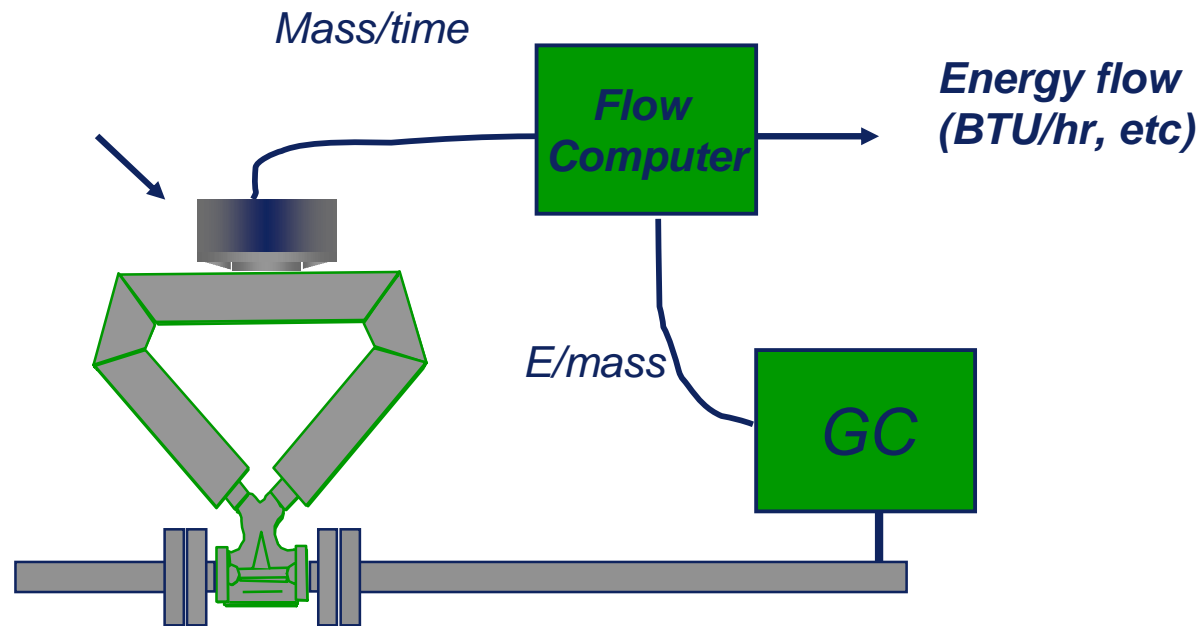
Current Method: CIP Makeup – 5% Caustic Cleaning Solution



The MMI Solution



Coriolis Energy Meter



Key advantage is that mass measurement is more accurate

Coriolis Energy Meter

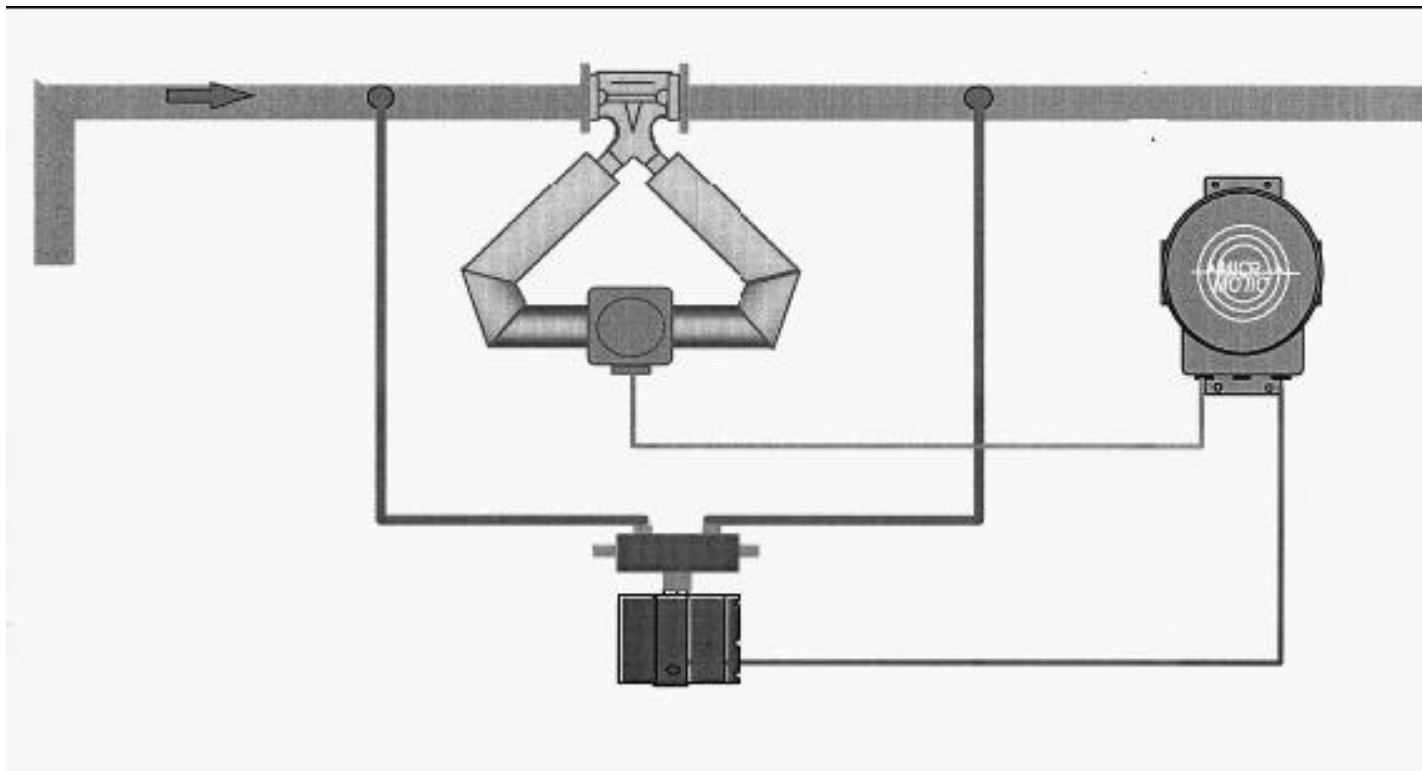
		<i>BTU / lb</i>	<i>BTU / scf</i>	<i>kJ/kg</i>	<i>kJ/Nm³</i>
Inerts	N2 & CO2	0	0	0	0
Methane	CH4	23887	1012	55537	37681
Ethane	C2H6	22323	1772	51902	66017
Propane	C3H8	21669	2522	50379	93957
<i>I</i>-Butane	C4H10	21186	3251	49257	121095
<i>n</i>-Butane	C4H10	21313	3270	49553	121823
<i>I</i>-Pentane	C5H12	21064	4012	48974	149463
<i>n</i>-Petane	C5H12	21105	4020	49069	149755
(<i>n</i>)Hexane+	C6H14	20804	4733	48370	176308
Hydrogen	H2	51900	273	120668	10169

Please Note

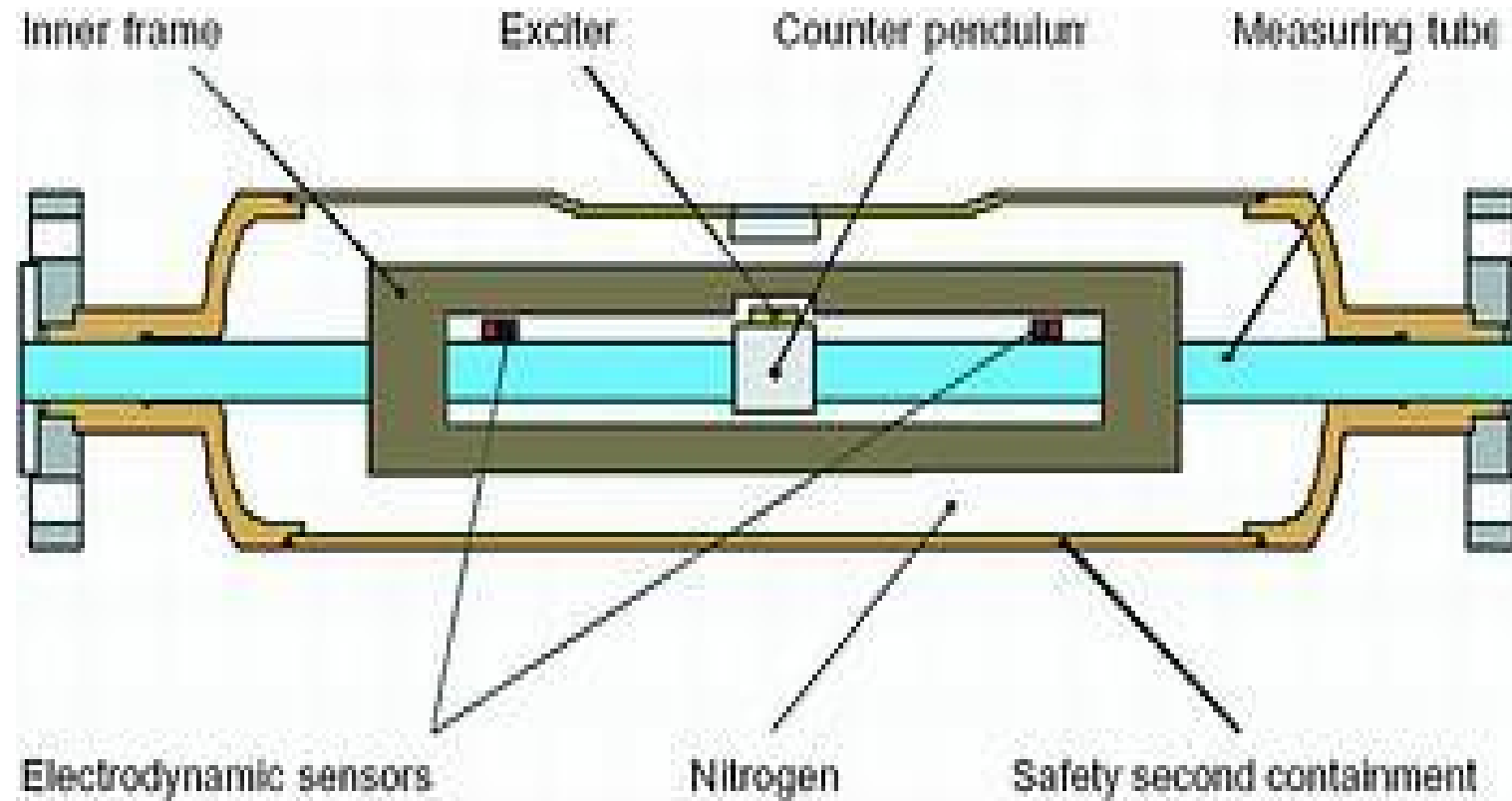
Heat per unit mass varies by +/- 4%
Heat per unit volume varies by +/- 54%

Taken from CRC Handbook, 57th edition
 Values are given at 25°C (77°F) CO₂ gas, H₂O liquid
 Represents "high heating value" in AGA terms

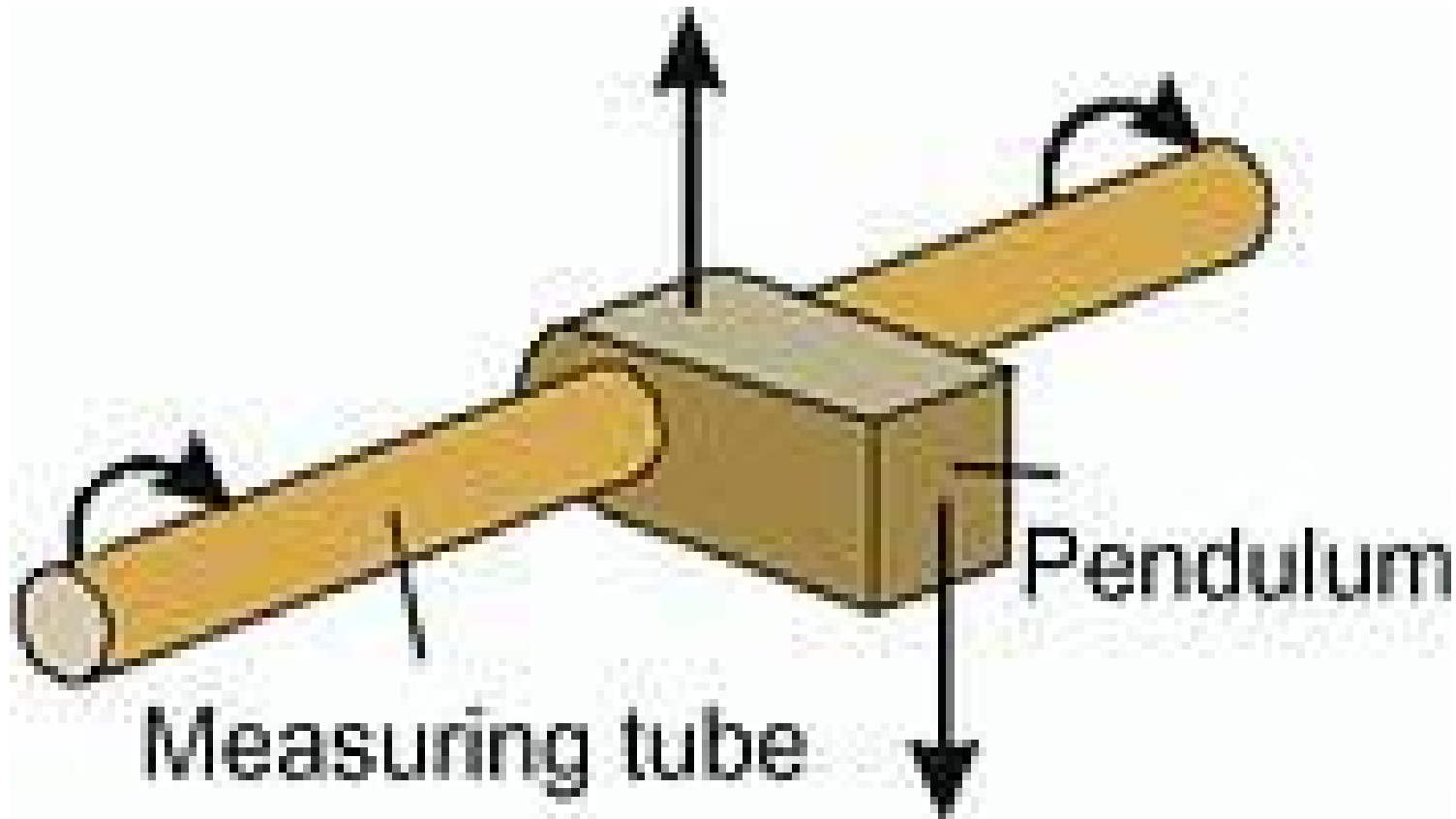
Viscosity



Viscosity



Viscosity



Viscosity

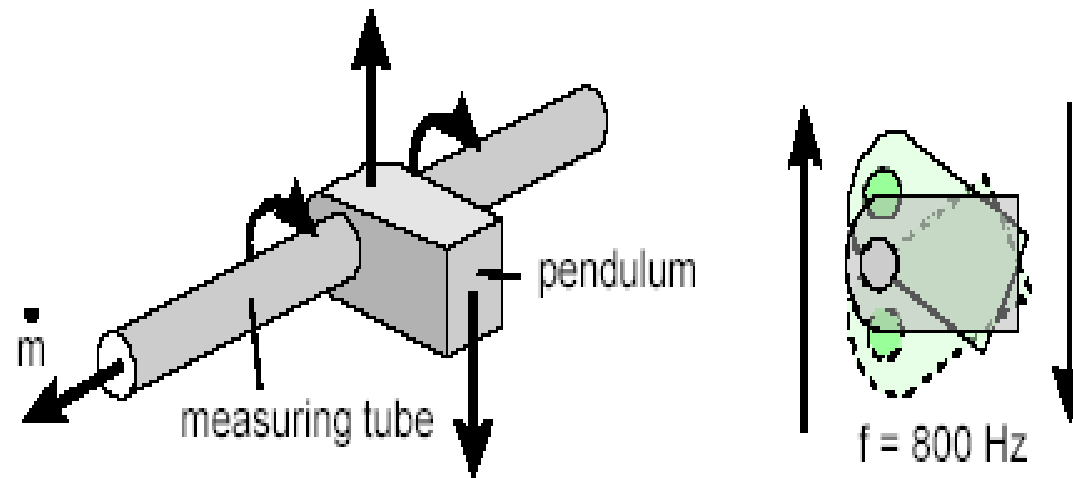
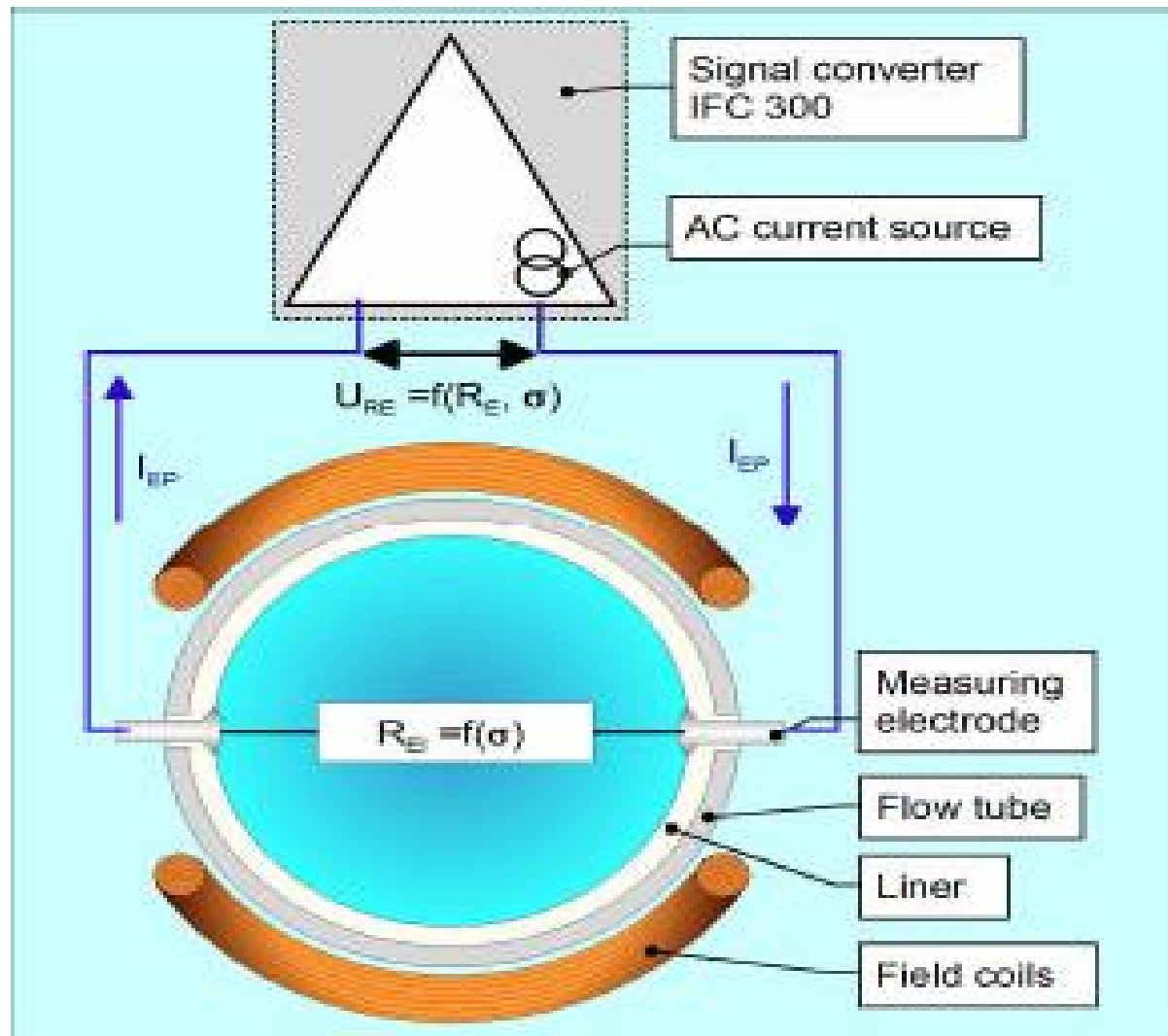


Figure 1 introducing torsional oscillation to balance the measuring tube (TMB™)

Mag Meter Conductivity





Thank You
KAMA Ltd

