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Kuwait Oil Company

الراعــي الرسمــي

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Multiphase & Wet Gas Solutions

Wet Gas Testing of Venturi, Coriolis & Ultrasonic Meter

Objective

- Traditionally, Venturi tubes are the most commonly used technology in the multiphase wet gas industry.
- With advancement of technology, Coriolis and Ultrasonic flowmeter that are traditionally seen as a single phase flowmeters, have a big potential to expand their use into the multiphase region.
- Test conducted at TUV NEL’s high-pressure wet gas facility
- Conclusion will be underpinned on:
  - Reliability of current venturi systems.
  - Potential use of Coriolis and Ultrasonic meters for Multiphase Wet Gas region.

Introduction to Wet Gas

Various parameters can be used to quantify the '**wetness**' of a wet gas flow:

- **Gas Volume Fraction** (*GVF*):
  - Volume fraction of gas compared to total fluids at line conditions.
  - Roughly for GVF>90% wet gas regime can exist.

$$GVF = \frac{Q_{vol,\,gas}}{Q_{vol,gas} + Q_{vol,liq}}$$

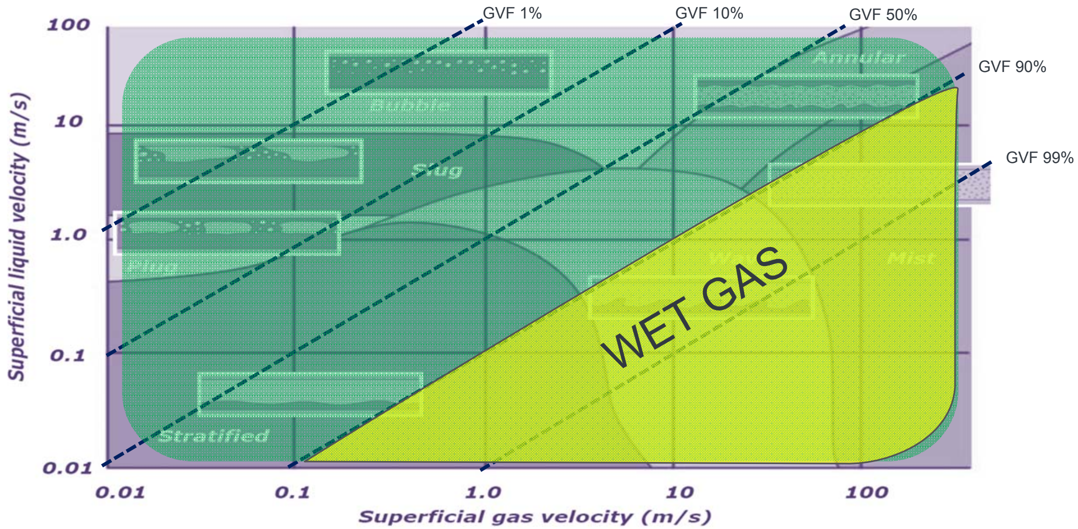
- **Lockhard-Martinelli** parameter (*LM* or *X*)
  - Ratio of the kinetic energy of the liquid compared to kinetic energy of the gas
    - Low X means gas dominated flow
    - High X means liquid affects the gas flow
  - Wet gas regime roughly for X<0.3

$$X = \frac{Q_{vol,\,liq}}{Q_{vol,gas}} \cdot \frac{\sqrt{\rho_{liq}}}{\sqrt{\rho_{gas}}}$$

- Gas densiometric **Froude number** (Fr_g)
  - Ratio of gas inertia to gravitation force
    - Low Froude number gives stratified flow (Fr_g<~1)
    - High Froude number gives mixed flow (Fr_g>~2)

$$Fr_g = \frac{v_{gas}}{\sqrt{gD}} \cdot \frac{\sqrt{\rho_{gas}}}{\sqrt{\rho_{liq} - \rho_{gas}}}$$

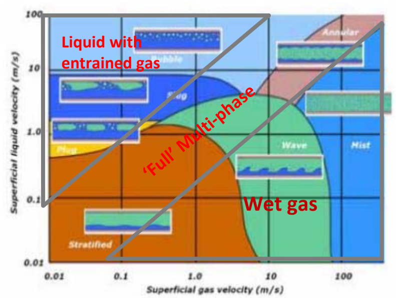
Introduction to Wet Gas



Introduction to Wet Gas

Problem statements in wet gas flows

- Single phase flowmeters might
  - stop working (e.g. acoustic crosstalk in ultrasonic meters)
  - lose accuracy (e.g. unsteady flow in turbine/PD flowmeters and density fluctuations in Coriolis flowmeters)
- Even if meter continue to measure they mostly cannot compensate for liquid fraction moving at a lower flow velocity than the gas fraction
- Wet gas comes in various, usually unstable, flow regimes, slugs of liquid can appear after a period of relatively dry gas
- Diagram shows different multiphase flow regimes for horizontal piping. Diagram is valid for one specific fluid, pressure and temperature only

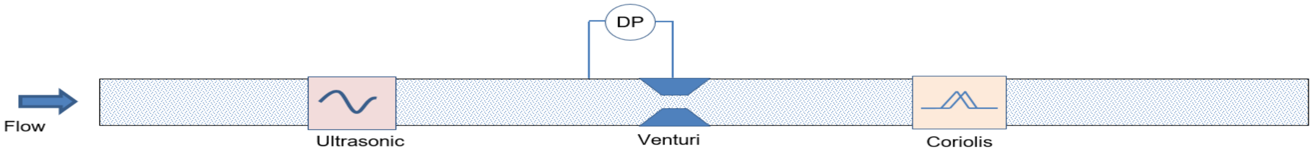


Wet Gas Test facility & Layout

Gas
Nitrogen
12.76 ~ 74.54 kg/m3

Oil
Exxsol D80
796.1 kg/m3

Water
H20
998.2 kg/m3

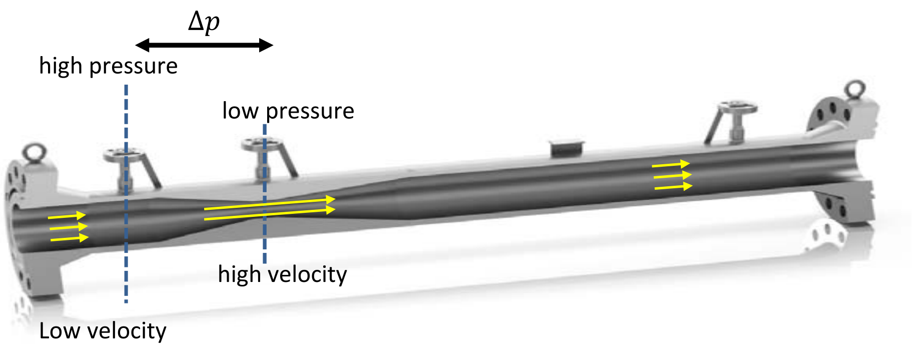


Measuring Principle - Venturi

Bernoulli principle:

- Low velocity → high pressure
- High velocity → low pressure
- **Pressure drop** between inlet and throat

- The **flow rate** is related to the differential pressure
- By measuring the differential pressure (∆p) between the inlet and the throat, the mass flowrate (Q) can be calculated



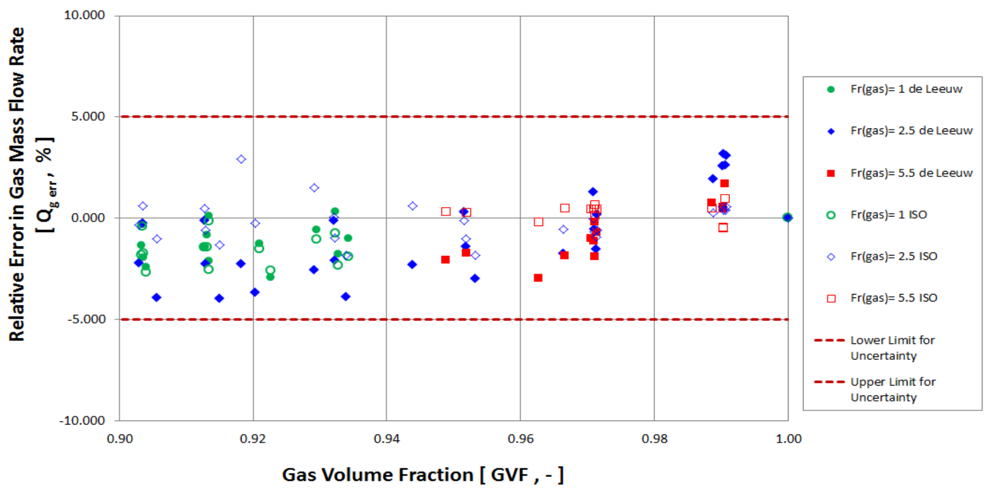
Measuring Principle - Venturi

- In case of wet gas, liquid is present in the gas
  - It takes extra energy to accelerate the liquid through the throat
  - For given gas flow rate, this results in an increased pressure drop
- When the wetness of the gas is not taken into account this results in an overreading of the gas flow rate.
- In case of wet gas, overreading correction, φ, needs to be applied
- The overreading correction, φ, depends on the wetness of the gas.
- Therefore the wetness of the gas has to be quantified.

$$Q \sim \sqrt{\Delta p} / \varphi$$

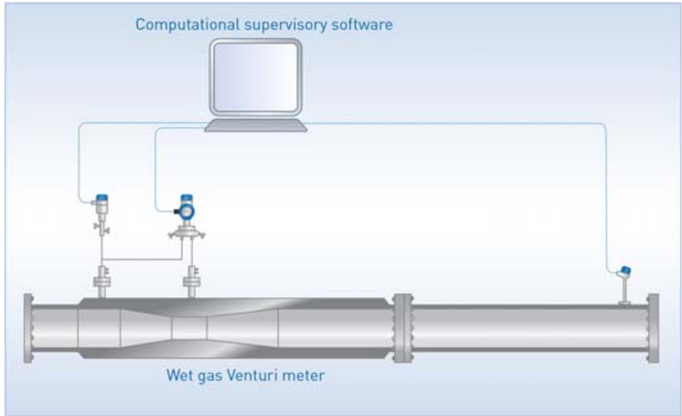
Measuring Principle - Venturi

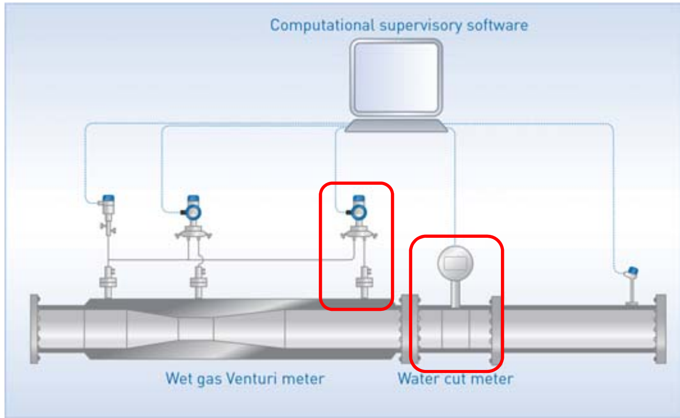
- Over-reading corrections implemented in KROHNE VFC:
  - ISO 11583
  - De Leeuw



Measuring Principle - Venturi

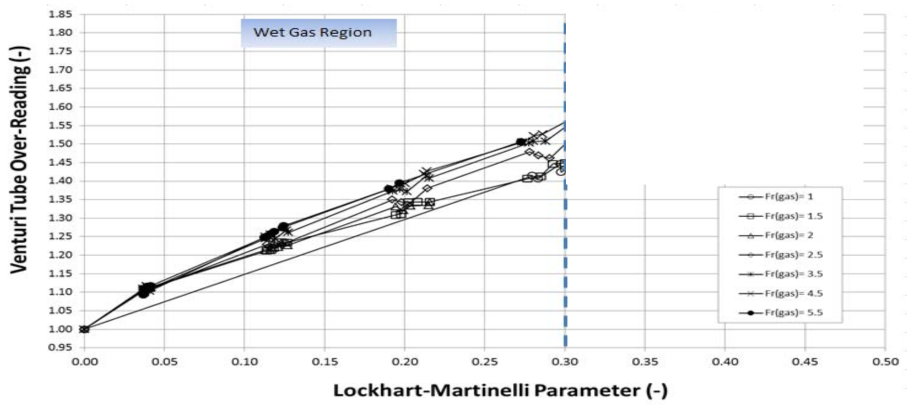
- Modular system can integrate complimentary technology
  - 3rd DP taping for PLR liquid calculation
  - Watercut meter for liquid fraction measurement

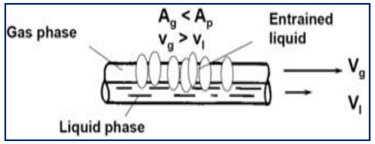




Wetness vs Over-reading

- To observe Venturi behavior throughout higher Fr (gas)/higher velocity and wetness





Measured and gathered data concur/in line with NEL published report, over reading affected by liquid content, pressure, gas velocity and beta ratio

Wetness vs Over-reading

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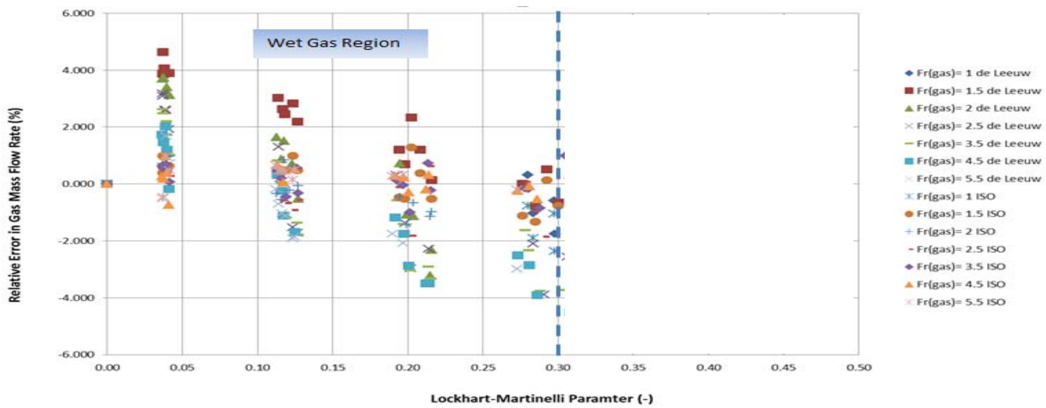

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Measuring Principle – Coriolis

Discovered by
Gaspar Gustav de Coriolis (1835)

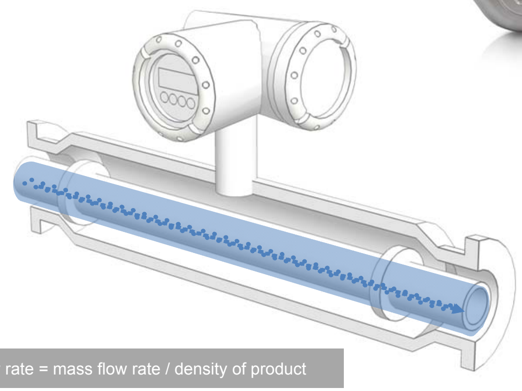
Coriolis effect
"Apparent deflection of a moving object in a rotating frame of reference."

The Coriolis mass flowmeter measures

- Mass flow
- Density

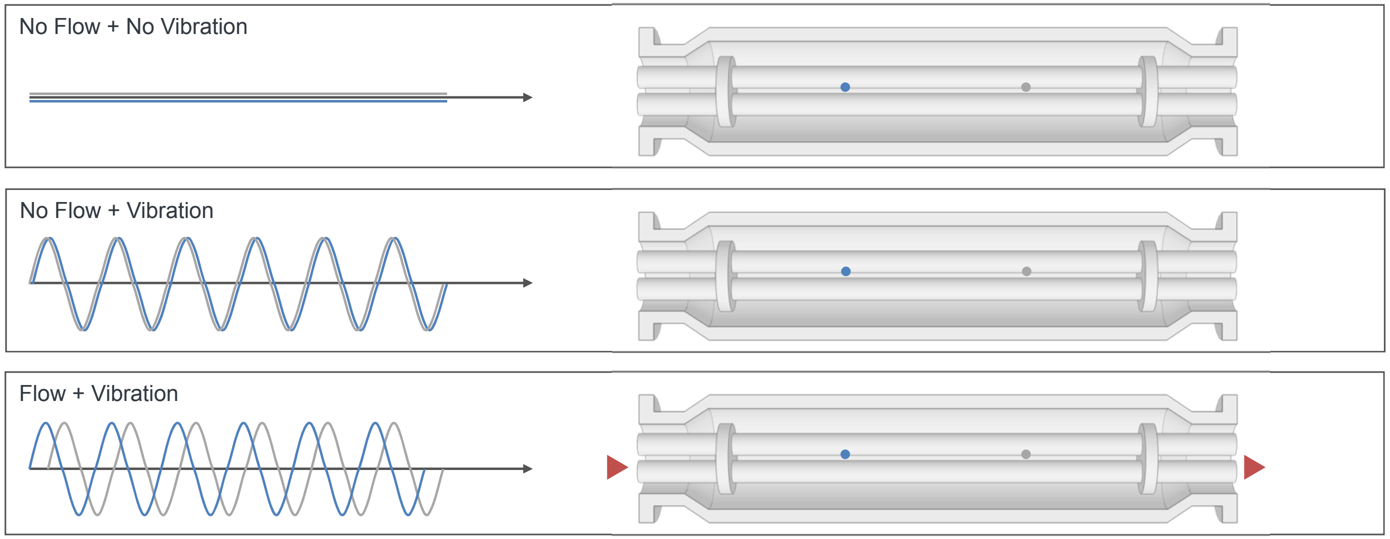
Provides calculation of

- Volume flow rate
- Total Volume



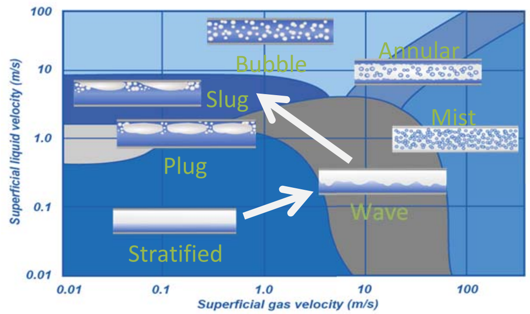
Volume flow rate = mass flow rate / density of product

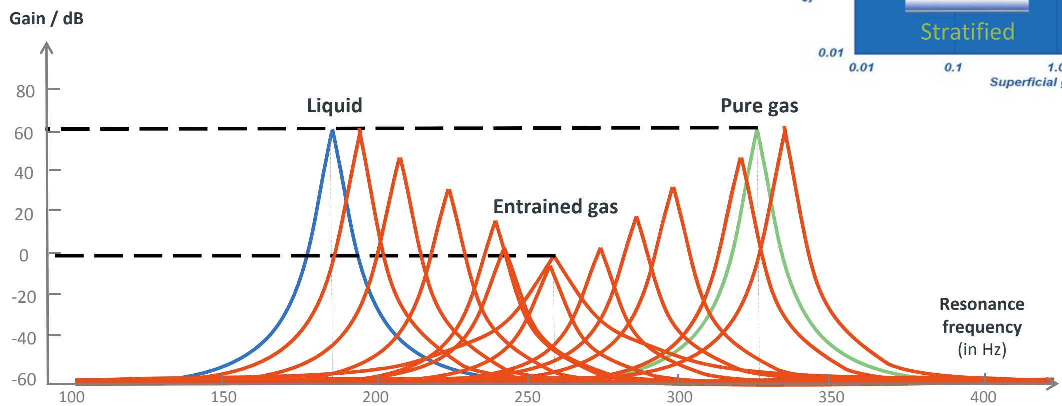
Measuring Principle – Coriolis



Measuring Principle – Coriolis

- Multiphase flow regimes have no sharp boundaries
- Can change smoothly from one regime to another
- KROHNE EGM the Coriolis is able to handle fluctuating multiphase/wetgas conditions and provide continuous reading

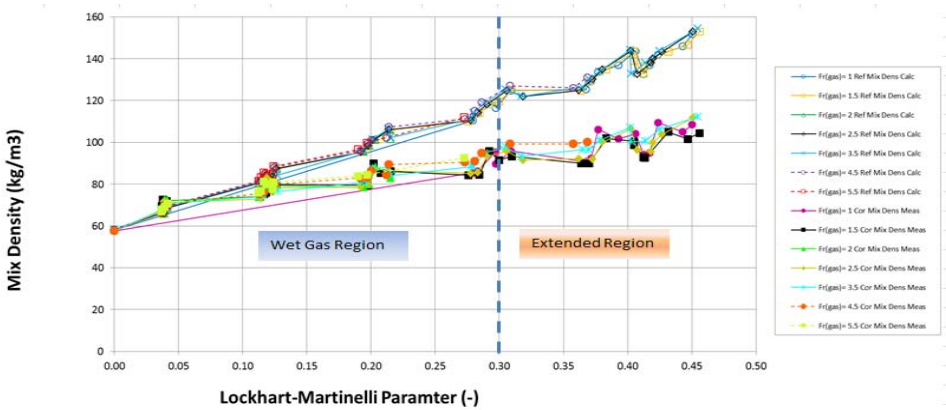


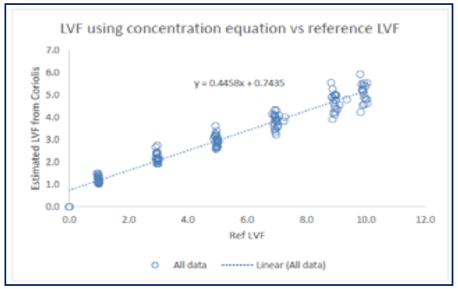


EGM™
Entrained Gas Management

Wetness vs Mixed Density

- To observe Coriolis behavior throughout higher Fr (gas)/higher velocity and wetness

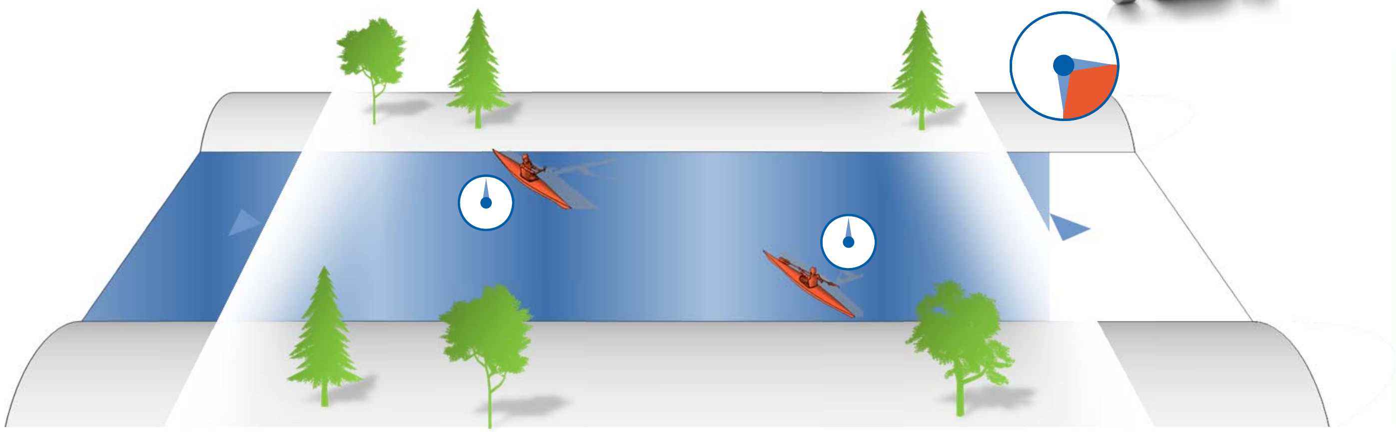




Plotted correlation between estimated LVF and Reference LVF, possible to find correction equations to compensate the Coriolis flowmeter reading against the wetness of the gas.

Measuring Principle – Ultrasonic

- **Velocity of sound =**
  The speed a sound wave propagates in a medium
- At a certain temperature every medium has its own velocity of sound
- Overreading due to presence of liquid stratified/mist in wet gas flow



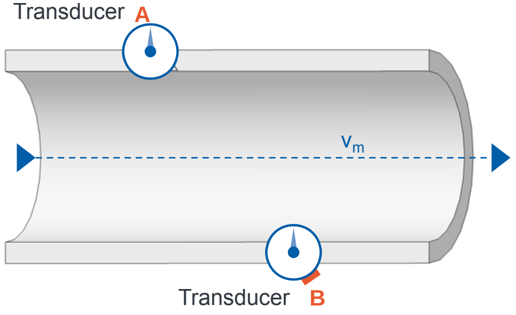
Measuring Principle – Ultrasonic

Differential transit time – Medium independent

Difference in transit time is proportional to the flow velocity

1 Transit time (t) = $\frac{\text{Distance}}{\text{Velocity}}$

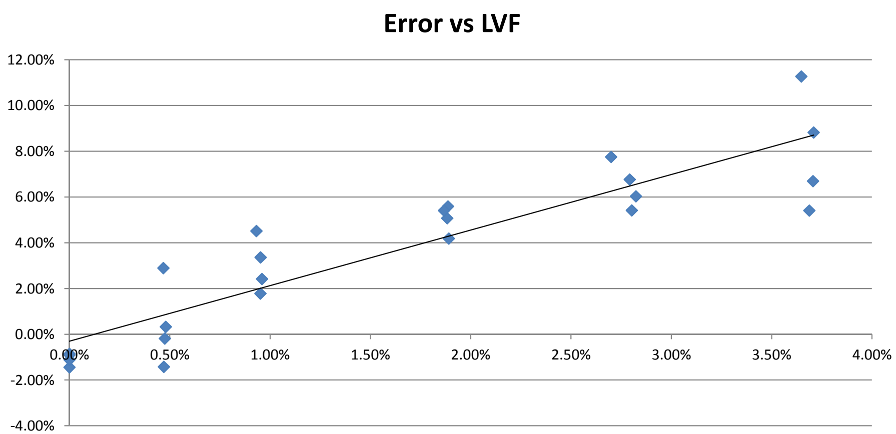
$T_{B \rightarrow A} - T_{A \rightarrow B} \sim v_m$



v_m = Flow velocity of the medium

Wetness vs Over-reading

- To observe USM behavior throughout higher Fr (gas)/higher velocity and wetness



Observed that there are correlation as function of the LVF, possible to define a proper overreading correction.

Conclusion

Venturi

- Reliable for single phase & wet gas application
- ISO 11583 dedicated for wet gas measurement
- Importance is on the quality of the venturi.
- Continuous improvements on over-reading correction
- Modular systems recommended to integrate complimentary technology

Coriolis

- Reliable for single phase application
- Suited for multiphase applications (EGM)
- Trend observed for mass flowrate measurement
- Trend observed for density measurement.
- High potential for wet gas application

Ultrasonic

- Reliable for single phase applications
- Able to measure under wet gas conditions
- Proper overreading corrections need to be defined

THANK YOU