Gas Flow Measurement

Reliable Flow Measurement.
What will you experience with gas rig?

- Response time
- Low flow limitation
- Impact of energy and pressure loss
- Impact on flowmeters installation
- Impact of the flow profile
- Impact of moisture
- Pressure and temperature simulation
- Impact of setting errors
Measuring Principles for Gas Measurement

**Coriolis**
Nominal diameters: DN 1 to 350 (1/24 to 14”)

**Vortex**
Nominal diameters: DN 15 to 300 (1/2 to 12”)

**Differential Pressure**
Nominal diameters: DN 10 to >DN1000

**Thermal Mass**
Nominal diameters: DN 15 to 1500 (1/2 to 60”)

**Ultrasonic (Biogas only)**
Nominal diameters: DN 50 to 200 (2 to 8”)

Endress+Hauser
**Conversion of Volume Flow to Mass Flow**

- **Simple Ideal Gas Equation:**
  
  \[ m = \rho \cdot V \]

- **Real Gas Equation:**
  
  \[ m = \rho \cdot V = \frac{p}{p_{\text{ref}}} \cdot \frac{T_{\text{ref}}}{T} \cdot \frac{Z_{\text{ref}}}{Z} \cdot \rho_{\text{ref}} \cdot V \]

  - \( m \) = mass flow
  - \( p \) = pressure
  - \( p_{\text{ref}} \) = reference pressure (typically 1013 mbar or 14.696 psi)
  - \( T \) = temperature
  - \( T_{\text{ref}} \) = reference temperature (typically 0 °C or 70 °F)
  - \( Z \) = compressibility
  - \( Z_{\text{ref}} \) = compressibility at reference conditions
  - \( \rho_{\text{ref}} \) = density at reference conditions
  - \( V \) = volume
## Real Gas Compressibility Factor - Z

<table>
<thead>
<tr>
<th></th>
<th>1 bar a</th>
<th>5 bar a</th>
<th>10 bar a</th>
<th>20 bar a</th>
<th>40 bar a</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Air @ 20 °C</strong></td>
<td>0.9997</td>
<td>0.9986</td>
<td>0.9972</td>
<td>0.9944</td>
<td>0.9889</td>
</tr>
<tr>
<td><strong>Air @ 100 °C</strong></td>
<td>1.0001</td>
<td>1.0007</td>
<td>1.0013</td>
<td>1.0027</td>
<td>1.0053</td>
</tr>
<tr>
<td><strong>CO2 @ 20 °C</strong></td>
<td>0.9945</td>
<td>0.9727</td>
<td>0.9453</td>
<td>0.8906</td>
<td>-</td>
</tr>
<tr>
<td><strong>CO2 @ 100 °C</strong></td>
<td>0.9978</td>
<td>0.9892</td>
<td>0.9785</td>
<td>0.9570</td>
<td>0.9140</td>
</tr>
<tr>
<td><strong>He @ 20 °C</strong></td>
<td>1.0002</td>
<td>1.0012</td>
<td>1.0024</td>
<td>1.0048</td>
<td>1.0096</td>
</tr>
<tr>
<td><strong>He @ 100 °C</strong></td>
<td>1.0002</td>
<td>1.0009</td>
<td>1.0019</td>
<td>1.0038</td>
<td>1.0076</td>
</tr>
<tr>
<td><strong>Ammonia @ 100°C</strong></td>
<td>0.9959</td>
<td>0.9797</td>
<td>0.9593</td>
<td>0.9187</td>
<td>0.8374</td>
</tr>
<tr>
<td><strong>Chlorine @ 100 °C</strong></td>
<td>0.9939</td>
<td>0.9697</td>
<td>0.9395</td>
<td>0.8789</td>
<td>-</td>
</tr>
<tr>
<td><strong>Argon @ 20 °C</strong></td>
<td>0.9993</td>
<td>0.9966</td>
<td>0.9933</td>
<td>0.9866</td>
<td>0.9731</td>
</tr>
</tbody>
</table>
Corrected Volume – Nm³ or Sm³??

- Normal cubic meter (Nm³) and Standard cubic meter (Sm³) both are corrected volume terms.

Corrected Volume, \( v_{ref} = \frac{\text{Mass, } m}{\text{Reference Density, } \rho_{ref}} \)

- Corrected volume is NOT a volume term, but a mass term.
- They refer to the same reference pressure but to different reference temperatures.

Examples:
- Air = 1.293 kg
- Hydrogen = 0.089 kg
- Chlorine = 3.220 kg

Examples:
- Air = 1.199 kg
- Hydrogen = 0.083 kg
- Chlorine = 2.936 kg

Deviation 6-10%!!!!
Special Application: Oxygen

1. Wetted part material. Note: Titanium and Zirconium should be avoided

2. Cleaning – All oxygen equipment must be cleaned from oil & grease
## Traceability chain of Endress+Hauses

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Standard Kilo at (BIPM) Paris</strong></td>
<td>Measuring uncertainty = +/− 0.000001%</td>
</tr>
<tr>
<td></td>
<td>+/- 10 microgram</td>
</tr>
<tr>
<td><strong>National Standard Kilo of METAS</strong></td>
<td>Measuring uncertainty = +/− 0.0001%</td>
</tr>
<tr>
<td></td>
<td>+/- 0.5g/500 kg, duplicate No 38</td>
</tr>
<tr>
<td><strong>Gravimetric scale of E+H Flowtec</strong></td>
<td>Traceable weights of OIML class F2</td>
</tr>
<tr>
<td></td>
<td>+/- 0.8g/50 kg = 0.0016%</td>
</tr>
<tr>
<td><strong>PremiumCal rigs in Reinach and Greenwood</strong></td>
<td>Measuring Uncertainty +/- 0.015%</td>
</tr>
<tr>
<td></td>
<td>accredited acc. to ISO 17025</td>
</tr>
<tr>
<td><strong>Meter accuracy</strong></td>
<td>Promass 83/84F DN 08 – 400</td>
</tr>
<tr>
<td></td>
<td>Premium Calibration +/-0.05%</td>
</tr>
</tbody>
</table>
Calibration

- Calibration with Air
- Repeatable and stable ambient conditions
- Controlled temperature (24°C +/- 0.5°C) and humidity (40% Rel)
- Undisturbed, fully developed flow profile
- Automated positioning of the Device Under Test
- Mass flow range: 0.05kg/h ... 10’000kg/h
- Measurement uncertainty ±0.3 % o.r.
- DIN17025 and ISO/IEC 17025 accredited
Calibration with Water for Gas Application?

- PTB Custody Transfer Approval mentioned if a gas device is calibrated with Water:

  Bei der Prüfung eines Gerätes mit Wasser betragen die zulässigen Fehlergrenzen:

  *If a device is tested with water, the maximum permissible errors are:*

  \[
  \begin{align*}
  - & \pm 1 \% \text{ für } Q_{\text{min}} \leq Q < Q_{\text{i}} \\
  - & \pm 0,3 \% \text{ für } Q_{\text{i}} \leq Q \leq Q_{\text{max}}
  \end{align*}
  \]

- External 3rd Party tested with different condition and different fluid the measuring performance is within the measuring error limit for both calibration with gas and water (Refer to White paper)
Coriolis

Reliable Flow Measurement.
Coriolis Measuring Principle

- $\Delta \phi = $ Phase shift
- $m = $ Mass flow
- $f_R = $ Resonance frequency
- $\rho = $ Density
- $\Omega = $ Resistance (PT1000)
- $T = $ Temperature

$\Delta \phi \sim m$
$f_R \sim \rho$
$\Omega \sim T$
Overview of calculated values

- \( V \) = Volume flow
  \[ V = \frac{m}{\rho} \]

- \( V_N \) = Standard volume flow = Volume flow at fixed \( p \) and \( T \)
  \[ V_N = \frac{m}{\rho_N} \text{ (note: } \rho_N \text{ is a fixed value for each fluid)} \]

- \( c \) = Concentration
  Concentration can be calculated from density

- \( \mu, \eta \) = Viscosity
  Viscosity can be calculated from oscillation damping. Viscosity measurement is only available with the Promass 83I.
Installation Guidelines

- Coriolis flowmeters **DO NOT** require straight inlet or outlet runs

- Elbow, valves or pumps upstream do not affect the performance of coriolis
Sizing of Coriolis Flowmeter

Sizing is the compromise of:

**Accuracy at minimum flow rate**
**vs.**
**Pressure loss at maximum flow rate**

For a reliable sizing the following information must be available:

- The measured fluid
- Flowmeter model to be sized
- Minimum and maximum flow rate to be measured
- The process condition (min. and max. pressure / temperature)
- Observe possible velocity limitations
Gas Flow Measurement

**Accuracy vs. Pressure Loss Promass 83F DN50**

---

**Full Flowmeter Measuring Range**

---

![Graph showing the relationship between measured error, pressure, and flow rate.](image)
Accuracy vs. Pressure Loss for Ideal DN

Min. Flow

Application Measuring Range

Max. Flow

Accuracy Min. Flow

Pressure Loss Max. Flow

Best compromise solution

Gas Flow Measurement
Accuracy vs. Pressure Loss for DN 40

Min. Flow

Application Measuring Range

Max. Flow

Upper flowmeter range

Pressure Loss Max. Flow

Accuracy Min. Flow

Optimized solution for high accuracy
Accuracy vs. Pressure Loss for DN 80

Min. Flow

Application Measuring Range

Max. Flow

Optimized solution for low pressure loss
Advantages and Limitations

**Advantages**
- Direct massflow measurement
- Independent of gas properties
- Independent of process conditions
- Independent of installation

**Limitation**
- Pressure loss
- Size max DN 350
 Thermal Mass Flow

Reliable Flow Measurement.
Gas Flow Measurement

Thermal Mass Flowmeter Measuring Principle

- Mass flow measurement base on thermal dispersion
- A heated body in a flowing gas stream gives off heat to the flowing gas due to the cooling affect of the gas molecules and mass velocity
- The amount of heat convected away by the *gas* is directly related to the mass flow rate
- Direct mass flow measurement
What influences the cooling rate of sensor?

Pressure
Temperature = Density

Velocity

Gas Properties
Influence of Pressure and Temperature

- The thermal properties of gases changes as pressure and temperature changes
- The influence is different for different gases
- i.e. Air is more temperature depending where CO₂ is more affected by changing pressure
- The influence can be compensated for by applying a correction factor
Pressure and Temperature influence of CO₂

As the process pressure increases the gas shows an increased specific heat absorption. To compensate for this effect the output must be corrected by applying a multiplication factor.
Influence of Moisture

- Moist gas will increase the cooling effect on the sensors
- This influence is minimal as long as condensation is avoided
- In case of condensation the influence is NOT predictable
- Typically the meter will read 30 to 50% too much if the gas is condensing
**t-mass for Industrial Gases Measurement**

**t-mass 150**
- Measures **Compressed Air, Nitrogen, Carbon Dioxide & Argon**
- Measuring accuracy up to ± 3.0% o.r.

**t-mass 65**
- Integrated Gas Engine with list of **20 gases**. Specific gas mixtures can be programmed up to 8 components
- Measuring accuracy up to ± 1.5% o.r.

---

**In-line version**
Cost-efficient gas flow measurement in large diameter pipes.

**Insertion version**
With optional ‘Hot Tap’ mounting tool
For inserting or removing the device under process condition.

---

Fits everywhere
What gas can be measured with t-mass?

Application recommended within the range of t-mass specification

Air
Oxygen $\text{O}_2$
Nitrogen $\text{N}_2$
Carbon Dioxide $\text{CO}_2$
Argon Ar
Methane $\text{CH}_4$

Biogas
Natural gas
Hydrogen $\text{H}_2$
Helium He
Butane $\text{CH}_3\text{CH}_2$
Propane $\text{C}_3\text{H}_8$

Care should be exercised, check;
Pressure
Temperature
Composition
Moisture
Flow rates
Customer expectations

Other gases: i.e. Ammonia
Chlorine

Get expert support for all gases not listed above!
Installation requirement

Flanged sensor

1. [Diagram]
2. [Diagram]
3. [Diagram]
4. [Diagram]
5. [Diagram]
6. [Diagram]

Insertion sensor

1. [Diagram]
2. [Diagram]
3. [Diagram]
4. [Diagram]
5. [Diagram]
6. [Diagram]
Gas Flow Measurement

t-mass Insertion Installation Guide

<table>
<thead>
<tr>
<th>Duct Installation</th>
<th>Calculated results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Horizontal assembly</td>
<td>Insertion depth X</td>
</tr>
<tr>
<td>Vertical mount</td>
<td>131 mm</td>
</tr>
<tr>
<td>Wall thickness</td>
<td>Insertion tube length</td>
</tr>
<tr>
<td></td>
<td>235 mm</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Accessory Selection</th>
<th>Dimension information</th>
</tr>
</thead>
<tbody>
<tr>
<td>Accessory</td>
<td>Height process conn. C1</td>
</tr>
<tr>
<td></td>
<td>Height sensor conn. C2</td>
</tr>
<tr>
<td></td>
<td>Total height C</td>
</tr>
<tr>
<td>E+H Mounting boss, onboard</td>
<td>60 mm</td>
</tr>
<tr>
<td>G 1A Thread (Fitting)</td>
<td>39 mm</td>
</tr>
<tr>
<td></td>
<td>99 mm</td>
</tr>
</tbody>
</table>

Diagram showing measurement points A, B, C, C1, C2.
Advantages and Limitations

**Advantages**
- Wide turndown ratio, 100:1
- Very low pressure loss (<2 mbar)
- Direct mass flow measurement

**Limitations**
- Not suitable for undefined gas mixtures
- Not recommended for condensate and dirty gases
Reliable Flow Measurement.
**Vortex Measuring Principle**

- f = Vortex frequency
- V = Volume flow
- $f \sim V$
**Differential Switched Capacitor Sensor**

Counter Electrode & Paddle have the same mass

= perfectly balanced system

= immune against vibrations

Laser welding not in touch with process

= no corrosion

The movement of the paddle generates sinusoidal voltage change between Electrode 1 and 2

Signal Amplitude

Trigger Level
Minimum flow requirement

- Physical limits based on principle (→ Karman street)
- 1) Depending on density

Prowirl 200 Standard

Example: Water

\[
V_{\text{min}} = \frac{6}{\sqrt{\rho}} = \frac{6}{\sqrt{1000}} = 0.19 \text{ m/s}
\]

Example: Air @ 0°C, 1.013 bara

\[
V_{\text{min}} = \frac{6}{\sqrt{\rho}} = \frac{6}{\sqrt{1.3}} = 5.3 \text{ m/s}
\]
Minimum flow requirement

2) Depending on Reynolds-Number

\[ \text{Re} = \frac{4 \cdot V \cdot \rho}{\pi \cdot d_i \cdot \mu} \geq 5000 \]

- \( V \): Volume flow [m\(^3\)/s]
- \( \rho \): Density [kg/m\(^3\)]
- \( d_i \): Diameter [m]
- \( \mu \): Kinematic viscosity [Pa \cdot s]

Question: What happens with the min. flow if the fluid viscosity is increasing? Min. flow decrease (-) or increase (+)?

NOTE: linear measuring range starts at Re=20’000!
### Applicator Sizing does the job

- **Operating range** – Vortex starts to measures at Reynolds number 5,000 and above
- **Linear Range** - Reynolds Number 20,000 and above with measuring uncertainty ±0.75% o.r.
Prowirl Sensor: Volume or Mass

The same type of sensor is used for all meter sizes means cost reduction of spare part handling.
Prowirl 200 with “Gas Engine”

Prowirl 200 features recognised calculation methods for gas parameters to enable an accurate gas flow measurement!

Customer specific settings
(gases/mixtures, reference conditions...)

“Gas Engine”

20 gases available, gas mixtures from up to 8 components

Accurate calculation of...
- Operating density
- Reference/standard density
- Energy
- Viscosity

Result
- Gas parameters for all process conditions
- Gas parameter for reference/standard conditions

Accurate measurement of gases (esp. Natural gas) and gas mixtures

Process parameters
(temperature, pressure)

Prowirl 200 features integrated temperature measurement and current input for easy wiring of a pressure transmitter.
Prowirl 200 offers multivariable solutions!

World’s first vortex flowmeter with current input enables fully compensated mass-/standard volume flow or delta heat measurement

Only available with “Mass flow” option
Common Vortex Installation

About 70% of all vortex installations require a reduction of line size, including:

1. reducer
2. min. 15 DN straight run (inlet)
3. Vortex
4. min. 5 DN straight run (outlet)
5. expander
All of this is replaced now – by one flow meter! with the same specifications...

- Prowirl R 200 sensor DN100/4” S Style
  super reduced by two line sizes to DN50/2”

- Prowirl F sensor DN100/4” R Style
  reduced by one line size to DN80/3”

- Prowirl F sensor DN100/4” standard
Installation requirement

1. 15 × DN 5 × DN

2. 20 × DN 5 × DN

3. 25 × DN 5 × DN

4. 40 × DN 5 × DN

5. 20 × DN 5 × DN

6. 17 × DN + 8 × h 5 × DN

7. 50 × DN 5 × DN

8. DN ≤ 25 (1):

9. DN ≥ 40 (1½):

- Difference in expansion
- Reduction by one nominal diameter size
- Single elbow (90° elbow)
- Double elbow (2 × 90° elbows, opposite)
- Double elbow 3D (2 × 90° elbows, opposite, not on one plane)
- T-piece
- Expansion
- Control valve
- Two measuring devices in a row where DN ≤ 25 (1½): directly flange on flange
- Two measuring devices in a row where DN ≥ 40 (1½): for spacing, see graphic
Flow conditioner to reduce inlet run
Vortex Installation with Pressure & Temperature Compensation

- PT  Pressure transmitter
- TT  Temperature transmitter

3...5 x DN
4...8 x DN
Advantages and Limitation

**Advantages**
- High pressure range
- Suitable for gas, steam and liquids
- High temperature range
- Independent of gas properties

**Limitations**
- Volumetric measurement
- Sizes max. DN 300
- Min. flow limitation
Differential Pressure

Reliable Flow Measurement.
Gas Flow Measurement

**Principle - Restriction Type Primary Elements**

\[ P_{\text{total}_1} = P_{\text{stat}_1} + P_{\text{dyn}_1} \]

\[ P_{\text{total}_2} = P_{\text{stat}_2} + P_{\text{dyn}_2} + dw \]

\[ dp = P_{\text{stat}_1} - P_{\text{stat}_2} \]

dp pressure
Flow Equation

\[ Q_m = \left[ 0.5961 + 0.0261 \cdot \beta^2 - 0.216 \cdot \beta^8 + 0.000521 \left( \frac{10^6 \cdot \beta}{Re_{xxx}} \right)^{0.7} + 0.0188 + 0.0063 \left( \frac{19000 \cdot \beta}{Re_{xxx}} \right)^{0.8} \right] \beta^{3.5} \left( \frac{10^6}{Re_{xxx}} \right)^{0.3} \]

\[ + \left( 0.043 + 0.08 \cdot e^{-10 \cdot L_1} - 0.123 \cdot e^{-7 \cdot L_1} \right) \left( 1 - 0.11 \left( \frac{19000 \cdot \beta}{Re_{xxx}} \right)^{0.8} \right) \frac{\beta^4}{1 - \beta^4} \]

\[ - 0.031 \left( \frac{2 \cdot L_2}{1 - \beta} - 0.8 \left( \frac{2 \cdot L_2}{1 - \beta} \right)^{1.1} \right)^{0.1} \beta^{1.3} + X_{\beta^2} \left[ 0.011(0.75 - \beta)(2.8 - \frac{D}{0.0254}) \right] \]

\[ \cdot \left[ 1 - (0.351 + 0.256 \beta^4 + 0.93 \beta^8) \left( 1 - \left( \frac{p_{r,nom} - \Delta p_{r,max}}{p_{r,nom}} \right)^{1/x} \right) \right]^{x_{\beta^1}} \frac{\pi}{4} \left( \frac{D \cdot \beta}{\sqrt{1 - \beta^4}} \right)^2 \sqrt{2 \cdot \Delta p_{r,max} \cdot \rho_{nom}} \]

\[ Q_m = C \cdot \varepsilon \cdot \frac{d^2 \pi}{4} \cdot \frac{1}{\sqrt{1 - \beta^4}} \cdot \sqrt{2 \cdot \Delta p} \cdot \rho_{nom} \]

\[ Q_m = K \cdot \sqrt{2 \cdot \Delta p} \cdot \rho_{nom} \]

\[ Q \approx \sqrt{\Delta p} \]
Simplified flow equation

\[ Q \approx \sqrt{\Delta p} \approx \neq = \]
Flow measurement with primary devices

ISO 5167-4: Venturi tube and Venturi nozzle

\[ \Delta p = p_+ - p_- \]

\[ q_m = K_\beta \sqrt{2 \cdot \Delta p \cdot \rho} \]

\[ q_v = K_\beta \sqrt{2 \cdot \Delta p \cdot 1/\rho} \]

Venturi tube: conical upstream opening

Diameter ratio of the primary device:

\[ \beta = \frac{d}{D} \]

Venturi nozzle: round upstream opening
Flow measurement with primary devices

Pitot tube

\[ \Delta p = p_+ - p_- \]

\[ q_m = K \cdot \sqrt{2 \cdot \Delta p \cdot \rho} \]

\[ q_v = K \cdot \sqrt{2 \cdot \Delta p \cdot 1/\rho} \]

According to calculations of manufacturer or sample calibration
Installation: Inlet/Outlet Run – How long?

- **Pitot tube**

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>7 ( \cdot D )</td>
</tr>
<tr>
<td>2</td>
<td>30 ( \cdot D )</td>
</tr>
<tr>
<td>3</td>
<td>9 ( \cdot D )</td>
</tr>
</tbody>
</table>

- **Orifice** \((\beta = 0,2 \ldots 0,8)\)

<table>
<thead>
<tr>
<th>A</th>
<th>B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10 ( \ldots 16 ) ( \cdot D )</td>
</tr>
<tr>
<td>2</td>
<td>18 ( \ldots 44 ) ( \cdot D )</td>
</tr>
<tr>
<td>3</td>
<td>14 ( \ldots 50 ) ( \cdot D )</td>
</tr>
</tbody>
</table>

- **Factor 1/2 if additional uncertainty of** \(e_K = 0,5 \%\) **is accepted!**

- **D = inner pipe diameter**
dp Flow: Compensation according to ISO 5167

Temperature and pressure compensation

<table>
<thead>
<tr>
<th>Temperature and pressure compensation</th>
<th>Separate process connections</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two additional probes are required for temperature and pressure compensation:</td>
<td></td>
</tr>
<tr>
<td>• <strong>An absolute pressure sensor</strong></td>
<td></td>
</tr>
<tr>
<td>According to ISO 5167, this probe must always be mounted on the upstream side of the orifice.</td>
<td></td>
</tr>
<tr>
<td>• <strong>A temperature probe</strong></td>
<td></td>
</tr>
<tr>
<td>In order to avoid disturbances of the flow profile, this probe must be mounted on the downstream side of the orifice.</td>
<td></td>
</tr>
</tbody>
</table>

1: Absolute pressure sensor
2: orifice and differential pressure transmitter
3: temperature probe
4: evaluation unit

1: upstream length; 2: downstream length;
a: 90° bend; b: valve; c: 2x45° bend
### Advantages and Limitations

#### Advantages
- Tradition and experience
- Wide application area
- Low cost for large DN

#### Limitations
- Low turndown
- High maintenance required
Ultrasonic (Biogas)

Reliable Flow Measurement.
Prosonic B200 for Biogas Measurement

Why Measure Biogas?
- Rate of gas produced by the digester is an indicator of the health of the digester. Decreasing output is a warning of a failing process.
- Rate of gas as input into engines, boilers or for diversion to storage
- Totalization of biogas diverted to flare
- Totalization of biogas production for accounting purposes

Prosonic B200
- For wet biogas, landfill or digester gas
- Direct measurement of the methane content (CH4) in the pipe
- Process Temperature: 0 to +80°C
- Nominal diameters: DN 50 to 200 (2" to 8")
- High accuracy: ±1.5% o.r.
How does Prosonic B200 Measure Methane?

- The Prosonic B 200 measures the time taken for the ultrasonic pulse to travel through the gas.
- As the path length is known the speed of sound in the gas can be accurately determined. As the speed of sound in a gas is dependent on the gas composition the B 200 can use the sound speed to calculate the methane content of the biogas.
**100% CH₄ @ 40 °C**

The speed of sound in 100% Methane at 40 °C is 458.5 m/s

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Methane</th>
<th>Carbon dioxide</th>
<th>Speed of sound</th>
</tr>
</thead>
<tbody>
<tr>
<td>°C</td>
<td>CH₄</td>
<td>CO₂</td>
<td>m/s</td>
</tr>
<tr>
<td>40</td>
<td>0.0%</td>
<td>100.0%</td>
<td>274.7</td>
</tr>
<tr>
<td>40</td>
<td>10.0%</td>
<td>90.0%</td>
<td>284.1</td>
</tr>
<tr>
<td>40</td>
<td>20.0%</td>
<td>80.0%</td>
<td>294.5</td>
</tr>
<tr>
<td>40</td>
<td>30.0%</td>
<td>70.0%</td>
<td>306.0</td>
</tr>
<tr>
<td>40</td>
<td>40.0%</td>
<td>60.0%</td>
<td>319.0</td>
</tr>
<tr>
<td>40</td>
<td>50.0%</td>
<td>50.0%</td>
<td>333.8</td>
</tr>
<tr>
<td>40</td>
<td>60.0%</td>
<td>40.0%</td>
<td>350.8</td>
</tr>
<tr>
<td>40</td>
<td>70.0%</td>
<td>30.0%</td>
<td>370.7</td>
</tr>
<tr>
<td>40</td>
<td>80.0%</td>
<td>20.0%</td>
<td>394.2</td>
</tr>
<tr>
<td>40</td>
<td>90.0%</td>
<td>10.0%</td>
<td>422.8</td>
</tr>
<tr>
<td>40</td>
<td>100.0%</td>
<td>0.0%</td>
<td>458.5</td>
</tr>
</tbody>
</table>
The speed of sound in 100% Carbon dioxide at 40 °C is 274.7 m/s

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Methane</th>
<th>Carbon dioxide</th>
<th>Speed of sound</th>
</tr>
</thead>
<tbody>
<tr>
<td>°C</td>
<td>CH₄</td>
<td>CO₂</td>
<td>m/s</td>
</tr>
<tr>
<td>40</td>
<td>0.0%</td>
<td>100.0%</td>
<td>274.7</td>
</tr>
<tr>
<td>40</td>
<td>10.0%</td>
<td>90.0%</td>
<td>284.1</td>
</tr>
<tr>
<td>40</td>
<td>20.0%</td>
<td>80.0%</td>
<td>294.5</td>
</tr>
<tr>
<td>40</td>
<td>30.0%</td>
<td>70.0%</td>
<td>306.0</td>
</tr>
<tr>
<td>40</td>
<td>40.0%</td>
<td>60.0%</td>
<td>319.0</td>
</tr>
<tr>
<td>40</td>
<td>50.0%</td>
<td>50.0%</td>
<td>333.8</td>
</tr>
<tr>
<td>40</td>
<td>60.0%</td>
<td>40.0%</td>
<td>350.8</td>
</tr>
<tr>
<td>40</td>
<td>70.0%</td>
<td>30.0%</td>
<td>370.7</td>
</tr>
<tr>
<td>40</td>
<td>80.0%</td>
<td>20.0%</td>
<td>394.2</td>
</tr>
<tr>
<td>40</td>
<td>90.0%</td>
<td>10.0%</td>
<td>422.8</td>
</tr>
<tr>
<td>40</td>
<td>100.0%</td>
<td>0.0%</td>
<td>458.5</td>
</tr>
</tbody>
</table>
The speed of sound in biogas (60% CH₄, 40% CO₂) at 40 °C is 350.8 m/s.

<table>
<thead>
<tr>
<th>Temperature</th>
<th>Methane</th>
<th>Carbon dioxide</th>
<th>Speed of sound</th>
</tr>
</thead>
<tbody>
<tr>
<td>°C</td>
<td>CH₄</td>
<td>CO₂</td>
<td>m/s</td>
</tr>
<tr>
<td>40</td>
<td>0.0%</td>
<td>100.0%</td>
<td>274.7</td>
</tr>
<tr>
<td>40</td>
<td>10.0%</td>
<td>90.0%</td>
<td>284.1</td>
</tr>
<tr>
<td>40</td>
<td>20.0%</td>
<td>80.0%</td>
<td>294.5</td>
</tr>
<tr>
<td>40</td>
<td>30.0%</td>
<td>70.0%</td>
<td>306.0</td>
</tr>
<tr>
<td>40</td>
<td>40.0%</td>
<td>60.0%</td>
<td>319.0</td>
</tr>
<tr>
<td>40</td>
<td>50.0%</td>
<td>50.0%</td>
<td>333.8</td>
</tr>
<tr>
<td>40</td>
<td>60.0%</td>
<td>40.0%</td>
<td>350.8</td>
</tr>
<tr>
<td>40</td>
<td>70.0%</td>
<td>30.0%</td>
<td>370.7</td>
</tr>
<tr>
<td>40</td>
<td>80.0%</td>
<td>20.0%</td>
<td>394.2</td>
</tr>
<tr>
<td>40</td>
<td>90.0%</td>
<td>10.0%</td>
<td>422.8</td>
</tr>
<tr>
<td>40</td>
<td>100.0%</td>
<td>0.0%</td>
<td>458.5</td>
</tr>
</tbody>
</table>
Field trial – Agrikracht NV BE

**Methane measurement**

- Pronova SSM 600 is a gas analyzer designed specifically for biogas applications.
- The methane concentration is measured using infra-red technology, the manufacturers state the accuracy to be 0.1% Vol.

- The B 200’s methane measurement differs by only 0.39%
Application of Prosonic B200 in Malaysia

Installation Location:
Poultry farm biogas plant at Negeri Sembilan, Malaysia

Prosonic B200 Features:
- Wet biogas measurement
- Direct measurement of methane, CH$_4$ content in the pipe

Prosonic B200 Benefits:
- Continuous, around-the-clock monitoring of gas quantity and quality
- Fast and targeted reaction in case of interference in the fermentation process
Best Fit for Gas Measurement?

Consider:
- Installation requirement
- Measuring accuracy
- Pressure loss
- Turndown
- Influence of moisture
- Changing pressure
- Changing temperature
### Turndown

<table>
<thead>
<tr>
<th>Measuring Principle</th>
<th>Turndown</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thermal</td>
<td>100:1</td>
</tr>
<tr>
<td>Coriolis</td>
<td>15:1</td>
</tr>
<tr>
<td>Vortex</td>
<td>13:1</td>
</tr>
<tr>
<td>DP</td>
<td>6:1</td>
</tr>
</tbody>
</table>

- For DP, the turndown can be increased by using the split-range functionality of RMC621.
# Pressure Loss

<table>
<thead>
<tr>
<th>Instrument</th>
<th>Measuring Principle</th>
<th>Pressure loss</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deltatop Orificeplate DN50</td>
<td>Differential Pressure</td>
<td>95 mbar</td>
</tr>
<tr>
<td>Promass 83F DN50</td>
<td>Coriolis</td>
<td>45 mbar</td>
</tr>
<tr>
<td>Prowirl 72F DN50</td>
<td>Vortex</td>
<td>25 mbar</td>
</tr>
<tr>
<td>t-mass 65F DN50</td>
<td>Thermal</td>
<td>&lt;2 mbar</td>
</tr>
</tbody>
</table>
Any Question
Thank you very much for your attention