Basics of Flow Measurement

Reliable Flow Measurement.
Overview

- Measuring principles
- Selection & sizing
- Device Specific Information
- Calibration
Flow measuring principles @ Endress+Hauser

- Vortex
- Electromagnetic
- Coriolis

- Differential pressure
- Thermal
- Ultrasonic
## Flow Measurement - Overview

### Selection of Flowmeter

<table>
<thead>
<tr>
<th>Nominal Diameter</th>
<th>1/24”</th>
<th>1/12”</th>
<th>1/4”</th>
<th>1/2”</th>
<th>1”</th>
<th>2”</th>
<th>3”</th>
<th>4”</th>
<th>10”</th>
<th>12”</th>
<th>40”</th>
<th>80”</th>
<th>100”</th>
<th>120”</th>
<th>160”</th>
</tr>
</thead>
<tbody>
<tr>
<td>liquids</td>
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<td>gas</td>
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<td>steam</td>
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</tr>
</tbody>
</table>

- **Coriolis**
- **Magmeter**
- **Ultrasonic**
- **Thermal**
- **Ultrasonic Biogas**
- **Vortex**

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*Slide 4  24/03/2013  Seoul Wei*
Product Portfolio for **liquids**

**Promass**
- Advantage
  - All liquids
  - No pressure loss
- Disadvantage
  - Pressure loss

**Prosonic Flow**
- Advantage
  - All liquids
  - High accuracy
  - Multivariable
- Disadvantage
  - Pressure loss
  - Price

**Prowirl**
- Advantage
  - All liquids
  - 2-Wire
- Disadvantage
  - Inlet run (5xDN)
  - Pressure loss

**Promag**
- Advantage
  - No pressure loss
- Disadvantage
  - Need Inlet run (5xDN)
  - Only conductive liquids
Product Portfolio for Gas

**Dp-flow/Prowirl**
- **Advantages**
  - Special material (dp)
  - 2-wire
- **Disadvantages**
  - Inlet run

**t-mass**
- **Advantages**
  - Direct mass flow
  - No pressure loss
- **Disadvantages**
  - Inlet run

**Prowirl**
- **Advantages**
  - Every gas
  - 2-wire
  - Pressure comp.
- **Disadvantages**
  - Inlet run
  - Pressure loss
  - Min. Flow Shut off

**Promass**
- **Advantages**
  - Direct mass flow
  - No inlet run
  - High accuracy
  - Multivariable
- **Disadvantages**
  - Pressure loss
  - High price

Performance
Selection & Sizing
Influences on the selection of the measuring system

- Mass or Volume
- Viscosity
- Abrasion
- Corrosion
- Price
- Accepted pressure loss
- Pipe inlet
- Required accuracy
- State of aggregation
  - Liquid / gas
- Conductivity
- Homogeneity
- Disturbances
- Temperature
- Density
- Pressure
- Pipe
- Flow profile
- Quantity
  - Diameter
- Measuring range
  - Turn-down
- Required accuracy
- Accepted pressure loss
- Price
- Corrosion
- Abrasion
- Viscosity
- Mass or Volume

Best fit measuring system?
## Selection of Flowmeter

### Best fit measuring system?

<table>
<thead>
<tr>
<th>Vortex</th>
<th>Electromagnetic</th>
<th>Coriolis</th>
<th>Differential pressure</th>
<th>Thermal</th>
<th>Ultrasonic</th>
</tr>
</thead>
</table>

- **State of aggregation**: liquid / gas
- **Conductivity**
- **Temperature**: Density
- **Mass or Volume**: Flow profile
- **Viscosity**: Diameter required
- **Corrosion**: Required accuracy
- **Price**: Accepted pressure loss

*Slide 9* Seou Wei
Selection of Flowmeter

How to select the best fit flowmeter for your process?

Go to www.my.endress.com ➔ Select & Size – Applicator
Selection of Flowmeter

Applicator Selection

- Product selection by filling up the Application requirements
Applicator Sizing

- Product sizing by input of process conditions

Your benefits using Applicator:
- Quick selection and sizing of products based on your requirements
- Different entry points matching your background
- Always available 24/7
application sizing

1. Select the fluid and enter the selected sensor and transmitter from Applicator Selection
2. Enter the process conditions: Flow rate, pressure and temperature
Flow velocity Guideline

For dimensioning of pipe diameter it is good engineering practice to follow the following recommendations:

<table>
<thead>
<tr>
<th>Fluid type</th>
<th>Velocity @ max. flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Liquids (low viscosity)</td>
<td>2...3 m/s</td>
</tr>
<tr>
<td>Gas</td>
<td>15...30 m/s</td>
</tr>
<tr>
<td>Steam</td>
<td>25...45 m/s</td>
</tr>
</tbody>
</table>

- APPLICATOR Sizing applies this rules → Measuring principle depending
- If large turn-down is required → Increased max. velocity is applied
- Often the ideal flowmeter DN is smaller then the pipe DN to optimize accuracy

If the proposed flowmeter DN is larger then the pipe DN there is most likely something wrong → Check plausibility of engineering units
Max. Flow Velocity – Special Cases

For certain fluids max. velocities exist for safety reasons, to protect the measured product from damage/quality loss, etc. Here a few examples:

- Oxygen gas
  - There are regulations regarding max. permitted gas flow velocity in various PIPE MATERIALS

- Slurries (Minerals in liquid)
  - Slurries must be conveyed at MIN. velocities to avoid settling that would lead to pipe blockage. But: High velocity = High abrasion!!

- Milk, Blood and similar
  - Sensitive liquid products should be conveyed with “reasonable” velocity → Customer will/should provide guidance
Procedure of the sizing process

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
Accuracy vs. Pressure Loss Promass 83F DN50

Full Flowmeter Measuring Range
Accuracy vs. Pressure Loss for Ideal DN

- Min. Flow
- Application Measuring Range
- Max. Flow
- Accuracy
- Min. Flow
- Pressure Loss
- Max. Flow

Best compromise solution
Accuracy vs. Pressure Loss for DN 40

Min. Flow

Application Measuring Range

Max. Flow

Accuracy

Min. Flow

Upper flowmeter range

Pressure Loss Max. Flow

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

- **Min. Flow**
- **Max. Flow**
- **Application Measuring Range**

Optimized solution for low pressure loss
**TriSize Function for Comparison of DN**

<table>
<thead>
<tr>
<th>TriSize Display</th>
<th>Next smaller size</th>
<th>Current size</th>
<th>Next bigger size</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meter Size / Pressure rating</td>
<td>DN 40 / FN 40 EN 1092-1 B1 / 1.4404/310L</td>
<td>DN 50 / FN 40 EN 1092-1 B1 / 1.4404/310L</td>
<td>DN 60 / FN 40 EN 1092-1 B1 / 1.4404/310L</td>
</tr>
<tr>
<td>Minimum</td>
<td>0 l/h</td>
<td>0 l/h</td>
<td>0 l/h</td>
</tr>
<tr>
<td>Maximum</td>
<td>5.25E+4 l/h</td>
<td>8.169E+4 l/h</td>
<td>2.101E+5 l/h</td>
</tr>
<tr>
<td>Pressure</td>
<td>0.0022 bar</td>
<td>7.359E-4 bar</td>
<td>1.526E-4 bar</td>
</tr>
<tr>
<td>Pressure loss at avg Flow nom.</td>
<td>0.2867 bar</td>
<td>0.0031 bar</td>
<td>0.0061 bar</td>
</tr>
<tr>
<td>Pressure loss at avg Flow max.</td>
<td>1.541 bar</td>
<td>1.008 bar</td>
<td>0.1684 bar</td>
</tr>
<tr>
<td>Velocity (meas tube) at avg Flow min.</td>
<td>0.57/9 m/s</td>
<td>0.2610 m/s</td>
<td>0.1078 m/s</td>
</tr>
<tr>
<td>Velocity (meas tube) at avg Flow max.</td>
<td>5.76 m/s</td>
<td>2.61 m/s</td>
<td>1.078 m/s</td>
</tr>
<tr>
<td>Velocity (meas tube) at max.</td>
<td>28.5 m/s</td>
<td>13.0 m/s</td>
<td>5.391 m/s</td>
</tr>
<tr>
<td>Measured error Vol. at avg Flow nom.</td>
<td>0.26 %</td>
<td>0.41 %</td>
<td>0.11 %</td>
</tr>
<tr>
<td>Measured error Vol. at avg Flow max.</td>
<td>0.41 %</td>
<td>0.11 %</td>
<td>0.11 %</td>
</tr>
<tr>
<td>Measured error Vol. at max.</td>
<td>0.26 % / 0.23 %</td>
<td>0.41 % / 0.41 %</td>
<td>1.05 % / 1.05 %</td>
</tr>
<tr>
<td>Measured error Vol. at avg Flow min.</td>
<td>0.1 % / 0.05 %</td>
<td>0.1 % / 0.05 %</td>
<td>1.11 % / 0.11 %</td>
</tr>
<tr>
<td>Measured error</td>
<td>0.1 % / 0.05 %</td>
<td>0.1 % / 0.05 %</td>
<td>0.1 % / 0.05 %</td>
</tr>
<tr>
<td>Reynolds No.</td>
<td>1.732E+4</td>
<td>1.172E+4</td>
<td>7.523</td>
</tr>
</tbody>
</table>

**Warnings/Messages**

- Cavitation may occur at max. conditions. This could interfere with accurate measurement results. To avoid cavitation either the diameter or pressure has to be increased or the flowrate or temperature has to be decreased. Pressure loss bigger than nom. pressure. Please increase the nom. pressure of the meter size.

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**Pressure Loss** vs. **Accuracy**
Special Case: Vortex Flowmeter

- Vortex flowmeters have a low-end measuring limitation due to the physical principle.
- Sizing is therefore more critical because it is necessary to ensure the meter NEVER falls below the minimum measurable flow rate.

Measuring Range Prowirl 72F DN50 for Water
Selection of Flowmeter

Device Specific Information

Process safety with SIL instrumentation
Reliable measurement of critical process parameters sets the basis for safe processes. In order to make your processes safe, for us, in all that we develop and produce, safety comes first.
More information >>>

Quick access
- Advanced product selection and sizing with Applicator >>>
- Access device specific information >>>
- Find spare parts >>>
- Check your device features >>>
- Login to W@M Portal >>>
- Check delivery status >>>
Device Specific Information

Device Viewer

Select the type of information you need and enter the requested information in the respective fields.

- device information and technical documentation
- device information and technical documentation incl. device specific documents
- selected documents of all devices per order

Serial number: eb0df202000

Search

Overview | Documents | Spare Parts | More Product Information | Device Integration

Device details

Serial number: EB0DF202000
Order code: 9B2B1H-1014/0
Short description: Prosonic Flow B 200, 9B2B1H, DN100 4"
Device type: Flow, Ultrasonic

- Obtain device information by entering serial number or order number
Selection of Flowmeter

What’s in Device Specific Information?

- Device details
- Calibration certificates
- Spare Parts
- Device manuals and technical information

Device details
- Serial number: EBD0F202000
- Order code: 9B2B1H-1014/0
- Short description: Prosonic Flow B 200, 9B2B1H, DN100 4"
- Device type: Flow, Ultrasonic
- Supplier: Endress+Hauser
- Manufacturing date: 24/03/2013

Spare parts for Prosonic Flow B 200, 9B2B1H, DN100 4"
- Order code: 9B2B1H-AACCCA2D231
- Product status: Available
Calibration
Calibration

- Calibration, the last step in production
- All new flow meters are being calibrated (exception, clamp on Ultrasonic)
- Elimination of deviations between individual units
- Balancing measuring result and specification
- Electronical correction at two points: Zero - Max.
- At zero = zero point adjustment (PIPO)
- At max. = calibration factor (Calf)
Electronical adjustment

1) Calibration factor

2) Sensor zero point

PIPO

2 adjustment points

1) Calibration factor

Calf

Oil & Gas Flow - precise and efficient
Calibration methods – primary calibration method

**Volumetric**

\[ V \cdot \rho = 2500 \text{ kg} \]

\[ \Delta = 3 \text{ dm}^3 \]

**Certified volume**

**Gravimetric**

\[ V \cdot \rho = 2500 \text{ kg} \]

\[ \Delta = 3 \text{ kg} \]

**Certified scale**

Oil & Gas Flow - precise and efficient
Calibration methods – secondary calibration method

Master Units → Unit Under Test → Water Reservoir

\[ \Delta = 3 \text{ dm}^3 \]
Approved calibration methods acc. to ISO 17025

- ISO/IEC 17025 is an internationally accepted standard covering “general requirements for the competence of testing and calibration laboratories”
- ISO 4185: Standard for calibration with gravimetric references

<table>
<thead>
<tr>
<th>Primary Calibration Method</th>
<th>Secondary Calibration Method</th>
</tr>
</thead>
<tbody>
<tr>
<td>Coriolis</td>
<td>Master meter</td>
</tr>
</tbody>
</table>

- Weight scale Flying-Start-Stop (diverter)
- Weight scale Standing-Start-Stop

Secondary methods must inherently have higher uncertainties than any primary calibration method. Reproducibility of master does add to uncertainty.
Solution: PremiumCal – calibration excellence!

- Improved accuracy from ±0.05% to the new level of ±0.015%
- Through the advancement and progression of two existing rigs each in Reinach and Greenwood
- Accredited to ISO/IEC 17025 by the Swiss accreditation body (SAS) in Bern (August 2007)
- March 2009: A2LA accreditation for second, identical PremiumCal rigs in Greenwood USA, same uncertainty!

Official inauguration of the new PremiumCal calibration rig in Reinach Switzerland, February 2008, with the crew.
Solution: new high-performance calibration rig

- The most accurate, accredited production calibration rigs in the world
- Depending on the calibration method, measuring uncertainty calculated with between 30 (gravimetric) and 60 (volumetric) parameters
- A lot of engineering know how needed (26 technicians and engineers)
- Deviation in 1000 liters = 1 glass of Champagne (0.015%)
PremiumCal - the summit of uncertainty

- FCP 7.1.5 (4-t scales) 0.015% gravimetric
- FCP 7.1.5 (400-kg scales) 0.015% gravimetric
- FCP 6.5 (pipe prover) 0.021% volumetric

4-t scales
DN 100 to 250

400-kg scales
DN 15 to 150

Pipe prover
DN 8 to 15
Solution: high-tech rig (±0.015%)

- Electro polished certified weights accuracy class F2 with 0.8 g/50 kg → ±0.0016%
- Class F2 weights: normally used for the weighing of precious metals or gem stones
- Spring-mounted weighing trays
- Load cells: OIML class C6
- The rig is calibrated fully automated every two weeks.
Traceability chain of Endress+Hauses

**Standard Kilo at (BIPM) Paris**
- Measuring uncertainty = +/- 0.000001%
- +/- 10 microgram

**National Standard Kilo of METAS**
- Measuring uncertainty = +/- 0.0001%
- +/- 0.5g/500 kg, duplicate No 38

**Gravimetric scale of E+H Flowtec**
- Traceable weights of OIML class F2
- +/- 0.8g/50 kg = 0.0016%

**PremiumCal rigs in Reinach and Greenwood**
- Measuring Uncertainty +/- 0.015%
- accredited acc. to ISO 17025

**Meter accuracy**
- Promass 83/84F DN 08 – 400
- Premium Calibration +/-0.05%
OIl & Gas Flow - precise and efficient

Endress+Hauser: World wide use of primary calibrations

“Accredited calibration stands (ISO 17025)” in all production locations used by Endress+Hauser for all produced Coriolis meters.

±0.05% Total Accredited Uncertainty

SAS ≡ A2LA ≡ SAS ≡ CNAS
Reinach/Cernay Greenwood Aurangabad Suzhou
Any Questions?
Thank you very much for your attention