Automation Committee Workshop Presentation

Basic Flow Metering Principles and Technologies

Presented by:
Nathan Chui
What’s a flowmeter?

- An instrument used to measure volumetric or mass flow rate of a liquid or a gas
Flowmeters typically fall into the following categories:

- **Volumetric** – directly measures the media as it passes through a known chamber

- **Inferential** – measures the speed of the media passing through the meter and calculates flow based on the velocity and a known area

- **Differential Pressure** – measures the inlet & outlet pressure created by a flow restriction, the resultant differential pressure is proportional to flow
Key flow metering terms:

- **Accuracy**
  - Measures the device’s performance and lists the expected error of a flow measurement if the device is properly installed and meets application requirements.
  - Typically expressed as a % of allowable error (i.e. % of flow reading or % of full scale range).
• **Turn Down**
  • Describes the range of flowrates between maximum and minimum within the manufacturer’s stated accuracy limit

<table>
<thead>
<tr>
<th>Turn Down or Operating Range</th>
<th>Minimum Flow</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flowmeter A</td>
<td>10:1</td>
</tr>
<tr>
<td>Flowmeter B</td>
<td>100:1</td>
</tr>
</tbody>
</table>

• **Repeatability**
  • The ability of a flow meter to indicate the same value for an identical flow rate on more than one occasion and under similar conditions
Volumetric Meters

- Positive or semi-positive displacement
  - Rotary, oscillating piston, nutating disc, oval gear, diaphragm
  - Turndown ratios of 50:1
  - +/- 1.5% accuracy of full scale range
  - For use on ‘clean fluids’ (without particulates or debris to foul mechanical operation)
Inferential Flowmeters

• Turbine 150:1
• Propeller 10:1
• Magnetic Flow 220:1
• Ultrasonic Transit time 10:1

Features
  • Varying Turndown
  • Good Accuracy .5%-2%
  • Application Flexible
  • Passes some suspended solids
  • Must be installed properly
Velocity Profile

- Well developed
- Evenly distributed
Distorting Effects of Pipe Configurations

- Inferential flowmeters often state minimum straight pipe requirements fore and aft of the meter so as to reduce the flow profile distorting effects of pipe configurations.
Electromagnetic Flowmeter

Power to Coils From mains or dedicated source

Converter

Flow Tube

Electrically Insulated Lining

Conductive Fluid

Field Coil

Electrode

Faraday's Law of Electromagnetic Induction states that a conductor moving in a magnetic field induces an electrical voltage.

\[ E_s = \frac{1}{C} B V D \]

- \( E_s \) = the induced electrode voltage
- \( B \) = the magnetic field density
- \( V \) = liquid velocity
- \( D \) = magmeter pipe diameter
- \( C \) = non-dimensional constant
Electromagnetic Flowmeter

Commonly used liners, electrodes and applications (consult chemical compatibility chart for other chemicals):

- Sodium hypochlorite
  - Tantalum electrodes and Teflon/Tefzel liner
    - Hastelloy C is more common but over time the nickel leaches out, leaving the electrode brittle and susceptible to damage
- Potable water
  - 316SS electrodes and NSF approved liner
    - Elastomer, Polyurethane, Teflon, FEP, etc
- Wastewater
  - 316SS electrodes and almost any liner
    - Elastomer, Polyurethane, Hard rubber, Ebonite, etc
**Electromagnetic Flowmeter**

<table>
<thead>
<tr>
<th><strong>Pros</strong></th>
<th><strong>Cons</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>High accuracy (up to 0.20% of rate)</td>
<td>Fluid must be conductive</td>
</tr>
<tr>
<td>No moving parts</td>
<td>Requires completely breaking pipeline for installation (magnetometer tube acts as a spool piece)</td>
</tr>
<tr>
<td>Low pressure drop</td>
<td>Requires full pipe</td>
</tr>
<tr>
<td>Works for all conductive liquids and slurries</td>
<td>Electrical grounding must be fully established</td>
</tr>
<tr>
<td>Can be made out of many materials for chemical compatibility</td>
<td>Electrode fouling (non-conductive coatings)</td>
</tr>
<tr>
<td>Can be submerged under water for IP68 installation</td>
<td></td>
</tr>
<tr>
<td>Requires little straight run</td>
<td></td>
</tr>
</tbody>
</table>
Ultrasonic – Sound waves transmitted via flow stream to determine velocity
<table>
<thead>
<tr>
<th><strong>Pros</strong></th>
<th><strong>Cons</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>Completely non-invasive</td>
<td>Higher cost for smaller line sizes</td>
</tr>
<tr>
<td>Same meter serves pipe lines from 1” to 200”</td>
<td>Interior pipe conditions could affect accuracy</td>
</tr>
<tr>
<td>Lower cost for larger line sizes</td>
<td>Technologies (doppler or transit time) each only work for certain fluids</td>
</tr>
<tr>
<td>Available as portable or fixed</td>
<td>5-10% solids is questionable</td>
</tr>
<tr>
<td>Accuracy 1.0% of rate</td>
<td></td>
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</tbody>
</table>

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Differential Pressure Flowmeters

- Mathematically predictable reduction of pipe size (orifice plate, venturi, manometer, pitot tube, etc) causes pressure drop proportional to flow (energy balance)

\[ P1 \quad \Delta P \quad P2 \]

Flow \[ Do \quad D \]
Venturi Flowmeters

- A device consisting of a **Primary Element** (venturi, wedge, nozzle or orifice) and a **Secondary Device** (dP transmitter or gauge)
- Commonly used to measure the flow rates of liquids, gases or steam

The Differential Pressure Generated is Proportional to the Square of the Flow

\[
v_1 = \sqrt{\frac{2(P_1 - P_2)}{\rho[(A_1/A_2)^2 - 1]}}
\]
Insert Style Venturi
Differential Pressure

**Pros**
- Works for liquids & gases
- Widely understood & used technology
- Not flow profile dependent
- Straight pipe not required
- Field provable

**Cons**
- Requires a flow obstruction & pressure drop
- Limited Turndown
  - Orifice plate 5:1
  - Pitot Tube 6:1
- Installation concerns with impulse lines
Thermal Dispersion

- Matched pair of high-accuracy RTD’s
- One RTD is heated
- Flow carries heat away from RTD

\[ \Delta R = 100 \text{ Ohms} \]
Thermal Dispersion

Pros
• No moving parts
• Factory calibrated to specific gases
• Capable of volumetric and mass flow
• Flow straighteners available for short pipe runs
• Insertion type available

Cons
• Expensive
• Must be sized based on gas composition prior to ordering
• Recalibration is expensive and sometimes not possible
• Wet gas
Open Channel

- Liquid in an open channel is constricted or blocked with a predictable shape (flume or weir)
- Level of constricted liquid is proportional to flow
Open Channel

V-Notch Weir

www.EngineeringToolBox.com
## Open Channel

<table>
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<tr>
<th><strong>Pros</strong></th>
<th><strong>Cons</strong></th>
</tr>
</thead>
<tbody>
<tr>
<td>• Full pipe not required, unlike all other meter technologies</td>
<td>• Flume / Weir has large physical size</td>
</tr>
<tr>
<td></td>
<td>• Open channel must have free-falling outfall</td>
</tr>
<tr>
<td></td>
<td>• Accuracies 5-10%</td>
</tr>
</tbody>
</table>
Mass Flow

• Measuring the flowing media mass (weight) passing through a known area per unit of time
  • \( m = \rho \times V \times A \)
    • \( m \) = mass flow rate
    • \( \rho \) = density
    • \( V \) = velocity
    • \( A \) = area
• Certain medias have a direct relationship between temperature and density. By including a temperature sensor that correlates its reading to a known density along with a volumetric flowmeter, the mass flowrate can be determined
• Mass flow can also be achieved in the form of a ‘cheat’ by assuming a constant density
Coriolis Mass Flowmeter

• Acceleration forces of fluids around bends create oscillations proportional to flow
Coriolis Mass Flowmeter

**Pros**
- No moving parts
- Turndowns as high as 1000:1
- High accuracy (to 0.1% mass flow)
- Line sizes down to 1/16”
- No straight run req’d

**Cons**
- Mass flow only - not volumetric
- Higher Cost
- Pressure drops can be high
Summary

- Accuracy expressed as a % of allowably error based on velocity
- Turn Down is the flow range which the meter operates within the allowable accuracy limits
- Repeatability is arguably the most important flow meter attribute, even a ‘bad meter’ can be ‘acceptable’ if it has repeatable results
- Volumetric flow meters are positive displacement type meters (i.e. gas pumps)
- Inferential flow meters are based on a measured velocity and known area
- Differential pressure flow meters creates a pressure drop which is proportional to flow and can be physically verified in the field
- Open channel flow meter attitude sensitivity and location of level sensor
- Mass flow of liquids or gases can be achieved with the addition a known density measurement
- Piping configuration importance (straight pipe, full pipe, flow profile, fluid velocity, etc)

Presenter contact info and location where this and other AWWA presentations are available:
- Nathan Chui with Revere Control Systems 727-366-0639  email nchui@reverecontrol.com
COMING ATTRACTIONS!!!

Taking the fear out of online liquid analyzers!

Be thrilled, chilled and mesmerized by The Amazing Don Whiting of the Hach Company as he turns the mysteries behind online liquid analysis into child’s play.

Scheduled for 3rd quarter of 2019.

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