DP-Flow Ltd

Liquid, Gas, Air and Steam Flow

Primary Flow Metering with Venturi / Dall Tubes

And

Air Flow Metering using Pitot and Orifice
DP Flow – A Brief Introduction

• We are a process instrumentation company that focus on d/p metering technology, whilst offering Flow, Pressure, Level, Temperature Inst. and VP’s.

• We perceive a declining skill base in the UK process sector, we aim to fill the gap

• Huge installed user base of primary metering technology in O&G

• Large range of solutions where migration to other technologies are not possible

• We additionally offer software products for engineering design including sizing valves, actuators, d/p elements, pipe sizing including pressure loss / span / surge. Additionally we offer d/p condition based monitoring systems.
What styles of primary devices?

Orifice plate
What styles of primary devices?

- PITOBAR
- Classical venturi tube
New styles of primary devices are available, as well as the more traditional products

- There is worldwide acceptance of the governing standards
- The transmitters are easy to calibrate
- Excellent repeatability
- Broad application range
- Proven reliability and stability
- Reduced installation of pipework
- Simplified installation and reduced time on site reducing the overall costs.
Measuring Principle

1. Based on Bernoulli’s equation of balance of energy.

2. A circular pipe fully contained with fluid.


4. Restriction.
How do they Work?

All primaries work essentially from the following equation...

\[ q_m = \frac{Cd}{1 - \beta^4} \cdot \varepsilon \cdot \frac{\pi d^2}{4} \cdot \sqrt{2 \cdot dp \cdot \rho} \]

**Cd** = discharge coefficient

**\( \beta \)** = d/D

**d** = throat

**D** = pipe bore

**\( \varepsilon \)** = Expansion factor (1 for liquids)

**\( \pi \)** = 3.142xxx

**dp** = diff pressure

**\( \rho \)** = operating density
Calculations - Standards


C = discharge coefficient (depends on element type)
E = inlet/velocity coefficient (diameters)
ε = expansion coefficient (gases, liquids)

American standards
ASME MFC-3M

\[ Q = \frac{C}{E} \times \varepsilon \times \frac{\pi}{4} \times d^2 \times \sqrt{2 \times \Delta P \times \rho_1} \]
Construction Standards

ISO 5167-2 – orifice plates
ISO 5167-3 - nozzles, venturi nozzles
ISO 5167-4 - classical venturi tubes
DIN 19205 – meter runs, pressure tappings
DIN 19206 – orifice plates between flanges
DIN 19211 – condensing chambers
DIN 19214 – orifice plates, orifice flanges
ASME PTC 6 - performance test code – steam turbines
ISO/TR 15377 - orifices, nozzles and venturi tubes – amendment to ISO 5167
VDI 2041 – orifice plates - amendment to ISO 5167
BS 1042 - English standard for orifices, nozzles and venturi
Fluids Standards

Properties of water and steam in SI units - steam table
ASME (NBS/NRC) steam equation - steam table
IAPWS-IF97 - steam table
VDI 2040 - thermodynamic values
AGA no.3 - natural gas
+ more
Decommissioned ‘Primary Devices’, Are they an Asset, Liability, Or a Flow Measurement Opportunity?

And....

Air flow metering using Pitot / Orifice in waste water applications
Venturi and Dall Tubes

- Dall Tube – Flindre
- Under roads/trunk mains
- Remote Sites
- Can we liberate more data?
- What about strategic capability?
- What about back up metering?

Flooding, DMZ meter failure, catastrophic event
Where are they?

Venturi Tube – B.W.V.P.S.

Populated, limited options of removal / replacement, Large population cut off during works, and traffic disruption
How can they be re-instated?

Venturi /Dall Tube – B.W.V.P.S.

Service impulse lines, use large bore 10-12 mm,
keep short, install service valve set,
use vents, drains, bleeds. Use smart high performance transmitters.
What skills do we need?
Piping - Installation, pressure testing, standards. Flow Knowledge – straight lengths, (Low flow can have <<<<D’s)
### Measuring Accuracy

a. Uncertainty of primary element.

b. Installation.

c. Uncertainty due to the fluid.

d. Uncertainty of secondary elements.

<table>
<thead>
<tr>
<th>Element</th>
<th>Diameter Range</th>
<th>β Range</th>
<th>Uncertainty Formula</th>
</tr>
</thead>
<tbody>
<tr>
<td>ISA 1932 nozzle</td>
<td>D : 50 – 500 mm</td>
<td>0.3 &lt; β &lt; 0.6</td>
<td>0.8 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.6 &lt; β &lt; 0.8</td>
<td>(2xβ – 0.4) %</td>
</tr>
<tr>
<td>Long radius nozzle, high β</td>
<td>D : 50 – 630 mm</td>
<td>0.2 &lt; β &lt; 0.8</td>
<td>2 %</td>
</tr>
<tr>
<td>Venturi nozzle</td>
<td>D : 65 – 500 mm, d &gt; 50 mm</td>
<td>0.316 &lt; β &lt; 0.775</td>
<td>(1.2 + 1,5xβ^4) %</td>
</tr>
<tr>
<td>Orifice Plates</td>
<td>D : 50 – 1000 mm, d &gt; 12.5 mm</td>
<td>0.2 &lt; β &lt; 0.6</td>
<td>0.5 %</td>
</tr>
<tr>
<td></td>
<td></td>
<td>0.6 &lt; β &lt; 0.75</td>
<td>(1.667xβ – 0.5) %</td>
</tr>
</tbody>
</table>
Venturi Tubes

**Orifice plates**

- D: 50 – 1000 mm, d > 12,5 mm
- 0,2 < β < 0,6: 0,5 %
- 0,6 < β < 0,75: (1,667xβ − 0,5) %

**ISA 1932 nozzle**

- D: 50 – 500 mm
- 0,3 < β < 0,6: 0,8 %
- 0,6 < β < 0,8: (2xβ − 0,4) %

**Long radius nozzle, high β**

- D: 50 – 630 mm
- 0,2 < β < 0,8: 2 %

**Venturi nozzle**

- D: 65 – 500 mm, d > 50 mm
- 0,316 < β < 0,775: (1,2 + 1,5xβ^4) %

**Classical venturi tube - as cast**

- D: 100 – 800 mm
- 0,3 < β < 0,75: 0,7 %

**Classical venturi tube - machined type**

- D: 50 – 250 mm
- 0,4 < β < 0,75: 1,0 %

**Classical venturi tube - welded sheet type**

- D: 200 – 1200 mm
- 0,4 < β < 0,7: 1,5 %

**Averaging Pitot tube**

- D: 50 – 6000 mm: 1 %
In Conclusion Venturi Tubes - It’s your asset....

• They can be reinstated to liberate data

• The benefit is the asset is already in place

• The incentives are:- Low capital outlay, new high performance transmitters increase turndown and reduce error, low overall ‘effort’ for new data from an existing installation
Air Flow Metering In Waste Water Applications

How can d/p meters help with your air flow metering?

• Low cost products

• Low cost installations

• Competitive in performance, easy to install and have short turnaround / site based calibration and inspection capability, all covered by standards
Orifice Plates

Weld in – type MES

Compact and multi hole styles

For insertion between flanges
Corner tapping - type MEF

For insertion between flanges
Flange tapping – type ISB/1
Orifice Flanges and Orifice Carriers

ISB/2

MEF/2
Pitot Tubes
Advantages and Disadvantages

• Pitot Tubes - Insertion and Hot Tap metering
• Orifice plates - Process optimised with improved performance and low flow capability.
• Orifice plates sized to suit the pipe size negating the need for reducer / pipe run combinations
• Maintained performance for existing pipe sizes...
Multi-hole flow conditioning orifice plates

Non standardized flow meters

EPSILON flow meter
1-5 D inlets for 0.2-0.6 Betas
Extensive development of differential pressure transmitters

*Multivariable differential pressure transmitters for mass flow measurement*

- Measure differential pressure, static pressure and has an input from a temperature sensor
- Built in flow computer with fluid density tables
- Dynamic discharge coefficient correction
- Transmitters with <0.075% Span Error
- Of reading accuracy now becoming available
Uncertainty

Installation
- Pipe Run
- Geometry of pipe
- Roughness
- Fluid
- Pressure
- Temperature
- Viscosity
- Composition at mixed fluids
- Choice of steam table
- Reynolds Number

Secondary Instrumentation
Accuracy of differential pressure transmitter:

0,075 % of calibrated span!
- or is it of measured differential pressure?

The curve shows accuracy of orifice plate + transmitter, Where the accuracy of the transmitter is expressed a percentage of calibrated span.
Measuring Range

A statement still often heard:

"An orifice plate has a range of 4 : 1"

According to ISO 5167-2 an orifice plate has a range specified by the relationship between min. and max. Reynolds Number i. e.: $10,000 < Re < 10^8 \sim 10,000 : 1$

In the past the analogue transmitters had an accuracy of 0,5% of calibrated range (22% @ 100:1)

Today: with an accurate transmitter/multivariable transmitter Flow Range 10 : 1 – or better

If larger range is required; use 2 transmitters

First transmitter 10 – 100% (~4% on flow @ 10%)
Second transmitter 1 – 12%
Cost of Air / Compressors

• Installation
• Maintenance
• Capital Cost
• Energy costs

• Source – The Carbon Trust GPG 385, DoE GPG 126
Advantages of d/p metering

• Capital Cost

• Installation Cost

• Operating Cost?
  • High or Low?
  • Do we have an unreasonable expectation of running cost?
Advantages of d/p metering

• Capital cost includes the primary and transmitter

• Approximate primary costs

<table>
<thead>
<tr>
<th>Size</th>
<th>Tab Handled Plate</th>
<th>Compact Orifice</th>
<th>Multi-Hole Orifice</th>
</tr>
</thead>
<tbody>
<tr>
<td>4”</td>
<td>£200</td>
<td>£750</td>
<td>£960</td>
</tr>
<tr>
<td>12”</td>
<td>£300</td>
<td>£1780</td>
<td>£2260</td>
</tr>
</tbody>
</table>
Advantages of d/p metering

Air Flow, 12” line 2400 kg/h max, 1500 kg/h operating @ 1 Bar G and 50 C

<table>
<thead>
<tr>
<th>Pipe size</th>
<th>Q min</th>
<th>Q nom</th>
<th>Q max</th>
<th>Turn down Q max to min</th>
<th>Velocity @ Q max</th>
</tr>
</thead>
<tbody>
<tr>
<td>12”</td>
<td>??</td>
<td>1500</td>
<td>2400</td>
<td>??</td>
<td>4.7 m/s</td>
</tr>
<tr>
<td>Meter type – 12” Vortex</td>
<td>1020</td>
<td>3x Qmin Recommended? No</td>
<td>84500</td>
<td>2.5:1</td>
<td>4.7 m/s</td>
</tr>
<tr>
<td>Meter type 8” Vortex</td>
<td>460</td>
<td>3x Qmin Recommended? Yes</td>
<td>38000</td>
<td>~5.2:1</td>
<td>10.5 m/s</td>
</tr>
</tbody>
</table>

Costs / Time

<table>
<thead>
<tr>
<th>Installation</th>
<th>2 days</th>
<th>£2K</th>
</tr>
</thead>
<tbody>
<tr>
<td>Meter</td>
<td></td>
<td>£2.9K</td>
</tr>
</tbody>
</table>
Advantages of d/p metering

Unrecoverable Pressure Loss – Energy Consumption

<table>
<thead>
<tr>
<th>Loss Location @ Qmax</th>
<th>Losses in mbar</th>
</tr>
</thead>
<tbody>
<tr>
<td>Across the meter</td>
<td>2.00</td>
</tr>
<tr>
<td>Across the 2m pipe reduction</td>
<td>2.50</td>
</tr>
<tr>
<td>Across the reducer</td>
<td>0.32</td>
</tr>
<tr>
<td>Total</td>
<td>4.82</td>
</tr>
</tbody>
</table>
Advantages of d/p metering

• What about an orifice plate?

• For the same flow rate and same pipe beta ratio, i.e. 12” pipe and 8” orifice bore – so a process optimised flow meter.....

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<tr>
<th>Loss Location @ Qmax</th>
<th>Losses in mbar</th>
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<td>d/p generated across the meter (Corner tap)</td>
<td>3.6</td>
</tr>
<tr>
<td>(N.B. Not losses! But d/p!)</td>
<td></td>
</tr>
<tr>
<td>Unrecoverable loss across the meter</td>
<td>2.0</td>
</tr>
<tr>
<td>Total</td>
<td>2.0</td>
</tr>
</tbody>
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Advantages of d/p metering

Costs:

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<tr>
<td>Unrecoverable loss across the meter</td>
<td>2.0</td>
</tr>
<tr>
<td>Costs</td>
<td></td>
</tr>
<tr>
<td>12” Compact Orifice + transmitter</td>
<td>£2900</td>
</tr>
<tr>
<td>Installation (~1/2 day)</td>
<td>£500</td>
</tr>
<tr>
<td>Cap Ex and Op Ex. Budget</td>
<td>Lower than vortex and easier install (107 yr PB)</td>
</tr>
</tbody>
</table>
Advantages of d/p metering

• How can we improve the installation?

• No pressure pipework to install, as it’s a compact orifice

• Reduce the beta to match the unrecoverable loss of the vortex meter, enabling multi-hole orifice plates – Now we can have a 5D inlet

• d/p increases to 6.8 mbar (unrecoverable loss matches the 8” vortex installation @ 4.8 mbar), and so increases the available turndown

• Minimum measurable flow decreases below the range of the vortex meter to 290 kg/h so is optimised to the process and pipework
Advantages of d/p metering

• Now have conditioning plates available for short inlet lengths of pipe (1-5D)
• Process optimised for the existing pipework and process conditions
• Can be calibrated quickly onsite (Or offsite on a 1-2 week turnaround)
• Primaries inspected to standards / manufacturers drawings
• Low cost, no flow calibrations required
• Non manufacturer calibration and verification
Advantages of d/p metering

• Accuracies:-
  • Pitot 1%
  • Orifice from 0.7%
  • Venturi from 0.7-1.5%
  • Transmitters – 0.075% and better – Of reading accuracy is on its way and is being optimised for lower d/p’s
  • T&P corrected affordable MV’s include dynamic Cd correction
Advantages of d/p metering

- Generic Thermal Mass Comparison – Single Point TMFM
- Typ. 1.5% of reading 10-100% URL (~5.5-55 NMPS)
- + 0.15%*URL for lower flows
- :: @ 0.5AMPS (290 kg/h) = 1 NMPS ~8% error

- Can we match the error?
- Cd error for an orifice sized at 1500 kg/h ~ 2.5%
- Error on d/p 2.5%
- Error on flow 3.6%
- If we use an MV, we can reduce the error further due to corrected Cd.
Advantages of d/p metering

Points to note:-

• It's not a single point device
• You can use a multi-hole orifice or multi-point pitot
• You can calibrate on site using local calibration companies at a time to suit you – enabling verifications
Advantages of d/p metering

Costs of metering:

(Payback on installation ~ 100 years @ £1500 savings)

<table>
<thead>
<tr>
<th>Energy costs @ 11 ppkWh</th>
<th>Based on 25 mbar (most sized well below this d/p)</th>
<th>4-20mA</th>
</tr>
</thead>
<tbody>
<tr>
<td>Orifice / Multi Hole</td>
<td>£30.00 (£5-£6 @ 4.8 mbar)</td>
<td>£0.30</td>
</tr>
<tr>
<td>Pitot</td>
<td>£6.00</td>
<td>£0.30</td>
</tr>
<tr>
<td>Mag meter comparison @ 8W</td>
<td>N/A</td>
<td>£10.00</td>
</tr>
<tr>
<td>@17W</td>
<td></td>
<td>£20.00</td>
</tr>
<tr>
<td>TMFM 8-14W</td>
<td>N/A</td>
<td>£7-£14</td>
</tr>
</tbody>
</table>
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