Highly Precise In-Situ Chemical Blending and Dispense System

Jürgen Hahn, Reto Schöb
Levitronix
Flow Control With Levitronix Pump

System Control
- Set Flow
- Actual Flow
- ON/OFF

Warning Signals
- Flow Alarm (Low Flow -> Line Clogged)
- Trend Warning (Dynamic Condition Trending)
Centrifugal Pump Characteristics

Low Flow Operation Range

Pressure

Flow

[liters/min]

[bar]

[gallons/min]

[psi]
Relationship between Pump Speed, Pump Pressure and Pipe Flow

For Low Flow Operation Range:

\[
\text{Pump Pressure} \sim \text{Pump Speed}^2
\]

Hazen-Williams Formula:

\[
\text{Pipe Flow} \sim \text{Pressure Loss}^{0.54}
\]

Flow Through Pump-Pipe-System:

\[
\text{Pipe Flow} \sim \text{Pump Speed}^{1.08}
\]

- Nearly Linear Relationship Between Pump Speed And Pipe Flow
  - Constant Control Gain
  - Good Resolution Over Wide Flow Range
Relationship between Pump Speed, Pump Pressure and Pipe Flow (Graph)

Pump Pressure & System Flow vs. Pump Speed

Nearly Linear Relationship Between Flow And Pump Speed!
Resolution of Open-Loop Flow Control

Resolution of speed control

10 rpm @ (200 – 6000 rpm)

With max. speed = 6000 rpm

Open-loop flow control resolution

0.15% of max. flow @ (3 – 100% of max. flow)
Resolution of Closed-Loop Flow Control

In closed-loop flow control, the resolution is mainly determined by the flowmeter.

Examples:

With Malema M-2100, Size 04: 0 – 4000 mL/min
- Repeatability in-between 50-4000 mL/min: ± 0.5%
- Absolute Accuracy (after fluid calibration) ± 1%

With Malema M-2100, Size 06: 1600 – 8000 mL/min
- Repeatability in-between 1600-8000 mL/min: ± 0.5%
- Absolute Accuracy (after fluid calibration) ± 1%
On-Line Blending of Chemicals with Levitronix Pump

Concentrated Slurry

Chemical 1

DI-Water

Main Liquid

Peroxide

Chemical 2

Levitronix Pump 1

Flow Meter

Pump Controller 1

Levitronix Pump 2

Flow Meter

Pump Controller 2

Levitronix Pump 3

Flow Meter

Pump Controller 3

Warning Signals
- Out of flow range
- System Warnings

System Control
- Flow setting
- Start/Stop

Main Flow
Accuracy of Blending System

Example:
Main flow 1 – 4 L
Part Flow 4 – 50 mL/min
Mixing ratio 1:80 – 1:800
Flowmeter Malema M-2100, Size 04 for all channels

Repeatability of Mixing Ratio ± 1%
Absolute Accuracy of Mixing Ratio ± 2%
(after fluid calibration)
Test Results I
MAINSTREAM + 1 PARTSTREAM, MIXTURE RATE 70:1, NO BUFFER TANK

<table>
<thead>
<tr>
<th>Mixture Rate 70:1</th>
<th>Max: 1,4853 wt% (+0,14%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mainstream Flow 3,5 l/min</td>
<td>Min: 1,4807 wt% (-0,18%)</td>
</tr>
<tr>
<td>(Concentration Sensor right after Blending System)</td>
<td>Aver: 1,4833 wt%</td>
</tr>
</tbody>
</table>

---

Graph showing concentration vs. time with measured concentration, average + 2%, and average - 2%.
Test Results II
MAINSTREAM + 1 PARTSTREAM, MIXTURE RATE 150:1, NO BUFFER TANK

Mixture Rate 150:1
Mainstream Flow 2.5 l/min
(Concentration Sensor right after Blending System)

Max: 0.7859 wt% (+0.39%)
Min: 0.7840 wt% (-0.25%)
Aver: 0.7859 wt%

Measured Concentration
Average + 2%
Average - 2%
Test Results III

MAINSTREAM + 1 PARTSTREAM, MIXTURE RATE 300:1, NO BUFFER TANK

Mixture Rate 300:1
Mainstream Flow 3.5 l/min
(Concentration Sensor right after Blending System)

Max: 0.3913 wt% (+0.44%)
Min: 0.3873 wt% (-0.58%)
Aver: 0.3896 wt%

Measured Concentration
Average + 2%
Average - 2%
Test Results IV
MAINSTREAM + 1 PARTSTREAM, MIXTURE RATE 600:1, NO BUFFER TANK

Mixture Rate 600:1
Mainstream Flow 3.5 l/min
(Concentration Sensor right after Blending System)

- Max: 0.2080 wt% (+0.66%)
- Min: 0.2053 wt% (-0.63%)
- Aver: 0.2066 wt%

<table>
<thead>
<tr>
<th>Time [sec]</th>
<th>Concentration [wt%]</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>0</td>
<td>0.202</td>
</tr>
<tr>
<td>100</td>
<td>0.204</td>
</tr>
<tr>
<td>200</td>
<td>0.206</td>
</tr>
<tr>
<td>300</td>
<td>0.208</td>
</tr>
<tr>
<td>400</td>
<td>0.210</td>
</tr>
<tr>
<td>500</td>
<td>0.208</td>
</tr>
<tr>
<td>600</td>
<td>0.208</td>
</tr>
</tbody>
</table>

- Measured Concentration
- Average + 2%
- Average - 2%
Test Results V
MAINSTREAM + 1 PARTSTREAM, MIXTURE RATE 800:1, NO BUFFER TANK

Mixture Rate 800:1
Mainstream Flow 3,5 l/min
(Concentration Sensor right after Blending System)

Max: 0.1413 wt% (+1.07%)
Min: 0.1377 wt% (-1.56%)
Aver: 0.1398 wt%
Test Results VI

MAINSTREAM + 1 PARTSTREAM: MIXTURE RATE 150:1, 16L BUFFER TANK

Mixture Rate 150:1
Mainstream Flow 3.5 l/min
System Off/On Behavior
(Concentration Sensor after 16L-Tank)

Max: 0.6653 wt% (+0.16%)
Min: 0.6633 wt% (-0.14%)
Aver: 0.6642 wt%

Turn Off/On
Generating Predictive Warnings with Dynamic Condition Trending (DCT)

- Max Speed Limit
- Speed Warning Limit
- Trend Warning
- Flow Alarm
- Advance Warning Time

Graph showing speed (rpm) vs. time (days) with marked trend limits and warning points.

- Flow: 200 mL, 0 mL
- Time: 0 2 4 6 8 10 12 days
- Speed: 0 1000 2000 3000 4000 5000 6000 rpm

Trending Band
Comparison Between Pump Control And Valve Control
Flow Control with Control Valve

Sorce: Malema MFC-4600 Flow Controller
Typical Flow Characteristic of Diaphragm Valve

Flow Coefficient vs. Valve Lift

Non-Linear Relationship Between Flow and Valve Lift!
Resolution of Open-Loop Flow Control with Control Valve

Example for valve characteristic from previous page
Max. valve lift = 4mm
Positioning resolution 0.25% (10µm) Problems: backlash, hysteresis…

Low flow range (0 < 10% of max flow)
Valve gain = 6
Flow control resolution = valve gain * positioning resolution = 1.5%

Medium flow range (10 - 70% of max flow)
Valve gain = 3
Flow control resolution = valve gain * positioning resolution = 0.75%

High flow range (> 70% of max flow)
Valve gain < 0.5
Flow control resolution = valve gain * positioning resolution = 0.1%