PIVOTAL

SYSTEMS

Improving Etch Tool Performance Using an In Situ Gas Flow Monitoring (GFM) & Control System

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Presentation Based on Joint Article with IBM

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Pivotal Systems – In Situ Monitoring & Control of Key Parameters for Wafer Processing

Real time gas flow measurement during wafer processing; accurate to +/- 0.5% of actual flow

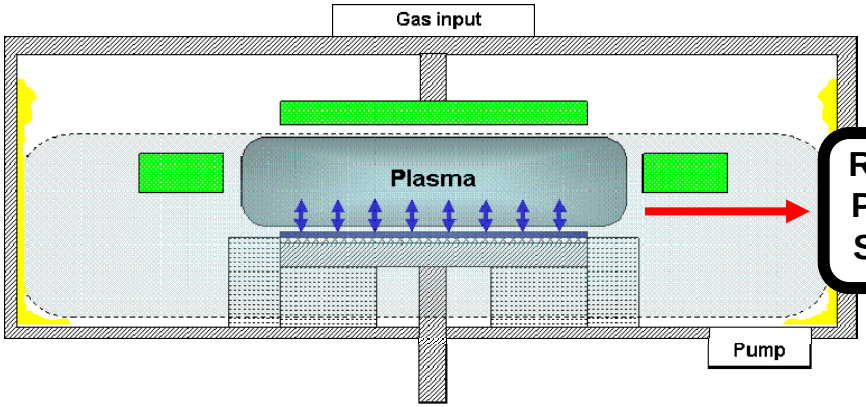
Gas Flow Monitor

TODAY'S FOCUS

Gas Flow Controller

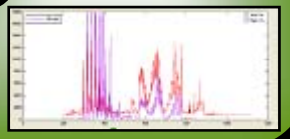
IN DEVELOPMENT

Breakthrough MFC technology offering accuracy +/-0.5% of set point with 0.5-100% flow range



Remote Plasma Sensor

Atomic gas composition analysis



Increasing Yield, Extending Equipment & Reducing COO

Demands on Gas Flow Delivery Systems Increasing

- **Smaller dimensions & features**
  - Gas flow rates as low as 2sccm
  - Accuracy & repeatability of flow to set point as low as ±0.5%

- **Continuous plasma processing (for RIE defect reduction)**
  - No gas flow stabilization steps
  - Repeatability of gas flow transients and settling times critical for optimized yield parameters (e.g., CD)

Gas Flow Delivery Systems Struggling to Keep Up

- **Best-in-class MFCs**
  - ±1% of set point
  - Typically >±1% at low flow (unless special low flow MFCs are used)
  - Run to run variability in transients and settling times

- **Existing MFC flow verification / calibration approaches**
  - Only off-line measurements (~2-3% of tool availability), no real-time
  - Accuracy ranges from ±1% to as high as ±5%

While power delivery, chamber temperature and pressure are monitored / controlled with tight accuracy, gas flow delivery systems are struggling to keep up

Pivotal's Gas Flow Monitoring (GFM) System

- **Real-time, In-situ: Gas flow monitoring during wafer processing**
- **First Principles Measurement: Rate of pressure drop**
- **High Accuracy and Repeatability: Better than ±0.5% of flow**
- **Quick Measurement: Less than 5 seconds (200ms for transients)**
- **Easy Installation: Standard wetted parts used in gas sticks today**

- **Significant benefits**
  - Identify out-of-spec MFC drifts and transients
  - Eliminate tool downtime from off-line MFC calibration
  - Reduce MFC troubleshooting costs, eliminating "no fault" found MFC FA
  - Avoid costly wafer scrap events due to gas flow variations
  - Improve chamber matching and device yield

Existing Gas Flow Verification Solutions

Existing solutions, often executed once per week or less, include:

- **Chamber rate of rise**
  - Typically ±3-5% (to do it right takes a long time for temp stabilization)
- **Flow path diversion methods such as the MKS GBROR® or Tru-Flo® Mass Flow Verifier**
  - Typically ±1% accuracy
- **Molbloc (Test Lab Standard)**
  - Typically ±0.2% accuracy

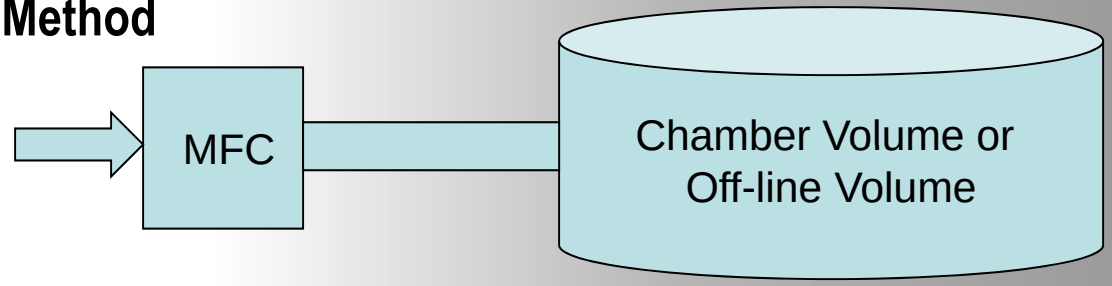
MKS GBROR®

De facto Industry Standard

- **Typically 60 seconds per measurement**
- **Flow path diversion measurement**
- **Loss of wafer processing time**

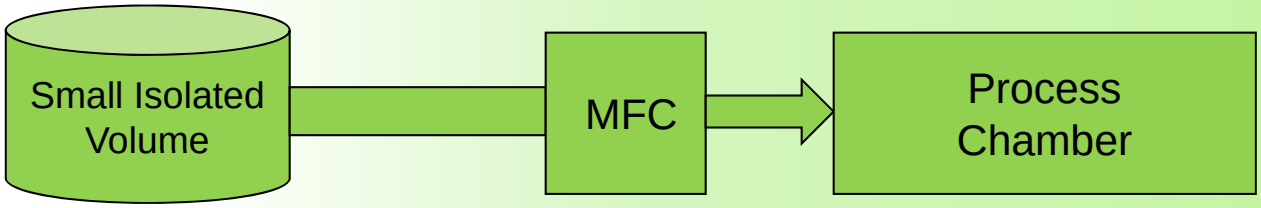
Pivotal's Real-Time GFM Method

Existing Method



- Measure pressure rate of rise in an isolated downstream volume.
- Must be run off-line
- Accuracy varies from ±1-5%

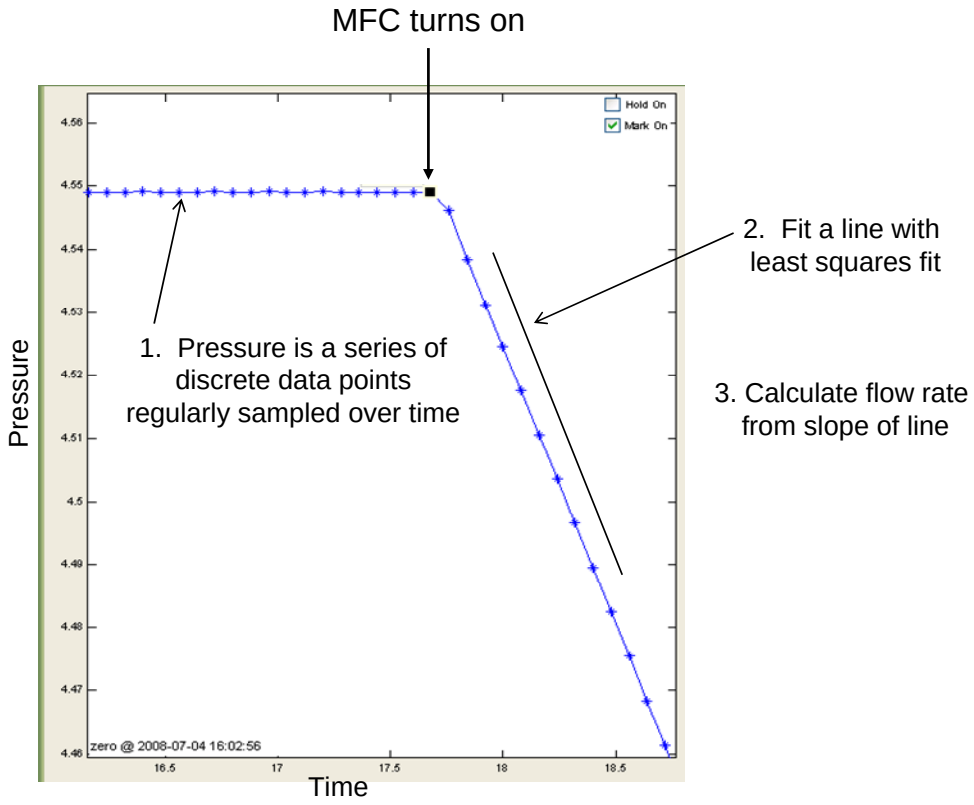
Pivotal's GFM Method



- GFM method is to observe pressure drop versus time in an isolated upstream volume providing real-time data during standard production flow
- Accuracy of ±0.5% of flow

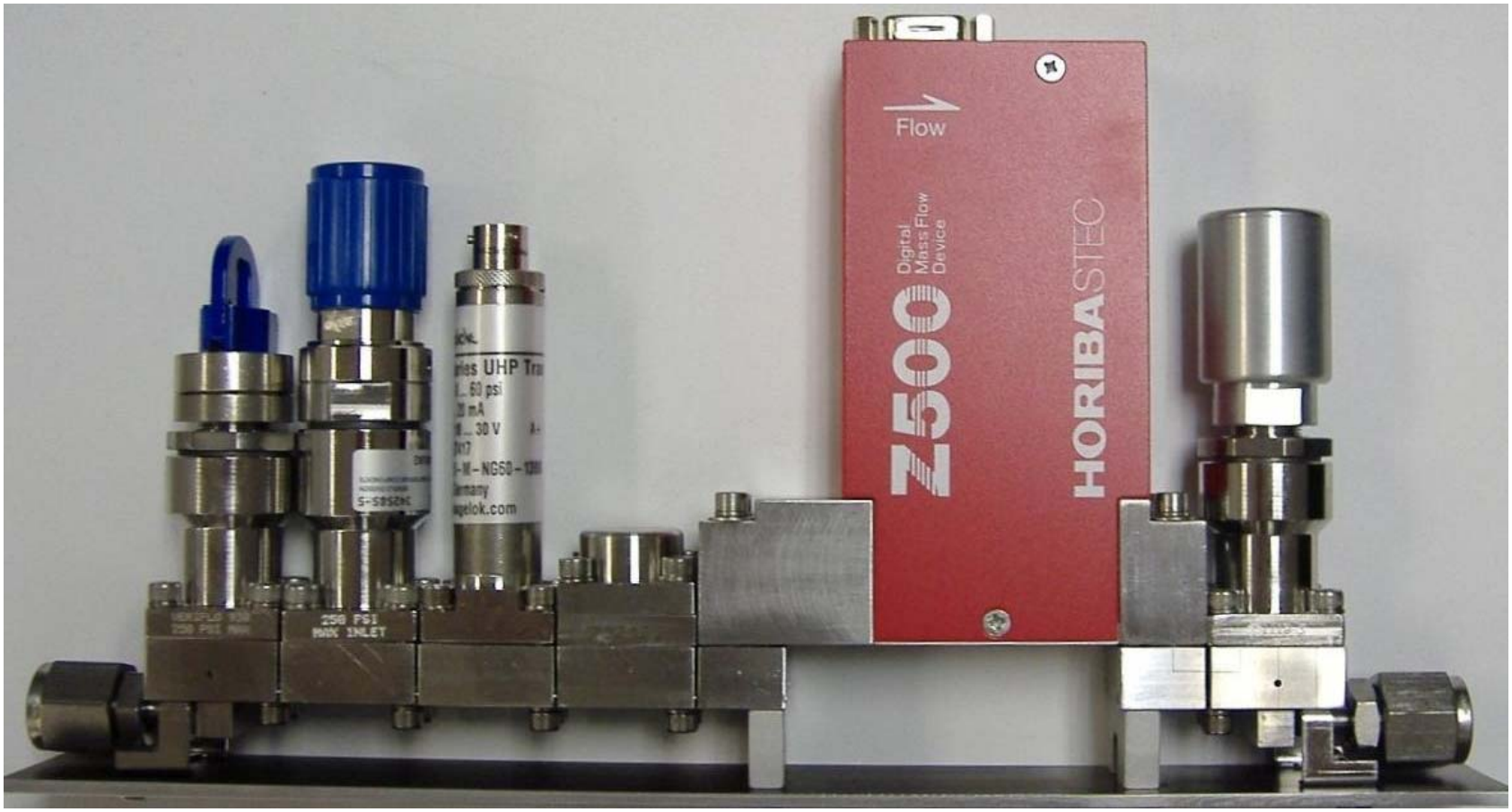
Operating Principle - Ideal Gas Law

- **From the Ideal Gas Law, we know pressure in an isolated volume will decrease linearly with time when the flow rate out of the fixed volume is constant**

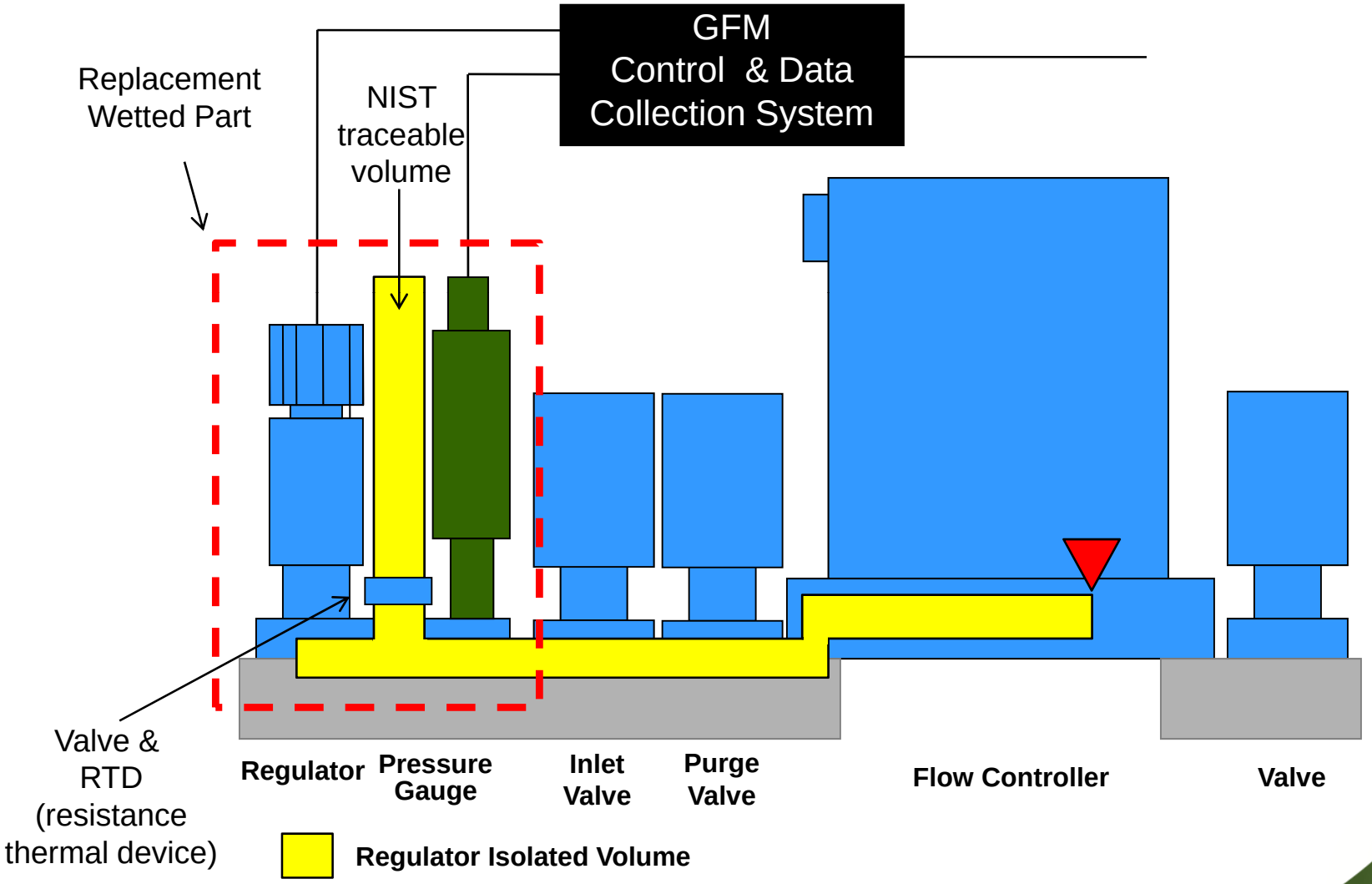


- **PV = nZRT**
  - P is the absolute pressure of the gas
  - V is the volume of the gas
  - n is the number of moles of the gas
  - R is the universal gas constant
  - T is the absolute temperature
  - Z is the compressibility factor
- **n = PV/ZRT**
- **$\Delta n = \Delta P\ V/ZRT$**

Typical Gas Stick



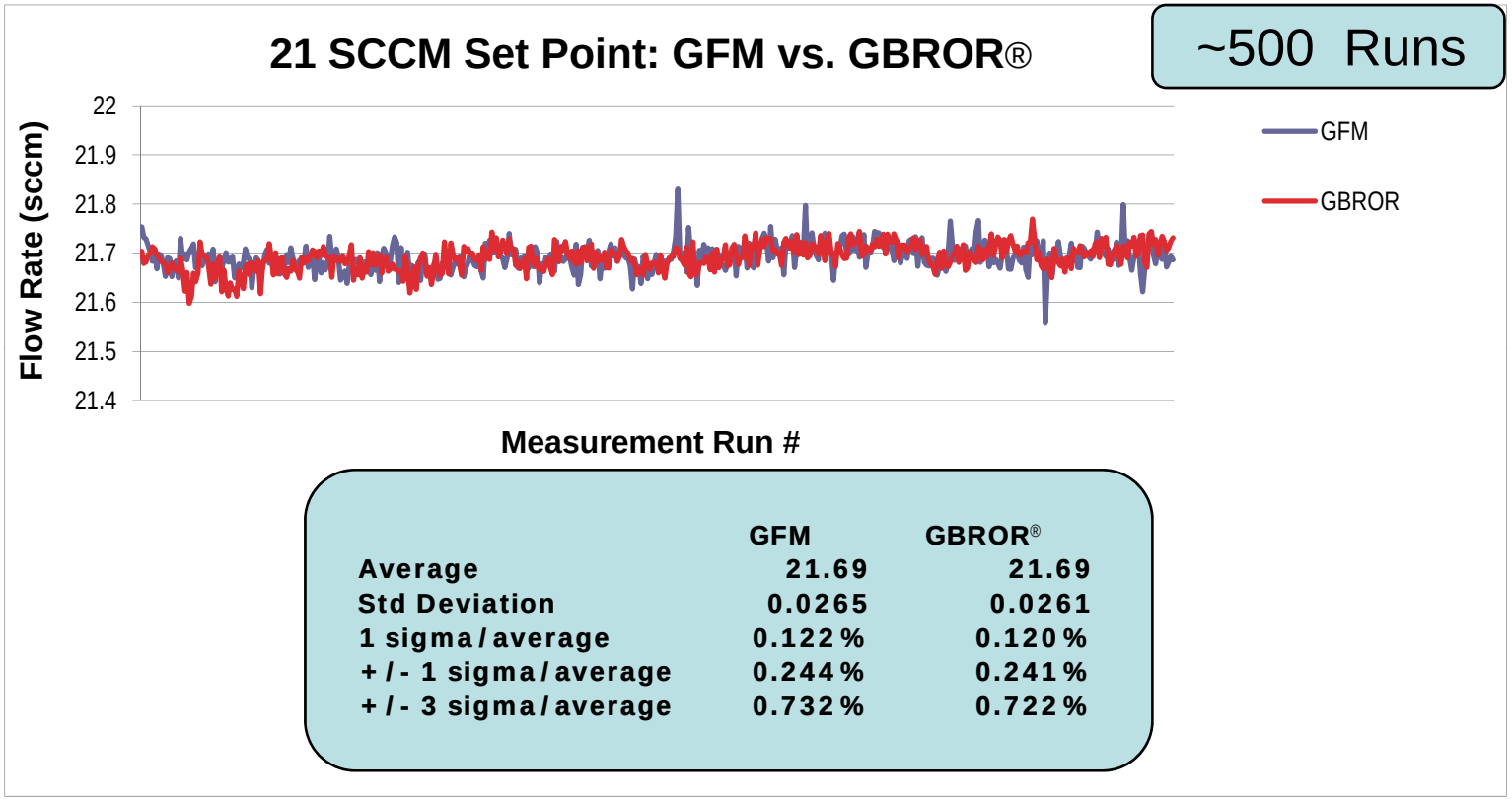
Pivotal's Solution: Gas Flow Monitor (GFM)



Pivotal Data for GFM

- Accuracy & Repeatability
- Production Data
- Transient Studies

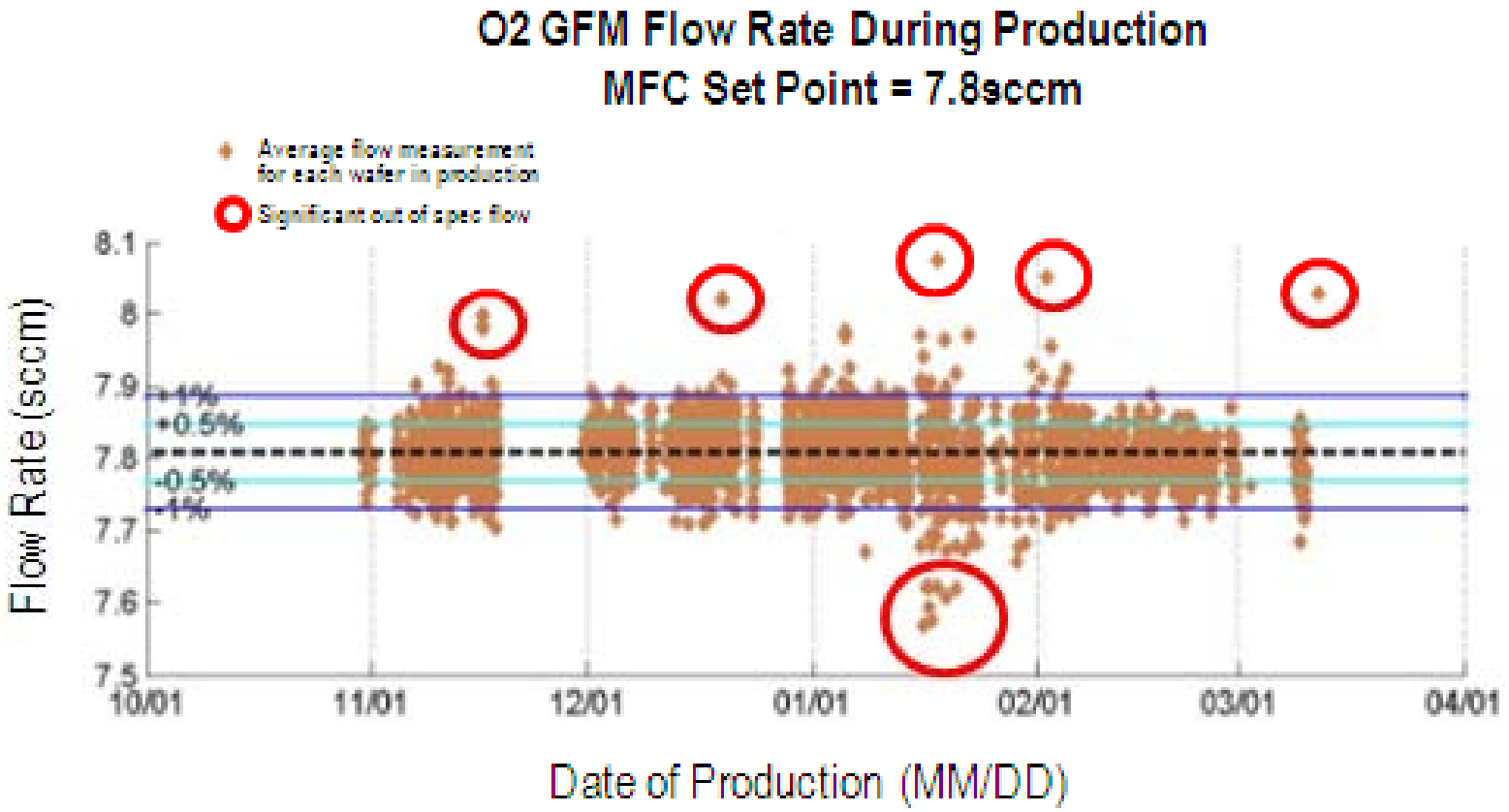
Excellent Agreement between GFM & MKS GBROR®



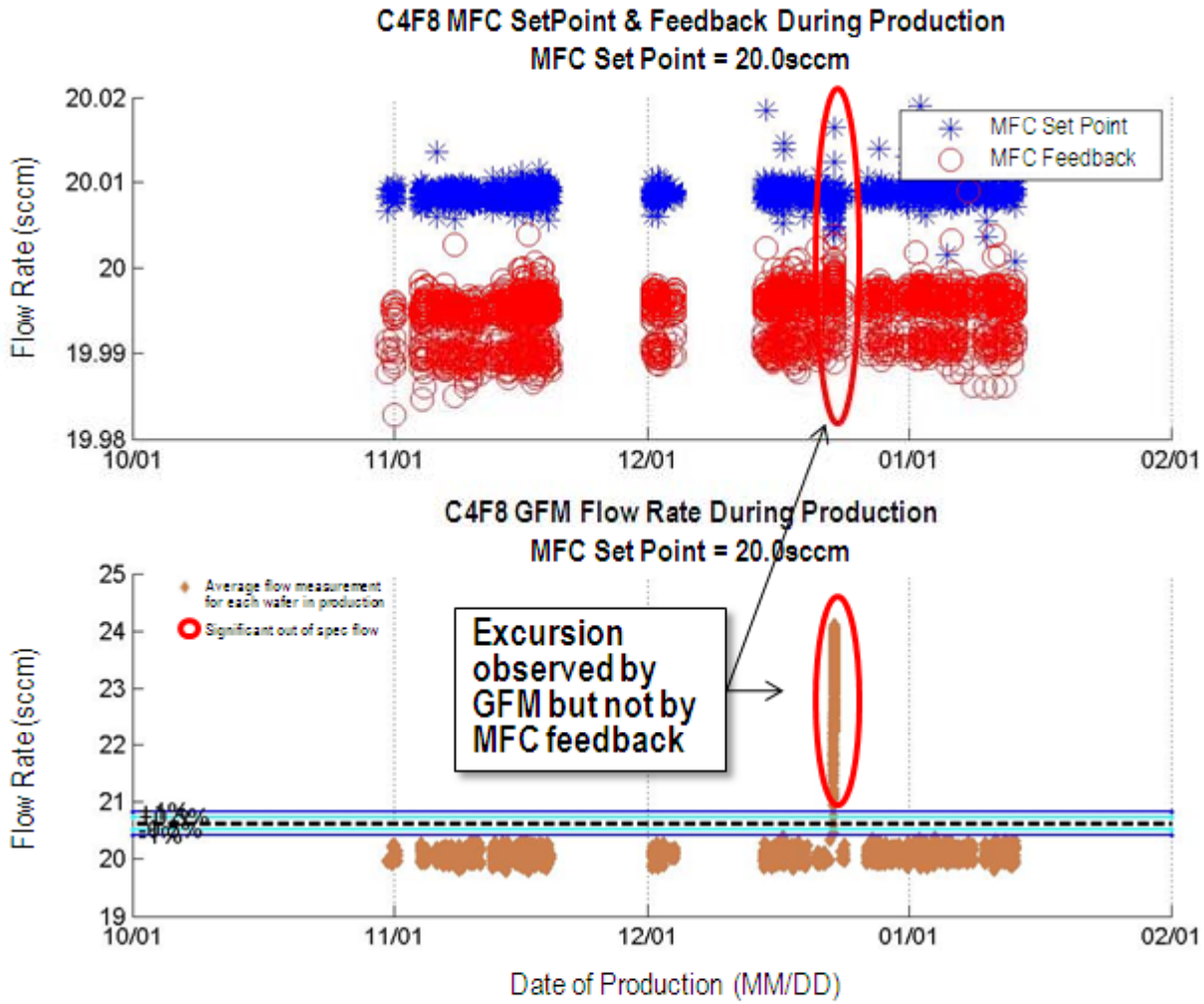
	GFM	GBROR®
Average	21.69	21.69
Std Deviation	0.0265	0.0261
1 sigma/average	0.122%	0.120%
+/- 1 sigma/average	0.244%	0.241%
+/- 3 sigma/average	0.732%	0.722%

- **Measurement techniques differ between GFM & GBROR®**
  - GBROR® measures average flow rate over 1 minute
  - GFM measures flow rate in the initial 5 seconds of gas flow

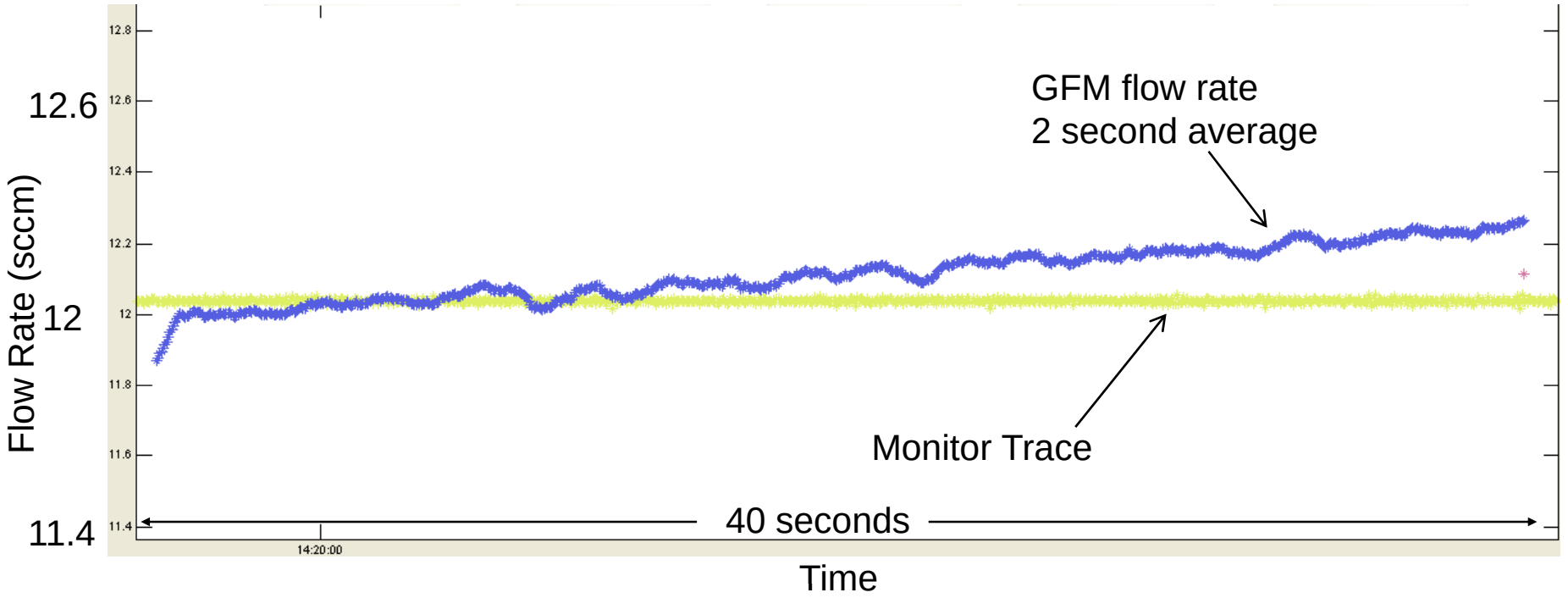
Example Production Data – O2 MFC



Example Production Data – C4F8 MFC

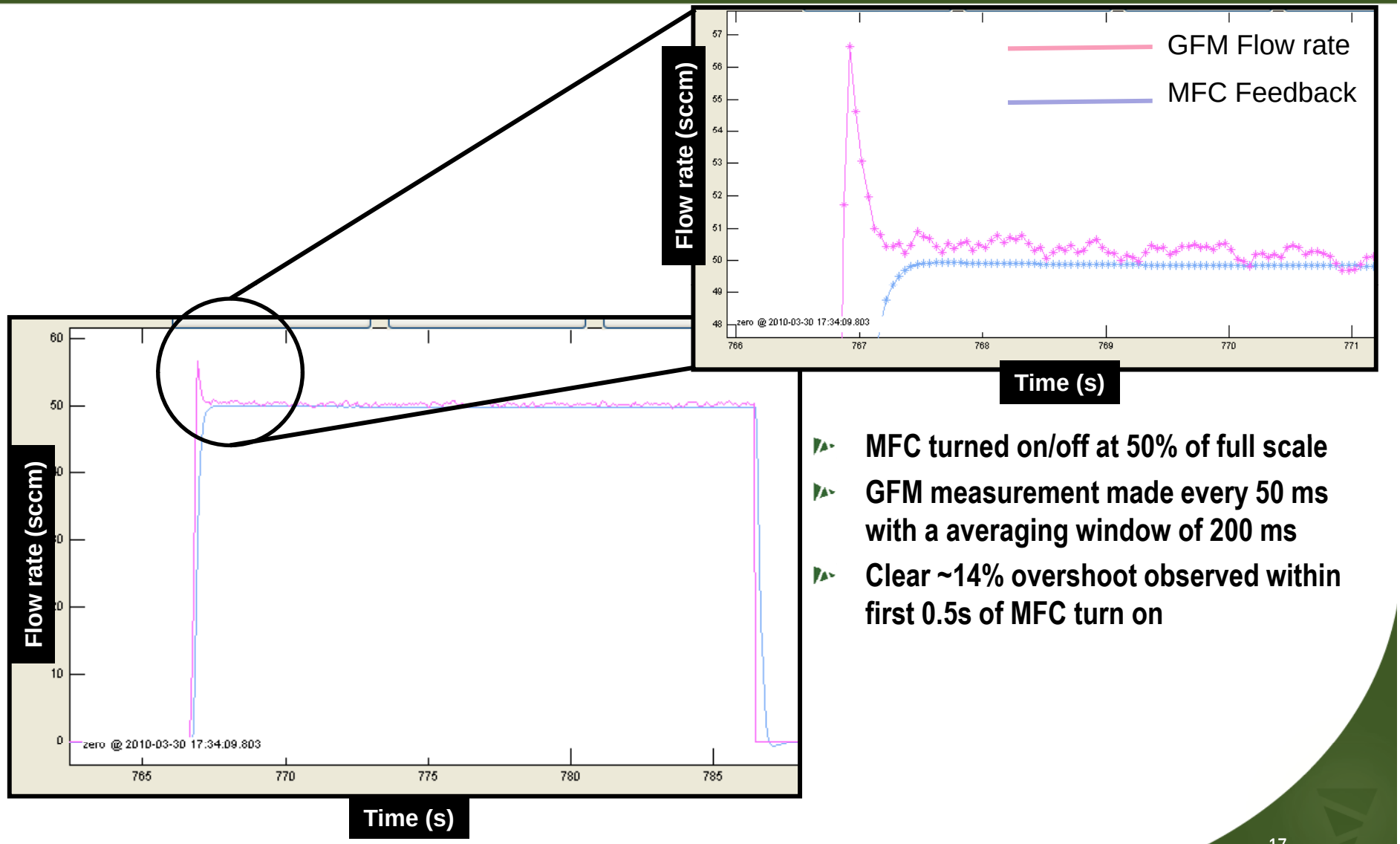


Example Production Data – HBr MFC



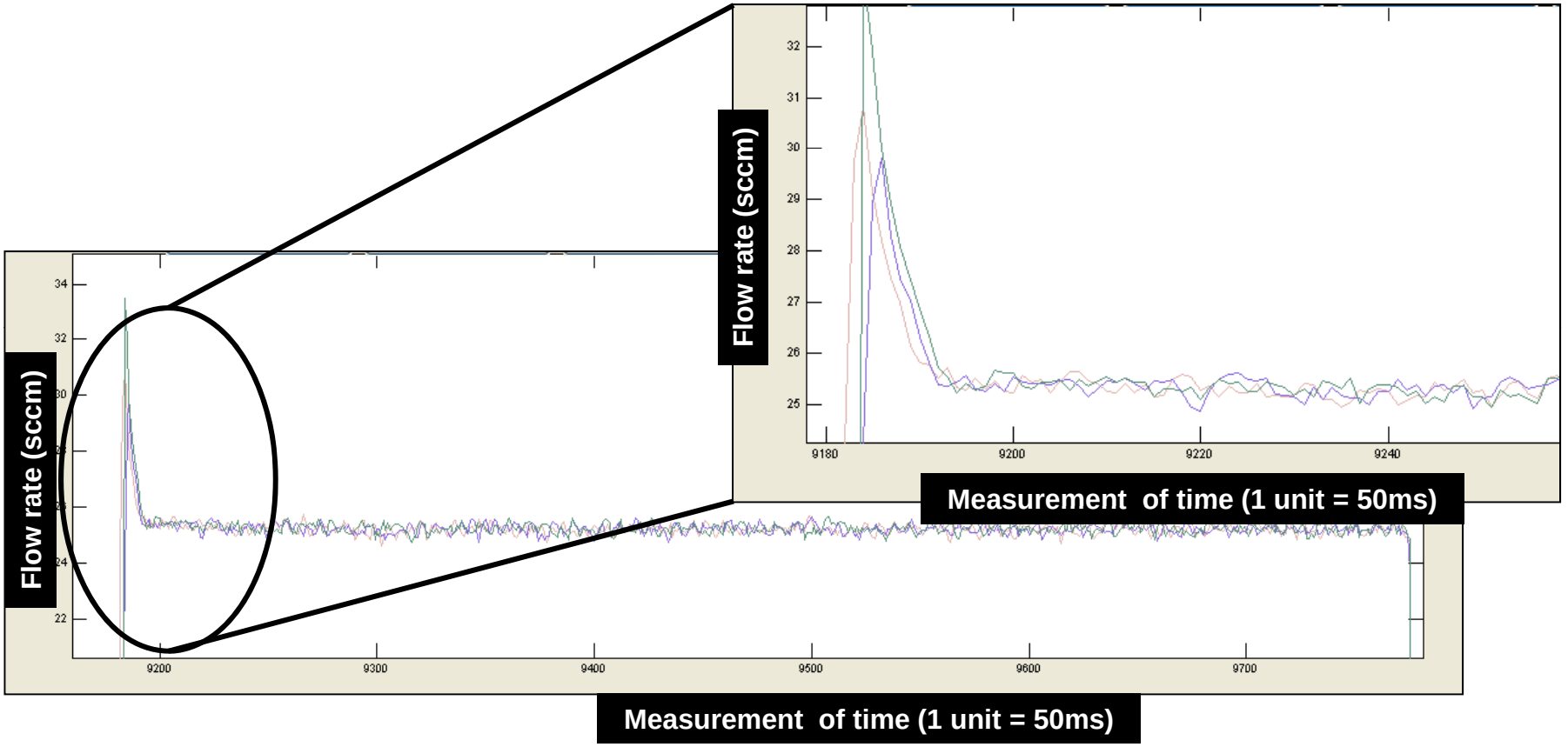
- **Example of a MFC with a set point that is drifting over time.**
- **GFM measurement made every 50 ms catches the drift**
- **The customer tried to recalibrate this MFC but it failed and was replaced**
- **<u>If MFC were tested by GBROR which averages data over ~1min it would pass!!</u>**

Transients – On/Off Square Wave (50% Full Scale)



- MFC turned on/off at 50% of full scale
- GFM measurement made every 50 ms with a averaging window of 200 ms
- Clear ~14% overshoot observed within first 0.5s of MFC turn on

Transients – On/Off Overlay (25% Full Scale)



- MFC turned on/off at 25% of full scale and cycled ~160 times
- GFM measurement made every 50 ms with a averaging window of 200 ms
- Three runs selected for display, from beginning, middle and end of cycling
- Overshoot ranging from ~15%-30% observed between runs

Control Schemes using GFM

When an MFC is observed to be out of flow specification during wafer processing, automatic control options include:

- **Alerting equipment engineer**
- **Stopping wafer processing- operator intervention**
  - Recalibrating troubled MFC
  - Swap MFC
- **Changing MFC set point for subsequent wafer (feedback control loop)**

Control Schemes using GFM

Without Pivotal GFM

- **Best-in-class MFCs**
  - ±1% of set point
  - Typically >±1% at low flow (unless special low flow MFCs are used)
  - Run to run variability in transients and settling times
- **Existing MFC flow verification / calibration approaches**
  - Only off-line measurements (~2-3% of tool availability), no real-time
  - Accuracy ranges from ±1-5%

With Pivotal GFM

- **Know what your MFC is running**
  - Accuracy & Repeatability to ±0.5%
  - 50ms sampling for Transients
- **Take action in real time**
- **Minimize service and diagnostic downtime**

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