



Automation | Valves | Measurement | Process Control

Regulatory Controls Audit
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November, 2019



A regulatory audit is a performance review of regulatory loops to identify loops that are not performing well

Why?

- Cut costs
- Improve quality
- Offload operators and engineers
- Great starting place for a neglected area with problems
- APC is performing poorly
- Is new APC required? Advisable?

The Audit

Regulatory Audit Steps

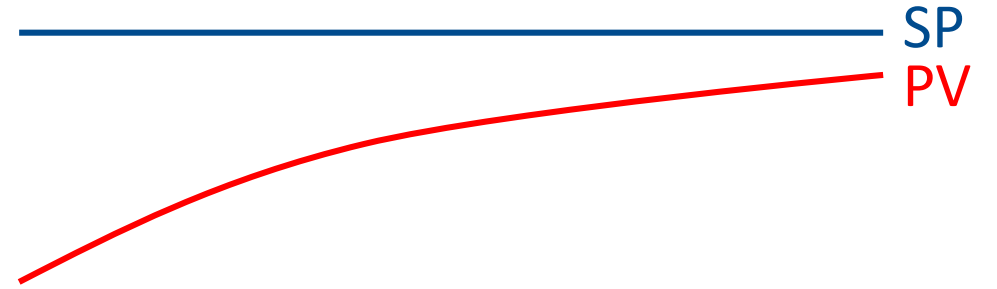
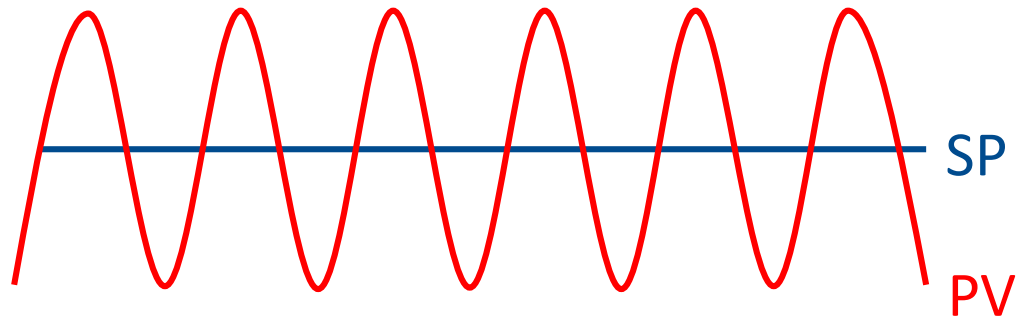
1. Create a list of important regulatory loops
2. Review each loop's operation
3. Identify problems
4. Basic trouble-shooting
 1. Causes of common failure modes
 2. Measurement specific problems

Identify Important (Bleaching) Regulatory Loops

- Chemical Flows
- Stock Temperatures
- pH
- Consistency
- Tower Levels
- Others

PV = SP?

Four Failure Modes



Manual

Data Flow



Measuring
Device



Transmitter



DCS

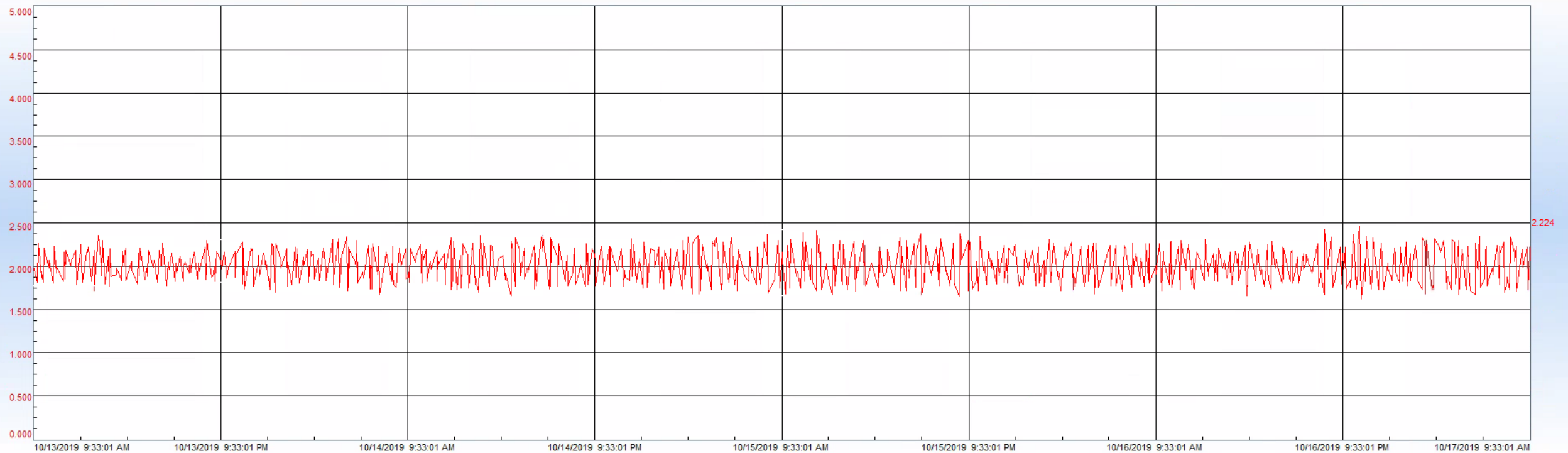


Historian

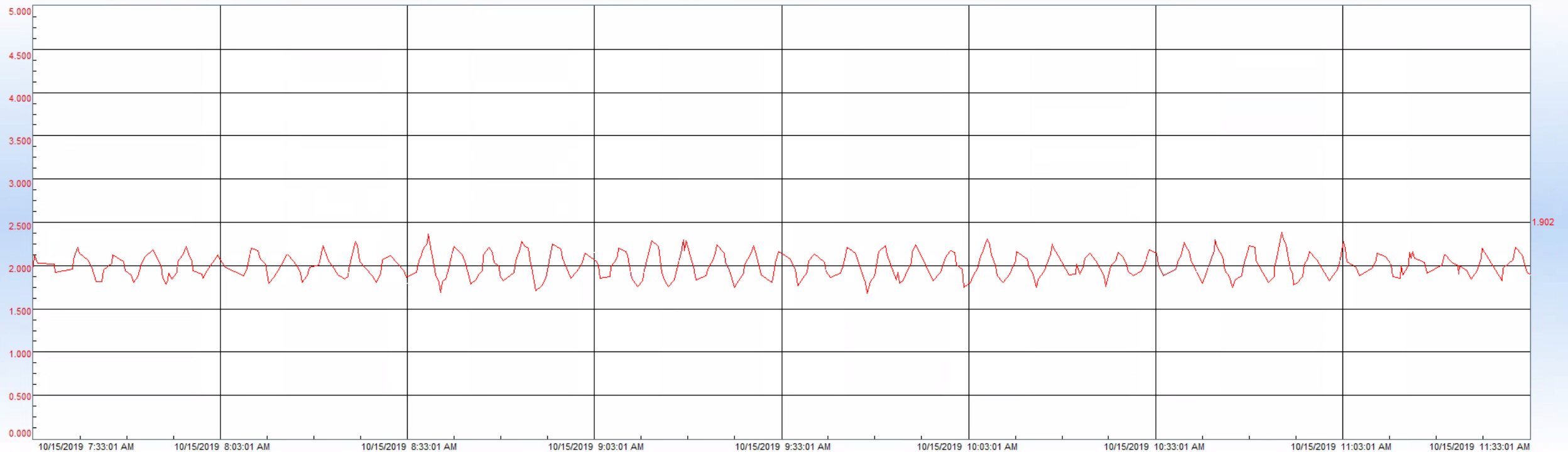
Review the Operation of Each Loop

- Minutes, hours, days
 - Cycling
 - Time Response
- Weeks or months
 - Saturated (0% or 100% output)
 - Manual mode
- Panning
 - Behaviour may only occur under certain process conditions
- Zooming
 - Behaviour might be clearer at higher resolution
- Historian may need more data or better resolution

Four Days of Data (Looks like Noise)



Four Hours of Data (Same Signal)

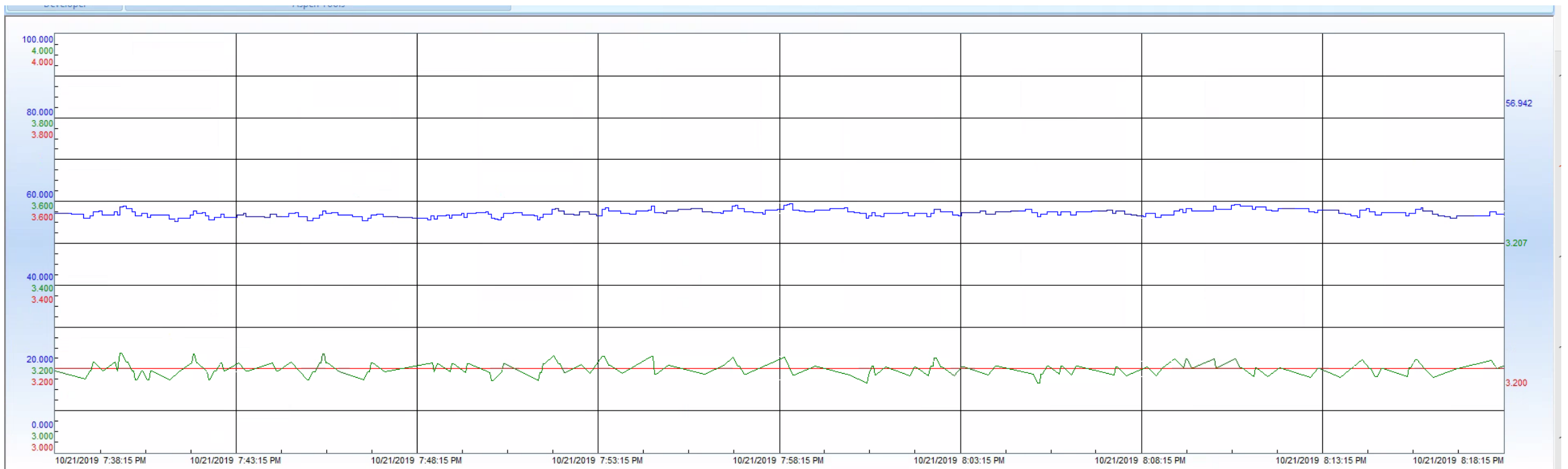


Controller Effectiveness

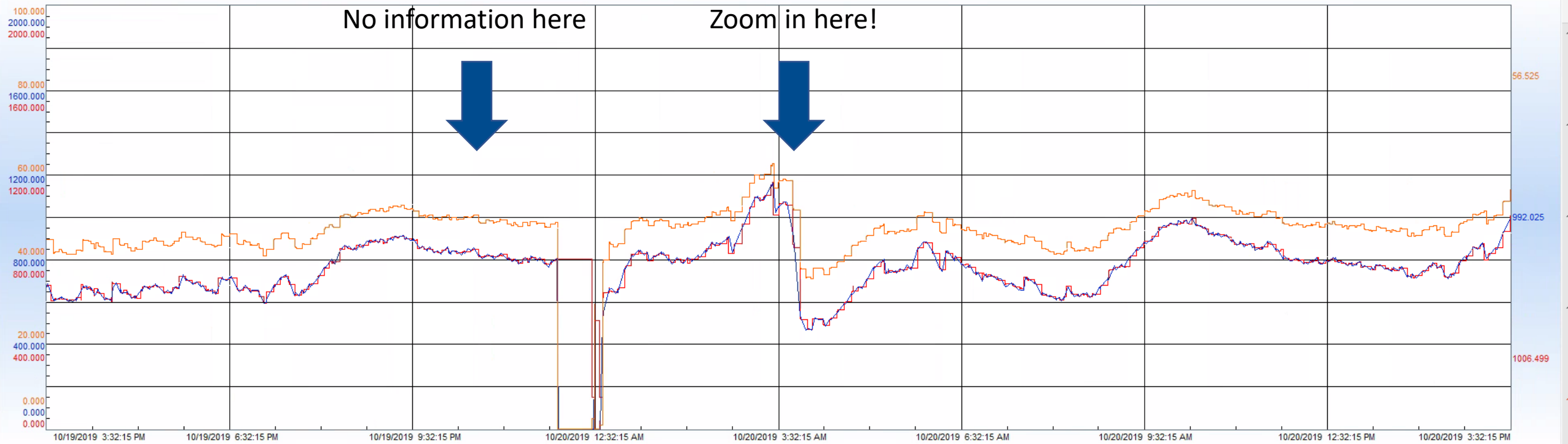
- Controller's purpose is to:
 - Follow setpoint changes
 - Reject disturbances
- If the setpoint and process are stable, controller is not excited
- Look for periods where either:
 - SP is moving (but not tracking PV)
 - SP is stable, but output is moving (disturbance rejection)

This is a Stable Process

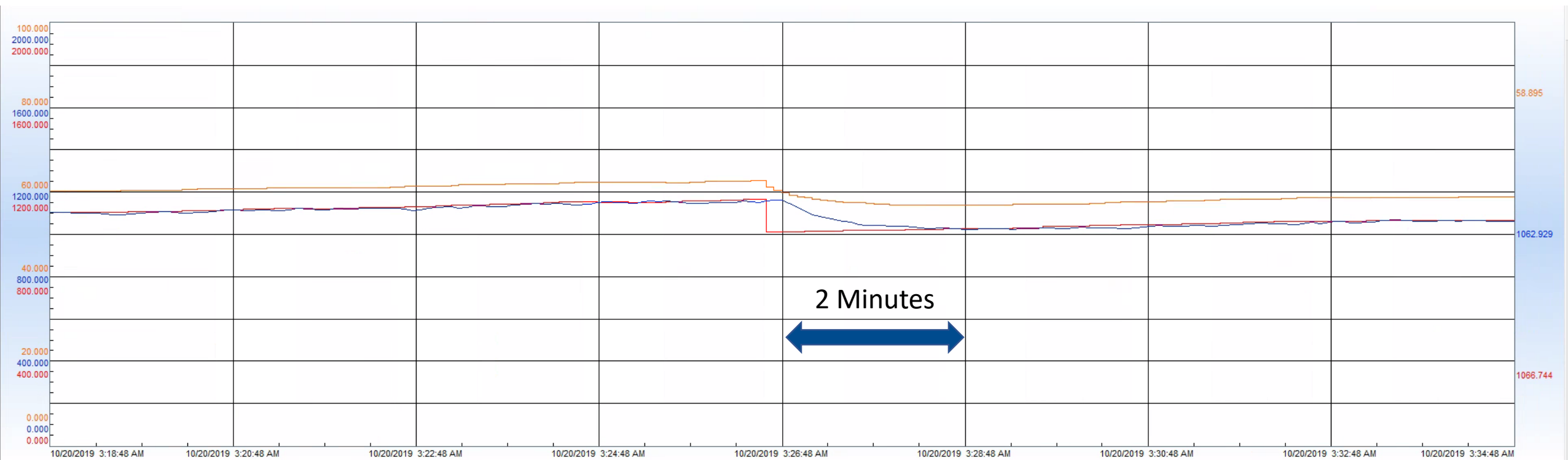
We don't know if the controller is functioning properly or not, as it is not stressed.



Where to Check Response Time

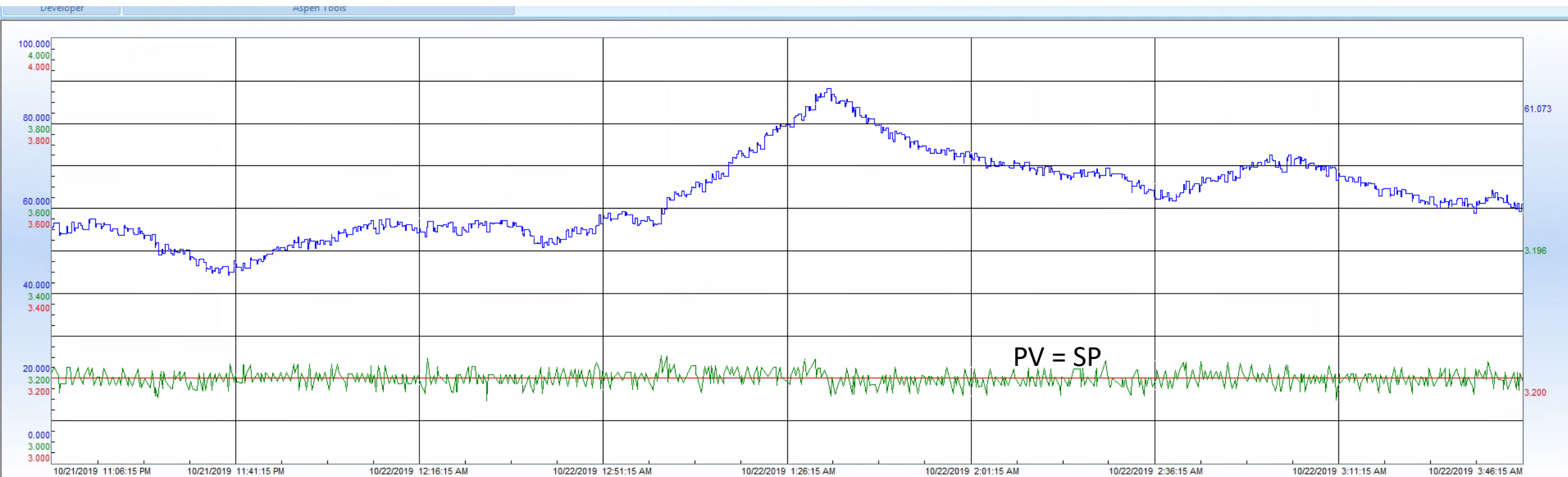


Setpoint Change Response



Controller is Rejecting Disturbances

Changes in output show that controller is rejecting disturbances.



Poorly Performing Loops

- Log the failure type
- Intermittent problems
 - At what dates & times did the problem occur?
 - What were the process conditions?
- Steady problems
 - When did the problem start?
 - Compare with maintenance records
- E.g. TIC100 started cycling on August 2nd at 8 am

Part 2: Basic Trouble-Shooting

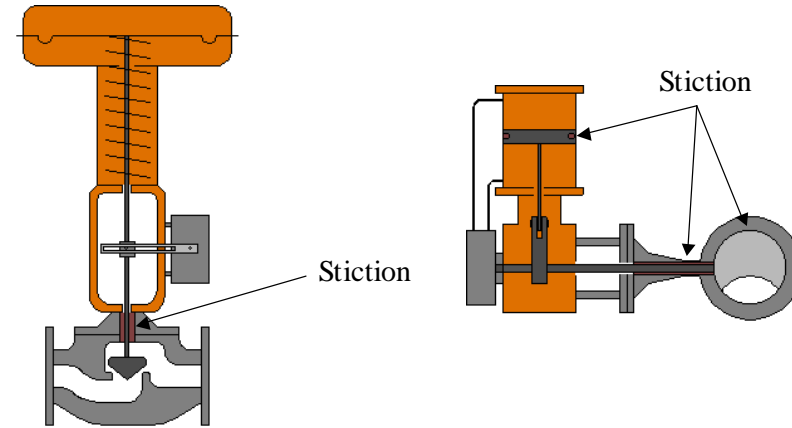
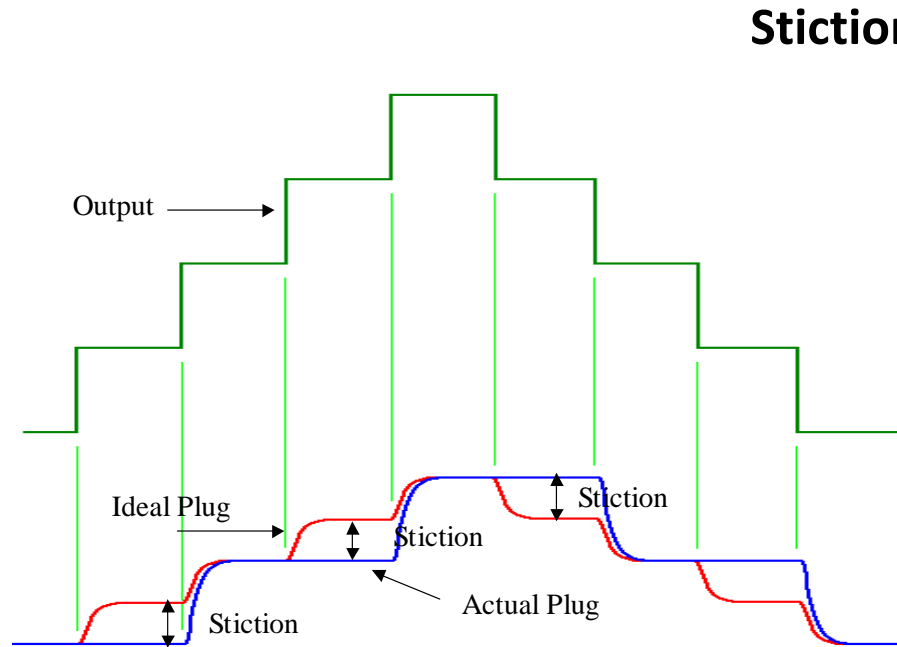
Failure Mode #1: Cycling

- Cycling disturbance
- Cycling setpoint
- Poor tuning
- Sticky or oversized valve

Cycling

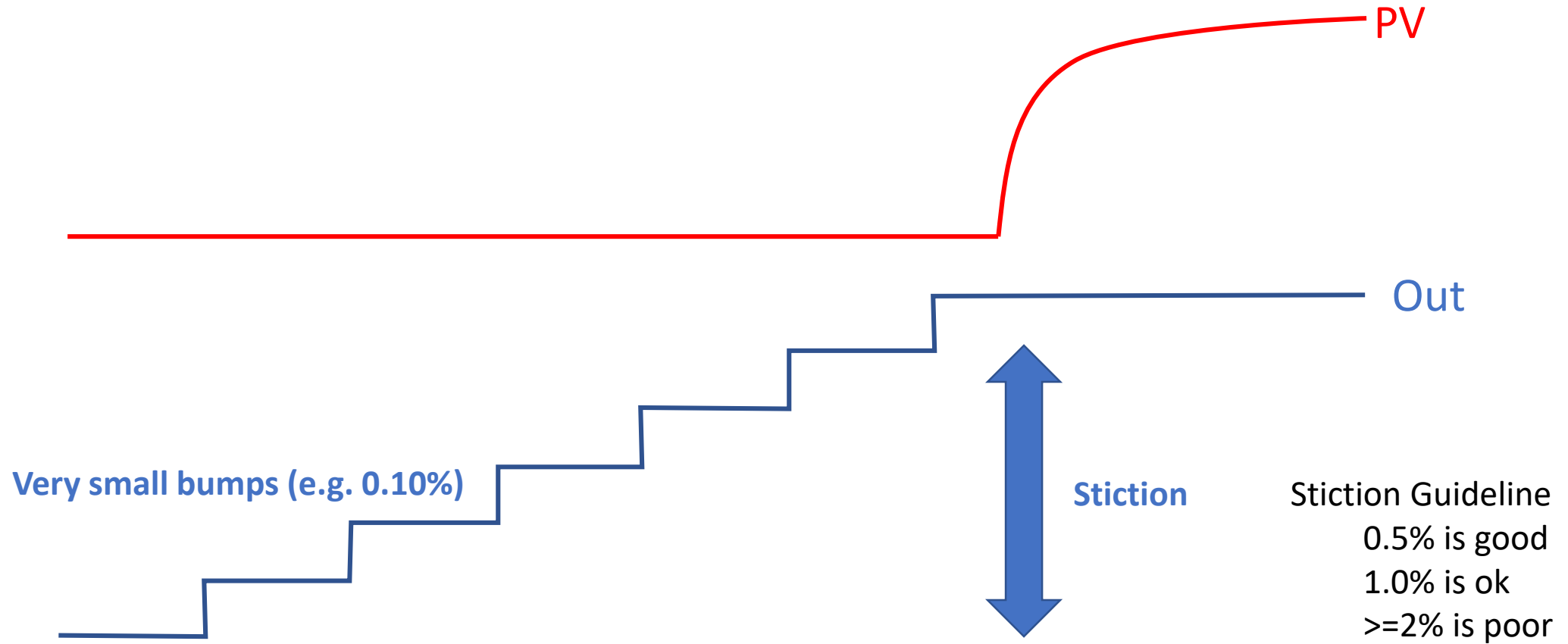
- Does PV cycle with valve in manual?
 - Cycling disturbance (e.g. header pressure)
- Is the setpoint cycling?
 - Fix the master controller
- Is the cycling intermittent?
 - Detune (tune for highest process gain, longest deadtime)
 - Use gain scheduling or linearize
- Check the valve stiction

Valve Stiction



The metal to metal or metal to packing contact is not frictionless. The valve must overcome the static friction before it will move.

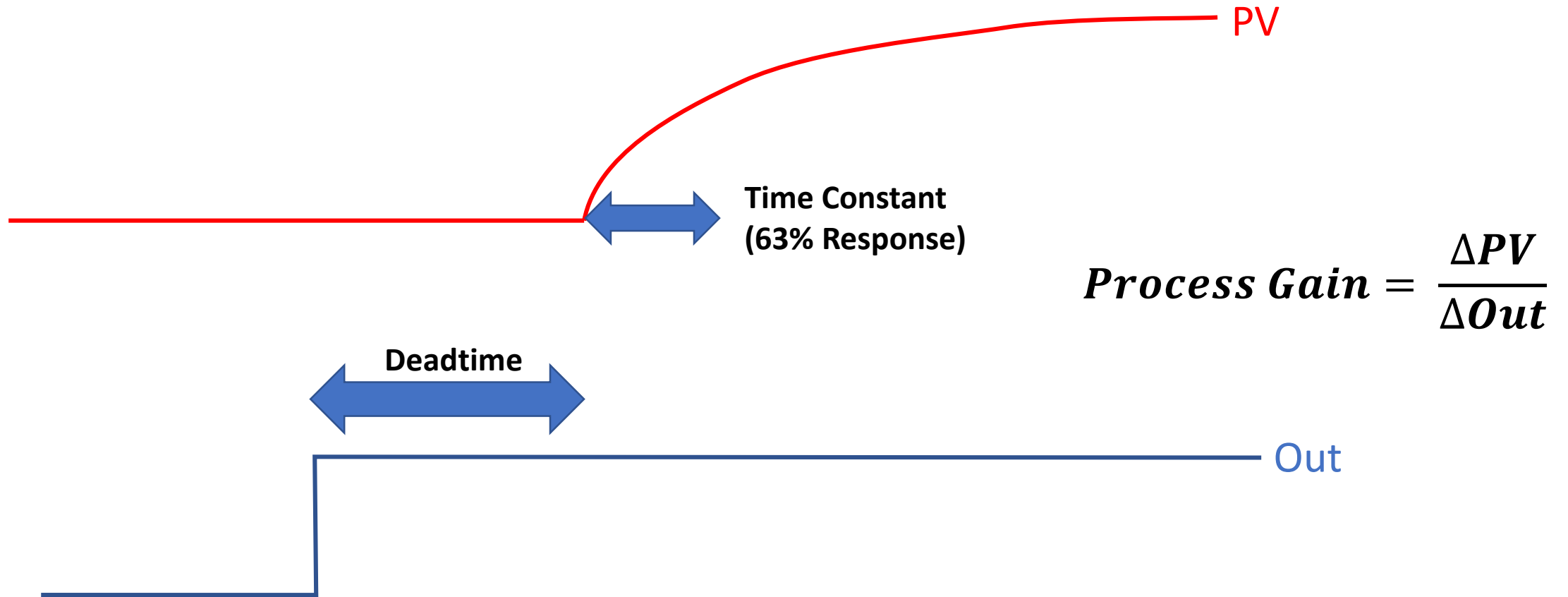
Stiction Testing



Stiction and Oversized Valves

- Stiction is 2%
- Valve is open 10%
- You can only control in step increments of 20% of SP
- Oversized valves will tend to cycle
- Replace with
 - Correctly sized valve (if always oversized)
 - Better quality valve (if sometimes oversized)

Quick Review Terminology



Tuning

- Controllers are tuned based on gain, deadtime, time constant (“response characteristics”)
- If any of these change a lot ($>2x$), the controller may be destabilized
- Response (process gain, time) often depends on the production rate
- The main driver of controller instability is deadtime

Digital Valve Positioners

- Positions the valve electronically
- Capable of self diagnostics, sends this information via HART
- Triggers alerts when maintenance is required
- Becoming very common in pulp mills
- Main advantage is diagnostic information



Digital Valve Positioner On-Line Diagnostics

- IP integrity test
 - E.g. mechanical damage, water ingress
- Relay integrity test
- Air mass flow diagnostic
 - Predicts tubing leaks, piston ring and diaphragm issues
- Supply pressure diagnostic
- Travel deviation alarm
- Friction and deadband values
 - Performance metrics

Failure #2: Valve is Saturated

- Easy to spot
- Look over very long time periods
- Note the process conditions
 - Startup?
 - High kappa?
 - High production rate?

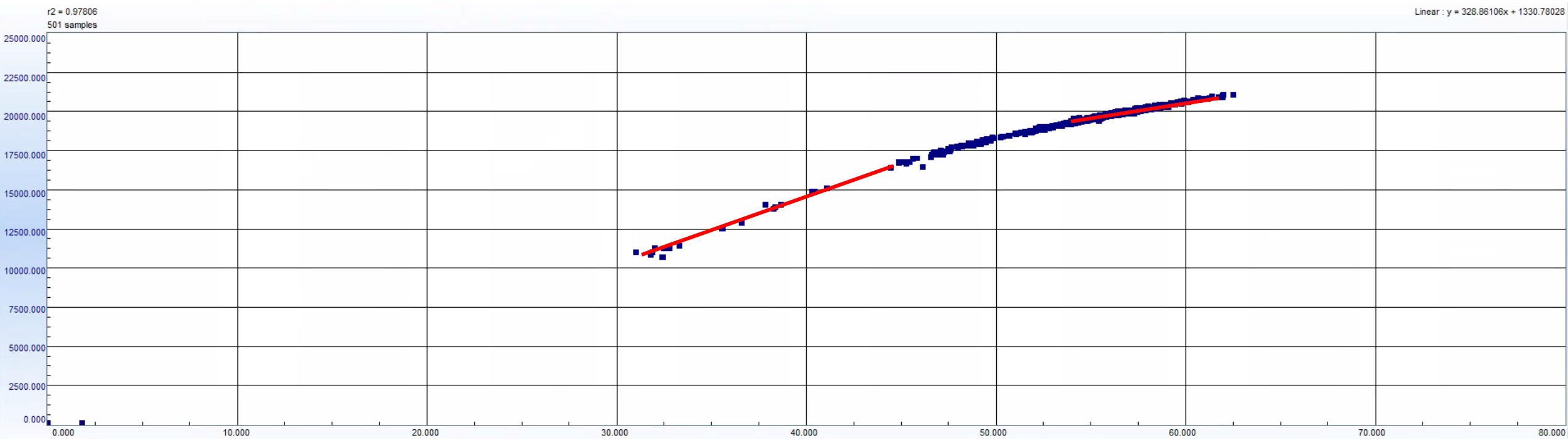
What is Good Performance? Rules-of-thumb

- The PV should not frequently stay on the same side of the SP for long periods (e.g. 3x) compared to the deadtime and time constant
 - E.g. Flow control should be at setpoint in seconds
- Auto mode with SP change should not be more than 3x slower than manual mode with output change
- One exception is when it is desirable to limit the control action
 - E.g. Tower level control may be slow to limit the effect on washer
- Master loop must be tuned much slower than slave (e.g. 5x)

Failure Mode #3: Slow Response

- Is the response saturated?
 - E.g. no effect between 20% and 100%
- Is it tuned slowly for a reason?
 - Dampens the cycling?
 - Variable process response?
- Can we gain schedule?
 - Set the gains based on a process measurement
 - Use a flow or charge controller as a slave
 - E.g. pH control as master, NaOH charge or flow as slave
- Only necessary if the process gain changes at least 2x

Non-linear Valve Response (3x)



Failure Mode #4: Manual

- When does this occur? Is it shift related?
- Talk to the operators!
- Problem often depends on unusual process conditions
 - It generally works “but” ...
- The solution often lies in adding logic
 - If situation “x” then do “y”
- Is there a measurement problem?
- Consider redesigning the control strategy

pH Measurement and Control

pH Measurement

- Hot alkali is very hard on probes
- Response time will increase as probe deteriorates
- Use slope and offset to determine replacement time
 - Offset > 50
 - Slope < 52
- Filtrate extractors are great for ease of maintenance
- pH 10 buffer is not as robust as other buffers
 - Calibrate using pH 4 and 7 for all probes
- Remember solution temperature compensation for hot alkali

pH Probe Problems (Simplified)

- **Scale buildup** is visible and can be cleaned
- **Poisoning** is not visible, gives a high offset, replace (sulfide, bisulfite)
- **Worn glass** gives a low slope, replace
- **Improper wiring, ground loop** will give a noisy or drifting reading
- **Dry sensor** has high glass impedance, soak in pH 4 solution

Keeps sensor moist



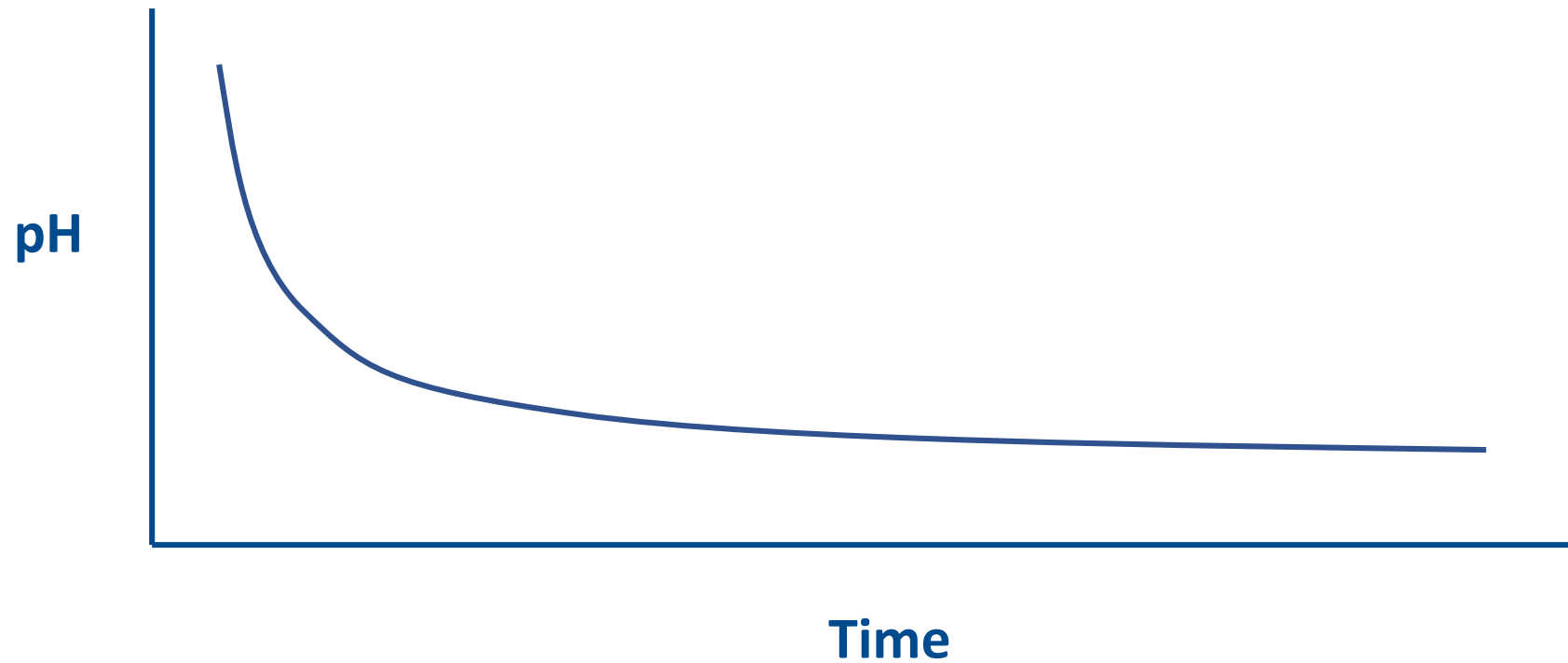
pH Calibration Issues – Symptoms / Probable Cause

- No response to buffers
 - Incorrect wiring
 - Broken glass, coated glass, dehydrated glass
- Slow response to buffers
 - Coated glass, dehydrated glass
 - Coated reference junction
- Low slope (<50mV/pH)
 - Coated glass, dehydrated glass
 - Coated reference junction
- High offset (>50mV)
 - Poisoned reference electrode
 - Coated reference junction
- Jumpy readings
 - Wiring
 - Ground loop
 - Coated reference junction

pH Measurement

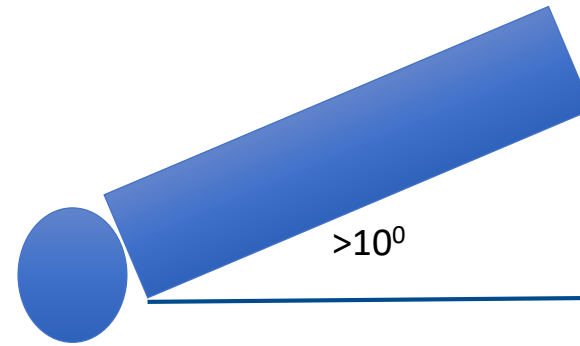
- There are a variety of probes available
- Large reference junction
 - Resists scale effects
- Multiple reference junctions
 - Resists poisoning
- Partially rebuildable
 - Replace the reference junction, clean, refill

Inlet pH Response with Time

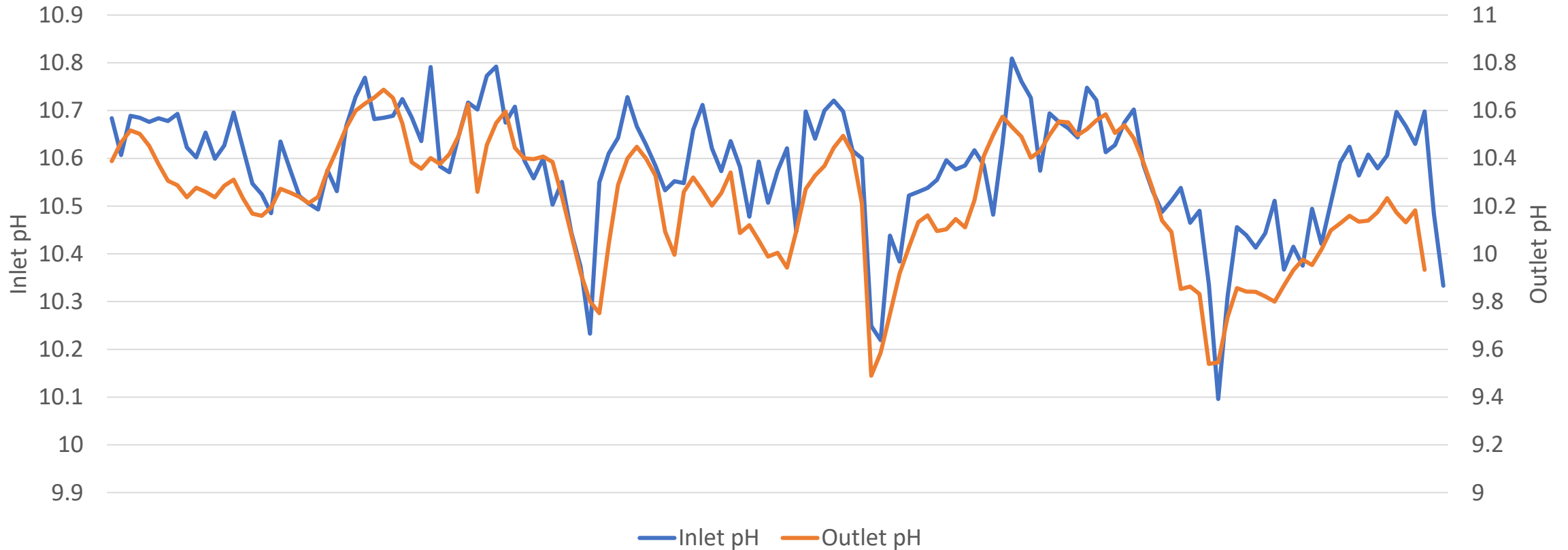


pH Probe Installation Tip

Probe tip is $>10^\circ$ below horizontal
Keeps the bubble away from the tip



Inlet & Vat pH Correlation for 6 Days



Inlet data is shifted by 2 hours

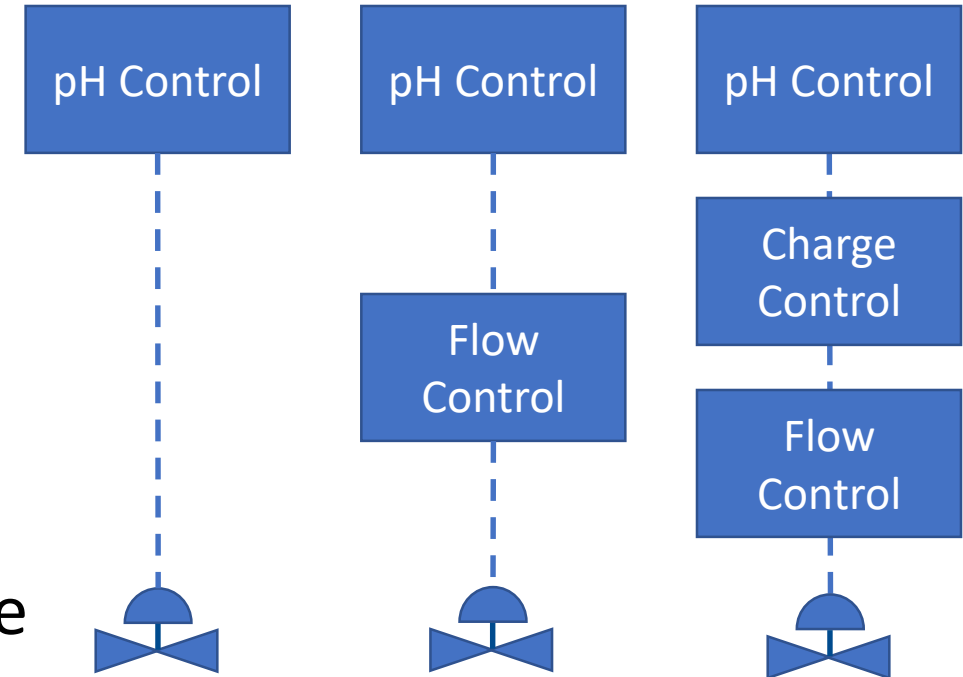
pH Control (Illustrative)

Condition	Low Production	High Production
Effect of valve change on flow	High	Low
Effect of flow change on pH	High	Low
Time Delay	High	Low

Effects multiply, so the effect of the valve position gain could change considerably!

Regulatory pH Control

- Flow control slave
 - Removes supply pressure effects
 - Removes valve characteristics
- Charge control slave
 - Removes production effect on pH process gain
 - Provides a useful backup and better limits
- Which to use largely depends on the deadtime
 - Short deadtime, simple will work
 - Long deadtime, use charge control

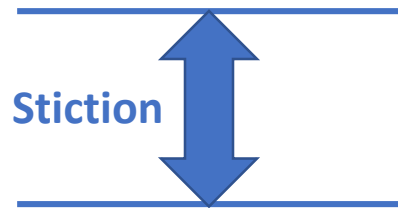


Level Measurement and Control

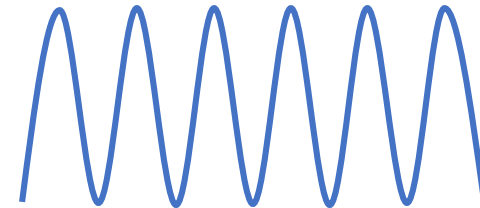
Bleach Plant Tower Level Control

- Tower levels very commonly cycle
- Level is integrating, so any valve stiction will create a cycle
 - Valve will oscillate around its steady-state value
 - Level will oscillate around its setpoint
 - This cannot be eliminated, only the frequency can be changed
 - Using low stiction valves or VFDs reduces amplitude
- Poor tuning and/or control design will amplify the cycle in later stages

Level Control



Steady-State



Minimum
valve
cycling

Choice is between:

High frequency valve cycle (high wear), low tower level cycle

Low frequency valve cycle (low wear), high tower level cycle

Tower Level Control

- Classic “Tanks-in-Series” problem
- Must use feedforward
 - Production rate
 - Tower/ring dilution
 - Careful with feedforward at startup
- Ensure good consistency control at D0 inlet

Temperature Measurement

- Normally measured using a Resistive Temperature Device (RTD)
- It MUST touch the thermowell!
- If it doesn't touch
 - Very slow response
 - Destabilizes the controller and cycling results
- RTDs wear out due to vibration
- Normally fails high, but (rarely) may get flaky

Flow Measurement and Control

Flow Meter Technology

- Differential Pressure



- Magnetic



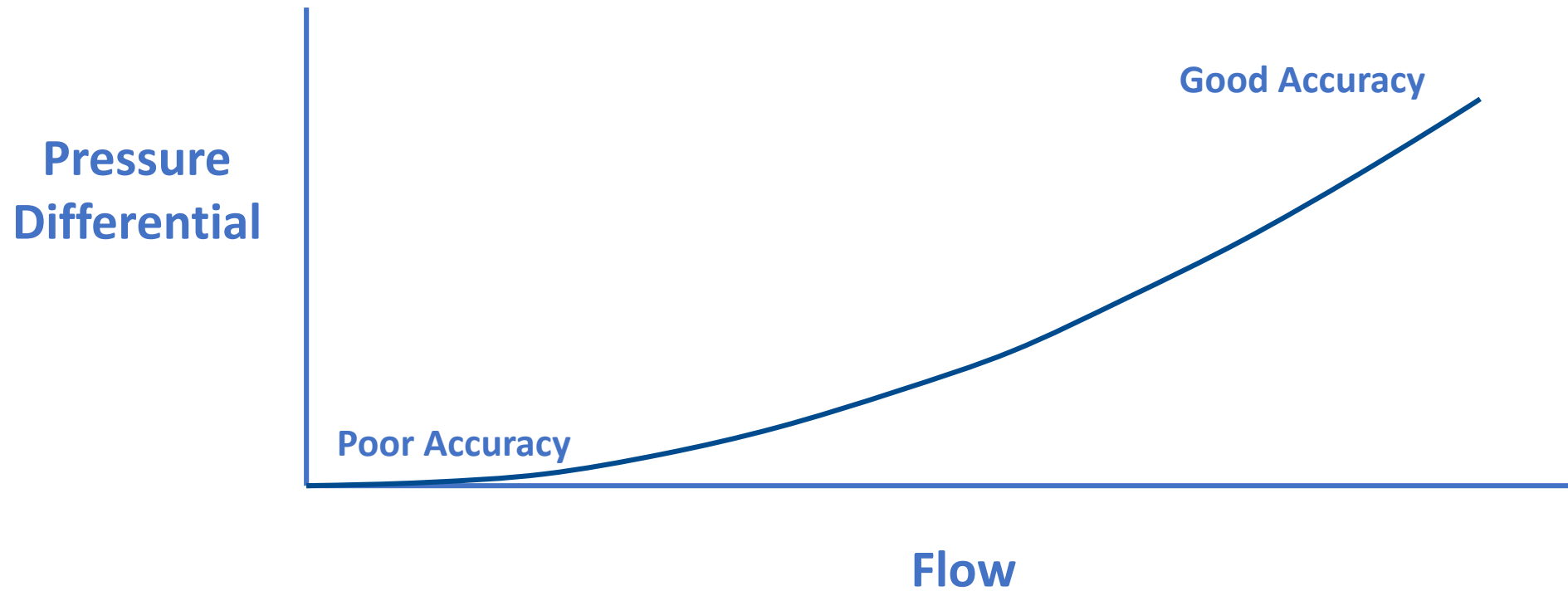
- Coriolis



Why Differential Pressure Flow Meters?

- Well Understood
 - Lots of research and testing
- Relatively Inexpensive
 - Simple designs that minimize parts/manufacturing
- Can offer easy installation
 - Small face:face / insertion styles available
- Technological advances
 - Multivariable
 - Increased turndown
 - Energy Calcs
 - Plugged Impulse Lines (automatic detection)
 - Wireless

ΔP Based Flow Measurement

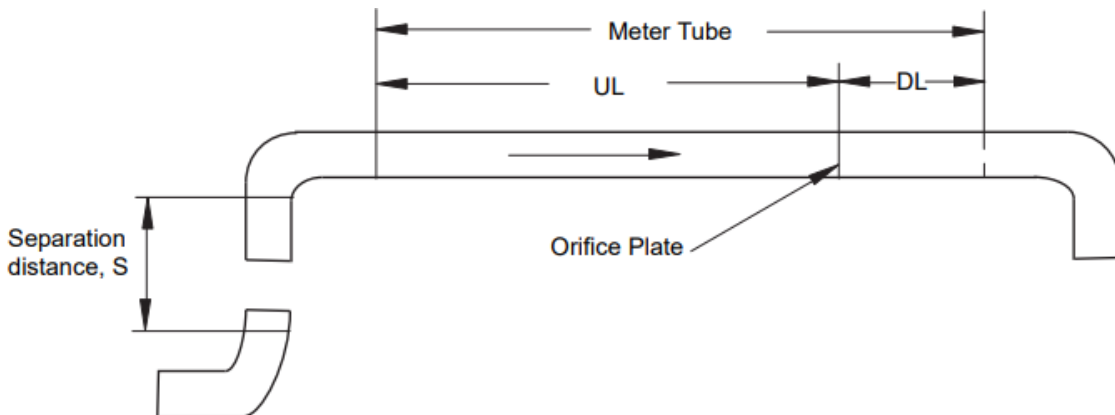


Orifice Straight Piping – ASME 2004



Upstream (inlet) side of orifice plate																
Diameter ratio β	Single 90° bend, two 90° bends in any plane: S-configuration ($S > 30D$) ⁽¹⁾		Two 90° bends in same plane: S-configuration ($30D \geq S > 10D$) ⁽¹⁾		Two 90° bends in same plane: S-configuration ($10D \geq S$) ⁽¹⁾		Two 90° bends in perpendicular planes: ($30D \geq S > 5D$) ⁽¹⁾⁽²⁾		Two 90° bends in perpendicular planes: ($5D < S$) ⁽¹⁾⁽³⁾		Single 90° tee with or without extension Mitre 90° bend		Single 45° bend, two 45° bends in same plane: S-configuration ($S \geq 2D$) ⁽¹⁾		Concentric expander 2D to D over length of 1.5D to 3D	
	1	2		3		4		5		6		7		8		9
	A	B	A	B	A	B	A	B	A	B	A	B	A	B	A	B
≤ 0.20	6	3	10	(4)	10	(4)	19	18	34	17	3	(4)	7	(4)	5	(4)
0.40	16	3	10	(4)	10	(4)	44	18	50	25	(4)	3	30	(4)	5	(4)
0.50	22	9	18	10	22	10	44	18	75	34	19	9	30	18	8	5
0.60	42	13	30	18	42	18	44	18	65 ⁽⁵⁾	25	29	18	30	18	9	5
0.67	44	20	44	18	44	20	44	20	60	18	36	18	44	18	12	6
0.75	44	20	44	18	44	22	44	20	75	18	44	18	44	18	13	8

Diameter ratio β	Concentric expander 0.5D to D over length of D to 2D		Full bore ball valve or gate valve fully open		Abrupt symmetrical reduction		Thermometer pocket or well of diameter $\leq 0.03D$ ⁽⁶⁾⁽⁷⁾		Downstream (outlet) side of the orifice plate	
									Fittings (columns 2 to 11) and densitometer pocket	
1	10		11		12		13		14	
≤ 0.20	A	B	A	B	A	B	A	B	A	B
0.40	6	(4)	12	6	30	15	5	3	4	2
0.50	12	8	12	6	30	15	5	3	6	3
0.60	20	9	12	6	30	15	5	3	6	3
0.67	26	11	14	7	30	15	5	3	7	3.5
0.75	28	14	18	9	30	15	5	3	7	3.5
Diameter ratio β	36	18	24	12	30	15	5	3	8	4



- Column A = 0% Additional Uncertainty
- Column B = 0.5% Additional Uncertainty
- (1) S = separation between two bands measured from downstream end of the curved portion of the upstream bend to the upstream end of the curved portion of the downstream bend
- (2) Values expressed as multiples of internal diameter D
- (3) This is not a good upstream installation; recommend flow conditioner to be used

Magnetic Flow Meters

- Advantages
 - Obstructionless
 - High rangeability (~30:1)
 - Compatible with wide range of liquids
 - High accuracy (can get 0.15% of rate)
 - Fluid profile has little effect on accuracy
- Limitations
 - Conductive liquids only
 - Entrained air



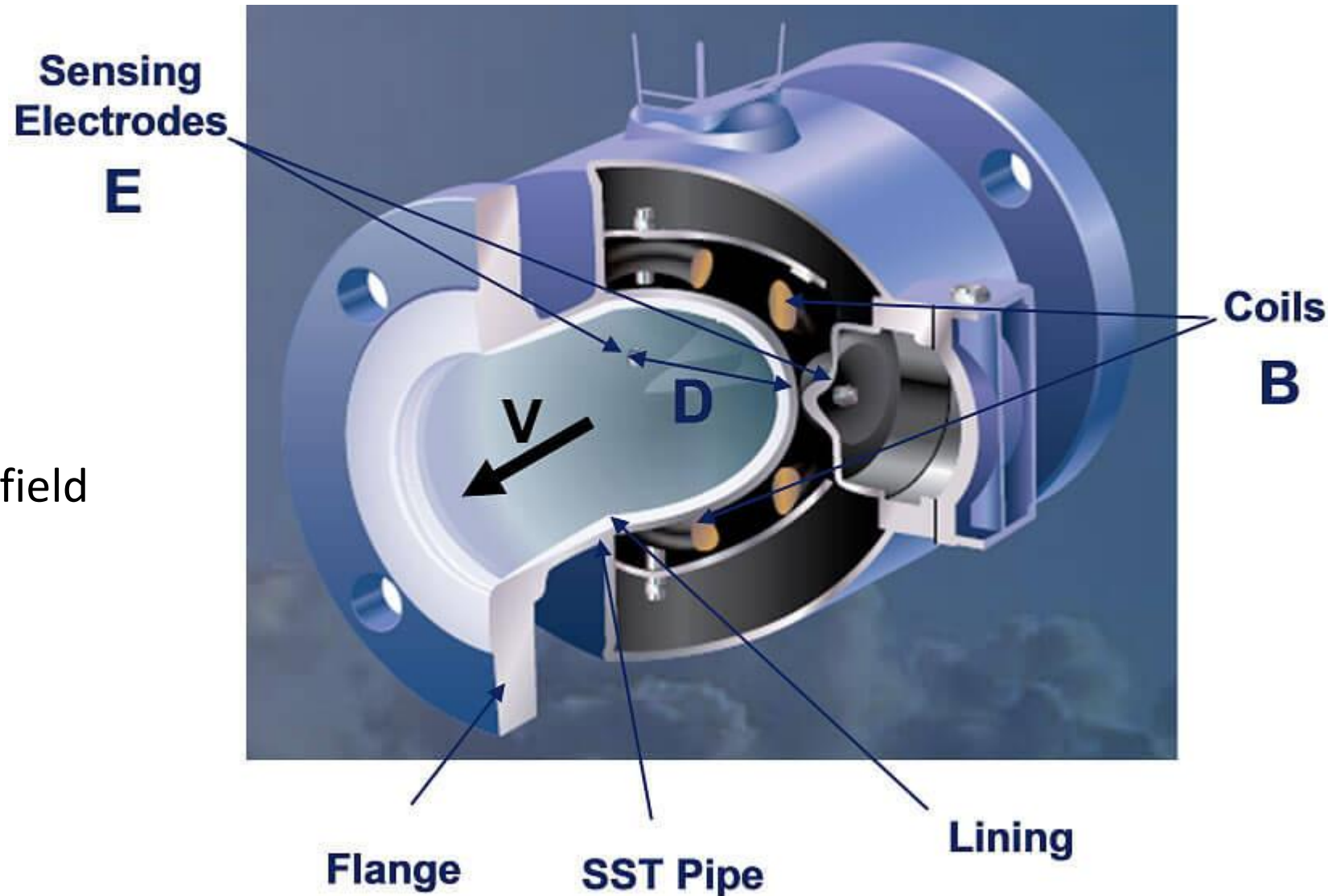
Magnetic Flow Meters – Theory of Operation

- Faraday's Law

$$E = kBDv$$

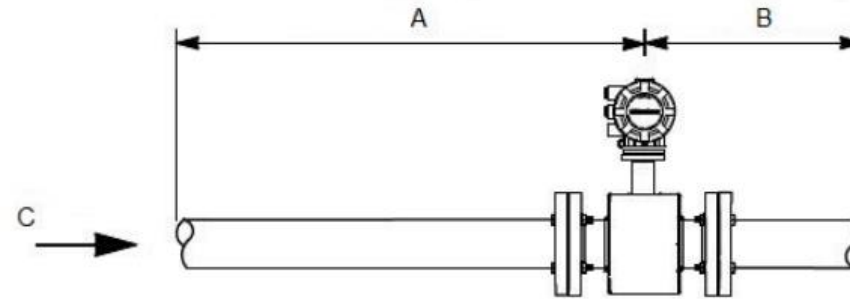
- Where:

- E = Voltage
- k = constant
- B = strength of magnetic field
- D = inner diameter
- v = velocity of fluid



Mechanical Installation

- 5D/2D Straight piping
- Orientation
 - Horizontal
 - Vertical – dewatering concerns



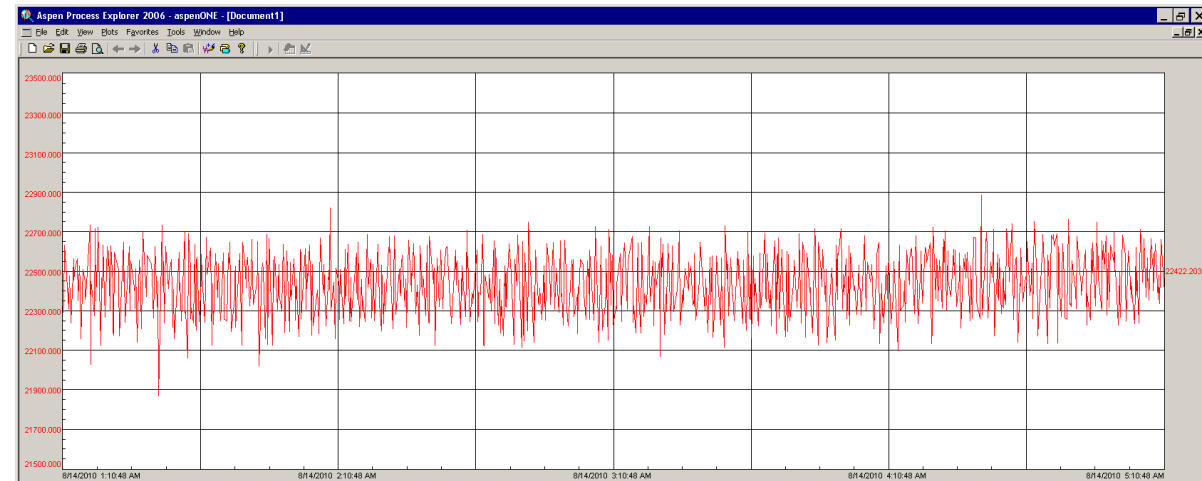
- A. Five pipe diameters (upstream)
- B. Two pipe diameters (downstream)
- C. Flow direction

Choosing a Magmeter for Stock

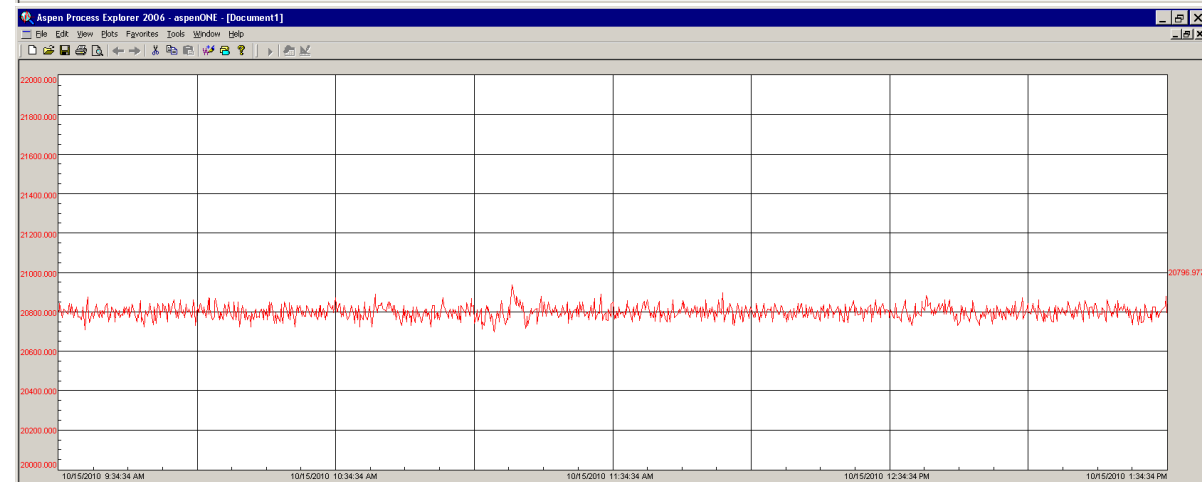
Magmeter Type	5 Hz	37.5 Hz	High Signal
Stock Consistency	<3%	3-5%	>5%

Use the Proper Magmeter for Stock Flow

9 sec of filtering
(ordinary magmeter)

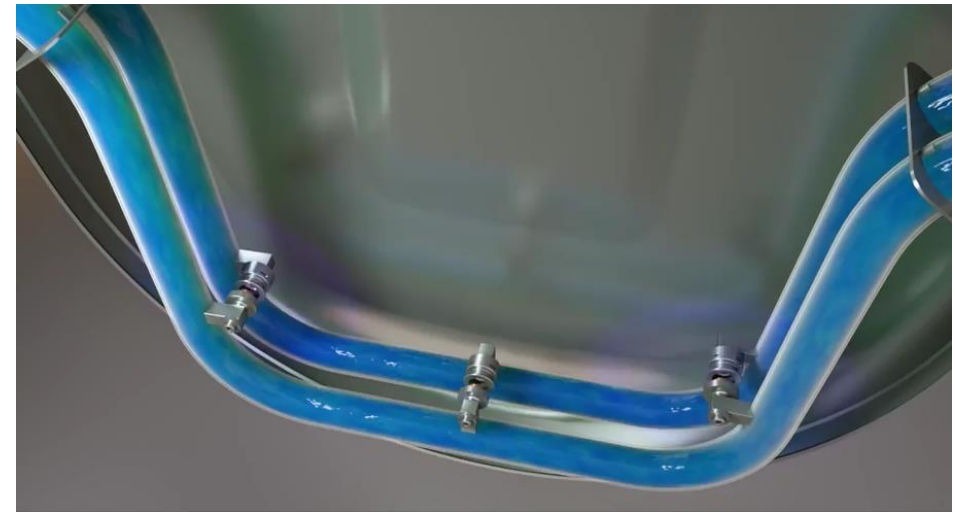
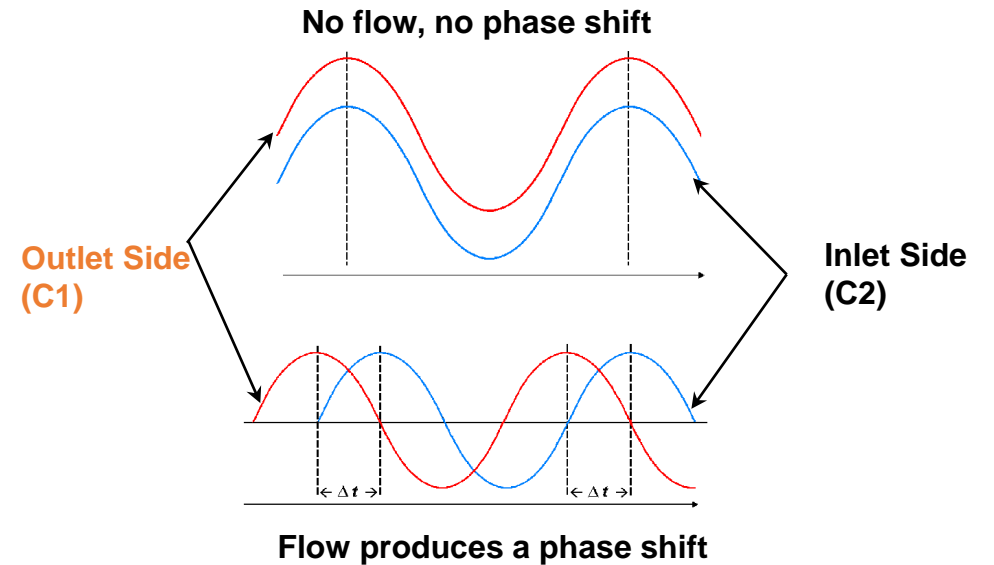


1 sec of filtering
(high signal strength)



Coriolis Meter

- Flow is split into two tubes
- Magnetic coil causes two tubes to vibrate at their natural resonant frequency
- Magnet and coil assemblies create a voltage in the form of a sign wave
- Tubes twist in proportion to mass flowrate
- Amount of twist produces a phase shift
- Mass flow is proportional to the phase shift
- Density is proportional to $1/f^2$



Coriolis Meters

Advantages

- Excellent repeatability (+/- 0.1%) and turndown (>100:1)
- Density accuracy is 0.0005 g/mL (0.0002 is available)
- Can be used with Liquids, Gases, and Slurries
- Non-obstructed flow path
- Low / No maintenance required
- No flow conditioning or straight runs required

Constraints

- Not available for line sizes over 16in
- Large meter footprint
- Some designs require high pressure drop



Pulp Machine Regulatory Audit Results

- 3 valves needed replacing
- 14 valves needed repairs
- 1 valve had a disconnected air supply
- 1 magmeter was wrong type, needed replacing
- 12 loops needed retuning
- 1 process line needed unplugging
- Control strategies needed upgrades

Regulatory Audit

- Review of key regulatory controls
- Cut costs, improve quality, fix APC, qualify APC
- Review SP, PV, output, & mode
- Four failure modes (cycling, slow, saturated, manual)
- Pan and zoom
- Document the failures (failure type, date and times or start date)
- Check the valve (stiction, sizing, on-line diagnostics)
- Check the measuring device

THE END