SPRING23 + 19TH GCPS

A Joint AIChE and CCPS Meeting

EMBRACING THE FUTURE OF CHEMICAL ENGINEERING

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Control Valve Modeling and Control

Improving valve response for better process control loop performance

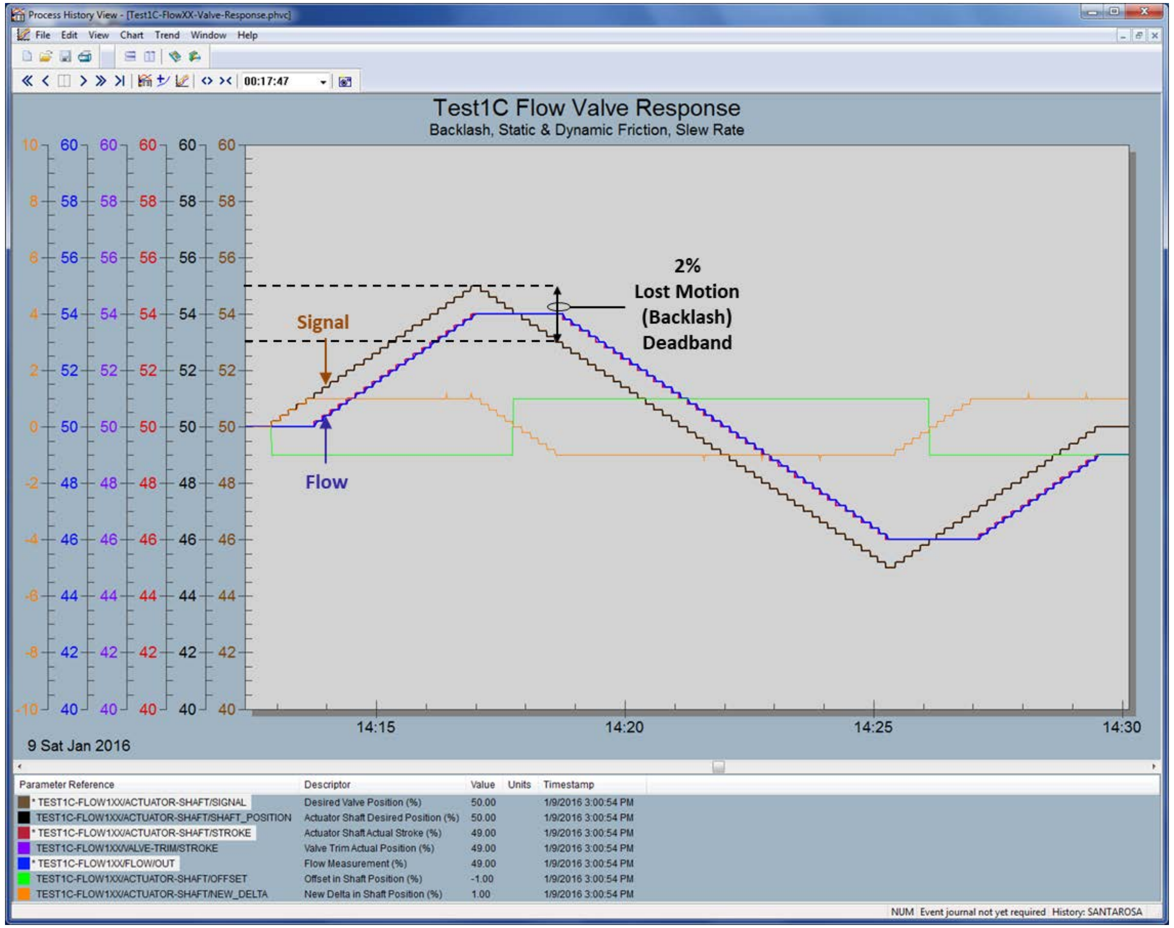
Presenter Bio

- Gregory K McMillan is a retired Senior Fellow from Solutia/Monsanto and an ISA Fellow. Greg was an adjunct professor in the Washington University Saint Louis Chemical Engineering Department 2001-2004. Greg is currently a Principal Senior Software Engineer for dynamic simulations in Emerson Automation Solutions.
- Greg received the ISA "Kermit Fischer Environmental" Award for pH control in 1991, the Control Magazine "Engineer of the Year" Award for the Process Industry in 1994, was inducted into the Control "Process Automation Hall of Fame" in 2001, was honored by InTech Magazine in 2003 as one of the most influential innovators in automation, and received the ISA Life Achievement Award in 2010. Greg is the author of over 300 articles and 31 books on process control, his most recent being *Process/Industrial Instruments and Controls Handbook - 6th Edition*, and *New Directions in Bioprocess Modeling and Control – 2nd Edition.* Greg has been the monthly "Control Talk" columnist for *Control* magazine since 2002.
- https://www.controlglobal.com/blogs/controltalkblog
- http://automation.isa.org/author/gregmcmillan/

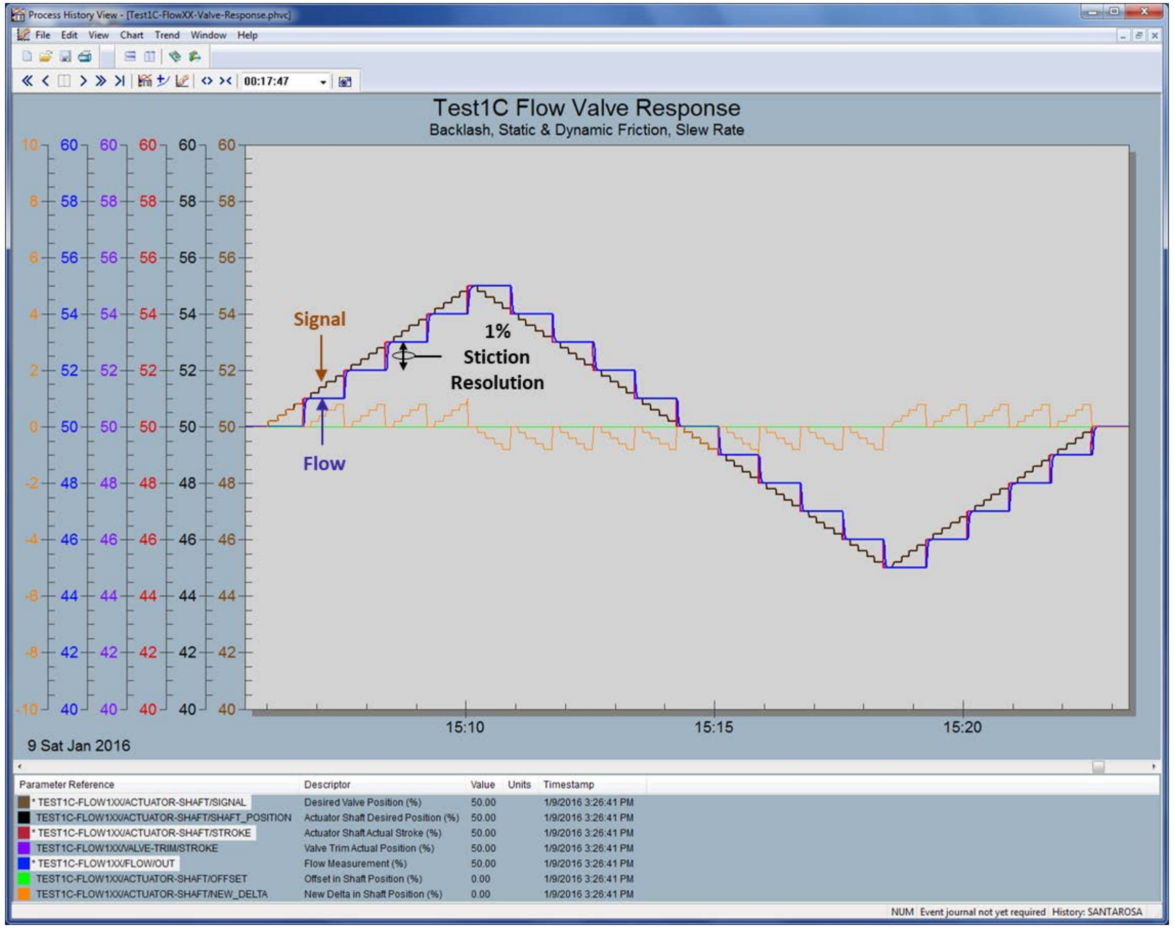
Control Valve Modeling and Control Topics

- The “Perfect Storm”
- Open loop valve response testing
- Valve response modeling
- External Reset Feedback
- Use of volume boosters for large actuators
- See paper and references for equations to estimate limit cycles, loop performance, rangeability, and installed flow characteristics, and examples of response requirements on valve specifications, and best practices for control valves and variable frequency drives
- Effect of lost motion (backlash), resolution (stiction), poor positioner sensitivity, and large actuator (slow stroking time)

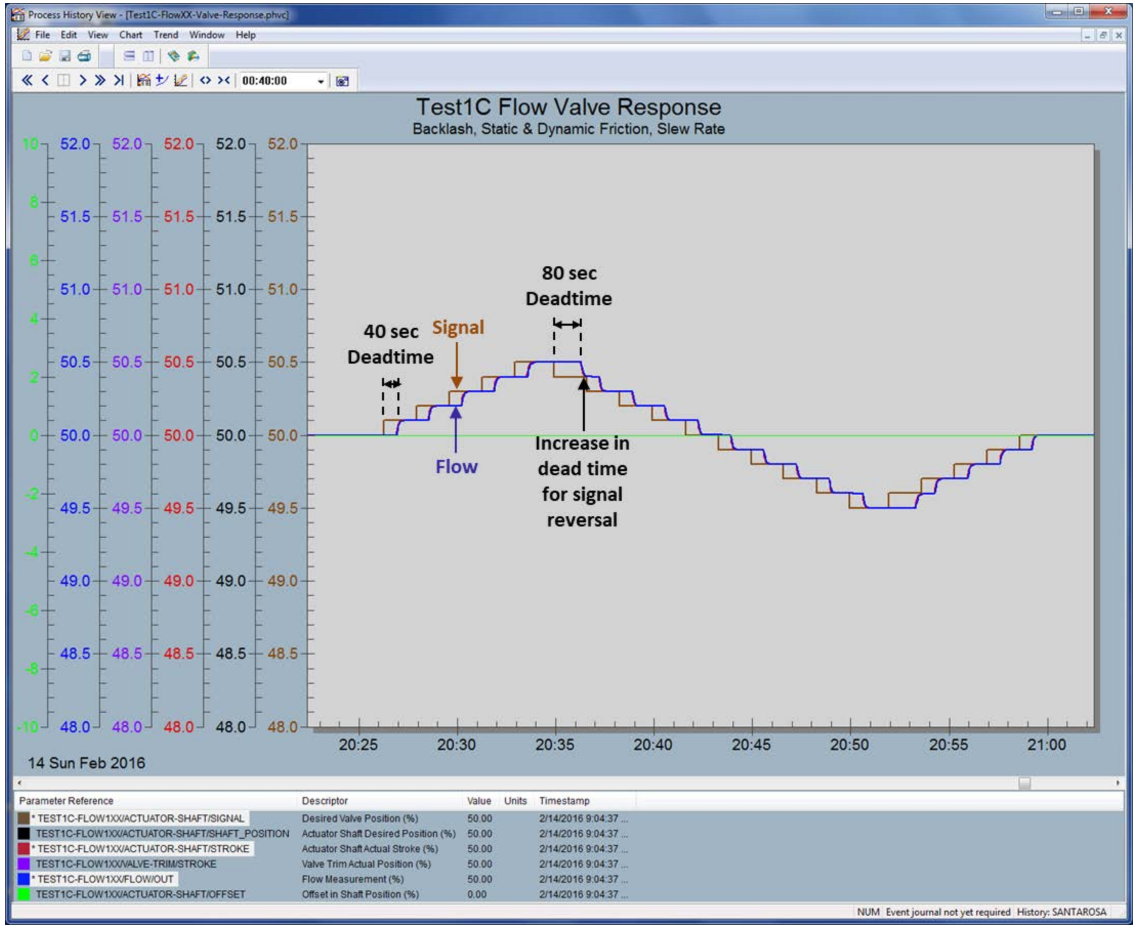
Open Loop Test Results for 2% Lost Motion (Backlash)



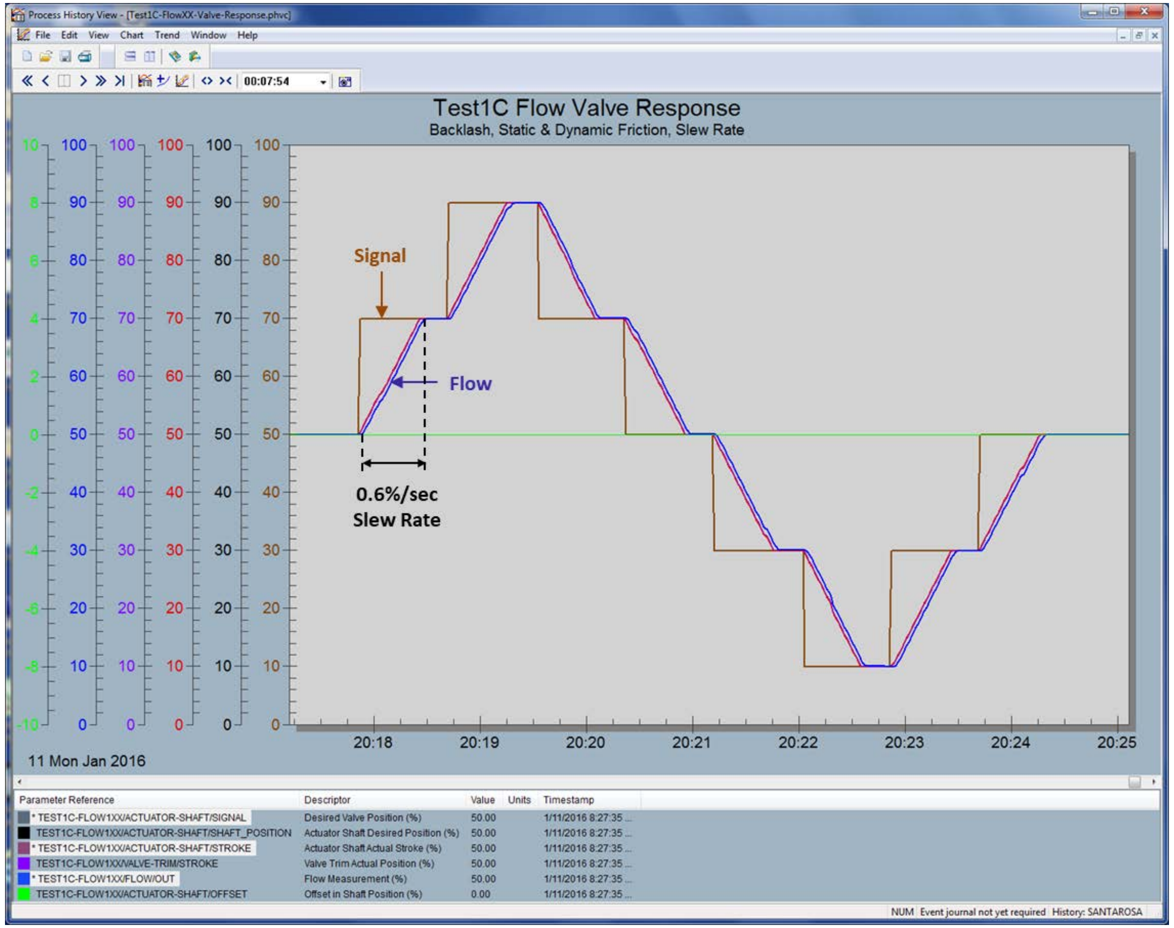
Open Loop Test Results for 1% Resolution (Stiction)



Open Loop Test Results for Poor Positioner Design



Open Loop Test Results for Large Actuator



Perfect Storm - 1

- Volume boosters instead of positioners recommended for fast loops
- Rangeability statements based on inherent flow characteristic rigor
- Lack of understanding of loss of rangeability due to installed flow characteristic and resolution (stiction) near the closed position
- Piston actuators instead of diaphragm actuators recommended
- Use of so called “high performance” (e.g., rotary on-off valves in piping spec) to minimize cost and leakage and maximize capacity
- Severe lost motion in rotary valves from positioner to shaft, shaft to stem, and stem to internal closure member (e.g., ball) connections
- Lack of recognition of limit cycles caused by lost motion when there is 2 or more integrators besides those limit cycles from resolution

Perfect Storm - 2

- Positioners with poor sensitivity (spool positioners with 2% resolution) and single stage relay that cause huge dead time for steps < 0.4%
- Lying smart positioners due to lost motion and shaft windup
- Lack of understanding of terms per ISA-TR75.25.01 that replace old terms (lost motion for backlash and hysteresis) (resolution for stiction)
- Use of integral action in positioners to eliminate offsets in open loop tests reducing gain, which increases response time and limit cycles
- Valve specification sheets that have entries for leakage, packing, and capacity but none for response time, lost motion, and resolution
- Common practice of tests doing 10% or 25% steps instead 0.2% steps

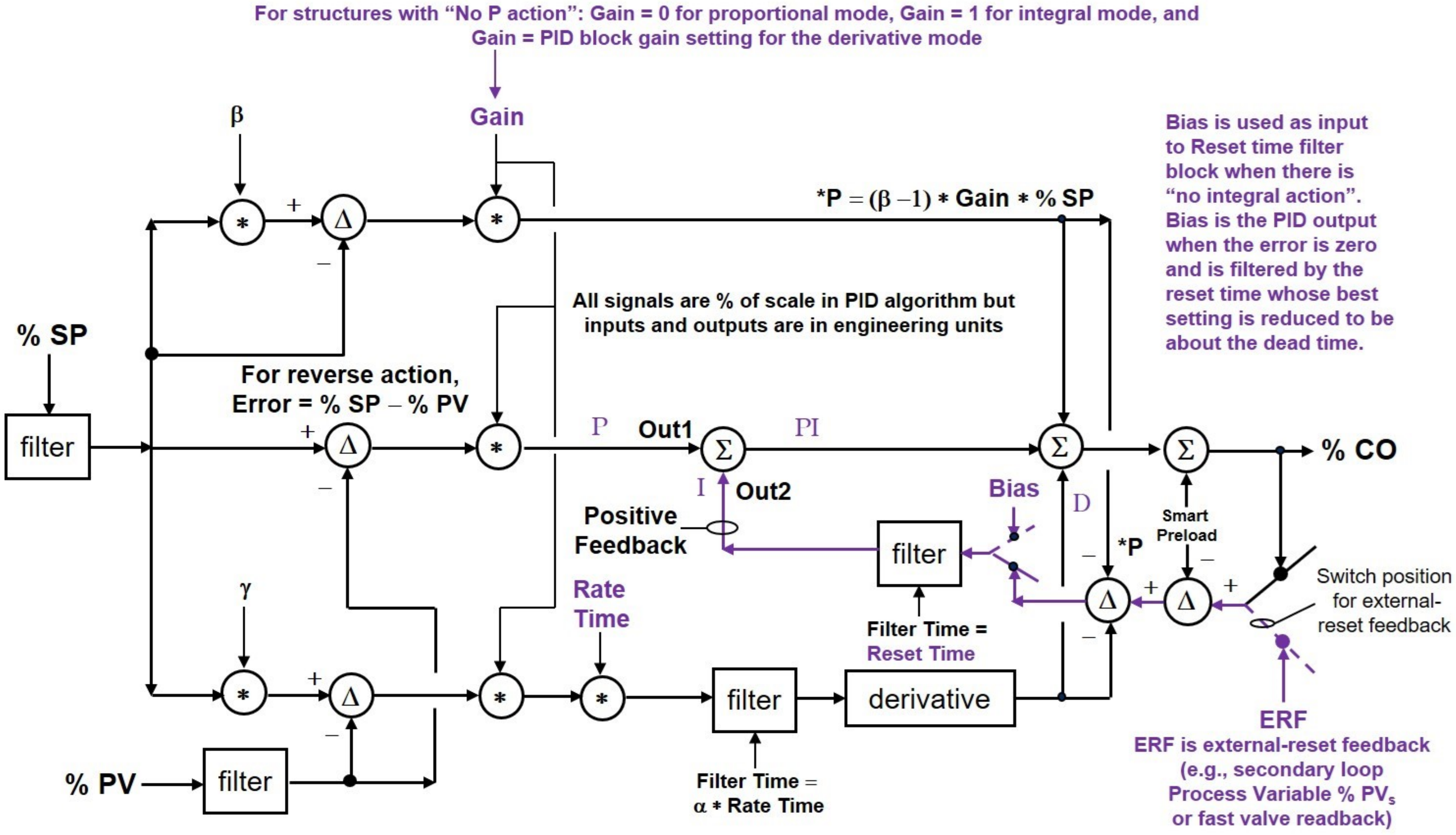
Perfect Storm - 3

- Reluctance of valve companies to do tests below 20% position to show effect of poorer resolution (greater stiction) near seal and seat
- Lack of sensitive, low noise, and high rangeability flow measurement to see actual flow response that includes lost motion for small steps
- Actuators marginally sized to lower cost resulting in poorer precision
- Purchase of "high performance" valve companies by throttling valve companies resulting in their offering to lower cost in bids
- Loss of external reset feedback capability in most PID algorithms
- Slow updates of actual valve position by HART and wireless
- Misconception that variable frequency drives (VFDs) have a faster, more linear, and more precise response (see McGraw Hill Handbook on slide 28 and best practices in paper for VFD issues and solutions)

Control Valve Response Modeling

- Deadband function for lost motion (backlash)
- Quantizer function for resolution (stiction)
- Rate limit function for slewing rate
- Variable deadtime block for pre-stroke deadtime and poor positioner sensitivity
- Filter functions for positioner response
- Equations for installed flow characteristics

External-Reset Feedback in PID Standard Form



Benefits of External Reset Feedback (ERF)

- Reduce oscillations and enable tighter control from:
  - Valve resolution (stiction) for one or more integrators in loop
  - Lost motion (backlash) for two or more integrators in loop
  - Poor valve positioner sensitivity
  - Slow valve stroking time (large actuator)
  - Unnecessary crossings of split range point (by ERF enabling directional move suppression by up and down rate limits)
  - Fast opening and slow closing valve for compressor surge control
  - Slow response and overshoot in override control
  - Analyzer cycle time (by ERF enabling enhanced PID solution)
  - Dead time (by ERF enabling dead time compensation)

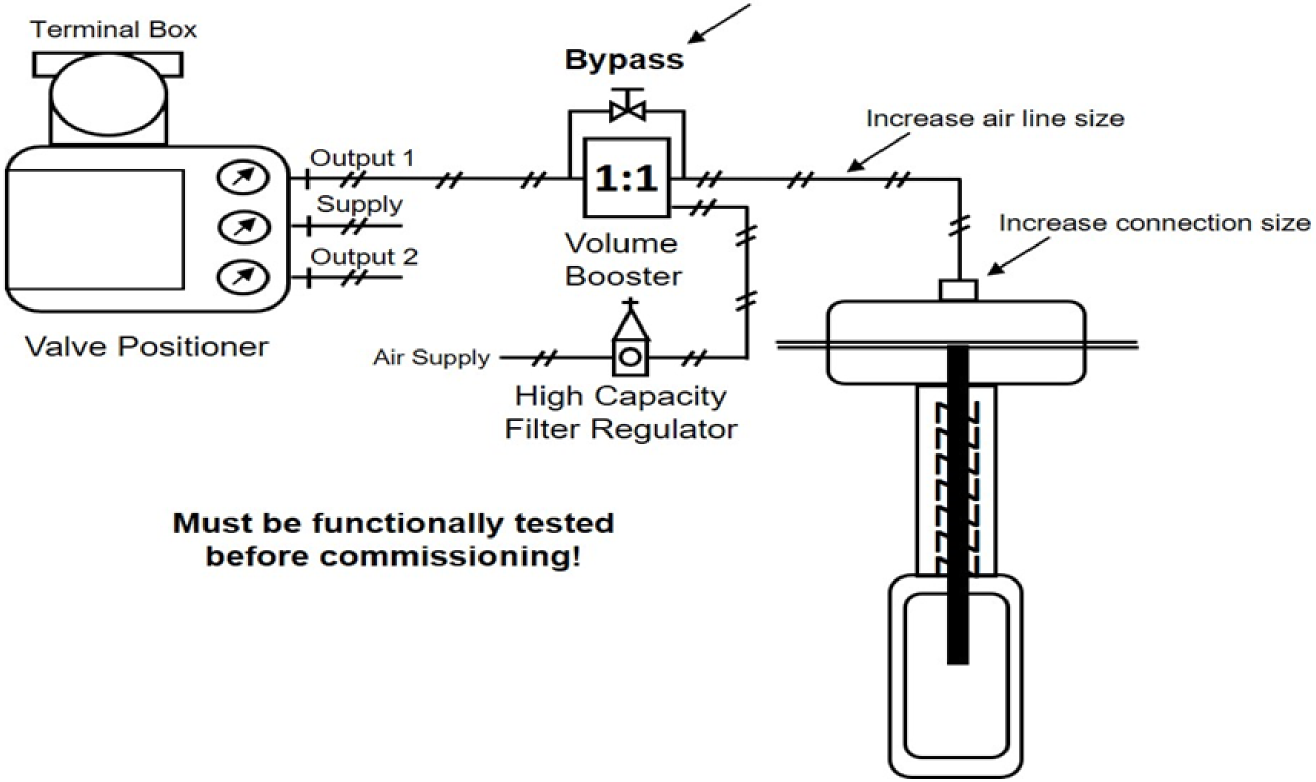
Use of Volume Boosters for Large Actuators

Despite age old guidelines, never replace positioner with volume booster! Potentially unsafe!

Please turn off integral that has been enabled as default by supplier!

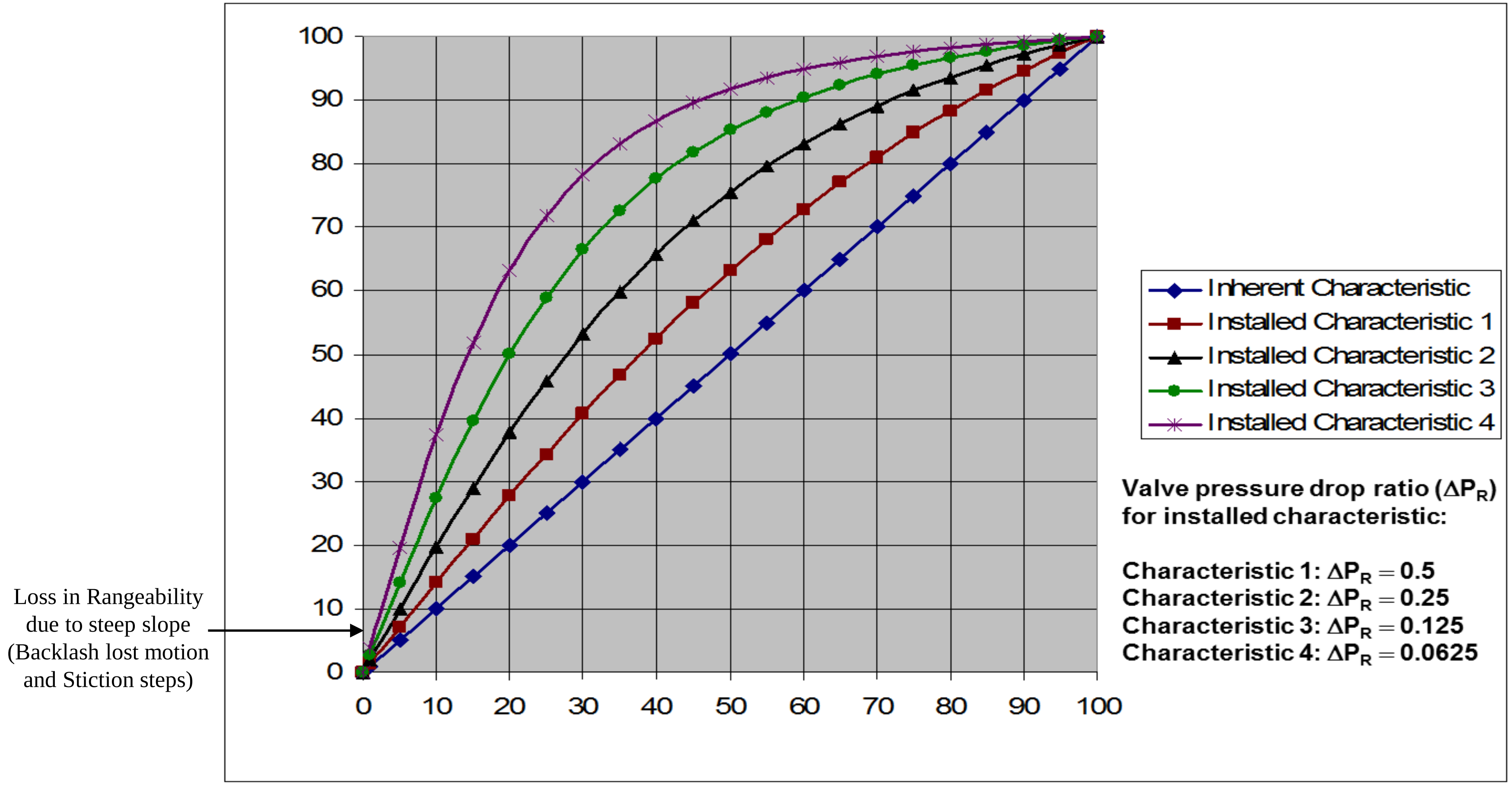
The air supply line from the air header to booster air set must be short and large and dedicated to booster. This air supply should not be shared with positioner and other users of air to ensure no dip and restriction in booster air flow.

Open bypass just enough to ensure a non-oscillatory fast response!



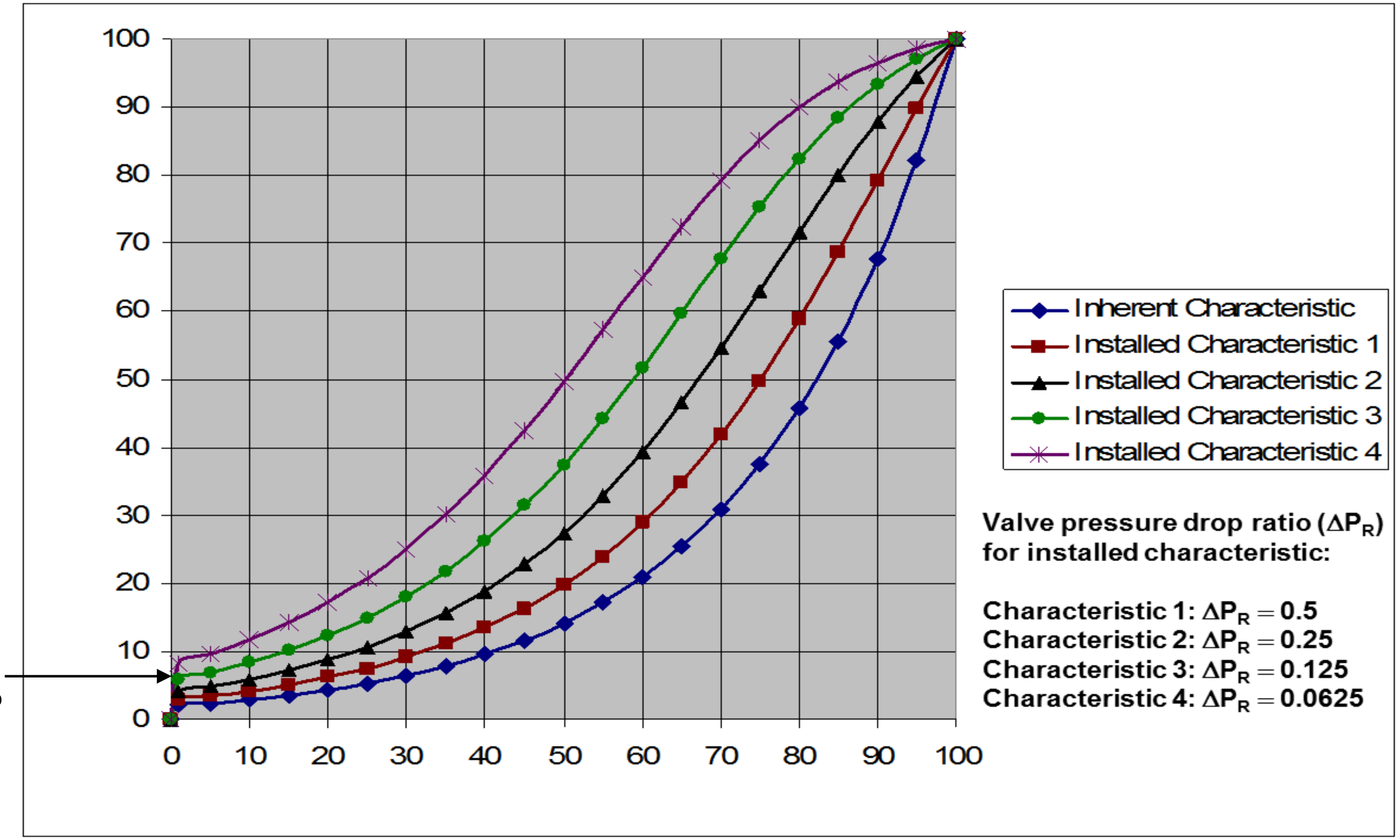
Must be functionally tested before commissioning!

Installed Flow Characteristic for Linear Trim

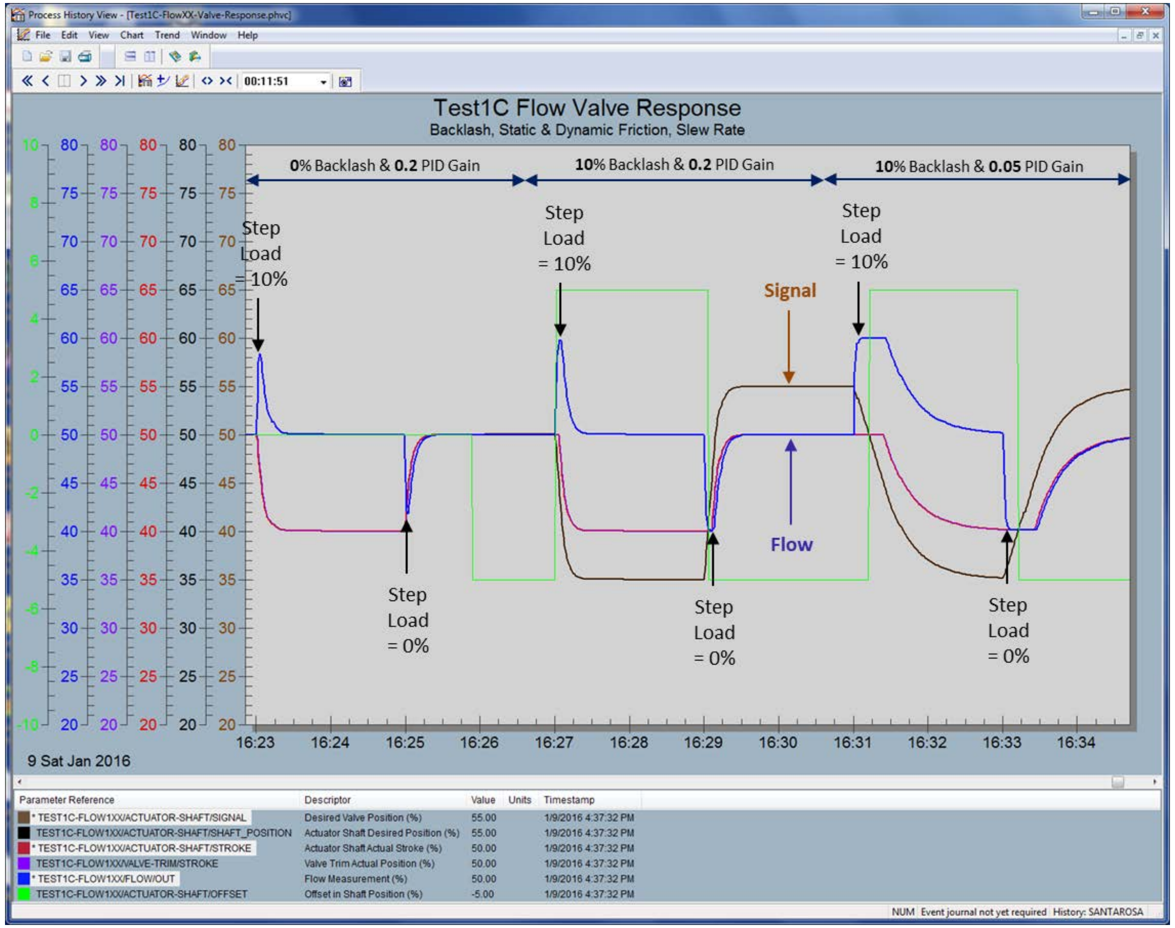


Installed Flow Characteristic for Equal Percentage Trim

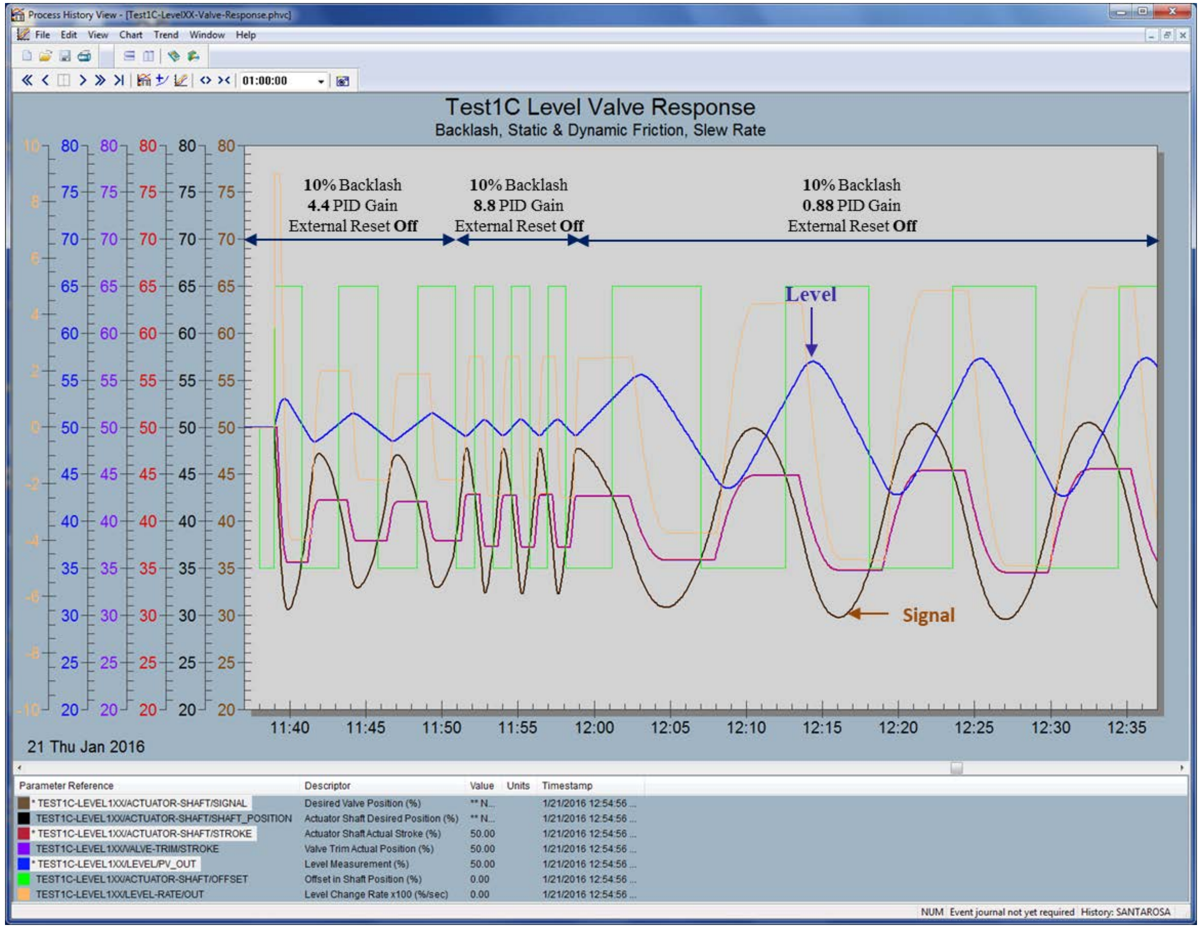
Loss in Rangeability due to flat slope (flow not going to zero until valve closes)



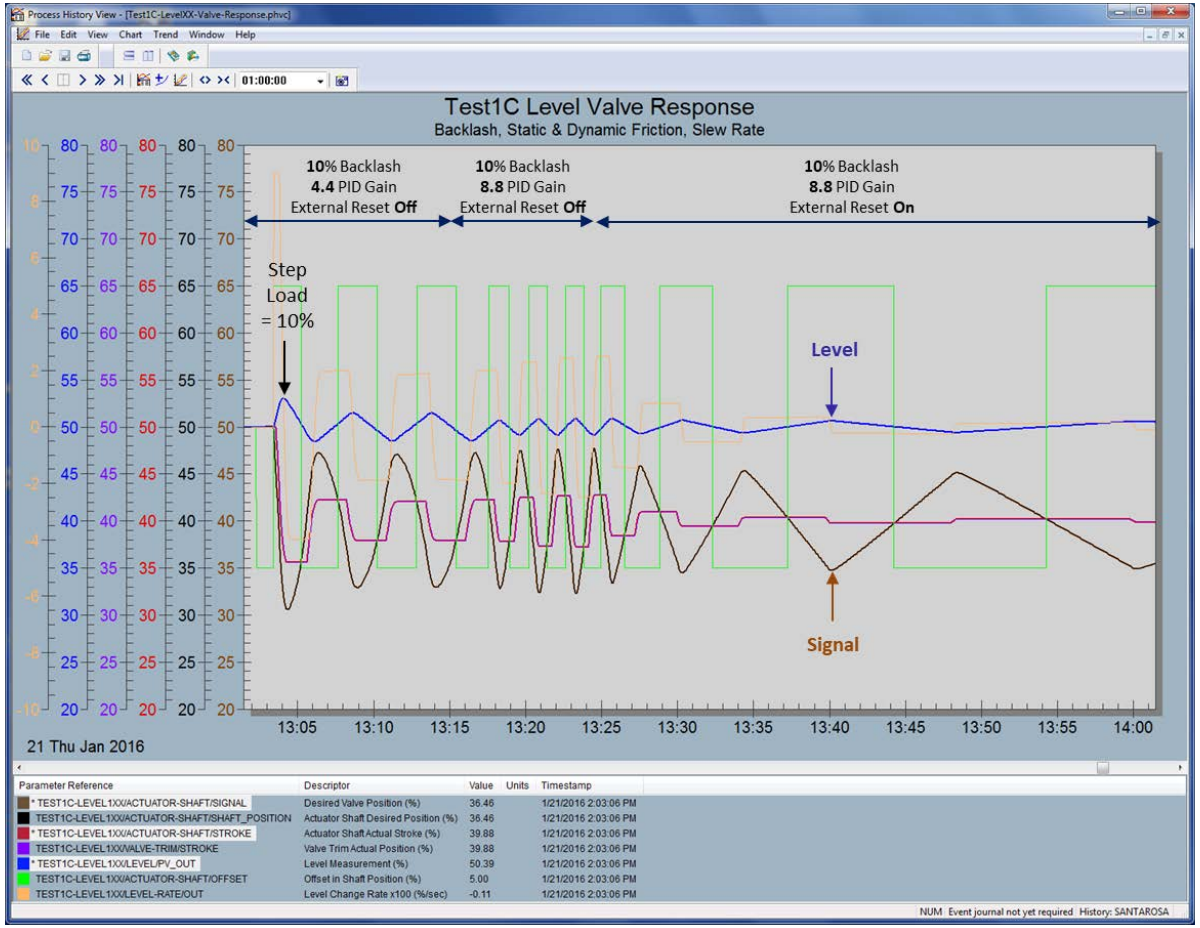
Effect of Backlash and PI Gain on Flow Loop



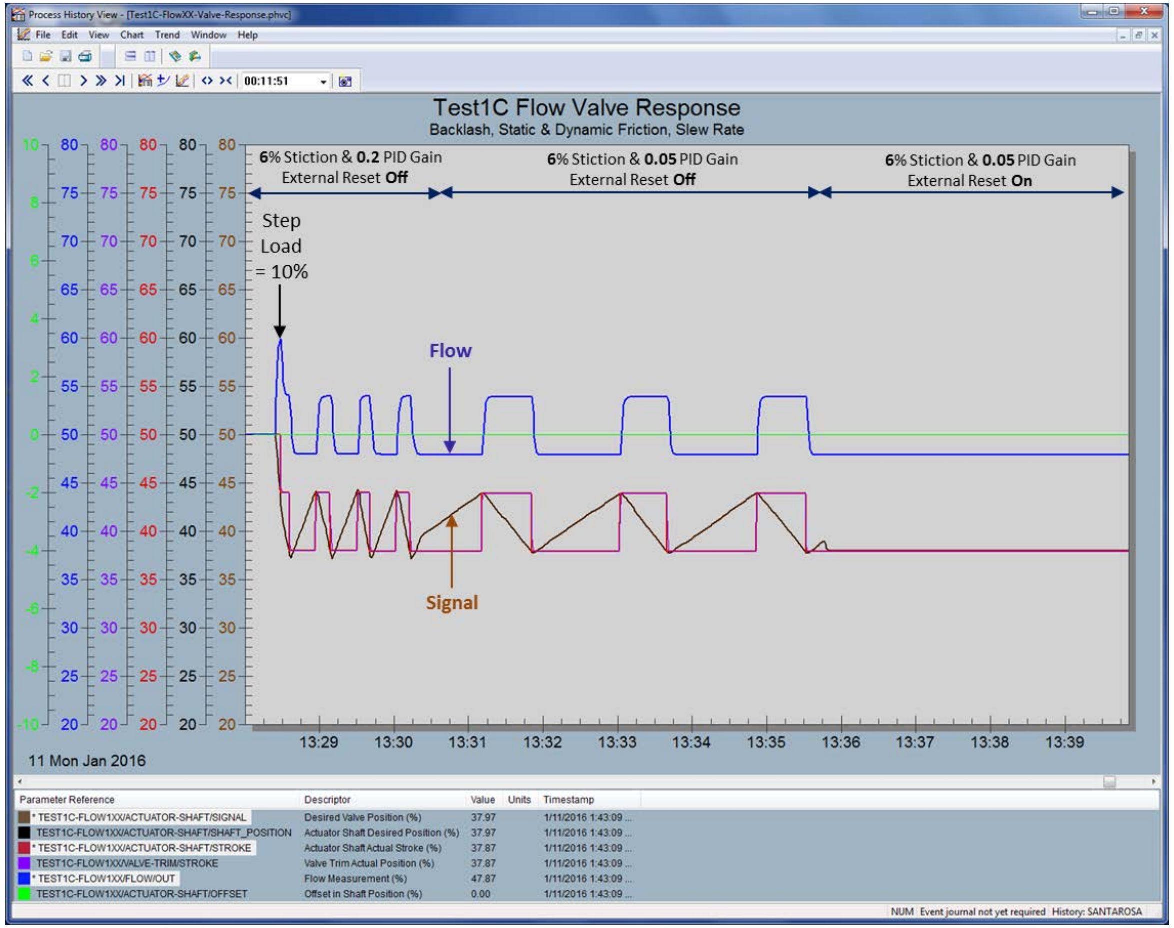
Effect of Backlash and PID Gain on Level Loop



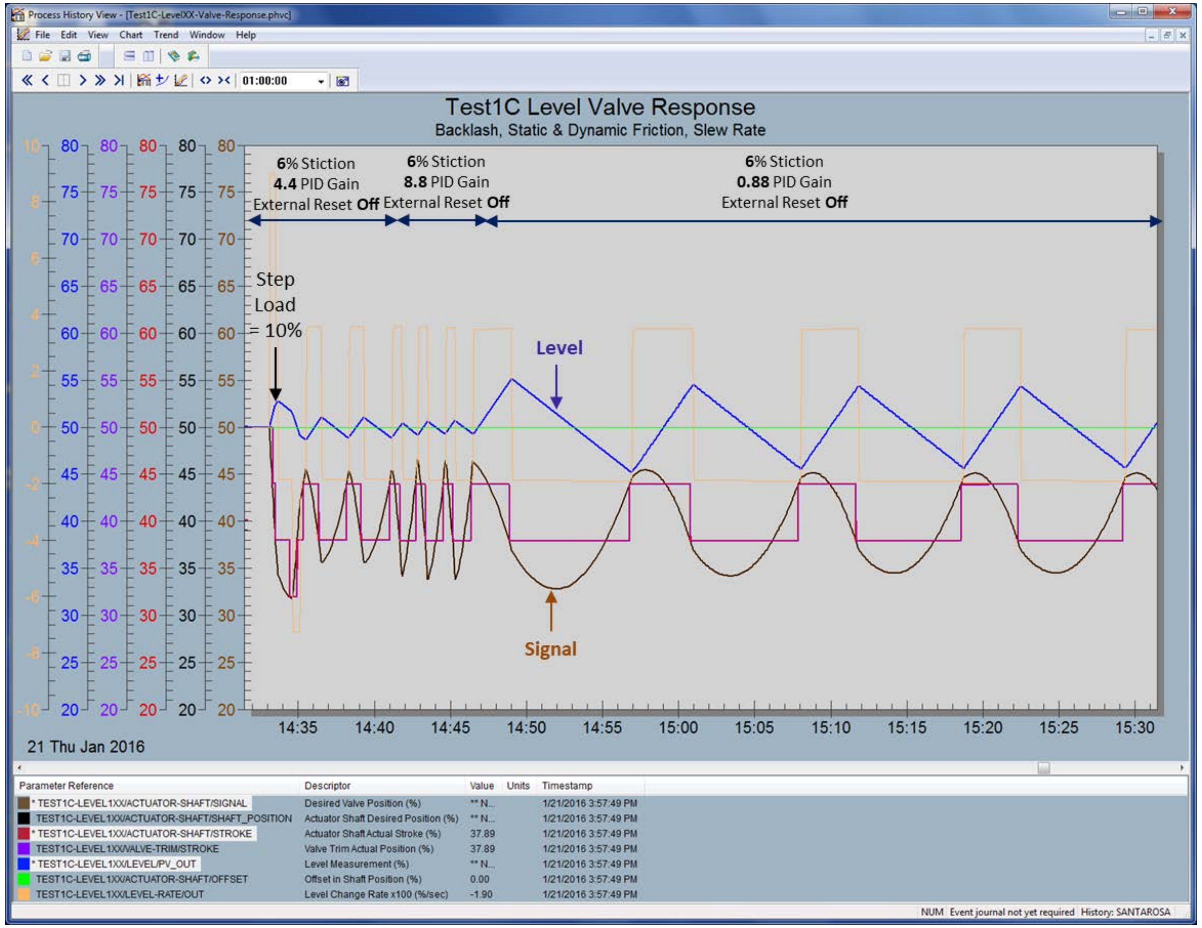
Effect of Backlash and External Reset on Level Loop



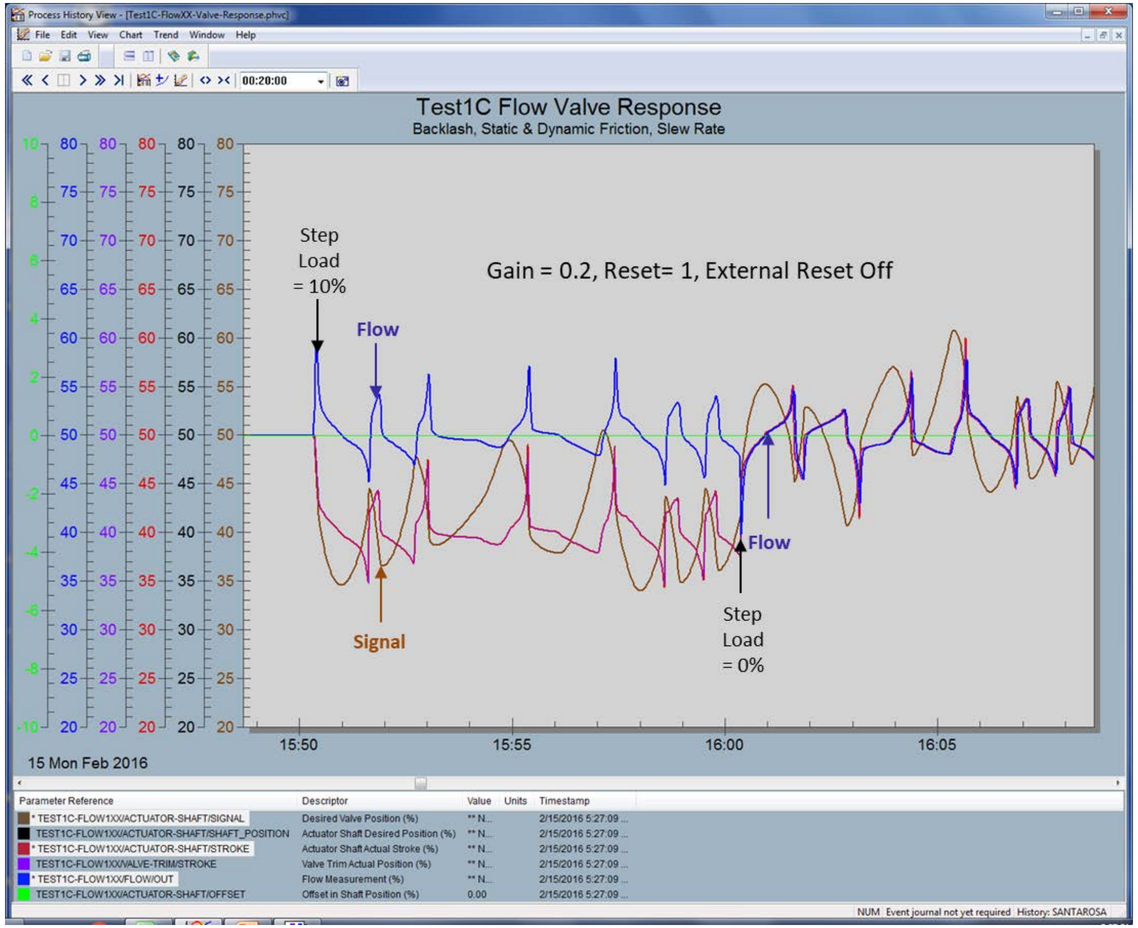
Effect of Stiction and External Reset on Flow Loop



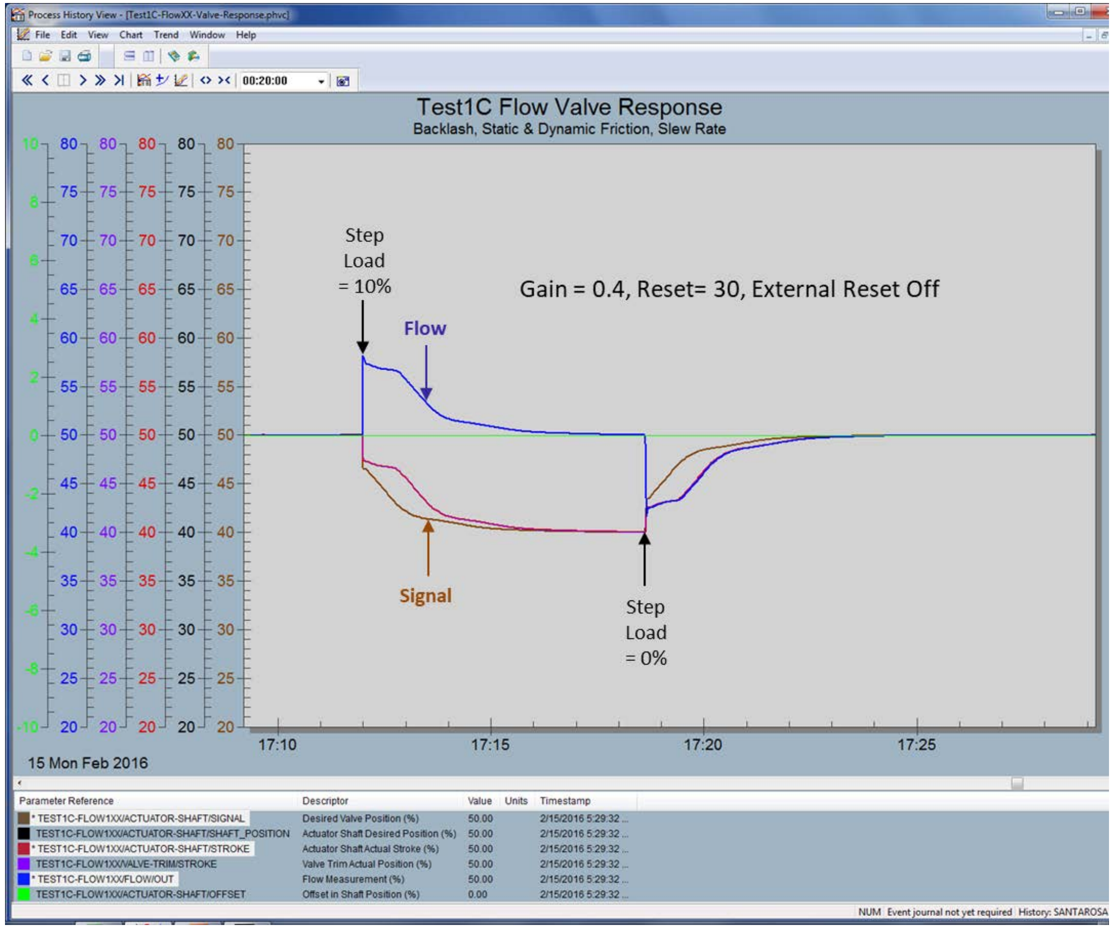
Effect of Stiction and PID Gain on Level Loop



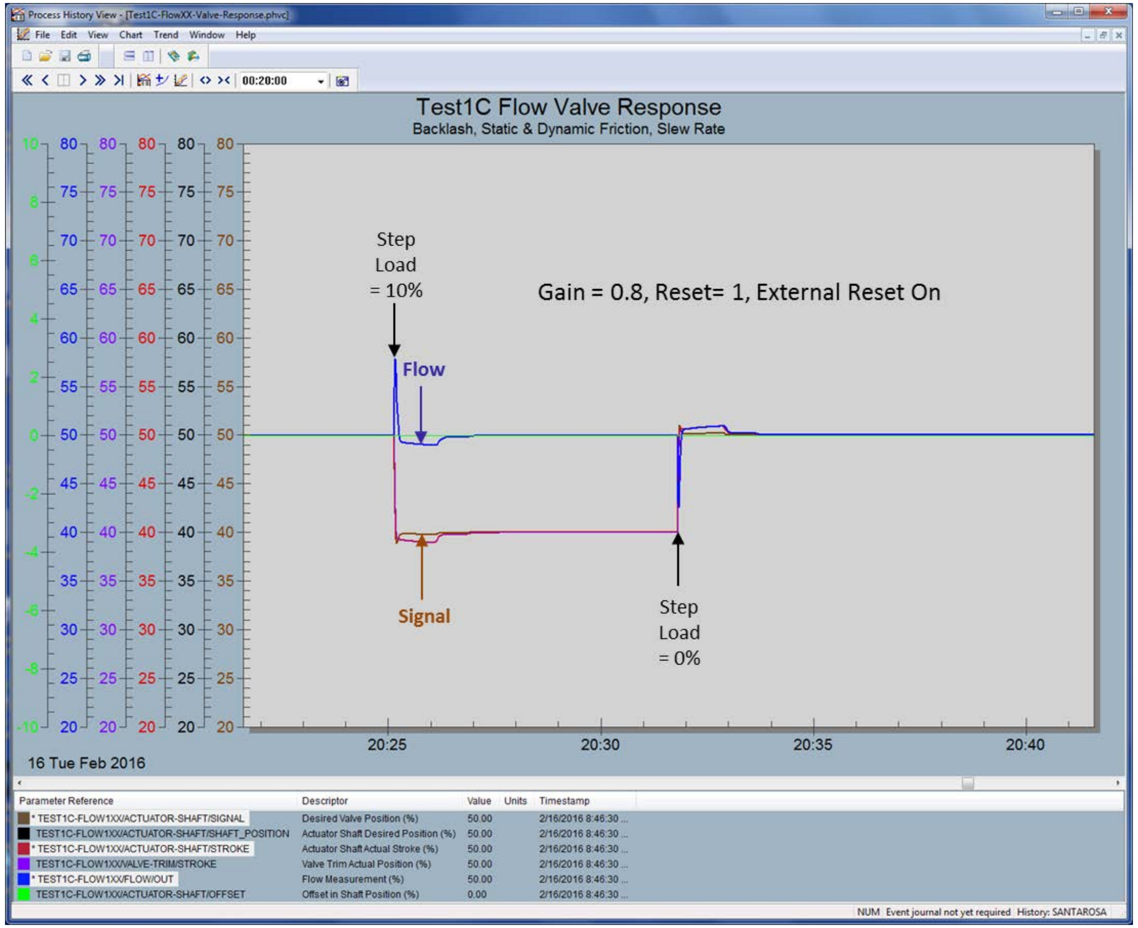
Effect of Poor Sensitivity Positioner on Flow Loop



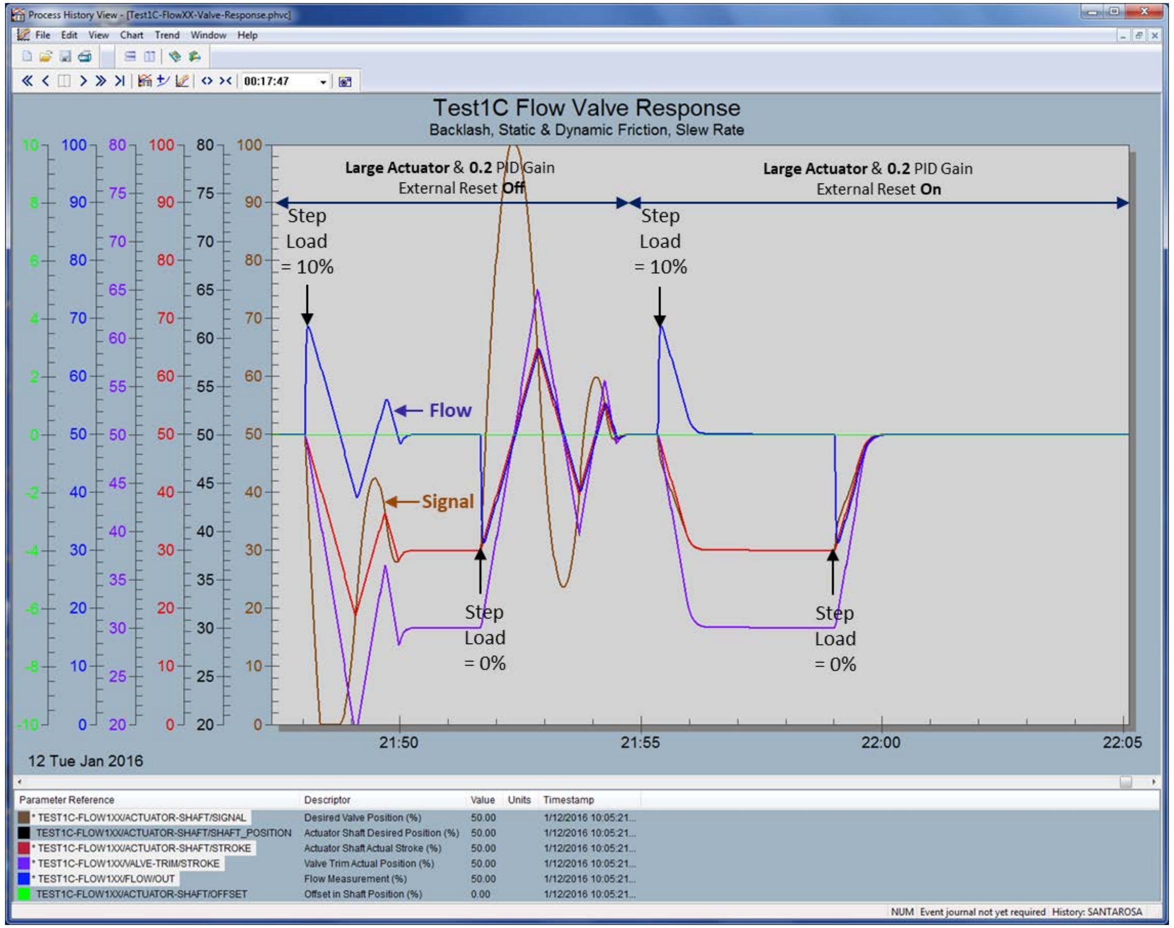
Effect of Poor Positioner and Tuning on Flow Loop



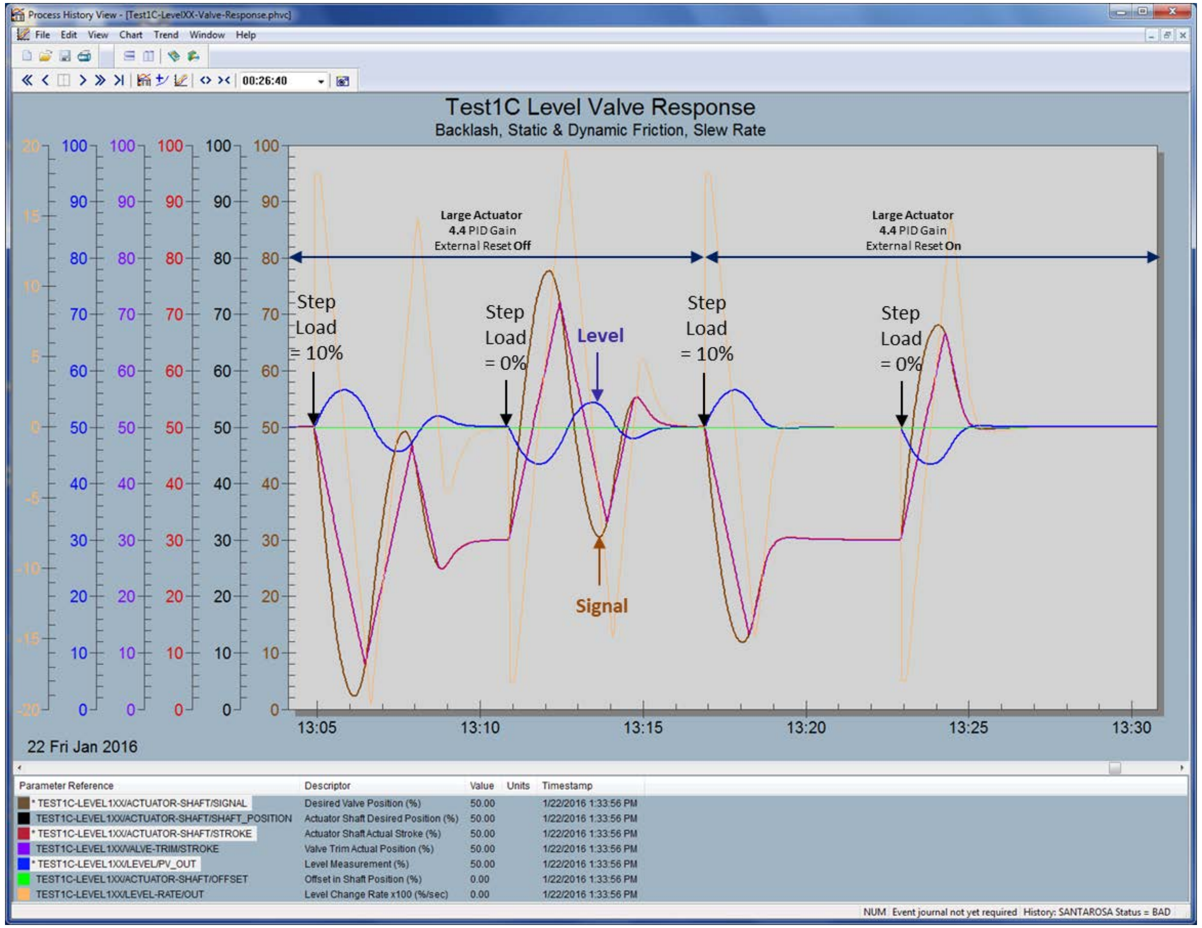
Effect of Poor Positioner and External Reset on Flow Loop



Effect of Large Actuator and External Reset on Flow Loop



Effect of Large Actuator and External Reset on Level Loop



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Best Practices by 50 Process Industry Experts