Control Valve Troubleshooting Workshop Introduction

- Shane Pirtle
- Joseph Dufresne
- James Beall
- Craig Jeane
- Bart Propst
**Agenda**

- Potential Cause Map – Bart Propst – 5 min
- Emerson Diagnostic Tools – Craig Jeane – 10 min
- Samson Diagnostic Tools - Joseph Dufresne – 10 min
- **Control Valve Case Studies**
  1. Erosion – Shane Pirtle – 10 min
  2. Diaphragm leak – Joseph Dufresne – 10 min
  3. Resolution – Joseph Dufresne – 10 min
  4. Dead Band – James Beall – 10 min
  5. Response time – James Beall – 10 min
Potential Failure Cause Map

- Think Reliability Root Cause Analysis
  - “The best RCA software you didn't know you had.” - Excel
Control Valve Potential Failure Cause Map

Loss of control valve function

Leak by
- Valve position feedback
- OR
- Actuator failure?
- OR
- Valve body washed-out

Failure to throttle
- OR
- Incorrect trim?
- OR
- Valve body washed-out

Loss of containment
- OR
- Actuator failure?
- OR
- Valve body washed-out?
Potential Failure Cause Map

- **Actuator failure**
- **Valve body washed-out**
- **Valve stem sticking (stiction)**
- **Incorrect trim**
- **Freezing, solidify**
- **Defective/worn trim**

**Loss of control valve function**

- **Leak by**
- **Failure to throttle**
- **Loss of containment**

**Components**

- Actuator failure
- Valve body washed-out
- Valve stem sticking (stiction)
- Incorrect trim
- Freezing, solidify
- Defective/worn trim
Control Valve Potential Failure Cause Map

- **Leak by**
  - Defective stem?
  - Actuator failure?
  - Valve body washout?

- **Failure to throttle**
  - Valve stem sticking (rotation?)
  - Incomplete turn?
  - Freezing, solidity?
  - Detectors/actuators fails?

- **Loss of containment**
  - Packing failure?
  - Flanged connection leak

- **Body leak**
  - Incorrect gasket
  - Gasket failure

- **Loss of control valve function**
  - Leaked by process shuts off
  - Control valve loss of function

- **Components**
  - Failed to throttle flow to set
  - Valves stem sticking (rotation?)
  - Incomplete turn?
  - Freezing, solidity?
  - Detectors/actuators fails?

- **Failure Modes**
  - Generic Rising stem Control Valve
  - Actuator
  - Fieldview positioner
Control Valve Potential Failure Cause Map

- Loss of control valve function
  - Actuator
  - Body
  - Positioner
  - Diaphragm
    - OR
    - Stem/Spring system
      - OR
      - Actuator housing
  - Etc...
  - Etc....
## Positioner Troubleshooting Checklist

1. Instrument serial number as read from nameplate: ________________________________

2. Is the digital valve controller responding to the control signal? Yes ______ No ______

If not, describe: _______________________________________________________________

3. Measure the voltage across the “Loop ♦” and Loop +” terminal box screws when the commanded current is 4.0 mA and 20.0 mA: _______ V @ 4.0 mA _______ V @ 20.0 mA. (For a DVC6000 pwbuilt prior to 2003, these values should be around 9.4 V @ 4.0 mA. For a DVC6000 pwbbuilt after 2003, these values should be around 9.6 V @ 4.0 mA.)

4. Is it possible to communicate via HART to the digital valve controller? Yes _______ No _______

5. What is the Diagnostic Tier of the digital valve controller? AC ____ HC ____ AD ____ PD ____ ODV ____

6. What is the firmware version of the digital valve controller? ____________________
Emerson Diagnostic Tools

ValveLink™ Software Diagnostics
Fundamentals of Diagnostics

Valve Alerts

- Travel Deviation
- Travel Hi
- Travel Lo
- Travel Hi Hi
- Travel Lo Lo
- Travel Accumulator
- Drive Signal
- Supply Pressure
- Cycle Count
- ESD Valve Stuck
- ESD Pressure Deviation
- Ref. Voltage Failure
- Pressure Sensor Fail
- NVM Fail
- Drive Current Fail
- Temp Sensor Fail
- Travel Sensor Fail
- Auto TVI Cal Failed
- Power Starvation Alert
- Calibration in Progress
- Alert Record Not Empty
- Alert Record Full
- Variable Out of Range
- Diagnostic in Progress
- No Free Time
- Integrator Saturated Low
- Internal Sensor Out of Limits
- Flash Integrity Error
- Integrator Saturated High
- Configuration Changed
- Aux Input
- Analog Input Saturated

Travel Deviation
Drive Signal
Supply Pressure
ValveLink Dashboard & Status Monitor
Monitoring and Basic Diagnostics
On-line analysis of friction and deadband can be compared with the off-line data for potential valve performance deterioration.
PD One Button

- On-Line In-Service
- 24/7 access
- Non-Intrusive
- Easy...

1. Supply Pressure
2. Relay Adjustment
3. I/P and Relay Integrity
4. Travel Deviation
5. Air Mass Flow

Problem Description
Possible Cause
Recommended Action

Red, Yellow, & Green Light
Quickly Indicates issue and severity
PD Valve Friction

- Friction/Dead Band Test
  - Friction is a key indicator of valve assembly degradation
  - Possible early indication of...
    - Stem deformation
    - Rotary plug wear
    - Packing issue
    - Trim damage
  - Calculates average...
    - Friction (sliding stem)
    - Torque (rotary)
    - Dead Band
- Friction/Dead Band Trend
  - User configurable Max/Min
  - Trend line to determine urgency
Triggered Profile

• If PD - Have you turned on the Recorder?
Triggered Data

When things happen while we are away, the combination of DVC and ValveLink Software capture & record the abnormal activity.

“Diagnostics Data Available” flag in AMS Device Manager

| Information | 00:00:00 | Data Collection Started |
| Error | 00:00:00 | Low Supply Pressure |
| Information | 00:00:00 | No Active Alerts Detected |

Possible Cause | Recommended Action
--- | ---
Low supply pressure | Increase supply pressure. Supply pressure should be 5 psig above the upper bench set. For piston actuators, supply pressure should be at least 40 psig. Check the calibration of the supply pressure sensor.
Improve Process Control

• Poor process control reduces valve life. Poor performance control valve will upset process.
• If control or tuning is poor, valves will cycle. This will increase process variability and quality problems.
• Cycling will accelerate valve wear, causing premature valve failure.

Ensure Sufficient Packing Friction to Prevent Process Leakage

Is There Sufficient Force to Close the Valve?

Dynamic Error Band

Valve Signature

Diagnostics (Bench Marking)

<table>
<thead>
<tr>
<th>Analyzed/Result</th>
<th>Data Points</th>
<th>Analyzed</th>
<th>Notes</th>
<th>Valve</th>
</tr>
</thead>
<tbody>
<tr>
<td>Zero Ranged Travel at:</td>
<td>3.94 mA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Full Ranged Travel at:</td>
<td>13.95 mA</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Dynamic Error:</td>
<td>0.95%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum Dynamic Error:</td>
<td>1.31%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum Dynamic Error:</td>
<td>0.59%</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Dynamic Linearity (ind):</td>
<td>0.17 %</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average Friction:</td>
<td>58 lbf</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Maximum Friction:</td>
<td>67.78 lbf</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Minimum Friction:</td>
<td>50 lbf</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expected Packing Friction:</td>
<td>168 lbf</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Expected Total Friction:</td>
<td>168 lbf</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Spring Rate:</td>
<td>682.23 lbf/in</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bench Set:</td>
<td>3.61 - 14.74 psig</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Seat Load As Tested:</td>
<td>214.81 lbf</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Service Seat Load:</td>
<td>221.81 lbf</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Required Seat Load:</td>
<td>257.04 lbf</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Valve Signature

- Valve Signature Graph
  - Out-Of-Service valve diagnostic
  - Diagnose valve and trim problems without opening up the valve.
    - Minimizes needless repair
    - Validates proper assembly after valve assembly repair
  - Verify seat profile
    - Assures proper seal load
    - Reduces damaged valve trim
  - Graph Overlay
    - Compare current graphs with past graphs to determine degradation
  - Export data for easy offsite analysis support
Fundamentals of Diagnostics Off-Line

- Valve Step Response
  - Out-Of-Service valve diagnostic
  - Exportable Performance Data
    - Gain %  Dead Time
    - Over Shoot  Error %
    - Time 63  Time 86

- Critical data for loop simulation
  - Preconfigured Performance Test
    - 25 Steps
    - 12 Reversals of travel
  - User Configurable Step Test
    - Up to 30 steps
Step Response Test

Loop / Calibration Check

The Step Response test graphically depicts the response of an instrument and valve. This test plots TRAVEL versus the TIME it takes to move through the specific steps.
By utilizing the “Batch Runner”, automate all the tests or perform calibration of multiple tags.

TIP: Great during the Plant Outage
Scheduler Benefits:
Perform repeated task with a user specified routine.
Run on a recurring daily, weekly, or monthly schedule.
Configurable tasks include:
1. Valve Friction Test
2. PD One Button
3. Partial Stroke
4. Upload PD or PST/SIS Diagnostics Data.

Too Much Hassle; Too Little Time – Schedule them!

TIP: Great when Plant is In-Service
Summary - Troubleshooting

Step 1 – Research
- Talk to Operations for obvious symptoms (Alert history, Problematic valves)
- Narrow down what tests to run – Work with your partner, Puffer-Sweiven

Step 2 – Connect with AMS and ValveLink software
- Integrated I/O: Use ValveLink SNAP-ON from a Maintenance Console
- Non-Integrated I/O: Use ValveLink Solo or Mobile from the marshaling cabinet or field

Step 3 – Level 1 & Level 2 Monitoring in ValveLink software
- Level 1: ValveLink Dashboard – Do parameters match (Setpoint, Travel, Pressure, etc.)
- Monitor Alert on AMS or AMS ValveLink Snap-On

Is instrument PD? - Step-Up if required
- Level 2: Watch PD Profile (online trend) - Is Travel following Setpoint?
- Run PD One Button (Scheduler available)
- Run PD Friction (Scheduler available)
- Analyze Triggered Profile (if available)

Step 4 – Offline Diagnostics (Valve must be OOS or bypassed)
- Performance Step Test, Compare to stored test
- Perform Valve Signature, Compare to stored test
- Set Triggered Profile (if not already done)
Samson EXPERTplus Diagnostics

• Design
  – Decrease Plant Downtime
  – Predictive Diagnostic Data
  – Integrated Diagnostics
  – Cost Optimization
SAMSON EXPERTplus Diagnostics

Performance | Valve
---|---
![Performance and Valve Indicators]

Condensed state
Maintenance demanded
SAMSON EXPERTplus Diagnostics

<table>
<thead>
<tr>
<th>Component</th>
<th>Parameters</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Positioner status</td>
<td>33 Parameters</td>
<td>✓</td>
</tr>
<tr>
<td>Valve status</td>
<td>4 Parameters</td>
<td>✓</td>
</tr>
<tr>
<td>Actuator status</td>
<td>10 Parameters</td>
<td>✓</td>
</tr>
<tr>
<td>Valve position status</td>
<td>11 Parameters</td>
<td>✓</td>
</tr>
</tbody>
</table>

- **Start-Up Monitoring**
  - Powering On
  - During Initialization

- **Self-Monitoring**
  - Device Faults: HW / SW / Internal Temperature
  - Control Signals: CV, MV, and Supply / Output Pressure
  - Control Performance
SAMSON EXPERTplus Diagnostics

- **Data Logger**
  - Travel \( x \), SP \( w \), Error \( e \), & Signal \( p_{\text{out}} \)
  - Snapshot of what is going on in the process
SAMSON EXPERTplus Diagnostics

- Valve Signatures
  - Signal Pressure
  - Hysteresis
• Change in Frictional Forces
SAMSON EXPERTplus Diagnostics

- Valve position x histogram
- Set point deviation e histogram
- Cycle counter histogram

- Travel
- Set Point Deviation
- Cycle Counter
SAMSON EXPERTplus Diagnostics

- Valve Position
SAMSON EXPERTplus Diagnostics

- Static Characteristic / Dead Band

```
Mean dead band: 0.08 %
Min. dead band: 0.04 %
Max. dead band: 0.20 %
```
SAMSON EXPERTplus Diagnostics

• End Position Trend
SAMSON EXPERTplus Diagnostics

- End Position Trend
SAMSON EXPERTplus Diagnostics

- Leakage Sensor
SAMSON EXPERTplus Diagnostics

- Partial Stroke Test (PST)
- Full Stroke Test (FST)
SAMSON EXPERTplus Diagnostics

- Error Code from Engineering Tools
- Error Codes from Position+ O&M Manual
Control Valve Case Studies

1. Erosion – Shane Pirtle – 10 min
2. Diaphragm leak – Joseph Dufresne – 10 min
3. Resolution – Joseph Dufresne – 10 min
4. Dead Band – James Beall – 10 min
5. Response time – James Beall – 10 min
Case Study 1 Erosion

Valve Failure
Valve Erosion

• High Velocity and pressure drops
  – Steam or high pressure letdown
• Process incompatibility
  – Acids or caustics
• Poor sizing
  – Operating almost closed – valve chatter
• Cavitation or Flashing
Cavitation

- Occurs when a liquid is subjected to rapid changes of pressure that cause the formation of voids or bubbles where the pressure is relatively low.
- When the pressure increases, the voids implode and can generate an intense shock wave.
Cavitation
Damage

- Collapsing voids or bubbles that implode near a metal surface which cause deformation through repeated implosion.
Bubbles

In water
Nuclei
Cavitation bubble
Rebound
Surface of solid
Micro jet
Shock wave
Plastic deformation

High speed / Low pressure
Decrease of speed
Valve Trim Erosion
Trim Erosion
Valve Body
Body Downstream
Pipe
Control Hazards

• Deterioration of process control
  – Eventually no control
• Trim is no longer per design conditions
• Control valve shut off is no longer possible
• Loss of control may not be immediately obvious
Troubleshooting

- Don’t wait until it’s too late
- Per engineering design
  - Approximate valve opening at specific conditions
- Process rates do not change with movement of the valve
  - Minimal or no pressure drop change
- Reduced noise levels
  - Due to erosion the pressure drop is decreased
Flashing

- Occurs when the vapor pressure downstream of a control valve is less than the upstream vapor pressure, part of the liquid changes to a vapor and remains as a vapor unless the downstream pressure recovers significantly.
Valve Sizing

- If the Cv is too small:
  - Valve under sized
  - Starving for fluid downstream
  - Buildup of upstream pressure
  - Higher pressure drops which may damage equipment
  - Cavitation & Flashing
Valve Sizing

- If the CV is too large:
  - Oversized valve is selected – larger pipe
  - Size & weight increases thus cost and support
  - Poor control, operating almost closed
  - Pinched flow - faster velocity - trim erosion
Minimizing Cavitation

- Engineering design
  - All components in the stream must be accounted for
  - Design for absolute minimum and maximum rates
- Use Low Noise (Lo DB) trim if possible
  - Provides multiple paths
  - Minimizes bubble creation
  - Typically clean fluids only
Low Db

*Plug/stem assembly*

*Seat ring*

*Anticavitation cage*

*Multiple path type low noise trim*
Low Db
Butterfly option

Monovar flow characteristic

Butterfly flow characteristic

3 x Pipe diameter

5 to 8 x Pipe diameter
Noise

- **Noise** is a byproduct of a control valve doing its job. However, sometimes the sound you hear may be a warning of cavitation damage.

- The noise, if loud enough, may also pose a health hazard to nearby employees.
Sound Measurement

Hearing protection may be required
SAMSON Case Study – # 2 Diaphragm Leak

Tag no.: -/-
Operating hours counter: 2:11:47:16
Current operating mode: Automatic
Switch position (ATO/ATC): ATO (air to open; closing)
Condensed state:
Set point [\(w]\): 90.6 %
Valve position [\(x]\): 89.3 %
Set point deviation [\(e]\]: 1.3 %
Supply pressure: 6.1 bar
Signal pressure p out: 1.0 bar
Temperature inside device: 26.9 °C

Performance | Valve | Actuator | Positioner
--- | --- | --- | ---
OK | OK | OK | OK
SAMSON Case Study – #2 Diaphragm Leak

- **Initialization status**: Not active
- **Diagnostics assessment starts in**: 00:00:00 d:h:mm:ss
- **Positioner status**: No
- **Valve status**: No
- **Actuator status**: Yes
- **Valve position status**: Yes
SAMSON Case Study – # 2 Diaphragm Leak

Device parameter cannot be edited

Status message triggered by diagnostics.
Possible cause: pneumatic leak.
Solution: check that pneumatic installations and connections are tight.
SAMSON Case Study – # 2 Diaphragm Leak
SAMSON Case Study – # 2 Diaphragm Leak
### SAMSON Case Study – # 3 Resolution

<table>
<thead>
<tr>
<th>Tag no.:</th>
<th>-/-</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating hours counter:</td>
<td>5,19:02:27</td>
</tr>
<tr>
<td>Current operating mode:</td>
<td>Automatic</td>
</tr>
<tr>
<td>Switch position (ATO/ATC):</td>
<td>ATO (air to open; closing)</td>
</tr>
</tbody>
</table>

**Condensed state:**

- Set point \([w]\): 10,6 %
- Valve position \([x]\): 10,6 %
- Set point deviation \([\Delta]\): -0,1 %
- Supply pressure: 5,8 bar
- Signal pressure \(p_{out}\): 1,9 bar
- Temperature inside device: 23,0 °C

### Performance

- Friction influences the action
- Friction: Higher in mid-point

### Valve

- Friction: Higher in mid-point

### Actuator

- OK

### Positioner

- OK
SAMSON Case Study – #3 Resolution

### Valve Diagnostics

<table>
<thead>
<tr>
<th>Name</th>
<th>Value</th>
<th>Unit</th>
<th>Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>Change in friction</td>
<td></td>
<td></td>
<td>Higher near CLOSED position</td>
</tr>
<tr>
<td>Seat leakage</td>
<td>No</td>
<td></td>
<td>No</td>
</tr>
<tr>
<td>Packing leakage</td>
<td>No</td>
<td></td>
<td>No</td>
</tr>
<tr>
<td>Total valve travel exceeded</td>
<td>No</td>
<td></td>
<td>No</td>
</tr>
</tbody>
</table>

#### Device parameter cannot be edited

Status message triggered by diagnostics.
Possible causes:
- Friction higher/lower across valve's entire travel range.
- Friction higher/lower in valve's mid-position.
- Friction higher/lower near valve's max. OPEN position.
- Friction higher/lower near valve's max. CLOSED position.
Solution: check valve's packing.
SAMSON Case Study – # 3 Resolution

Druckkennlinie p out(x)

- Reference
- Repetition

p out [bar]

x [%]
SAMSON Case Study – # 3 Resolution

Diagram showing pressure output (p out) in bars (bar) against x (in %) for different conditions:
- Fill with air
- Vent
- Monitoring
- Supply pressure
- Min. supply pressure (p s min)
- Max. supply pressure (p s max.)

Graph plotted with various markers and lines indicating the different conditions and their respective pressure outputs.
SAMSON Case Study – # 3 Resolution

Diagram

Valve signature, friction(x)

Hysteresis [%]

Friction reference
Calculated friction

71st Annual Instrumentation and Automation Symposium for the Process Industries
Case Study 4 – Dead Band

PV Cycles With Controller in Auto

Controller Output

~4% PP - OUT

Setpoint

Process Variable

2% PP - PV

45 Min

Process: Integrator
Kp=0.00358 %Span/Sec/%Out, Td=16.8 Sec
Controller: Emerson Delta V (Standard, D on PV), Standard PID (D on PV), Units=%Out/%Span, Ctrl Int.=1 Sec
KC=2.106 Gain, TR=496.8 Sec/Rep

For Help, press F1
Case Study 4 – Dead Band

Manual step test to determine valve dead band.

1% Steps of Output in Manual

Dead Band ~4 - 5% Output

PV responds

Process: Integrator
Kp=0.00358 %Span/Sec/%Out, Td=16.8 Sec
Controller: Emerson Delta V [Standard, D on PV], Standard PID (D on PV), Units=%Out/%Span, Ctrl Int.=1 Sec
KC=2.106 Gain, TR=2000 Sec/Rep
Case Study 4 - Limit Cycle Gone!

Added positioner- Dead band < 0.1%

No cycling!

Process Disturbance

Controller Output

Setpoint

Process Variable

Process: Integrator
Kp=0.00358 %Span/Sec/%Out, Td=16.8 Sec
Controller: Emerson Delta V [Standard, D on PV], Standard PID (D on PV), Units=%Out/%Span, Ctrl Int.=1 Sec
KC=2.106 Gain, TR=496.8 Sec/Rep
Case Study 5 – Slow Response Time

Steam Flow

Controller Output

Limit cycle in Auto
Valve Step Response Time ($T_{86}$)
Per ANSI/ISA S.75.25

$T_{86}$ – Includes Dead Time
Case Study 5 – Slow response time

1% Output Steps

Valve Feedback

< 5 min. →

90 second response time (T98) for some steps
Case Study 5 – Slow Response Time

Solution: Re-tune Smart Positioner

1% Output Steps

Valve Feedback

< 5 min. →

Slowest response time (T98) is 8 seconds
Case Study 5 – Slow response time

Results: Variability reduced by 80%

Before: 2 Sigma = 8% of mean
After: 2 Sigma = 1.28% of mean
Joseph R. Dufresne

• Sr. Product Manager for SAMSON
• 10 years experience
• Masters in Electrical Engineering - Control Systems
• Member of ISA 75 Control Valve Std. Committees
• Co-Chair of ISA 108.2.5 Intelligent Valve Management
• joseph.dufresne@samsongroupna.com
Speaker Bio

- Craig Jeane, Severe Service Business Manager
  - Local Business Partner for Emerson Process Management, Specializing in Fisher® Control Valves and Instruments
  - 30 years in various roles as an Application Engineer, Asset Manager, and Account Manager, in Alaska, Washington, Oregon, and the Gulf Coast of Texas.
Shane W. Pirtle, P.E.
Sr. Consultant
Instrument Reliability, SIS, Design Engineering

Testengeer Inc., - EPC, Division Manager
Mangan Inc. - EPC, Engineer Manager
Dow Chemical Co. – Instrument Technology, Engineering & Maintenance
– retired 30 yrs
Speaker Bio

• Craig Jeane, Severe Service Business Manager
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  – 30 years in various roles as an Application Engineer, Asset Manager, and Account Manager, in Alaska, Washington, Oregon, and the Gulf Coast of Texas.
Speaker Bio

• Bart Propst, Process Control Manager, Ascend Performance Materials Inc.

– 20 years in various roles as process controls engineer, process engineering manager.