A KPI for control valve reliability used in projects with SPI

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The presenter

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  - Active in software development since 1979
  - Developing instrumentation and process design software since 1985
  - Doing engineering services since 2001
Overview

• Common risks on problems in control valve sizing and selection
  – Capex projects
  – Turnarounds
• Solution by predictive reliability analysis
• Lessons learned
  Applying reliability index “Ri” in real life together with SPI
## What you’ll see and what not

<table>
<thead>
<tr>
<th>Topic</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control valve</td>
<td>Calculation and optimization especially from the control engineering point of view</td>
</tr>
<tr>
<td>Control valve (two phases)</td>
<td>Calculation and optimization of control valves with two-phase flow at the inletsa</td>
</tr>
<tr>
<td>Steam conditioning valve</td>
<td>Calculation of the steam conditioning unit including the required cooling water flow</td>
</tr>
<tr>
<td>Actuator forces</td>
<td>Calculation of required actuator forces of globe valves</td>
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<tr>
<td>Differential pressure flow element</td>
<td>Flow measurement according to ISO, API and ASME with orifice elements, venturi tubes, nozzles and pitot tubes</td>
</tr>
<tr>
<td>Restriction orifice plate</td>
<td>Sizing, adaptation and optimization</td>
</tr>
<tr>
<td>Pressure loss</td>
<td>Taking into account the pipe length, individual resistances and elevation differences</td>
</tr>
<tr>
<td>Pressure surge</td>
<td>Pressure surge characteristics with variable closing times and different valve characteristics</td>
</tr>
<tr>
<td>Sizing</td>
<td>Cross-sectional area, jacket area, flow velocities, Joukowsky peak, etc.</td>
</tr>
<tr>
<td>Pipe compensation</td>
<td>Calculation of the changes in length, pipe support loads and compensation (L or U-bend)</td>
</tr>
<tr>
<td>Span calculation</td>
<td>Taking into account the dead weight, insulating material and maximum permissible sag</td>
</tr>
<tr>
<td>Pipe wall thickness</td>
<td>This calculation according to EN 13480 and DIN 2413 applies to pipes subjected to an internal pressure</td>
</tr>
</tbody>
</table>
What you’ll see and what not

- **Shell-and-tube heat exchangers**: Sizing and recalculation of liquid-liquid shell-and-tube heat exchangers from the process engineering point of view.
- **Condenser**: Calculation of liquid-cooled condensers.
- **Material data calculation**: Computation of the characteristics of tubing and equipment materials.
- **Pressure relief valve**: According to AD, ISO, API and ASME, pressure losses and piping forces, two-phase flow.
- **Rupture discs**: Calculation of rupture discs according to API 520 and ISO 4126.
- **Thermowells**: Calculation of thermowells according to ASME PTC 19.3.
- **Level calibration**: Measurement of drum level using a differential pressure transmitter.
- **Tank depressurization**: A tank filled with gas is depressurized either into the atmosphere or into a second tank.
- **Pump and compressor output**: The motor power requirements of pumps, fans and compressors are determined.
- **Substance calculation**: Calculation of pressure and temperature-related properties.
- **Thermodynamics module**: Calculate and plot thermophysical properties of substances in the fluid phase.
- **Regression**: Graphical representation and adaptation of a curve to a series of measuring points.
Control Valve Cost Distribution

Small number

Number of valves

- 94% Standard Control Valves
- 6% Critical / High Performance Control Valves

Big impact on purchase cost

Proportional purchase cost

- 62% Standard Control Valves
- 38% Critical / High Performance Control Valves
Scenario: Capex projects

- High performance valves are not fit for the application
- Risk of valves failing during commissioning and startup
- Real example of a Petrochemical plant
  - Major problems with high performance valves
  - >2,5 million $ reengineering and replacement cost
  - Startup delay > 30 days
Scenario: Turnarounds

- Detection of unexpected damages on High Performance Control Valves
- Spare part lead time several month
- Workarounds are introducing further cost
- Risk off project and startup delays
Common to both scenarios

• Root cause analysis necessary
  – Based on the “real” process data (hard to get)

• Reengineering
  – Depending on vendor recommendations for the solution
  – Risk of repeatedly selecting a poor solution

• Replacement
  – Long lead times may impact operation
  – Risk of operation loss
What if...

• you could predict if a Control Valve is “fit for the application” at all?
• you could predict reliability problems (e.g. due process data changes) to preorder spare parts for turnarounds.
• you get rating for how good a valve fits to the process conditions to select the best available solution
• you could apply “Ri” on large control valve populations
• you could thereby minimize the risk of capital losses
Control Valve sizing and selection

• Select a valve that
  – works stable in the required range of control
  – give you some reserve on control
  – fulfills its job reliable

• Verify that the selection meets all the requirements

• Don’t rely on a vendors recommendation only
Why do we need a KPI?

• Are you a valve nerd?
  Some, maybe most of us will answer “For sure not”
• “How can I reproducible decide if a valve matches the given process conditions so that it performs reliable in any mode of operation?”
  – Gut instinct?
  – Rules of thumb?
  – Applying best practices?
Why do we need a KPI?

• Ensure that independent from the individual doing the analysis the given rating is reproducible identical
• Allow analysing valve cases by “non-nerds” having “only” the process conditions
• Quickly detect the severe cases in big number of cases
• To predict the impact of changing process conditions
• ...
Why do we need a “Ri” KPI?

• To review the full range of operating conditions: (Min, Norm, Max, Start-up, ... 0% to 100% of valve opening)

• To ensure that you don’t miss something
Quick definition of “Ri”

• A single number for each operating / process condition
• The range of the value is defined
  – 0 to 0.1  •  No reliability problems expected
  – 0.1 to 0.5  •  Possible reliability problems
  – 0.5 to 1  •  Limited reliability
  – >1  •  Possible mechanical damage

• Additional info on the root cause and options to improve
Building the “Ri” in brief

• To calculate the “Ri”, all major reliability influencing factors need to be taken into account.
  • General parameters like
    – Δp
    – Energy conversion
    – Noise level
    – Outlet flow velocity
    – Valve type

• Flow conditions
  – Cavitation
  – Flashing
  – Choked flow

• Fluid properties

• Process conditions
  – Normal operation
  – Start-up
  – Special operation

• ...

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How to apply a “Ri” in projects?

• Import latest data from SPI and vendor tools
• Determine the “Ri” with final operating conditions for all modes of operation for all control valves
• Follow the hints, discuss and select more suitable solutions
• Ensure that finally no valve will be selected with a “Ri” > 0.1

• Sounds easy, isn’t it?
Challenges applying the “Ri”

Process data / specification

• Tools involved
  – Process simulators
  – SPI
  – Vendor tools

• One time handover
  – Process Data Sheet
  – Instrument Data Sheet

• Bulk processing

Interfaces involved

• Import from
  Process Simulator Software

• Import from SPI
  – Process Datasheet
  – Instrument Datasheet

• Import from Vendor tool
  – Fisher First 2
  – Fisher Specification Manager
CAT General processing

C - Preprocessing/Importing
EPC / Vendor Client datasets
Legacy data Excel SPI ...

I - CAT Import dataset

R - CAT Result/Verification datasets

V - Exporting/Reporting

Challenges Non-compliances
Comparisons Most Effective Engineering Solutions

CAT BLOCK DIAGRAM
**CAT Control Valves Verifications - package 1**

**Identifier:** 26NAG

<table>
<thead>
<tr>
<th>Valve Name</th>
<th>Type</th>
<th>Size</th>
<th>DN</th>
<th>Cv 100</th>
<th>Notes</th>
</tr>
</thead>
<tbody>
<tr>
<td>26FV1302</td>
<td>D</td>
<td>11/4</td>
<td>14</td>
<td>125</td>
<td>SPL 124/165/98.1 DB(A)</td>
</tr>
<tr>
<td>V26E8</td>
<td>Full bore</td>
<td>12</td>
<td>2600</td>
<td>SPL 96/68/82 DB(A)</td>
<td></td>
</tr>
</tbody>
</table>

**Valve Size:** Conval recommends a larger valve size

**Noise Calc:** Pressure level correction

**Model:** Consider a larger valve size

**Reliability Influencing Factors:**
- Cv100: Lower than Conval suggested minimum flow coefficient
- Valve outlet too small
- Conval has compared EPC properties vs. extended properties data and made 2 cases

**Pipe Schedule:** Missing in EPC package. Std assumed. Possible impact on noise calculation

**Fluid Properties:** Conval has compared EPC properties vs. extended properties data and made 2 cases

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**26PV3112A**

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<th>Cv 100</th>
<th>Notes</th>
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<tr>
<td>A31A 1/4&quot;</td>
<td>D</td>
<td>1/4</td>
<td>1</td>
<td>1000</td>
<td>Heavy duty valve</td>
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**30PV208A**

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<tr>
<td>D</td>
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**Fluid Properties:** Conval has compared EPC properties vs. extended properties data and made 2 cases

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**Evaluation Criteria:**

- Cv100: Lower than Conval suggested minimum flow coefficient
- Valve outlet too small
- Conval has compared EPC properties vs. extended properties data and made 2 cases
- Conval recommends a special valve

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**Noise Calc:** Heavy duty valve

**Valve Performance Class:** Conval recommends a special valve

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**Impact Downstream Schedule on Noise Calculation:** Impact fit if flow passage (AVP) used 500?
CAT Verification issues statistics
CAT issues pareto chart

- VALVE OUTLET: Valve outlet too small.
- VALVE TYPE: Vendor selected a different valve type than EPC specified.
- VALVE SIZE: Conval recommends a larger valve size.
- NOISE CALC: Conval yields a substantial higher SPL (sound pressure level) according to latest IEC 60534-8-4.
- NOISE CALC: High SPL.
- VALVE DBASE: Valve missing in Conval vendor valve database.
- PROCESS DATA: missing in EPC and vendor package.
- NOMINAL FLOW COEFF: Cv100 lower than CONVAL suggested minimum flow coefficient.
- NOMINAL FLOW COEFF: Cv100 lower than Cv at max flow.
- VALVE PERFORMANCE CLASS: Conval recommends a special valve.

number of issues

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Challenges applying the “Ri”

Data contend
• Data not complete
• Data not correct
• Data changing last minute
• Data not covering all modes of operation (e.g. Start-up)

Data format
• Data structure specification not consistent
• Data not structured (e.g. Notes)
• Flashing / Outgassing data in SPI process datasheet
• Lots of relevant data un UDFs
Special challenges in projects

Communication

• The biggest challenge at all
• 3+ parties involved
• Project workflow is not yet designed to use a “Ri” as a central quality control element
• There is no common data language for cycling specification and selection data
• No common practice established yet

Collaboration

“Ri”

- EPC process design
- Owner Operator requirements
- EPC I & C
- Valve Vendor selection