PSV RBI
Pressure Safety Valve RBI - Using Half a Billion Hours of Data
Chris Bell – Digital Innovation Team

25 Feb 2020
DNV GL – Our History

LOOKING TO THE FUTURE WITH 150 YEARS OF EXPERIENCE

- Oil and Gas
  - Verification
  - Engineering Consultancy

- Digital
  - Maritime (classification)
  - Energy
  - Business Assurance
PSV RBI - Agenda

- Pressure Safety Valves
  - Maintenance processes
- RBI
  - Philosophy and approach
  - RBI process
  - Results and benefits
- Other applications
  - BDV
  - EX equipment
  - etc.
Pressure Safety Valves

Installed to mechanically relieve pressure

1. From a source such as a well, pump, spec break in pipework
   • PSV often, though not always, sized for full flow i.e. to relieve inflow if the normal pressure outlet is blocked

2. In a fire scenario

3. From thermal changes e.g. solar heating

• Most PSVs offshore are installed for reason (1)
• Across process and non-process pressure containing equipment
• Typically 100s of PSVs on a platform
Valve Contractor:

- Replacement PSV taken from onshore stock
- Certificate generated (PSV retested if needed) and PSV sent offshore

Operator:

- Operator identifies that PSV is approaching change-out date
- New PSV fitted
- Old PSV sent onshore
- Maintenance interval changed as required

Pre-pop test carried out on PSV and then overhauled

PSV Maintenance Process

- PSV has hidden failures modes
  - Blockage e.g. wax, corrosion products
  - Drift – gradual change in set-point of the PSV
- Therefore must be tested and maintained
  - Cannot be done in-situ (Trevi testing aside)
- Testing and Maintenance process offshore can be costly (averaging £1,000s per PSV) and have knock-on effects (shutdown driven)
- So it is worth optimising the maintenance interval
8.8 Nomenclature

\( A_{\text{prod}} \) is the entire area of the PRD.

\( A_{\text{total}} \) is the total installed area.

\( C_{\text{env}} \) is the environmental condition.

\( C_{\text{fin}} \) is the PRD COF to open.

\( C_{\text{off}} \) is the consequence of an event.

\( D_{\text{d}} \) is the demand rate associated with the \( j \)-th overpressure demand case, failures/year.

\( D_{\text{pfo}} \) is the duration of a stuck open PRD, days.

\( D_{\text{prod}} \) is the total demand rate on a PRD, demand/year.

\( D_{\text{prod}} \) is the demand rate reduction factor associated with the \( j \)-th overpressure demand case.

\( E_{\text{prod}} \) is the consequence associated with the \( j \)-th overpressure demand case.

\( F_{\text{prod}} \) is the confidence factor for conventional vales.

\( F_{\text{prod}} \) is the adjustment factor for environmental of the test.

\( F_{\text{prod}} \) is the confidence factor for historical inspection records.

\( F_{\text{prod}} \) is the adjustment factor for overpressure.

\( F_{\text{prod}} \) is the adjustment factor for overpressure.

\( F_{\text{prod}} \) is the adjustment factor for the ratio of open.

\( F_{\text{prod}} \) is the factor for the lost inventory of the PRD.

\( F_{\text{prod}} \) is the cost of lost inventory of the PRD.

\( G_{\text{prod}} \) is the production loss, $.

\( G_{\text{prod}} \) is the production loss, $.

\( G_{\text{prod}} \) is the maintenance and operation.

\( H_{\text{prod}} \) is the damage factor as a function of time.

\( P_{\text{prod}} \) is the POF (loss of containment) of the protected equipment, failures/year.

\( P_{\text{prod}} \) is the conditional POFOD, failures/demand.

\( P_{\text{prod}} \) is the POF (loss of containment) of the protected equipment, failures/demand.

\( P_{\text{prod}} \) is the prior POFOD, failures/demand.

\( P_{\text{prod}} \) is the weighted POFOOD, failures/demand.

\( P_{\text{prod}} \) is the weighted POFOOD, failures/demand.

\( P_{\text{prod}} \) is the PRD POFOD associated with the \( j \)-th overpressure demand case.

\( P_{\text{prod}} \) is the PRD probability of leakage, failures/year.

\( P_{\text{prod}} \) is the weighted probability of leakage, failures/demand.

\( P_{\text{prod}} \) is the overpressure likely to occur as a result of a PRD failing to open upon demand, kPa (psig).

\( P_{\text{prod}} \) is the overpressure likely to occur as a result of a PRD failing to open upon demand, associated with the \( j \)-th overpressure demand case, kPa (psig).

\( P_{\text{prod}} \) is the prior probability of failing on demand, failures/demand.

\( P_{\text{prod}} \) is the storage or operating pressure of the protected equipment, kPa (psig).

\( P_{\text{prod}} \) is the set pressure of the PRD, kPa (psig).

\( P_{\text{prod}} \) is the total risk for a PRD, $/year.

\( P_{\text{prod}} \) is the risk of a PRD failure to open, $/year.

\( P_{\text{prod}} \) is the risk of the PRD failure to open associated with the \( j \)-th overpressure demand case, $/year.

\( P_{\text{prod}} \) is the risk of PRD leakage, $/year.

\( P_{\text{prod}} \) is the risk as a function of time, $/year (m²/yr) or $/year.

\( t \) is the time, years.

\( t_{\text{prod}} \) is the actual duration between inspections associated with the \( j \)-th historical inspection record, years.

\( \mu \) is the mean time to failure.

\( \beta \) is the Weibull shape parameter.

\( \beta_{\text{prod}} \) is the Weibull characteristic life parameter based on the default service severity chosen for a specific PRD, years.

\( \beta_{\text{prod}} \) is the Weibull characteristic life parameter modified to account for installation factors, design features, overpressure and environmental factors, years.

\( \beta_{\text{prod}} \) is the Weibull characteristic life parameter updated to account for inspection history, years.

\( \hat{D}_{\text{prod}} \) is the dimensionless production margin on the unit, $/dty.

\( \hat{D}_{\text{prod}} \) is the daily production margin on the unit, $/dty.
Methodologies

Semi-Quantitative

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<th>Consequence of Failure</th>
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Maximum maintenance interval:
- Grade 0: 2 years, No data
- Grade 1: 3 years, Some Data
- Grade 2: 6 years, Good data

Methodologies are either very complex, or very simple

DNV GL RBI APPROACH

- Modelling is extremely difficult and needs a massive amount of data to prove
- DNV GL use a combination of quantitative and qualitative methods
## FAILURES, QUANTATIVE AND QUALITATIVE APPROACHES

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<tr>
<th>Random Failures</th>
<th>Systemic Failures</th>
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<tr>
<td>• Failures can occur anywhere</td>
<td>• A specific cause gives a large number of failures in a particular area</td>
<td>• More amenable to qualitative approach</td>
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<td>• May be different failure rate for different PSVs services</td>
<td>• Cause may be clear and temporary, or unknown, or permanent</td>
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<td>- May be due to unknown factors</td>
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<td>• Inspection interval set such that residual risk of failure is acceptable</td>
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<td>More amenable to quantitative approach ((\lambda T/2))</td>
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**DNV GL & Repsol-Sinopec data**

- \( \frac{1}{2} \) billion service hours
- 10,311 tests, 544 failures
- Failure rate of 2.7% (though less without air)
- Intervals 6 months (rare) to 6 years (with 4 years being most common)

**OREDA2009**

- \( \frac{2}{3} \) million hours
- 1.2% failure rate
**QUANTITATIVE (III) – Risk assessment**

- QRA assessment uses:
  - Fixed demand rates on each class of PSV ($D$)
  - Thermal / Pressure / Fire
  - PSV Failure rate ($\lambda$)
  - POB

- Range of consequences from minor mechanical failure to full, ignited rupture ($N$)
  - Size of equipment protected
  - Set pressure
  - Fluid phase
  - Fluid flammability

**PLL = \frac{1}{2} \lambda \times T \times D \times N**

- PSV failure rate is compared to a Potential Loss of Life ($PLL$) limit ($10^{-5}$)
- Results in an upper interval limit ($T$)
Quantitative (IV) – Data consistency

- The history of each failure class is examined to determine improving or worsening behaviour
- Confidence limits assessment is carried out

- Data from similar assets are merged to prevent small differences in data leading to differences in interval
- Avoids 3.49 and 3.51 becoming 3 and 4 years respectively
QUALITATIVE – Individual PSVs

Three basic rules

1. **Halve** the interval if a **failure** occurs (e.g. 4F→2 years)
   - CAUTIOUS - If all failures were “random”, there would be no need to do this

2. **Add 50%** to interval if repeated **good** history (e.g. 2P, 2P→3 years)
   - Takes longer to increase interval than decrease it

3. Require repeated good history to move past a failure (e.g. 4F, 2P, 2P, 3P, 3P, 3P, → 4), though may never move past 3

Complexity added to above given some complex history
A “group” is a set of PSVs under identical conditions
- Same pressure
- Same fluid
- Same part of the process (almost guaranteed by two points above)

PSVs are grouped with identical service and location for optimising credit from combined performance history, or considering adverse impact of a failure in the group.

Gives confidence that the single failure is “random” and the interval can be 60 months (could be higher if failure had not occurred)

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<th>PSV Tag</th>
<th>PSV Tag history</th>
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<td>2-PSV-1005K</td>
<td>3p 3p 2.8p 2.9p 5p</td>
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<td>2-PSV-1005R</td>
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Results
Failure Rate Comparison

Pre RBI
Higher failure rates, lower intervals

Post RBI
Lower failure rates, higher intervals

Issues with air PSVs

Positive validation of methodology, though at a high level
RESULTS AND BENEFITS – Cost savings & safety improvements

- Average maintenance interval has changed from 37 months to 44 months
- Failure rate has dropped (apart from recent air failures – previously no testing done on these valves)
- For an average PSV maintenance cost of a few £1,000, the total cost reduction is from £6.5m per year to £5.4m per year (£1.1m saving)
RESULTS AND BENEFITS – Overview

- **Average Interval**
- **Total PLL**
- **Average Annual Cost**

**Increase**

- Average Interval: 49.1
- Total PLL: 9.76E-003
- Average Annual Cost: £3.32M

**Reduction**

- Increase: 49.30
- Total PLL: 9.60E-003
- Reduction: £3.31M

Various gains offset by poor air performance

Intervals more static after many years of running analysis
Trends easily seen and correct action taken where required – air in this case
RESULTS AND BENEFITS – Readily available information

- **PSV Manager gives**
  - **Insights** on performance
  - Allows poor performance to be **rectified**
  - Reduces maintenance costs when appropriate

- **Regarding the data**
  - Some trends can be **identified**
  - Benefits can be **lost** if changes in maintenance intervals are implemented
  - Obvious, but small intervals can **dominate** changes in cost
  - ½ **billion** hours of data is a lot
## RESULTS – Decrease interval to improve reliability
### Heating medium (3 assets)

- **37 tests, 8 fails**
- **Poor performance corrected through shorter maintenance intervals**

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- **Opportune test can be undertaken for operational reasons (shutdown driven usually)**
- **Poor performance at higher maintenance intervals**
- **Intervals reduced and no failures recorded recently**
### RESULTS – Overall no interval change but more targeted Production fluids (HP) (All assets)

- 498 tests, 16 fails
- Performance improved through more targeted maintenance and no overall change in interval

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- Performance variable with 13 failures in this period
- Maintenance optimised (no increase) and reduction to 2 failures in this period
- Only represents two failures
## RESULTS – Small increase in inspection interval
Produced water (6 assets)

- 170 tests, 9 fails
- Performance steady, though maintenance interval increased

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<tr>
<td>All Intervals</td>
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<td>2.5</td>
<td>2.6</td>
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<td>2.8</td>
<td>2.5</td>
<td>2.5</td>
<td>2.3</td>
<td>2.5</td>
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<td>3.0</td>
<td>3.3</td>
<td>3.4</td>
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</tr>
</tbody>
</table>

- Interval averaging 2.7 years
- Interval 3.2 years
Expansion of Method

- General process readily extendable to
  - Fire and Gas detection
  - Emergency shutdown valves
  - Blowdown valves
    - Issues can be more physical valve specific – low failure rates outside this
  - Instrumentation
  - EX equipment
  - Deluge (while the number of pumps is small, a large number of tests are carried out)
  - UPS batteries
Many thanks to Repsol-Sinopec for data

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