

Risk-Based Method to Establish Inspection Intervals for Pressure Relief Devices

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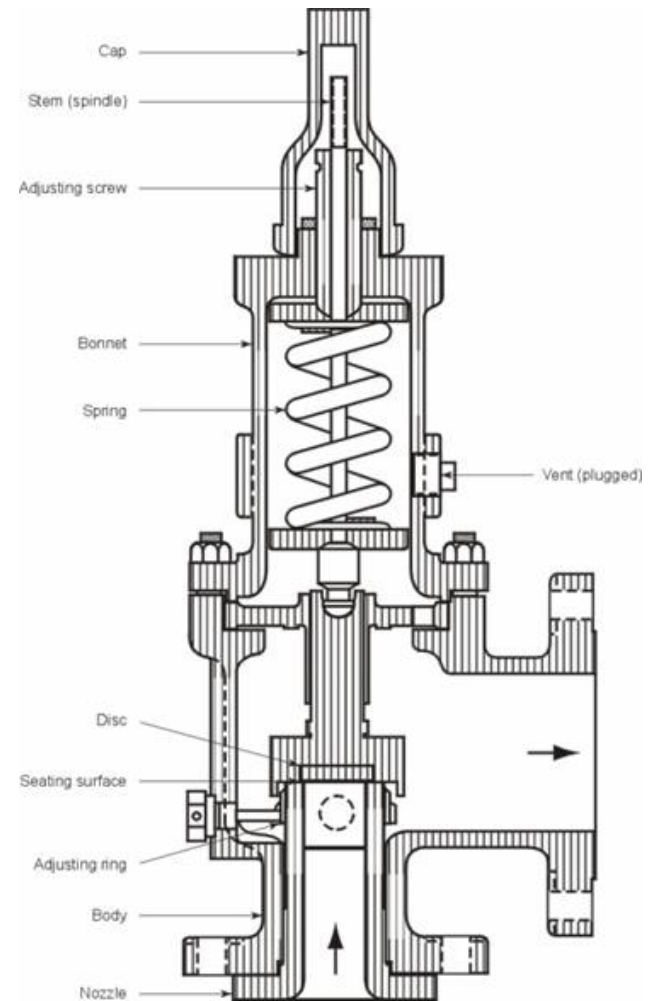


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Risk-Based Method to Establish Inspection Intervals for Pressure Relief Devices

- Background
- Methodology
- Probability of Failure
- Consequence of Failure
- Calculation of Risk
- Inspection Planning using Risk Targets
- Case Study
- Lessons Learned



Background

- PRD Inspection Intervals – How do they get established?
- API 510 Inspection Code
 - “pressure relief valves shall be tested at intervals that are frequent enough to verify that the valves perform reliably.”
 - “Intervals between pressure relieving device testing or inspection should be determined by the performance of the devices in the particular service concerned and maybe increased to a maximum of 10 years”
 - Latest version of 510 allows use of RBI to set intervals
- Inspection Programs per API 510 and NBIC
 - Condition Based (probability based)
 - Set an Interval, inspect and adjust based on results of inspection
- API RBI methodology evaluates both probability and consequence, i.e. risk-based

API RBI PRD Methodology

- Highly Quantitative
- Risk for PRDs are calculated for two failure modes
- Fail to Open (FAIL)
 - PRD does not open on demand during an overpressure scenario (fire, blocked discharge, CV failure, Loss of Cooling, Power failure, etc.)
 - Over pressures can be well over normal operating, for some scenarios burst pressure ($\approx 4 \times \text{MAWP}$)
 - Evaluate loss of containment (leaks or ruptures) from the protected equipment at the overpressure calculated for each applicable overpressure scenario
 - Includes repair costs of equipment, personnel injury, environmental and production losses
- Leakage Failure (LEAK)
 - PRD leaks in-service
 - Considers cost of lost fluid inventory, repair costs, production losses if downtime is required to repair PRD
- $\text{RISK} = \text{POF} \times \text{COF} + \text{POL} \times \text{COL}, \text{ \$/year}$

Probability of Failure

- Probability of Failure

$$POF = POFOD \times DR \times (GFF \times DF)_{OP}$$

- *POF* is probability of PRD failure to open during emergency situations causing an overpressure situation in the protected equipment resulting in loss of containment (failures/year)
- *POFOD* is the probability of the PRD failing to open on demand (failure/demand)
- *DR* is the demand rate on the PRD or how often an overpressure situation arises that causes a demand on the valve (demands/year)
- (*GFF x DF*) is the probability of failure (loss of containment) from the vessel in its current damaged state

Consequence of Failure

- Calculate impact area (consequence area) of release of hazardous fluids
 - Flammable
 - Toxic
 - Non-flammable (splash, spray, physical explosion, BLEVE)
- Consequence areas are based on damage to equipment and serious injury (fatality) to personnel
- Impact area is based on thermal radiation exposure overpressure from explosion, toxic concentration and dosage limits
- Financial consequences include
 - Replacement cost of damage equipment
 - Cost of business interruption
 - Cost of serious personnel injuries
 - Environmental clean-up costs

Calculation of Risk

- The calculation of risk for a PRD failing to open upon demand is calculated for EACH applicable demand case using the demand rate, the probability of failure of the PRD and the calculated overall consequence of failure for the demand case as follows:

$$Risk_{DC} = POF_{DC} \times COF_{DC}$$

- The overall risk is then determined by adding up the individual risks associated with the applicable demand cases as follows:

$$Risk_{fto} = \sum_{i=1}^n POF_{DCi} \times COF_{DCi}$$

where i represents each of the n number of applicable overpressure demand cases

- Accounts for the fact that PRDs may have many different overpressure scenarios, some PRDs more critical than others
- Enables the criticality of the PRD service to impact Risk, i.e. more critical services result in more risk

Inspection Planning Using Risk Target

- Consequence of failure is not time dependent
- Probability of failure increases with time

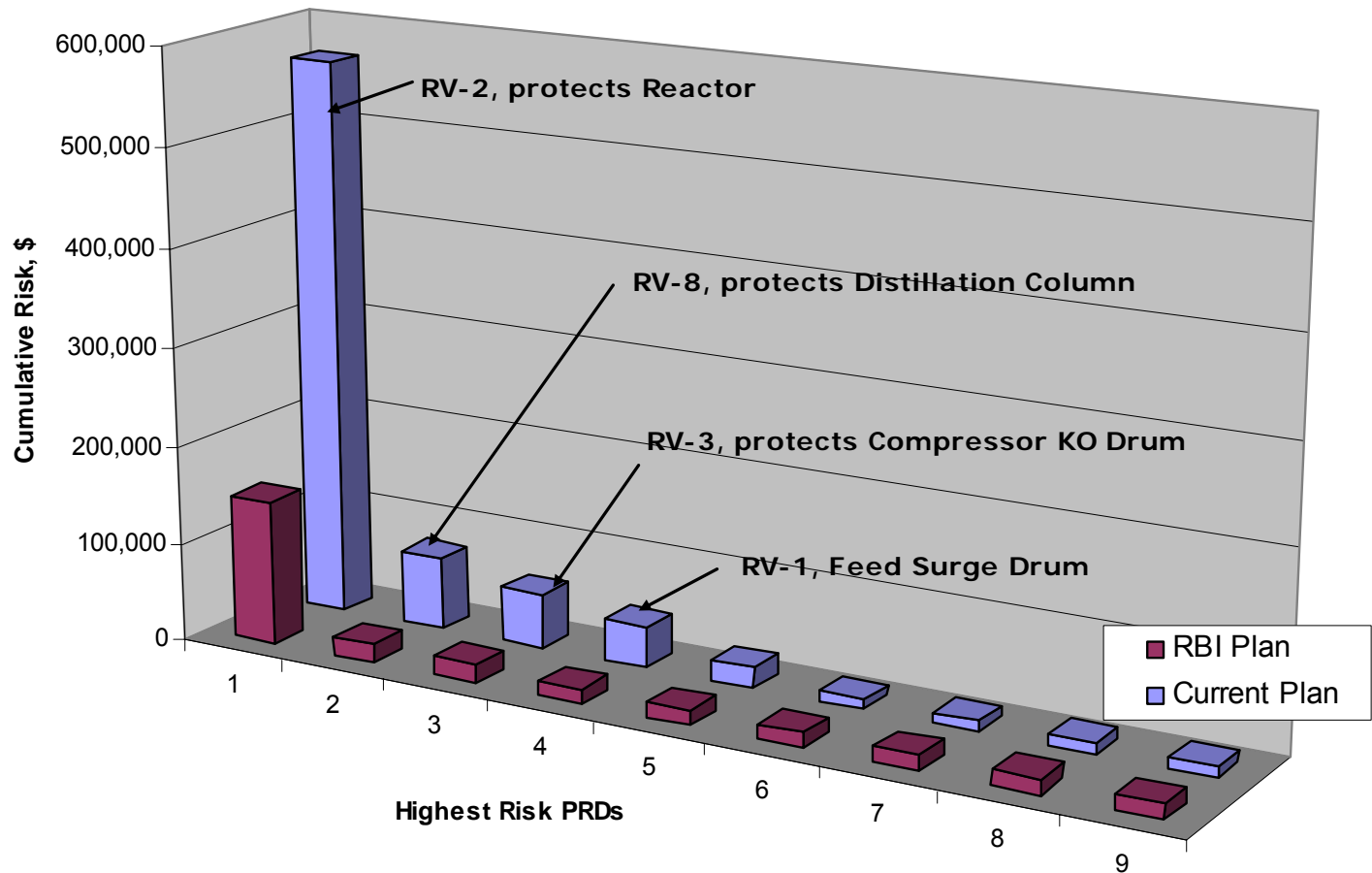
$$POF = POFOD \times DR \times (GFF \times DF)_{OP}$$

- As equipment damage increases, equipment probability of loss of containment ($GFF \times DF$) increases
- Number of Demands on PRD increases (DR increases)
- $POFOD$ increases as PRD condition deteriorates
- Inspection interval for each PRD is set based on a risk target
- Default risk target for API PRD RBI is \$15,000
 - Balances reduction in risk with reduced inspection costs when compared to condition based inspection program (API 510)
 - Typically reduces risk by 60-70% while average inspection interval increase 20%
 - Not a bad value for Cost Benefit Analysis
 - Calibration tool

Case Study Summary

- No. Hydrotreating Unit
 - 18 PRDs: 9 in process service, 1 on piping, 8 utility service
 - Intervals set according to API 510, typically set at 5 years (60 months)
 - Case study assumed \$15,000 risk target with minimum and maximum intervals of 2 and 10 years, respectively
 - RBI reduced inspection interval on 5 PRDs, 7 devices were shifted to 6.5 year intervals, increased intervals to 10 years for 6 PRDs
 - Average interval increased from 5 to 6.7 years
 - Risk reduction of 60%
 - Typically no isolation valves installed under PRDs on the unit, one of the goals of the study was to determine where, if any isolation valves were needed to provide flexibility

Case Study - Cumulative Risk



Lessons Learned from API RBI

- Focus on most critical valves, others increase to 10 years
- 70-75% of the PRDs can be increased to the API 510 maximum of 10 years (higher??)
- 10-20% of the PRDs will need to be reduced to 2 years, refiners need to come to grips with the possibility of adding isolation valves
- Validation Step Critical - Highest risk valves have been further reviewed to take credit for other layers of overpressure protection that reduce overpressure demand rates, where applicable. Results in significant reduction in overall risk on the unit
- Need to get involvement for process/operations group
- Some reduced PRD inspection intervals can be attributed to inappropriate or insufficient inspection data on equipment, where the equipment RBI predicts a high damage factor
- Credit for and rationalization with LOPA is critical
- “Uninspectable” Risk
- Need to accept the good with the bad