Vysus Group

Whitepaper

Relief valve optimisation using adaptive reliability based risk reduction targets

Abstract

Traditional API 581 risk calculation approach can have mixed results for establishing PRVs inspection interval. The problem here is twofold – Probability of Failure (PoF) is low for most cases, therefore Consequence of Failure (CoF) drives risk, leading to impractical inspection frequencies at extreme ends of the spectrum. This coerces the engineering teams to evaluate other more realistic inspection intervals for cost/safety reasons either based on experience or industry data rather than asset information.

An alternative adaptive methodology is discussed in this presentation where PoF and CoF are based on user defined Risk Reduction Targets and Safety Integrity Levels, rather than financial risk basis. This methodology captures how using actual in-service testing results rather than default values in a Weibull distribution can deliver a more representative Probability of Failure on Demand (POFOD) and how it ultimately can be reliably used to deliver an optimum test frequency based on quantitative assessment of failure modes.

1 Introduction

Vysus Group advocates the use of a robust risk based strategy in accordance with API 581 to manage inspection programs in downstream industries. This approach when correctly implemented leads to safe and efficient operation of piping and fixed equipment. In contrast, utilising the traditional risk based approach for PRVs, instrumentation and rotating equipment can have mixed results leading to impractical inspection frequencies at extreme ends of the spectrum. To understand why this is the case, a discussion of probability and consequence of failure with respect to API 581 [1] is necessary.

This section gives an overview of API 581 with respect to PRVs, followed by an overview of the Vysus Group philosophy and methodology for setting PRV inspection intervals.

Agile approach that offers a sound alternative to the traditional RBI approach.

This methodology supports timely and effective interruption to production streams for valve testing, minimising unnecessary process disruption and optimising availability with an allied reduction in maintenance and materials costs.

1.1 API 581

1.1.1 Overview

API 581 provides direction on the use of risk assessment to determine the maintenance intervals for pressure relief valves, and expresses risk as the product of the probability of a failure event and the financial consequence of a failure event. API 581 introduces the concept of maintaining pressure relief valves at an interval such that a financial risk target is met i.e. a pressure relief device is maintained at an interval such that the residual financial risk exposure is acceptable [1]. No specific guidance is given on acceptable risk targets, and facility owners are directed to consider their own internal risk tolerability (tolerance level) and acceptance criteria when determining an inspection interval. An example is provided showing that the same relief valve

can be maintained at maximum intervals of 3 or 5 years if risk targets of $10k and $25k per annum respectively are considered acceptable. Essentially API 581 suggests that pressure relief valves are tested such that a user-defined financial risk reduction is achieved.

1.1.2 Probability of failure

In API 581 the probability of failure can be estimated by considering the probability of a failure event occurring by estimating the likelihood of the pressure relief device being demanded, failing to operate and a subsequent loss of containment being experienced [1]. This is calculated by estimating three independent failure events for each device:

1. Overpressure event.
2. Failure of pressure relief device to operate on demand.
3. Protected equipment loss of containment.

The first step in evaluating the probability of failure is to determine the demand rate placed on the device. This is estimated by referring to guidance where the demand rate is typically once in 10 years to once in 50 years. The next step is to obtain the probability that the pressure relief device will fail to open upon demand in service. API 581 proposes the use of a two parameter Weibull function and modelling to determine this probability of failure to open [1]; however, this may be simplified by considering the exponential distribution (constant rate failure pattern) and API 581 recognises this in Table 7.4 [1] where it characterises moderate and severe service relief valves as having predominantly random failure patterns. Similarly, industry standard data sources such as OREDA data sources [2] consider all failure patterns to be random in nature.

API 581 considers the potential loss of containment from the protected equipment item in the case of an initiating event and the pressure relief device functional failure. Provision is made for calculating the probability of the loss of containment event; however, a conservative assumption can be made such that where elevated overpressures occur, and that these overpressures will approach four times the Maximum Allowable Working Pressure (MAWP), generally considered to lead to the rupture case [1]. Given this, it is assumed that the probability of the protected equipment leading to a loss of containment is 1.0 in the event of an initiating event and the relief valve functional failure.

Vysus Group has found that using this approach to determine a probability of failure can result in a very low overall probability of failure on demand such that the resulting inspection intervals can be significant.

1.1.3 Consequence of failure

API 581 describes the consequence of failure of pressure relief devices in terms of financial consequences associated with the failure of operation. These financial consequences include, but are not limited to:

1. Equipment repair and replacement.
2. Damage to surrounding equipment in affected areas.
3. Production losses and business interruption as a result of downtime to repair or replace damaged equipment.
4. Personnel injuries associated with a failure.
5. Environmental clean-up.

API 581 provides guidance on the equipment damage and replacement costs, and typical downtime estimates associated with common equipment items through rupture.

1.1.2 Inspection planning

API 581 then proposes that the recommended interval is determined for pressure relief valves by calculation of the risk as a function of time and determining the time at which the risk is equal to the risk target.

1.2 Philosophy

The methodology applied by Vysus Group is similar to API 581 in that a probability and consequence methodology is used to determine an appropriate inspection testing interval based on achieving a user-defined risk reduction. However, Vysus Group does not use a financial risk basis to determine the testing interval, and instead uses the Risk Reduction Factor (RRF) used in the assessment of Safety Integrity Levels (SIL) for protective systems. Vysus Group derives the probability of failure from the installed in-service testing results and uses this to calculate an in-service reliability for the pressure relief valves. The testing interval is then determined based on the pressure relief device achieving the required RRF as stipulated in the facility safety studies.

Vysus Group's proposed approach is to determine the optimum test frequency for each device based on analyzing plant data rather than using default values in a Weibull distribution. This approach will deliver a more concise representative value for Probability of Failure on Demand (POFOD) and adapts by "learning" about the plant's PRV population as the test history increases over time.

In summary:

- Vysus Group reliability based approach assesses PRVs in populations e.g. sites, service categories, types etc.
- Reliability targets based on reliability (risk reduction) required from safety studies e.g. SIL.
- Typical targets 98% for safety critical PRVs; 90% for non-safety critical PRVs
- Individual PRV test results can also be considered in isolation to enable a representative sample and provide a more stringent testing regime for these valves where necessary – 'bad actor' analysis
- Increases population and sample size; reduces sensitivity to individual test results

1.3 Methodology

Vysus Group methodology consists of three general steps; data preparations, analysis and reporting and finally implementation which are broken down in more details below.

1.3.1 Data Gathering

Data gathering and analysis includes the following activities:

- Obtaining data and documentation associated with the PRVs
- Relief valve test results
- Existing benchmarking reports and assessments
- Agreeing the target reliability for the PRVs

1.3.2 Grouping

A key element of the strategy is that PRVs are 'grouped' into collections of PRVs of similar service to obtain a greater population from which to derive reliability and failure data.

1.3.3 Failure Rates

Failure rates are derived for each grouping of relief valve by the review of the historical testing data to determine a dangerous failure rate applicable to each group. This is carried out by assessing the operational life of each grouping of valves and the number of dangerous failures that had occurred in the operational life. This is then used to calculate a relevant failure rate and represents the actual in-service demonstrated reliability of the protective devices.

1.3.4 Reliability Calculations

Using the reliability theory [3] for component found to have a constant failure rate, the in-service reliability of the categories of PRV can be calculated.

It is generally accepted that demand on safety systems and components occurs randomly overtime, therefore it is necessary to evaluate the POFOD function during the fault exposure time.

1.3.5 Test Interval

The testing interval for each grouping of PRV will then be determined by considering the reliability demonstrated, how this compares with the required reliability of the protective device and how this in-service reliability will be affected by modulating the testing interval. The existing testing interval must be considered in determining the new testing interval, as it may be imprudent to extend the intervals to the maximum limit. Similarly, in addition to the application of a testing interval per fluid service, each individual PRV should be assessed in turn to ensure that specific 'bad actors' are dealt with appropriately.

Using the above and given the reliability target for a given PRV, we can calculate the required test interval based on the failure history:

2 Results

2.1 Downstream Oil and Gas

Significant reductions in maintenance activity and materials costs were observed by applying the methodology in comparison to the existing planned maintenance. Majority of intervals were extended and some maintenance test intervals were reduced based on actual operational performance. Whilst maintenance interval extensions tended to be more limited for safety critical service valves, the reduction in maintenance activity and materials costs are nonetheless significant. Furthermore, greater asset size and population of PRVs in comparison to upstream applications creates a powerful potential for optimisation as seen in the results captured below.

Pilot studies were initiated for:

- Major onshore gas processing plant with approx. 1,000 PRVs
- Refinery with a total of 1,000+ PRVs

2.1.1 Gas Processing Plant

Previous results with Air PRVs allowed a 40-50% reduction in maintenance

Oil & Gas Major gas plant with 961 PRVs, 391 valves are air PRVs. This suggested high potential for maintenance optimisation based on previous results seen in upstream applications.

Table 1. Gas Processing Plant Analysis Results

PRV Service Fluid	PRV Count	PRV Count (with Test Cert)	Test Certs Analysed	Dangerous Failures	PM Annualised Hours (Before)	PM Annualised Hours (After)	% Change
AIR	391	73	74	2	665	448	-33%
OIL	95	78	80	1	474	262	-45%
TOTAL	486	151	154	3	1139	710	-38%

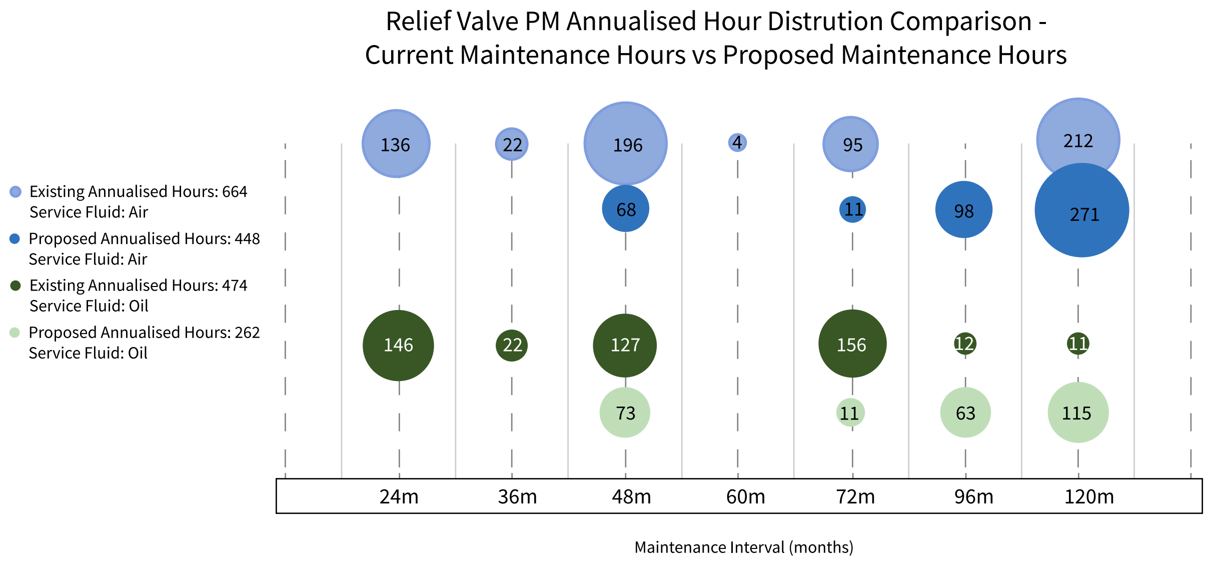
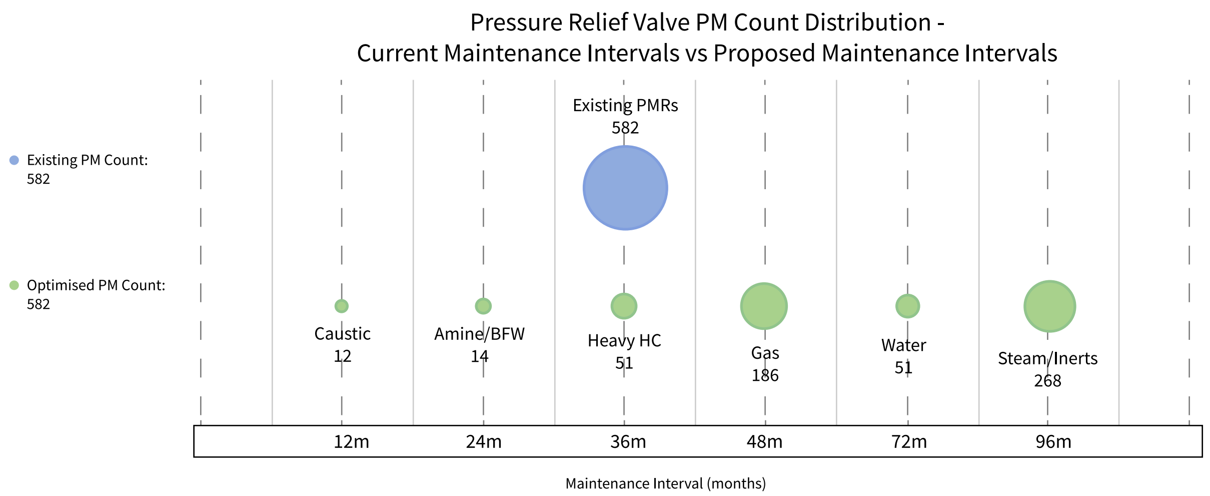


Figure 1. Downstream application Existing PM and optimised PMs for AI and Oil PRVs

These failure rates compare favourably with industry comparators e.g. SINTEF failure rate of 0.0044 failures/month [4], providing confidence in the interval extensions.



2.2 Upstream Oil and Gas Installations

This methodology has been proven in the Methodology has also been proven in the downstream refining industry in the US over the past 5 years and the results have been positive:

- Success in identifying opportunities to extend testing intervals
- Quick response times in analyzing data
- Analysis tools have led to speedy identification of optimised maintenance intervals
- These tools provide detailed analysis reports that can be used to support Management of Change (MoC) for maintenance management systems and maintenance strategies

Results for offshore and onshore installation are captured in the subsequent sections.

2.2.1 Fixed Offshore Installation

Pre & post optimisation testing distributions for all PRVs:

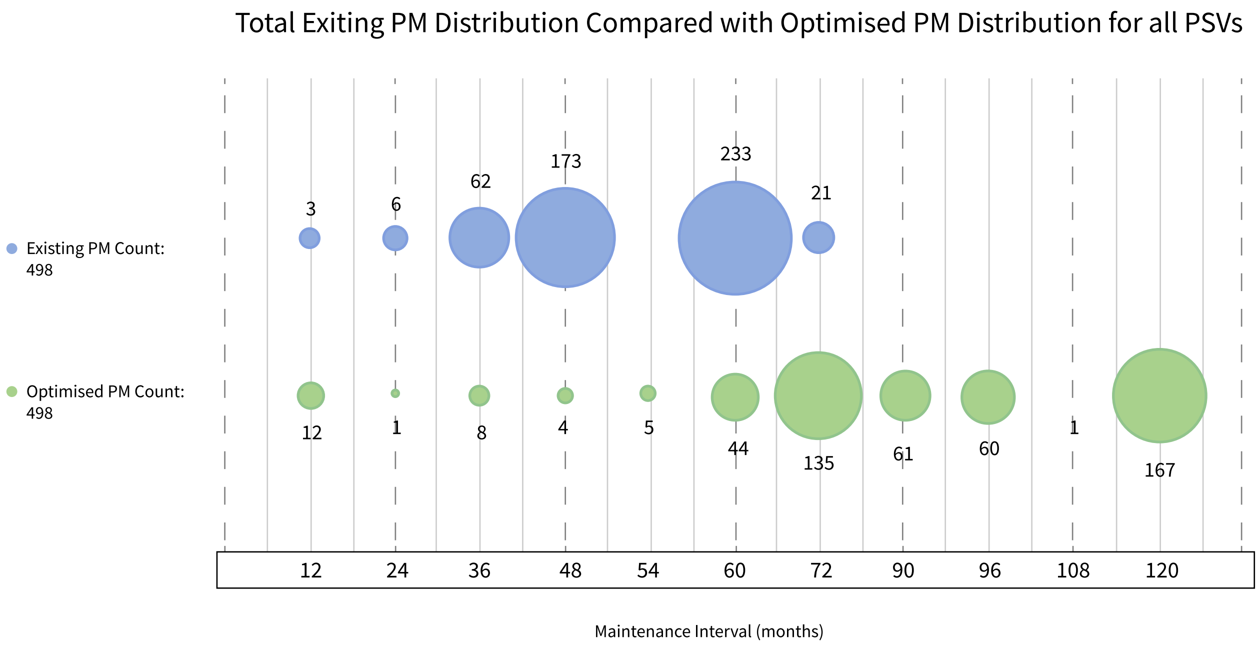


Figure 2. Existing PM and optimised PMs for all PRVs

Pre & post optmisation testing distributions for Air Service PRVs:

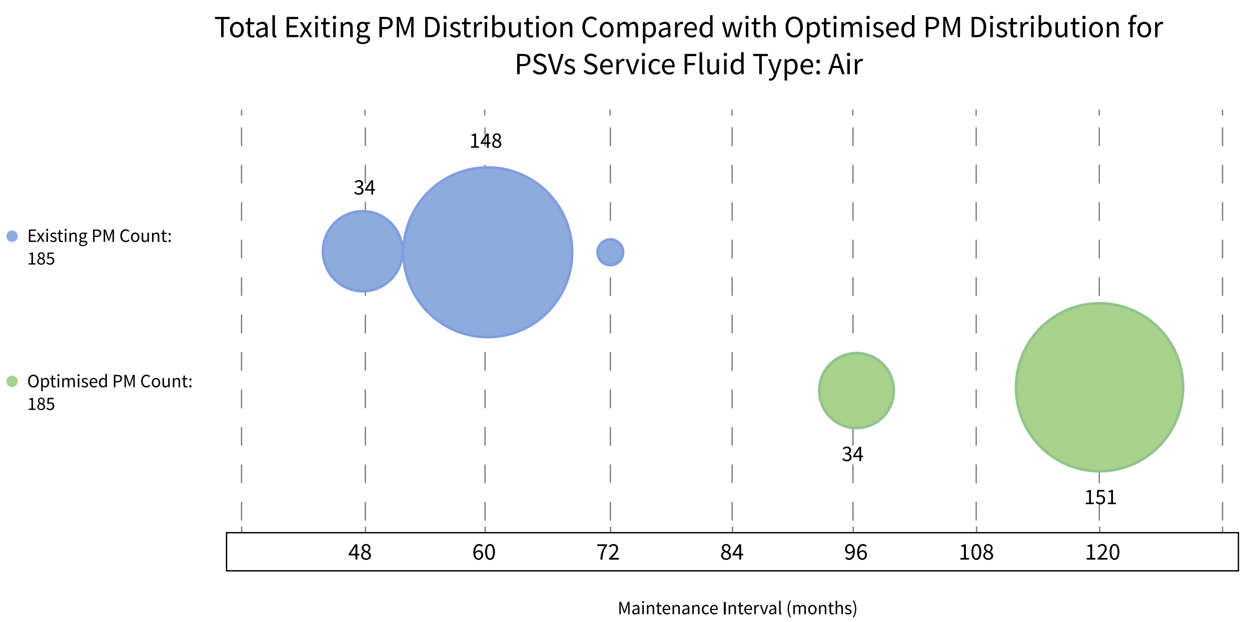


Figure 3. Existing PM and optimised PMs for Air PRVs

Pre & post optimisation testing distributions for Hydrocarbon Gas Service PRVs:

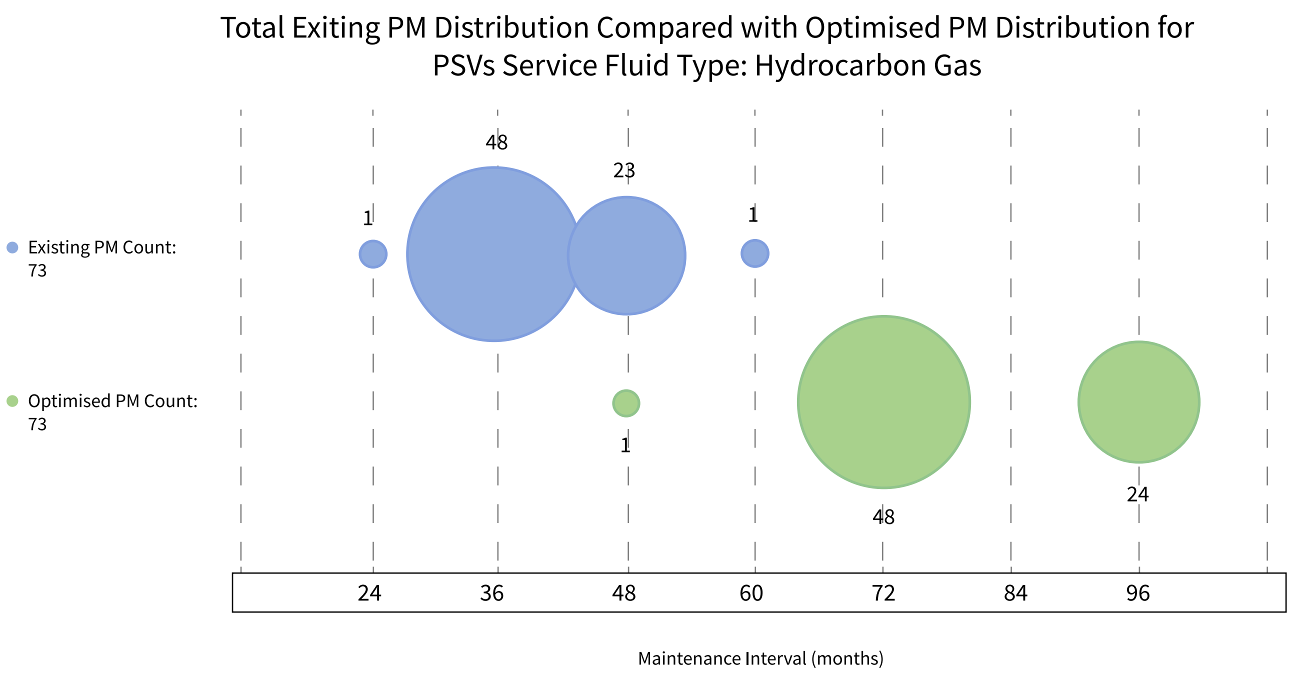


Figure 4. Existing PM and Optimised PMs for HC Gas PRVs

2.2.2 FPSO

Pre & post optimisation testing distributions for Hydrocarbon Gas Service PRVs:

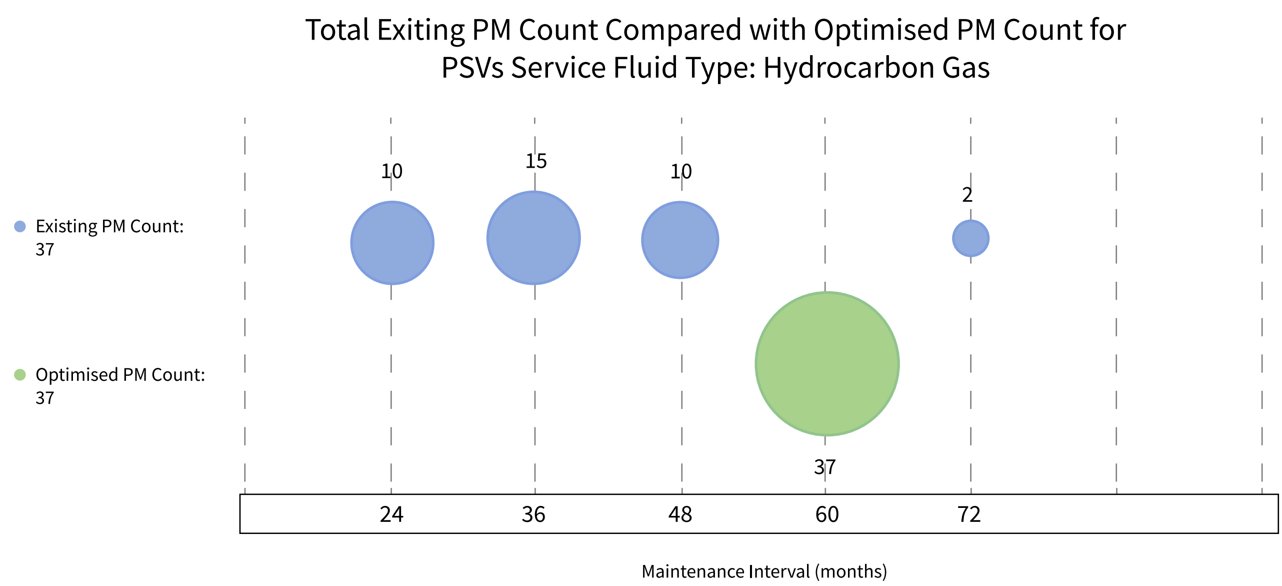


Figure 5. FPSO Existing PM and optimised PMs for HC Gas PRVs

3 Conclusions

- Agile approach that offers a sound alternative to the traditional RBI approach
- Reliability centred analysis of PRV testing intervals can be conducted quickly and effectively based on actual asset performance data
- Reliability targets can be set appropriately for safety critical and non-safety critical services
- This Reliability centred approach uses grouping of valves to obtain a greater sample size when determining reliability data to support review of the testing regime
- This approach allows a deterministic link between relief valve testing and risk
- Proven approach with strong track record in offshore oil & gas platform and processing facilities, very applicable to downstream as shown via results
- This methodology supports timely and effective reduction in OPEX, through reduced maintenance and materials costs, delivering maintenance capacity back to operators
- Similar methodology can be applied to optimise PM of Rotating equipment and instrumentations such as pumps and fire and gas detection systems

4 References

[1] American Petroleum Institute. “Risk-based Inspection Methodology, 3rd ed,” API RECOMMENDED PRACTICE 581, pp 34 - 83, April 2016

[2] OREDA. “Offshore and Onshore Reliability Data, 6th ed. ‘Volume 1 – Topside Equipment’”, pp 240 – 260, 2015

[3] J.C.H. Schüller, J.L. Brinkman, P.J. Van Gestel and R.W. van Otterloo. “Methods for determining and processing probabilities ‘Red Book’” The State Secretary of Housing Spatial Planning and the Environment (VROM), pp 5.10-5.28, 1997

[4] SINTEF Technology and Society. “Reliability Data for Safety Instrumented Systems, PDS Data Handbook”, SINTEF Research, pp 30-40, 2013

The above study was presented by Shervin Sadeghi of Vysus Group at the 15th Global Congress on Process Safety.

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