OIL & GAS

PRESSURE SAFETY VALVES – RISK BASED INSPECTION

Technical Paper

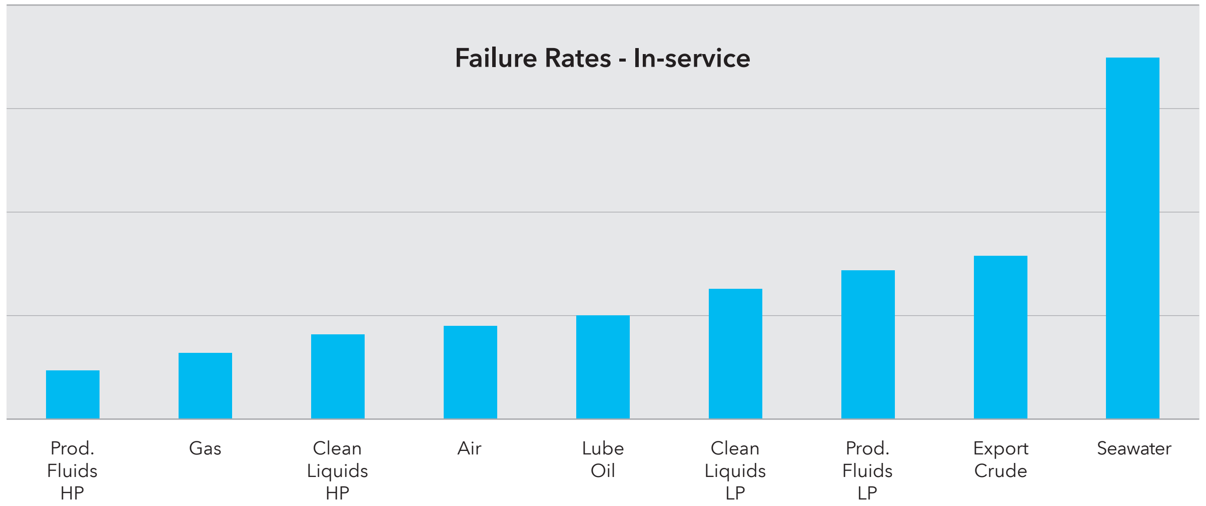
SAFER, SMARTER, GREENER

INTRODUCTION

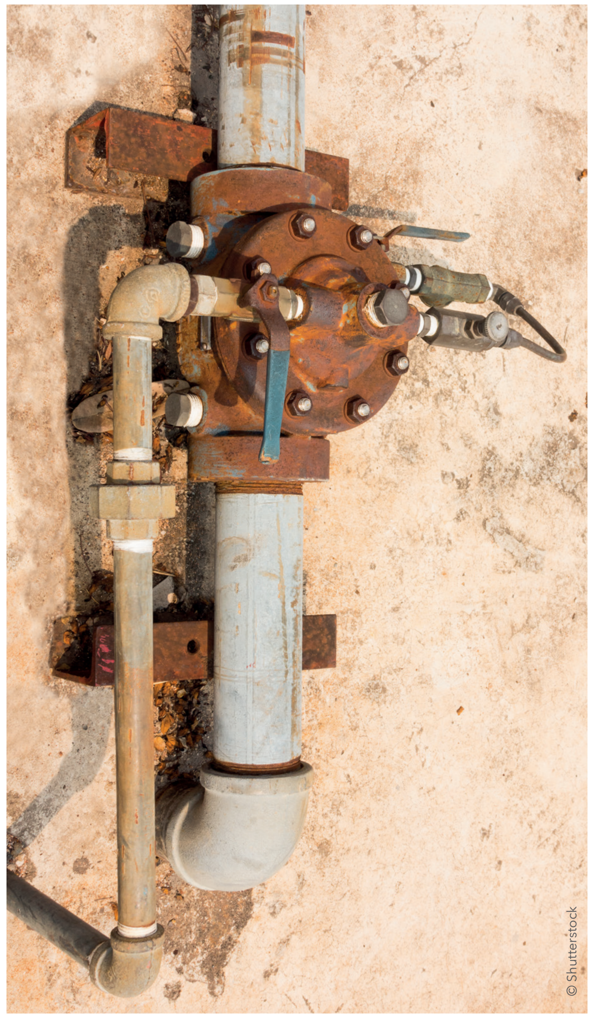
With an ever increasing focus on reducing the cost of maintenance expenditure and the need for safety critical equipment to function reliably, Operators need to ensure maintenance is correctly focused. As preventative maintenance on Pressure Safety Valves is one of the more significant integrity costs, DNV GL has developed and implemented a risk-based inspection methodology that allows Operators to reduce cost by focusing maintenance effort, while simultaneously maintaining or improving safety.

Pressure Safety Valves and Testing
Pressure Safety Valves (PSVs) are installed in process and utility systems to prevent failure during a process upset with a build-up of pressure, or for the "fire case" to prevent failure through pressure build-up when exposed to an external fire. Over pressurisation of a vessel, or other equipment item, can have significant consequences from the energy released from the pressurised fluid, or the hazardous nature of the contents, which are often flammable. For this reason, PSVs are classed as safety critical when protecting hydrocarbon containing equipment and, even on non-hazardous services are always safety related.

The safety criticality designation indicates that PSVs should be reliable. However, for a passive system such as a PSV, which will only operate on demand, it is not easy to check that it will lift if required to do so. Therefore, PSVs undergo periodic preventative maintenance where they are removed from their normal operating location and subject to an as received pre-overhaul pop (pre-pop) test to determine whether they would lift at the pressure that they are set to. Following the pre-pop test, any failures or degradation in condition are identified and rectified to return the PSV to an 'as-new' condition ready for re-installation on-site. Some smaller PSVs are simply replaced at regular intervals as repair is not economically viable. The frequency of preventative maintenance is critical to the reliability of a PSV successfully lifting on demand.



The pre-pop test and refurbishment is generally carried out onshore which necessitates prior replacement of the PSV offshore, which can often only be done during a shutdown. The combination of logistics, pre-pop testing, and refurbishment can therefore incur considerable costs. This cost can be reduced by in-situ online tests such as 'trevi-testing', but not all failure modes of a PSV are identified by this test and it is only ever an interim solution. Notwithstanding the cost, PSVs are one of the few safety critical elements that are tested off-site by a third party. This can often lead to the history of their performance not being readily available to the Operator with no corresponding justification for a particular maintenance interval. This in itself is a risk, as the Operator may lose sight of the maintenance approach on their asset.



There is therefore a significant driver to ensure that the frequency (and hence associated cost) of PSV test intervals is optimised so that the residual risk from their potential failure to lift is as low as reasonably practicable (ALARP), i.e. a risk-based inspection (RBI).

Failures Modes and Rates
From over 28 thousand PSV-years (¼ billion hours) of pre-pop data gathered by DNV GL, it is apparent that there are very significant differences in the state (and success of the pre-pop) of PSVs in different operating conditions. PSV failure modes that are typically experienced include blockage due to scale or wax and mechanical drifting of the set-point both of which are time dependent failure modes. A maintenance interval can be set to address these, but there is always the possibility of a background rate of 'random failures' from multiple sources (e.g. human error, fluctuations in process conditions) that is harder to avoid.

While the pre-pop test may reveal that PSVs known to have wax issues have relatively high failure rates, small PSVs on clean chemical lines, or, in some cases, clean process gas, may have a failure rate over 100 times lower. The data also reveals that the fluid service a PSV "sees" is the strongest driver of its failure rate and so this is the key parameter used in the DNV GL RBI scheme.

PSV Historical Data and Grouping
While the issue of determining an optimised maintenance interval for a single PSV can be straightforward, the challenge comes when dealing with the sheer number of PSVs on a typical installation, which may be several hundred. Data quality can also be an issue. Without a previous pre-pop history for a PSV, it is difficult to justify extending the maintenance interval.

Example: For a PSV maintained every two years, an increase from two to three years cannot be considered without knowing how the PSV performed at the two-year interval. In the worst-case, with the PSV subject to a time-dependent failure mechanism, there may be a relatively high probability of failure at two years meaning that on a three-year interval, the PSV would be inoperable for a year creating a safety issue due to the equipment being vulnerable to a process upset. Proof of successful pre-pop tests at 2 years helps to justify an increase.

Regardless of past performance, there is no guarantee that a PSV will not fail in service, therefore increasing a maintenance interval does come with an associated risk. However, the RBI methodology uses as much historical data as possible to ensure that this risk is controlled.

This mirrors the IP Model Code of Safe Practice for Pressure Vessels (part 12), which states that new PSVs should be maintained on a two year interval, those with some history on a 4 year interval and those with good history on a 6 year interval.

In an RBI scheme, each PSV could be considered on its own merits, but given the inevitable gaps in the pre-pop testing records, which may need to stretch back over a decade, this would limit the benefit of the RBI. However, groups of PSVs operate under similar, if not identical, conditions and can be expected to exhibit similar modes and frequencies of failure: analysis of the pre-pop data shows that this is the case. To set the interval of a PSV, this allows use of an increasingly large data set:

- The specific PSV under consideration;
- PSVs seeing exactly the same conditions (i.e. fluid type and pressure); and
- PSVs seeing the same fluid and in the same pressure banding (termed a grouping).

At the simplest level, if there are four PSVs all seeing the same fluid with the same set pressure, with three of the PSVs having good maintenance history and the fourth having limited data, it gives confidence that the fourth could be set at the same interval. Grouping of PSVs and consideration of the maintenance record across the group allows for a more pragmatic approach to the RBI than has traditionally been the case.

RBI – qualitative assessment
Failure of a PSV to lift in a pre-pop test may be due to an issue like waxing and be repeatable, or due to a 'random failure' that is unlikely to be repeated. However, the cause of the failure often cannot be determined and so the conservative approach is to reduce the maintenance interval following any failure.

Since PSV failures are relatively rare, the overall aim of an RBI scheme is to increase the maintenance interval while ensuring that the residual risk of failure remains ALARP. It may be difficult to determine the cause of a failure, random or with a specific cause, intervals must be increased cautiously, though this can be mitigated by the inclusion of a greater dataset than just the PSV being examined as outlined above.

GROUP 1 - Extend Interval	
PSV-1 Pass	PSV-4 Pass
PSV-2 Pass	PSV-5 Pass
PSV-3 Pass	PSV-6 Pass

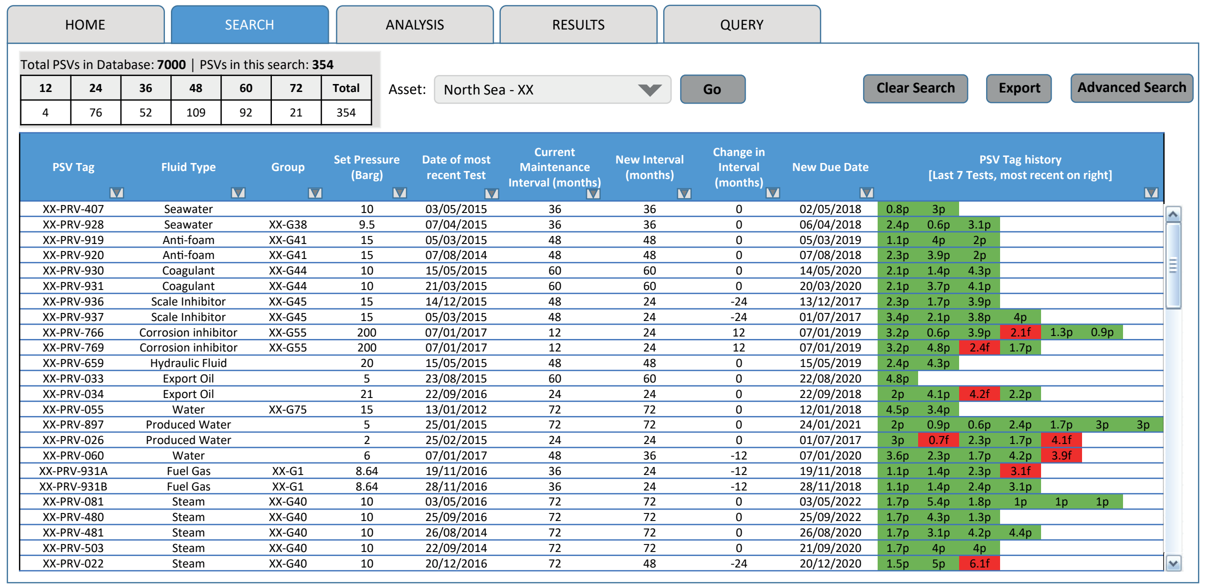
Example: Consider six PSVs seeing the same fluid and set at the same pressure, each with a successful test following four years' service. In isolation each PSV has minimal information and limited justification for its interval to be increased. However, collectively, there are six sets of data for PSVs that have the same failure modes and so an increase is justified. Taking a cautious approach, in most cases the maximum increase is 50% and hence the PSVs are moved to 6 years, which gives a 33% maintenance saving.

Larger increases are usually only possible when the maintenance interval of a PSV has deviated from that of similar ones. For example, with good history, a PSV on an interval of 2 years could double to 4 years if there is good history at 4 years for other PSVs in the same group.

The above gives the flavour of the RBI system developed by DNV GL that has been successfully applied across thousands of PSVs. Historically-set intervals, unexpected change-outs and other deviations affect the methodology, but the general rule is always that a failed PSV has its interval decreased and good maintenance history is rewarded with increased intervals.

RBI – risk component
The second component of the RBI methodology demonstrates that the risks of PSV failure are being managed. While the approach discussed to this point is purely qualitative; lowering intervals for failures and increasing them for good history, there is also a need to determine the overall risk impact when potentially many changes are being made across an installation. While the risk implications of a single changed interval may be small, the risk impact of multiple changes across the installation is larger.

DNV GL have taken this further by adopting a similar approach to that used for safety instrumented systems (SIS), which for PSHHs with the ESD they trigger perform the same safety function as a PSV. For SIS, one key aspect of the IEC61511 code is to ensure that the residual risk from failure of an SIS is below a pre-defined target, adherence to which automatically means that the risk from this aspect is ALARP. This same quantitative approach is used by DNV GL for PSVs.



HOME | SEARCH | ANALYSIS | RESULTS | QUERY

Total PSVs in Database: **7000** | PSVs in this search: **354**

12	24	36	48	60	72	Total
4	76	52	109	92	21	354

Asset: North Sea - XX | Go | Clear Search | Export | Advanced Search

PSV Tag	Fluid Type	Group	Set Pressure (Barg)	Date of most recent Test	Current Maintenance Interval (months)	New Interval (months)	Change in Interval (months)	New Due Date	PSV Tag history [Last 7 Tests, most recent on right]
XX-PRV-407	Seawater		10	03/05/2015	36	36	0	02/05/2018	0.8p 3p
XX-PRV-928	Seawater	XX-G38	9.5	07/04/2015	36	36	0	06/04/2018	2.4p 0.6p 3.1p
XX-PRV-919	Anti-foam	XX-G41	15	05/03/2015	48	48	0	05/03/2019	1.1p 4p 2p
XX-PRV-920	Anti-foam	XX-G41	15	07/08/2014	48	48	0	07/08/2018	2.3p 3.9p 2p
XX-PRV-930	Coagulant	XX-G44	10	15/05/2015	60	60	0	14/05/2020	2.1p 1.4p 4.3p
XX-PRV-931	Coagulant	XX-G44	10	21/03/2015	60	60	0	20/03/2020	2.1p 3.7p 4.1p
XX-PRV-936	Scale Inhibitor	XX-G45	15	14/12/2015	48	24	-24	13/12/2017	2.3p 1.7p 3.9p
XX-PRV-937	Scale Inhibitor	XX-G45	15	05/03/2015	48	24	-24	01/07/2017	3.4p 2.1p 3.8p 4p
XX-PRV-766	Corrosion inhibitor	XX-G55	200	07/01/2017	12	24	12	07/01/2019	3.2p 0.6p 3.9p 2.1f 1.3p 0.9p
XX-PRV-769	Corrosion inhibitor	XX-G55	200	07/01/2017	12	24	12	07/01/2019	3.2p 4.8p 2.4f 1.7p
XX-PRV-659	Hydraulic Fluid		20	15/05/2015	48	48	0	15/05/2019	2.4p 4.3p
XX-PRV-033	Export Oil		5	23/08/2015	60	60	0	22/08/2020	4.8p
XX-PRV-034	Export Oil		21	22/09/2016	24	24	0	22/09/2018	2p 4.1p 4.2f 2.2p
XX-PRV-055	Water	XX-G75	15	13/01/2012	72	72	0	12/01/2018	4.5p 3.4p
XX-PRV-897	Produced Water		5	25/01/2015	72	72	0	24/01/2021	2p 0.9p 0.6p 2.4p 1.7p 3p 3p
XX-PRV-026	Produced Water		2	25/02/2015	24	24	0	01/07/2017	3p 0.7f 2.3p 1.7p 4.1f
XX-PRV-060	Water		6	07/01/2017	48	36	-12	07/01/2020	3.6p 2.3p 1.7p 4.2p 3.9f
XX-PRV-931A	Fuel Gas	XX-G1	8.64	19/11/2016	36	24	-12	19/11/2018	1.1p 1.4p 2.3p 3.1f
XX-PRV-931B	Fuel Gas	XX-G1	8.64	28/11/2016	36	24	-12	28/11/2018	1.1p 1.4p 2.4p 3.1p
XX-PRV-081	Steam	XX-G40	10	03/05/2016	72	72	0	03/05/2022	1.7p 5.4p 1.8p 1p 1p 1p
XX-PRV-480	Steam	XX-G40	10	25/09/2016	72	72	0	25/09/2022	1.7p 4.3p 1.3p
XX-PRV-481	Steam	XX-G40	10	26/08/2014	72	72	0	26/08/2020	1.7p 3.1p 4.2p 4.4p
XX-PRV-503	Steam	XX-G40	10	22/09/2014	72	72	0	21/09/2020	1.7p 4p 4p
XX-PRV-022	Steam	XX-G40	10	20/12/2016	72	48	-24	20/12/2020	1.5p 5p 6.1f

The DNV GL two-pronged approach has a number of advantages:

- It considers the behaviour of the specific PSV;
- It can include data from a wider set of PSVs as required; and
- The change in risk from a change in interval is known and the risk from potential failure of any PSV is limited.

The risk assessment determines failure rates across meaningfully large groups of PSVs. Consequences are then defined within the group and, as the risk depends on the maintenance interval, the maximum interval that meets the risk criteria can be determined. This acts an upper limit for the maintenance interval of a PSV with good history. The consequence assessment is conservative and accounts for the equipment or system that the PSV is installed on, so that the maintenance interval is the same for PSVs under the same conditions, but will differ based on characteristics such as vessel size. For PSVs with a lower risk profile e.g. chemical injection with few failures and lower consequences, the quantitative limit is highly unlikely to bite, but for process systems with a higher failure rate, it may limit the maintenance interval.

Further Advantages

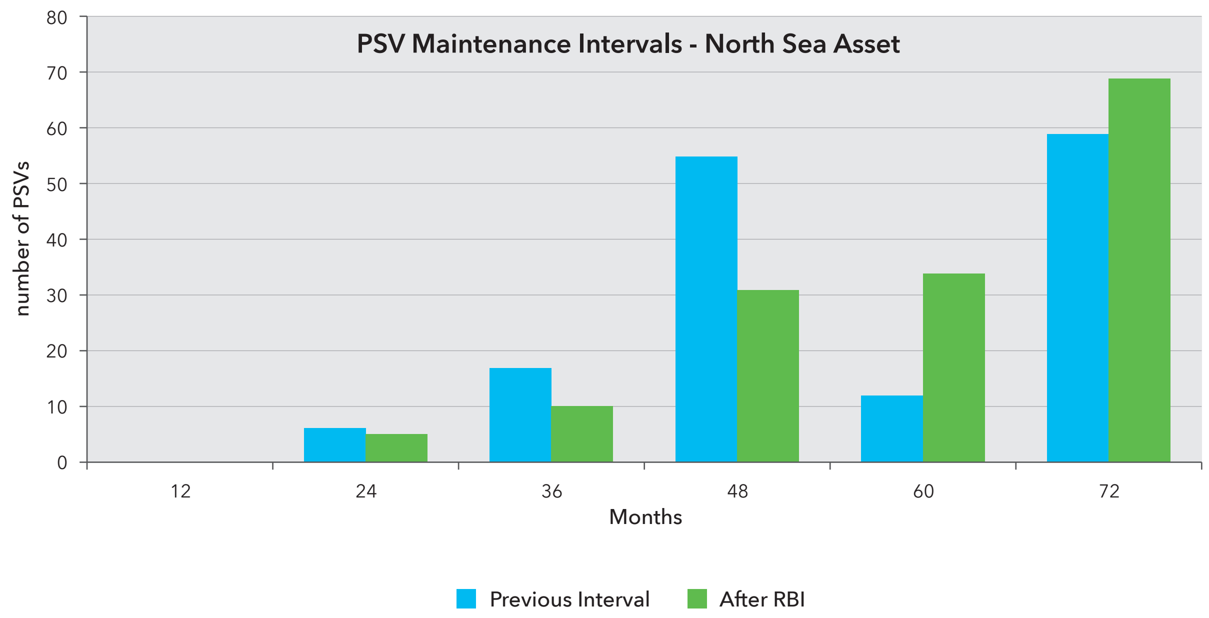
On top of the RBI itself, the system improves the visibility of the performance of the PSVs, which are one of an installation's key safety systems. Rather than complex interaction with a maintenance management system to find the history of a PSV, it is an output of the process:

PSV-1	PSV-2
2012 Pass	2012 Pass
2014 Pass	2014 Pass
2016 Pass	2016 Fail
Next PM: 2019	Next PM: 2017

Not only does this give confidence in the assessment, but it gives the operator information required for deferrals should maintenance not be possible at the intended time.

Collation of the maintenance information for PSVs can also feed into shutdown planning. The need to test some PSVs can even drive a shutdown and this dependency can be critically tested with the data from the RBI assessment.

Asset	Registered Valves	Average Interval		% Change	Yearly Saving (£)
		Pre RBI	Post RBI		
A	189	4.00	5.05	26%	£102,000
B	386	3.01	4.71	56%	£281,000
C	248	4.20	5.27	25%	£86,000
D	477	3.64	4.73	30%	£104,000
E	341	3.38	4.72	40%	£120,000
F	197	3.16	4.12	30%	£116,000
G	654	3.92	5.18	32%	£206,000
H	208	3.78	5.44	44%	£92,000
I	412	3.92	4.69	20%	£96,000
Total	**3112**	**3.67**	**4.89**	**33%**	**£1,173,000**



Application Experience

Typically, the first application of the RBI scheme can lead to upwards of 20% reduction in maintenance, also with a decrease in risk by concentrating maintenance on areas of higher risk. The cost reduction is significant, as, in addition to total (logistics, onshore effort, offshore effort) PSV change out cost of around £5,000, there is also the associated shutdown cost for many PSVs.

The table above shows an example of maintenance load reduction on a number of different assets, along with the associated average cost reduction.

The system is most beneficial when used on a regular basis to take benefit from the gradually improving performance of the PSVs: this way benefits of 5-10% are achievable for a number of years. And, of course, these benefits are not just in a single year, but for the lifetime of the facility.

Further information

For further information contact:
Dr John Morgan, DNV GL, Aberdeen
+44 203 81 65323
john.morgan@dnvgl.com

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