CRITICALITY-BASED CRITERIA FOR VALVE SPECIFICATION IN PRODUCTION FACILITIES

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Abstract

This work presents main novel concepts and features already implemented on major revision of industrial valve specification for Oil & Gas topside production facilities, based on criticality-level and application of such valves.

Topside valves were divided into different criticality categories, with increasing technical requirements according to service severity and safety impact in case of failure. Those new criteria in one hand can be easily correlated with other standards and specification levels used in the valve industry to better assist the definition of technical requirements, while on the other hand contribute to fair competitiveness in bidding.

Case studies and simulation results have shown that the new valve selection methodology and criteria can reduce significantly the amount of critical valves misplaced or over specified, in comparison to previously used corporate selection directive and criteria for the upstream segment.

Key words: Oil. Gas. Exploration. Piping. Production. Valves. Specification. Topside

1. Introduction

Valves are the main piping system component as they are responsible for stablishing, interrupting and controlling flow, although for decades the industry has classified them more as piping accessories than as a mechanical equipment. This point of view becomes harmful especially for valves requiring higher reliability and performance, such as those used in HIPPS (High Integrity Pressure Protection System), used as safety valves (shutdown valve - SDV, blowdown valve - BDV), or where a failure may have catastrophic consequences (e.g. automatic deluge valve – ADV).

Historically, industrial valves used in topside production facilities were divided into two categories: conventional and special application. Despite the fact that this division allows for valves used in severe service to be specified accordingly, it had resulted in a large volume of items with additional and special requirements.

The amount of valves classified as “special” reached up to 35-40% in some FPSO units (Floating Production Storage and Offloading). Requirements that made a valve to be considered “special” such as fire testing, fugitive emissions, special sealing systems and tight metal to metal sealing requirements were not necessarily needed for most applications. Previous criteria also focused on assuring quality mostly through material selection rather than objective test requirements and design features. Although material selection is an important factor for a brand new valve, it may not be sufficient to guarantee the expected minimum long-term performance. Meanwhile, it will definitely have a strong impact on the component acquisition costs and may restrict the number of suppliers. Taking into account that an FPSO unit may contain in-between 10 to 15 thousand valves and their total cost correspond in average to 8% of a process facility, according Silva Telles (2001), this kind of valve classification will most likely have an undesirable impact the total unit cost.

2. Methodology

A new classification criterion, named as Valve Specification Level (VSL), presents concepts similar to others well-known classifications in the valve world attending oil and gas industry. First of all, with the API 6A (2011) Product Specification Level (PSL), originally applicable for wellhead and christmas tree equipment. Second, with the standard for piping and pipeline valves API 6D that in its latest revision introduced the concept of QSL (Quality Specification Level).

While the API 6A clearly states the logic used to classify the PSL and recommends the minimum level with its increasing quality, design and performance requirements, the main standard used for industrial valves specification, API 6D, allows the purchaser to select and differentiate quality levels, but does not present a guideline for QSL selection.

2.1. Classification Parameters for VSL

In order to create the new criteria that would satisfactorily reflect the criticality of the valve, the definition of the VSL was based on four main parameters:

1. Application (type)
2. Service (fluid)
3. Accumulated Energy
4. Demand (number of cycles)

The application was divided into two types: safety and regular (process) valves; the first type comprehend HIPPS, SDV, BDV, ADV/ADV block and PIG launcher/receiver valves, according Table 1. For PIG L/R valve, despite not having a safety function, it was classified this way as it works as the last barrier between the process and the operator.

Regular valves, non-safety related, are classified according Table 2 based on service, accumulated energy and demand of operation, where a larger concern is given to combustible, toxic and hot water, being transported inside high-pressure, large bore lines. Special attention is given to valves that are frequently operated or cycled, such as molecular sieve, filter blocks and actuated block valves. These valves may degrade their performance faster and therefore require a more adequate specification, design verification (qualification) and overall inspection.

Upon the definition of the engineering rules used for the VSL classification, the parameters shown in tables 1 through 3 where extracted from the database of a 2D model of one FPSO, and where then processed using a classification algorithm. The results where analyzed and used as feedback to further refine the criteria, until the final version of the criteria was obtained. The results are shown in the next section.

Based on the results valves were classified into four categories of VSL, instead of the two categories previously used. It is possible to correlate these four categories with common types of valves available in the market, where VLS-2 to VLS-4 require increasing degree of customization and engineering:

- VSL-1: Commodity valves;
- VSL-2: Engineered valves;
- VSL-3: Critical valves;
- VSL-4: Special application.

Table 1. Valve Specification Level (VSL) classification for safety valves

	Application	Level
Safety Valves	HIPPS, SDV Platform limits	VSL-4
	SDV, BDV, L/R PIG	VSL-3
	ADV, ADV Block	VSL-2

Table 2. Valve Specification Level (VSL) classification for regular valves

	Service	Accumulated Energy	High Demand	
			Yes	No
Regular valves	Hydrocarbon Hot water Combustible Steam Toxic	High	VSL-3	VSL-2
		Low	VSL-3	VSL-2[1]
	Other services	High	VSL-2	VSL-2[1]
		Low	VSL-2	VSL-1

[1] In case of 2nd block or redundancy, VSL is reduced by one level

Table 3. Classification of accumulated energy and high demand valves

Accumulated Energy	High	Pressure Class ANSI 600 and 900, NPS ≥ 6 Pressure Class ANSI 1500 and above
	Low	Pressure Class ANSI 300 and below Pressure Class ANSI 600 and 900, NPS ≤ 4
High Demand	E.g.: Filter valves, Actuated valves, molecular sieve	

2.2. Design Validation and VSL

It is expected that a given valve, operating in more demanding or more critical application, would need better assurance that it would perform as designed. However, it is well discussed among valve community that API 6D and many other industrial valve standards are mainly concerned with FAT (Factory Acceptance Tests) on new products, as they do not address design or testing requirements – mandatory or supplementary ones – that would state minimum performance requirements throughout valve life cycle nor integrity management requirements.

For valves classified as VLS-1, no additional design validation is required for performance assurance.

For valves graded as VLS-2, the manufacturer would need to demonstrate valve was adequately designed and calculated, analytically or numerically (as Finite Element Analysis - FEA), complying to applicable standards and recommended engineering practices.

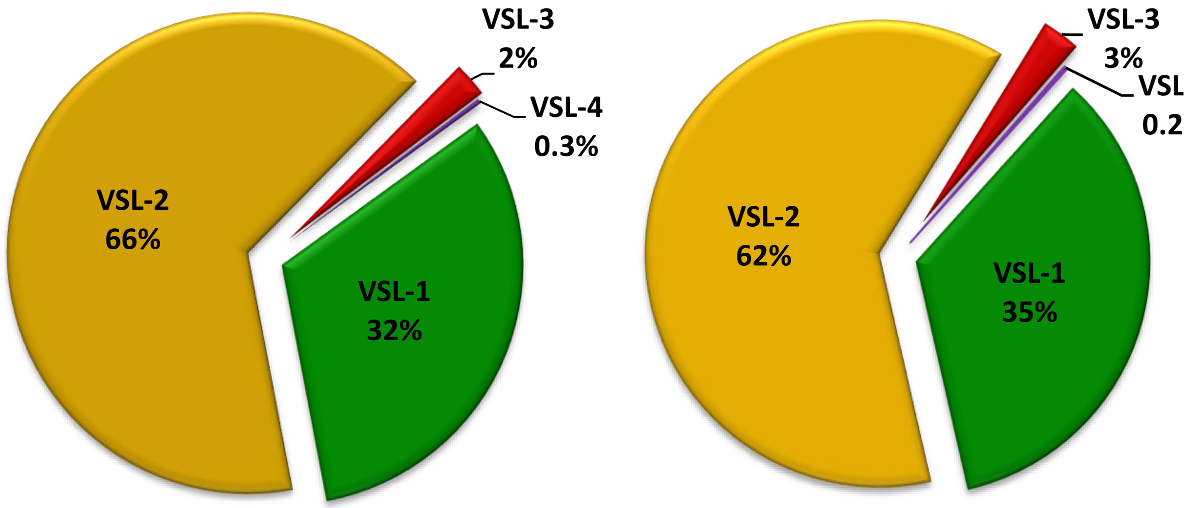
For valves classified as VSL-3 or VSL-4, it will be required that a given valve design has passed on Performance Verification Tests (PVT) that validate their design. This approach is not new: According to Euthymiou (2002, 2013), since 1989 oil and gas operators have performed hundreds of PVTs on subsea gate and ball valves, following dedicated technical specifications, similar to API-6A and API-17D. About this, API-6A standard have addressed design validation and PVT based on performance requirements (PR), where major valve manufacturers for oil industry have widely adopted PR-2 as minimum on their performance verification tests. In addition, some industrial valves already pass through similar design verification processes on specific features such as Fugitive Emissions.

Although these design validation tests have better demonstrated performance and reliability on subsea, on Christmas tree and on wellhead related valves, topside valves are not covered by such standards or specifications and do not benefit from them. Also, they do not cover several valve types also used on topside facilities. An initiative to overcome this constraint, stablishing PVT requirements for a wider scope of valves, was made with Brazilian standard ABNT-NBR 15827 (2014), improving compatibility for several design and test requirements.

Design validation through performance tests requires not only the manufacture of a prototype but also long periods of testing. Even with scaling (used to validate "similar" valves according design features, nominal size, temperature or pressure class), it is not difficult to imagine that performing design validation for all valve types and models in the universe of products on a FPSO, regardless of intended criticality, might be economically unfeasible. This is the main reason why design verification with PVT is required only for the most critical valves, graded VSL-3 and VSL-4, which are small fractions in topside facilities.

3. Results and Discussion

When simulating the VSL classification algorithm in existing FPSO units, a total amount between 2 to 5% of critical valves and special application, VSL-3 and VSL-4, were obtained, as displayed in Figure 1. Taking into account that dedicated engineering efforts should be focused to assure proper specification, manufacture, inspection and tests of such reduced set of valves found in a FPSO, it is fair to assume that these valves could receive better actual follow-up and contribute to significant effort and cost reductions, when compared to the 30-35% of "critical valves" specified in previous projects.



(a) (b)

Figure 1. Example of VSL distribution for two FPSO units: (a) FPSO "1"; (b) FPSO "2".

For each category, increasing technical requirements are specified as shown in Table 4. Even at the lowest VSL, the tests, documentation and NDE requirements are at least set as QSL-2 of API 6D, which is slightly above minimum stated on that standard, as it compulsorily requires the low pressure gas seat testing, otherwise considered supplementary. VSL-2 (except for Table 4 Note 1) and VSL-3 escalate to QSL-3 in order to include supplementary high pressure gas seat test as well, while VSL-4 means to increase quality assurance, testing duration and number of test repetitions, as it selects QSL-4.

It is important to highlight that the VSL does not affect directly the material selection, as they are specified solely according fluid, contaminants and working temperatures. However, process fluid conditions can demand certain design features and minimum VSL, which could result in scenarios that certain valve application would not use elastomeric seals, but plastomeric ones (e.g. lip seals).

Table 4. Valve specification level (VSL requirements)

VSL Requirements	VSL-1	VSL-2	VSL-3	VSL-4
API 6D QSL	QSL-2	QSL-3	QSL-3	QSL-4
Low-pressure gas seat test	Mandatory	Mandatory	Mandatory	Mandatory
High-pressure gas seat test	N/A	Note 1	Mandatory	Mandatory
Fire Tested	No	Optional	Optional	Mandatory
Design Validation	No	Design analytical approval	Design validation test approval (PVT)	Design validation test approval (PVT)
Type	All	All	Axial Valve Ball Valve Slab Gate Triple-offset butterfly	Axial Valve Ball Valve Slab Gate
Process	Casting (up to CL900)	Casting (up to CL900)	Forging	Forging
Specific Requirements for Ball Valves				
Partial Clad	No	SS 316	Inconel 625	Inconel 625
DBB testing	Optional	Optional	Optional	Mandatory
DIB-2 configuration	No	Optional	Optional	Mandatory
Metal seated tightness	ISO 5208 Rate D	ISO 5208 Rate D	ISO 5208 Rate C	ISO 5208 Rate C
Hard Coating	Chromium Electroplate (up to CL300)	Chromium Electroplate (up to CL300)	Tungsten or Chrome Carbide or Cr-Ni Spray and fuse	Tungsten or Chrome Carbide or Cr-Ni Spray and fuse

Note 1 – For liquid service application, except for hydrocarbon, it may be considered QSL-2.

Approximately 10% of valves, which were previously classified as “special”, may now be treated as “conventional” or VSL-1, according this new classification. It is surprising to see that the universe of commodity valves in an FPSO can reach up to 1/3 of an entire production facility. This share would probably be even higher if this classification methodology is expanded to address valves in the hull as well. In addition, it goes against the common sense that highly engineered segments, such as the oil & gas, would mostly require critical components for its applications. Commodity valves as VLS-1, with upgraded standardized requirements (as QSL-2) do represent a vast market niche to be explored, with lower cost, lower delivery time and larger number of suppliers.

The VSL was conceived also to optimize inspection and engineering efforts, fine-tuning their activities to the criticality expected for a given valve. At the entry level of VSL-1, it is expected that eligible valve manufacturers would meet all requirements for a product valve, which would be properly documented and registered by quality system staff and verified by periodic auditing. On the other side, at VSL-3 and VSL-4, eligible valve manufacturer would be more comprehensively evaluated and closer follow-up by end-user and inspection teams would better confirm proper design and applicable type-approval tests (as PVT, Fire-test and Fugitive-emission tests), resulting in a product valve that will present its performance quite similar to the prototype valve previously tested, as best assurance that such product valve will work with reliability and predictability, even on the most critical and severe application.

4. Conclusion

The classification of valves in the VSLs allowed better integration of the corporate valve directive with international standards and specification levels. It also made possible the use of design validation for safety applications, which is expected to increase quality, performance, reliability and durability. Additionally it improved the set of rules used to grade valve criticality. This resulted in significant reduction of the amount of valves properly classified as critical, which will enable efforts from customer to follow and receive measurable evidences of performance and durability. Last but not least, the proposed criteria could guide the prioritization of inspection and engineering efforts among lower and higher criticality valves and quality system metrics from each manufacturer.

Future works will focus on using similar criteria to enhance technical specification of other piping components, such as pressure-safety valves (PSV), control valves and hydraulic/pneumatic actuators.

5. References

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