PART ONE

Project and Validation of Industrial Valves for **Low Fugitive Emissions**

Abstract

It is remarkable how the world is concerned over the control of fugitive emission rates on equipment installed in the oil and gas industry. Losses arising from the fall in production and from the environmental impact make the companies in the field seek projects which are more efficient, particularly with respect to industrial valves, which is a piece of equipment used to manage fluids with the purpose of blocking, guiding or controlling the flow of a certain flowing product in an industrial plant.

Fugitive emissions are leaks of chemicals, which come into contact with the atmosphere in an unexpected or undesired way in equipment. This study aims at developing and validating the project of an industrial ball valve type for applications requiring low fugitive emissions. We initially identified and assessed the requirements stated in standard ISO 15848-1, as to the tests that should be performed on a isolating valve prototype for project qualification. The sealing systems were sized for a ball valve prototype, Top Entry, Trunnion, gauge NPS 4", CL600 pressure class, using, as construction patterns, standards API 6D, ASME B16.34 and ABNT NBR 15827. A prototype of this equipment was manufactured and used to perform project qualification tests. Opening and closing cycles of the valve plug were carried out using the maximum working pressure according to the construction standards and helium gas was used as the test fluid. The tests were performed in a valve cycling chamber fitted with a helium mass spectrometer, where it was possible to monitor and record test data such as: leaks, number of cycles, test pressure, temperature and torque during the valve actuation.

The results obtained with respect to the requirements in standard ISO 15848-1 were as follows: number of cycles 2500, complying with rating CO3, Class B leak class, qualification temperature from -29°C to 200°C. Fire Test qualification according to standard ISO 10497 was also held as a complement. In conclusion, this paper achieved its preset goals concerning the approval of the prototype and contributed to the preservation of the environment, because the design of efficient projects, which minimize atmosphere pollution rates, contribute to the preservation of ecosystems. (Teles, 2015).

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Introduction

The term Fugitive Emissions may be defined as any chemical or mixture of substances, in any physical form, which come into contact with the atmosphere through unexpected or undesired leaks in equipment installed on an industrial site (ISO 15848-1, 2015). Fugitive emissions result from industrial processes, where chemical compounds are handled by tanks interconnected through pipes, valves, pumps and other equipment. All these components have sealing systems which, over time, due to operational wear, may allow gases to be released to the atmosphere, detrimentally affecting the environment because they are considered toxic, and often carcinogenic (Teles et al., 2014).

Over the last few decades, there have been an increase in the global concern about the reduction and control of gases to the atmosphere due to environmental damage and to the high costs of product loss during handling and storage, especially in the oil and gas industry (Laitinen, 2013). Through the tests performed in the 1990s in oil refineries to the current days, it can be seen that 60% of all fugitive emissions of the segment are related to leaks in industrial valves, because, in a medium-sized refinery, we estimated that there are 80 to 95,000 valves. There are two types of seals in a valve: static seals and dynamic seals. In flanges and on the body-cover joint, they are static, and on the stem, they are considered dynamic, because this component moves to open and close the plug to release or block the flow of fluid (Holmesle't, 2013) (Patil e Ramakrishnan, 2013).

Therefore, the in depth understanding of the subject related to topic Low Fugitive Emissions is becoming extremely important for the development of valve designs which may perform their duties in order to minimize the emission of pollutants to acceptable rates. Currently, there are several tests standards to control fugitive emissions in valve designs. This paper uses the parameters of standard ISO 15848-1:2006 for prototype testing, and the regulatory validation of a ball valve design is performed for this application (Teles, 2015).

Literature Review

Ball Valve

Ball valves are basically of on-off operation, in which a ball is used as a ball with a through hole, which describes a rotating movement from 0° to 90°

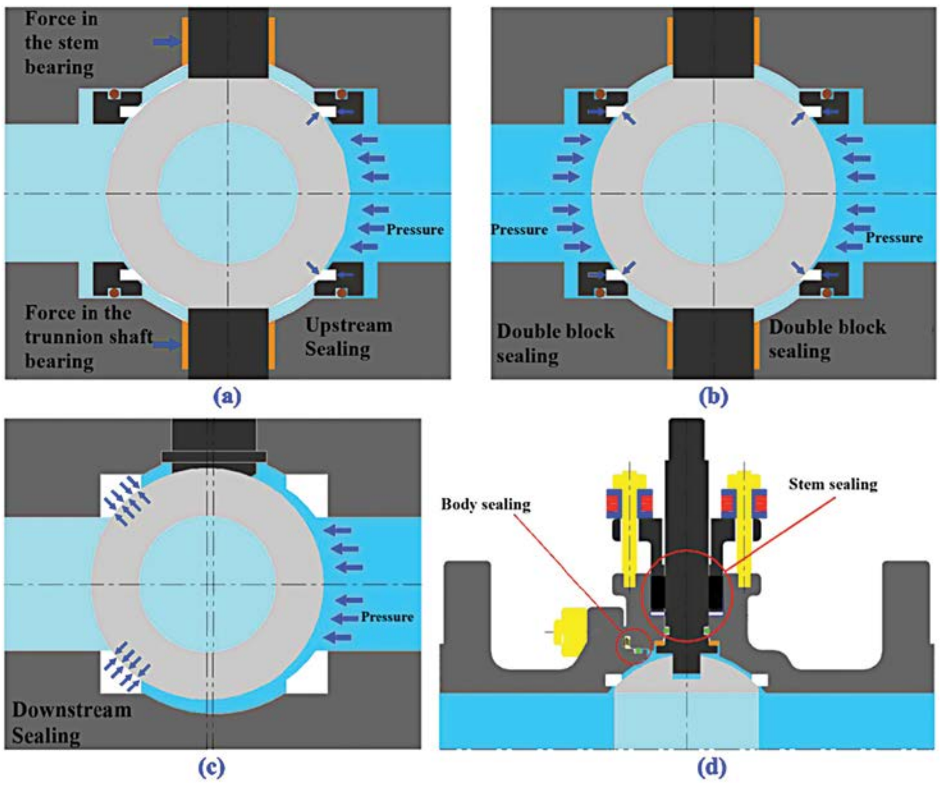

Figure 1: *Basic concepts and sealing components in ball valves type. (a) Trunnion valve, upstream sealing (b) Trunnion valve, double block sealing (c) Floating ball valve, downstream sealing (d) Ball valve, representation of the local of the body and stem sealing.*

relative to the direction of flow of the fluid in the pipe or container to open and close. In the open position, the ball passage hole is completely aligned with the pipe, allowing the flow of fluid. In the closed position, the ball hole is perpendicular to the direction of the flow, blocking the passing fluid (Teles, 2015). More specifically, the ball valve sealing system with the ball may have two construction patterns denominated trunnion and floating.

Trunnion ball valve: the ball is bi supported by axes in which the sealing component is generally called a seat ring, consisting of a metallic ring with an insert of a sealing ring made of a resilient material called 'seat', which moves with a piston effect, performing an upstream sealing. The ball is supported by the trunnion shaft at the bottom and by the stem at the top, in which it rotates to move the ball into open and closed positions. The efforts are absorbed by

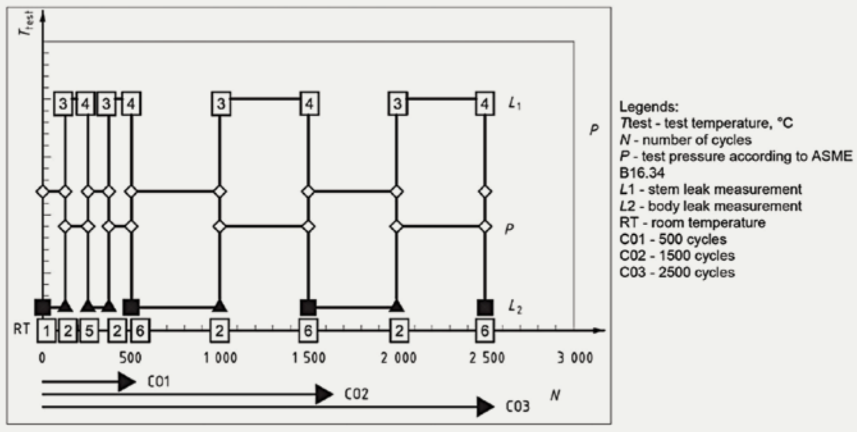

Figure 2: Classification regarding prototype cycling according to ISO 15848-1:2006.

Test temperature (°C)	Qualification
-196	Rates the valve in the -196°C range up to room temperature
- 40	Rates the valve in the -46°C range up to room temperature
RT (Room Temperature)	Rates the valve in the -29°C to 40°C range
200	Rates the valve in the RT to 200°C range
400	Rates the valve in the RT to 400°C range

***Table 1:** Temperature classes.*

self- lubricating bearings, which also serve to minimize friction during valve operation. The vertical centerlines of the ball and the valve body remain always aligned. In addition to the upstream sealing, the trunnion concept allows tightness of the fluid on both flow directions, making the so-called double block sealing, as illustrated in Figure 1 (a) and (b) (Teles, 2013).

Floating ball valve: this design allows the ball to move freely, and in the closed position, the ball floats, moving toward the sealing ring. A small displacement occurs from the vertical center axis of the ball relative to the vertical center axis of the valve during the process of obstruction of the flow. When the upstream flow pressure is applied, i.e., at the valve inlet, the ball moves and compresses the seat, sealing the downstream flow, i.e., at the output of the valve internal cavity, Figure 1 (c) (Teles 2013).

For the analysis of fugitive emissions in valves, it is not the seals between seat and ball that should be examined, but the seals between body and cover of the valve is considered static seals, and dynamic seals should be applied to the stem, where the axis moves to open and close the valve, Figure 1 (d) (Teles, 2015).

Low Fugitive Emission Test According to Standard ISO 15848-1

Standard ISO 15848, part 1, aims to enable the performance classification of different projects of industrial valves in the reduction of fugitive emissions. This part of the standard also defines the type of test for evaluation and qualification of valves in which standardized limits of fugitive emissions are specified.

The assessments of fluid leakage to the outside occur in the valve stem seals and in the valve body joints. Applies to control and block type valves, intended for application in volatile atmospheric pollutants and hazardous liquids (ISO 15848-1, 2015).

Test fluid should be helium or methane gas with purity of at least 97%. The same test fluid should be used throughout the test. The test using methane may be potentially dangerous due to its flammable condition, which is why helium is commonly used as test fluid.

The valve design qualification for low fugitive emission may be ranked according to its compliance with four criteria, namely:

1. **Tightness Class:** sealing class with standards defined for the stem seals of the valve. The preset leak limit is related to the diameter of the stem of the prototype tested. For example, for a 50 mm diameter stem, the limits are: Class A = 8.8E-07, Class B = 8.8E-05 and Class C = 8.8E-03, in the unit [atm·cm3/s]. This is a mass flow unit that means cubic centimeters of gas at atmospheric pressure in normal temperature and pressure conditions. To be perceived, 1.0E-5 atm·cm3/s means approximately 1 cm3 of gas leak per day and 1.0E-7 atm·cm3/s, the equivalent to 3 cm3 per year. The method generally used for this measurement is the Vacuum and this is referenced in annex A of standard ISO 15848-1.The Sniffing method should be used to measure the leakage concentration adjacent to the valve body coming from the body seals. This method is to Annex B of standard ISO 15848-1. Maximum concentration allowed is 50 ppmv.
2. **Endurance Class:** performance class related to the number of cycles. It could be rated as CO1 for 500 cycles, CO2 for 1500 and CO3 for 2500 cycles. Figure 2 shows the number of cycles and sums up the whole qualification process according to ISO 15848-1:2006.
3. **Temperature Class:** rating according to the test temperature. Concerning the test temperature, the prototype valve, which will go through mechanical cycling, is maintained at room temperature and, in some steps of the test, is subjected to extreme temperatures, as selected by the manufacturer in compliance with the regulatory requirements and customer requests. Temperature should be monitored next to the body, inside the valve and in the stuffing box, and should be stabilized for the start of the tests.
4. **Stem Seal Adjustment (SSA):** number of adjustment in the stem seal. Generally, the valve prototypes have sealing devices on the local of the stem, allowing a re-tightening throughout the operation. Mechanical adjustments in the sealing system of the stem during the qualification test are allowed when the required leak rate is exceeded. It may be performed only once, for each qualification phase, according to the performance criterion due to the number of cycles. The torque applied must comply with the manufacturer's procedure. Example: only one adjustment is accepted for CO1. An adjustment may be added, if necessary, to each subsequent step in CO2 and CO3, totaling a maximum of three adjustments for qualification extending to CO3.

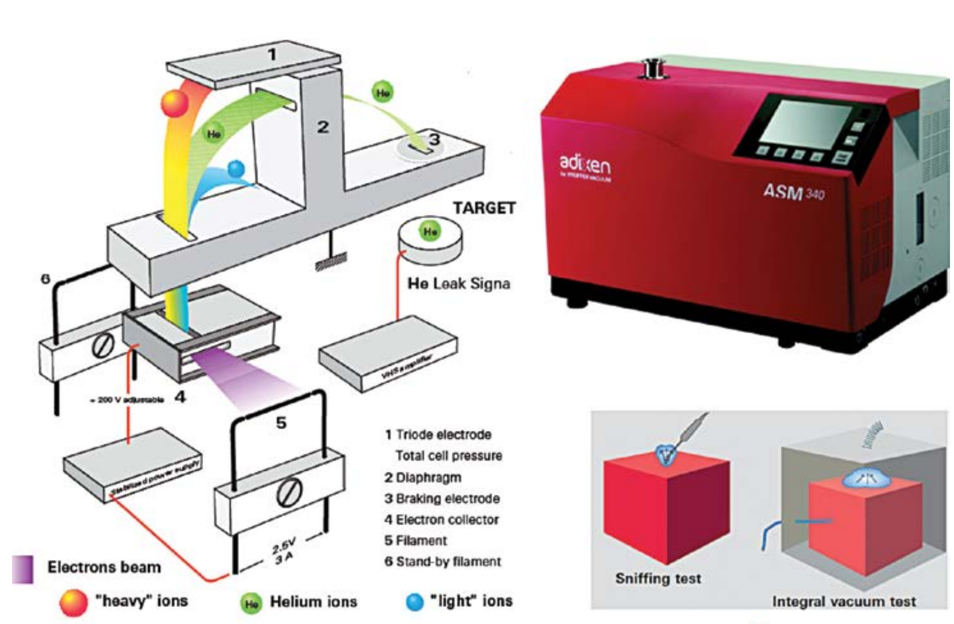

Figure 3: (a) Operating principle of the helium mass spectrometer (b) Helium mass spectrometer used in the model test: Helium Leak Detector ASM 340.

Figure 4: Photographs of testing procedure Fire Test according to standard ISO 10497:2010. (a) Valve mounted in the furnace. (b) Burning of the prototype. (c) Opening of the furnace just before initiating the cooling. (d) Cooling carried out with water at room temperature. (e) Opening of the valve after burning to perform the final hydrostatic test. (f) Valve disassembled after the test. Proceed to the inspection of components.

Helium Mass Spectrometer

The helium mass spectrometry is a method used for leak detection in industrial processes. This is because helium gas has several properties that contribute to this application, such as: it is inert, non-condensable, non-toxic, relatively inexpensive, has a great capacity of finding a place through which to leak due to its small atomic mass and non-flammable. Helium gas is present in the air of the Earth atmosphere at a ratio of 5 ppm (Pfeiffer Vaccum, 2013).

Regarding its operation, the mass spectrometer is divided into three essential parts: ionization source, analyzer and detector. The method used for ionization, in this case, is called electrical ionization. As for the mass analyzer, its primary function is to separate the ions formed in the ionizer of the mass spectrometer according to their m/e ratio. The spectrometer used in this paper contains an analyzer of the 180° magnetic sector type. The analyzer is fitted with a cell that is subject to a magnetic field with a property of deflecting the paths of the ions along different curves according to the (m/e) ratio. The helium ions (m/e = 4) are separated, because the constant magnetic field and the accelerator electric field are adjusted so that the helium ions follow a preset path, passing through the filter or diaphragm, until it reaches the target of direct current inlet of the amplifier, Figure 3 (a). As for the mass detector, its function is to monitor the ions and to amplify the signal, transmitting to a data gathering system (Pfeiffer Vaccum, 2013).

The equipment used in the test of low fugitive emissions is the helium mass spectrometer, model Helium Leak Detector ASM 340. Its job is to detect and quantify the external leakage of the valve during the qualification process. It has the capacity of performing both Vacuum and Sniffing test methods, with enough sensitivity to detect the leak values provided for in standard ISO 15848 Figure 3 (b).

Fire Test According to Standard ISO 10497

Standard ISO 10497:2010 provides the requirements and methods to assess the performance of the valves when exposed to defined fire conditions. Test pressure during burning is set at two bar for resilient seats valves of CL150 and CL300 pressure classes. For CL600 and larger pressure classes, the pressure to which the valve is subjected during burning is 75% of the PMT.

The test principle is a closed valve, totally filled with water under pressure. The valve is fully engulfed in flames with a temperature in the valve area between 750°C and 1000°C for a period of 30 minutes. The temperature is monitored using thermocouples and calorimeter cubes installed in the valve body and its surroundings. During burning, the internal and external leaks of the valve are monitored and recorded.

After the fire is extinguished, they force the cooling of the test valve with water at room temperature, so that the temperature of the outer surface of the valve is reduced and remains below 100°C. The time for cooling may not exceed 10 minutes.

After the system is cooled, the valve is hydrostatically pressurized to 2 bar pressure for five minutes. During this time, leaks, which can occur between the seat and the ball, are monitored and recorded during this period. After this step is complete, the valve plug is opened and pressure rises to 75% of the PMT. During this time, leaks in the valve body seals are monitored and recorded.

Figure 4 shows photographs of the testing procedure of a ball valve prototype NPS 4" CL600 carried out in technical laboratory Micromazza according to standard ISO 10497:2010.

ACKNOWLEDGEMENTS

To the Professors at PPGE3M/UFRGS, especially to Prof. Dr. Telmo Roberto Strohaecker. To the co-workers who helped with this paper. To Company Micromazza Válvulas Industriais.

REFERENCES

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Part two of this article will be published in the November 2017 issue of Valve World Americas.

ABOUT THE AUTHOR

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