Industrial valves and fugitive emissions: new perspectives

Fugitive emissions is a recurring theme for the last three decades. Many improvements have been made, both from the public as the private sector. However, it would be interesting to see what could be improved further. One aspect could be the packing. Is it better to pass the LE test or should the focus lie on maximising its performance when the valve is in operation?

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About the author

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Fugitive emissions from industrial valves is a topic which has been discussed with surprising regularity over the last 30 years. After an initial period characterised by guidelines which were sometimes not entirely clear, in which the manufacturers of valves and packings addressed the matter, a low emission regulatory framework was consolidated.

Today, the requirements of the products and the tests to be carried out are well defined. Together with the LDAR (Leak Detection and Repair) protocol, which monitors the correct functioning of valves at industrial plants in relation to emissions, they constitute a Reasonably Achievable Control of Technology (RACT) to reduce and contain the emissions of VOCs and HAPs from valves. However, times change and environmental impact and sustainability has become more prominent in today's industry. Therefore it is worthwhile to take stock of the situation, to investigate what could drive improvement for each of the players involved like O&G and chemicals producers, EPCCs, valve and sealing product manufacturers.

The regulatory framework for low-emissions tests

Many recent publications have illustrated and compared the main low-emission (LE) test standards concerning valves and packings. In general terms, however, a quick summary will be useful to the reader.

The ISO 15848 test, both prototyping and production, is in its scope a test for valves even if it approves the configuration of valve and packing as an assembly. In no way, however, does it qualify the requirements of the packing which are instead defined by ASTM F2168 and F2191 and by EN 14772 section 6.7, sometimes amended in some part in the technical specifications of the end users.

The API 622 test, on the other hand, is aimed at the approval of the packing and uses a fixture for the test. It also defines the physical-chemical requirements of the packing by detailing the Packing Materials Test and referencing the MSS SP-120 for other requirements. The conferment of the LE attribute to the valves using API 622 approved packings requires the execution of the API 624 (rising, rotating, rising and rotating stem valves) and API 641 (quarter-turn valves) tests.

IOGP-specifications

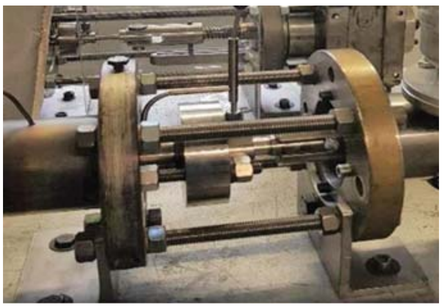
Finally, the TA- Luft VDI 2440 test, which is aimed at approving both the packings, with a specific test conducted on a fixture, as well as the valves. It is worth remembering that the three standards also differ in the combination of temperature and pressure applied, as well as in some other technical details.

It is important to add that the IOGP association - International Oil & Gas Producers - published two specifications for industrial valves in 2019: the

S-562 (Supplementary Requirements to API Specification 6D Ball Valves) and the S-511 (Supplementary Requirements to API 600 Steel Gate Valves and to API 603 CRA Gate Valves), in which ISO 15848, ASTM F2168 and 2191 together with EN 14772 with some amendments are adopted as a standard to define the LE requirements for valves and graphite packing. It appears inevitable, since many of IOGP-associates are American and the importance of the American Petroleum Institute standards, that the specifications will be harmonised over time with API 622, 624 and 641 as well as MSS SP-120. In fact, the current trend, from the point of view of LE packings, is to acquire all three approvals to meet the demand for LE products in compliance with all standards.

Key aspects of low emission tests

What we can say after so many years is that "pure" graphite is unable to pass a Low Emission test without having undergone specific treatments. There are at least three things we have learned about graphite when facing an LE test: in relation to braided packings (wiper rings) according to the ASTM F2191 classification, Type I and II yarns (continuous and discontinuous carbon yarns) are unusable while the Type III (flexible graphite) is functional for the purpose, as correctly indicated by the IOGP specification S-511 and S-562 which prescribes this type. The typical permeability of pure expanded graphite is too high as well as the coefficient of friction, affecting the endurance acceptance criteria of the LE tests.
To fill these gaps, it is necessary to add impregnation to the graphite to improve permeability and friction. But what is the price to pay? Typically, added impregnations alters the chemical resistance of the packing which increases the risk of corrosion of the stem. But the real problem is that, beyond higher temperature › 300 °C, depending on the impregnating agents used, there is inevitably a weight loss of the packing. This phenomenon is due to degradation, with an immediate reflection on the elastic thrust towards the stem and the stuffing box, verifiable by a reduction of the gland pressure.



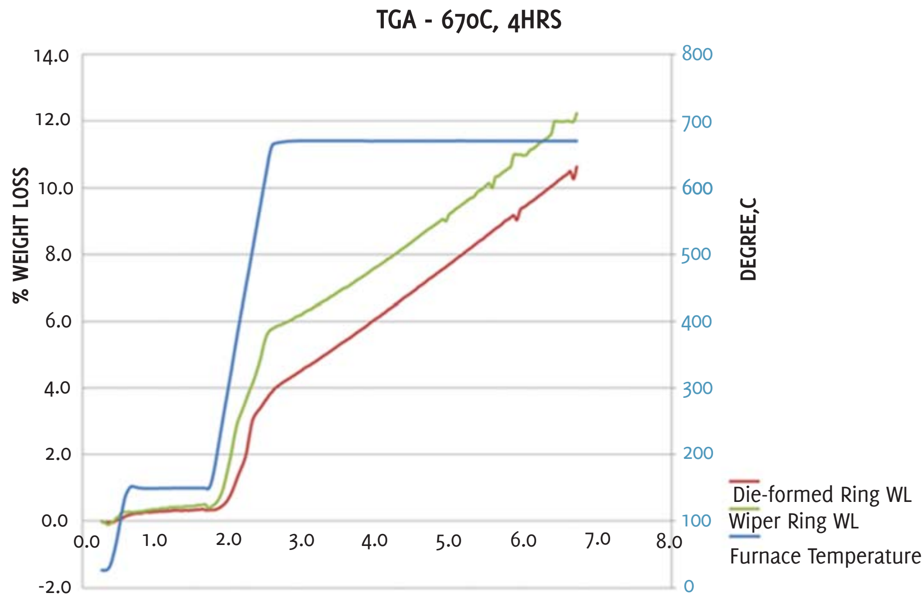


Figure 1: TGA diagram of low emission packing.

Conflict

The TGA diagram in Fig.1 shown below perfectly illustrates the situation described above (in the valve stuffing box the phenomenon occurs more slowly but the mechanism is the same). At the end of the first hour at 150°, to eliminate residual water, the weight loss is about 1 per cent. As soon as the temperature rises to the test threshold (670°C) after a few minutes, the impregnating agents deteriorate and subsequently the graphite, protected by oxidation retardants, oxidises by just 5 per cent in the following 5 hours.
Based on the requirements of EN 14772 section 6.7, we could say that this TGA is not compliant in the first phase, because the oxidation is higher than 4 per cent per hour, while it certainly is in the second phase and in its entirety, we could still define the overall performance as excellent because the weight loss was between 10 and 12 per cent in the 5 hours of testing.
Some aspects are immediately evident. The first is that the execution of a TGA test for a packing with a LE target is perhaps at conflict with the main objective (to contain emissions). This seems to be highlighted by the IOGP specification S-511 which states in section F.3. 13.12 Oxidation Test - F.3. 13.12.1 Purpose: "This test does not apply to packing materials containing polymeric lubricants (e.g., PTFE) or blockers".

Limitations

The second aspect that immediately catches the eye that there are limitations in temperature of the stuffing box to guarantee successful LE test. For its purpose, API 622 defines the applicability of the standard for graphite packings for use from -29°C to +538°C, prescribing, among the packing materials test, the weight loss test, the low and high temperature corrosion test, verification of the content of PTFE and wet lubricants, and finally the measurement of leachable content (chloride and fluoride). We remind you that the Low Emission test is carried out at 260°C measured in the stuffing box.
Therefore, in this technical context, the packing design must use impregnation within extremely precise weight limits since service at 538°C must be guaranteed. The weight loss test intends to monitor this circumstance. Let us consider what we can ask of materials from the point of view of their resistance to temperature. Up to which temperature and for how long can impregnants perform their function? Generally steam appears to be in some ways irreconcilable, asking the packings to fulfil the LE requirement and at the same time be suitable for service at 538°C.

Endurance acceptance criteria

So far, the argument has been essentially about temperature, and nothing has been said about the endurance acceptance criteria. In summary, the API 622 test requires 1510 cycles (310 for API 624 and 610 for API 641), the ISO 15848 test for isolating valves requires 205 cycles for the C01 class and 1500 for the C02 class, the TA-Luft VDI 2440 is traditionally consolidated at 200 cycles, in the absence of substantial specific indications of the standard.
But why is the number of mechanical cycles so high in such a limited amount of time? This fatigue test that stresses the packing (and the valve) in a rather unnatural way, gives us indications of the quality of the ▶

Table 1: API Analysis of refinery screening data - valves highlight from table 3-1. Screening results for seven refineries (5.5 years)

Components	Total Components Screened	Leak definition (ppmv)	Total Leaking		Total Leaking 2X		Total Leaking 3X		Total Leaking 4X	
			No	%	No	%	No	%	No	%
Valves in Gas Service	1,45E+06	500	14.453	0,997	2.503	0,172	511	0,035	81	0,006
		1.000	12.731	0,878	1.962	0,135	392	0,025	48	0,003
		10.000	4.123	0,248	389	0,027	52	0,004	1	0,000
		50.000	1.563	0,108	116	0,008	15	0,001	2	0,000
		100.000	1.174	0,081	83	0,006	12	0,001	1	0,000
Valve in Light Liquid Service	1,34E+06	500	13.817	1,031	2.567	0,192	569	0,045	94	0,007
		1.000	11.472	0,856	1.777	0,133	349	0,026	45	0,003
		10.000	3.872	0,289	316	0,024	44	0,003	9	0,001
		50.000	1.379	0,103	90	0,007	6	0,000	0	0,000
		100.000	1.058	0,079	64	0,005	0	0,000	0	0,000

packing (or of the valve together with the packing) or rather obliges the packing manufacturer to adopt every possible strategy to reduce the coefficient of friction of graphite, which in the absence of interventions is around 0.15 to 0.25.
The problem arises above all with the ISO 15848 standard in which the test is conducted at the valve rating pressure while in the others (API 622, 624, 641 and TA-Luft VDI 2440) it is conducted at a maximum of 40 bar. This determines, with the same configuration of sealing system, the application of a higher gland load on the packing which directly affects the friction coefficient of the graphite which is not constant but increases according to the applied load.

API-publication

From a conceptual point of view, would it be correct to design a packing to pass the low emission test or would it be better to design a packing capable of maximising its performance when the valve is in operation? Does the first objective include the second or are they not in opposition with each other? But does anyone know how valves in operation behave from an emission point of view?
The information about the emission behaviour of valves in operation is available to the plant LDAR manager, where the LDAR surveillance programme is implemented, but objectively very few aggregate data exist.
A unique document of its kind is the 1997 API publication “Analysis of Refinery screening data”. The document illustrates the data collected at seven Californian refineries between the fourth quarter of 1991 and the second quarter of 1996 performed according to the EPA method 21 technique (the same adopted in the API 622 test) at all the equipment leaks of the refineries participating in the project.

Leakers

Table 1 below shows that in the total of screenings carried out (1,450,000 for gas service and 1,340,000 for light liquid service), compared to the leak definition of 500 ppmv, the leak frequency of the valves was about 1 per cent. Compared to the leak definition of 10,000 ppmv, the leak frequency was about 0.25 per cent. The following columns indicate the repetitiveness of the leakage on the same components or measure how many valves identified as leakers in the previous campaign were also so in the following campaign. The complete report, available in the API library, details the performance of the components of each refinery unit, highlighting what can be expected, namely that the leak frequency is correlated to the temperature, pressure and volatility of the fluid and therefore differs between different business units. These data are very far removed estimations by EPA in the publications of the 1980s, which attributed to valves in gas service a leak frequency of 11.40 per cent and for those in light liquid service equal to 6.90 per cent based on a leak definition 10,000 ppmv.

Cornerstones

The results of the API publication, dating back almost a quarter of a century, are still substantially confirmed today by the numbers collected in the field from companies that carry out LDAR monitoring, which rarely detect aggregate leak frequencies higher than 1.00 per cent within a limit of 500 ppmv. The aggregate term implies that there may be production units where the leak frequency is higher but considering the number of all production units the leak frequency converges to lower average values.
On the basis of LDAR experience, we know that the cluster of leakers is made up of valves characterised by one or more of the following attributes: valves with frequent actuation (compared with those that remain in a state of rest for a long time which tend to have a much better leak frequency); valves characterised by use at temperatures above 260°C measured in the stuffing box; valves characterised by a pressure higher than the 600 psi class; rising rotating, rotating stem valves (on the other hand quarter turn-off valves have negligible leak frequency). In conclusion, the area of possible improvement is coming from this cluster of more severe applications.
To conclude, the low emission strategy linked to industrial valves is based on some cornerstones that are not in question. These are the qualification of products specifically engineered for the purpose (valves and packings) and the control of equipment in operation with the LDAR surveillance routine. Thanks to the growing potential of information management, it is possible to highlight in advance, right from the design and purchase phase of the equipment, those valves that belong to the cluster with greater probability of high leak frequency and to pursue practical solutions. Finally, from a regulatory point of view it would be advisable for the test standards to clarify some points of conflict. This conflict (in the API std 622 test) is between the endurance requirement (which ask 1510 cycles) that can be met only lubricating the packing and the weight loss requirement (which ask a low oxidation rate in high temperature of the packing). These requirements are divergent. This is in the common interest to improve the quality of the products and their safety of use.