Keeping our air clean

A valve manufacturer's perspective

The US EPA enhanced LDAR consent decrees have driven valve manufacturers and their stem packing and gasket suppliers to develop new and innovative valve and sealing technologies. The focus on downstream oil, gas and chemical facilities has expanded to upstream production and midstream transportation and processes. Articles written on the subject of valve fugitive emissions as recently as one year ago are already out of date. But the good news is that technology continues to advance to further reduce emissions in valves. This overview reflects the perspective of a valve manufacture as the valve industry wades through the drivers to reduce emissions, new standards, areas requiring focus and attention, design parameters, differences in emissions of valve operation types, and the importance of reliability to the reduction of fugitive emissions.

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New valve technology is driven by industry need, but that industry need is often due to new processes, safety improvements, or economic factors. In the case of new valve stem packing and gaskets for pressure-containing parts of valves, the technology drivers are different. They originated from recognition that improvements are necessary to further reduce or eliminate the release of emissions of valves to the atmosphere. Industry leading valve manufacturers have responded with analysis of their designs, incorporating the best available packing and gasket technology, and implementing qualification and production testing to assure methods and technology comply. In addition, the reliability of these new designs is applied and guaranteed with application of sound manufacturing and quality control methods, followed up with field support.

Technology drivers

The drivers of improved performance of valves to reduce emissions of volatile organic compounds may be classified as

follows: (1) *laws*, (2) *industry standards*, (3) *end user specifications*, and (4) *engineering and personal responsibility*.

Laws: In the United States, the Clean Air Act[1] and subsequent amendments are federal law with the goal to improve, strengthen, and accelerate programs for the prevention and abatement of air pollution. These laws are administered by the U.S. Environmental Protection Agency (EPA), and enforced by leak detection and repair (LDAR)[2] programs and enhanced consent decrees. In Europe, the EU Air Quality Directive 2008/50/EC[3] was a major legislation integrating several earlier directives and creating a renewed focus. In Canada, the CCME developed codes of practice in 1993 for measurement and control of fugitive VOC emissions from equipment leaks. In China, the 2014 Air Pollution Control Law[4] was put in place. Other countries have legislation in place, and in the US, many local air quality districts have been established to implement and enforce pollution control initiatives.

Industry Standards: Various industry organizations such as American Petroleum Institute (API), International Organization for Standardization (ISO), Manufacturers Standard Society (MSS), Instrument Society of America (ISA), Canadian Standards Association (CSA) and others developing new standards or enhancing existing standards to address industry needs.

End User Specifications: Many major oil and gas majors have developed type tests, qualification requirements, general specifications, and even project specifications to reduce emissions. These specifications are enforced through order contract requirements to valve suppliers, and in some cases, include 5-year warranty commitments.

Engineering Responsibility: All persons within the industries affected, and particularly engineers, have a personal and professional responsibility to protect our environment. The quality of the environment is one of our legacies and we must do our part to improve the performance of our products and processes to maintain or improve air quality.

API, ISO, MSS and other standards activity:

API has led standard development efforts to comply with the US Clean Air Act using elements of EPA Method 21[5]. These include API 622[6] (Type Testing of Process Valve Packing for Fugitive Emissions, Second Edition). Initially developed in 2006, it includes fixture testing for emissions with 1510 mechanical cycles and 5 thermal cycles, corrosion tests, as well as evaluation of density and other packing material composition and properties. A task group is currently working on changes for the Third Edition which includes reduction of acceptance criteria to 100 ppmv maximum and possibly with no packing adjustments permitted.

API 624[7] (Type Testing of Rising Stem Valves Equipped with Graphite Packing for Fugitive Emissions, First Edition) is currently applied to rising and rising/rotating stem valves. Many leading rising stem ball valve manufacturers have qualified to this standard. Typical valve designs that fall under the scope of API 624 are gate, globe, and rising-stem ball valves. Some valve manufacturers have applied this standard to quarter-turn valves at the urging of end users and contractors, but that is a misapplication.

API 641[8] (Type Testing of Quarter-turn Valves for Fugitive Emissions, First Edition) was published in late 2016 and is applicable to ball, butterfly and plug type valves. This standard covers ASME B16.34[9] valves up to and including 24 NPS and Class 1500. The testing requires methane testing based on elements of EPA Method 21, and requires 610 mechanical cycles and 3 thermal cycles, with both static and dynamic leakage measurements. Valve qualification groups are defined based on variables of the valve's elevated temperature, pressure at elevated temperature, and pressure at ambient temperature. Maximum test temperature is 260C (500F). Acceptance criteria are 100 ppmv maximum with no packing adjustments.

Following the direction of TA-Luft[10] and VDI 2440[11] in Germany in the 1980's, ISO developed two of the industry's most comprehensive standards, followed by important updates in 2015. **ISO 15848-1:2015**(12) (Industrial valves – Measurement, test and qualification procedures for fugitive emissions – Part 1: Classification system and qualification procedures for type testing of valves) includes testing procedures for evaluation of external leakage of valve stem seals and body joints of isolating valves and control valves. It requires 97% purity helium as the test media, except that an alternate method is specified that permits the use of methane. Two specific methods are noted, one called the "global" method using bagging and pulling a vacuum or another local leakage measurement technique (referred to as "sniffing"). The performance class is defined by a combination of criteria for "tightness", "endurance" and "temperature" classifications. Acceptance criteria depend on the tightness classification and the media, and are different for body joints than for stem packing. When the test fluid is helium, the tightness classes are identified as Class AH, Class BH, and Class CH, and when the test fluid is methane, the tightness classes are identified as Class AM, Class BM, and Class CM.

A valve manufacturer may perform testing for a specific tightness class, endurance class (mechanical cycles and thermal cycles), and for a test temperature. This is a comprehensive test in which the various class designations may be chosen based on both the valve type and the intended application. The downside is that it is not truly a uniform procedure for evaluation of emission performance, which makes it challenging for end users to compare overall performance from one valve manufacturer to another valve manufacturer. Different manufactures may decide on different performance classifications, and thus, end users must evaluate the test results for the specific need. End users in the United States are required to provide documentation utilizing EPA Method 21 and methane as media, and so ISO 15848-1 testing is not consistently accepted for consent decree documentation of valves.

ISO 15848-2:2015(13) (Industrial valves – Measurement, test and qualification procedures for fugitive emissions – Part 2) is a production acceptance test that has been well received by the industry, particularly valve manufactures, engineering contractors, and end users to help assure consistent quality on production valves.

Manufacturers Standardization Society (MSS) SP-121(14) (Qualification Testing Methods for Stem Packing for Rising Stem Steel Valves) is currently under review for possible changes. In addition, MSS is currently reviewing the development of a new emissions standard for instrument and other valves that do not fall under the scope of API 641.

ISA 93.00.01(15) (Standard Method for the Evaluation of External Leakage of Manual and Automated On-Off Valves) continues to be referenced and applied to valves. Additional cycle requirements may be added to this document by end users.

CSA Z620.1(16) (Reduction of Fugitive and Vented Emissions for Upstream Petroleum and Natural Gas Industry Systems) addresses fugitive emissions for upstream oil and gas industry processes and equipment.

Areas requiring focus and attention

Design of the sealing systems: Valve manufacturers must design bolted joints and stem packing compartments to comply with the low fugitive emissions requirements. This involves addressing multiple design parameters.

Selection of sealing components (packing and gaskets): There are several major packing manufacturers with

graphitic seal products, often multiple products depending on the application, qualified to API 622. The available technology for low emissions packing has improved exponentially over the past five years. So choices must be made by the valve manufacturer. From a manufacturer's standpoint, this is both good and bad. The good is that valve manufacturers have multiple options and can make appropriate selections for the applications for which the valve is intended. The bad is that end users develop specification and partnering arrangements with particular packing and gasket manufacturers, which may then require requalification packing or gaskets that may not be "standard" for that valve manufacturer.

Prototype qualification of valves: To meet the industry demands, valve manufacturers are required to type test their designs to established industry standards such as API 641, ISO 15848-1, or ISA 93.00.01. This involves multiple valves to be tested, usually 3rd party testing, and for various service parameters – all which adds up to a substantial investment in money, time, and resources taken away from other important design initiatives. The testing is required to provide end users with valve purchase options and for the manufacturer to do business in the oil, gas and chemical markets. But the cost is real to the manufacturer, and ultimately is shared with valve buyers and end users.

Production testing of valves: ISO 15848-2 (Production acceptance test of valves) is the most significant industry standard that addresses production testing in a valve manufacturing environment. This standard includes helium sniffing. The equipment is expensive from a valve manufacturer's standpoint, but the use of helium within a production environment is relatively safe. While this provides the end user with a level of confidence in stem packing and bolted joints, it does not produce specific documentation that is acceptable to auditors in the US who are applying EPA Method 21 using methane gas as the test media.

Compliance at site: While at first thought this may not seem a major concern for valve manufacturers, it is not uncommon for one of two situations to occur at site that contribute to additional work by manufacturers. One is the possibility, and even likelihood, that valves will sit in a warehouse for long periods of time before being placed in service. When this occurs, re-adjustment of packing prior to valve installation may be required. The second possibility is that packing adjustment bolts may be over- torqued during routine "bolt tightening" prior to start-up, which also leads to re-adjustments – particularly with automated valves. Over-tightening packing gland torque may lead to higher stem torque and effect ability of valve to open, close, or have tight shut-off. Often, both of these situations result in consultation with manufacturers to assure optimal performance of stem packing – despite Installation, Operation and Maintenance information addressing these concerns.

Design parameters

With consideration to stem packing only, there are multiple parameters which are considered in the valve design. Among those are:

- Packing Material (graphite, PTFE, combinations)
- Packing Form (yarn, die-formed)
- Density
- Purity
- Number of Rings
- Cross-sectional area of Rings
- Stem Finish
- Packing Chamber ID Finish
- Stem-to-Packing Gap
- Stem-to-Chamber Gap
- Packing Pressure (torque)
- Lubrication

The service application of the valve must be considered, which will likely result in different packing selection and design based on service conditions, application, mode of operation, and other factors. These include:

- Frequency of operation
- Service fluid compatibility
- Lethal services
- Temperature (high temperature and cryogenic conditions)
- Fire-test requirements
- Stem position (horizontal may increase side-loading)

Operation types

Valve operation types fall into two broad categories – (1) *rising or rising and rotating stems*, and (2) *quarter-turn (part-turn) stems*. Rising and rising and rotating stems normally are used in gate, globe, and rising stem ball valves.

Typical stem packing in low emission ball valve.

These designs are considered the most susceptible to stem leakage since the stem is exposed to the service fluid and then drawn through the packing during the valve operation. These valve designs are the most prevalent used in refineries. Quarter-turn valves, which include most ball valves, double and triple offset butterfly valves, and plug valves, are often considered significantly less susceptible to stem leakage due to the short quarter-turn rotation and the service fluid not being drawn through the packing during the valve operation. However, if not properly designed, manufactured or maintained, quarter-turn designs are still possibilities for release of emissions. Quarter-turn valves are often used in applications with infrequent operation, such as for emergency shutdown application, but they may also be used in high cycle processes and control valve applications. It is not uncommon that engineering and operations personnel consider the operation type (favoring quarter-turn) as a factor in valve selection, as they evaluate other factors in valve selection. The design of the packing chamber, selection of packing, torque, and the other parameters are different for rising stem designs than for quarter-turn stem designs.

Reliability

Having a fundamentally sound, compliant design is only the first step in a valve manufacturer's ability to consistently provide a low fugitive emissions valve. Manufacturing, assembly, test, and handling processes at all manufacturing and test facilities must be consistent. Reliability[17] is the probability of a product performing without failure, a specified function, under given conditions, for a given period of time. Precise, clear, understandable work instructions, even multi-language documents, are required to assure consistency in manufacture and testing.

Manufacturing Validation: As important as it is to validate a design, it is even more important to validate the manufacturing processes, due to the multitude of variables involved in assuring low fugitive emissions performance. Maintaining consistency in the packing and gasket supply, finishes of stems and packing chambers, assembly process, torqueing of gland fasteners – all of this is important, and manufacturing validation programs are necessary to assure consistency.

Production Testing: API 598[18] (valve testing) includes a requirement that valves with adjustable stem seals, leakage through the stem seals during the shell test shall not be cause for rejection, but the manufacturer must be able to demonstrate that the stem seals are capable of retaining pressure at least equal to the rating without visible leakage. However, this is a hydrostatic test, checking for drops of water – not gas leakage. ISO 15848-2 is sometimes applied to production orders on a sample basis using helium as the test media and specifying a particular tightness class (A or B). As a production test, the cycles are low (5) and the test is at ambient, but this specification is relatively safe to apply in a manufacturing environment to validate manufactured valve supply on a contract basis. It is applied to not only stem backing but all body joints.

Continuous Improvement: Improvements in sealing technology in valves will continue, which will result in more and better choices for both valve manufacturers and end users. It is important that manufacturers continue to monitor and participate in the development and testing. It is equally important for Engineering, Procurement, Construction companies and end users to stay abreast of current and developing technologies affecting the equipment they specify and use.

References

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About the author

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