The development of effective fugitive emissions control for valves

This article discusses development and testing work carried out to help reduce fugitive emissions of VOCs through valves. As restrictions tightened, the scope of the programme was widened to include the development of a new stem packing design. This packing was subsequently evaluated in the laboratory and during field trials.

By Dave Cornelsen, Walworth

The industrialized nations of the world have all placed increased emphasis on the control of "volatile organic compounds" (VOC) being emitted to the atmosphere. These compounds not only cause visible pollution to the air we breathe, they can also contribute to many respiratory problems. The valve manufacturing industry has borne the brunt of the problems due to the fact that "valves" of all types, gate, globe and check, are widely used in all process industries and had been found to be a major source of the VOC emissions. This is particularly true of valves found in refineries, chemical plants, pulp and paper mills and power generating plants even though the need for emissions control exists as well in other industries whose processes require valves for positive flow control.

However, it is refineries and chemical plants whose processes frequently include volatile organic compounds that have caused the greatest concern to the safety of our environment. It is the emission or leakage of these VOCs to the atmosphere that has lead to the enactment of the "Clean Air Act" in North America and the "TA Luft" regulation in Europe. These regulations set limits on the amount of allowable VOC emissions from any source and/or installation.

It was because of the need to control and reduce these emissions that Walworth, as a manufacturer of valves, initiated a development program to identify the problems inherent in the design of valves, packing and gaskets, problems that were contributing to the fact that valves were identified as a major source of VOC emissions.

Fig. 1a: Stem / gate interface.

Fig. 1b: Packing rings after test.

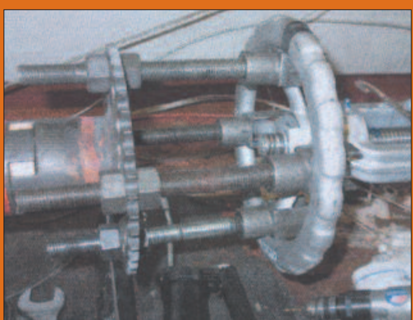

Fig. 2a: A connection from the gearmotor to the handwheel is made to minimize side-loading.

Fig. 2b: During the test, the valve is insulated.

Development and testing

There are two possible sources of VOC emissions from a valve; one is the body to bonnet joint and the other is the valve stem packing. The body/bonnet sealing problem was readily solved through the use of graphite filled spiral wound gaskets, gaskets of flexible graphite laminated to a 316 stainless steel tanged metal core with inner and outer eye-letted edges, or metal ring joint gaskets; depending on the pressure class and type of valve.

The stem packing presented a more difficult problem due to the dynamics of the stem moving through the packing. The traditional ▶

stem packing set of a flat ring or square cross-section design, while effectively sealing most fluids, did not prevent the fugitive emissions leakage of VOC from greatly exceeding the allowable limits.

We established a VOC emissions test protocol (Figures 1 through 4) using a standard 6" Class 300 cast steel gate valve that required over 3500 open-closed-open operating cycles, including three thermal cycles at 350 degrees, made at the rated pressure for the 350°F temperature, using 99% pure methane as the test fluid. The test protocol followed the requirements of the EPA Method 21. The test consisted of alternating 500 cycles at ambient temperature with 500 cycles at 350°F with the last 500 cycles at ambient temperature. The standard stem packing in use at that time failed to meet the initial objective of achieving a better than a 500 ppm leak rate.

Several aspects of valve design; including tolerances, surface finish, stem straightness and the overall alignment of the stem, stem nut and stuffing box were found to be contributing factors to either the failure and/or success of a particular stem packing to meet the emission requirements. As a result of this investigation, tighter tolerances, improved control of surface finishes and stem/stem nut alignment were incorporated as a standard requirement in all valves.

Testing continued on various commercially available designs and configurations of stem packing. Attention was also paid to the tighter manufacturing tolerances, improved surface finishes and the stem/stem nut alignment. Our objective had now become to develop a system that would meet a 100 ppm maximum emissions leak rate consistent with the tighter emissions restrictions imposed by the State of California. We were able to achieve this objective by working in conjunction with Garlock using their Garlock Style EVSP 9000 stem packing. Subsequently, the tests were repeated with 2", 3", 4", 6", and 8" Class 300 valves to verify the consistency and repeatability of the system. These tests were all made in our test laboratory following the same test protocol previously described. These test results* were subsequently independently verified in January 1998 at the Yarmouth Research and Technology Laboratory and allowed Walworth to guarantee a 100 ppm maximum VOC leak rate on all "off the shelf" valves using the Garlock stem packing.

New stem packing

However, the industry regulatory agencies continued to impose tighter restrictions on the amount of allowable VOC emissions. These greatly reduced allowable levels of emissions and would require a stem packing that would meet single digit and/or very low double digit leak rates. In response to this requirement, the research program was expanded to develop an own "stem packing design". This was done in conjunction with another packing manufacturer, EMPAK-MEX, in order to take advantage of their expertise in the molding and manufacturing of flexible graphite packing. The final design that evolved from this joint effort utilized the long established and proven packing design with the sealing rings shaped as a "vee" or "chevron" to take full advantage of the "pressure activated" principle. The packing set consists of two braided carbon filament end rings that encapsulate an Inconel wire mesh with three molded flexible graphite center rings. The initial tests of this design yielded very low emissions rates that were in the single digit ppm leakage range.

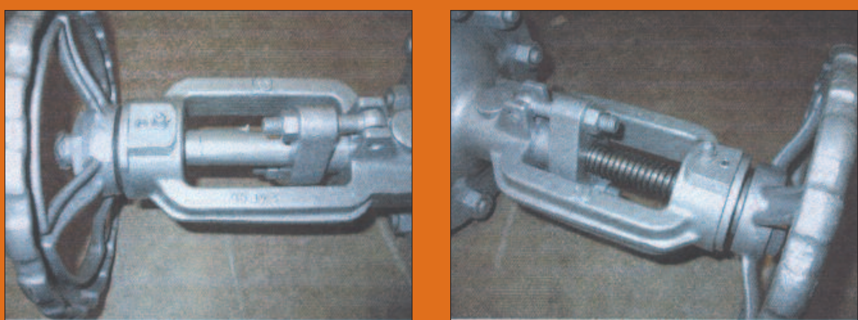

Fig. 4: Valve as received.

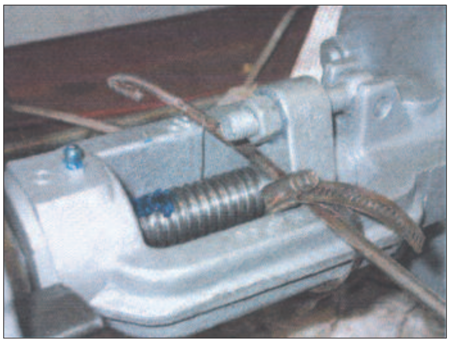

Fig. 3: Testing notes

The gland nuts were torqued to 17 ft-lb the day before the start of testing, but cycled five times and retorqued on the day of the test.

A 1/4 tube was fitted to the bonnet so that the leakage readings were made from the same location each time. The bonnet was wrapped in foil to capture most of the leakage.

The grease fitting and stem were lubed at start of the test and every 500 cycles. A 600°F synthetic lubrication was used.

These initial tests were followed by a series of tests in our test laboratory using different size valves in the 300 pressure class. The tests followed the previously established test protocol where the stuffing box area was totally enclosed and the methane leakage could be accurately measured with a Foxboro OVA-128 Organic Vapor Analyzer. These tests confirmed that the ppm emission leakage rate was consistently in the single digit and/or very low double digit range.

Independent verification

The earlier tests made at the Yarmouth Research and Technology Laboratory were repeated with the new Walworth packing design following the established protocol where an operating cycle consisted of the valve being operated from the open position to closed and back to open, stopping short of either the back seated position and/or the full closed position. These independent tests were made using a 6" Class 300 cast steel gate valve and a 2" Class 800 forged steel valve. Both valves required re-setting the packing gland nuts to the proper torque to compensate for some packing consolidation after the initial run-in cycles were made under pressure in order to achieve a single digit ppm leak rate. The ppm leakage rate for both valves stayed in either the single digit range or low double digit range ▶

through out the 3500 cycles and the leakage rate for both was reduced to a single digit after re-setting the gland nut torque at cycle 3500. These independent tests were made in December 1999. These test results* allowed us to guarantee a 50 ppm maximum VOC emissions leak rate for all "off the shelf" valves.

A recent test of a 4" Class 300 cast steel gate valve was made at the Yarmouth Research and Technology Laboratory using the Walworth design stem packing but to a much more demanding test protocol. This test consisted of 5000 open-close-open cycles and ten thermal cycles at 600 psi with 99% pure methane over a ten day period. The criteria allowed a 30 cycle initial run-in and then the packing gland nut torque was to be re-set to the correct value. The test required 500 cycles in one day, starting at ambient and increasing to 500°F during the first approximately 250 operating cycles and then being slowly cooled back to ambient at operating cycle 500. The "at rest" static leak measurement was allowed to reach 500 ppm before the packing gland nuts were required to be re-set. The packing gland nuts were required to be re-set at cycle 4000 as the ambient "at rest" leakage exceeded 500 ppm. However, the static leak rate had remained in the low double digit range during the heating and cooling cycles. After the gland nut torque was reset, the static leak rate remained in the single digit and very low double digit leak rates from operating cycle 4000 to operation cycle 5000, finishing in the single digit emissions leak rate at the final measured "at rest" ambient temperature position. This test was made in October 2004 and documented as part of our ongoing test/development program.

The results of these several independent tests* support the statement that the Walworth design can be said to have achieved a true "Ultra Low Emissions" valve packing system.

Long-term field test results

In February 2000, the Southern California Air Quality Management District (SCAQMD) began a program to verify actual VOC emissions of a product against the manufacturer's claims. This was because actual performance of some products often did not coincide with the vendor's claims and the vendors had little or no regulatory accountability for the VOC emissions results. Walworth, in an attempt to demonstrate to the SCAQMD that absolute minimum VOC emissions could be achieved without resorting to expensive metal-to-metal bellows seals, furnished three valves to a Southern California refinery that utilized the exact same stem packing as previously documented and tested. The only significant difference in the "packing system" was that the stem packing was "live loaded" with Belleville type conical disc springs to keep the correct compressive load on the packing regardless of any wear or change in operating conditions.

Three valves were furnished; a 4" class 150 gate valve, a 6" class 150 gate valve and an 8" class 150 gate valve. The 4" valve was installed in a harbor loading facility, the 6" valve was installed in an alkylation unit in the refinery and the 8" valve was installed in a reformer/desulfurizer unit in the refinery. All three valves were installed in light hydrocarbon service and located in positions that would be cycled frequently. The valves were installed in mid-year 2000.

The VOC emission from these valves is measured once a week in order to develop documented and quantified experience history. The method of VOC measurement requires that the "background" VOC level first be established some distance away from the equipment being monitored and then the maximum VOC reading taken at the point being checked. The background reading is subtracted from this maximum reading to obtain the "net" reading indicative of the actual VOC emission at the point being monitored. This can be assumed to be the actual VOC emission coming from the valve.

A June 2005 up-date of the VOC emissions history for these valves finds that the "net" VOC emission for these valves is consistently in the 0 to 2 ppm range. This confirms the previous "independent laboratory" test results, that even after 5000 cycles,

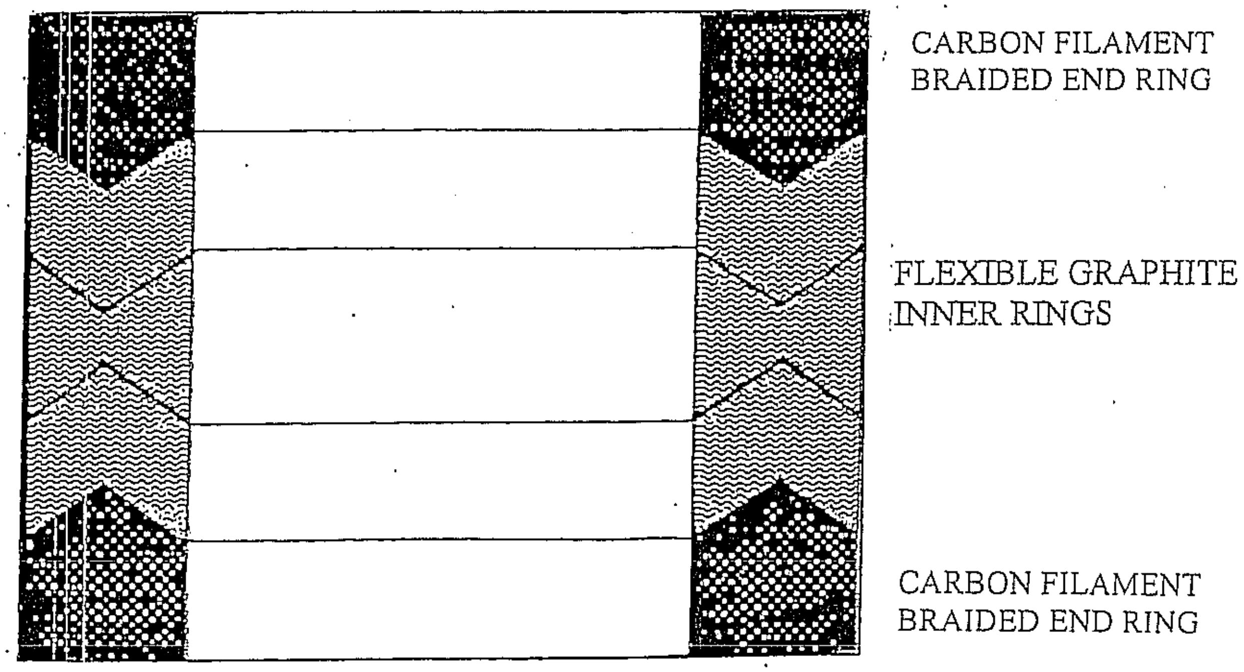

Fig. 5: Cross-section of the Walworth Style EAF 100-001 stem packing.

the VOC emission can be reduced to single digit after the packing gland is adjusted to the correct packing compression load. The use of the "live loaded" packing in these three valves has provided the continuous correct packing gland adjustment and eliminated the need for the occasional maintenance packing adjustment.

This five-year history of the packing in actual installations has proven the Walworth design to be an "Ultra Low Emission" stem packing that requires only occasional field maintenance, even when installed as a standard valve without the "live loaded" feature. We believe the Walworth VOC control system qualifies as meeting the "Best Available Control Technology" available today.

Packing design

The Walworth Style EAF 100-001 stem packing (see Figure 5) has demonstrated that it is designed to give the best possible control of VOC emissions coupled with extended life and minimum maintenance. It consists of two molded carbon/graphite filament end rings that encapsulate an Inconel wire mesh with three molded flexible graphite center rings. The center rings are shaped as a "vee" or "chevron" to take full advantage of the "pressure activated" principle. The design provides a relatively solid initial make-up without damage to the sealing contact faces. The design requires a relatively low "preload" to set the packing and therefore allows a lower operating torque due to the lower friction component between the packing and the stem.

The material is 95% minimum pure carbon. This was verified by an independent test at the Anderson Laboratory where two packing sets were weighed on a calibrated laboratory balance scale to four decimals and baked at 650°F for two hours. After cooling, the sets were weighed again to determine weight loss due to impurities and to establish the purity percentage. The sets were found to be 96.99% pure and 97.93% pure, respectively.

* Copies of the Yarmouth Research and Technology Laboratory Tests are available upon written request to Walworth at 4300 Campbell Road, Suite 100, Houston, Texas 77041. ■

About the Author

David Cornelsen is the Vice-President of Engineering and Quality Assurance for Walworth. He assumed that position in 1982 bringing a background of product design and Quality Assurance gained over 31 years in a related petroleum industry where he was responsible for developing the sealing technology required for high pressure surface and sub-surface drilling and production equipment including pumps, valves and sub-sea production manifolds; equipment designs that are still in use today. He is active in related standards writing committees for API, NACE and is Chairman of the Quality Standards Committee for MSS. He graduated from the University of Denver in 1955 with a BS degree in Mechanical Engineering and is a USA registered professional engineer in the State of Texas.