SUMMARY REPORT – Rev01

European Commission

COMPETITIVE AND SUSTAINABLE GROWTH

CONTRACT No.:	**SMT4-CT97-2158**
TITLE:	**Valve Stem Leak-Tightness Test Methodologies**
PROJECT COORDINATOR:	**BHR Group Limited**
PARTNERS:	**CETIM** **Neles Automation** **Chesterton** **European Sealing Association** **Association Francaise des Industries de la Robinetterie** **Elf Antar** **Inficon** **Alcatel CIT**
REFERENCE PERIOD:	**FROM: October 1997 TO: September 2000**
STARTING DATE:	**1ST October 1997 DURATION: 36 months**
Date of issue of this report:	**Rev01 - 26th October 2000**

Project funded by the European Community under the Standards Measurement and Testing Programme (SMT)

Contents

1. Introduction

Standards are currently under development covering valve leak-tightness qualification and quality assurance testing. If these standards are to gain widespread acceptance, they must balance the conflicting requirements of:

- end-users' needs for ppm targets to comply with site emissions legislation;
- regulatory authorities' concerns over VOC (volatile organic compound) leakage;
- cost and safety of laboratory or factory testing.

The draft standards define:

- test methods and procedures
- leak-tightness criteria
- measurement methods

There are a number of issues yet to be resolved concerning leakage measurement and leak-tightness criteria. This project has focussed on these issues and has provided technical information intended to help find solutions with the potential to satisfy the conflicting requirements identified above.

2. The issues

There are essentially two approaches to specifying leak-tightness targets:

- leakage rate
- concentration (ppm) near the leakage source using a "sniffer" device.

On-site leakage detection practice has widely led to the severity of valve stem leakage being assessed by sniffing. Whilst this does not actually measure leakage rate, it is widely misunderstood to do so, and many end-user valve test protocols specify it, because sniffing is relatively quick and simple, hence low cost.

There are also two classes of test gas: a safe gas for testing purposes (helium is accepted as the most suitable) and VOCs representative of the intended duty.

Thus there are four possible combinations as the basis of any leak-tightness test. The conflicting requirements in relation to these possibilities are represented in Fig. 1, which shows that no single combination of test gas and measurement is satisfactory to all concerned.

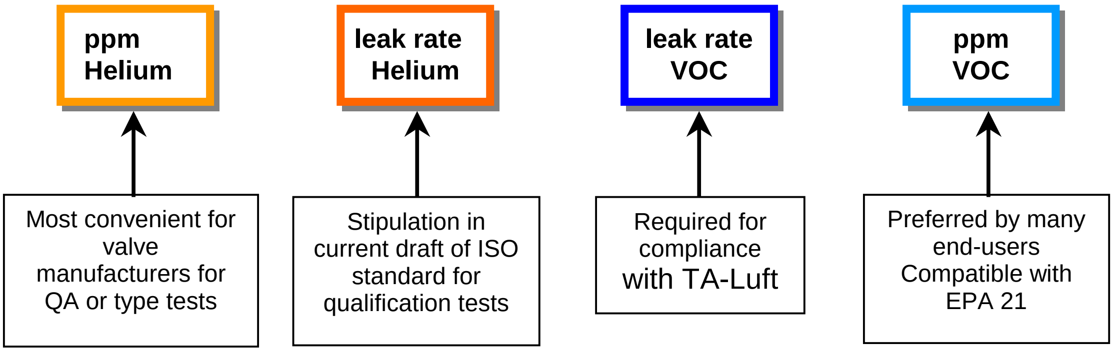

Fig. 1 – Four possible combinations of test gas and leak-tightness specification: conflicting requirements

If there were a reliable means of translating between the basic measurements, these conflicting requirements could be simply resolved by taking measurements in the most convenient manner, and “converting” the results to any other desired form. For example, a helium leak rate measurement might be taken to satisfy the ISO standard, and the result “translated” to an equivalent ppm of methane to satisfy an end-user’s requirements. Unfortunately, however, a straightforward conversion (as if between units, for example) is not currently possible.

3. Aims

In view of the foregoing, the overall aims of the project were:

- to establish measurement practices and procedures which improve accuracy and repeatability and, crucially, which avoid ambiguity
- to clarify why simple “conversions” are not possible between results using different measurement approaches and test gases
- to suggest, if possible, means of “translating” between the measurement possibilities identified in Fig. 1 and evaluate associated error and scatter

Experimental work was concentrated on valves representative of typical volatile organic compound (VOC) duties over a range of sizes and types (but particularly 4” Class 300 gate valves) with several different packing types (but mostly graphite) over a range of leakage rate representative of this duty.

4. Measurement methods

A preliminary survey of candidate measurement methods was carried out and three techniques identified as suitable for valve stem leakage measurement.

4.1 The vacuum method

The vacuum method is an established technique, known to be suitable over a wide range of helium leakage rates. It may involve minor modifications to a valve, however, to ensure a good vacuum seal. It was decided to use the vacuum method as a reference for the determination of leak rate in the evaluation of other approaches.

4.2 The flush method

In initial evaluation tests, variants of the flush method were tested for accuracy against measurements taken by the vacuum method, as reference with no adjustment to the valve between the two measurement methods. The impact of factors thought likely to affect accuracy was also investigated. A limited data set was produced, sufficient to identify the “blow-through” approach as the most accurate variant. In subsequent confirmatory tests the flush method was confirmed as a reliable technique for helium leak rate measurement, along with the vacuum method. For measuring leakage rate of VOCs, where the vacuum method is expensive, flushing was found to be a suitable alternative.

4.2 Sniffing

Sniffing does not measure leakage rate. It is a local measurement based the uptake, by a probe, of test gas leaking to atmosphere. (This contrasts with the “global” methods that rely on capturing all test gas leakage into an enclosed area). There is a large degree of scatter in sniffing results as a function of leak rate.

Evaluation of the sniffing method involved the identification of factors having a significant effect on this scatter. These were found to be as follows.

- Probe flow rate affects dilution of test gas uptake by the sniffer
- Local wind speed affects the quantity of test gas that disperses to atmosphere

Use of a single detector at zero wind speed reduced scatter by two orders of magnitude.

- Packing type had some effect, which derived from a tendency to produce localised or uniformly distributed leakage around the stem.
- Valve type had a small effect, thought to be due to two possible factors:
  - orientation of stem scratches in rising or rotary stem valves
  - the length of the gland follower in different valves imposing different distances between the actual source of leakage through the packing and the point at which the sniffer measures resulting concentration dilution effects.
- Neither stem diameter (range: 19 to 35 mm) nor change of skilled operator had a significant effect.

5. Correlations

5.1 Leak rate - vs - ppm: alternative approaches

- There is large scatter in power law correlations between ppm measured by sniffing and the actual leak rate. This is discussed in Section 4.2, above.
- Under well-controlled circumstances (one detector and zero wind speed), ppm is approximately proportional to leak rate. This suggests an alternative approach to the relationship between these quantities based on an empirical “sniffing factor” (percentage of leaking gas taken up by the detector) and known probe flow rate.
- The probe flow rate is a function of the detector employed.
- The “sniffing factor” is not a constant, it is known to vary with leak rate, and is likely to depend on other factors such as stem diameter, packing type, valve, etc. Therefore, if it is averaged over a range of measurement conditions, the error band associated with its use will be increased, and understanding of the underlying behaviour may be obscured.
- By specifying “sniffing factor” and probe flow rate, ambiguity is avoided, whilst use of this approach can reduce scatter.

5.2 Relationship between leak rates of different gases

Work focused on:

- identification of the leakage mechanism
- evaluation of the error incurred by the use of the resulting predictive models

5.2.1 Room temperature

A test valve with a given level of gland load was pressurised first with helium and then with methane, across a range of pressures. Examination of the relationship between leak rate and pressure enabled assessment of leakage mechanism. This was repeated at 3 levels of gland load and on another valve with helium and ethane. Theoretical relationships based on leakage mechanism were used to predict VOC leakage rate from measured helium leakage rate. The results were compared with measured VOC leakage rate, enabling both an assessment of accuracy and a further indication of the leakage mechanism.

Only at intermediate gland load (packing stress of approximately 30 MPa with braided graphite packings) were all the data are consistent with one leakage mechanism (molecular flow). Under other conditions, there was conflicting evidence. Some suggestions of laminar flow at high gland load were particularly surprising. However, there was no condition examined at which there was consistent evidence for laminar flow, and most of the evidence suggests molecular flow.

5.2.2 Elevated temperature

Helium tests were conducted in the laboratory across a range of gland load, temperature and pressure, whilst selected conditions were reproduced in an enclosed area on site, with different VOCs, in the same valve. This way, comparisons could be made between predicted and measured VOC leakage as a means of testing various proposed correlation rules. The sequence for the helium tests involved: first setting a gland load and temperature whilst stepping up through a pressure range, measuring leakage rate at each step. This sequence was then repeated at each of four temperatures. The entire sequence was then repeated for different gland loads. The VOC tests, conducted for each of three different hydrocarbons involved a similar sequence, but at fewer combinations of pressure, temperature and gland load.

The observed relationship between leakage rate and pressure strongly suggested the dominance of molecular flow as leakage mechanism at medium and high gland load with braided graphite packings. However, the temperature dependence of leakage was substantially different from that predicted by molecular flow theory. This suggests some other effect of temperature (possibly changes in the distribution of leakage channel dimensions through the packing). Furthermore, VOC leakage rates estimated from molecular flow theory differed widely from measured values.

5.3 Relating helium leakage to VOC ppm

This requires a two-step procedure:

- Step 1: relating helium leakage to VOC leakage (via leakage model)
- Step 2: relating VOC leakage to VOC ppm (via empirical correlation)

In the first step, predictive relationships for laminar, molecular and intermediate flow were used to predict VOC leakage from helium data under the same temperature and pressure. In the second step, three published power law correlations were used. Consequently, nine possible predicted VOC ppm values could be derived (3 leakage mechanisms x 3 ppm –vs- leak rate correlations). These predictions could be checked against experimentally measured VOC ppm.

Three principal sources of error were established: inherent scatter in the sniffing measurement itself; the quality of the ppmv-vs-leak rate relationship; and ignorance of the VOC gas flow regime. The combined error was typically a decade or more, even with tight control of experimental factors and with the most appropriate ppm –vs- leak rate correlation (the one derived from the same detector as used in the VOC measurements).

6. Effect of set-up on leakage rate: implication for QA tests

A series of tests was conducted in which leak-tightness was assessed as a function of the first few stem cycles. In nearly all cases tested, leakage was within ±50% of a final steady value by 40 stem cycles. There was often (but not always) an increase over the first 10 cycles, followed by a decrease to the final value.

The qualification test is designed to provide information about the longer-term response of the sealing performance through thermal and mechanical cycling, but this does not address the issue of the relationship between the qualification test and an “acceptable” leakage in a QA test. Clearly, it is impractical to suggest conducting, say, 40 stem operations as part of a QA test procedure. However, the deviation of early seal leakage readings from their “bedded-in” values, might suggest the use, in a QA test, of an appropriate “safety factor” on a threshold leakage value defined by the qualification test.

7. Dissemination

A full programme of dissemination is currently being implemented. This is targetted primarily at the valve industry but also to end-users and seal manufacturers.

There are close working links with ISO/TC153/ SC1/WG10, which is preparing a draft standard on leak-tightness testing of industrial valves. The results of this study have been summarised to this committee.