EFFECT OF PACKING MATERIAL AND CONFIGURATION ON ISOLATION VALVE STUFFING BOX LEAKAGE AT CRITICAL OPERATING CONDITION

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ABSTRACT

Valves are used enormous numbers in the refineries and process plants. Leakage from these valves to atmosphere through different joint and glands are significant during the operation. It is required to have good sealing mechanism to avoid such leakages. Leakage from valves, especially through the stem seal, body bonnet joint and stuffing box during critical operating condition of great concern to the environment and safety aspects. Special packing materials with PTFE and Graphite as base constituent are used in valves for critical applications. To evaluate the performance of such materials while used with valves, are to be tested as per international standards. During test, helium is used as the test fluid for pressuring the test valve. The leakage part the seal will be measured with Helium mass by vacuum method as specified in ISO 15848 part-1. Tests were performed with PTFE and graphite packing at various test conditions Different packing material pattern arrangement also tried. All types of valves up to an ANSI rating of 1500 class was evaluated during the test program. A detailed study is also planned for the effect of surface finish of the valve stem to on the stuffing leakage.

KEY WORDS

Fugitive emission, Packing, Valve, Graphite,

1.0 INTRODUCTION

A fugitive emission is an emission to the atmosphere which is not vented to a stack or other extraction equipment. Some fugitive emissions occur as a result of an accident and are relatively. A fugitive emission can be defined as any chemical or mixture of chemicals in any physical form which represents an unanticipated or spurious leak from anywhere on an industrial site.

An organic liquid that evaporates readily at normal temperature and pressure, giving rise to volatile organic compound (VOC) emissions. In frequent other fugitive emissions may be due to leaking equipment, such as valves and pumps, or may arise as a result of incomplete solvent capture for example when filling containers. Fugitive emissions are inherently difficult to identify as they often involve leaks to atmosphere, and due to the nature of organic solvent any visual liquid leak will rapidly evaporate.

The individual components contributing to emissions are valves, connectors, pressure-relief valves, compressor seals and open ended lines. The non-compressor related equipment, reciprocating and centrifugal compressor related components, cryogenic equipment and vents and flares are considered to have methane as the primary hydrocarbon fraction and contribute about 90% of the total methane emissions from gas plants.

Fugitive emissions may be due to wear, corrosion, incorrect specification, incorrect installation, incorrect maintenance, incorrect process operation, poor working practices.

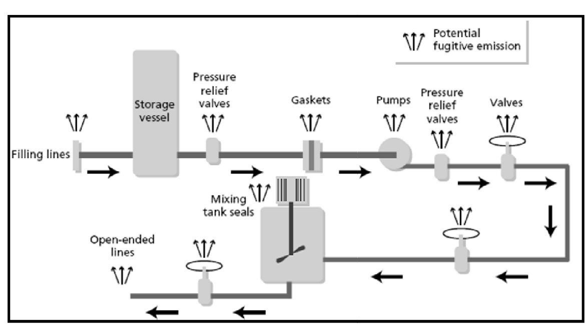


Fig. 1 Fugitive emission sources.

Popular valves such as 'gate' and 'ball' designs can be a major source of fugitive emissions, with most of the leakage occurring at the valve gland.

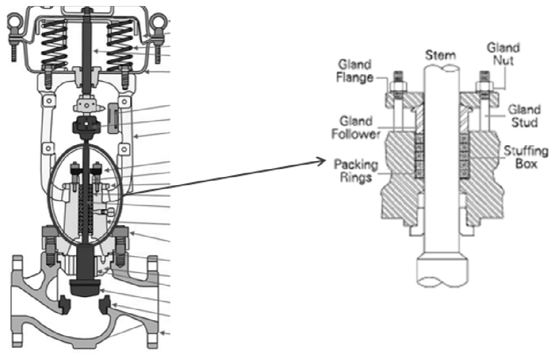


Fig. 2 Valve Stem seal packing

Valve gland seals traditionally consisted of a packing of braided cotton or asbestos yarn, wrapped around the valve stem and compressed into the stuffing box of the valve. Modern packing materials such as PTFE, and graphite have generally replaced the traditional materials. These newer packing materials offer better sealing properties. A usual valve packing arrangement details shown in the figure 2

"In a typical petroleum or chemical processing plant, 60% of all fugitive emissions come from the valve stem Packing ". as shown in the figure 3. Leak detection and repairing is the costly process and some time the entire valve will be replaced. This will consume more time and money also. So it is required a long lasting sealing element to withstand the leakage."

Various types of VOC monitors are available to detect fugitive emissions in the workplace. The choice of instrument depends on the extent of the study, process, budget, human resources, accuracy required.

In many small companies, checks on a limited number of components can be made as part of a regular monitoring programme. Provided accuracy is not required, and the results are only used to identify deterioration in the plant, the same equipment can often be used for both purposes.

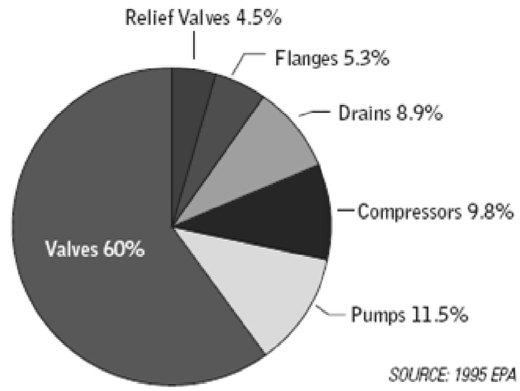


Fig. 3 Sources of Fugitive emission

2. DESIGN OF THE SETUP

This test setup covers testing of gate, check, ball and butterfly on/off valves and control valves used in a elevated temperature service range from RT to 400℃. This setup consists of test fixture to fix the valve and it was insulated with ceramic wool of thickness 3" and the outside was shielded with aluminum shielding.

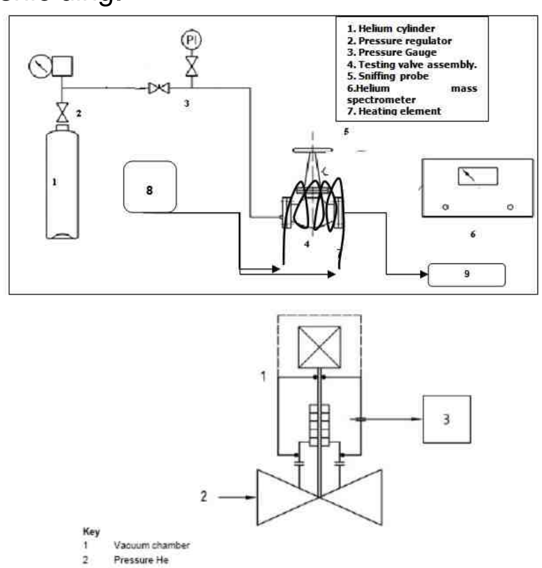


Fig. 4 Schematic of the experimental setup

2.1 Test equipment and instruments

Helium Mass spectrometer with sniffing prope measurement range of 1.0×10^{-7} to 1.0×10^{-1}. Pressure Gauge with range of Pressure 0-600 bar at accuracy level of

0.1bar. Double stage Pressure Regulator with pressure range of 0-250 bar and booster pump capacity of 600 bar. Helium with pressure of Pressure: 150 bars and purity: 99.995%. Hoses and Fittings with size of 6 mm, Soap film burette range of 500 ml, with accuracy level of: 0.1ml.

A vacuum cover is used to measure the total leakage from the stuffing box was used. Additional vacuum pump for roughing purpose is also used in the system.

The thermocouples is placed on the body/bonnet. Inside of the valve body at the thinnest wall thickness adjacent to the seating, as shown in the figure no. 5

To reduce instrument response and clean up time, the tubing (Detector probe) length shall be less than 5 m, unless the test set-up is specifically designed to attain the reduced response and clean up time for longer tubing lengths. The instrument is equipped with a probe or probe extension for sampling not to exceed 6 mm (1/4 ") in outside diameter with a single end opening for admission of samples.

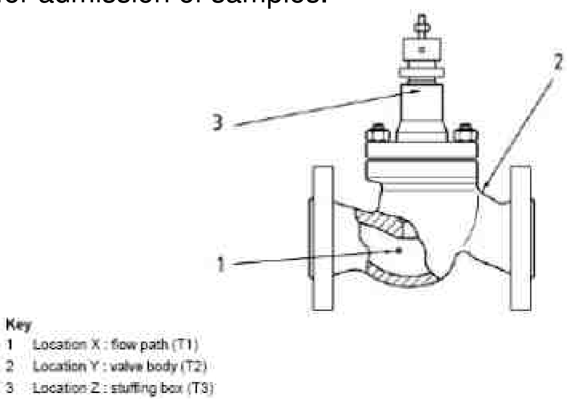


Fig. 5 Measurements of temperature at three different locations

The test valve is covered with heater coil in the valve body up to stem packing. Thermocouples is fixed on the valve body , bonnet and stem packing. Thermocouples is connected to PID temperature controller to control the temperature of the valve body. Heater coil is connected to Heater driver and PID controller. The entire valve body and stem packing is insulated with Ceramic insulation cover.

To measure the actual pressures both pressure recorder and pressure gauges can be used. Fugitive volatile emission from the stuffing box, gland, bonnet and cover connection of the valve is detected by means of mass spectrometer.

All measuring equipment and instruments shall have a system calibration certificate issued not earlier than 6 months prior to the test. The valve shall be mounted in the test setup and heated up with the stem in the vertical position.

2.2 Helium leak detector- The mass spectrometer

A leak detector capable of sensing the leak detection (tracer) medium is used. Helium leak detector measures the leak with the help of an analyser cell. The analyser cell works on the principle of mass spectrometry and is set to the mass of helium. In the analyser cell a heated tungsten filament ionises the helium atom which when passes through the constant magnetic field (Permanent magnet) produces a current. The current produced is equal to the partial pressure of helium in the part and by measuring it we can find the flow rate of the leak that has been detected.

The testing in the leak detector can be done mainly in two methods are Evacuation method and Pressurised method

In evacuation method the part to be tested is completely evacuated and vacuum is created inside the part. Then the helium gas is sprayed around the part and if there is a leak in the part tested the helium will enter the part due to differential pressure and thus the helium entered the part can be collected and measured and hence the flow rate can be calculated. This method is also called the spray method.

In pressurised method the part to be tested is completely pressurised with helium gas and a sniffer probe is passed over the part and if any leak occurs from the part it is detected by the sniffer probe and the leak rate is thus found. This method is also called as sniffer method.

3. EXPERIMENTATION

Testing was done at manufacturer's works, end-user's facilities or third party testing institutes and is executed under controlled conditions. Only a fully assembled valve is used for the test.

Fig. 6a Valve under Test

Fig. 6b Experimental setup

The valve and bolt tightening prior to the test is in accordance to manufacturer's specifications. If a test valve is equipped with a manually adjustable stem (or shaft) seal(s) it is initially adjusted according to the manufacturers instructions.

For fugitive emission testing, fully assembled valves with all accessories were taken. The test valve interior was checked for dryness and the packing also checked prior to the test. The valve was mounted in a test rig as shown in figure no.4. Thermocouples of three numbers were fixed in the valve body, bonnet joint and near the valve seat. The entire assembly was kept in the test setup. The test valve was pressurised with He through a pressure regulator to set rated pressure. Downstream of the valve was blinded with blind flange.

Heater coil is powered and the valve get heated. The temperature indicator was noted down. Once the temperature reached the required temperature, the PID controller cut the power supply and temperature is maintained the required level. After reaching the uniform temperature the leakage rate of the valve was noted down. Several reading of the leakage was measured.

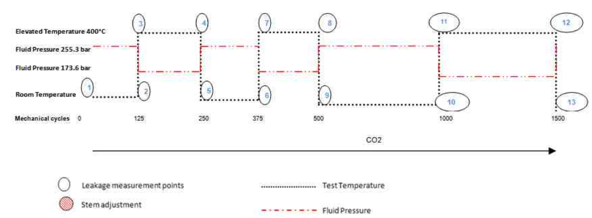


Figure 7 Test procedure for ON/OFF valves as per ISO 15848

Bonnet joints were checked by sniffing probe method. Leakage through the bonnet seals were measured using He mass spectrometer. The test fluid was used in the test was helium gas of 99.995 % purity.

Pressurised method can be started by entering into sniffer mode by pressing sniffer key and the leak can be detected by moving the sniffer probe around the part. The sniffing method with a detection probe shall be used to evaluate the local concentration of the tracer medium. Sniffing with a detector probe is a semi quantitative technique used to detect and locate leaks and shall not be considered quantitative.

3.1 Leak measurement in the body bonnet joint using the sniffing method

Helium leak detector was fitted with a detector probe (sniffer), to measure helium concentration due to emissions from body seals.

Before starting the test, helium spectrometer was activated in the auto-calibration mode. Prior to each measurement, the ambient helium concentration around the source was determined by moving the probe randomly at a distance of one or two meters from the source. End connections of the valve body have been checked to insure that they do not affect the results of the evaluation of the body seals. The probe was positioned as close as possible to the potential leak source.

Probe was moved, while observing the instrument readout maximum. The method has been repeated two times. The maximum leakage values were recorded.

3.2 Leak measurement in the stem seal using the vacuum method

Helium leak detector was fitted with a vacuum cover which cover the stem seal arrangement , to measure helium concentration increase due to emissions from stem sealing systems.

Before starting the test, helium spectrometer was activated in the auto-calibration mode. The helium leak detector was connected and maximum leakage from the stems seal was measured and recorded.

3.3 Preliminary tests at the room temperature

Test valve was pressured with the test fluid to the test pressure as specified in the relevant standard (ASME B16.34). After the test pressure was stabilized, measure both leakages from the stem seal and the body-bonnet seals were measured. The test result was recorded in the data sheet.

3.4 Mechanical cycle test at the room temperature

The test valve was subjected to rated pressure at ambient temperature with 125 mechanical cycles. Opening the valve from 5% to 95% of the rated stroke and back to 5% was considered as one mechanical cycle. The leakage from the stem seal before and after 125 cycles were noted and recorded in the data sheet. All leakage measurements specified in the standard were verified with allowable leakage. All results of leakage measurements were recorded in the data sheet.

3.5 Mechanical cycle test at elevated temperature

After completion of 125 mechanical cycles at ambient temperature, the test valve was elevated to 400 ° C and pressure was reduced (as per the class ASME / PN). Test valve was subjected to 125 mechanical cycles at this condition. The leakage from the stem seal before & after cycles was noted down. The test result has been recorded in the data sheet. This is considered as one thermal cycle; one more thermal cycle with 250 (125+125) mechanical cycles as described was performed. This completes CO1 endurance class as per ISO 15848-1.

3.6 CO2 cycles

After completion of CO1 endurance cycle class, valve was tested for additional 1000 mechanical cycles with one thermal cycles (Room Temperature & 400 °C) under the endurance class of CO2, comprising of one thermal cycle as shown in the Figure no. 7. The leakage from the stem seal and bonnet seal was measured after every 500 cycles. This cover 1500 mechanical cycles with 3 thermal cycles as shown in the figure no. 7 for class CO2. The test result has been recorded in the data sheet.

All leakage measurements are verified equal or lower than the values specified for the target performance class. All results of leakage measurements shall be recorded in the test report.

4. TESTING

Various number of valves with different packing were tested.

4.1 Case 1: Teflon packing for ON/OFF valves 200° C

Table 1- Different PTFE packing and the description.

Seal Type and pattern	Description	Effectiveness
Pure PTFE	Temperature 160°C Pressure : 200bar	100 ppm leak performance
Braided PTFE with inconel wire mesh	Temperature 200 °C Pressure : 250 bar	200 ppm leak performance
PTFE with synthetic fiber	Temperature 220 °C Pressure : 250bar	50 ppm leak performance
Combination of PTFE & Graphite	Temperature 240 °C Pressure : 250 bar	50 ppm leak performance

Table 2- configuration arrangement of PTFE packing

Configuration arrangement					
Packing type	Pressure	Temperature	Seal performance	Service life	Packing friction
Single PTFE Vring	40 bar	230 ° C	good	Long	Low
Double PTFE Vring	60 bar	230 °C	good	Long	Low
Single PTFE packing with SS rings	130 bar	230 °C	best	v.Long	Low
Duplex PTFE packing with SS rings	160 bar	230 ° C	best	v.Long	Low

Table 1 and 2 showing that PTFE packing details and configuration arrangement. In the First case Teflon packing with different packing pattern were tested. Maximum pressure of 148 bar and maximum temperature of 200℃ were tried. First test PTFE with braided wire mesh was tested. Second test PTFE with synthetic fiber was tested and the third test combination of PTFE and graphite was tested. All the test 1500 mechanical cycles and three thermal cycles was applied on the test valve.

4.2 Case 2 : Graphite packing for ON/OFF valves 400 ° C

Table 3 showing that graphite packing details. In the second case Graphite packing with different pattern was tested. Maximum 278 bar pressure and 400℃ temperature were applied on the test valve.
First test Die formed graphite and end carbon rings was tested. Different numbers of Graphite rings were tested starting from 6 numbers to 9 numbers. Finally Combination of die formed graphite and rings was tested. Total 1500 numbers of mechanical cycles and 3 thermal cycles were applied on the test valve.

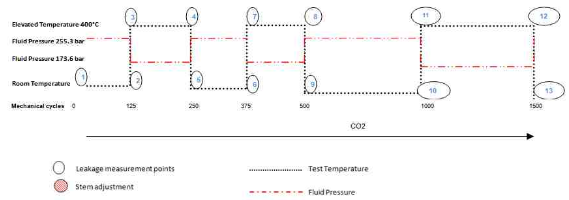
Table 1- Different Graphite packing and the description.

Seal Type and pattern	Description	Effectiveness	Seal Performance	Service life	Packing friction
Die formed graphite with carbon thread packing end ring	Temperature 450 °C Pressure : 250 bar	500 ppm leak performance	Best	Very long	medium
Braided flexible graphite	Temperature 450 °C Pressure : 250 bar	Leakage performance from 100 ppm to 500 ppm	better	Very long	medium
Set of rings Combination of die formed graphite with braided graphite	Temperature 450 °C Pressure : 600 bar	50 ppm leak performance	best	Long	High
Braided graphite, reinforced inconel wire matrix	Temperature 450 °C Pressure : 600 bar	Ultra low emission	best	Long	High

5. RESULTS AND DISCUSSION

Two case study has been tested as per the Standard. The leakage measurement in stem seal and bonnet seal are recorded.

Leakage rate obtained for various conditions are tabulated. Leakage values compared with allowable values (100 PPM) specified in the standards.



Test procedure for ON/OFF valves as per ISO 158548-1

	Pressure 148 bar and temperature 200 ° C, Allowable leakage : 100 ppm														
	Packing material and pattern arrangements	1	2	3	4	5	6	7	8	9	10	11	12	13	Remarks
1	Double PTFE pack with braided wire mesh	27	32	16	22	112*	72	51	57	98	156 *	148 #			* Exceeding and adjusted # failed
2	Double PTFE pack with synthetic fiber	13	42	28	36	84	89	45	61	140*	66	51	58	165*	* Exceeding and adjusted
3	Combination of PTFE and graphite	56	61	40	45	61	60	62	64	61	65	49	50	48	qualified

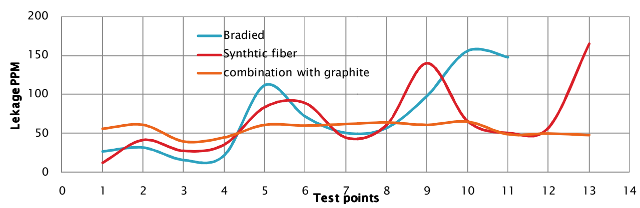
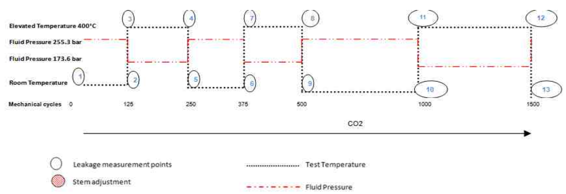


Fig. 8 - Teflon packing results and graph

In the first case PTFE packing with different combination tested and the comparison results and graph are shown in the figure 8. In the first test the leakage values exceeding at the end of second thermal cycles. Second test the leakage values at the end of third thermal cycles. After that the stem seal was adjusted and lekage was within allowable and valve was qualified. During the test packing was damaged it was shown in the figure 9.Third test the leakage values are within allowable limit and valve is qualified as per standard without any stem seal adjustment.

In the second case Graphite packing with different combination were tested and the comparison results and graph are shown in the figure 10. Die formed graphite test was exceeding at the end of second thermal cycles. Braided graphite rings with 6 numbers was exceeding the allowable limit at the end of second thermal cycle. Nine number of combination was exceeding but the stem seal was adjusted and it was qualified. The damaged graphite packing was shown in the figure 11. Combination of die graphite and rings was qualified without any stem seal adjustment as per standard.

Fig.9- Damaged Teflon Packing



	Pressure 278 bar and temperature 400 ° C, Allowable leakage : 100 ppm														
	Packing material and combination	1	2	3	4	5	6	7	8	9	10	11	12	13	Remarks
1	Die formed graphite with carbon packing end rings (5 nos)	11	25	18	21	90	115 *	81	89	160#					*Exceeding, adjusted, #Failed
2	6 nos of braided graphite	47	50	52	56	102 *	90	83	89	150#					
3	9 nos of braided graphite	36	38	40	45	71	80	72	77	110*	81	69	71	114*	qualified
4	Combination of die graphite and braided graphite with end carbon end packing (12 nos)	21	26	11	24	49	54	41	47	62	65	51	54	78	

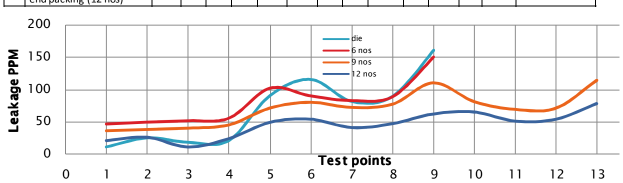


Fig. 10 - Graphite packing results and graph

Fig. 11 Damaged Graphite Packing

6. CONCLUSION

There are two case study were tested for isolation valves. Teflon packing was suitable for elevated temperature of 200 ℃ at 148 bar pressure. In this test Combination of PTFE and graphite packing working without any adjustment.

Graphite packing was suitable for elevated temperature of 400℃ at 278 bar pressure. In this test combination of 12 number of rings working without any adjustment.

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