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ASME B16.20 SPIRAL WOUND GASKETS PERFORMANCE TESTING

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ABSTRACT

Spiral Wound Gaskets have widespread use in the Process Industry, with adequate results in both piping and equipment applications. The current revision of ASME B16.20-2012 provides several details of gasket construction and dimensions. Paragraph 3.2.6 of the referenced standard has been the object of many discussions, and some question its effectiveness since it does not assure a suitable sealing performance. This paper proposes to address this issue showing results of sealability tests with many different sizes of gaskets. It also proposes a test protocol that could eventually rewrite Paragraph 3.2.6 with a protocol for sealability in addition to the compression evaluation.

INTRODUCTION

ASME B16.20 Spiral Wound Gaskets ⁽¹⁾ have widespread use in the Process Industry, with acceptable results in both piping and equipment applications. Since it has been found that majority of identified leaks in the Process Industry are in valve stems, Low Emission packing products were the first to be developed. The American Petroleum Institute (API) has published standards for stem packing (API 622 Type Testing of Process Valve Packing for Fugitive Emissions ⁽²⁾) and valves (API 624 Type Testing of Rising Stem Valves Equipped with Graphite Packing for Fugitive Emissions ⁽³⁾). However, there is no standard test protocol to assure that Spiral Wound Gaskets also meet Low Emissions performance levels. The current revision of ASME B16.20 (2012) provides several details of gasket construction and dimensions. Even if the gaskets meet these requirements there is no assurance of an acceptable or consistent level of performance, since many other critical features like the filler thickness, and its protrusion beyond the metal are not specified ^(4,5).

In Figures 1 and 2, sealability charts of gaskets of the same brand, but from different manufacturing locations are shown.

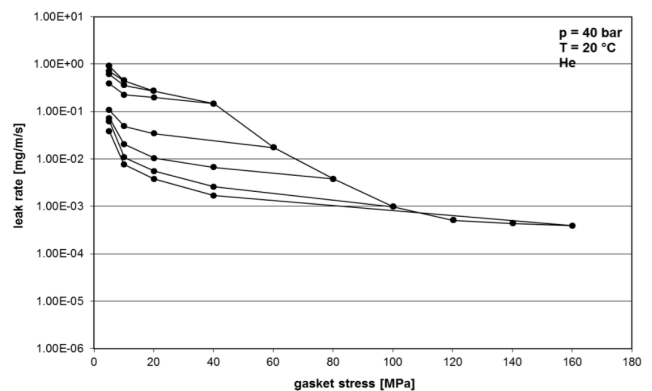


Figure 1- Sealability chart of a gasket.

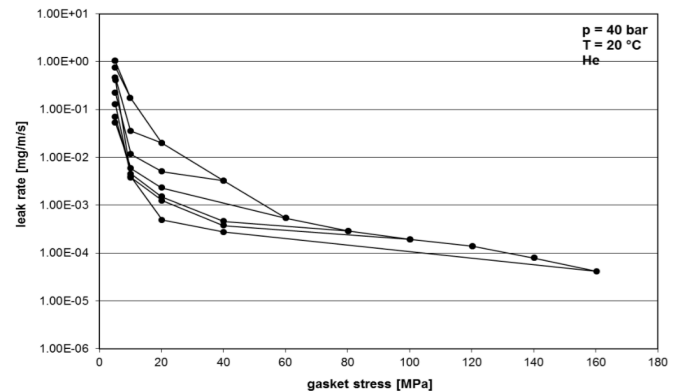


Figure 2- Sealability chart of a gasket (different manufacturing location).

Our proposal is to develop a test method to assure that spiral wound gaskets made per ASME B16.20 meet an acceptable and established leak rate level of performance in addition to the compression test required in Paragraph 3.2.6. It

considers the bolting capability of each flange class, with a low Yield Stress bolt per ASTM series. The test should be easy to implement without any special tooling, and using equipment available in the market.

NOMENCLATURE

bar: pressure, 1 bar = 14.50377 psi
in: inch
kg: kilogram
ksi: pressure, 1ksi = 1000 psi
lb: pound weight
 L_{Rm} : mass leak rate
m: meter
mg: milligram
Mpa: pressure, mega Pascal
NPS: nominal pipe size
p: pressure
ppmV: parts per million by volume
psi: pressure in pounds per square inch
s: second
 G_{OD} : gasket winding outside diameter
MW: gas molecular weight
T: test temperature in Kelvin
TVA 2020 from Thermo Fisher Scientific Inc Flow rate =
l/iter per minute
l: liter
mg: milligram
s: second
m: meter
in: inch
R: universal gas constant in l.bar/K.mol

or

$$L_{Rm} = 7.67E - 10 \frac{lb}{s.in}$$

Table 1 shows values for each NPS/Pressure Class combination for ASME B16.20, adjusted for gasket outside diameter, given that the leak rate per the API 624 level of 100 ppmV is equivalent to 0.0137 mg/(s.m).

Table 1 – Gasket leak rate of 100ppmV.

Concentration in ppmV per API 624 Level							
NPS (in.)	Pressure Class						
	150	300	400	600	900	1500	2500
1/2	123	123		123		123	123
3/4	154	154		154		154	154
1	185	185		185		185	185
1 1/4	235	235		235		235	235
1 1/2	271	271		271		271	271
2	333	333		333		333	333
2 1/2	382	382		382		382	382
3	468	468		468	468	468	468
4	579	579	579	579	579	579	579
5	689	689	689	689	689	689	689
6	813	813	813	813	813	813	813
8	1022	1022	1022	1022	1022	1022	1022
10	1231	1231	1231	1231	1231	1231	1231
12	1453	1453	1453	1453	1453	1453	
14	1576	1576	1576	1576	1576	1576	
16	1798	1798	1798	1798	1798	1798	
18	2044	2044	2044	2044	2044	2044	
20	2241	2241	2241	2241	2241	2241	
24	2659	2659	2659	2659	2659	2659	

LEAKAGE CRITERIA

The API 624 standard has established the definition for Low Leak valves as 100 ppm, using Methane (CH₄) as media and a Volatile Organic Compound Analyzer such as the type TVA 2020 from Thermo Fisher Scientific Inc. ⁽⁸⁾. There is no definition for flanges. We propose to keep the 100-ppmV concentration of Methane per EPA Method 21 ⁽⁹⁾ and API 622 stem diameter as reference for the calculation of leakage. However, due to the range of the gasket outside diameters, it is not feasible to have a single value (100 ppmV) as for valve stems. Our proposal is to convert it to a leak rate per millimeter (or inch) of a gasket outside diameter as shown in Annex A.

Considering that the diameter of the test device stem per API 622 is 1 inch, we can establish the leak rate per millimeter (or inch) of stem perimeter. Per Annex A, the values for calculating a gasket maximum leak rate equivalent to 100 ppmV are as follows (metric and imperial values respectively):

$$L_{Rm} = 0.0137 \frac{mg}{s.m}$$

It is possible then to estimate the gasket emission level in a given period of time, and determine whether the gasket is accepted or rejected, in a quality control type operation which can be conducted typically at the manufacturer's location. The calculation is performed multiplying the gasket perimeter by the leak rate of 0.0137 mg/(s.m), and the time in seconds being considered. It is further possible to even consider standardized values characteristic to a group of gaskets.

Table 2 shows the leak in kilograms per gasket for a period of one year considering the API 624 level.

If gaskets received in a plant meet the proposed criteria, the total product loss due to emissions can be estimated multiplying the number of gaskets in the plant per the value in Table 2. If a tighter sealability level is established, the product loss savings due to this change can also be estimated

Table 2 – Gasket leak in kilograms per year

Leak per gasket size for API 624 Level (kg/year)							
NPS (in.)	Pressure Class						
	150	300	400	600	900	1500	2500
1/2	0,043	0,043		0,043		0,043	0,043
3/4	0,054	0,054		0,054		0,054	0,054
1	0,065	0,065		0,065		0,065	0,065
1 1/4	0,082	0,082		0,082		0,082	0,082
1 1/2	0,095	0,095		0,095		0,095	0,095
2	0,117	0,117		0,117		0,117	0,117
2 1/2	0,134	0,134		0,134		0,134	0,134
3	0,164	0,164		0,164	0,164	0,164	0,164
4	0,203	0,203	0,203	0,203	0,203	0,203	0,203
5	0,241	0,241	0,241	0,241	0,241	0,241	0,241
6	0,284	0,284	0,284	0,284	0,284	0,284	0,284
8	0,358	0,358	0,358	0,358	0,358	0,358	0,358
10	0,431	0,431	0,431	0,431	0,431	0,431	0,431
12	0,509	0,509	0,509	0,509	0,509	0,509	
14	0,552	0,552	0,552	0,552	0,552	0,552	
16	0,629	0,629	0,629	0,629	0,629	0,629	
18	0,715	0,715	0,715	0,715	0,715	0,715	
20	0,784	0,784	0,784	0,784	0,784	0,784	
24	0,931	0,931	0,931	0,931	0,931	0,931	

Class 150: 5000 psi
 Class 300 and 400: 8000 psi
 Class 600 and above: 10000 psi

Only one flange does not meet the proposed criteria: NPS 8 in – Class 150. It is well known that it is considered a “bad actor”.

Table 3- Gasket stresses for 30 ksi bolt stress.

Gasket Seating for 30 ksi Bolt Stress (psi)							
NPS (in.)	Pressure Class						
	150	300	400	600	900	1500	2500
1/2	30105	30105		30105		70966	70966
3/4	20143	32082		32082		47484	47484
1	14047	22372		22372		45703	45703
1 1/4	13694	21811		21811		26185	34351
1 1/2	9031	21289		21289		27253	35568
2	11215	22430		22430		26563	34847
2 1/2	9616	28466		28466		28075	36640
3	6310	18678		18678	19077	29116	36822
4	8400	12433	13260	13260	22703	25922	38687
5	10447	10447	10380	13617	22475	29106	40615
6	7060	10590	11257	14768	19274	27497	41163
8	4889	10122	10494	13695	23927	29071	45384
10	8341	14590	13260	16770	26173	29921	59473
12	6034	13774	12674	15842	21316	38292	
14	7268	15809	15549	19194	23541	52638	
16	7080	14607	14568	17614	24373	42576	
18	6317	11983	13547	16238	22411	40292	
20	7167	10898	14860	17679	26232	43787	
24	6944	12437	17355	20122	35092	45195	

It is a common practice in the industry to use an “ideal seating stress”. With this in consideration we propose a test at 15 ksi for Class 150 and at 25 ksi for higher classes and an additional test at an intermediate gasket stress so we can have a chart of sealability versus gasket stress. The sealability tests are then performed at the following gasket stresses:

- For Class 150: 5000, 10000 and 15000 psi.
- For Class 300 and 400: 8000, 15000 and 25000 psi
- For Class 600 and higher: 10000, 15000 and 25000 psi

To assure that the raised portion of the flange does not hit the guide ring, the winding compressed thickness is recorded at each seating stress, and compared with the guide ring thickness. To assure that there is no “guide ring seal”, the winding shall be determined to be thicker than the guide ring.

SEATING STRESS CRITERIA

To establish the minimum seating stress for each flange size and pressure class, consider that all gaskets meet ASME B16.20 dimensions.

Current gasket research has shown that the ASME B16.20 design requirement of Paragraph 3.2.6 to assemble gaskets to a constant bolt stress is out of step with the ASME – PCC-1-2013 Guidelines for Pressure Boundary Bolted Flange Joint Assembly⁽¹⁰⁾ technology because, per Appendix O, PCC-1-2013 targets gasket stress instead of bolt stress.

To establish the minimum gasket seating stress considering the value of 30 ksi for the bolt stress, we have calculated the gasket stresses shown in Table 3. This value is calculated the Yield Strength of ASTM A193 B8 Class 1 Stainless Steel bolt, a weak material in the ASTM series.

The chosen gasket seating stresses are intentionally selected on the “low end” because, ideally, we want a gasket to hold a seal at a very low stress, to account for relaxation, flange stiffness, assembly inconsistencies, etc.

Analyzing Table 3, we can propose the following minimum seating stress for each pressure class:

TEST MEDIA AND PRESSURE

The API 622/624 standards specify Methane (CH_4) as test media and a pressure of 41.4 bar (600 psi) as the maximum test pressure for valves. This value can be used for all flange Classes 300 and higher. For Class 150, the maximum pressure at room temperature per ASME B16.5 is 19.6 bar (285 psi). For reference, EN 13555 specifies 40 bar for all sizes.

Our proposal is then:

- For Class 150: 20 bar (290 psi)
- For Class 300 and higher: 40 bar (580 psi)

Testing Flexible Graphite gaskets with CH_4 has to be done with proper care for safety reasons. In addition, if the gasket is not seated properly or the leak rate is too high, it takes a long time to “decontaminate” the gasket^(11,12,13,14). This may show as a high leak rate however, it is just the Flexible Graphite impregnated by the CH_4 . The EN 13555 protocol of increasing and reducing the gasket stress to evaluate the leak rate at each step may not be feasible with CH_4 due to the contamination issue. For this reason our proposal does not address the gasket characteristics determination for ASME Boiler and Pressure Vessel Code, Section VIII⁽¹⁵⁾ calculations.

GASKET SAMPLES

All gaskets samples used for the development of this test protocol included:

- Dimensions and other features like welding and wraps per ASME B16.20-2012
- Winding metal: Stainless Steel type AISI 304
- Filler: Flexible Graphite
- Outer Ring: Carbon Steel
- Inner Ring: Stainless Steel type AISI 304

TEST RIGS

Two test rigs were used in this research. An AMTEC Temes fl.ai1 Multifunctional Test Rig⁽¹⁶⁾ (Figure 3) equipped with an Oerlikon Phoenix L300i Mass Spectrometer⁽¹⁷⁾ for the Helium EN 13555 leak tests. And, a 50-ton Hydraulic Press with a Volatile Organic Compound Analyzer TVA 2020⁽¹³⁾ as shown in Figure 4 for the Methane leak tests.

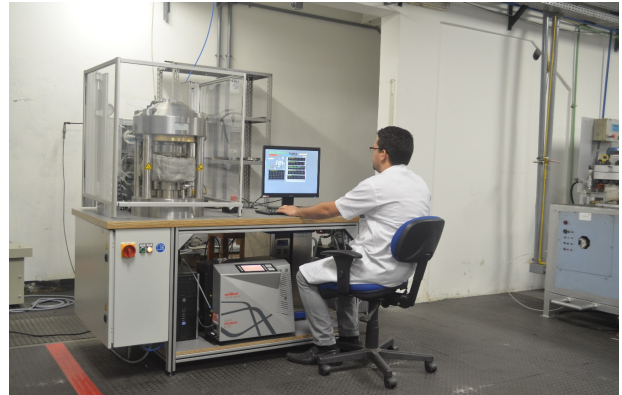


Figure 3 – AMTEC Temes fl.ai1.

TEST PROTOCOLS

The EN 13555 standard is well known and will not be described in this paper.

The Methane test protocol determined during preliminary evaluations that is necessary to seal the gasket as close as possible to the winding outside diameter. Otherwise the CH_4 will concentrate and reach the VOC inlet probe in bursts. Tests were also performed in standard ASME B16.5 flanges and the same effect was found; the concentration in ppmV was not stable, but oscillating, making it impossible to evaluate the actual gasket leak.

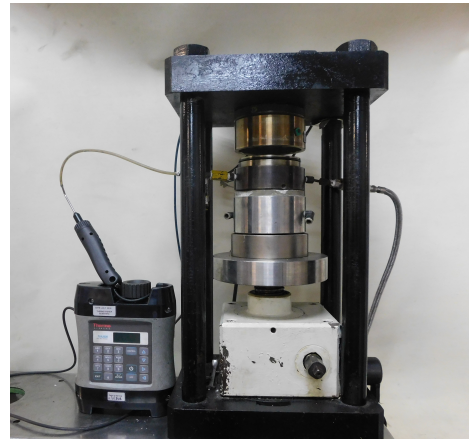


Figure 4 -50-ton Hydraulic Press with a Volatile Organic Compound Analyzer TVA 2020.

A simple fix was developed sealing the gap between platens with a 5mm thick rubber O-ring fitted around the Guide Ring OD. The O-ring has two locations of double “V cuts”, 180 degrees apart, one for the VOC probe and the other for the air inlet. The double “V cut” is one cut facing up, the other cut facing down. This way, any leak is directed to the probe of the measuring instrument. The Methane inlet is through a hole in the center of one of the platens. This set up is shown in Figures 5 through 7.

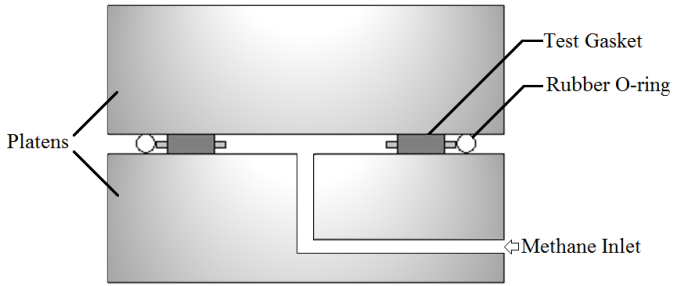


Figure 5 – Platens schematics.

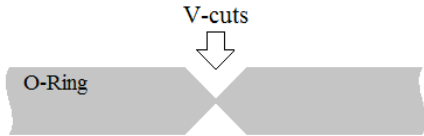


Figure 6 – Double “V cuts” O-ring.

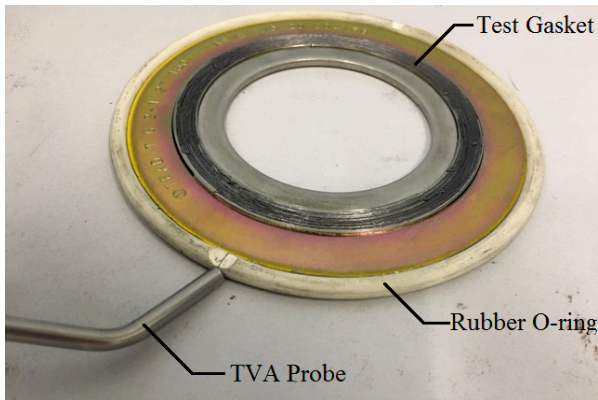


Figure 7- Test Schematics.

A summary of the Methane test procedure is as follows:

- 1 – Record the winding full thickness.
- 2 – Record the inner ring thickness.
- 3 – Record the guide ring thickness.
- 4 – Install the gasket sample (with O-ring) between the hydraulic press platens. Assure that the platens are clean from a previous test and the gasket is centered.
- 5 – Close platens according to the gasket seating stress of the first step in Table 6.
- 6 – Install the VOC TVA probe and turn it on.
- 7 – Pressurize the rig with Methane. Test pressure is 20 bar for Class 150, or 40 bar for Class 300 and above.
- 8 – Record the leak in ppm each 10 minutes until the ppmV reading stabilizes. Stabilization is considered after 3 consecutive equal values or the most recent value is lower than the previous one. The reported concentration value is the highest of the last three values.
- 9 – Record the gap between press platens for the current step.
- 10 - Release the Methane pressure.

11 – Change the force on press to the second step in Table 4 and repeat steps 7,8, 9 and 10.

11 – Change the force on press to the third step in Table 4 and repeat steps 7,8, 9 and 10.

12. – Finish test, remove the gasket and record the winding full thickness.

13 – Report the ppmV concentration and the gap between platens for each step, the winding initial and final thickness and the inner and guide ring thickness.

Table 6 - Gasket seating stress steps.

Media Pressure	Pressure Class	Step	Seating Stress (psi)
20 bar	150#	1	5000
		2	10000
		3	15000
40 bar	300# and 400#	1	8000
		2	15000
		3	25000
	600# and above	1	10000
		2	15000
		3	25000

TEST VALIDATION

To validate the proposed procedure, several tests were performed with both Helium and Methane. The Helium tests were performed following the EN 13555 protocol. Since this is a well-known and proven test procedure, a correlation with it would be desirable. Gaskets acquired in the market from several manufacturers were tested and results compared.

Figure 8 shows the EN 13555 gasket test results for 7 different manufacturers (legends A to G). All gaskets are NPS 4 in, Class 300 as specified in EN 13555. The leak is expressed in mg/(s.m) and the seating stress in psi.

Figure 9 shows gaskets of the same size and origin as Figure 7 tested with Methane (legends A to G), following our proposed protocol. The leak is expressed in ppmV and the seating stress in psi.

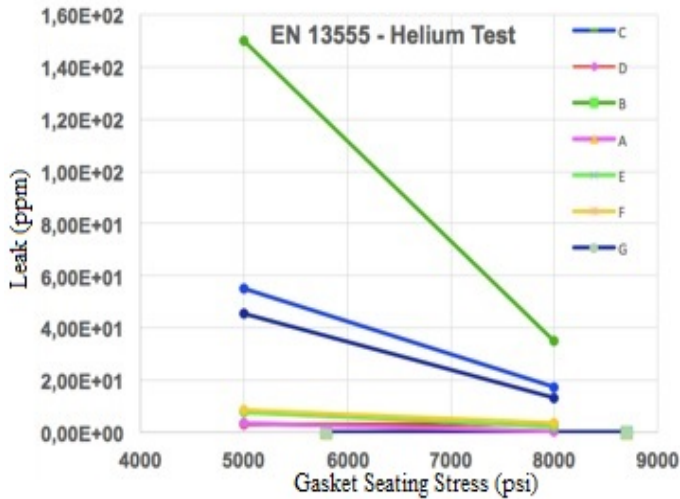


Figure 8 – EN 13555 tests results.

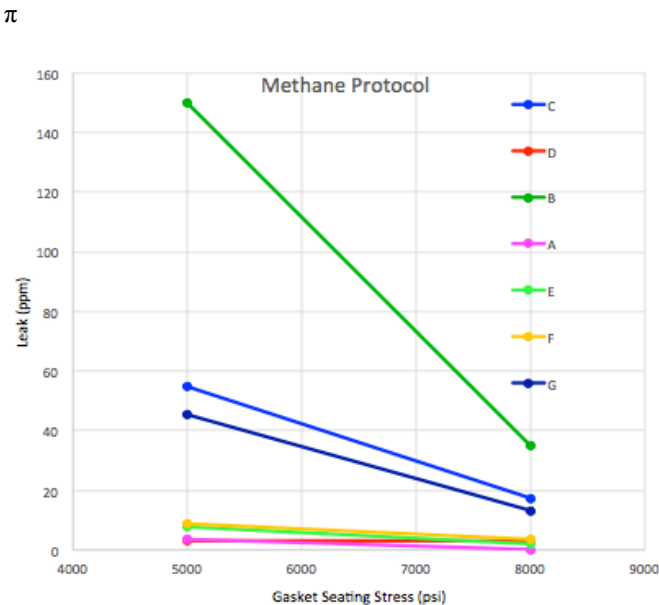


Figure 9 – Methane test results.

As can be seen in these graphical representations, that even though it is difficult to develop a numeric correlation, Helium and Methane tests have a similar behavior; gaskets that performed better with Helium did the same with Methane. These gaskets are all dimensionally per ASME B16.20, but their performances have shown a major variation. However, all reach the minimum API level of 588 ppm for the NPS 4 in Class 300 size as per Table 1.

For the same gaskets, in Annex B there is a leakage chart according to the EN 13555 protocol, and the corresponding gasket thickness. It can be observed that none of the gaskets tested reached the ASME B16.20 winding thickness specification, which for this gasket size is 77.4 Mpa. This supports removing the existing language in the paragraph.

However, a replacement criterion is needed to ensure that the gaskets do not compress to the guide ring at a low gasket stress. For this reason, we are proposing a test at a higher seating stress and measuring the winding thickness, along with the guide ring thickness.

Methane leak tests were also performed with NPS 1 1/2 in Class 150 gaskets acquired in the US market from different manufacturers. The results are shown in Figure 10. It can be observed that some gaskets reach the API level at seating stresses higher than 10000 psi, a value that is above the maximum for the NPS 1 1/2 in Class 150 flange with B8 Class 1 bolts (see Table 3).

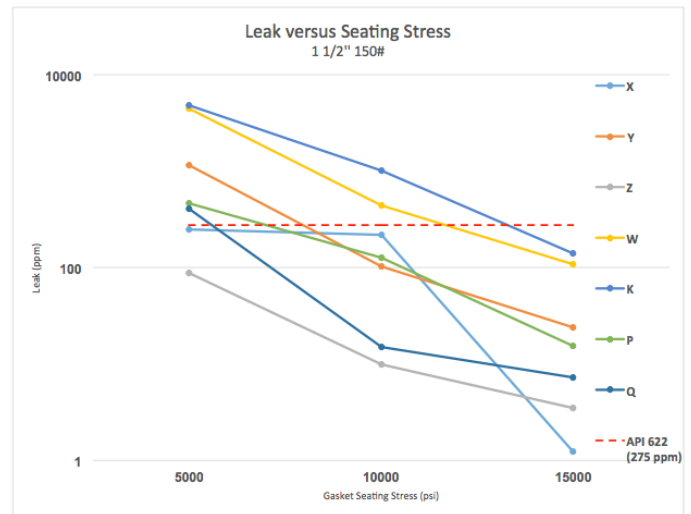


Figure 10 – Methane leak test results

Due to the limitation of the 50-ton test rig it was not possible to evaluate larger gasket sizes.

It was also not possible to perform crush tests to reach the maximum seating stress found in larger pressure class flanges. This test is to assure that the gasket is not sealing on the guide ring.

To further validate the Hydraulic Press feasibility, twelve NPS 3 in – Class 300 gaskets were produced; six of them with a set of manufacturing parameters; and another six with a different set. Of each set, 3 gaskets were installed in a NPS 3 in Class 300 ASME B16.5 flange, and 3 in the 50-ton Hydraulic Press. The objective was to show gasket manufacturing differences as well as to verify the correlation between the flat press platens and a standard flange. The NPS 3 in Class 300 was selected due to its low bolt load and large spacing between its four bolts. Results are shown in Figures 11 and 12, the “mfg 1” represents one set of manufacturing parameters and “mfg 2” represents the other set. It can be seen that there is a strong correlation between the results. And, as expected, the gaskets installed in 50-ton flat platens press showed better results due to the more uniform seating. It also validates that changing the manufacturing parameters will

affect the gasket leak performance. Manufacturers can use this test to improve their products and end users have a tool to specify/inspect spiral wound gaskets.

A typical performance evaluation is made on a spiral wound gasket with Stainless Steel wire and Flexible Graphite filler, but can be performed using any filler material or metallurgy for the wire.

Even though all gaskets tested met current ASME B16.20 dimensional requirements, leak performance varies between and also within different manufactures.

The current Paragraph 3.2.6 of ASME B16.20 does not assure an acceptable gasket performance.

SUGGESTIONS FOR FUTURE RESEARCH

Perform the same evaluation for larger gasket sizes to confirm the validity of the proposed procedure.

Since the research of this proposal considered only Stainless Steel windings with Flexible Graphite filler, other metallurgies such as Inconel and Monel, etc. should be evaluated. The same applies to other fillers such as PTFE and Mica.

ACKNOWLEDGMENTS

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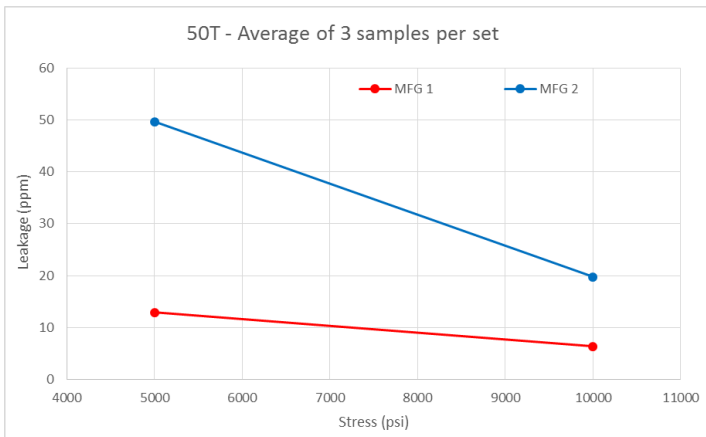


Figure 11 – Tests results of both sets at Flange BN3 in CL150.

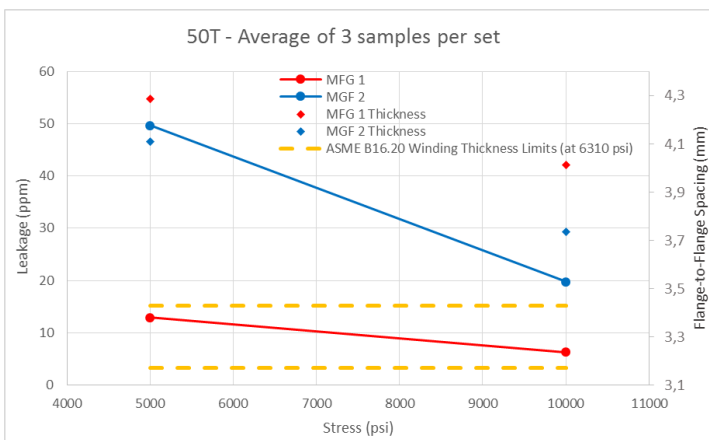


Figure 12 – Tests results of both sets at Hydraulic Press.

CONCLUSIONS

It is possible for a manufacturer or end-user of ASME B16.20 spiral wound gaskets to easily perform an evaluation of product, per above guidelines, across a wide array of NPS/Pressure Classes.

With dimensional verification and a performance evaluation, other known variables that are not specified by ASME B16.20 (such as filler thickness, wire profile, etc.) are rendered irrelevant.

With the proposed procedure is possible to estimate a site product loss due to gasket leaks.

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ANNEX A

METHANE VOC TVA 2020 PPM READING CONVERSION TO MASS LEAK RATE

The API 622 standard determines the use of Methane as media to tests involving low leak packings for valves. It also establishes that a Volatile Organic Compound Analyzer shall be used to read the gas leakage, a typical VOC Analyzer is the TVA 2020 ⁽⁸⁾ that presents the result in parts per million reading (ppm). This ppm reading is a concentration of the Organic Compound dissolved in the surrounding air. Since we want a leak rate, it is necessary to convert this value to a leak per unit of time.

In air literature ppm applied to a gas generally means parts per million by volume. In metric units is 1 liter of the gas per one thousand cubic meters of the air.

$$ppm [=] \frac{1 \text{ l}}{1000 \text{ m}^3} \quad (1)$$

To convert a ppm unit to a leak rate unit it is necessary the corresponding gas density and the equipment flow rate. At 1bar and considering 1 mole of the gas, the density is calculated by the following expression:

$$\text{density} = \frac{MW}{R \times T} [=] \frac{g}{l} \quad (2)$$

In this case:

$$\text{CH}_4 \text{ density} = \frac{16.04}{0.083145 \times T(K)} = \frac{192.92}{T(K)} \text{ g/l} \quad (3)$$

The TVA 2020 has a flow rate of one liter per minute. Considering this flow rate and the unit conversion, the expression of the leak rate is then:

$$\frac{\text{ppm reading} \times \text{density} \times \text{flow rate}}{1000 \times 60 \times T(K)} [=] \frac{mg}{s} \quad (4)$$

$$\frac{\text{ppm reading} \times 192.92 \times 1.0}{1000 \times 60 \times T(K)} = \frac{mg}{s} \quad (5)$$

Simplifying this equation:

$$L_{Rm} = \frac{0.00322 \times \text{ppm reading} \text{ mg}}{T(K) \text{ s}} \quad (6)$$

Considering laboratory conditions, 21⁰C (69,8⁰F or 294K):

$$L_{Rm} = 1.095E - 5 \times \text{ppm reading} \frac{mg}{s} \quad (7)$$

The API 622 specifies a maximum of 100 ppm for a stem diameter of 1 inch. We can then calculate the leak rate per the perimeter of the stem:

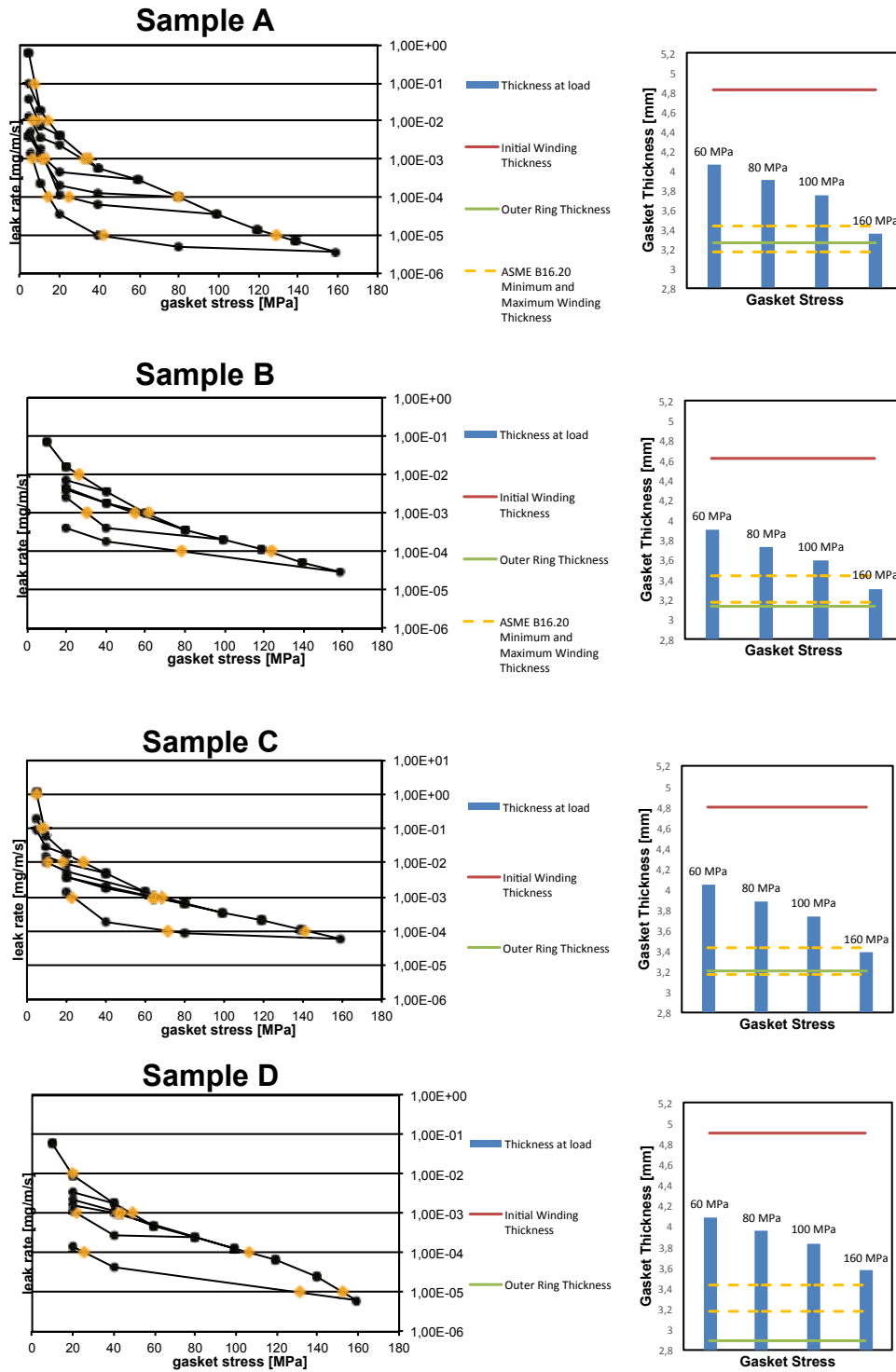
$$L_{Rm} = \frac{1.095E-5 \times 100 \text{ mg}}{\pi \times 0.0254 \text{ s.m}} \quad (8)$$

$$L_{Rm} = 0.0137 \frac{mg}{s.m} \quad \underline{\text{or}} \quad L_{Rm} = 7.67E - 10 \frac{lb}{s.in}$$

The maximum gasket leak rate following the API622 100 ppm criteria can be obtained multiplying the L_{Rm} above by the gasket outside winding diameter.

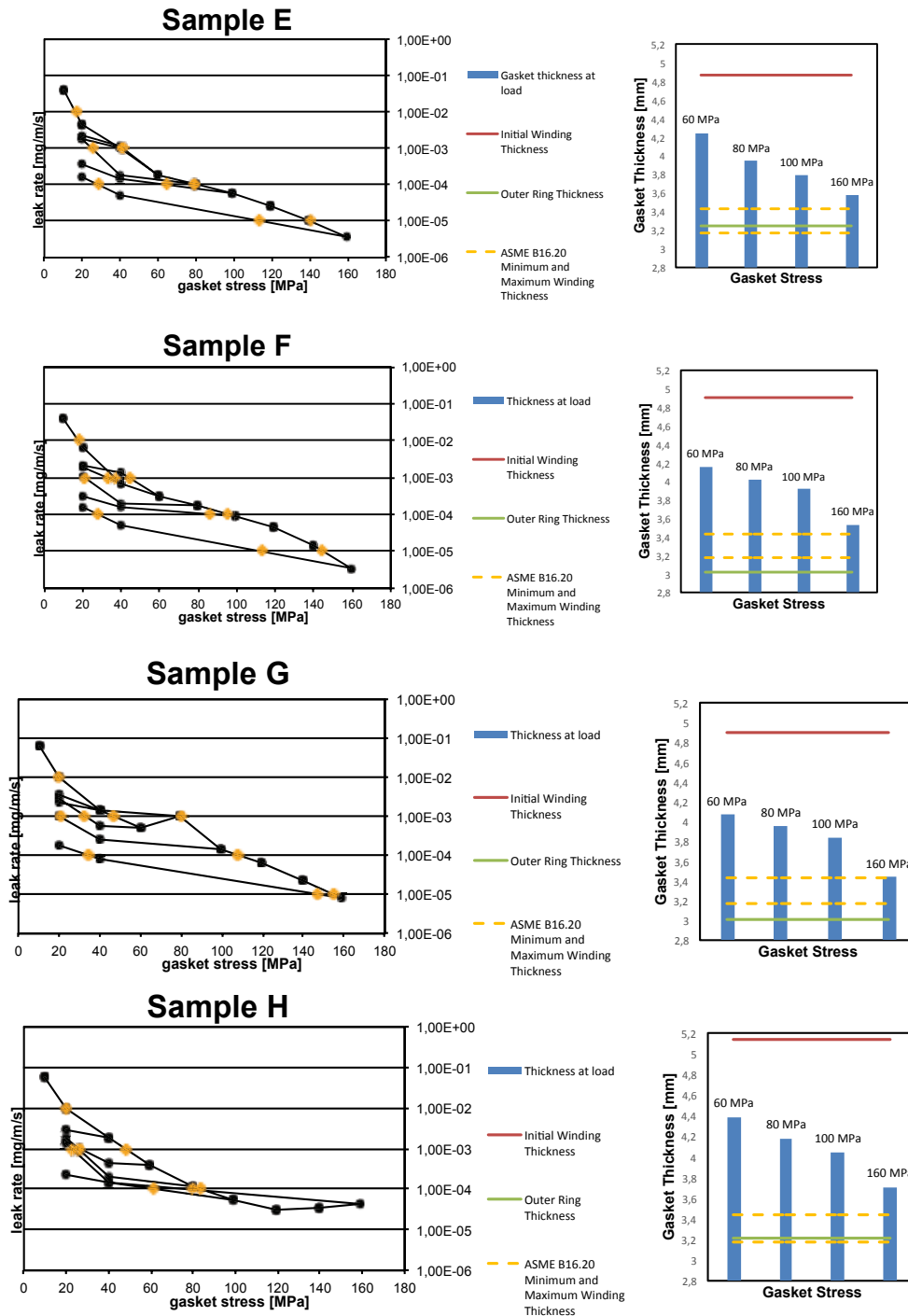
ANNEX B

EN 1355 HELIUM LEAK AND GASKET THICKNESS CHARTS



ANNEX B

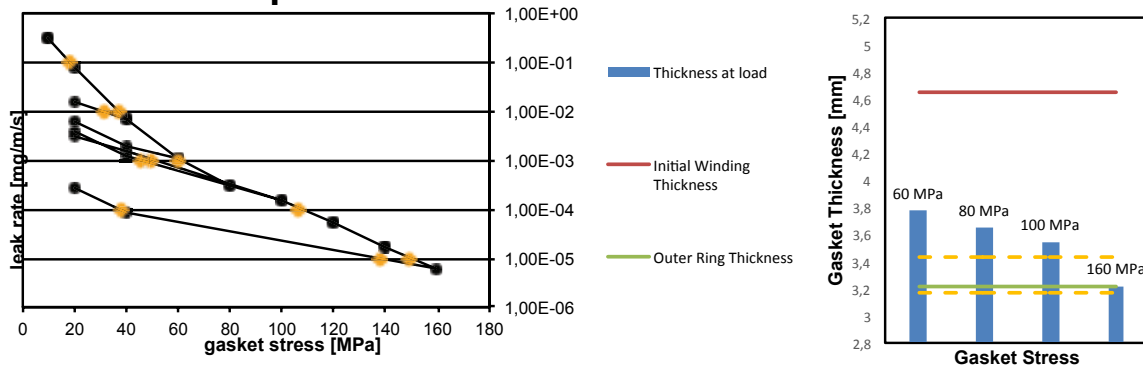
EN 13555 HELIUM LEAK AND GASKET THICKNESS CHARTS



ANNEX B

EN 13555 HELIUM LEAK AND GASKET THICKNESS CHARTS

Sample I



Sample J

