**Proceedings of the ASME 2017 Pressure Vessels and Piping Conference**
**PVP2017**
**July 16-20, 2017, Waikoloa, Hawaii, USA**

# PVP2017-65371

## ASME B16.20 SPIRAL WOUND GASKETS PERFORMANCE TESTING

**Scott Hamilton**
Hex Technology
Houston, TX, USA

**Joel Baulch**
Teadit North America
Houston, TX, USA

**José Veiga**
Teadit Ltda
Rio de Janeiro, RJ, Brasil

## 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.

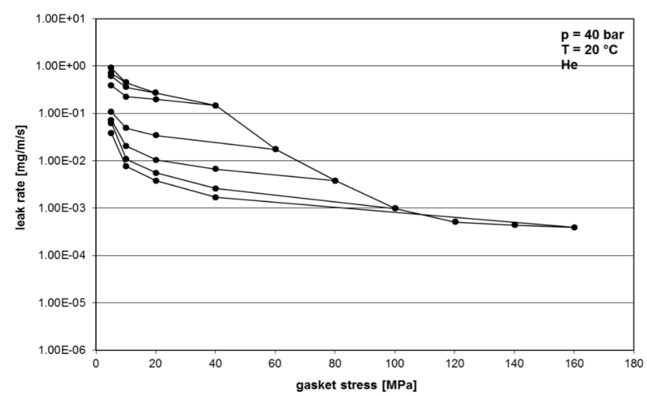



**Figure 1- Sealability chart of a gasket.**

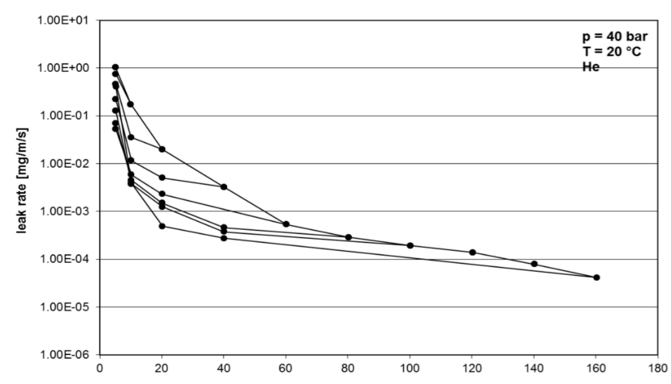



**Figure 2- Sealability chart of a gasket (different manufacturing location).**

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


Copyright © 2017 ASME

Downloaded From: http://proceedings.asmedigitalcollection.asme.org/ on 11/05/2017 Terms of Use: http://www.asme.org/about-asme/terms-of-use

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 = 1liter pe rminute
l: liter
mg: milligram
s: second
m: meter
in: inch
R: universal gas constant in l.bar/K.mol

## LEAKAGE CRITERIA

The API 624 standard has established the definition for Low Leak valves as 100 ppm, using Methane ($CH_4$) as media and a Volatile Organic Compound Analyzer such us 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):

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

or

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

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 | |

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


Copyright © 2017 ASME

Downloaded From: http://proceedings.asmedigitalcollection.asme.org/ on 11/05/2017 Terms of Use: http://www.asme.org/about-asme/terms-of-use

**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 | |

## 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:

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.


Copyright © 2017 ASME

Downloaded From: http://proceedings.asmedigitalcollection.asme.org/ on 11/05/2017 Terms of Use: http://www.asme.org/about-asme/terms-of-use

## 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.

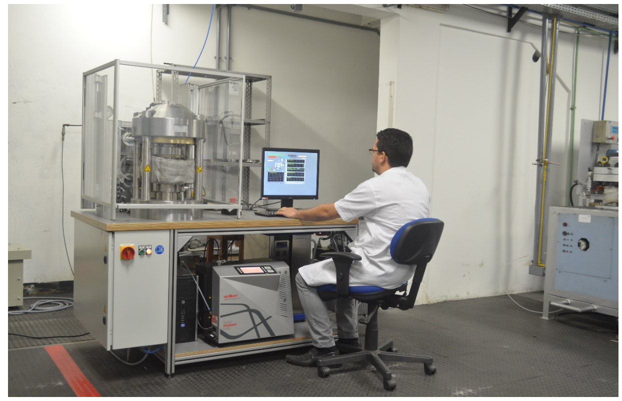


**Figure 3 – AMTEC Temes fl.ai1.**

## 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.

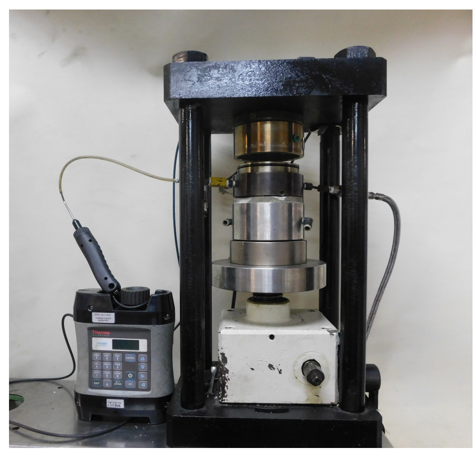


**Figure 4 -50-ton Hydraulic Press with a Volatile Organic Compound Analyzer TVA 2020.**

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.


Copyright © 2017 ASME

Downloaded From: http://proceedings.asmedigitalcollection.asme.org/ on 11/05/2017 Terms of Use: http://www.asme.org/about-asme/terms-of-use

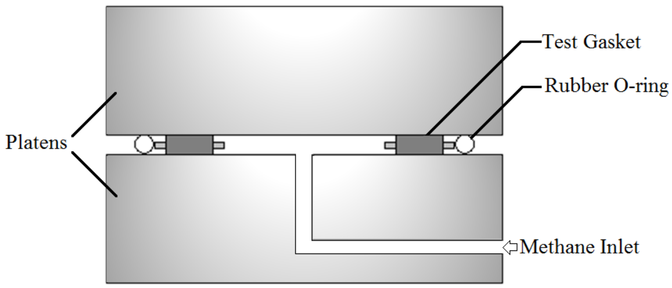



**Figure 5 – Platens schematics.**

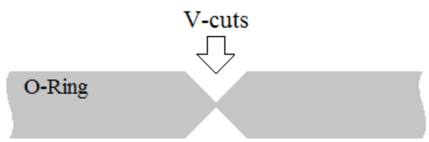



**Figure 6 – Double "V cuts" O-ring.**

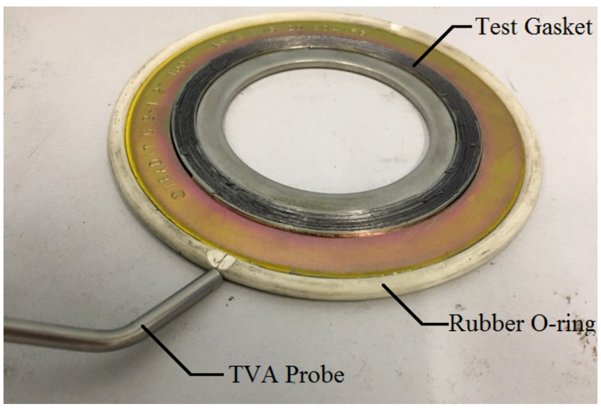



**Figure 7- Test Schematics.**

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 patens 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.


Copyright © 2017 ASME

Downloaded From: http://proceedings.asmedigitalcollection.asme.org/ on 11/05/2017 Terms of Use: http://www.asme.org/about-asme/terms-of-use

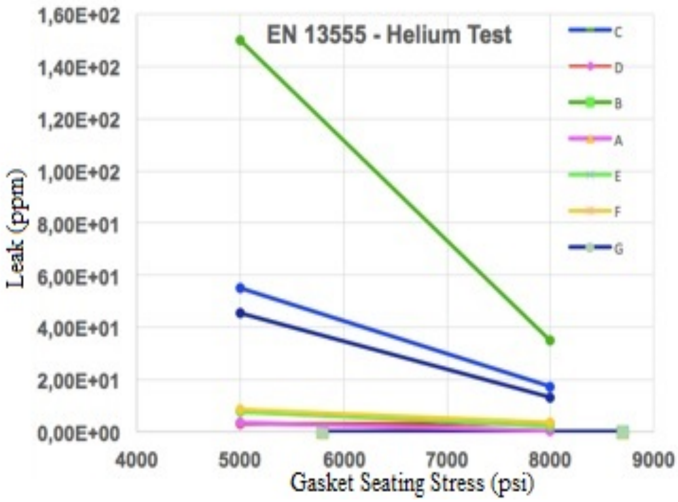



**Figure 8 – EN 13555 tests results.**

π

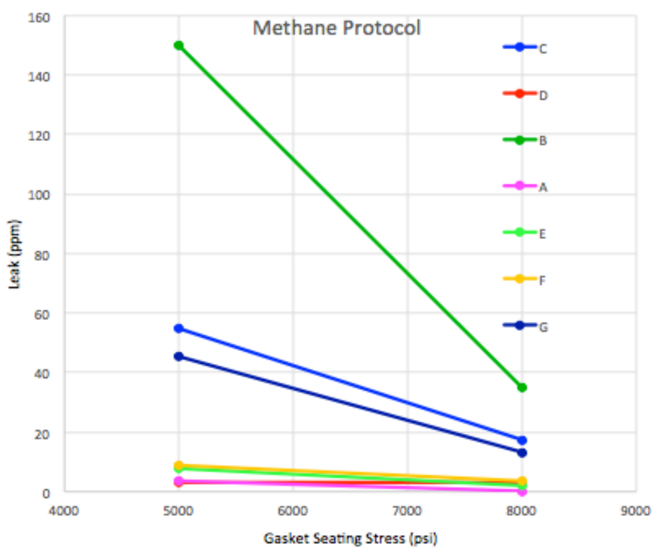



**Figure 9 – Methane test results.**

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 ½ 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 ½ in Class 150 flange with B8 Class 1 bolts (see Table 3).

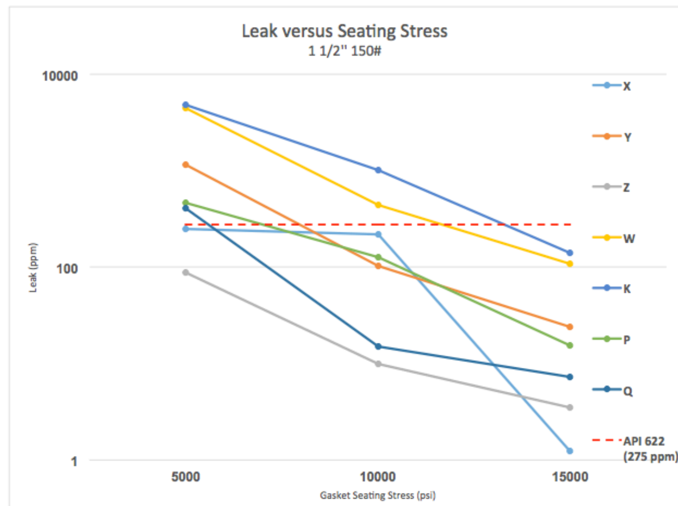



**Figure 10 – Methane leak test results**

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


Copyright © 2017 ASME

Downloaded From: http://proceedings.asmedigitalcollection.asme.org/ on 11/05/2017 Terms of Use: http://www.asme.org/about-asme/terms-of-use

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.

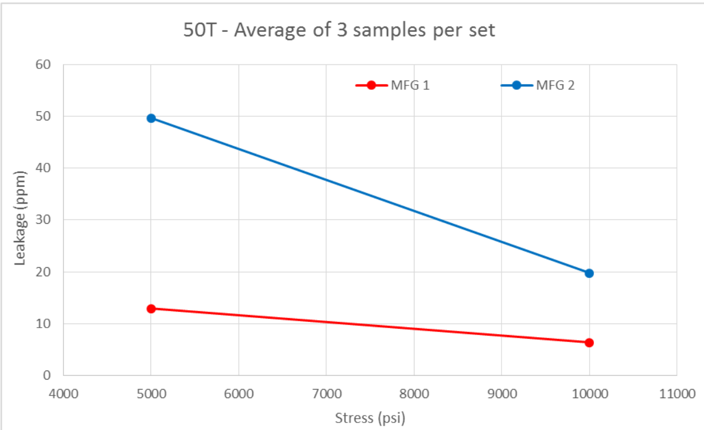



**Figure 11 – Tests results of both sets at Flange BN3 in CL150.**

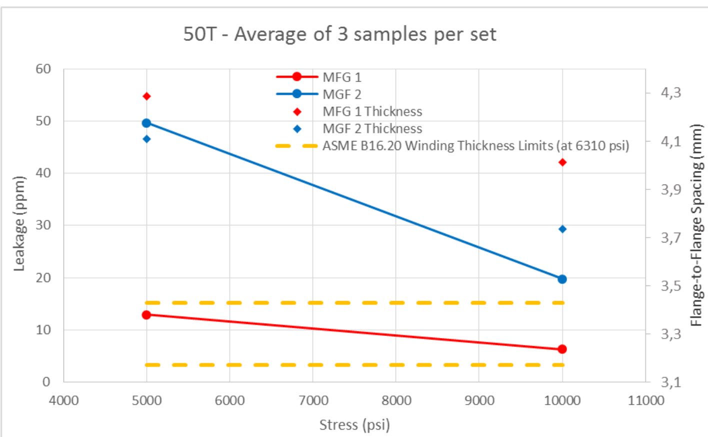



**Figure 12 – Tests results of both sets at Hydraulic Press.**

## 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.

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 filers such as PTFE and Mica.

## ACKNOWLEDGMENTS


The authors would like to acknowledge assistance from Benjamin Hantz, Technology Advisor, Mechanical Reliability, Valero Energy Corp for his advice with an end-user perspective. Also, Luiz Paulo Romano, P.E., Teadit R&D Manager for coordinating the testing and collecting results. Isabel Gomes Moura, undergraduate student, Rio de Janeiro Federal University for the Annex A calculations. Diego Santos Duarte, undergraduate student at Rio de Janeiro Federal University for the charts and the Annex B.



Copyright © 2017 ASME

Downloaded From: http://proceedings.asmedigitalcollection.asme.org/ on 11/05/2017 Terms of Use: http://www.asme.org/about-asme/terms-of-use

## REFERENCES

1. ASME B16.20 2012- Metallic Gaskets for Pipe Flanges: Ring-Joint, Spiral-Wound, and Jacketed, The American Society of Mechanical Engineers, 2 Park Avenue, New York, NY, USA.

2. API 622 - Type Testing of Process Valve Packing for Fugitive Emissions, Second Edition, American Petroleum Institute, Washington, DC, USA.

3. API 624 - Type Testing of Rising Stem Valves Equipped with Graphite Packing for Fugitive Emissions, First Edition, American Petroleum Institute, Washington, DC, USA.

4. PVP2016-63366 Quality Assurance Guide to B16.20, 2016 ASME Pressure Vessel and Piping Conference, Vancouver, Canada.

5. PVP2011-57556 The Influence of Winding Density in the Sealing Behavior of Spiral Wound Gaskets, 2011 ASME Pressure Vessel and Piping Conference, Baltimore, USA.

6. EN 13555 – Gasket Parameters and test Procedures Relevant to the Design Rules for Circular Flange Connections.

7. PVP2009-77882 Gas Leakage Correlation, 2009 ASME Pressure Vessel and Piping Conference, Prague, Czech Republic.

8. TVA2020 Toxic Vapor Analyzer, Thermo Fisher Scientific Inc, www.thermofisher.com/order/catalog/product/TVA2020.

9. Environmental Protection Agency (EPA) Method 21 www3.epa.gov/ttnemc01/promgate/m-21.pdf).

10. ASME – PCC-1-2013 Guidelines for Pressure Boundary Bolted Flange Joint Assembly, The American Society of Mechanical Engineers, 2 Park Avenue, New York, NY, USA.

11. Mao, Z., Sinnott, S., "Separation of Organic Molecular in Carbon Nanotubes & Bundles : Molecular Dynamics Simulation", Phys. Chem. B 105, (2001) 6916 – 6924.

12. Frutuoso, L., Caracterização de Carbono Ativado por Adsorção e Simulação Molecular usando Metano como gás-sonda – Universidade Federal do Ceará, 2010.

13. Jagiello, J. et al. Absorption near Ambient Temperatures of Methane, Carbon Tetrafluoride, and Sulfur Hexafluoride on Commercial Activated Carbons. Journal of Chemical & Engineering Data, v. 40, n. 6, p. 1288-1292, 1995.

14. Policicchio, A. et al. Higher methane storage at low pressure and room temperature in new easily scalable large-scale production activated carbon for static and vehicular applications. Fuel, v. 104, p. 813-821, 2013.

15. ASME Boiler and Pressure Vessel Code, The American Society of Mechanical Engineers, 2 Park Avenue, New York, NY, USA

16. Temes fl.a1 Multifunctional Test Rig, AMTEC Messtechnischer Service GmbH, Lauffen am Neckar, Germany, https://www.amtec.eu/gasket-test-rig-all-in-one.html

17. Phoenix L300i, Leybold GmbH, Cologne, Germany https://www.leyboldproducts.us/products/leak-detecting-instruments/leak-detectors/750/phoenix-l300i?c=1456

 Copyright © 2017 ASME

Downloaded From: http://proceedings.asmedigitalcollection.asme.org/ on 11/05/2017 Terms of Use: http://www.asme.org/about-asme/terms-of-use

## 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.

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

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:

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

In this case:

$$\text{CH4 density} = \frac{16.04}{0.083145\ x\ T(K)} = \frac{192.92}{T\ (K)}\ g/l \quad (3)$$

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:

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

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

Simplifying this equation:

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

Considering laboratory conditions, 21$^0$C (69,8$^0$F or 294K):

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

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:

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


Copyright © 2017 ASME

Downloaded From: http://proceedings.asmedigitalcollection.asme.org/ on 11/05/2017 Terms of Use: http://www.asme.org/about-asme/terms-of-use

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

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.

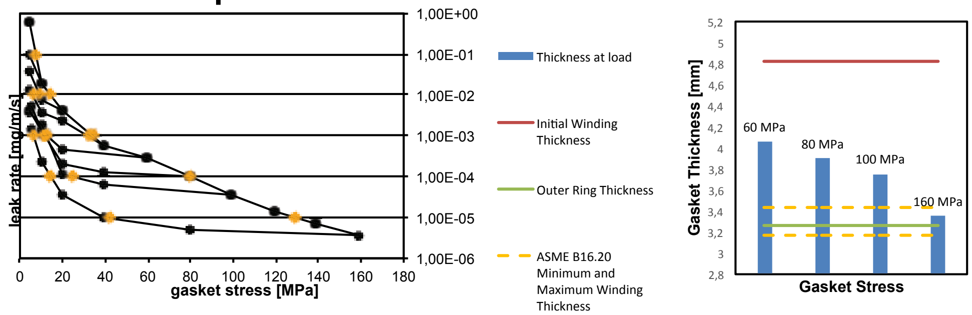

Copyright © 2017 ASME

Downloaded From: http://proceedings.asmedigitalcollection.asme.org/ on 11/05/2017 Terms of Use: http://www.asme.org/about-asme/terms-of-use

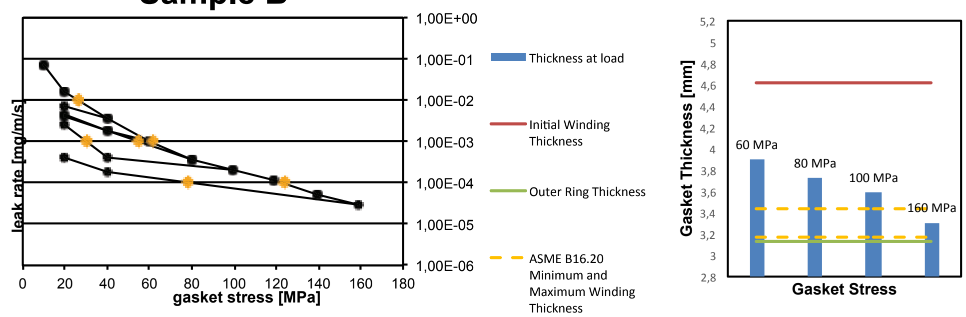
## ANNEX B

## EN 13555 HELIUM LEAK AND GASKET THICKNESS CHARTS

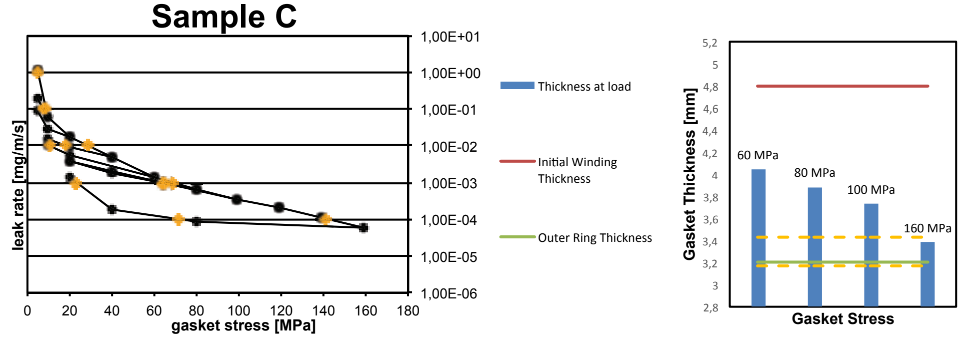
### Sample A



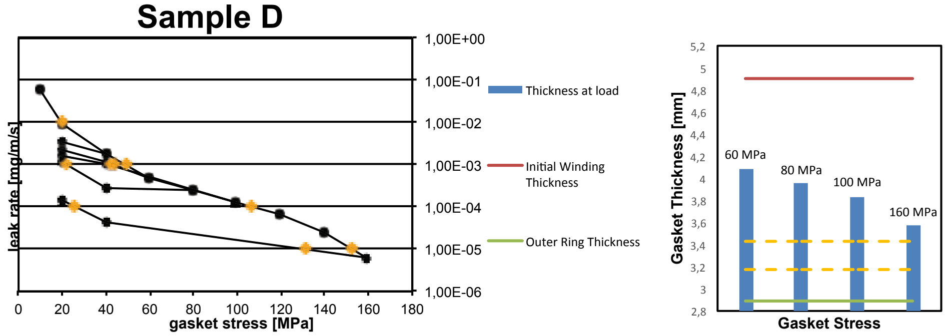

### Sample B




### Sample C




### Sample D



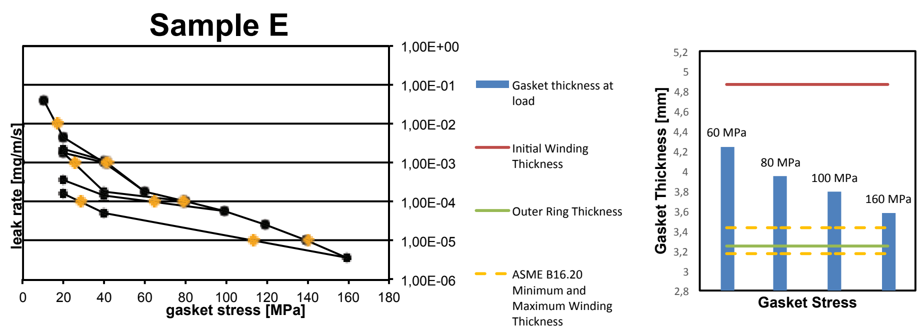


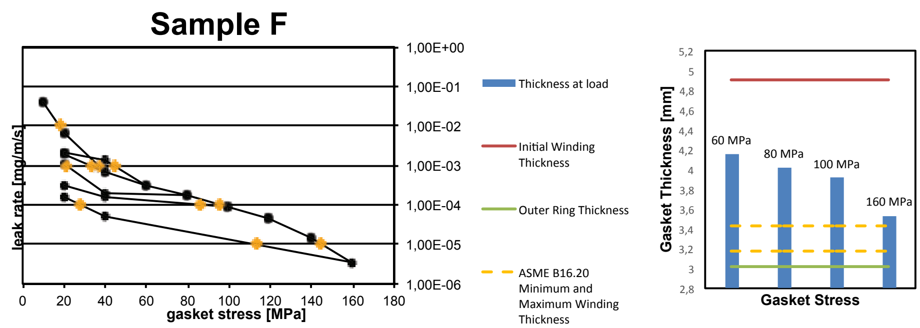
Copyright © 2017 ASME

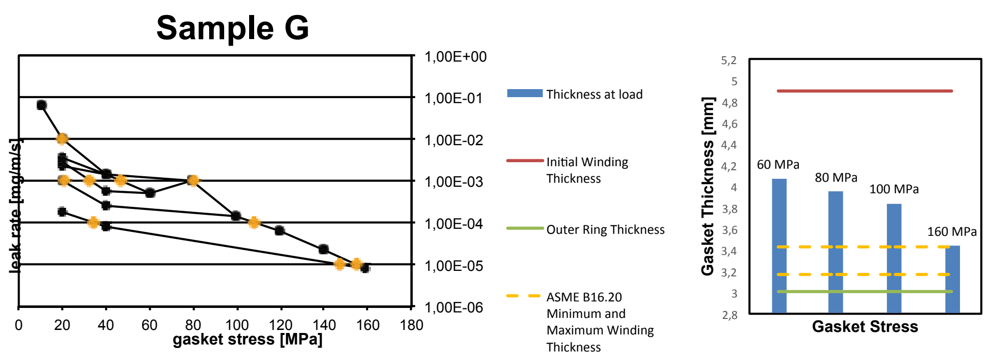
Downloaded From: http://proceedings.asmedigitalcollection.asme.org/ on 11/05/2017 Terms of Use: http://www.asme.org/about-asme/terms-of-use

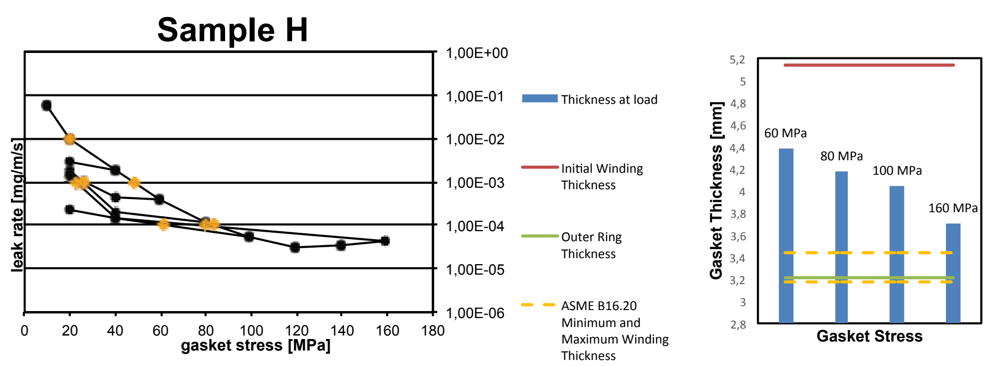
# ANNEX B

## EN 13555 HELIUM LEAK AND GASKET THICKNESS CHARTS



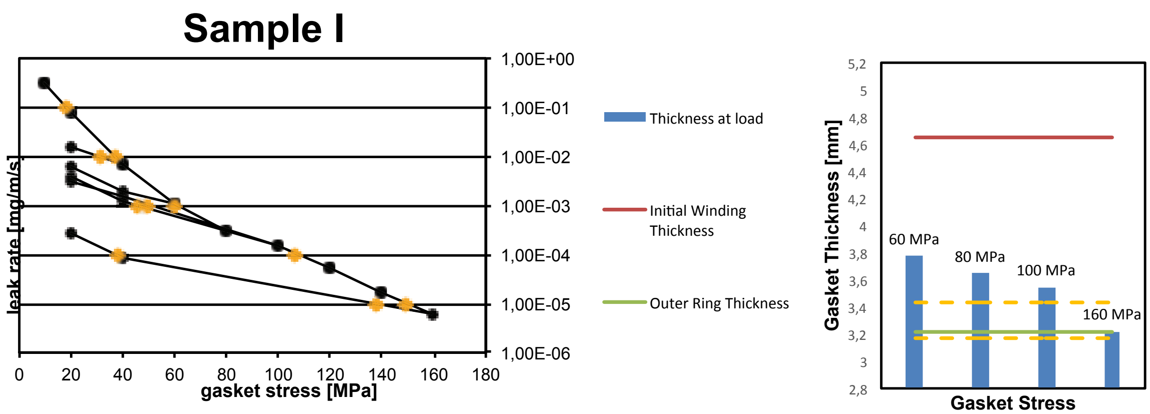

\

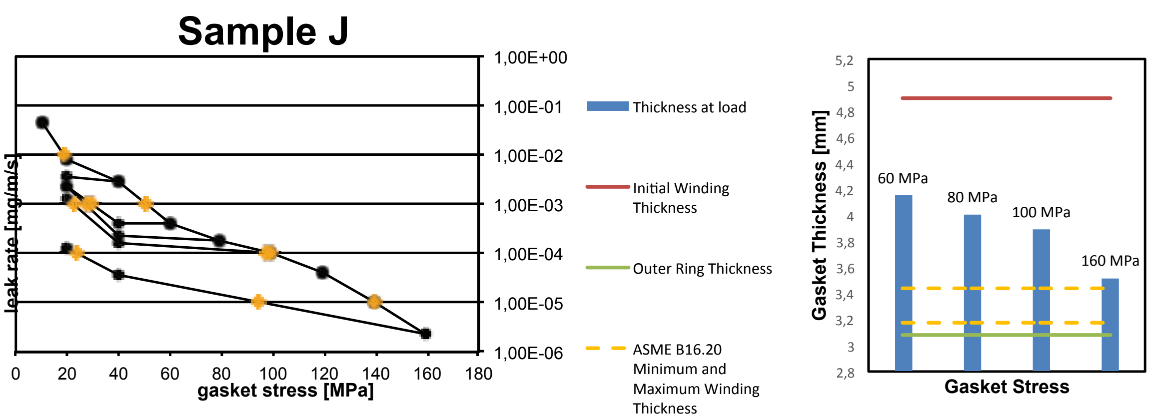

Copyright © 2017 ASME

Downloaded From: http://proceedings.asmedigitalcollection.asme.org/ on 11/05/2017 Terms of Use: http://www.asme.org/about-asme/terms-of-use

# ANNEX B

## EN 13555 HELIUM LEAK AND GASKET THICKNESS CHARTS





Copyright © 2017 ASME

Downloaded From: http://proceedings.asmedigitalcollection.asme.org/ on 11/05/2017 Terms of Use: http://www.asme.org/about-asme/terms-of-use