Check of PVP2017-65371
"ASME B16.20 - Spiral Wound Gaskets Performance Testing
Hamilton, Baulch, Veiga
App A - methane VOC TVA2020 PPM Reading Conversion To Mass Leak Rate

Assumptions/~~Bas~~ Inputs.

P - Pressure - atmos = 1 bar absolute
T - ambient 21°C = 294°K
n - number of moles of test gas = $\frac{m (g)}{M (g/mole)}$ (moles)
m - mass of test gas - (g)
M - molecular weight of test gas (g·mole)
  CH_4 - 16.04 g/mole
  He - 4.0026 g/mole
V - volume of test gas (ℓ)
R - Gas constant = 0.08314 $\frac{\ell\text{-bar}}{°K \frac{g}{g\,mole}}$

ρ - density (g/ℓ) of gas - calculated from perfect gas law
$[\rho = \frac{m}{V}]$

SOD - stem diam - API 622 = 1" = 0.0254 m

GOD - Gasket OD = OD of SWG winding
  For 3" Class 300 SWG = 120.7 mm = 0.1207 m

LR_{mass} - leak rate in mass flow per length of circumference. $\left(\frac{mg}{s\cdot m}\right)$

Q - Flow rate of sampling instrument

$PPMV_{read}$ - parts per million as read from sampling instrument = Reading / 10^6
  $PPMV_{read}$ = 100 ppm for API 622

$$LR_{mass} = \frac{\left(\frac{PPMV_{read}}{10^6}\right)(\rho)(Q)}{SOD(\pi)}$$

← Mass leak rate per unit of stem circumference (or gasket)

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Plug in numbers for methane, with 1" stem at 21°C and 100 ppmv leak level and compare to Hamilton et al.

1) $$\dot{L}_{R\,mass} = \frac{\frac{ppmv_{read}}{10^6} \times \rho \times Q}{S_{OD} \times \pi}$$

a) $\rho = \frac{m}{V}$

b) $PV = nRT = \frac{m}{M} RT$

$$P = \frac{m}{V}\frac{RT}{M} = \rho \frac{RT}{M}$$

$$\rho = \frac{PM}{RT}$$

1) $$\dot{L}_{R\,mass\ CH_4/100ppm} = \frac{100(10^{-6}) \times \left(\frac{1\,bar\,(16.04\,g/mole)}{0.0834\,\frac{l\text{-}bar}{°K\,gmol}(294°K)}\right) \times \left(1\frac{l}{min} \times \frac{min}{60\,s}\right) \times \left(1000\frac{mg}{g}\right)}{0.0254\,m \times \pi}$$

ppmv read; ρ (density CH_4 at 1 bar abs. 21°C); Q = flow rate of instrument

$$= \frac{100(10^{-6})\left(0.6562\frac{g}{l}\right) \times \frac{1}{60}\frac{l}{s} \times 1000\frac{mg}{g}}{0.0254 \times \pi\ m}$$

Maximum API 624 Std CH4

1) maximum $\dot{L}_{R\,mass\ CH_4@100ppmv} = 1.371(10^{-2})\frac{mg}{s\cdot m} = 0.01371\frac{mg}{s\cdot m}$ ✓

Hamilton et al page $\dot{L}_{Rm} = 0.0137\frac{mg}{s\cdot m}$ ✓

J.P. 11 Sept 2018

Using value for ~~CH4 / 100~~ CH_4 and 100 ppmv
Calculate the max. if gas is He.

*using molar mass is the same as the ratio of each gas's density.

Maximum API 622 std He

$$L_{R\,mass\ He/100ppm} = L_{r\,mass\ CH_4/100ppm} \left(\frac{4.0026\ g\,mole\ (He)}{16.04\ g\,mole\ (CH_4)}\right)^{*}$$

$$= 0.0137\ \frac{mg}{s \cdot m}\left(\frac{4.0026}{16.04}\right) = 3.42(10^{-3})\ \frac{mg}{s \cdot m}$$

TA Luft Standard is $1(10^{-2})\ \frac{mbar \cdot l}{s \cdot m}$ for PN40, DN40 flanges with Helium.
Convert to mass leak rate.

$$L_{R\,mass\ TA\,Luft\text{-}He} = 10^{-2}\ \frac{mbar \cdot l}{s \cdot m}^{⊛} \times \rho_{He}$$

$$\rho_{He} = \frac{1\ bar\ (4.0026\ g\,mol)}{0.0834\ \frac{l \cdot bar}{°K\ \frac{g}{g\,mole}} \times 294°K}$$

$$\rho_{He} = 0.1637\ \frac{g}{l}$$

$$⊛\ \frac{mbar \cdot l}{s \cdot m} = 1\ \frac{cc}{s \cdot m}$$

$$= 10^{-2}\ \frac{cc}{s \cdot m} \times \frac{l}{1000\ cc} \times 0.1637\ \frac{g}{l} \times \frac{1000\ mg}{g}$$

Maximums TA Luft Helium

$$L_{R\,mass\ TA\,Luft\ Helium} = 1.637(10^{-3})\ \frac{mg}{s \cdot m}$$

TA Luft Methane

$$L_{R\,max\ CH_4} = \left(\frac{16.04\ g\,mole}{4.0026\ g\,mole}\right) 1.637\ (10^{-3})\ \frac{mg}{s \cdot m}$$

$$= 6.56(10^{-3})\ \frac{mg}{s \cdot m}$$

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Calculation of ppmv for FSA 3" Class 300 SWG Gasket

$$\rho_{CH4} = 0.6562 \frac{g}{l}\left(\frac{1000\, mg}{g}\right) = 656.2 \frac{mg}{l}$$

$$\rho_{He} = 0.1637 \frac{g}{l}\left(\frac{1000\, mg}{g}\right) = 163.7 \frac{mg}{l}$$

$$ppmV = \frac{LR_{mass} \times 10^6 \times G_{OD} \times \pi}{\rho_{gas} \times Q}$$

$$Q = 1 \frac{l}{min} \times \left(\frac{min}{60\, s}\right) = 0.0167 \frac{l}{s}$$

$$ppmv_{CH4} = \frac{LRate_{mass}\,(10^6)\,(0.1207)\,\pi\,(m)}{656.2 \left(\frac{mg}{l}\right) \times 0.0167 \left(\frac{l}{s}\right)} = LR_{mass\ CH4} \times 3.46(10^4) \frac{s \cdot m}{mg}$$

$$ppmv_{He} = \frac{LR_{mass}\,(10^6)\,(0.1207)\,\pi\,(m)}{163.7 \frac{mg}{l} \times 0.0167 \frac{l}{s}} = LR_{mass\ He} \times 1.39(10^5) \frac{s \cdot m}{mg}$$

Allowed Maximum Leaks for API 622 and TA-Luft Standards for Methane and Helium, Class 300, 3" SWG Flange Gasket at atm pressure, 21°C, Instrument Flow = 1 l/min.

~~API 622~~	CH4 - METHANE ppmv	mg/s	He - HELIUM ppmv	mg/s
API 622 / B16.20-2017 max leak	475	$5.19(10^{-3})$	475	$1.30(10^{-3})$
TA-Luft Max leak	227	$2.49(10^{-3})$	227	$6.21(10^{-4})$
FSA max leak	100	$1.09(10^{-3})$	100	$2.74\ 10^{-4}$
"	50	$5.46(10^{-4})$	50	$1.37(10^{-4})$
"	25	$2.73(10^{-4})$	25	$6.84(10^{-5})$

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