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Leak rate investigation of expanded polytetrafluoroethylene flat gasket

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Abstract. This article examines expanded polytetrafluoroethylene (PTFE) flat gaskets used in the industry to seal flange connections that prevent mixing of working fluids and leakage of fluids into the environment. Expanded PTFE gaskets and existing solutions to improve tightness are reviewed. Using test equipment for measuring the mass of gas passed through the gasket per unit time, which is one of the main operating characteristics of the gasket, a comparison of the required contact stress applied to the gasket during installation to achieve the same leakage rates was made. An annular expanded PTFE gasket with locally increased density is presented. Comparative tests were conducted to determine the mass of helium gas passed through the gaskets when changing the density in the sealed area to the inner diameter of the gasket. The results of the tests carried out show an improvement in the sealing ability and indicate a reduction in the mass of passed gas with the application of a lower contact stress on the seal while increasing the density in the area of the inner diameter.

1 Introduction

Due to its good chemical resistance and a wide operating temperature range, expanded polytetrafluoroethylene (ePTFE) is used as a sealing material in the form of tape, packing or flat gasket in the chemical, energy, refinery, petroleum, food, pharmaceutical, cosmetic and other industries. The microstructure of interconnected nodes and fibrils leads to reduced density and increased compressibility [1, 2]. As a result ePTFE gaskets are able to compensate for uneven/misaligned flanges, imperfections and damages of the sealing surfaces that occur during equipment operation. ePTFE gaskets are applicable for installations with both solid and thin steel flanges, as well as fragile flanges [3] such as plastic and glass, but require increased care during installation and application of a lower contact stress on the gasket according to the type of flange. Achieving compaction with reduced gasket stress and achieving a high tightness class expands the gaskets' application in industries where there are introduced requirements for permissible levels of leakage into the atmosphere. Tightness tests are conducted at room temperature, but it is also possible to conduct tests at elevated temperatures [4]. Gasket characteristics are standardized but differ in America and Europe [5]. There exist ePTFE gaskets with a diffusion barrier [6], with

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alternating layers of low and high density [7], with a locally increased density that leads to a reduction in the mass of gas passed through the gasket without it being clear what the effect of the increased density is on the leakage rate of the gasket. When examining the leakage rate of an ePTFE gasket with a locally increased density, which changes radially from the inner to the outer diameter of the gasket, a decrease in the mass of gas passed through the gasket was found when the increased density was in the area next to the inner diameter [8].

The purpose of the present study is to investigate the effect caused by increased density in the inner diameter region on the leakage rate of the ePTFE gasket.

2 Methodology of the experiment

For the purposes of the experiment were used ePTFE flat gaskets with different densities in the area of the inner diameter, occupying 25% of the gasket width with a configuration shown in Fig.1, equal to 20% of the area subjected to pressure

Fig. 1. Photo and diagram of the gasket before testing

The seven types of flat gaskets tested were cut from ePTFE sheet AVKOSEAL eC [9] with a thickness of 3±0.2 mm, density 0.8±0.02 g/cm^3, with an outer diameter of 92±0.5mm and an inner diameter of 49±0.5 mm corresponding to DN40 and PN10-40 according to BDS EN 1514-1 standard. With each subsequent seal, the density in the inner diameter area was increased by 0.13±0.005 g/cm3 in the range of 0.8 to 1.6 g/cm3 using additional layers of the same material.

To measure the leakage rate, test equipment "TEMES fl.ai1" fig.2 was used with software controlling the effective gasket surface stress, supplying test gas under pressure and reading the mass of gas passed through the gasket [10, 11, 12]. Helium was used as the test gas in the test.

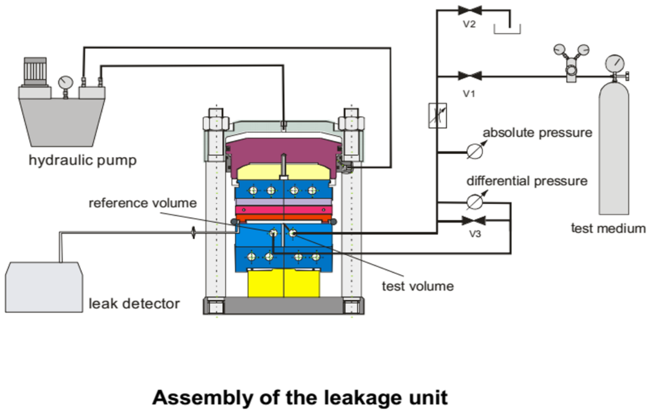

Fig. 2. Scheme of test equipment "TEMES fl.ai1"[12]

The seal is centered in the lower stationary test plate, fig.3. After starting the test, the upper test plate moves down and closes the chamber and provides the effective gasket surface stress, helium gas is supplied and the mass of gas passed through the gasket is read by a leak detector.

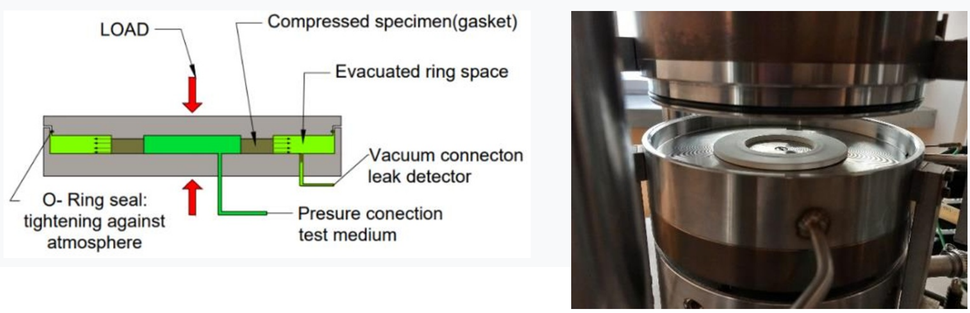

Fig. 3. Position chart of the tested gasket

The determination of the tightness class L_N (Table 1) and the gasket parameters: $Q_{min(L)}$ - the minimum gasket surface pressure on assembly required at ambient temperature in order to seat the gasket into the flange facing roughness and close the internal leakage channels so that the tightness class achieves the required level L for the internal test pressure at the given internal pressure; $Q_{Smin(L)}$ - the minimum gasket surface pressure required under the service pressure conditions, after off-loading and at the service temperature, so that the required tightness class L_N [13] is maintained for the internal test pressure , is done according to standard EN 13555, fig.4. The standard defines the parameters of gaskets and provides the test procedures for establishing the values of these parameters

A specific leakage rate is determined by dividing the measured mass in mg of gas passed in one second by the arithmetic mean length of the inner and outer circumferences of the compressed effective sealing surface in meters, $\pi/2$ ($D_S + d_S$), where D_S and d_S are outer and inner diameter of the pressed part of the gasket.

Tightness classes are defined as specific leakage rate.

Table 1. Tightness classes according to EN 13555

Tightness classes	L_1	L_0	$L_{0,01}$	$L_{0,001}$	$L_{0,0001}$	$L_{0,00001}$
Specific leakage rate [mg s^{-1} m^{-1}]	≤ 1,0	≤ 0,1	≤ 0,01	≤ 0,001	≤ 0,0001	≤ 0,00001

ePTFE gaskets, used in equipment with solid metal flanges, are subjected to compressive stress about 25-30MPa and rarely exceeding 60MPa. This is due to the type of flanges and the strength class of the fasteners. During the test, a step-by-step effective gasket surface stress equal to loading up to 100 MPa and unloading up to 5 MPa is applied to the gasket, the pressure of the test gas is increased and the mass of gas passed is measured by means of a leak detector.

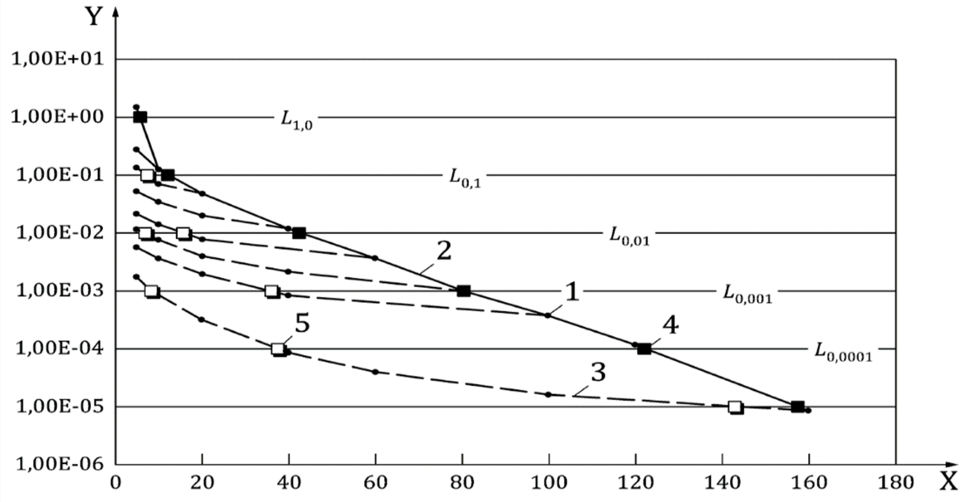

Fig. 4. Leakage rate as a function of gasket stress, 1 - measurement pont; 2 – loading; 3 – unloading; 4 - $Q_{min(L)}$; 5 - $Q_{Smin(L)}$; X – effective gasket surface pressure, MPa; Y – leakage rate, [mg/(m.s)]

To determine $Q_{min(L)}$ and $Q_{S\ min(L)}$ during the test, the gasket is loaded and unloaded cyclically by measuring the specific leakage rate at the effective contact stress levels specified in Table 2 at an internal gas pressure of 40 bar.

Table 2. loading and unloading to determine $Q_{min(L)}$ and $Q_{S\ min(L)}$

Load to this effective gasket surface stress **[MPa]**	Unload to this effective gasket surface stress **[MPa]**
5	No unloading
10	5
20	10, 5
30	20, 10, 5
40	20, 10, 5
60	20, 10, 5
80	40, 20, 10, 5
100	40, 20, 10, 5

The test method involves loading up to 5 MPa, holding the load and measuring the specific leakage rate, then increasing the load to 10 MPa. The load is held while a specific leakage rate is measured. The next step is to reduce the load to 5 MPa and measure the specific leakage rate again. Measurements are performed at 20 MPa, 10 MPa, 5 MPa, etc., until the 100 MPa load/unload cycle is completed.

3 Results

Table 3 shows the values of the tests carried out to determine the required contact stress applied to the seal during installation Qmin(L) to achieve tightness class L_N with an increased density in the area around the inner diameter of ePTFE gasketsn

Table 3. Results of the permeability test at different densities area around the inner diameter of ePTFE gaskets

Test No	Density in the area of the inner diameter, g/sm^3	The minimum level of surface pressure required for leakage rate class L_N on assembly [MPa]			
		Tightness class $L_{0,01}$	Tightness class $L_{0,001}$	Tightness class $L_{0,0001}$	Tightness class $L_{0,00001}$
1	0,805	27	31	36	46
2	0,933	19	24	29	43
3	1,067	15	18	22	41
4	1,201	14	16	19	37
5	1,333	13	16	18	35
6	1,467	11	14	17	28
7	1,601	12	15	18	37

The values in the table 3 of this type of test show that to achieve a tightness class above $L_{0.01}$, a gasket with increased density in the area of the inner diameter as in test 6 requires a lower contact stress during installation compared to other gaskets.

The results in the table 3 show that to achieve the same tightness class in the tests carried out, the increase in density leads to a decrease in the contact stress on the sealer, with the exception of test 7.

Figure 6 shows a graph from test 4 of a flat gasket with 50% increased density in the area of the inner diameter of the gasket. Based on the figure and table 3 it is clear that the tightness class $L_{0.0001}$ is achieved when the contact stress acting on the gasket during installation reaches 19 MPa.

For example, applying an installation contact stress of 20 MPa to a gasket with 50% increased density in the area of the inner diameter, a leakage rate of less than 1.10-4 (mg.s-1.m-1) is achieved, covering tightness class $L_{0,0001}$, which is maintained in operation even when the contact stress drops to 5 MPa.

Fig. 5 shows the general appearance of the gaskets after conducting the tightness test, conventionally marked with 4 and 6.

Test 4 Test 6

Fig.5. General appearance of the gaskets after conducting test 4 and 6

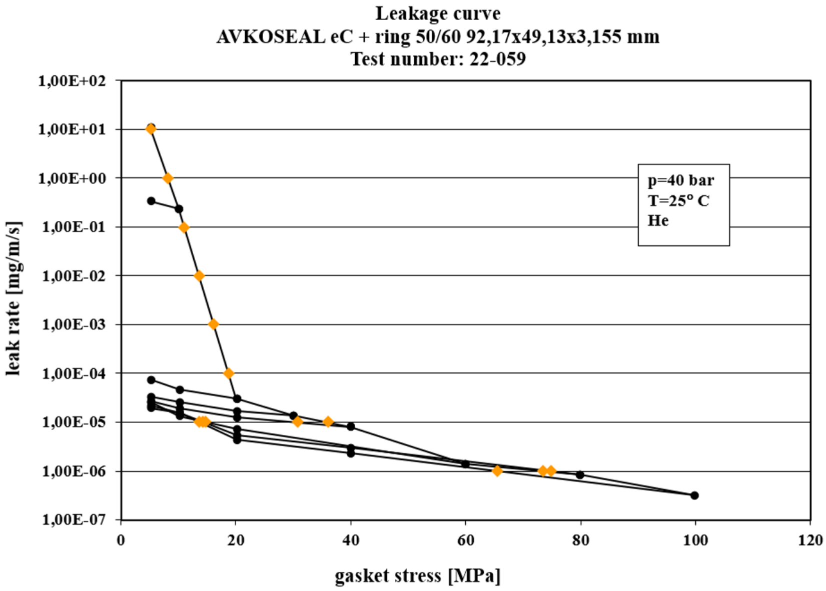

Fig. 6. Graph from test #4 of a seal with 50% increased density in the inner diameter area

4 Conclusion

1. The increase in density in the area around the inner diameter of ePTFE gaskets leads to a decrease in the mass of gas passed through the gasket. The least mass of gas passed was established in test 6.
2. The use of gaskets with increased density lowers the contact stress required to achieve the same tightness class, compared to gaskets without increased density.
3. The seal used in test 4 shows good performance parameters at installation contact stresses above 20 MPa. For example, an in-service leakage rate of 1.10^{-4} (mg.s-1.m-1) is

achieved when an assembly contact stress of 20MPa is applied. Applying a contact stress during installation of 40 MPa achieves a tightness class of $L_{0.00001}$.
4. The gaskets used in test 6 and 7 are destroyed when a contact stress of more than 80 MPa is applied.

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