amtec Services GmbH
Hoher Steg 13
D-74348 Lauffen
Tel.: +49 7133 9502-0
Fax: +49 7133 9502-22
E-Mail: info@amtec.de
Internet: www.amtec.de

quality certified
ISO 9001
KTA1401

DAkkS Deutsche Akkreditierungsstelle D-PL-12008-01-00

Test Report

Customer:	Kukil Inntot Co., Ltd. 17 Tapgeol-gil, KOR - 689-871 Ulsan
Project number (amtec):	303 259
Report number:	303 259 2/-
Test procedure:	Shell Specification MESC SPE 85/300
Material:	Serrated Metal Gasket K/# OC
Date:	October 7th, 2016
Pages:	13
Appendices:	27

Dipl.-Ing. B. Unser
Test Engineer

Dipl.-Ing. F. Herkert
Head of Laboratory

Test results are only relevant to the test objects submitted.

1. Subject of Investigation

The subject of investigation was a kammprofile gasket manufactured by Kukil Inntot Co., Ltd. which is named

- Serrated Metal Gasket K/# OC.

The serrated metal gasket has a center ring according to ASME B16.20 resp. EN1514-6. The material of the metal core and center ring is 316/316L for all geometries. Flexible graphite is the layer material.

2. Goal of Investigation

The goal of the investigation was the qualification of the gasket material Serrated Metal Gasket K/# OC in accordance to the Shell Specification MESC SPE 85/300 (dated September 2012: Procedure and Technical Specification for Type Acceptance Testing (TAT) of Gaskets).

The Shell Specification MESC SPE 85/300 describes several testing procedures for the evaluation of the gasket compressibility and the tightness characteristics of the gasket material at ambient and elevated temperature.

In this project, 9 different tests were performed in respect of the Shell approval:

- Shell leakage test at ambient temperature (MESC SPE 85/300 - 3.3.2),
- Shell leakage test at 400 °C (MESC SPE 85/300 - 3.3.2),
- Fire Test (MESC SPE 85/300 - 3.3.3: API 6FB),
- Compression test at ambient temperature (MESC SPE 85/300 - 3.3.4: EN 13555),
- Compression test at 400 °C (MESC SPE 85/300 - 3.3.4: EN 13555),
- Relaxation test at ambient temperature (MESC SPE 85/300 - 3.3.4: EN 13555),
- Relaxation test at 400 °C (MESC SPE 85/300 - 3.3.4: EN 13555),
- Leakage test (MESC SPE 85/300 - 3.3.4: EN 13555) and
- Shell cycle test at 400 °C (MESC SPE 85/300 - 3.3.5).

The Fire Test according API 6FB is not part of the accreditation.

3. Test Specimens

The dimensions of the test specimens for the different tests were 4" Class 300.

The contact area of the gasket is OD = 154.1 mm and ID = 124.2 mm. The thickness of the Serrated metal gasket was 4.0 mm.

4. Testing Equipment

The gasket tests were carried out on the following testing equipment:

Multifunctional test rig TEMES$_{fl.ai1}$ No.: 010 181 and 010 506

Photos and the schematic view of the testing equipment TEMES$_{fl.ai1}$ and of the Fire Safe testing device are shown in **appendices 1 and 2**.

4.1 Multifunctional Testing Equipment TEMES$_{fl.ai1}$

The servo-hydraulic press TEMES$_{fl.ai1}$ is capable to load up to 1 MN. Gaskets up to 180 mm diameter can be tested.

Depending on the type of test, different components (heating platens for temperatures up to 450 °C, insulation and cooling platens, different flange face designs etc.) can be used.

The load (gasket stress) is measured by a load cell on the bottom of the test rig, the gasket deformation is recorded by three displacement transducers and the temperature profile is controlled, too. LabView-Software is used for data logging and online evaluation. The entire test can be performed under software-control, thus automatic tests according to international standards or user defined procedures are possible.

Also, the simulation of different flange stiffnesses can be realized within the equipment. In dependence on the gasket deformation the gasket surface pressure is reduced automatically according to the nominal stiffness.

Due to the modular design, the above test rig can be modified to perform leakage tests. The platens for compression tests are replaced by platens for leakage tests, which are connected to a separate measurement device, see appendix 1. The leak rate measurement principle is based on the pressure decay method. Using a differential pressure leak rates down to about 1.0 10^{-4} mg/m/s can be measured. For higher tightness classes a leak detector can be used.

4.2 Fire Safe Testing Device

The fire safe testing device is used to simulate a fire for a period of 30 minutes.

Depending on the type of test, different type of flanges and valves can be tested in this testing device.

The water pressure is measured by a pressure transducer; the weight of the water volume is measured with a scale. The temperature of the fire is measured with 6 thermocouples and with 5 calorimeters which are placed around the test specimen. The control of the fire is done manually. Software is used for data logging and online evaluation.

5. Test Procedure

5.1 Fugitive Emission: Shell leakage test at ambient and elevated temperature (MESC SPE 85/300 - 3.3.2)

The Shell leakage test is carried out at ambient and at elevated temperature. For the tests at elevated temperature first the temperature is raised to the required test temperature under an initial gasket stress. Afterwards the gasket is compressed in steps of 10 MPa to a maximum gasket stress of 140 MPa at ambient and at elevated temperature. After reaching the first gasket stress level the test volume is pressurised with 51 bar at ambient temperature and 34.7 bar at 400 °C according to ASME B16.5-2003 - PT-Rating for Group 1.1 Materials. For the leakage measurement helium is used as test medium.

The leak rate can be classified in tightness classes:

- Class A: $\leq 1.78 \cdot 10^{-9}$ Pa·m³/s/mm,
- Class B: $\leq 1.78 \cdot 10^{-8}$ Pa·m³/s/mm.

Shell TAT recommends a maximum gasket stress of 87.2 MPa, which is equivalent to a maximum bolt stress of 361 MPa. The calculation of the gasket stress, which is calculated from the bolt stress, was done with an effective cross section area of 199 mm² per bolt referred to an OD of 154 mm and ID of 123.8 mm of the serrated metal gasket.

5.2 Fire Test API 6FB (MESC SPE 85/300 - 3.3.3)

The Fire Test according to API 6FB (dated December 2008) requires that any sealing end connection withstands for 30 minutes a flame condition and the following cool down period. After the specimen is cooled down to room temperature the line is depressurised and then pressurised again. During all facets of the test the gasket must not exceed an API proscribed leak rate.

In the Fire Test API 6FB a 6" Class 300 flange is pressurised with a test pressure of 75% of the API rated working pressure. The test pressure is maintained during the burn and cool-down period. After 5 minutes a fire is established and the flame temperature is monitored. The average temperature of the thermocouples must reach

760 °C within 2 minutes and the average of the calorimeter shall reach 650 °C within 15 minutes after fire ignition. The burn period shall last for 30 minutes. After the burn period the flange connection is air-cooled down to 100 °C or less. After cooling down the flanges are depressurised and the pressure is increased again to the test pressure and held for 5 minutes.

The maximum leak rate is 1 ml/inch per min of mean gasket circumference.

5.3 EN 13555 (MESC SPE 85/300 - 3.3.4)

According to the European Standard DIN EN 13555 (dated July 2014) the determination of the following gasket characteristics, which are necessary for the calculation according to DIN EN 1591-1 (dated April 2014), was done:

- Maximum allowable gasket stress Q_{smax} (RT, 400 °C),
- Modulus of elasticity E_G (RT, 400 °C),
- Creep relaxation factor P_{QR} (90 MPa – RT, 400 °C),
- Change in gasket thickness due to creep Δe_{Gc} (90 MPa – RT, 400 °C),
- Minimum required gasket stress in assembly $Q_{min(L)}$ (40 bar) and
- Minimum required gasket stress in service $Q_{smin(L)}$ (40 bar).

5.3.1 Compression test

The compression test can be carried out at ambient or at elevated temperature. For the tests at elevated temperature first the temperature of the gasket is raised to the required test temperature under an initial gasket stress. Then cyclic compression and recovery loadings on the gasket at progressively higher surface pressures are carried out until the gasket collapses or the maximum load of the test machine or the maximum gasket stress specified by the manufacturer is reached.

The gasket stress of the loading cycle prior to collapse is taken to be the maximum allowable gasket stress at ambient temperature Q_{smax}(RT) or the maximum allowable gasket stress at the test temperature Q_{smax}(T).

The unloading cycles of the Q_{smax} test allow the generation of values of the modulus of elasticity E_G. The E_G value is determined for each gasket stress level of the

different unloading cycles, the E_G value is also dependent on the test temperature level.

5.3.2 Creep relaxation test

The factor P_{QR} is the ratio of the residual and the initial gasket stress from a relaxation test. The deflection Δe_{Gc} is the change in gasket thickness due to creep.

The test is performed by using the stiffness simulated control mode. The load will be decreased according to the creeping of the gasket and the nominal set point for stiffness simulation. A stiffness of 500 kN/mm is typical for a PN designated flange and 1500 kN/mm for a Class designated flange. For this test the stiffness of the rig shall be 500, 1000 or 1500 kN/mm.

The test procedure consists of loading the test gasket until the initial load is applied. The loading is then held for 5 minutes. Then the temperature of the test rig is raised until the test temperature is reached and the temperature is held constant for a period of 4 hours. During the heating period and at elevated temperature the stiffness controlled mode of the equipment is activated. After the 4 hour period the remaining load after relaxation is noted and P_{QR}, the ratio of the residual load to the original load, and deflection Δe_{Gc} are calculated.

5.3.3 Leakage test

The leakage test procedure consists of loading and unloading the gasket in a cyclic manner with measurement of the leak rate at several effective gasket stress levels with an internal gas pressure of 40 bar.

The procedure therefore consists of loading to 5 MPa, holding the load and measuring the leak rate and then raising the gasket stress to 10 MPa. The load is then held whilst the leak rate is measured. In the next step the load is reduced to 5 MPa and the leak rate is measured. Then measurements are done for the next loading - unloading cycle at 20 MPa, 10 MPa, and 5 MPa and so on until either the 160 MPa loading - unloading cycle is completed or the value of Q_{smax} would have been exceeded.

The lowest gasket stress level is set to 10 MPa due to high leak rates at 5 MPa.

The test gas used for this test shall be helium.

From the generated leakage curve the minimum required gasket stress in assembly $Q_{min(L)}$ (40 bar) and the minimum required gasket stress in service $Q_{smin(L)}$ (40 bar) in dependence on the gasket surface pressure prior to the unloading Q_A can be evaluated for different tightness classes L.

5.4 HOTT: Shell cycle test at 400 °C (MESC SPE 85/300 – 3.3.5)

In the leakage test at elevated temperature the gasket is compressed with a gasket stress of 87.2 MPa. After heating up to 400 °C the specimen was pressurized with 34.7 bar helium (in accordance to ASME B16.5-2003 - PT-Rating for Group 1.1 Materials), no load compensation of the internal pressure is done.

After one hour the test rig is cooled down to ambient temperature. The thermal cycle is repeated three times. During the last thermal cycle, the pressure loss shall not exceed 1 bar.

6. Results

All test results of the gasket material Serrated Metal Gasket K/# OC are summarized in **appendices 3 to 5**.

6.1 Fugitive Emission: Shell leakage test at ambient and elevated temperature (MESC SPE 85/300 - 3.3.2)

In the Shell leakage test at ambient temperature the gasket was compressed in 8 steps from 70 MPa to 140 MPa. The detected leak rate at 70 MPa gasket stress at an internal pressure of 51 bar was $5.3 \cdot 10^{-9}$ Pa·m³/s/mm, see **appendix 5**. The leak rate was decreasing with increasing gasket stress up to 140 MPa. The leak rate at a gasket stress of 80 MPa, which is equivalent to a bolt stress of 331 MPa, was $3.8 \cdot 10^{-9}$ Pa·m³/mm/s, which is lower than the Tightness Class B.

For the maximum gasket surface stress of 140 MPa the leak rate was $1.0 \cdot 10^{-10}$ Pa·m³/s/mm, which is lower than the Tightness Class A.

In the Shell leakage test at 400 °C the gasket was compressed in 6 steps from 80 MPa to 130 MPa. The leak rate at 80 MPa gasket stress at an internal pressure of 34.7 bar with a measuring period of 24 hours was not measurable. The leak rate at higher gasket stress levels was also not measurable. For all gasket stress levels the leak rate is set to $1.5 \cdot 10^{-8}$ Pa·m³/mm/s, see appendix 5.

Therefore the leak rate at a gasket stress of 80 MPa, which is equivalent to a bolt stress of 331 MPa, was set to $1.5 \cdot 10^{-8}$ Pa·m³/mm/s, which is a lower than the Tightness Class B.

6.2 Fire test API 6FB (MESC SPE 85/300 - 3.3.3)

In the fire test API 6FB the gasket Serrated Metal Gasket K/# OC was mounted in a 4" Class 300 flange with hydraulic spanners to a bolt load of 88.8 kN which means a total load of 710.4 kN and a gasket surface stress of 111 MPa.

After that the flange was pressurized with an internal pressure of 40 bar. The test medium was water. After 5 minutes the flame impingement starts for a period of 30 minutes, see **appendices 7 to 9**. During burning period the flame temperature was nearly constant. After 30 minutes of burning the flange was cooled down to a temperature less than 100 °C and the system was depressurized.

During burning period of 30 minutes a leakage was measurable. The leak rate of the burning period is measured to 0.41 ml/inch/min.

During the complete pressurization with water no further leakage could be measured. The leak rate of the complete test is measured to 0.5 ml/inch/min and therefore below the allowable leak rate of 1 ml/inch/min.

The gasket Serrated Metal Gasket K/# OC passed the fire test according to API 6FB.

6.3 EN 13555 (MESC SPE 85/300 - 3.3.4)

All tests according to EN 13555 with the material Serrated Metal Gasket K/# OC were performed twice; they are listed in appendices 3 and 4. All gasket characteristics

which are necessary for the use of the flange calculation code EN 1591-1 are summarized in these tables.

6.3.1 Compression tests

In appendix 3 the results of the compression tests with loading and unloading cycles are given, the gasket characteristics are

- the maximum allowable gasket stress Q_{smax} (RT),
- the modulus of elasticity E_G (RT),
- the maximum allowable gasket stress Q_{smax} (400 °C) and
- the modulus of elasticity E_G (400 °C).

Compression tests were performed at ambient temperature and at elevated temperature at 400 °C. According to EN 13555 loading and unloading cycles were carried out to determine the deformation behaviour of the gasket material. The compression curves and the corresponding graphs of the modules of elasticity for the different test temperature levels are shown in **appendices 10 to 13.**

In both compression tests at ambient temperature no collapse of the gasket specimens can be recognized until the maximum load of the testing equipment of 140 MPa is reached. Also in the diagrams of the modules of elasticity no distinctive feature is visible which would indicate a damage of the gasket material.

The maximum allowable gasket stress Q_{smax} at RT is set to 140 MPa.

In both compression tests at 400 °C no damage of the gasket specimen can be recognized until the maximum load of the testing equipment of 140 MPa is reached. Also in the diagrams of the modules of elasticity no distinctive feature is visible which would indicate a damage of the gasket material.

The maximum allowable gasket stress Q_{smax} at 400 °C is set to 140 MPa.

The modulus of elasticity E_G at ambient temperature increases steadily with increasing gasket stress. For the tests at 400 °C the modulus of elasticity E_G remains at a certain level between approx. 30,000 MPa and 40,000 MPa with gasket stress levels higher than 50 MPa.

A good repeatability of the double test is noticeable.

6.3.2 Creep relaxation tests

In appendix 3 the gasket characteristics of the creep relaxation tests for one gasket stress, two temperatures and one stiffness levels are listed:

- creep relaxation factor P_{QR} (90 MPa, RT, 500 kN/mm) and
- creep relaxation factor P_{QR} (90 MPa, 400 °C, 500 kN/mm).

In total 4 creep relaxation tests were performed. The initial gasket stress level was set to 90 MPa, the temperature was assessed to RT and 400 °C. For the stiffness the typical value for a PN designated flange (500 kN/mm) was chosen.

The results of all creep relaxation tests are given in **appendices 14 to 17**. The creep relaxation factors P_{QR} are 1.00 (90 MPa, RT, 500 kN/mm) and 0.99 resp. 1.00 (90 MPa, 400 °C, 500 kN/mm). The deflection Δe_{Gc} of the gasket Serrated Metal Gasket K/# OC at RT are 3 µm and in tests at 400 °C are 12 µm resp. 4 µm.

A good repeatability of the double test is noticeable.

6.3.3 Leakage tests

The tightness behaviour of the gasket material Serrated Metal Gasket K/# OC was examined in two leakage tests at 40 bar helium. In appendix 4 the determined gasket characteristics

- minimum required gasket stress in assembly $Q_{min(L)}$ and
- minimum required gasket stress in service $Q_{smin(L)}$ in dependence on the gasket surface pressure prior to the unloading Q_A

are listed for both tests in dependence on the tightness class L.

For the determination of the leak rate two different measurement devices were used in parallel. The pressure drop method with a differential pressure was used for the leak tightness evaluation for leak rates higher than $1.0 \cdot 10^{-3}$ mg/m/s, for lower leak rates the signal of the helium leak detector was taken for the calculation of the leak rate.

The graphical presentation of the leakage curves are shown in **appendix 18**. The tightness class $L_{0.01}$ was reached when the gasket stress raised above 17 MPa or 16 MPa, respectively. Therefore the minimum gasket stress in assembly for the tightness class $L_{0.01}$ is set to $Q_{min(0.01)}$ = 17 MPa. The lowest tightness class which could be reached was $L_{0.000001}$; therefore a gasket stress of 135 MPa resp. 123 MPa is necessary.

The leak rate is decreasing with an increasing gasket stress up to 140 MPa. The lowest leak rate which could be measured was $3.3 \cdot 10^{-7}$ mg/m/s at 140 MPa in test 16-563.

During the unloading cycles the leak rate is increasing again, but the gasket is clearly tighter as during the first loading to a defined gasket stress level. In all unloading curves up to a preload of 60 MPa no drastic increase of the leak rate (or sudden blow-out) is observed.

With a higher preload of 80 MPa, 100 MPa and 140 MPa a big increase of the leak rate during unloading from 10 MPa to 5 MPa could be observed. This is not a normal behaviour of a gasket. These values of Q_{smin} are marked grey in the table of appendix 4. A calculation according to EN1591-1 with these values may cause trouble.

The minimum gasket stress in service for the tightness class $L_{0.01}$ for an initial gasket surface pressure Q_A of 60 MPa is $Q_{smin(0.01)}$ = 5 MPa in both tests.

A good repeatability of the double test is noticeable.

6.4 HOTT: Shell cycle test at 400 °C (MESC SPE 85/300 – 3.3.5)

For the Shell cycle test at elevated temperature the serrated metal gasket was compressed initially with 87.2 MPa. After heating up to 400 °C, the specimen was pressurized with 34.7 bar helium. During the thermal cycles in the leakage test at 400 °C, nearly no pressure drop could be measured, see **appendix 19**.

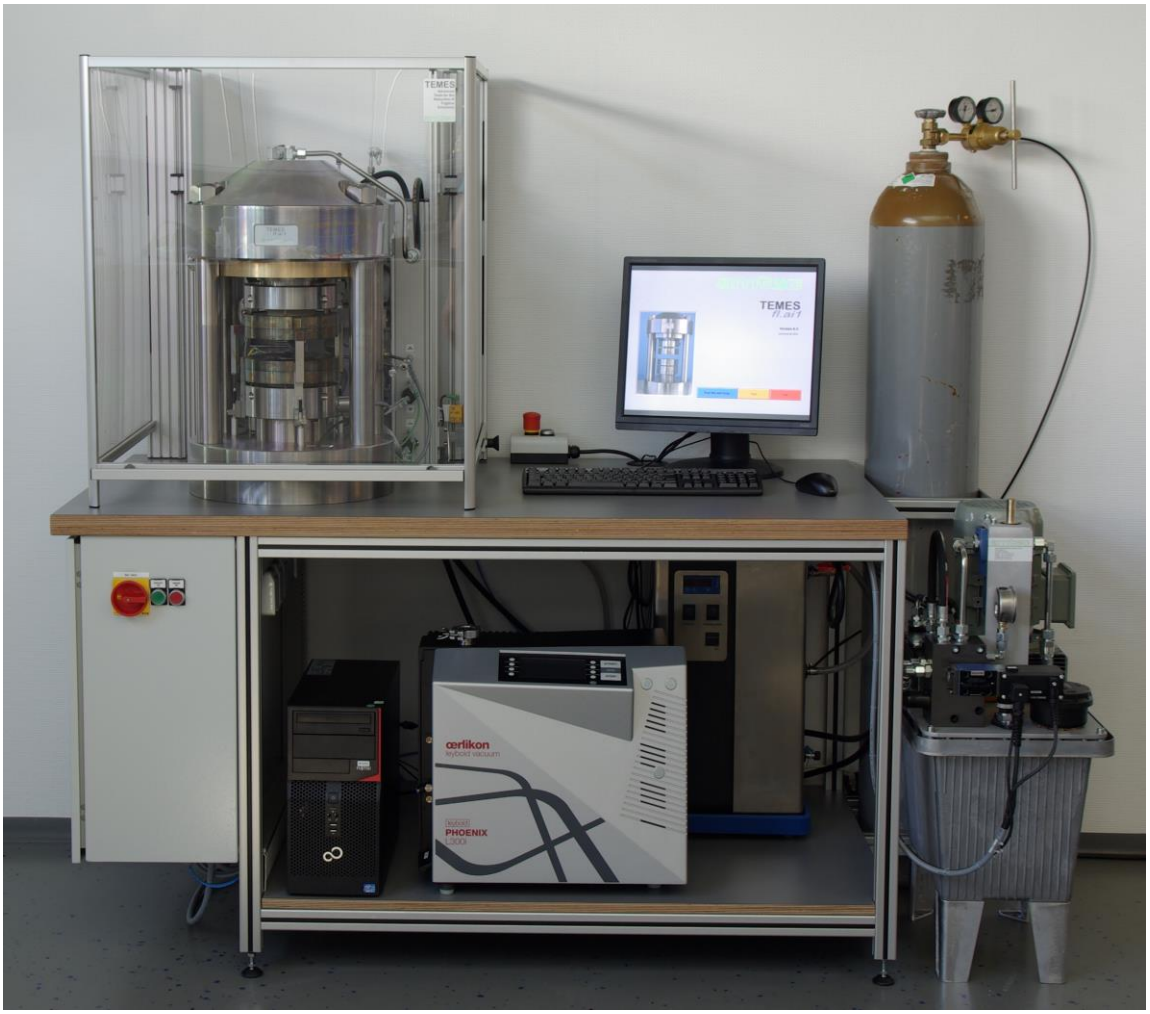
During the last thermal cycle the pressure loss is less than 0.2 bar. The gasket material Serrated Metal Gasket K/# OC has passed the Shell requirement of a pressure drop less than 1 bar.

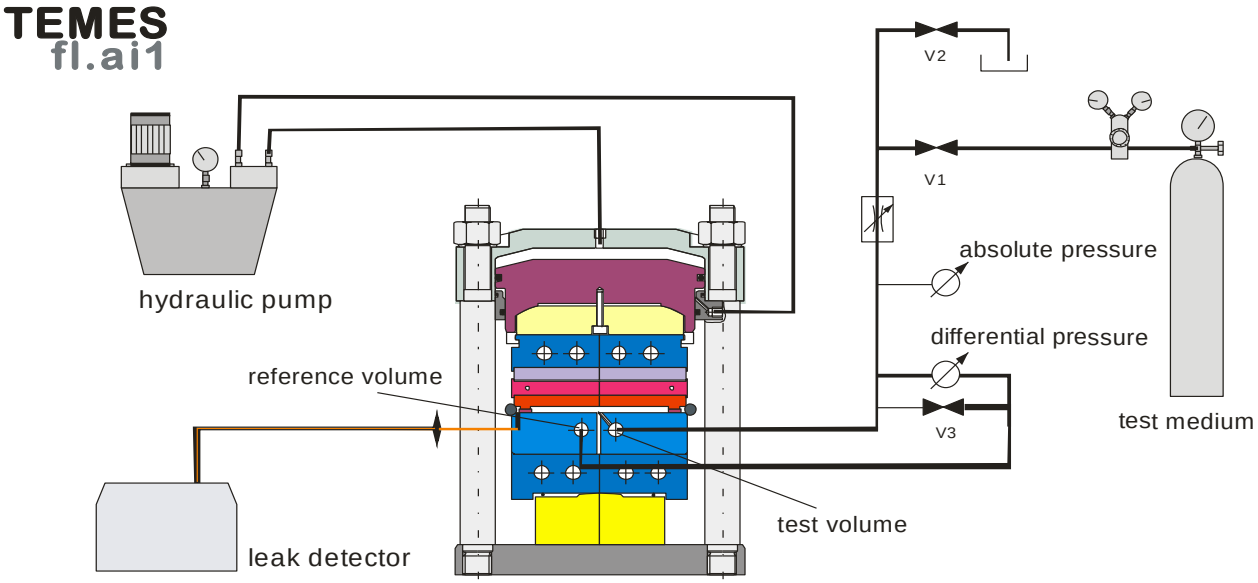
6.5 Gasket adhesion (MESC SPE 85/300 – 3.3.13)

In **appendices 19 and 20** photos of the adjacent flanges after tests at ambient temperature with the gasket specimen's Serrated Metal Gasket K/# OC are represented. The gasket does not stick on the flange. Slight traces of graphite material at the adjacent flanges after the test are visible. The gasket adhesion could be considered as acceptable.

7. Photo documentation

In **appendices 21 to 27** photos of the tested gasket specimen's Serrated Metal Gasket K/# OC for the different test procedures are presented. With all high temperature tests the graphite layers were peeled off after the tests.





Testing Equipment TEMES*fl.ai1* (1000 kN)

Fire Safe Testing Device

Table 1: Data Sheet for Gasket Characteristics (EN 13555)

Manufacturer: Kukil Inntot Co., Ltd.

Product: **Serrated Metal Gasket K/# OC**

Maximum allowable Gasket Stress Q_{smax} [MPa]

T [°C]	25	25	400	400
Q_{smax} [MPa]	140	140	140	140
Test #	16-535	16-537	16-552	16-554

Modulus of Elasticity E_G [MPa]

T [°C] / Q [MPa]	25		25		400		400	
	E_G [MPa]	e_G [mm]	E_G [MPa]	e_G [mm]	E_G [MPa]	e_G [mm]	E_G [MPa]	e_G [mm]
0		4.120		4.130		4.120		4.110
1		3.992		4.002		4.015		3.991
20	7016	3.428	7144	3.490	4527	3.438	6365	3.396
30	12252	3.366	13161	3.418	56607	3.394	74566	3.354
40	14848	3.333	16432	3.382	33249	3.359	44402	3.323
50	16005	3.311	18668	3.358	30085	3.339	34413	3.303
60	17835	3.294	19677	3.341	28957	3.325	30641	3.290
80	21048	3.271	22992	3.316	29411	3.306	27711	3.270
100	24179	3.256	26246	3.300	34371	3.292	33486	3.258
120	28268	3.245	29271	3.288	38660	3.282	39412	3.247
140	29603	3.236	32201	3.279	35478	3.271	35493	3.236
Test #	16-535		16-537		16-552		16-554	

Creep-/Relaxation Factor P_{QR} [-]

Change in gasket thickness due to creep Δe_{GC} [µm]

C = 500 kN/mm	T [°C] / Q [MPa]	25	25	200	200
	90	1.00	1.00	0.99	1.00
	Δe_{GC} [µm]	3	3	12	4
	Test #	16-538	16-539	16-540	16-551

Table 2: Data Sheet for Gasket Characteristics (EN 13555)

Manufacturer: Kukil Inntot Co., Ltd.

Product: **Serrated Metal Gasket K/# OC**

Minimum required Gasket Stress in Assembly $Q_{min(L)}$ [MPa]

L / p [bar]	10	1	0.1	0.01	0.001	0.0001	0.00001	0.000001	0.0000001
40	5	5	7	17	31	62	98	135	-
Test #	16-541								
40	5	5	7	16	31	56	87	123	-
Test #	16-563								

Minimum required Gasket Stress in Operation $Q_{smin(L)}$ [MPa]

	L / Q_A [MPa]	10	1	0.1	0.01	0.001	0.0001	0.00001	0.000001	0.0000001
p = 40 bar	10	5	5	5	-	-	-	-	-	-
	20	5	5	5	9	-	-	-	-	
	40	5	5	5	5	21	-	-	-	-
	60	5	5	5	5	13	-	-	-	-
	80	5	5	5	6	10	27	-	-	-
	100	5	5	6	8	9	20	93	-	-
	140	5	5	7	8	9	13	36	114	-
	Test #	16-541								

Minimum required Gasket Stress in Operation $Q_{smin(L)}$ [MPa]

	L / Q_A [MPa]	10	1	0.1	0.01	0.001	0.0001	0.00001	0.000001	0.0000001
p = 40 bar	10	5	5	5	-	-	-	-	-	-
	20	5	5	5	8	-	-	-	-	-
	40	5	5	5	5	16	-	-	-	-
	60	5	5	5	5	12	52	-	-	-
	80	5	5	5	5	8	28	-	-	-
	100	5	5	5	5	8	19	70	-	-
	140	5	5	5	6	8	13	37	92	-
	Test #	16-563								

Table 3: Data Sheet for Gasket Characteristics ()

Manufacturer: Kukil Inntot Co., Ltd.

Product: **Serrated Metal Gasket K/# OC**

Shell leakage test at ambient temperature

Test pressure:	51	bar
Shell required gasket stresss level:	80.1	MPa
Leakage rate:	3.79E-09	Pa·m³/s/mm
Shell tightness class:	B	
test no.	16-570	

Shell leakage test at 400 °C

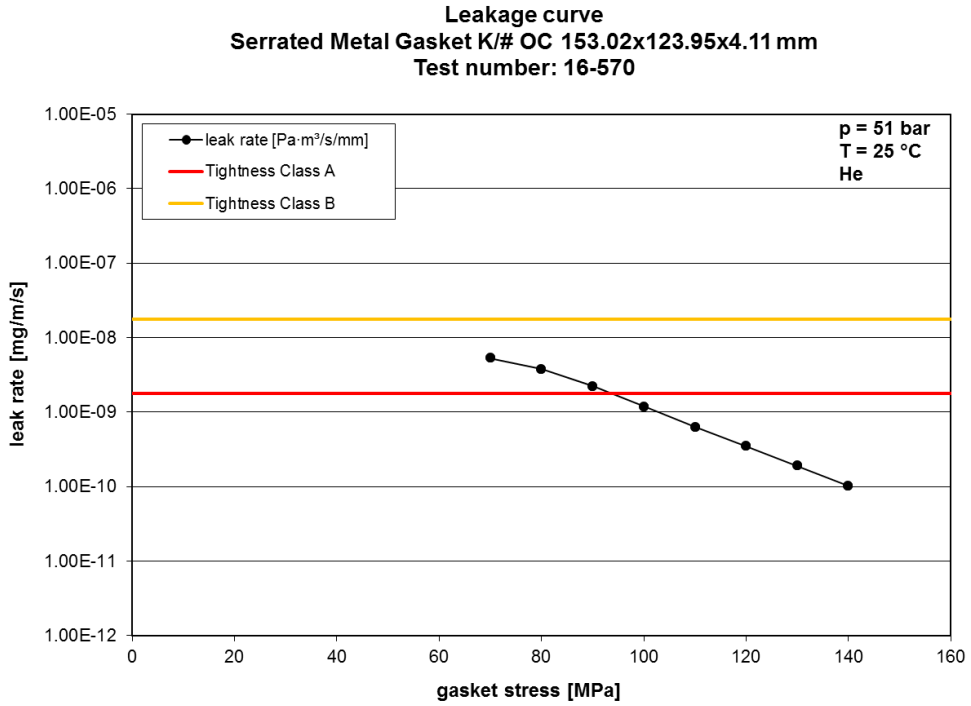
Test pressure:	43.8	bar
Shell required gasket stresss level:	80.1	MPa
Leakage rate:	1.54E-08	Pa·m³/s/mm
Shell tightness class:	B	
test no.	16-588	

Shell cycle test at 400 °C

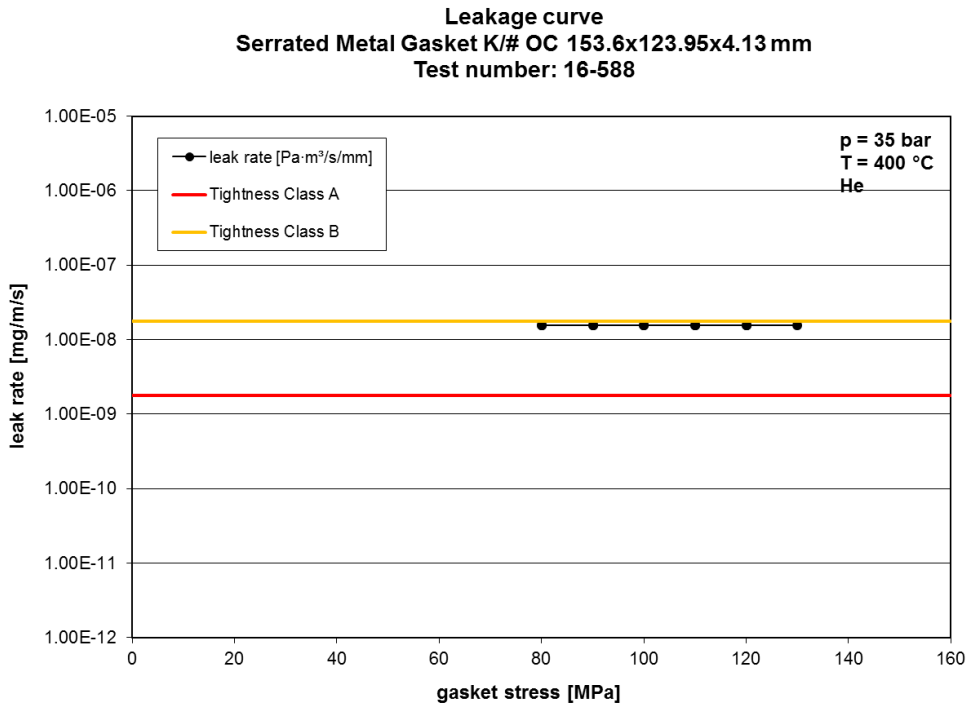
Test pressure:	34.7	bar
Initial gasket stress level:	87.2	MPa
Pressure drop in last cycle:	< 0.2	bar
Requirements	passed	
test no.	16-577	

Fire test API 6FB

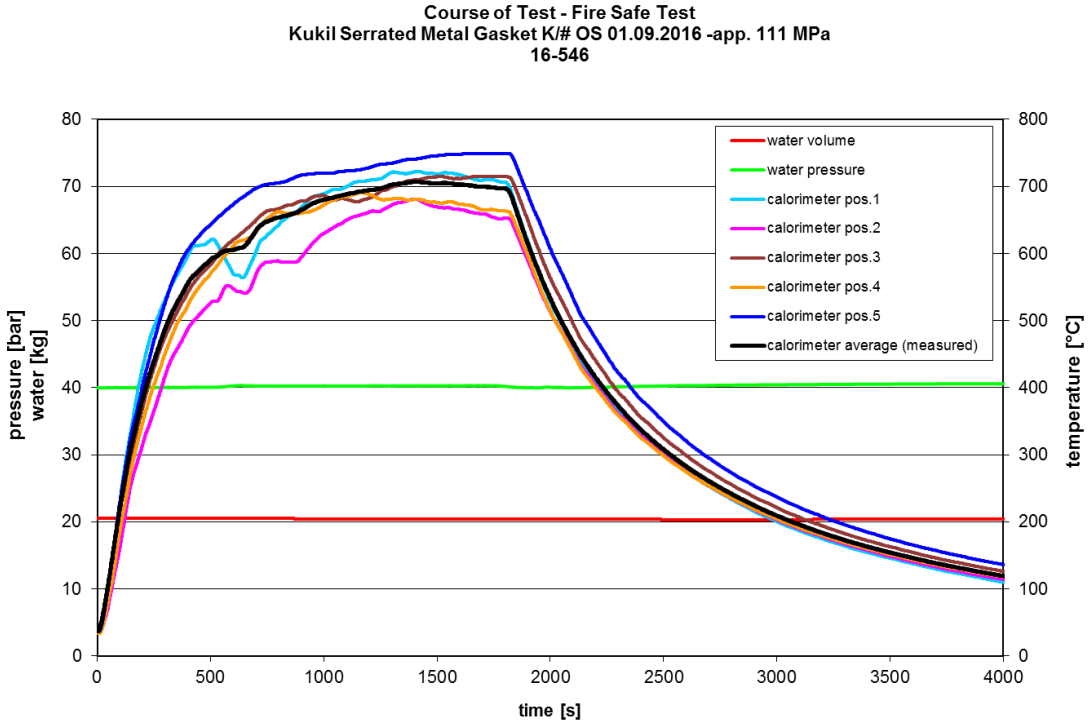
Test pressure:	40	bar
Initial gasket stress level:	111	MPa
Leak rate (complete test):	0.50	ml/inch/min
Requirements	passed	
test no.	16-546	



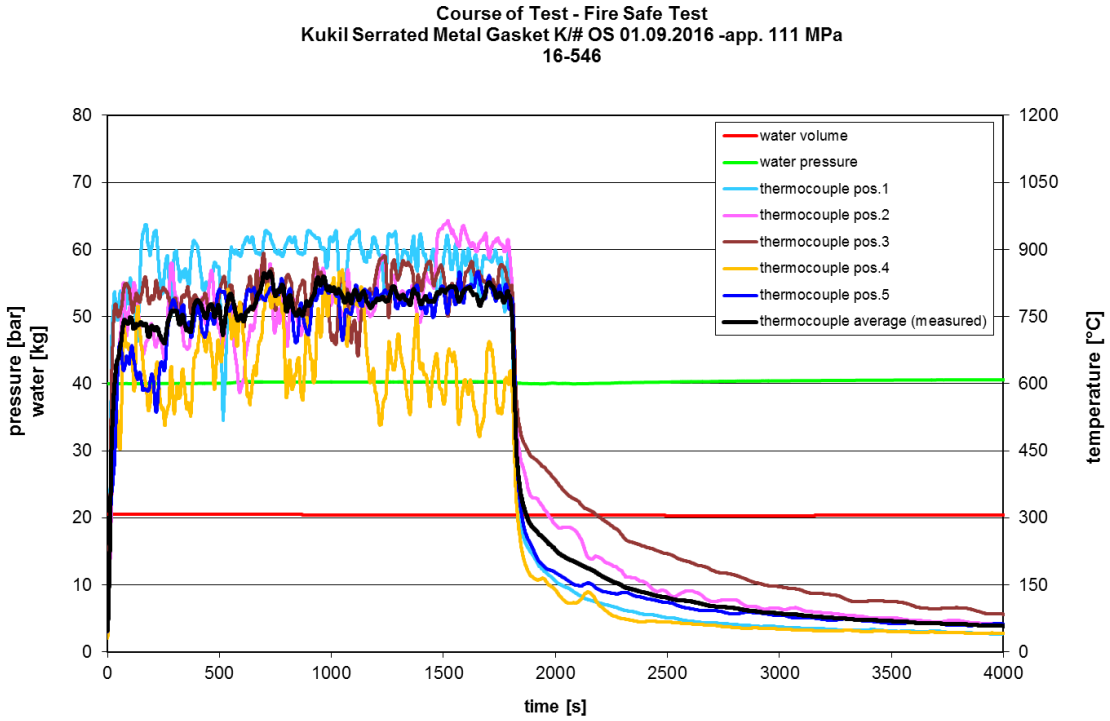
Shell leakage test (RT) according MESC SPE 85/300 - 3.3.2



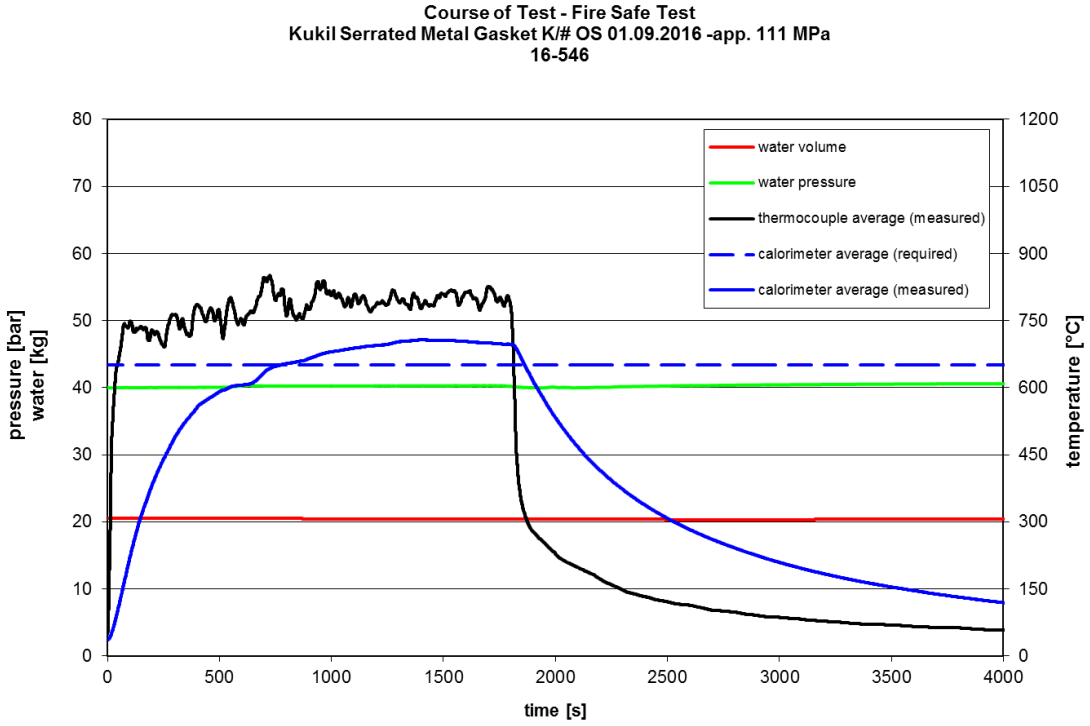
Shell leakage test (400 °C) according MESC SPE 85/300 - 3.3.2



3.3.3 Fire test API 6FB - calorimeters



3.3.3 Fire test API 6FB – thermocouples



3.3.3 Fire test API 6FB

Serrated Metal Gasket K/# OC

geometries

bolts	8	-
OD gasket	153.6	mm
ID gasket	124.3	mm
mean gasket circumference contact area	436.5	mm
gasket area	6395.1	mm²
gasket contact area	6395.1	mm²
OD raised faces flange (4" Class 300)	155	mm
leak rate criteria	1	ml / inch / min
burning period	30	min
maximum allowable leakage during burning period	**515.58**	**ml**

calculation of gasket stress

hydraulic spanners - No.	GS 3/1	-
calibration factor	0.19	kN/bar
pressure	480	bar
force per bolt	88.80	kN
force total	710.40	kN
gasket stress	111.09	MPa

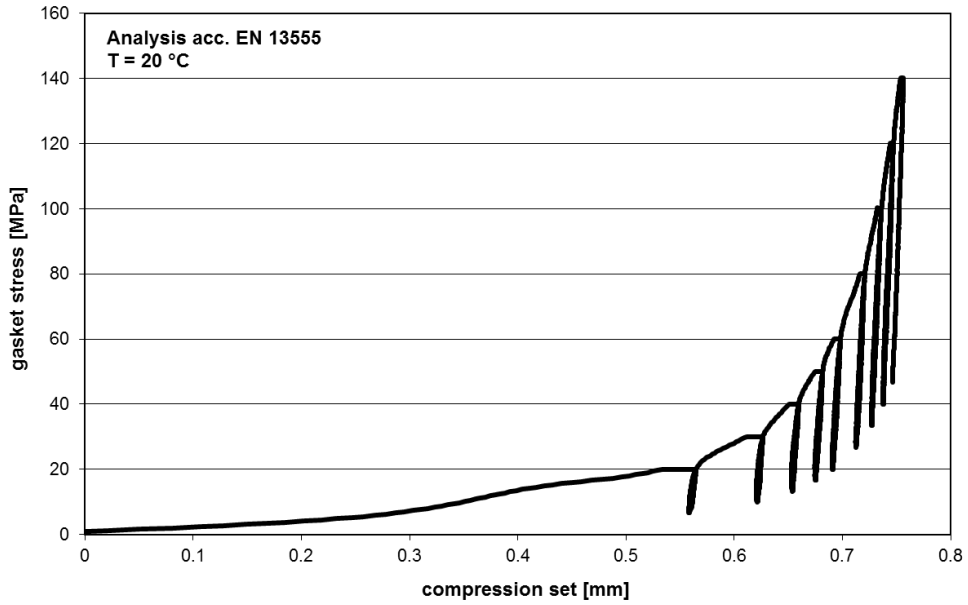
calculation of leak rate of complete test

start value scale	20.59	kg
end value scale	19.92	kg
start test	08:53:23	
end test	10:11:33	
test duration (min)	78.17	min
leakage	669.60	ml
leak rate	**0.50**	**ml / inch / min**

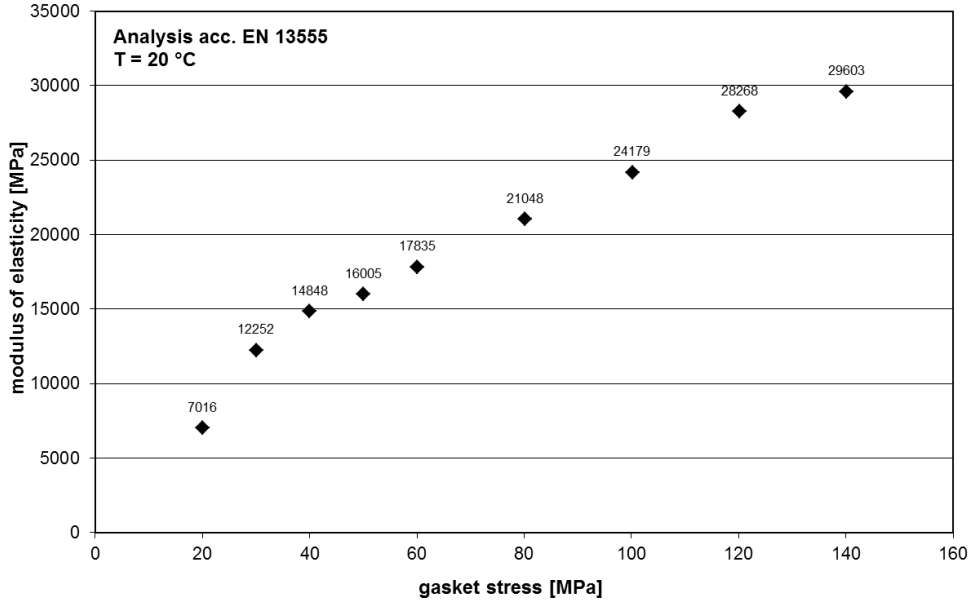
calculation of leak rate of burning period

start value scale	20.59	kg
end value scale	20.38	kg
start test	08:53:23	
end test	09:23:23	
test duration (min)	30	min
leakage	211.90	ml
leak rate	**0.41**	**ml / inch / min**

Compression curve
Serrated Metal Gasket K/# OC 153.91x124.07x3.992 mm
Test number: 16-535

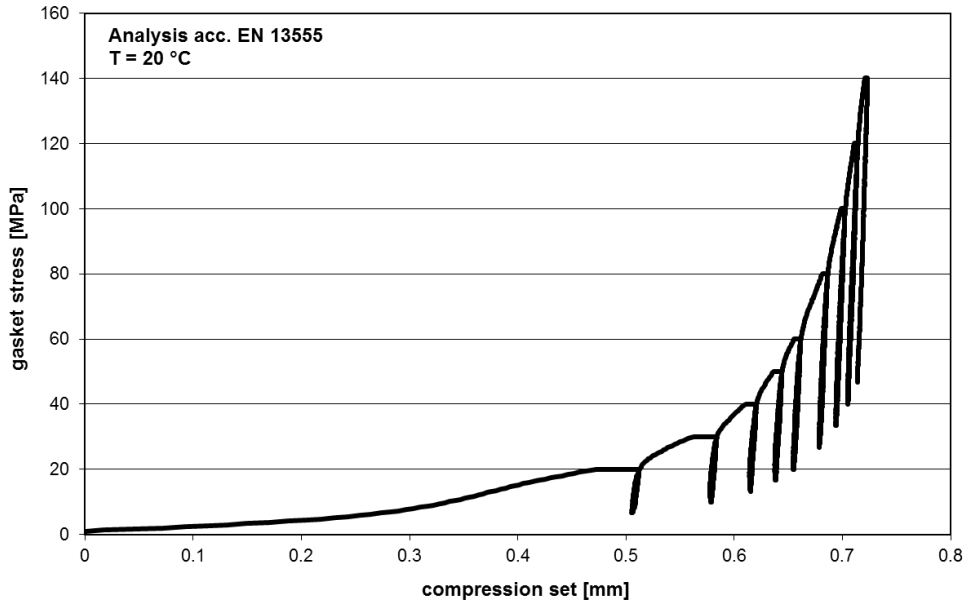


Modulus of elasticity
Serrated Metal Gasket K/# OC 153.91x124.07x3.992 mm
Test number: 16-535

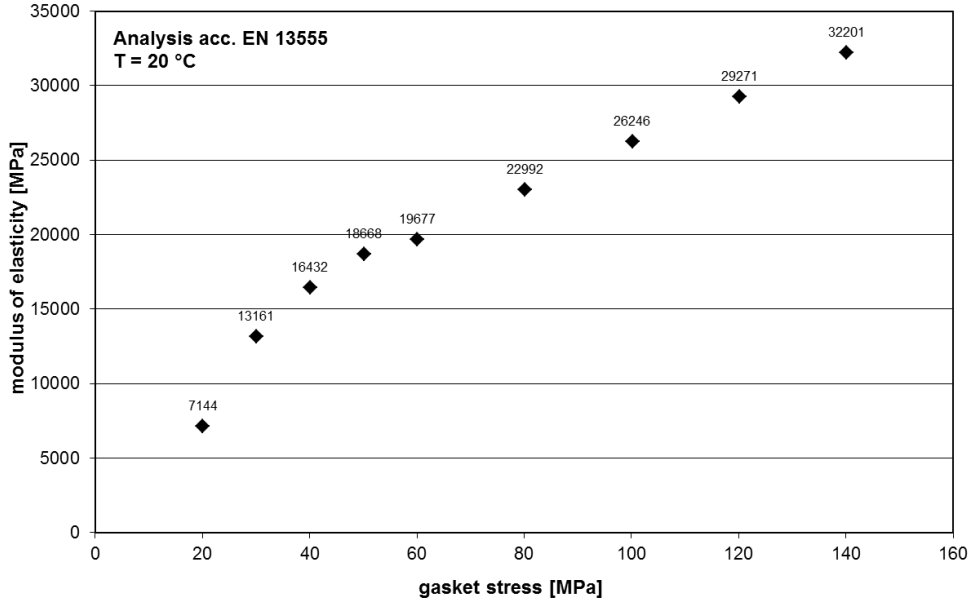


Compression test (RT) according EN 13555

Compression curve
Serrated Metal Gasket K/# OC 154.07x124.21x4.002 mm
Test number: 16-537

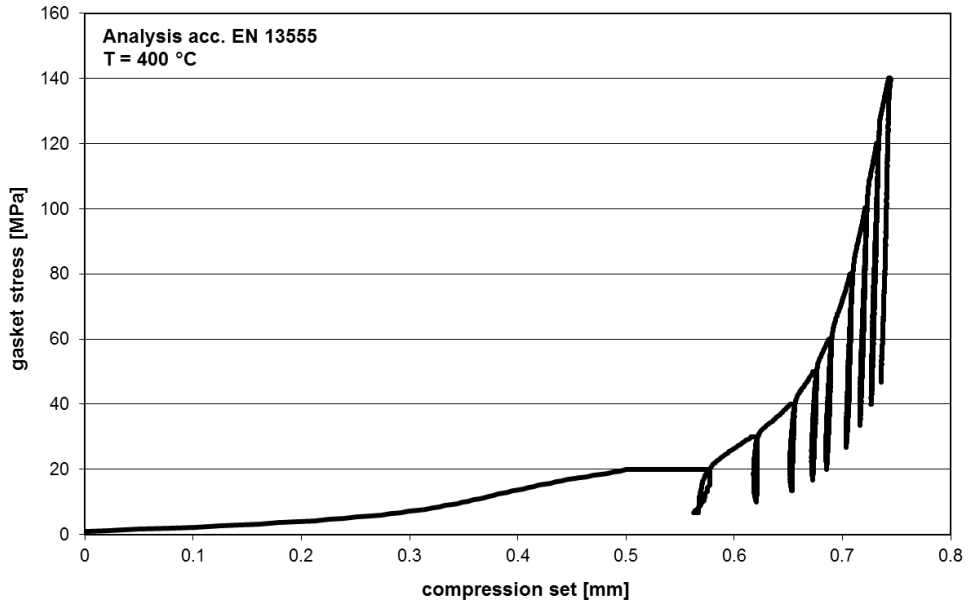


Modulus of elasticity
Serrated Metal Gasket K/# OC 154.07x124.21x4.002 mm
Test number: 16-537

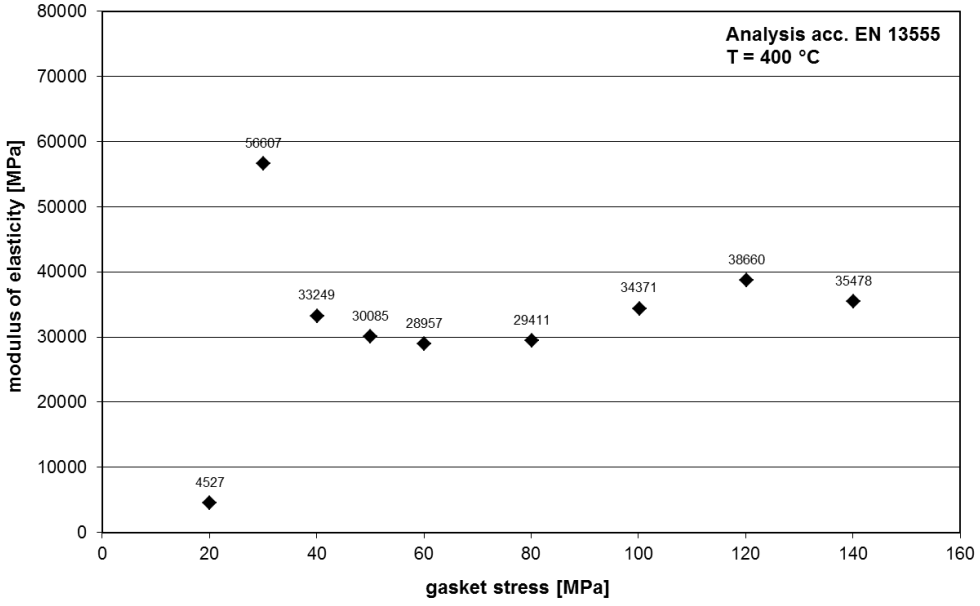


Compression test (RT) according EN 13555

Compression curve
Serrated Metal Gasket K/# OC 154.03x124.08x4.015 mm
Test number: 16-552

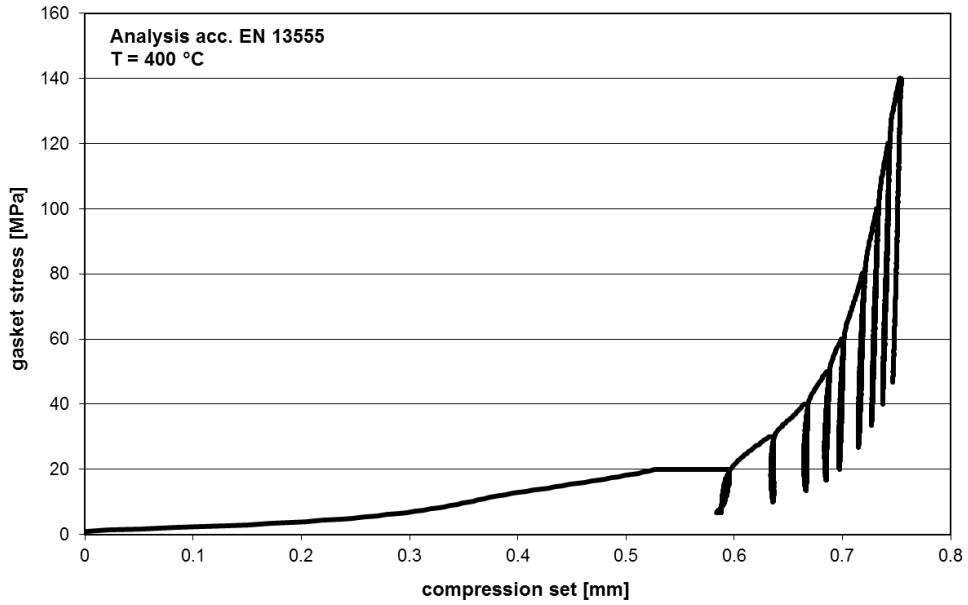


Modulus of elasticity
Serrated Metal Gasket K/# OC 154.03x124.08x4.015 mm
Test number: 16-552

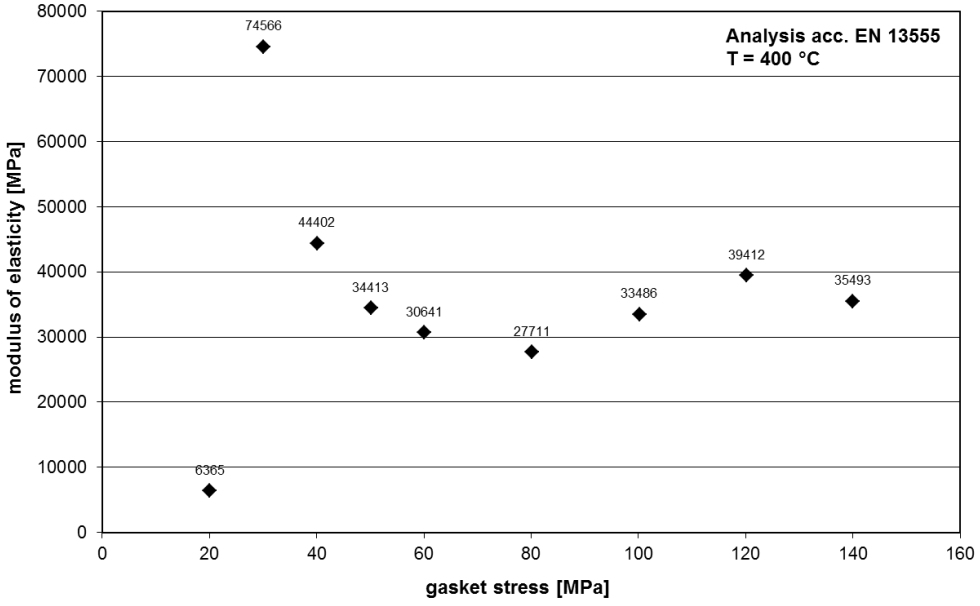


Compression test at 400 °C according EN 13555

Compression curve
Serrated Metal Gasket K/# OC 154.94x124.24x3.991 mm
Test number: 16-554



Modulus of elasticity
Serrated Metal Gasket K/# OC 154.94x124.24x3.991 mm
Test number: 16-554



Compression test at 400 °C according EN 13555

Creep relaxation test (EN 13555)

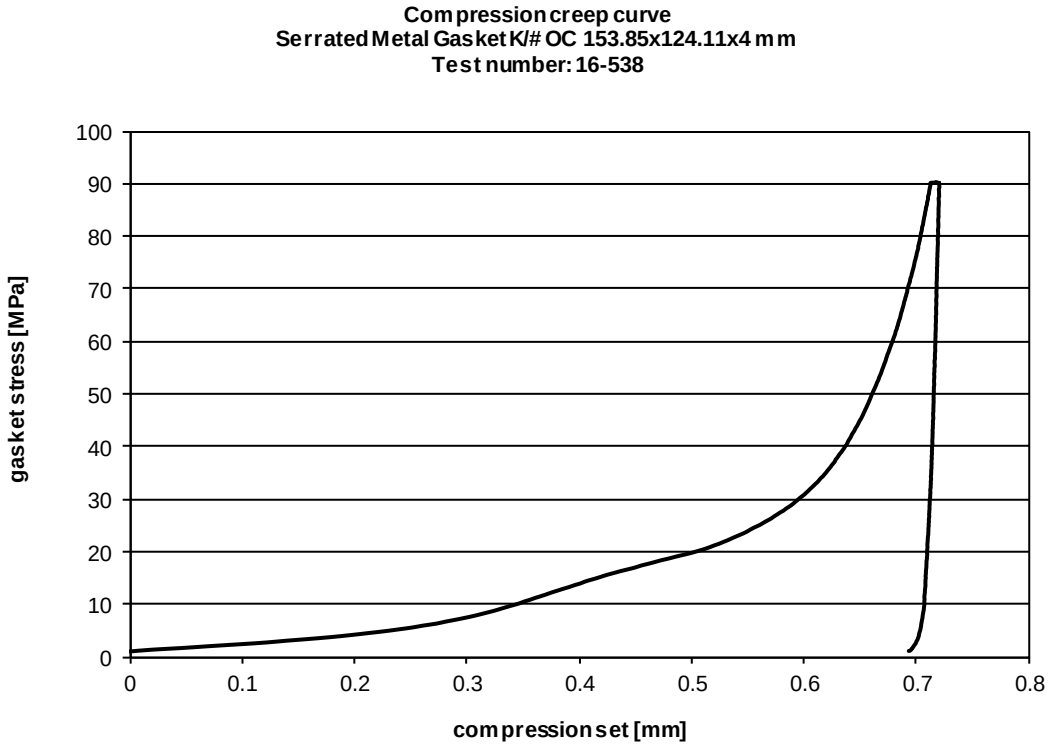
Serrated Metal Gasket K/# OC
153.85x124.11x4 mm
Test number: 16-538

Test parameters

Initial gasket stress Q_i:	90.2	MPa
Test temperature T_P:	25	°C
Time at T_P:	3:59	hh:mm
Stiffness C:	500	kN/mm

Test results

Remaining gasket stress Q_r:	89.9	MPa
Relaxation factor P_{QR} (T_P):	1.00	
Deflection Δe_{Gc}:	3	µm



Creep relaxation test (EN 13555)

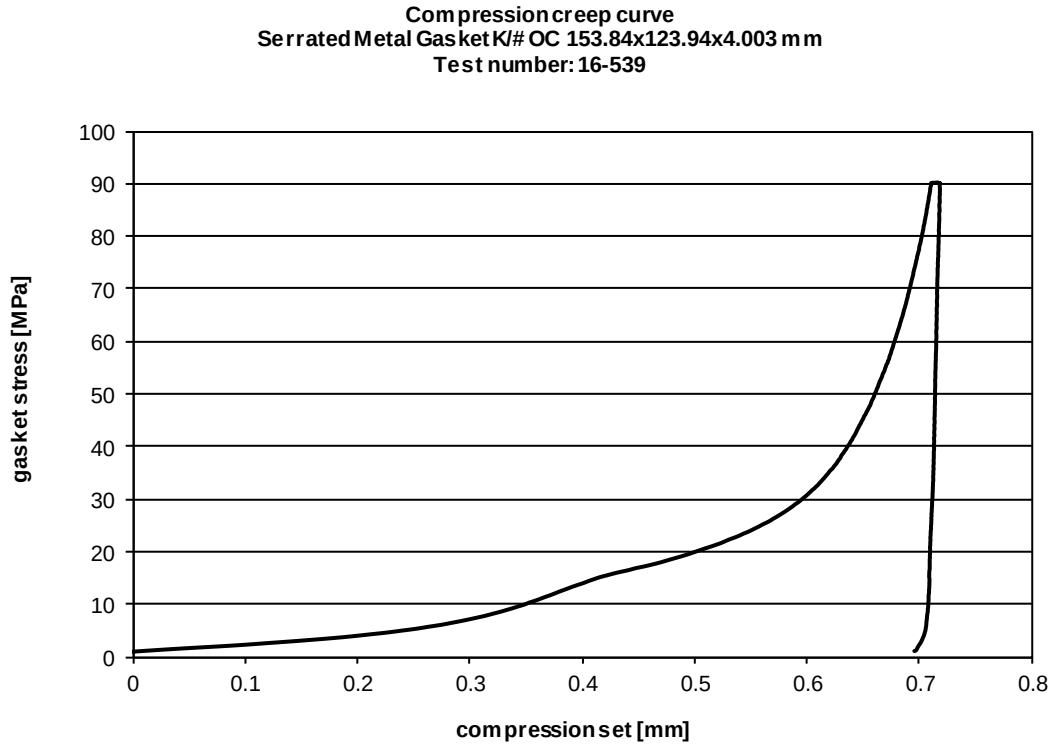
Serrated Metal Gasket K/# OC
153.84x123.94x4.003 mm
Test number: 16-539

Test parameters

Initial gasket stress Q_i:	90.1	MPa
Test temperature T_P:	20	°C
Time at T_P:	3:59	hh:mm
Stiffness C:	500	kN/mm

Test results

Remaining gasket stress Q_r:	89.8	MPa
Relaxation factor $P_{QR}(T_P)$:	1.00	
Deflection Δe_{Gc}:	3	µm



Creep relaxation test (EN 13555)

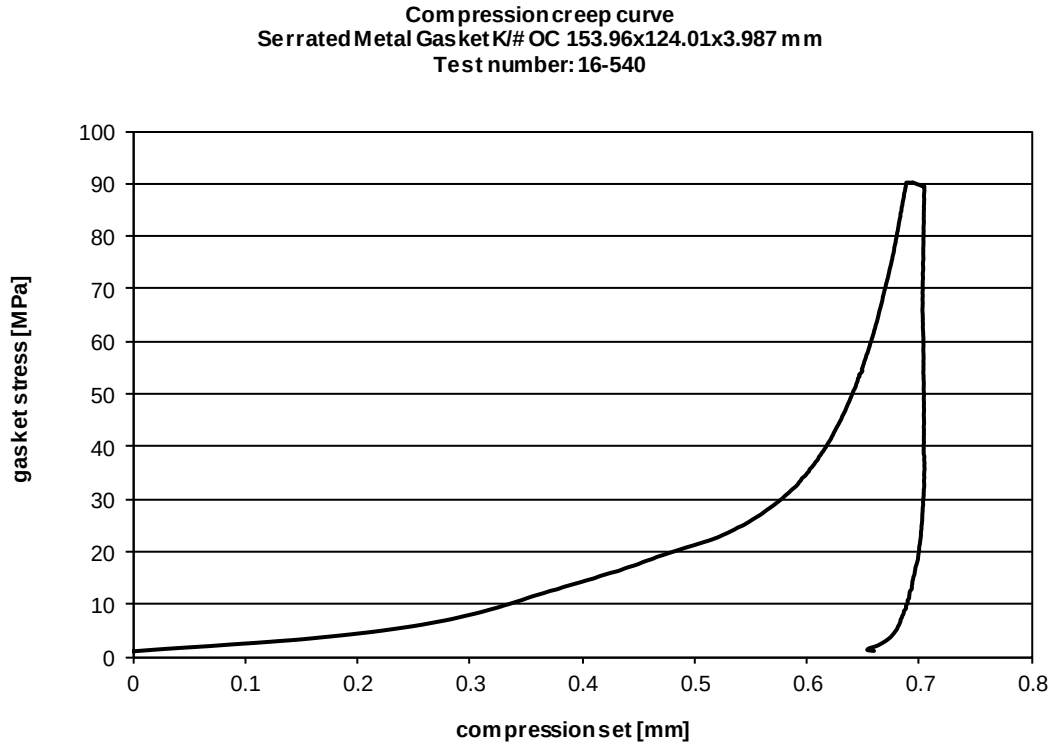
Serrated Metal Gasket K/# OC
153.96x124.01x3.987 mm
Test number: 16-540

Test parameters

Initial gasket stress Q_i:	90.2	MPa
Test temperature T_P:	400	°C
Time at T_P:	4:00	hh:mm
Stiffness C:	500	kN/mm

Test results

Remaining gasket stress Q_r:	89.3	MPa
Relaxation factor $P_{QR}(T_P)$:	0.99	
Deflection Δe_{Gc}:	12	µm



Creep relaxation test (EN 13555)

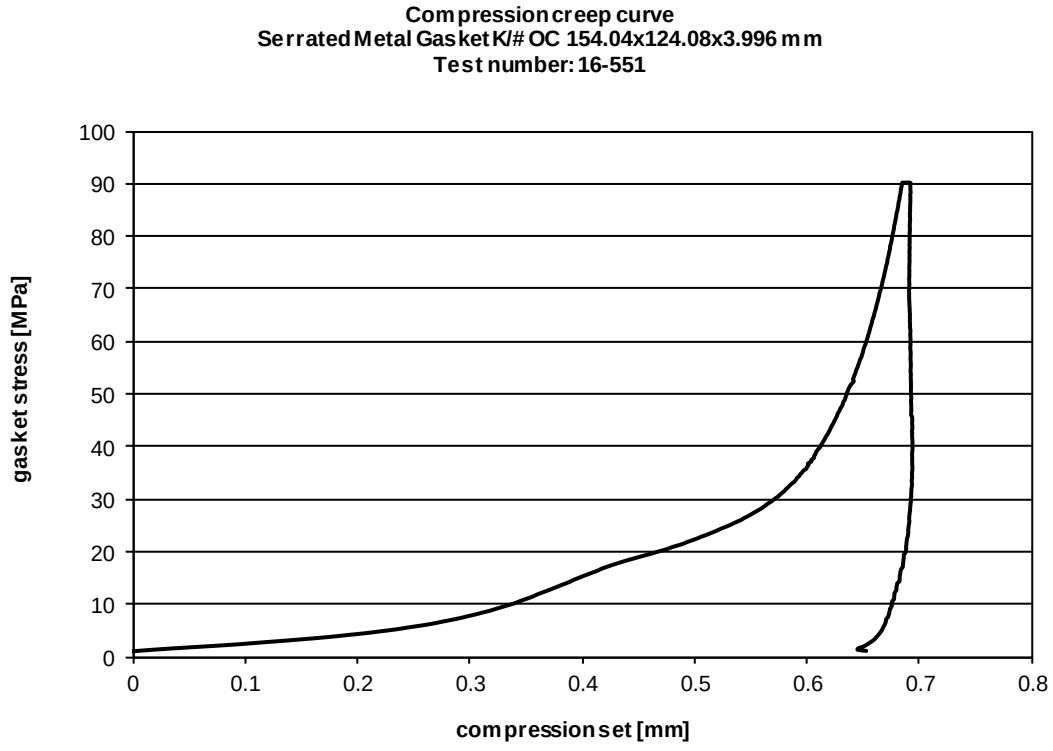
Serrated Metal Gasket K/# OC
154.04x124.08x3.996 mm
Test number: 16-551

Test parameters

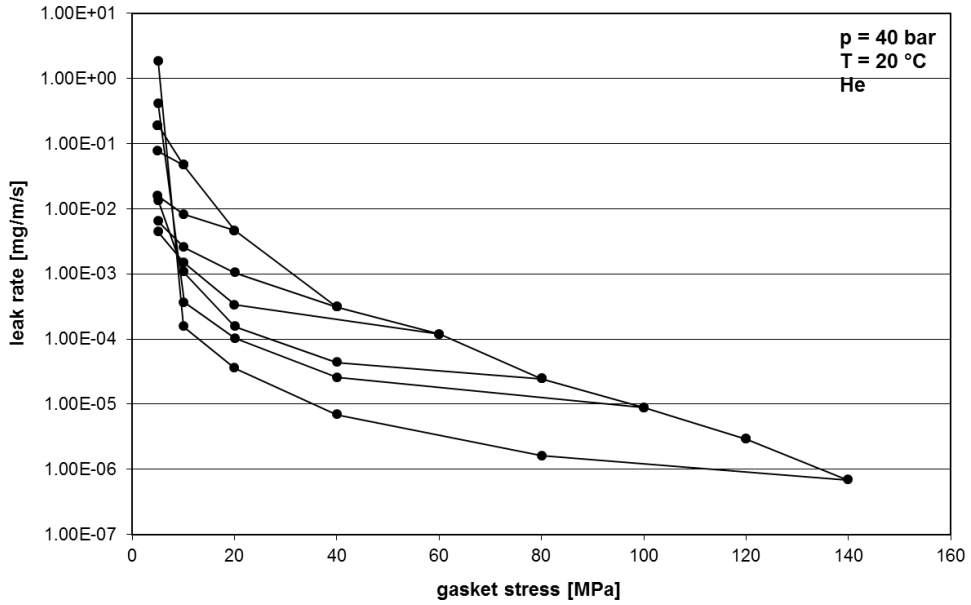
Initial gasket stress Q_i:	90.2	MPa
Test temperature T_P:	400	°C
Time at T_P:	4:00	hh:mm
Stiffness C:	500	kN/mm

Test results

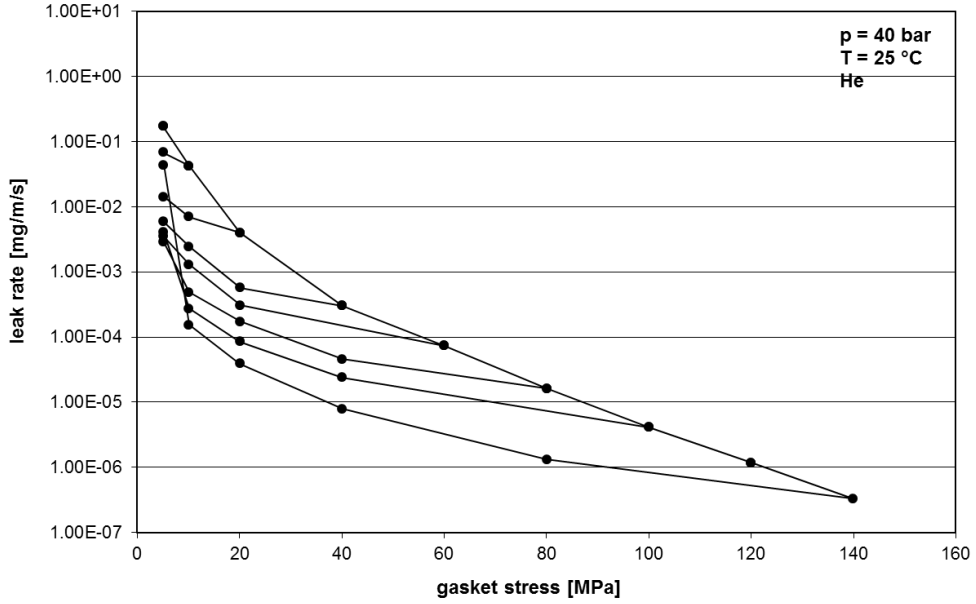
Remaining gasket stress Q_r:	89.9	MPa
Relaxation factor $P_{QR}(T_P)$:	1.00	
Deflection Δe_{Gc}:	4	µm



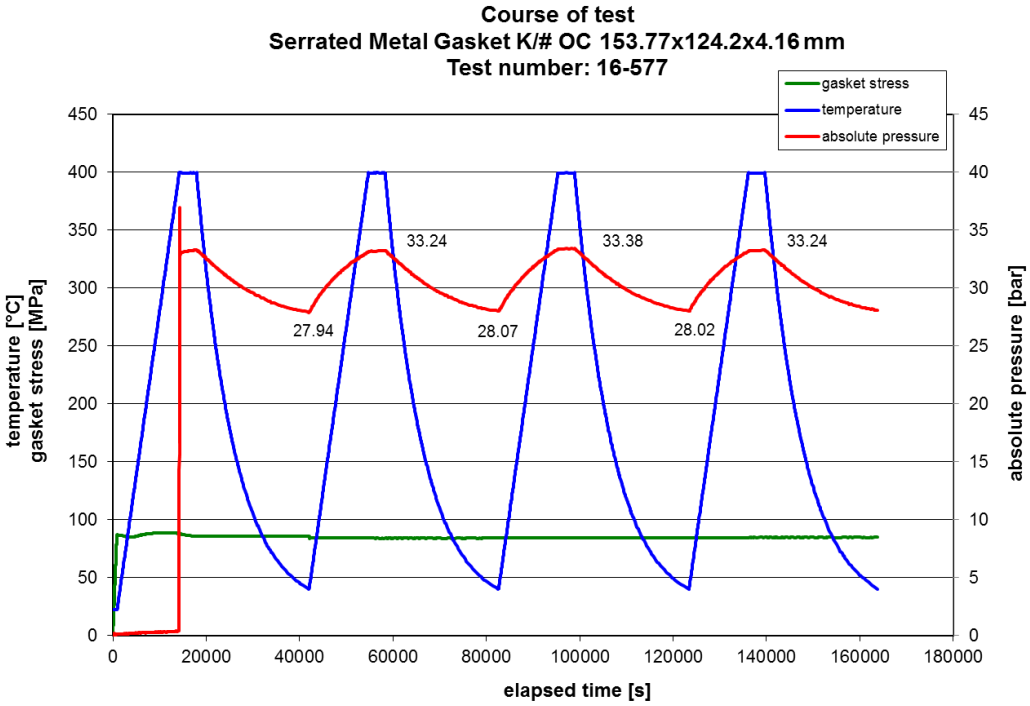
Leakage curve
Serrated Metal Gasket K/# OC 154.11x124.14x3.946 mm
Test number: 16-541



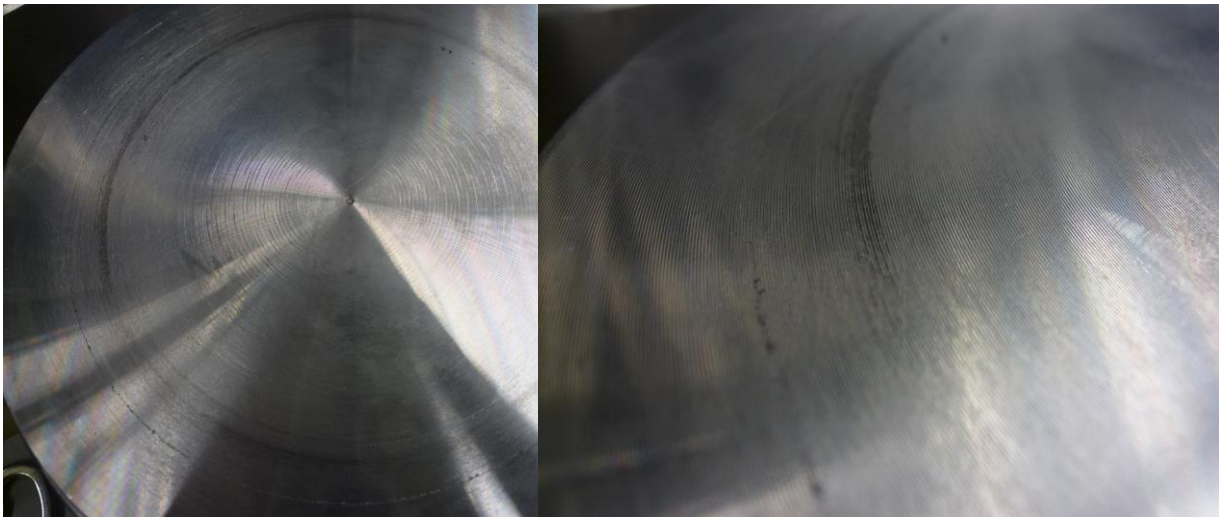
Leakage curve
Serrated Metal Gasket K/# OC 154.06x124.17x3.938 mm
Test number: 16-563



Leakage test according EN 13555

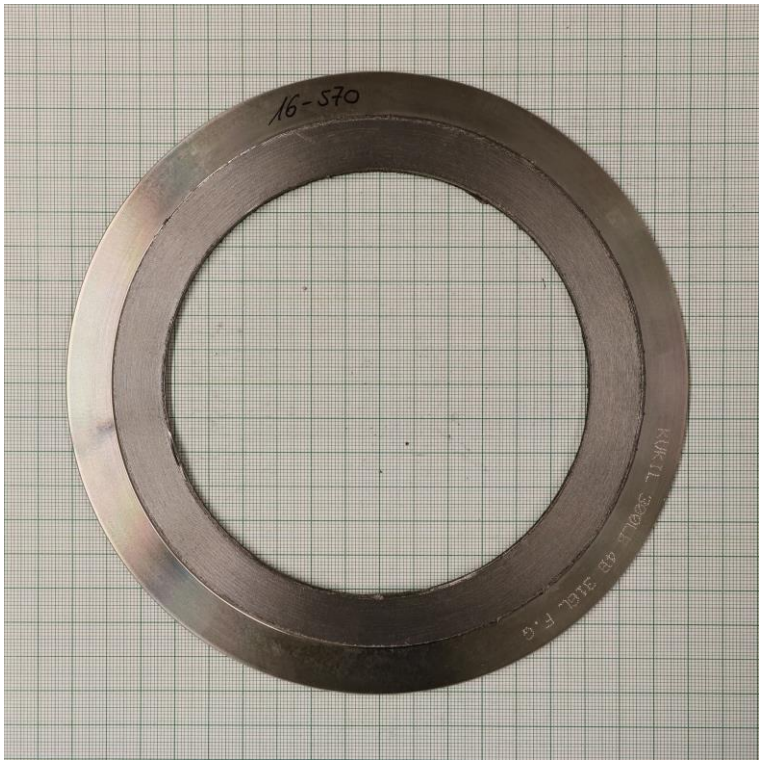


Shell cycle test at 400 °C according MESC SPE 85/300 - 3.3.5

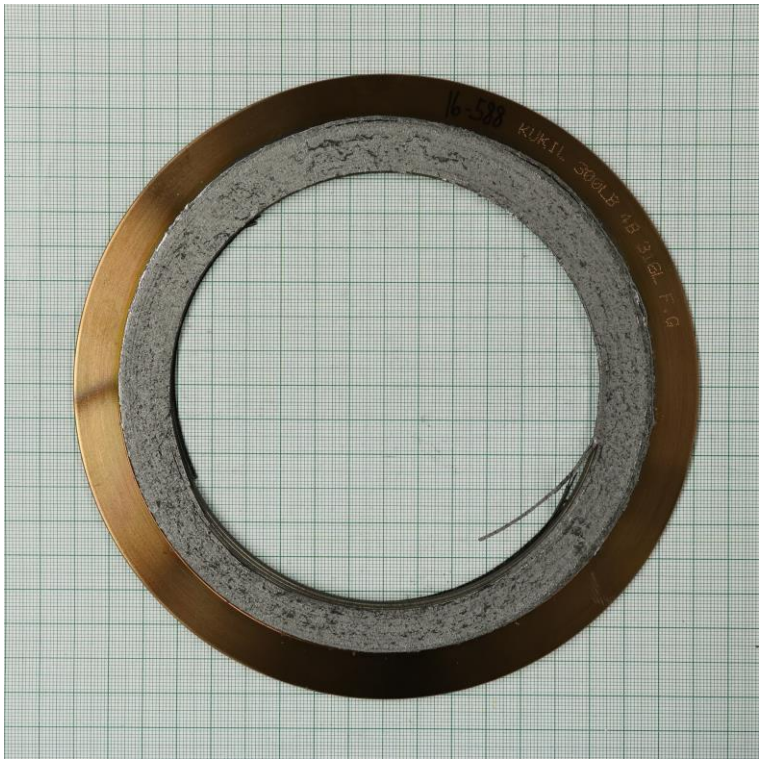


Top flange gasket adhesion

Bottom flange gasket adhesion



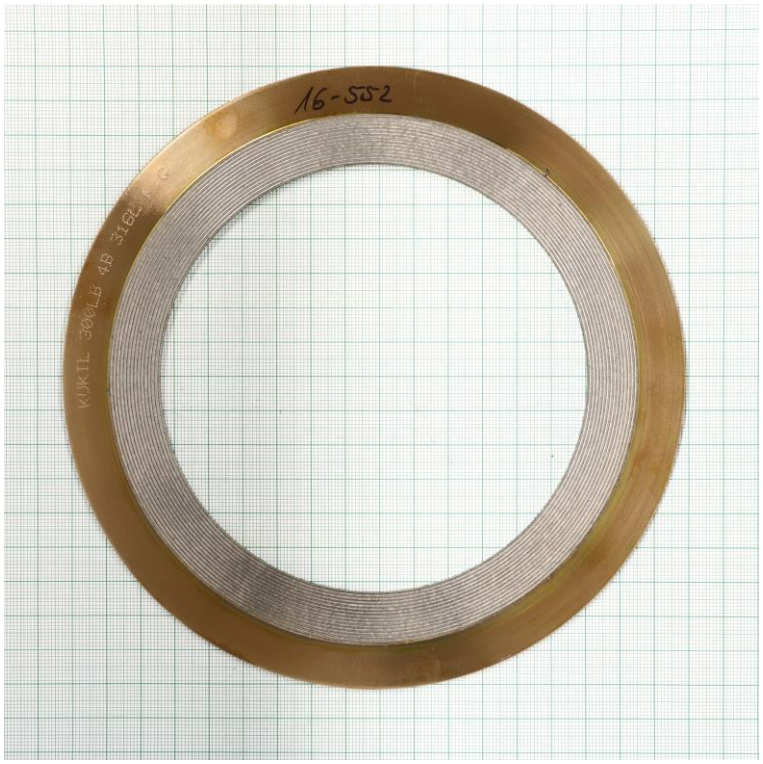
Shell leakage test (RT) according MESC SPE 85/300 - 3.3.2



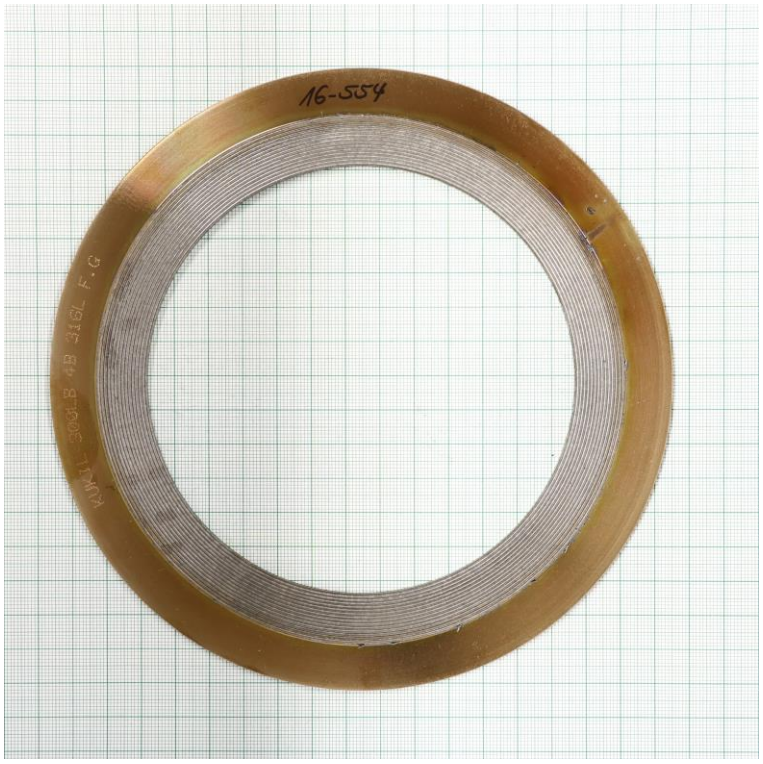
Shell leakage test (T) according MESC SPE 85/300 - 3.3.2

Compression test at RT (EN 13555)

Compression test at RT (EN 13555)



Compression test at 400 °C (EN 13555)



Compression test at 400 °C (EN 13555)

Creep relaxation test at 90 MPa - RT (EN 13555)

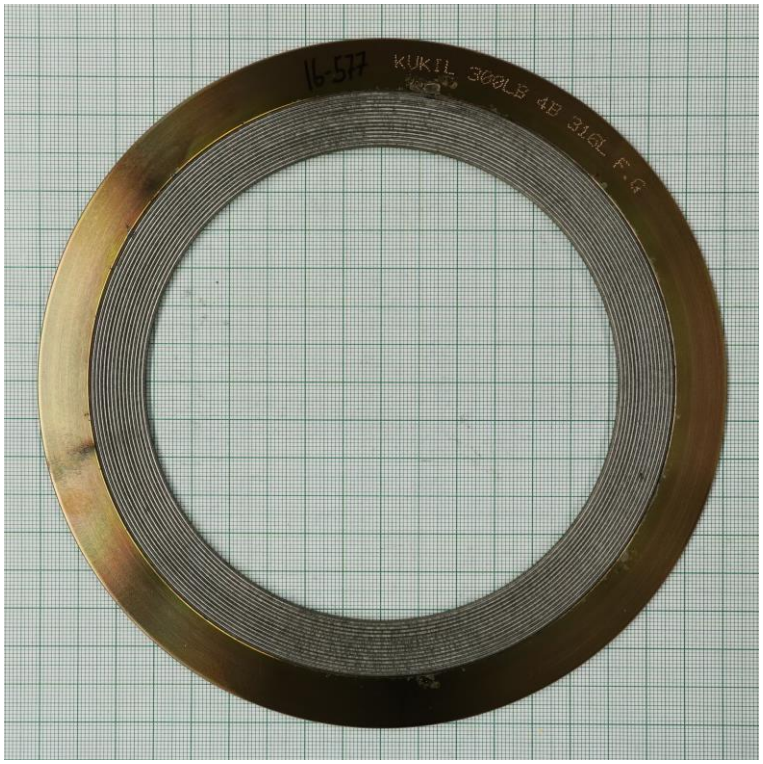
Creep relaxation test at 90 MPa - RT (EN 13555)

Creep relaxation test at 90 MPa - 400 °C (EN 13555)

Creep relaxation test at 90 MPa – 400 °C (EN 13555)

Leakage test at RT (EN 13555)

Leakage test at RT (EN 13555)



Shell cycle test (T) according MESC SPE 85/300 - 3.3.5

Fire test according to API 6FB (MESC SPE 85/300 - 3.3.3)