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Test Report

Customer:	Kukil Inntot Co., Ltd. 17 Tapgeol-gil, KOR - 689-871 Ulsan
Project number (amtec):	303 259
Report number:	303 259 1/c
Test procedure:	Shell Specification MESC SPE 85/300
Material:	Spiral Wound Gasket K/# OSI
Date:	December 23th, 2016
Pages:	13
Appendices:	27

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Test results are only relevant to the test objects submitted.

1. Subject of Investigation

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

- Spiral Wound Gasket K/# OSI.

The spiral wound gasket has an inner and outer ring according to ASME B16.20. The material of the outer ring, the inner ring and the metal strip is 316/316L for all geometries. Flexible graphite is the filler material.

2. Goal of Investigation

The goal of the investigation was the qualification of the gasket material Spiral Wound Gasket K/# OSI 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 = 150.5 mm and ID = 126.0 mm. The thickness of the Spiral Wound Gasket was 4.7 mm.

The thickness of the outer ring was 3.0 mm.

4. Testing Equipment

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

Multifunctional test rig TEMES$_{fl.ai1}$ No.: 010 181, 010 362 and 010 506

Photos and the schematic view of the testing equipment TEMES$_{fl.ai1}$ are shown in **appendix 1**.

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 160 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 118.2 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 149.4 mm and ID of 127 mm of the spiral wound 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} (100 MPa – RT, 400 °C),
- Change in gasket thickness due to creep Δe_{Gc} (100 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 118.2 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 Spiral Wound Gasket K/# OSI 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 10 steps from 70 MPa to 160 MPa. The detected leak rate at 70 MPa gasket stress at an internal pressure of 51 bar was $4.6 \cdot 10^{-7}$ Pa·m³/s/mm, see **appendix 6**. The leak rate was decreasing with increasing gasket stress up to 160 MPa. The leak rate at a gasket stress of 110 MPa, which is equivalent to a bolt stress of 336 MPa, was $4.0 \cdot 10^{-11}$ Pa·m³/mm/s, which is lower than the Tightness Class A.

For the maximum gasket surface stress of 160 MPa the leak rate was $6.4 \cdot 10^{-12}$ 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 90 MPa to 140 MPa. The leak rate at 90 MPa gasket stress at an internal pressure of 34.7 bar could not be measured, see appendix 6. The leak rate at a gasket stress of 110 MPa, which is equivalent to a bolt stress of 336 MPa, was $1.5 \cdot 10^{-8}$ Pa·m³/mm/s, which is a lower than the Tightness Class B.

For the maximum gasket surface stress of 140 MPa the leak rate was also set to $1.5 \cdot 10^{-8}$ Pa·m³/s/mm, which is lower than the Tightness Class B. The leak rate during at stress levels was set to a dummy-value. All the leak rates were below the resolution limit and not measurable even after 24 hours measuring period.

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

In the fire test API 6FB the gasket Spiral Wound Gasket K/# OSI was mounted in a 6" Class 300 flange with hydraulic spanners to a bolt load of 67.5 kN which means a total load of 540.2 kN and a gasket surface stress of 103 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 0.19 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 0.15 ml/inch/min and therefore below the allowable leak rate of 1 ml/inch/min.

The gasket Spiral Wound Gasket K/# OSI 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 Spiral Wound Gasket K/# OSI 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 180 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 180 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 180 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 180 MPa.

The modulus of elasticity E_G at ambient temperature increases nearly linear with increasing gasket stress. For the tests at 400 °C the modulus of elasticity E_G increases also nearly linear with increasing gasket stress, but at a higher level than at ambient temperature.

A good repeatability of the double tests 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} (100 MPa, RT, 500 kN/mm) and
- creep relaxation factor P_{QR} (100 MPa, 400 °C, 500 kN/mm).

In total 4 creep relaxation tests were performed. The initial gasket stress level was set to 100 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 0.99 (100 MPa, RT, 500 kN/mm) and 0.97 resp. 0.98 (100 MPa, 400 °C, 500 kN/mm). The deflection Δe_{Gc} of the gasket Spiral Wound Gasket K/# OSI at RT is 10 µm resp. 11 µm and in tests at 400 °C is 30 µm resp. 21 µm.

A good repeatability of the double test is noticeable.

6.3.3 Leakage tests

The tightness behaviour of the gasket material Spiral Wound Gasket K/# OSI 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 23 MPa or 24 MPa, respectively. Therefore the minimum gasket stress in assembly for the tightness class $L_{0.01}$ is set to $Q_{min(0.01)}$ = 24 MPa. The lowest tightness class which could be reached was $L_{0.00001}$; therefore a gasket stress of 155 MPa resp. 147 MPa is necessary.

The leak rate is decreasing with an increasing gasket stress up to 160 MPa. The lowest leak rate which could be measured was $3.0 \cdot 10^{-6}$ mg/m/s at 160 MPa in test 16-567.

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 no drastic increase of the leak rate (or sudden blow-out) is observed.

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 $Q_{smin(0.01)}$ = 9 MPa in both tests.

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 spiral wound gasket was compressed initially with 118.2 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 only a slight pressure drop could be measured, see **appendix 19**.

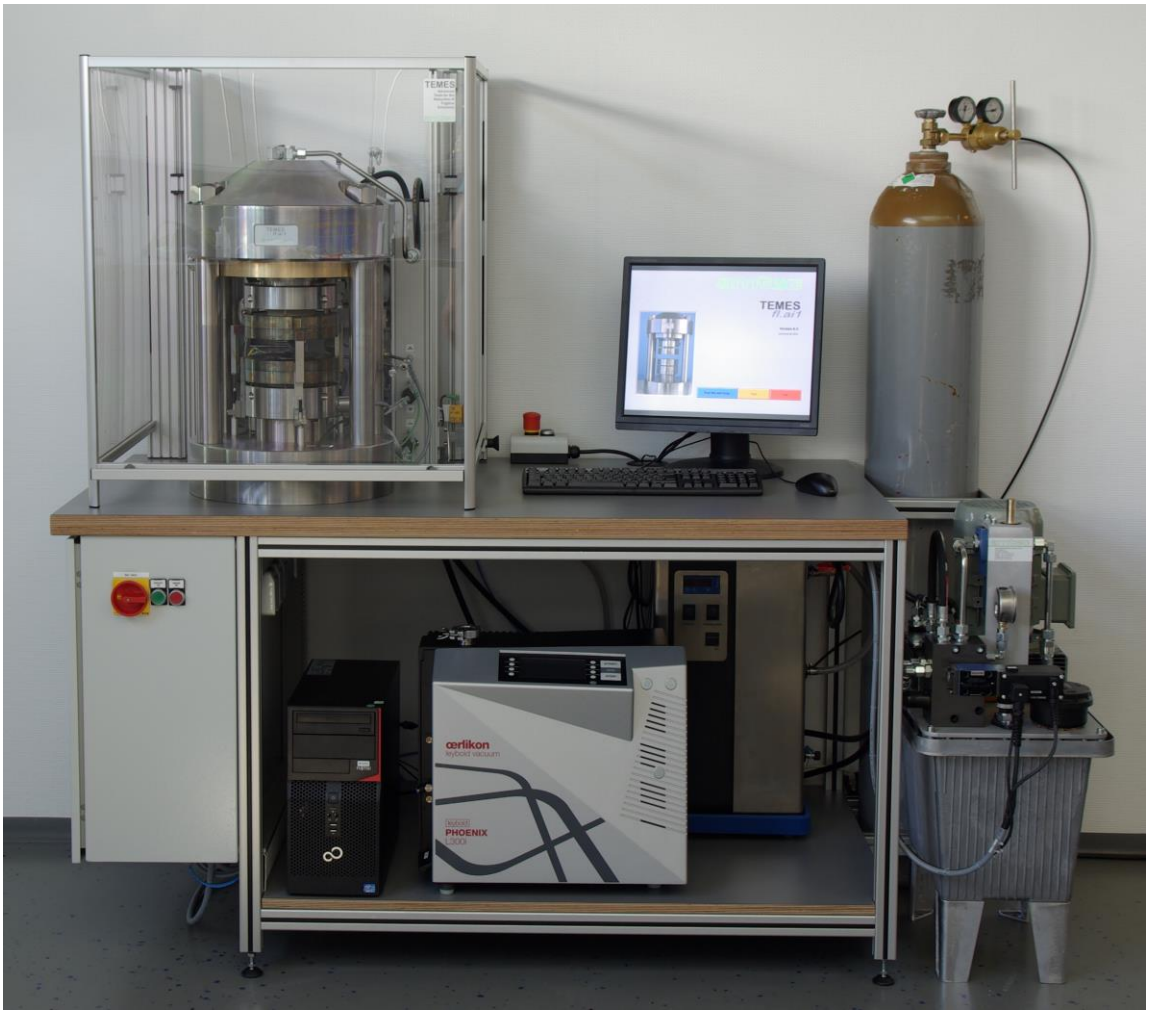
During the last thermal cycle the pressure loss is less than 0.1 bar. The gasket material Spiral Wound Gasket K/# OSI has passed the Shell requirement of a pressure drop less than 1 bar.

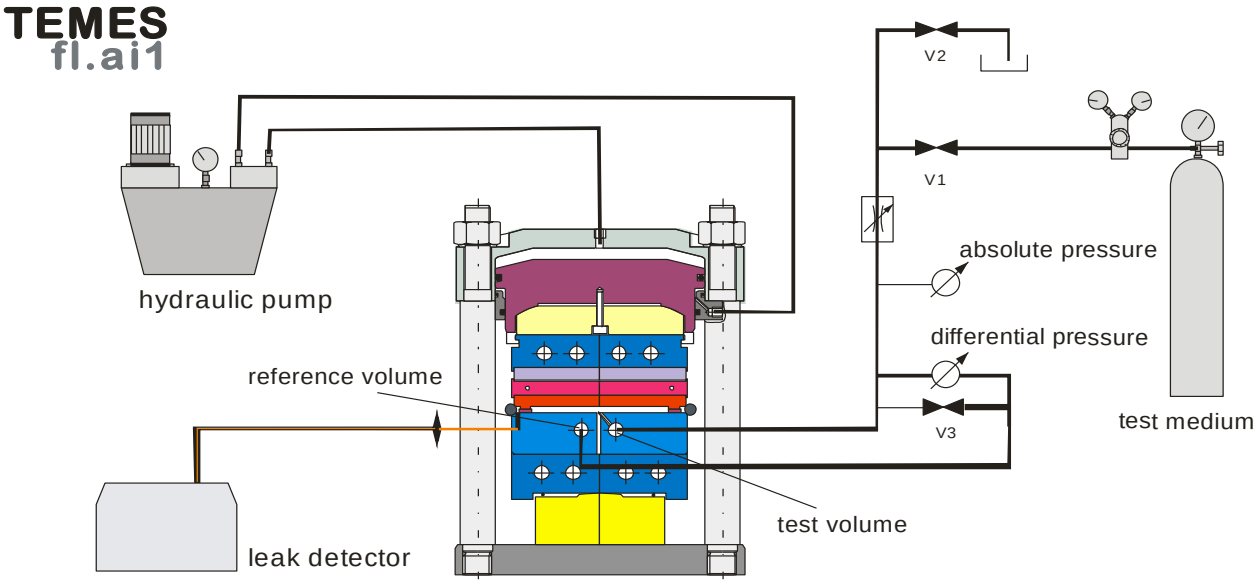
6.5 Gasket adhesion (MESC SPE 85/300 – 3.3.13)

In **appendices 19 and 20** photos of the adjacent flanges after tests at ambient temperature with the gasket specimen's Spiral Wound Gasket K/# OSI are represented. The gasket does not stick on the flange. No traces of filler 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 Spiral Wound Gasket K/# OSI for the different test procedures are presented.





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: **Spiral Wound Gasket K/# OSI**

Maximum allowable Gasket Stress Q_{smax} [MPa]

T [°C]	25	25	400	400
Q_{smax} [MPa]	180	180	180	180
Test #	16-547	16-548	16-559	16-564

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		4.750		4.660		4.700		4.710
1		4.707		4.658		4.719		4.712
20	2185	4.587	2161	4.548	2734	4.605	2616	4.604
30	2866	4.541	2969	4.507	4477	4.565	4683	4.567
40	3858	4.491	3838	4.452	6339	4.510	6589	4.515
50	4742	4.427	4739	4.378	8830	4.449	8940	4.454
60	5457	4.347	5539	4.300	10754	4.377	12036	4.389
80	7451	4.188	7334	4.148	15261	4.202	16510	4.238
100	9765	4.005	9429	3.979	20069	3.995	20947	4.045
120	11680	3.878	11711	3.858	24238	3.871	25225	3.904
140	11233	3.763	13384	3.767	29207	3.782	27504	3.797
160	13175	3.665	15721	3.695	32764	3.712	26961	3.712
180	14816	3.578	16363	3.640	34186	3.653	23144	3.635
Test #	16-547		16-548		16-559		16-564	

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
	100	0.99	0.99	0.97	0.98
	Δe_{GC} [µm]	10	11	30	21
	Test #	16-550	16-555	16-558	16-562

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

Manufacturer: Kukil Inntot Co., Ltd.

Product: **Spiral Wound Gasket K/# OSI**

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	10	10	13	23	48	115	155	-	-
Test #	16-566								
40	10	10	13	24	46	110	147	-	-
Test #	16-567								

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	8	-	-	-	-	-	-	-
	20	5	5	8	-	-	-	-	-	-
	40	5	5	5	10	-	-	-	-	-
	60	5	5	5	9	36	-	-	-	-
	80	5	5	5	9	17	-	-	-	-
	100	5	5	5	9	17	-	-	-	-
	160	5	5	5	5	9	38	127	-	-
	Test #	16-566								

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	8	-	-	-	-	-	-	-
	20	5	5	9	-	-	-	-	-	-
	40	5	5	5	9	-	-	-	-	-
	60	5	5	5	9	27	-	-	-	-
	80	5	5	5	8	17	-	-	-	-
	100	5	5	5	8	16	-	-	-	-
	160	5	5	5	6	9	29	72	-	-
	Test #	16-567								

Table 3: Data Sheet for Gasket Characteristics ()

Manufacturer: Kukil Inntot Co., Ltd.

Product: **Spiral Wound Gasket K/# OSI**

Shell leakage test at ambient temperature

Test pressure:	51	bar
Shell required gasket stresss level:	110	MPa
Leakage rate:	3.96E-11	Pa·m³/s/mm
Shell tightness class:	A	
test no.	16-652	

Shell leakage test at 400 °C

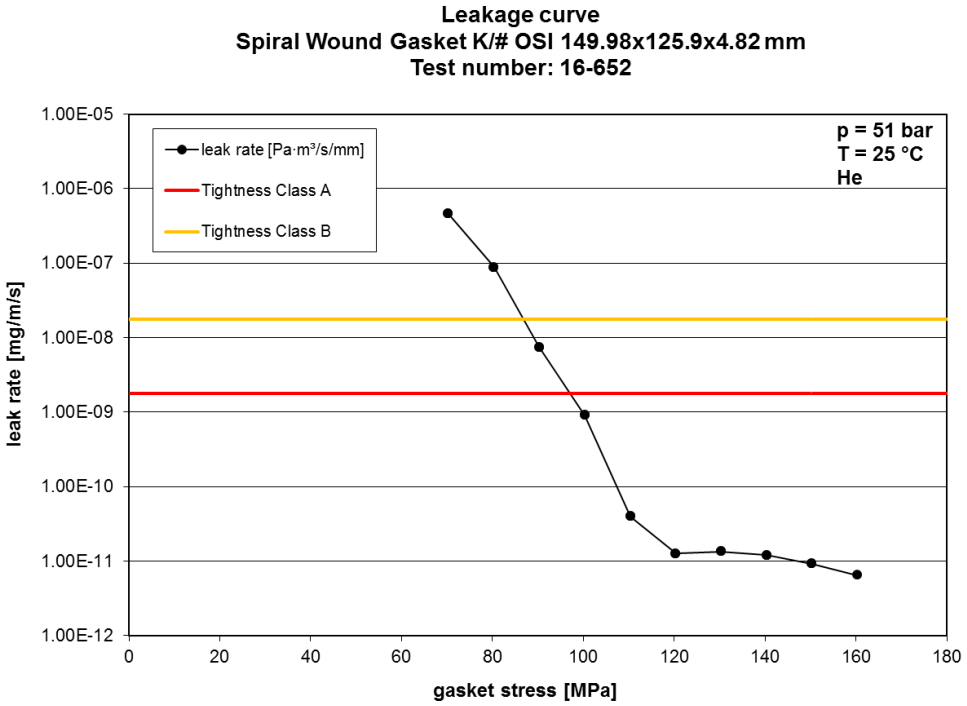
Test pressure:	34.7	bar
Shell required gasket stresss level:	110	MPa
Leakage rate:	1.50E-08	Pa·m³/s/mm
Shell tightness class:	B	
test no.	16-663	

Shell cycle test at 400 °C

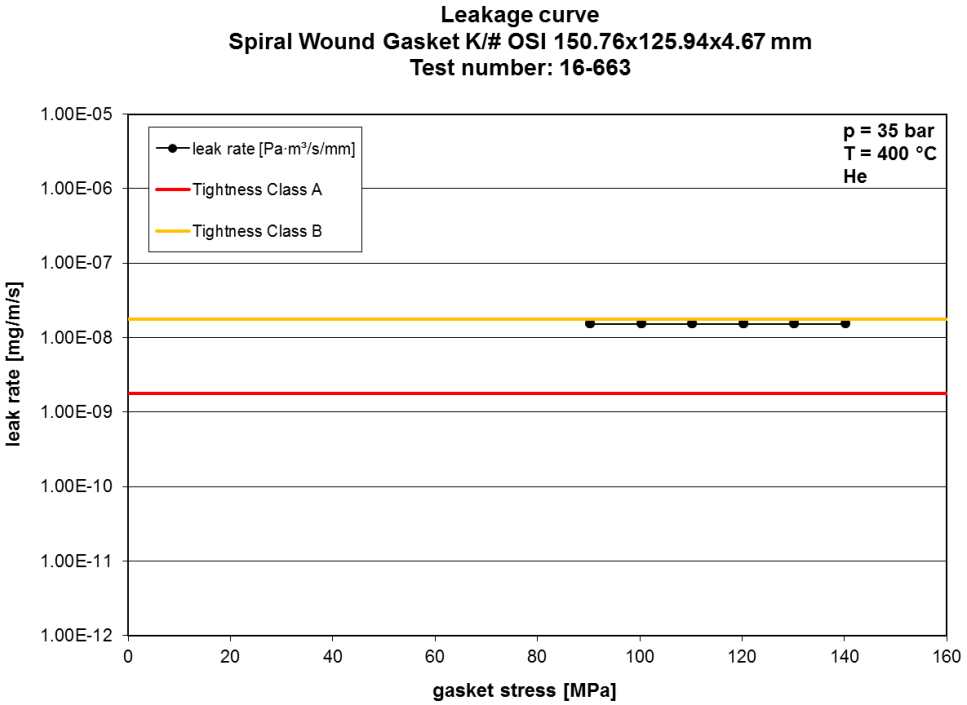
Test pressure:	43.8	bar
Initial gasket stress level:	118.2	MPa
Pressure drop in last cycle:	no	
Requirements	passed	
test no.	16-574	

Fire test API 6FB

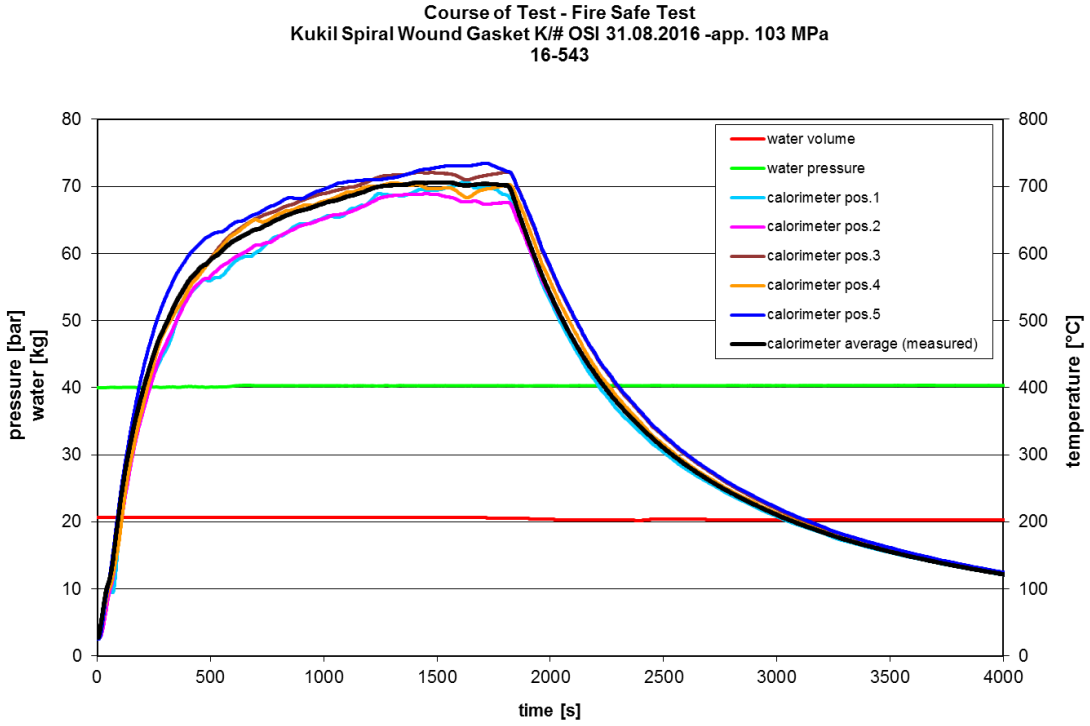
Test pressure:	40	bar
Initial gasket stress level:	103	MPa
Leak rate (complete test):	0.15	ml/inch/min
Requirements	passed	
test no.	16-543	



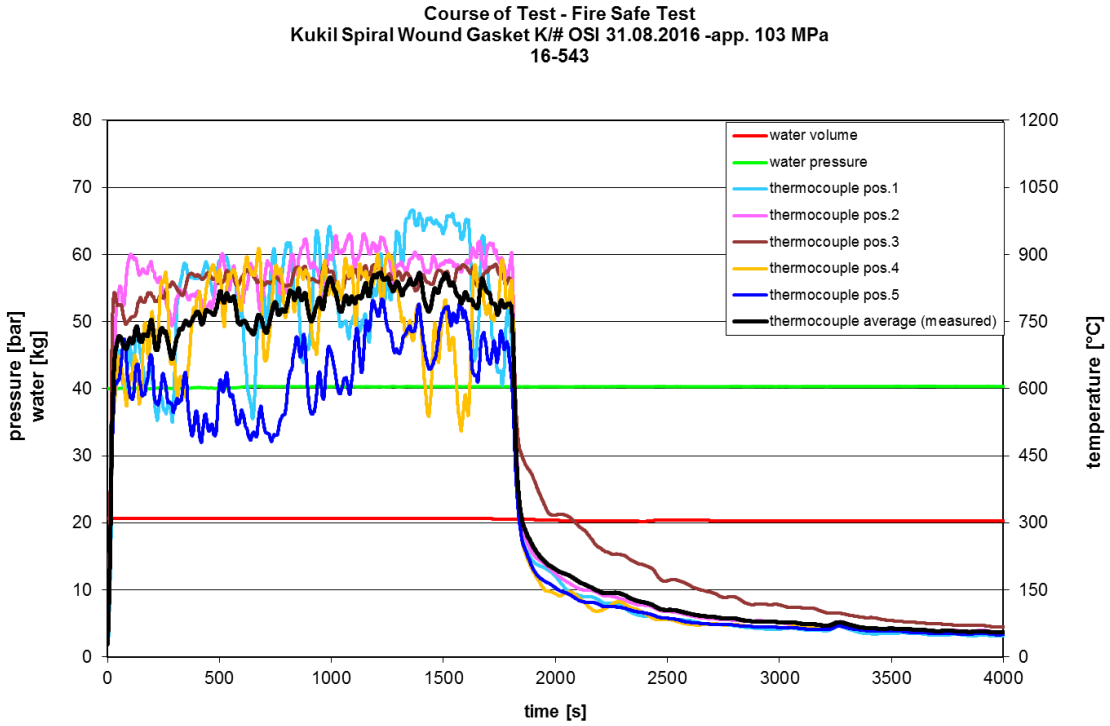
Shell leakage test (RT) according MESC SPE 85/300 - 3.3.2



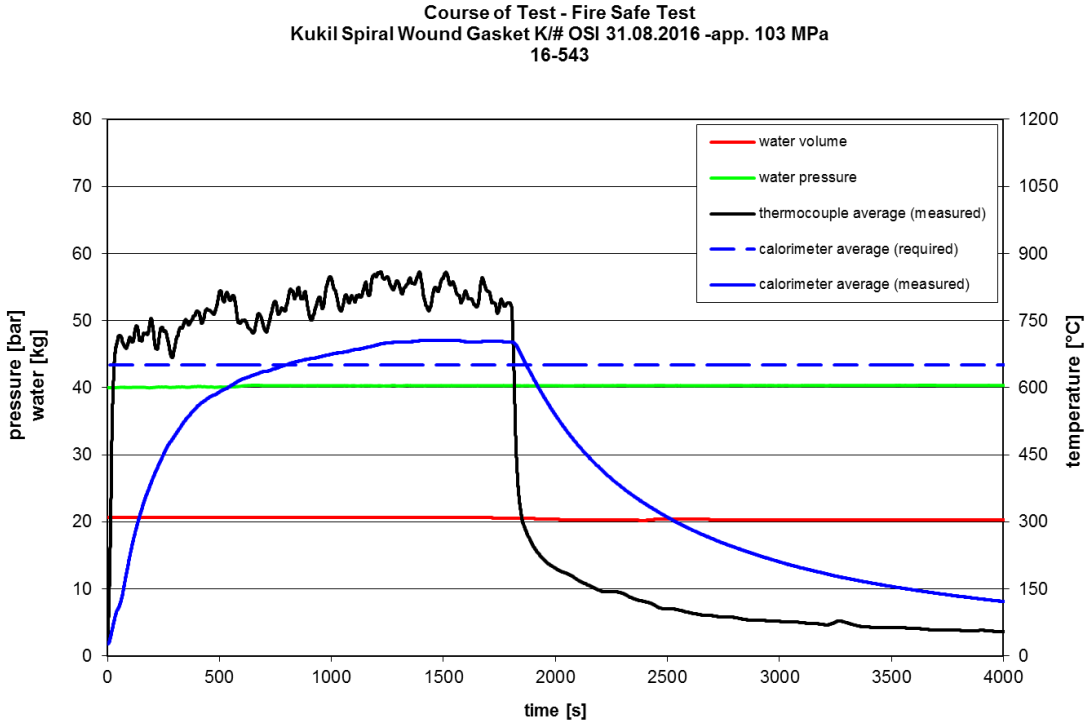
Shell leakage test (400 °C) according MESC SPE 85/300 - 3.3.2



3.3.3 Fire test API 6FB - calorimeters



3.3.3 Fire test API 6FB – thermocouples



3.3.3 Fire test API 6FB

Spiral Wound Gasket K/# OSI

geometries

bolts	8	-
OD gasket	150.1	mm
ID gasket	125.9	mm
mean gasket circumference contact area	433.5	mm
gasket area	5245.8	mm²
gasket contact area	5245.8	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	**512.05**	**ml**

calculation of gasket stress

hydraulic spanners - No.	GS 3/1	-
calibration factor	0.19	kN/bar
pressure	365	bar
force per bolt	67.53	kN
force total	540.20	kN
gasket stress	102.98	MPa

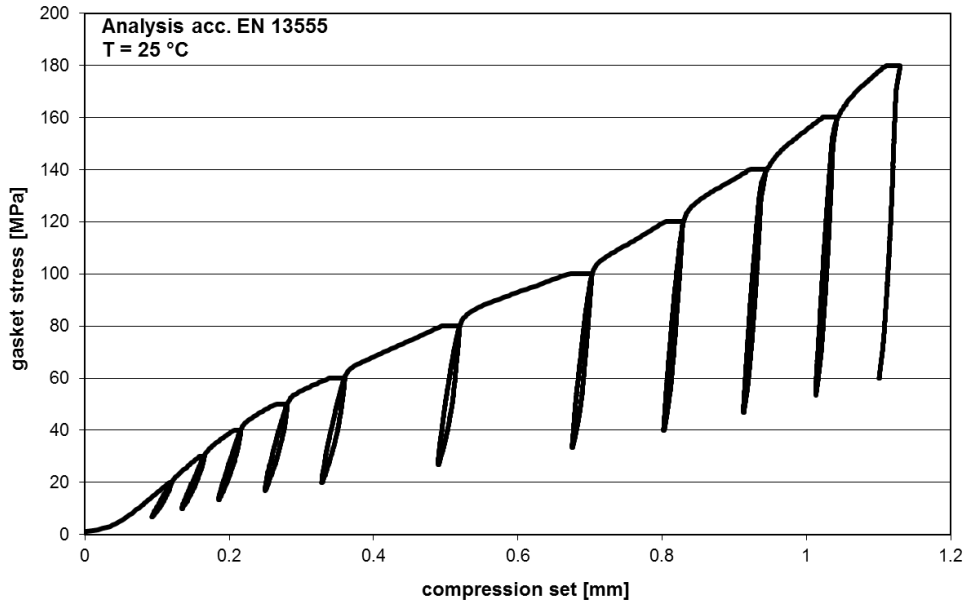
calculation of leak rate of complete test

start value scale	20.63	kg
end value scale	20.23	kg
start test	11:21:02	
end test	13:56:20	
test duration (min)	155.30	min
leakage	401.20	ml
leak rate	**0.15**	**ml / inch / min**

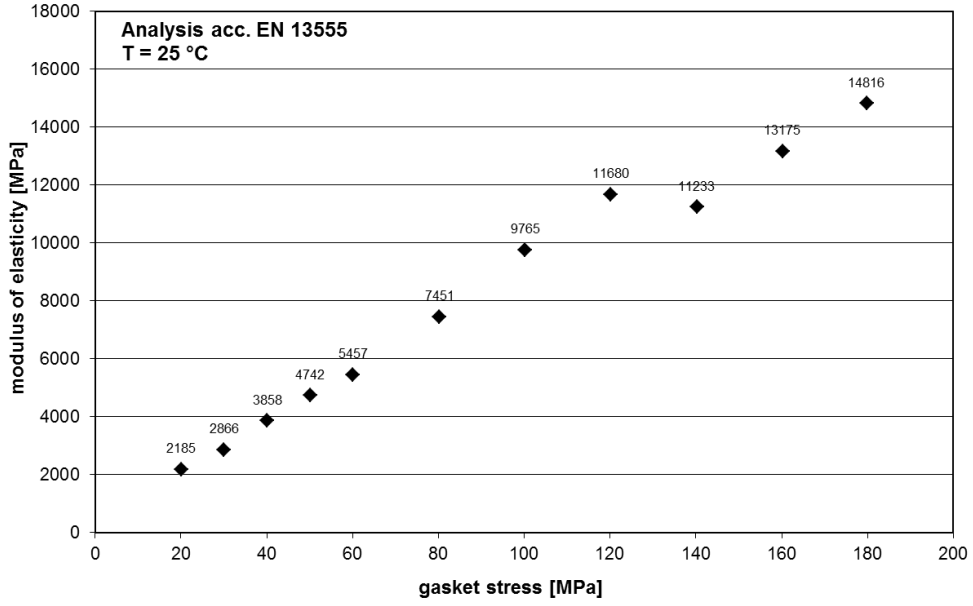
calculation of leak rate of burning period

start value scale	20.63	kg
end value scale	20.53	kg
start test	11:21:02	
end test	11:51:02	
test duration (min)	30	min
leakage	98.90	ml
leak rate	**0.19**	**ml / inch / min**

Compression curve
Spiral Wound Gasket K/# OSI 150.34x125.64x4.707 mm
Test number: 16-547

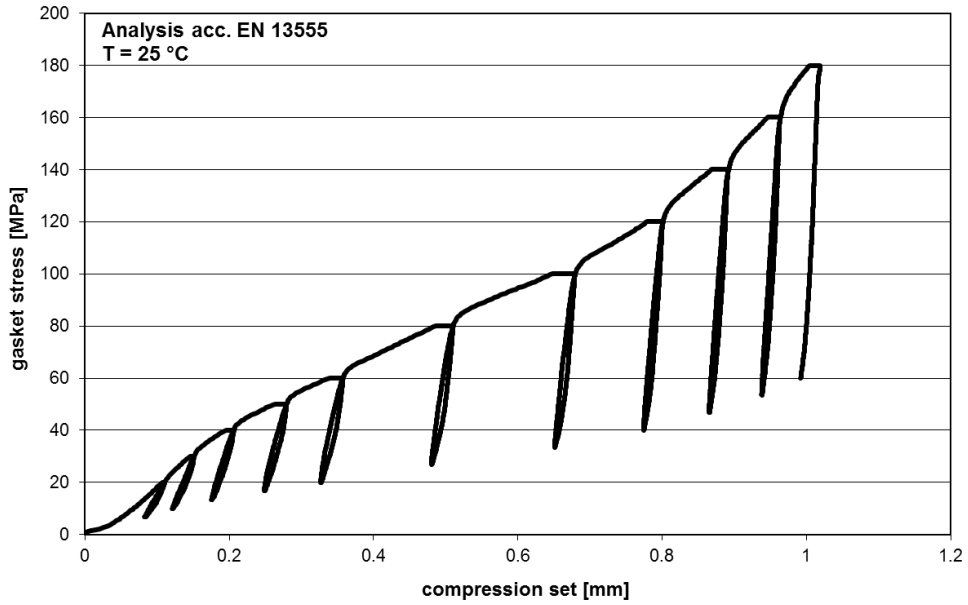


Modulus of elasticity
Spiral Wound Gasket K/# OSI 150.34x125.64x4.707 mm
Test number: 16-547

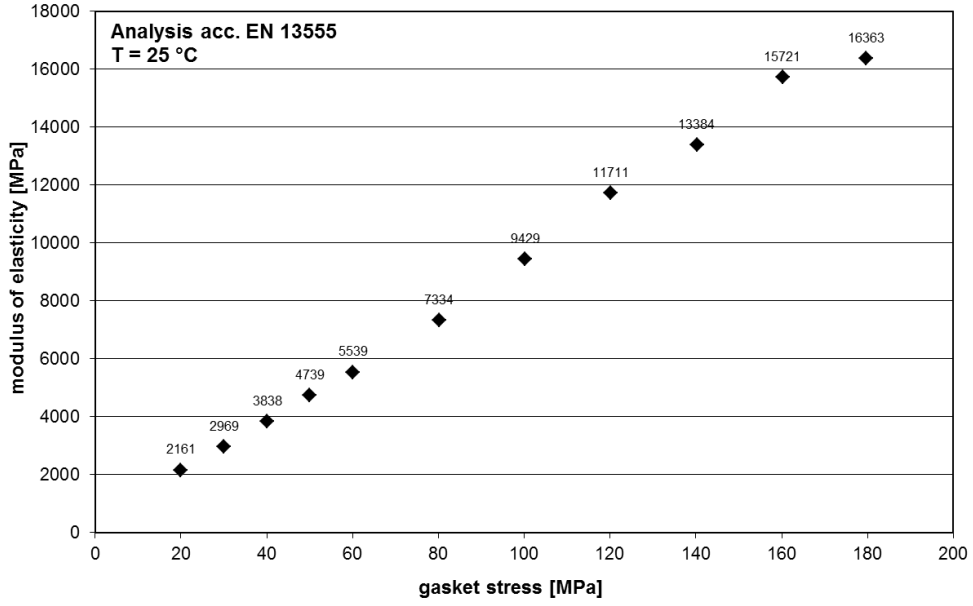


Compression test (RT) according EN 13555

Compression curve
Spiral Wound Gasket K/# OSI 150.52x125.63x4.658 mm
Test number: 16-548

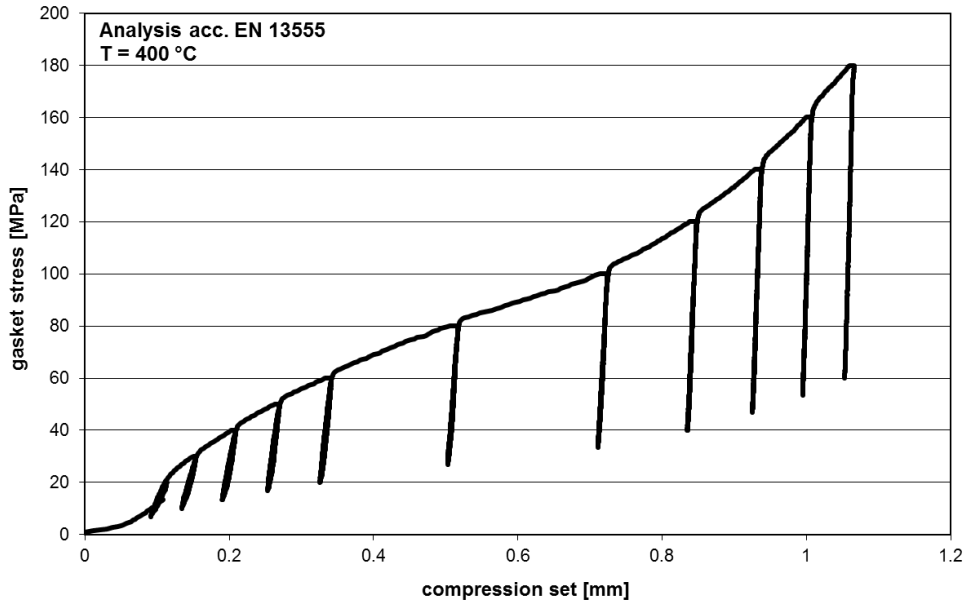


Modulus of elasticity
Spiral Wound Gasket K/# OSI 150.52x125.63x4.658 mm
Test number: 16-548

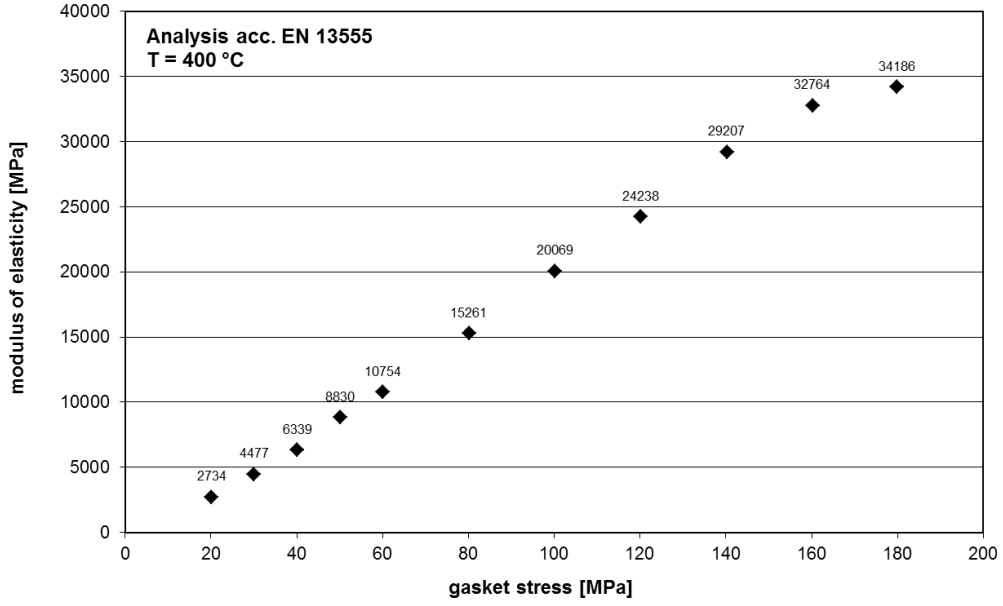


Compression test (RT) according EN 13555

Compression curve
Spiral Wound Gasket K/# OSI 150.43x125.95x4.719 mm
Test number: 16-559

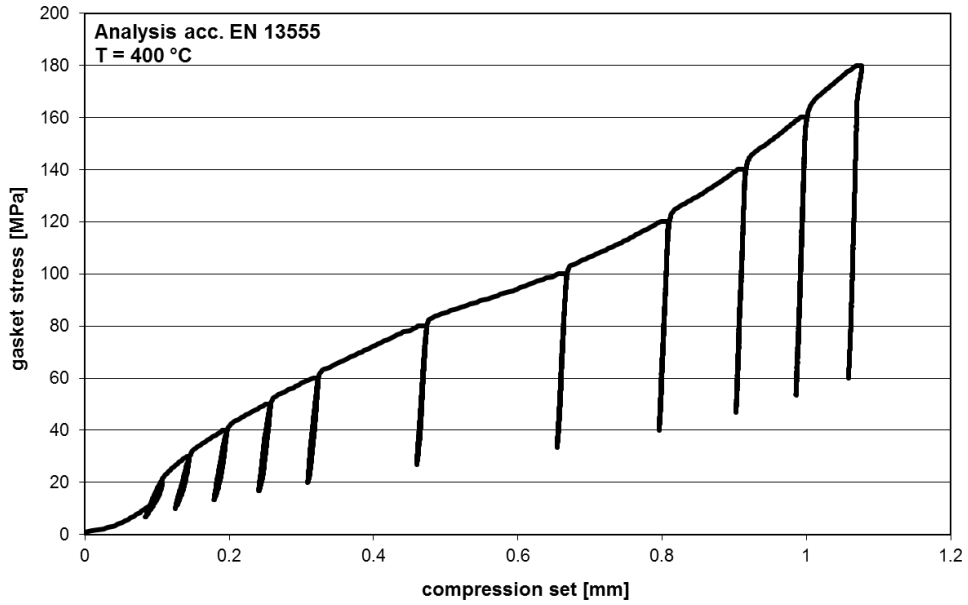


Modulus of elasticity
Spiral Wound Gasket K/# OSI 150.43x125.95x4.719 mm
Test number: 16-559

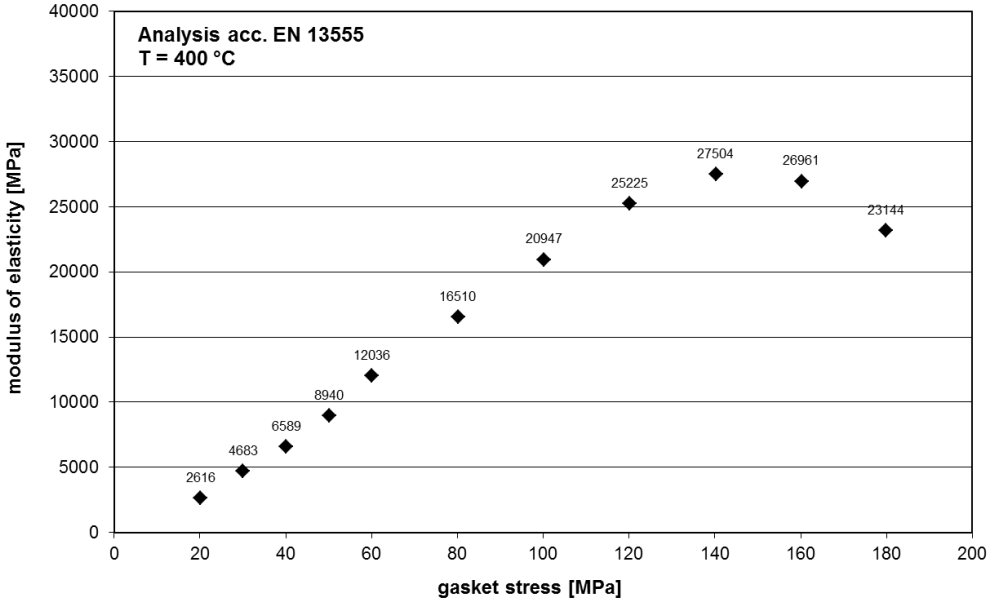


Compression test at 400 °C according EN 13555

Compression curve
Spiral Wound Gasket K/# OSI 150.55x125.98x4.712 mm
Test number: 16-564



Modulus of elasticity
Spiral Wound Gasket K/# OSI 150.55x125.98x4.712 mm
Test number: 16-564



Compression test at 400 °C according EN 13555

Creep relaxation test (EN 13555)

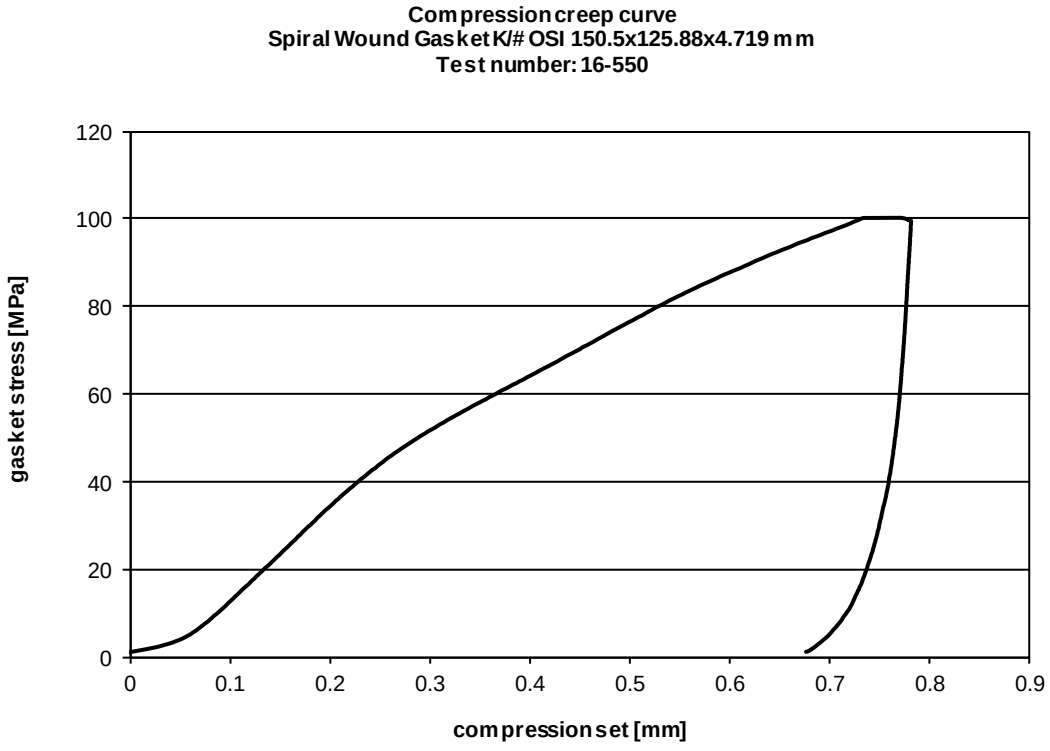
Spiral Wound Gasket K/# OSI
150.5x125.88x4.719 mm
Test number: 16-550

Test parameters

Initial gasket stress Q_i:	100.2	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:	99.3	MPa
Relaxation factor $P_{QR}(T_P)$:	0.99	
Deflection Δe_{Gc}:	10	µm



Creep relaxation test (EN 13555)

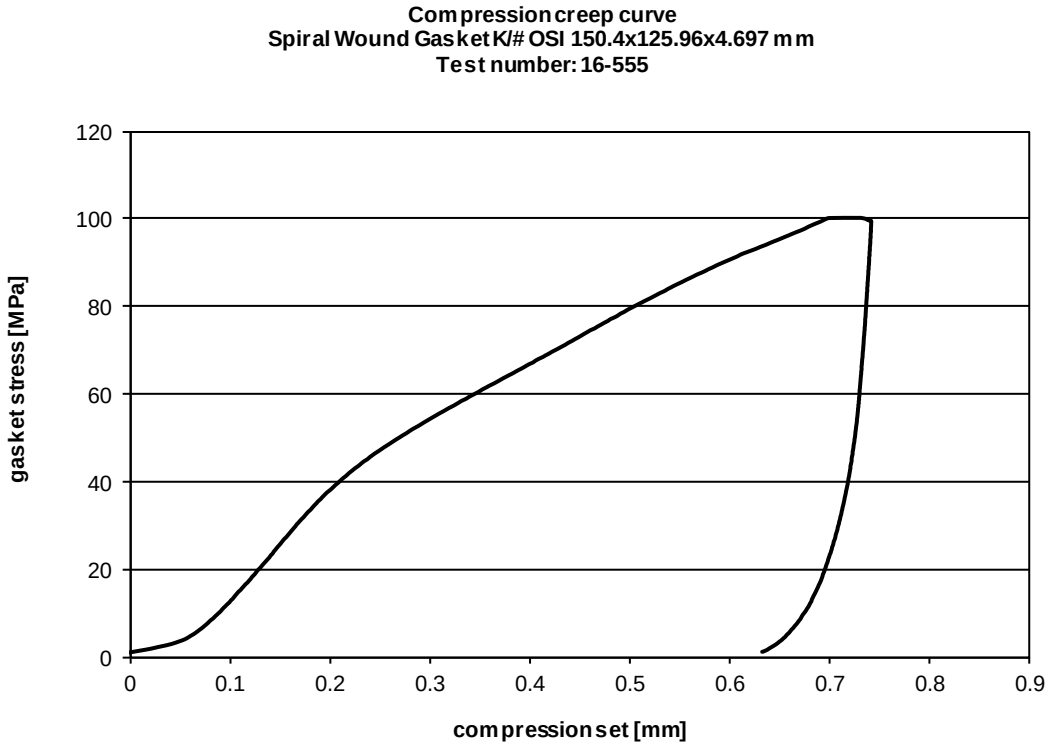
Spiral Wound Gasket K/# OSI
150.4x125.96x4.697 mm
Test number: 16-555

Test parameters

Initial gasket stress Q_i:	100.2	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:	99.2	MPa
Relaxation factor P_{QR} (T_P):	0.99	
Deflection Δe_{Gc}:	11	µm



Creep relaxation test (EN 13555)

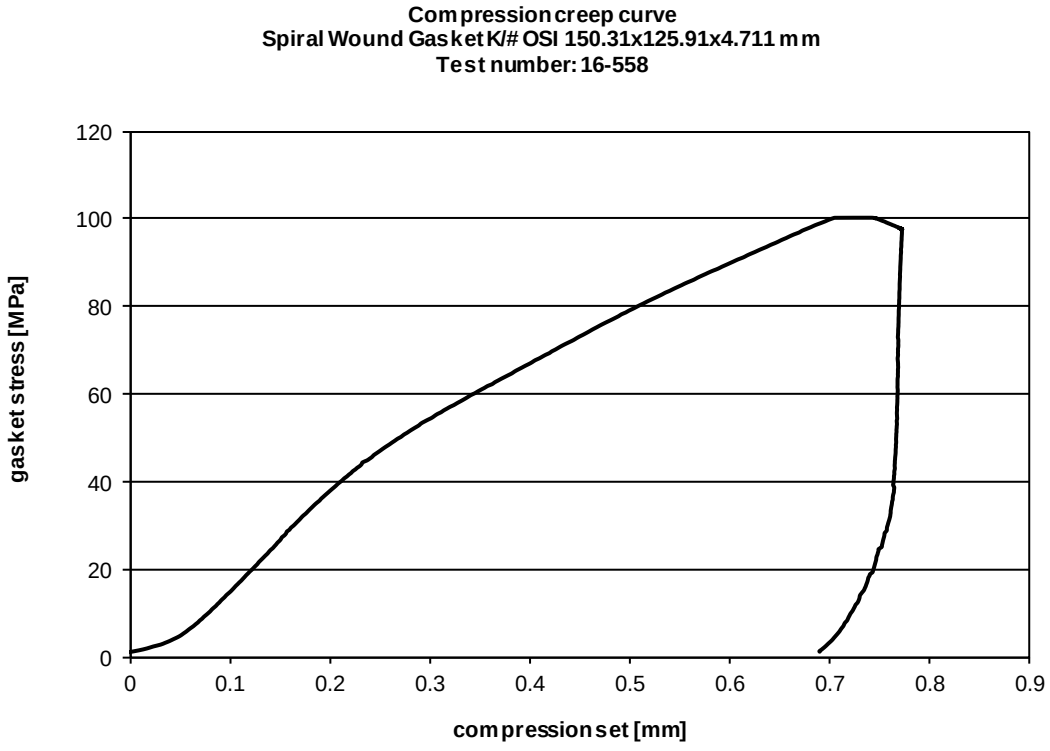
Spiral Wound Gasket K/# OSI
150.31x125.91x4.711 mm
Test number: 16-558

Test parameters

Initial gasket stress Q_i:	100.2	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:	97.4	MPa
Relaxation factor $P_{QR}(T_P)$:	0.97	
Deflection Δe_{Gc}:	30	µm



Creep relaxation test (EN 13555)

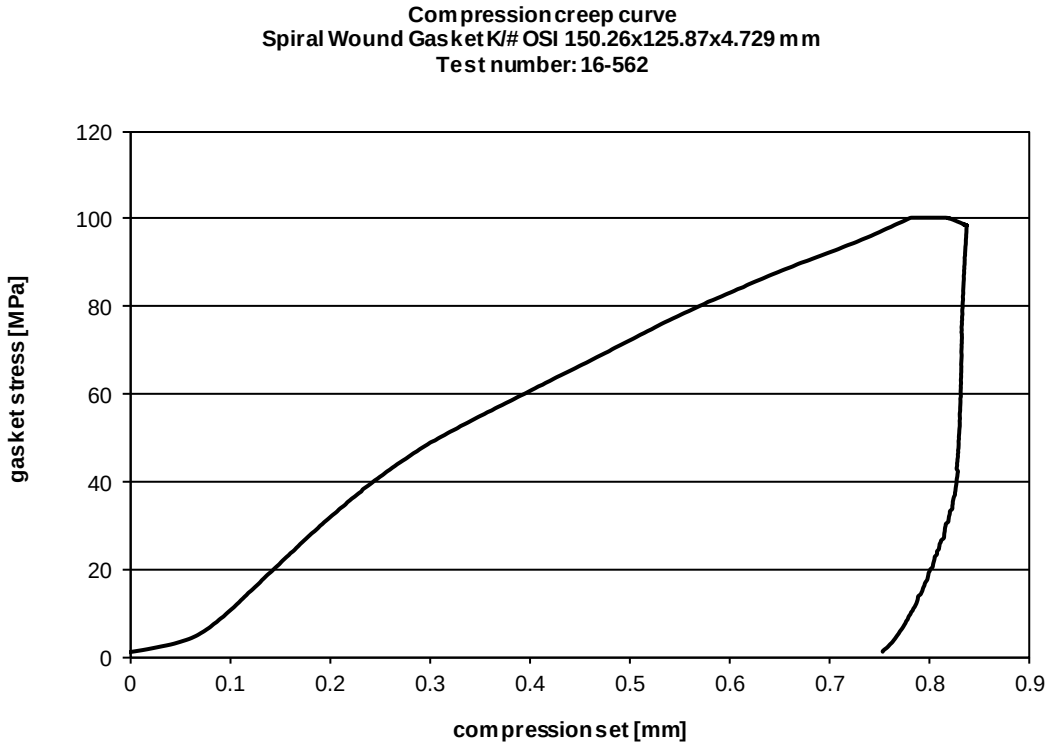
Spiral Wound Gasket K/# OSI
150.26x125.87x4.729 mm
Test number: 16-562

Test parameters

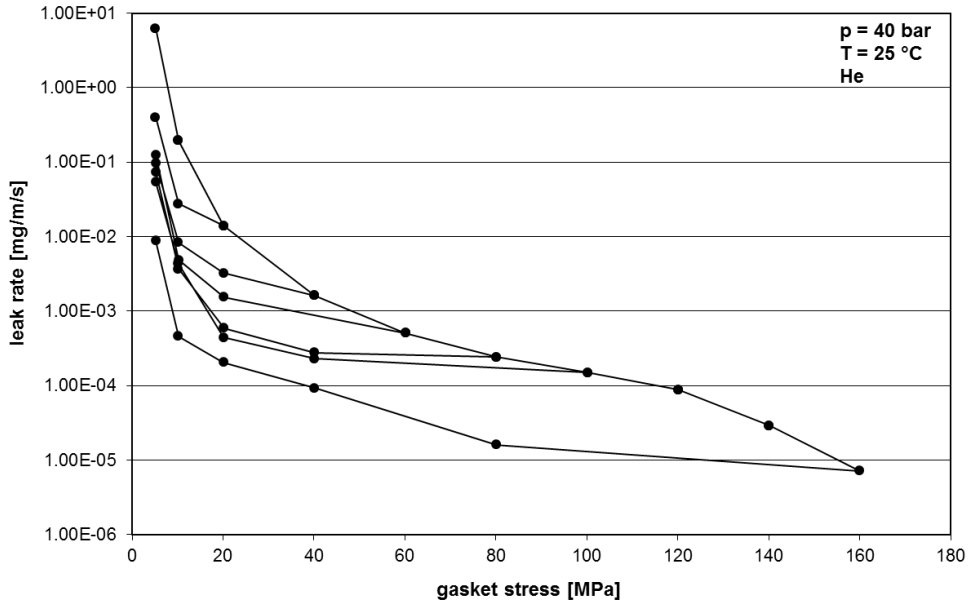
Initial gasket stress Q_i:	100.2	MPa
Test temperature T_P:	400	°C
Time at T_P:	4:00	hh:mm
Stiffness C:	500	kN/mm

Test results

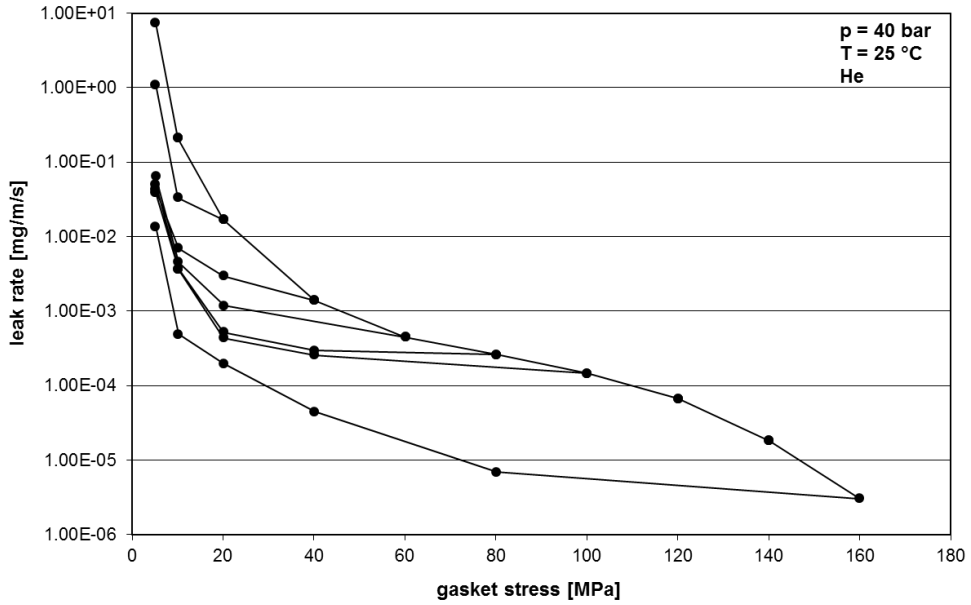
Remaining gasket stress Q_r:	98.2	MPa
Relaxation factor $P_{QR}(T_P)$:	0.98	
Deflection Δe_{Gc}:	21	µm



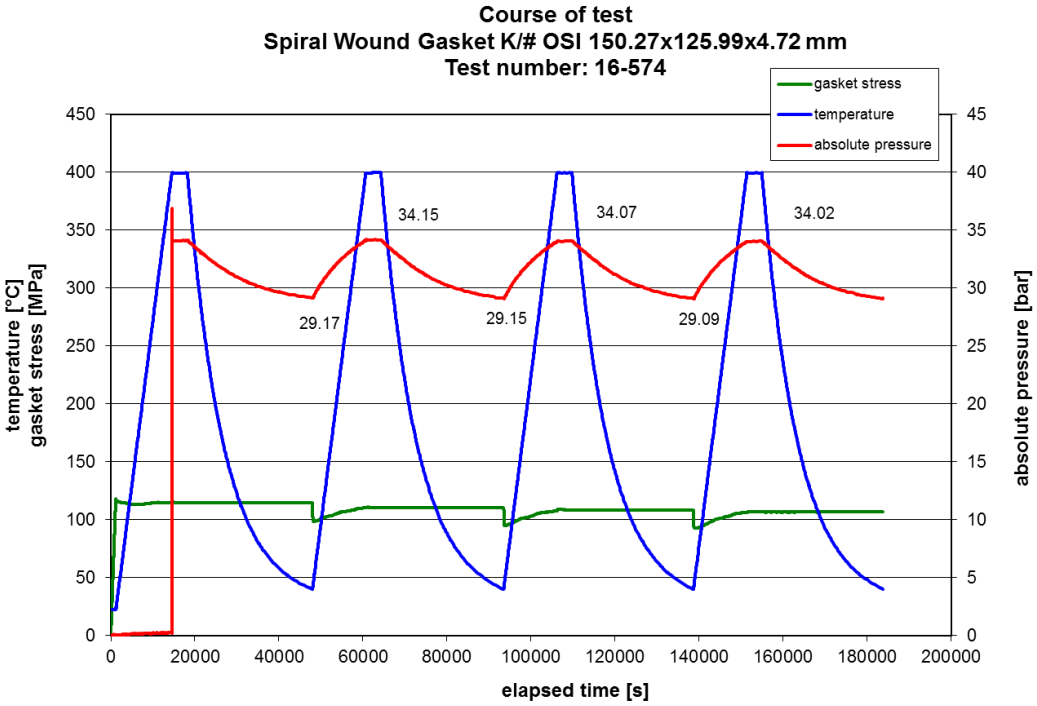
Leakage curve
Spiral Wound Gasket K/# OSI 150.18x125.8x4.686 mm
Test number: 16-566



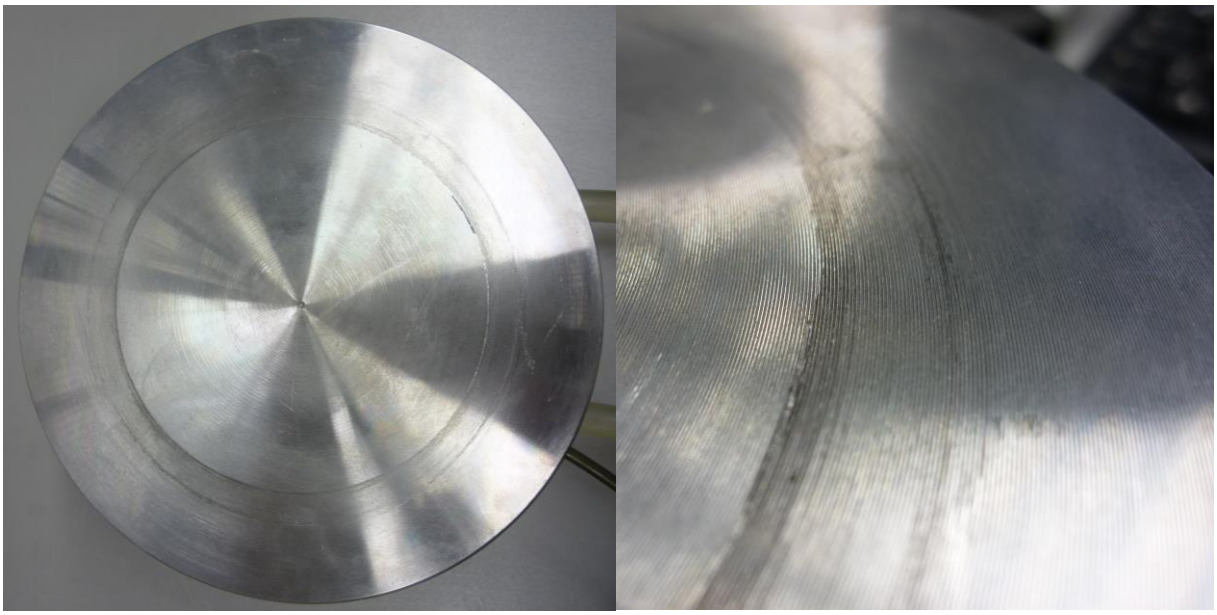
Leakage curve
Spiral Wound Gasket K/# OSI 150.59x125.61x4.672 mm
Test number: 16-567



Leakage test according EN 13555

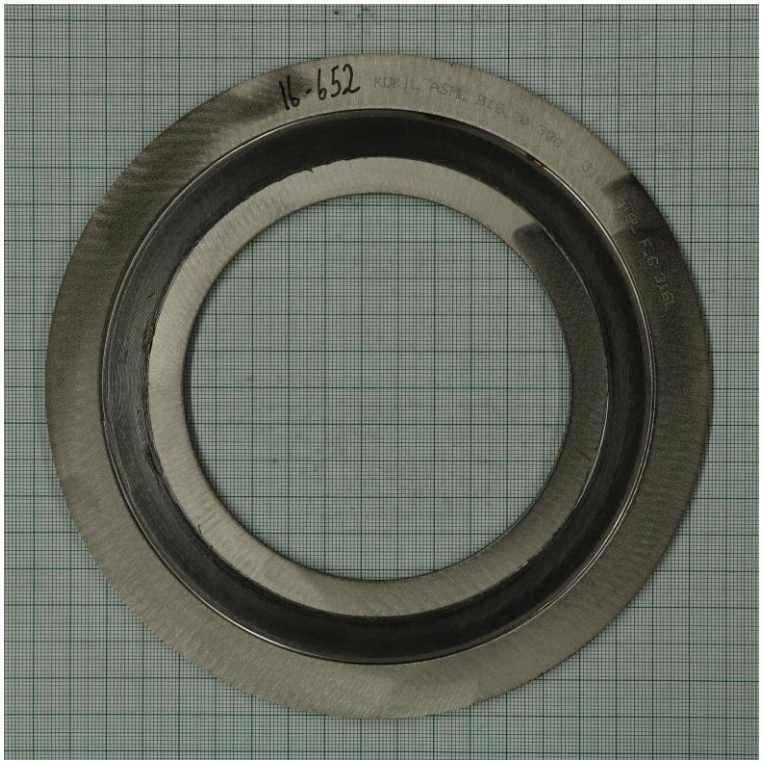


Shell cycle test at 400 °C according MESC SPE 85/300 - 3.3.5



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)

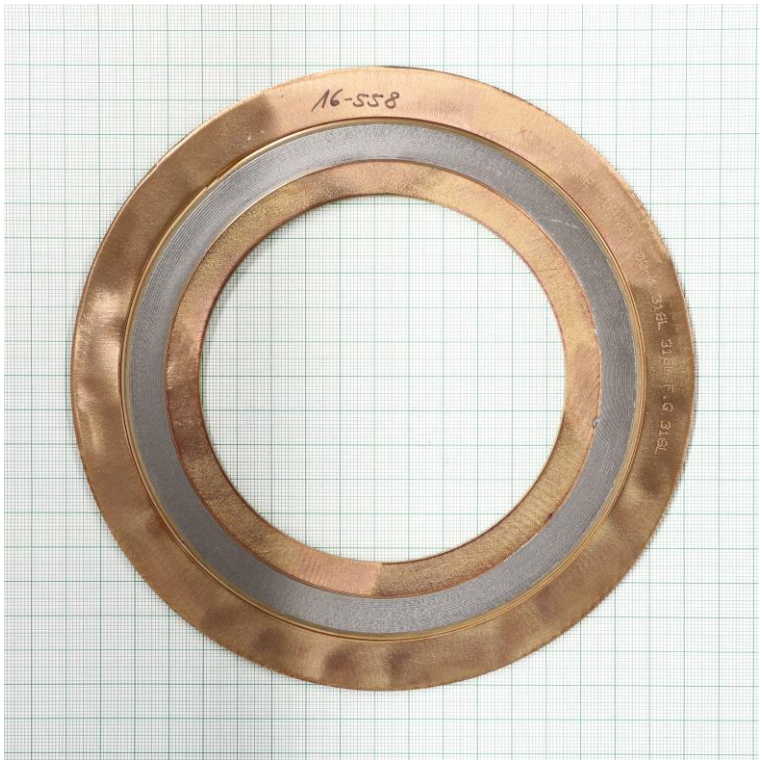
Compression test at RT (EN 13555)

Compression test at 400 °C (EN 13555)

Compression test at 400 °C (EN 13555)

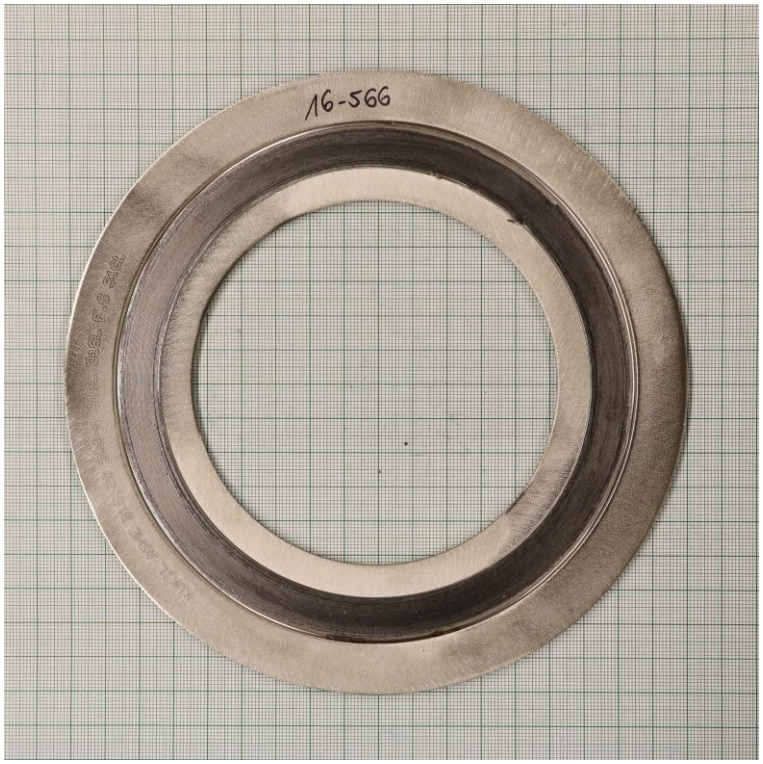
Creep relaxation test at 100 MPa - RT (EN 13555)

Creep relaxation test at 100 MPa - RT (EN 13555)

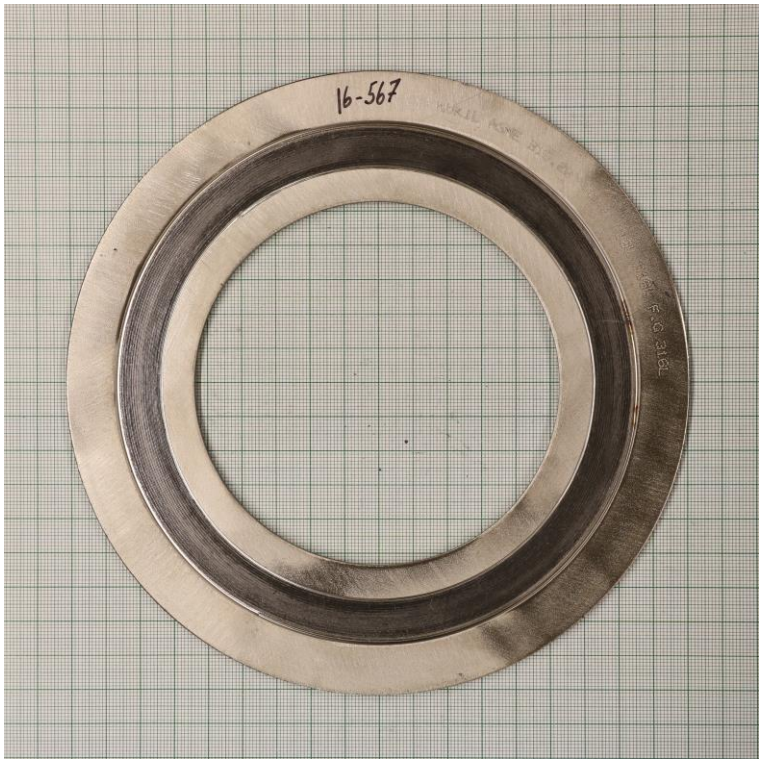


Creep relaxation test at 100 MPa - 400 °C (EN 13555)

Creep relaxation test at 100 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)