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Test Report

Customer:	Spira Power Gasket Factory, LLC. Sohar Industrial Estate, 311 Falaj Al Qabail OM - Sultanate of Oman
Project number (amtec):	304 792
Report number:	304 792 1/-
Test procedure:	Shell Specification MESC SPE 85/300 (dated February 2019)
Material:	Kammprofile Gasket
Date:	February 18th, 2022
Pages:	13
Appendices:	27

Author:	Approval:
Dipl.-Ing. F. Herkert	B. Eng. M. Metzger
Head of Laboratory	**Test Engineer**

Test results are only relevant to the test objects submitted.

1. Subject of Investigation

The following documents and samples were submitted to amtec.

The subject of investigation was a kammprofile gasket manufactured by Spira Power Gasket Factory, LLC. which is customer named

- Kammprofile Gasket.

The kammprofile Gasket has an integral outer ring according to ASME B16.20. The material of the metal core is 316L. The facing material on each side of the gasket is flexible graphite.

2. Goal of Investigation

The goal of the investigation was the qualification of the gasket material Kammprofile Gasket in accordance to the Shell Specification MESC SPE 85/300 (dated February 2019: 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),
- Shell cycle test at 400 °C (MESC SPE 85/300 - 3.3.5).

3. Test Specimens

The dimensions of the test specimens for the different tests were 4" Class 300 gaskets, IBC style with OD = 154 mm and ID = 123 mm. The thickness of the gasket was 5.0 mm.

The contact area of the gasket with the test platens is OD = 154 mm and ID = 123 mm.

A visual examination of all test specimens was done prior and after testing. All test specimens are in accordance to the applicable design standard (MESC SPE 85/300 - 3.3.1).

To bond the graphite layers onto the metal core 3M Super 77 adhesive was used as a glue during the manufacturing process (MESC SPE 85/300 - 3.3.7).

Within this report two charges of gaskets were tested. First charge of gaskets and tests were made in 2018. The second charge of gaskets was produced in 2021. With the second charge of gaskets only Fugitive Emission tests (MESC SPE 85/300 - 3.3.2) were performed in 2022. All other tests were performed with the first charge of gaskets.

4. Testing Equipment

The gasket tests were carried out on the following testing equipment in the laboratory of amtec:

Multifunctional test rig TEMES$_{fl.ai1}$	No.: 010 181 and 010 506
Fire Safe Testing device TEMES$_{fire.safe}$	No.: 010 595

Photos and the schematic view of the testing equipment TEMES$_{fl.ai1}$ and TEMES$_{fire.safe}$ 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 400 °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 TEMES$_{fire.safe}$

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 gasket stress of 100 MPa at ambient temperature and in steps of 10 MPa to a gasket stress of 100 MPa 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 AH: $\leq 1.78 \cdot 10^{-8}$ Pa·m³/(s·mm_{dia}),
- Class BH: $\leq 1.78 \cdot 10^{-7}$ Pa·m³/(s·mm_{dia}).

Shell TAT recommends a maximum gasket stress of 87.2 MPa, which is equivalent to a maximum bolt stress of 361 MPa. The leak rate of this gasket stress level is measured separately during the leakage test. 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 153.9 mm and ID of 123.7 mm of the kammprofile 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} (80 MPa - RT and 80 MPa - 400 °C),
- Change in gasket thickness due to creep Δe_{GC} (80 MPa - RT and 80 MPa - 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. In the next step the load is increased to 10 MPa and the leak rate is measured and then 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 80 MPa loading - unloading cycle is completed or the value of Q_{smax} would have been exceeded.

The lowest gasket stress level is set to 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 maximum 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

Test date first charge of gaskets: May 11th to June 19th, 2018.
Test date second charge of gaskets: January 3rd to January 28th, 2022.

All test results of the gasket material Kammprofile Gasket 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 6 steps from 60 MPa to 100 MPa. The detected leak rate at 60 MPa gasket stress at an internal pressure of 51 bar was $2.0 \cdot 10^{-11}$ Pa·m³/(s·mm_{dia}), see **appendix 6**.

The leak rate was at a very low level throughout the complete test. The leak rate at a gasket stress of 87.2 MPa, which is equivalent to a bolt stress of 361 MPa, was $2.0 \cdot 10^{-11}$ Pa·m³/(s·mm_{dia}) which is lower than the Tightness Class AH.

For the maximum gasket surface stress of 100 MPa the leak rate was $2.0 \cdot 10^{-11}$ Pa·m³/(s·mm_{dia}), which is lower than the Tightness Class AH. Note: the leak rate of 2.0 E-11 Pa·m³/(s·mm_{dia}) is a dummy-value and close to the resolution limit of the leak detector

In the Shell leakage test at 400 °C the gasket was compressed in 6 steps from 60 MPa to 100 MPa. The leak rate at a gasket stress of 87.2 MPa, which is equivalent to a bolt stress of 361 MPa, was $4.7 \cdot 10^{-8}$ Pa·m³/(s·mm_{dia}), which is below the Tightness Class BH.

The leak rate at all gasket stress levels was not measurable with a measuring time of 24h. Therefore the leak rate is set to $4.7 \cdot 10^{-8}$ Pa·m³/(s·mm_{dia}), which is lower than the Tightness Class BH, see appendix 6.

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

In the API Specification 6FB the Kammprofile Gasket was mounted in a 4" Class 300 flange with hydraulic spanners to a bolt load of 96.75 kN which means a total load of 774 kN and a gasket surface stress of 112.5 MPa. The calculation of the gasket stress referred to the kammprofile area of the gasket.

After that the flange was pressurized with an internal pressure of 40 bar. The test medium was water. After 5 minutes 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 0.14 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 0.03 ml/inch/min and therefore below the allowable leak rate of 1 ml/inch/min.

The Kammprofile Gasket **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 Kammprofile Gasket 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.

The modulus of elasticity E_G at ambient temperature increases steadily with increasing gasket stress up to 60 MPa.

In both compression tests at elevated 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.

Due to very low recovery of the kammprofile gasket in the tests at 400 °C the modulus of elasticity E_G at different gasket stress levels was set to a dummy-value of 180.000 MPa, see also appendix 3.

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} (80 MPa, RT, 500 kN/mm) and
- creep relaxation factor P_{QR} (80 MPa, 400 °C, 500 kN/mm).

In total 4 creep relaxation tests were performed. The initial gasket stress level was set to 80 MPa at RT and 80 MPa at 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 (80 MPa, RT, 500 kN/mm) and 0.99 (80 MPa, 400 °C, 500 kN/mm). The deflection Δe_{GC} of the gasket Kammprofile Gasket at RT is 3 µm resp. 4 µm and in tests at 400 °C is 10 µm resp. 6 µm.

6.3.3 Leakage tests

The tightness behaviour of the gasket material Kammprofile Gasket 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 26 MPa or 28 MPa, respectively. Therefore the minimum gasket stress in assembly for the tightness class $L_{0.01}$ is set to $Q_{min(0.01)}$ = 28 MPa. The lowest tightness class which could be reached was $L_{0.0001}$; therefore a gasket stress of 110 MPa resp. 99 MPa is necessary.

The leak rate is decreasing with an increasing gasket stress up to 120 MPa. The lowest leak rate which could be measured was $3.7 \cdot 10^{-5}$ mg/m/s at 120 MPa in test 18-479.

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

With a higher preload of 100 MPa and 120 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 $Q_{smin(L)}$ 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 40 MPa is $Q_{smin(0.01)}$ = 13 MPa resp. 11 MPa.

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 Kammprofile 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 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 Kammprofile Gasket has **passed** the Shell requirement of a pressure drop less than 1 bar.

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

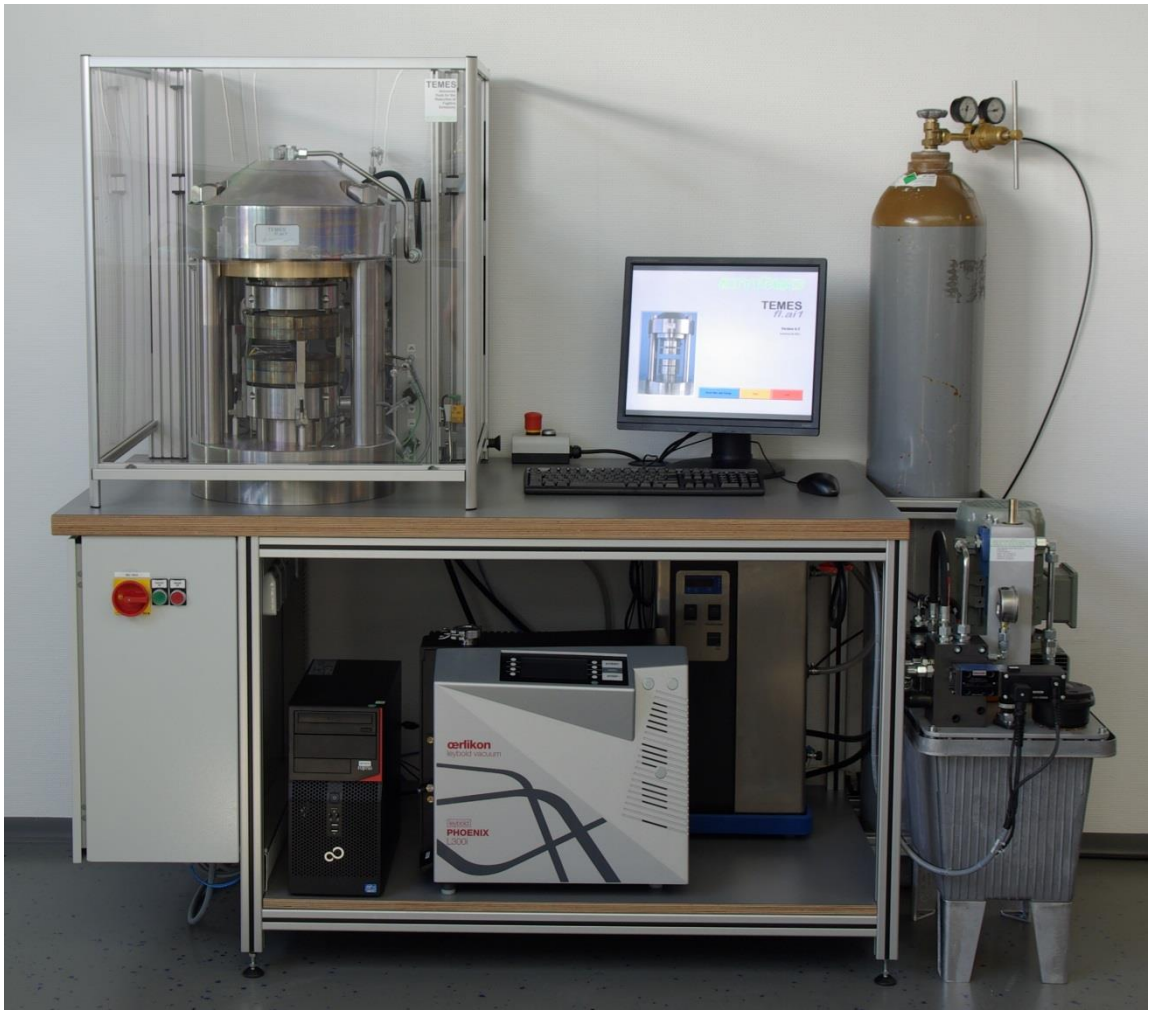
In **appendix 20** photos of the adjacent flanges after tests at ambient temperature with the gasket specimen's Kammprofile Gasket are represented. The gasket does not stick on the flange. Slight traces of graphite material at the adjacent flanges after the test are visible.

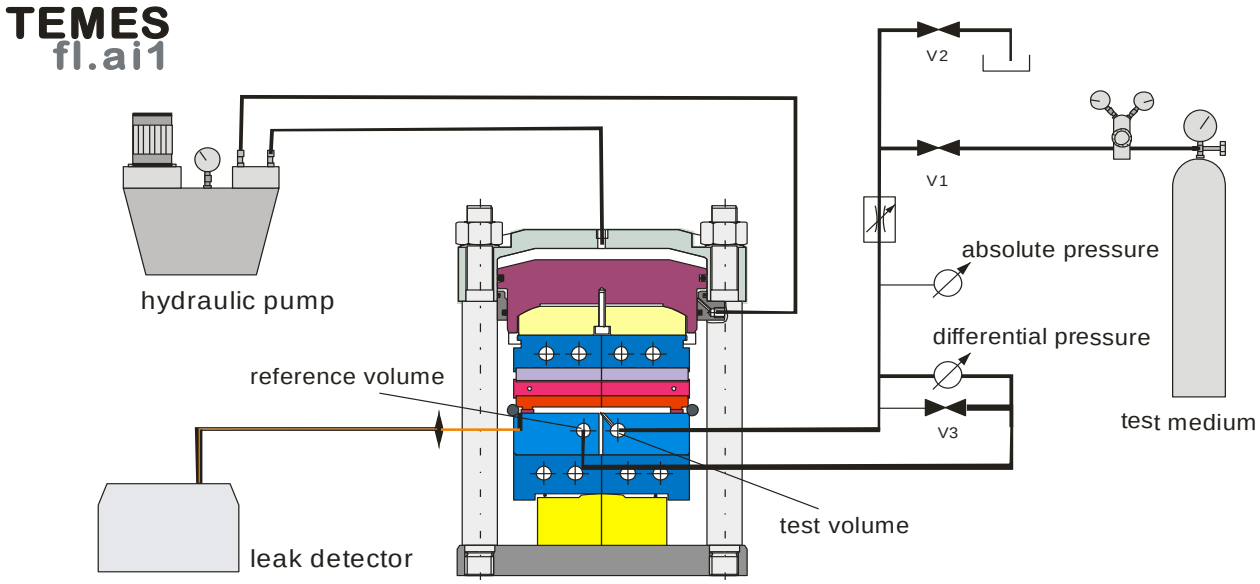
The gasket adhesion could be considered as acceptable.

7. Photo documentation

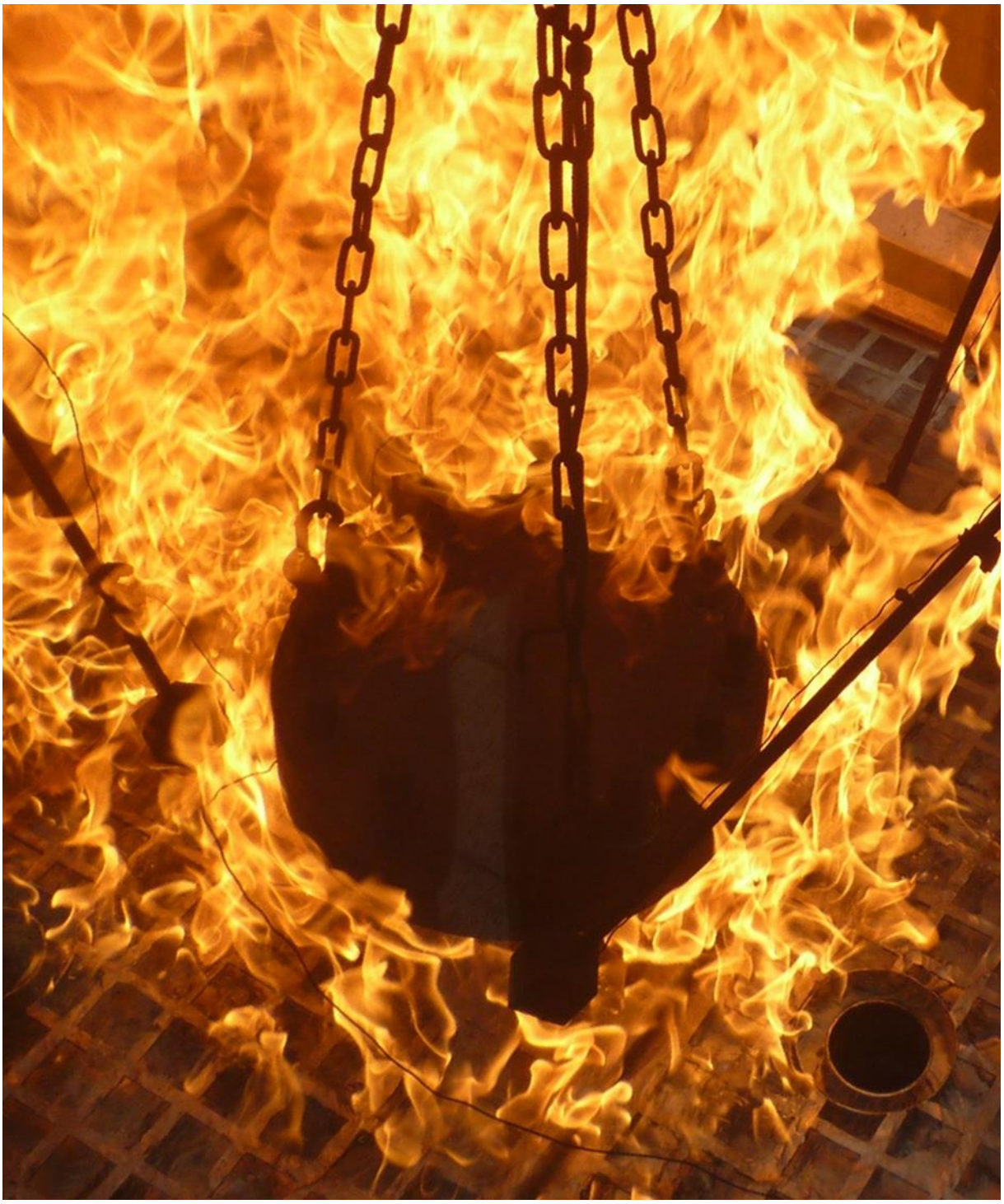
In **appendices 21 to 27** photos of the tested gasket specimen's Kammprofile Gasket for the different test procedures are presented.

With all tests at elevated temperature the graphite layer on both sides of the Kammprofile Gasket was loosened after the test.





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



Fire Safe Testing Device

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

Manufacturer: Spira Power Gasket Factory, LLC.

Product: **Kammprofile Gasket**

Maximum allowable Gasket Stress Q_{smax} [MPa]

T [°C]	25	25	400	400
Q_{smax} [MPa]	140	140	140	140
Test #	18-506	18-511	18-517	18-519

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		5,160		5,170		5,100		5,190
1		5,076		5,083		5,094		5,134
20	4606	4,681	4420	4,655	12996	4,601	180000*	4,608
30	12583	4,595	11216	4,543	15905	4,536	39382	4,533
40	25857	4,550	20711	4,499	92107	4,488	180000*	4,495
50	38610	4,522	26128	4,472	180000*	4,460	180000*	4,474
60	51498	4,504	32397	4,453	180000*	4,441	180000*	4,459
80	49753	4,477	34702	4,424	180000*	4,416	180000*	4,439
100	43131	4,459	36755	4,405	180000*	4,398	180000*	4,426
120	39534	4,446	37394	4,392	103177	4,385	180000*	4,416
140	37589	4,435	37817	4,381	64688	4,373	180000*	4,407
Test #	18-506		18-511		18-517		18-519	

* Due to very low recovery of the gasket the Modulus of Elasticity EG [MPa] could not be determined and is set to a dummy-value of 180.000 MPa

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	400	400
	80	1,00	1,00	0,99	0,99
	Δe_{GC} [µm]	3	4	10	6
	Test #	18-480	18-482	18-521	18-522

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

Manufacturer: Spira Power Gasket Factory, LLC.

Product: **Kammprofile Gasket**

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	1,00E-06	1,00E-07
40	5	5	9	26	65	110	-	-	-
Test #	18-466								
40	5	5	9	28	56	99	-	-	-
Test #	18-479								

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

p = 40 bar	L / Q_A [MPa]	10	1	0,1	0,01	0,001	0,0001	0,00001	1,00E-06	1,00E-07
	10	5	5	7	-	-	-	-	-	-
	20	5	5	5	-	-	-	-	-	-
	40	5	5	5	13	-	-	-	-	-
	60	5	5	5	10	-	-	-	-	-
	80	10	10	10	10	55	-	-	-	-
	100	10	10	10	10	50	-	-	-	-
	120	10	10	10	14	46	92	-	-	-
	Test #	18-466								

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

p = 40 bar	L / Q_A [MPa]	10	1	0,1	0,01	0,001	0,0001	0,00001	1,00E-06	1,00E-07
	10	5	5	7	-	-	-	-	-	-
	20	5	5	5	-	-	-	-	-	-
	40	5	5	5	11	-	-	-	-	-
	60	5	5	5	8	53	-	-	-	-
	80	5	5	5	8	33	-	-	-	-
	100	5	5	5	5	28	98	-	-	-
	120	5	5	7	9	23	66	-	-	-
	Test #	18-479								

Table 3: Data Sheet for Gasket Characteristics (Shell)

Manufacturer: Spira Power Gasket Factory, LLC.

Product: **Kammprofile Gasket**

Shell leakage test at ambient temperature

Test pressure:	51,1	bar
Shell required gasket stress level:	87,2	MPa
Leakage rate:	1,94E-11	$Pa \cdot m^3/(s \cdot mm_{dia})$
Shell tightness class:	AH	
test no.	22-149	

Shell leakage test at 400 °C

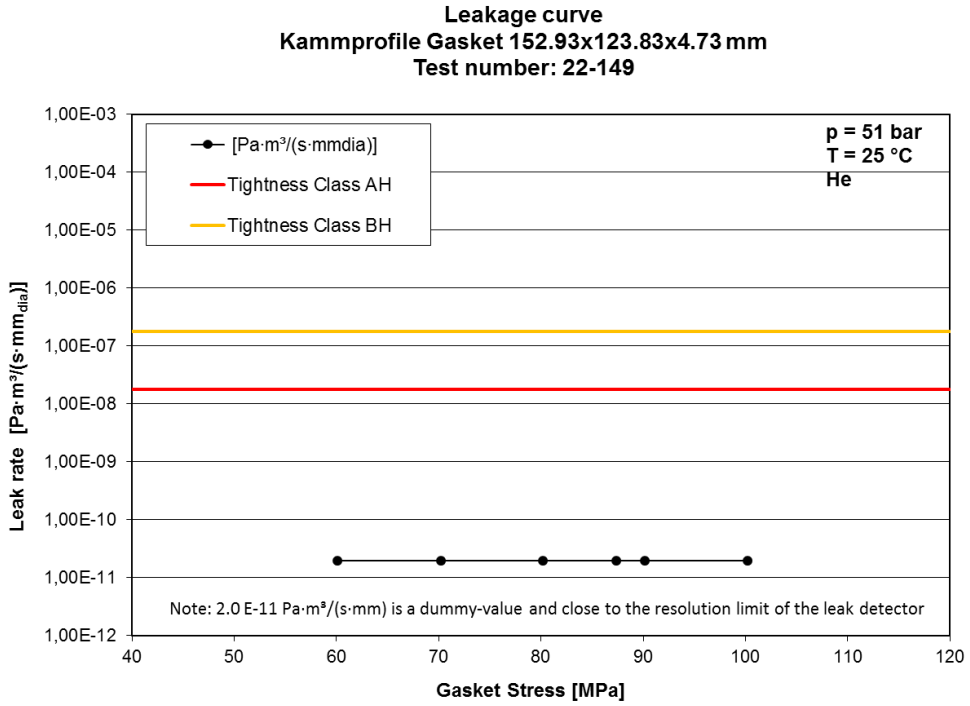
Test pressure:	34,7	bar
Shell required gasket stress level:	87,2	MPa
Leakage rate:	4,70E-08	$Pa \cdot m^3/(s \cdot mm_{dia})$
Shell tightness class:	BH	
test no.	22-082	

Shell cycle test at 400 °C

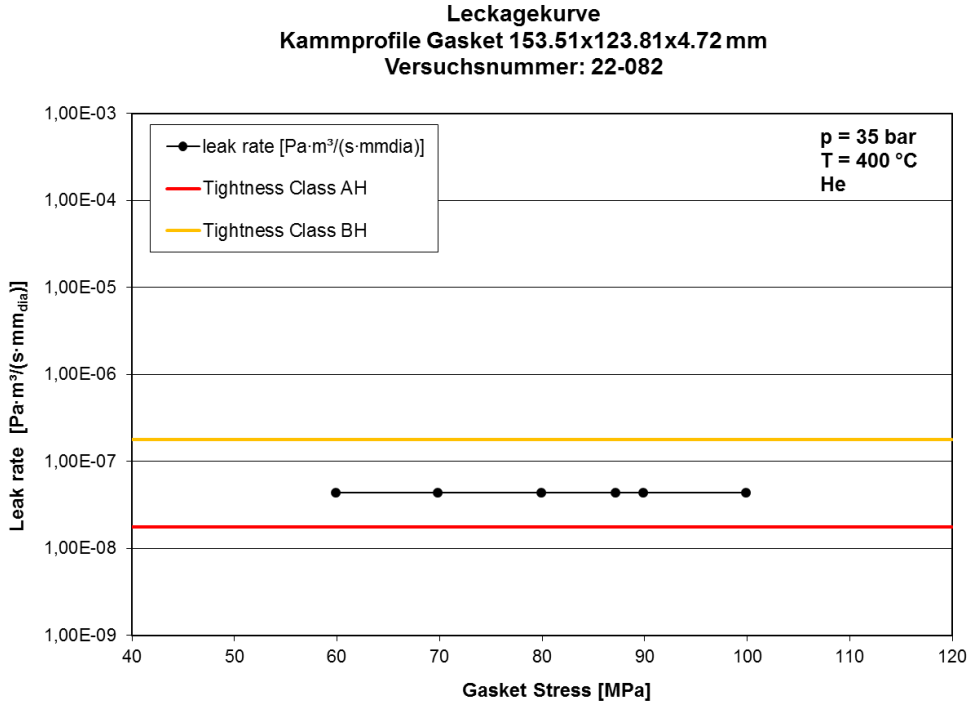
Test pressure:	34,7	bar
Initial gasket stress level:	87,2	MPa
Pressure drop in last cycle:	< 0.1	bar
Requirements:	passed	
test no.	18-426	

Fire Test API 6FB

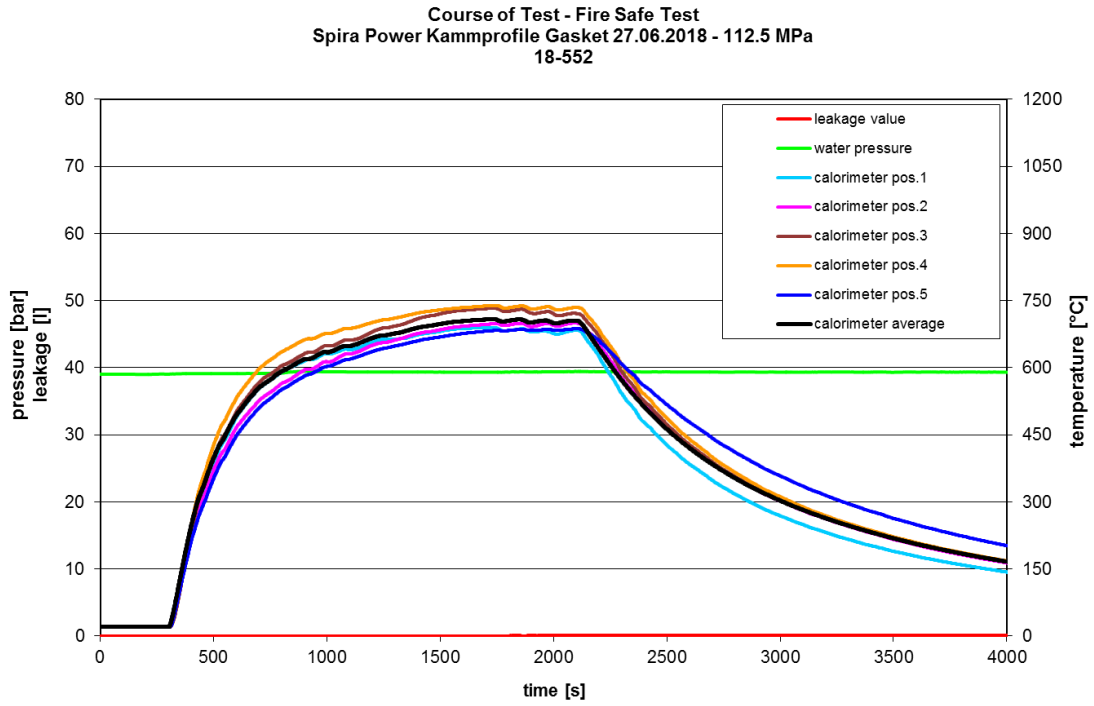
Test pressure:	39	bar
Initial gasket stress level:	112,5	MPa
Leakage rate (complete test):	0,03	ml/inch/min
Requirements:	passed	
test no.	18-552	



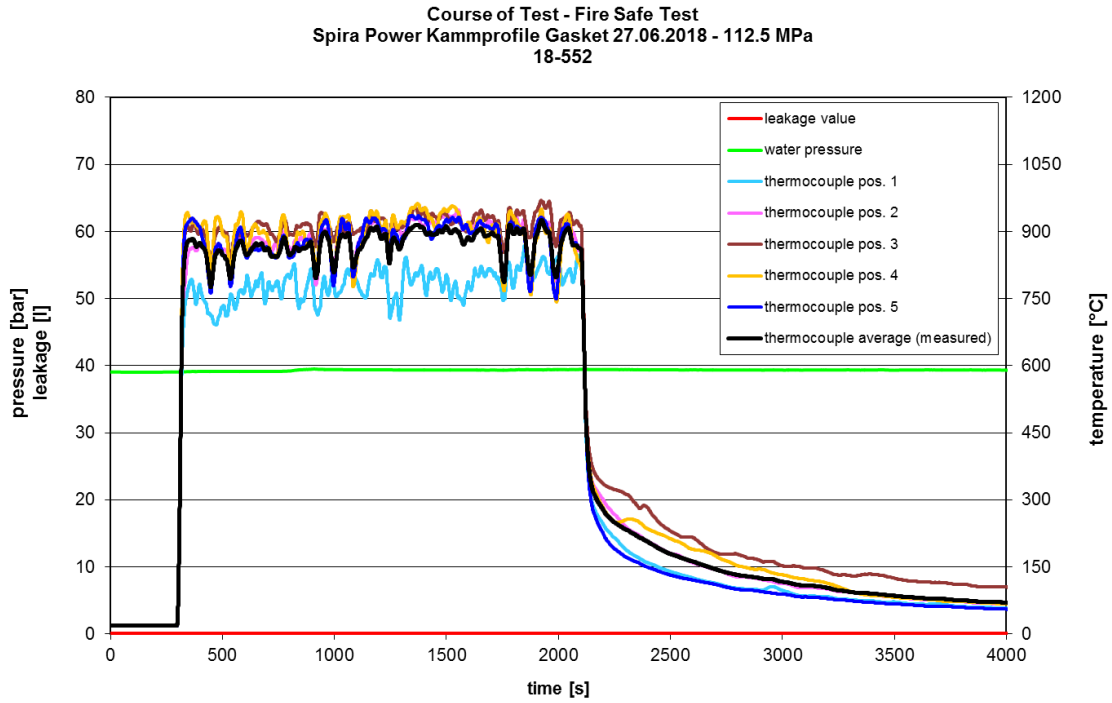
Shell leakage test (RT) according MESC SPE 85/300 - 3.3.2



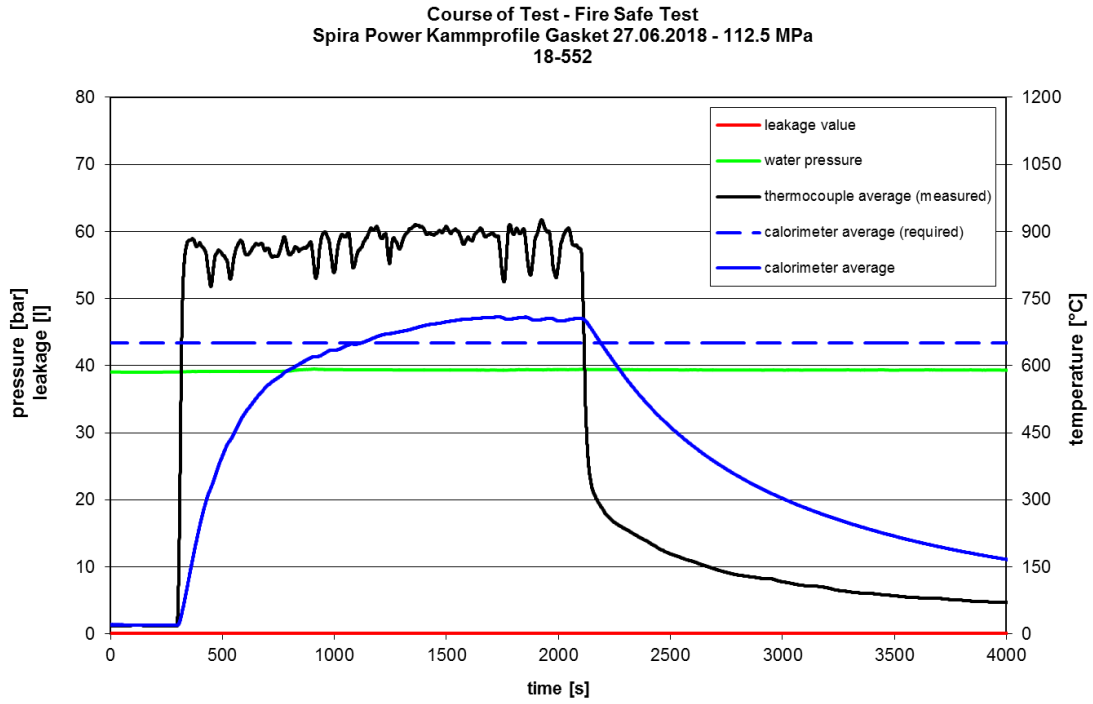
Shell leakage test (400 °C) according MESC SPE 85/300 - 3.3.2



Calorimeters Fire Safe Test according MESC SPE 85/300 - 3.3.3



Thermocouples Fire Safe Test according MESC SPE 85/300 - 3.3.3



Fire Safe Test according MESC SPE 85/300 - 3.3.3

Fire Safe Test 18-552 Spira Power Kammprofile Gasket

geometries

bolts	8
OD gasket	154.8 mm
ID gasket	123.3 mm
Height gasket	4.8 mm
mean gasket circumference	436.8 mm
gasket area	6880.21 mm²
mean gasket circumference total	436.84 mm
gasket area total	6880.21 mm²
OD raised faces flange (4" Class 300)	155 mm
leak rate criteria	**1 ml / inch / min**

calculation of gasket stress

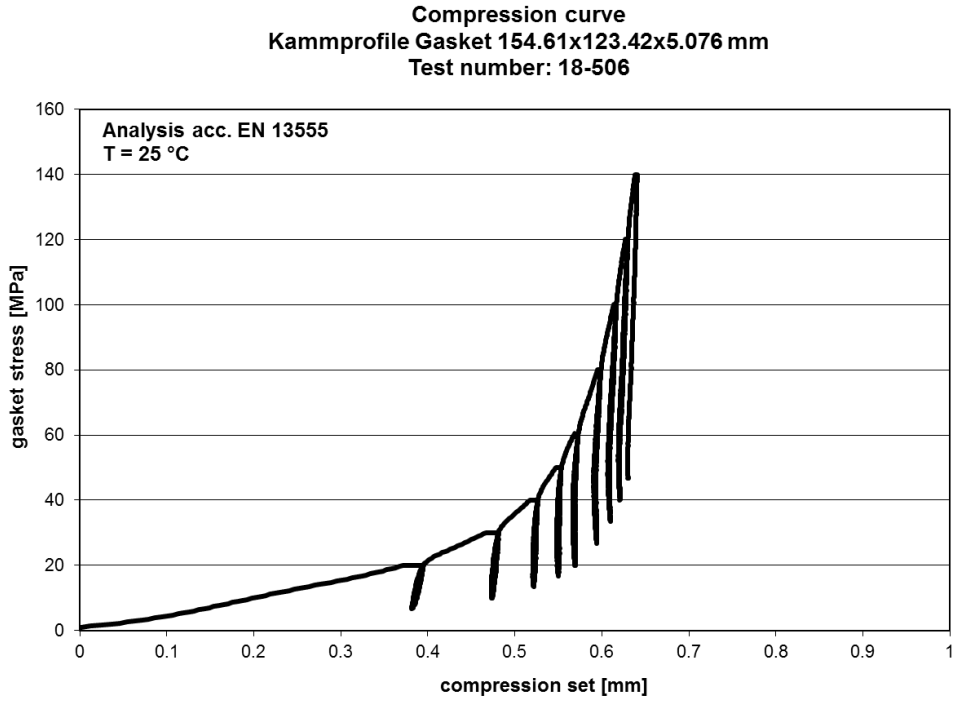
hydraulic spanners - No.	GS 3/1
calibration factor	0.14 kN/bar
hydraulic pressure	713 bar
force per bolt	96.75 kN
force total	774.02 kN
gasket stress sealing element	**112.50 MPa**

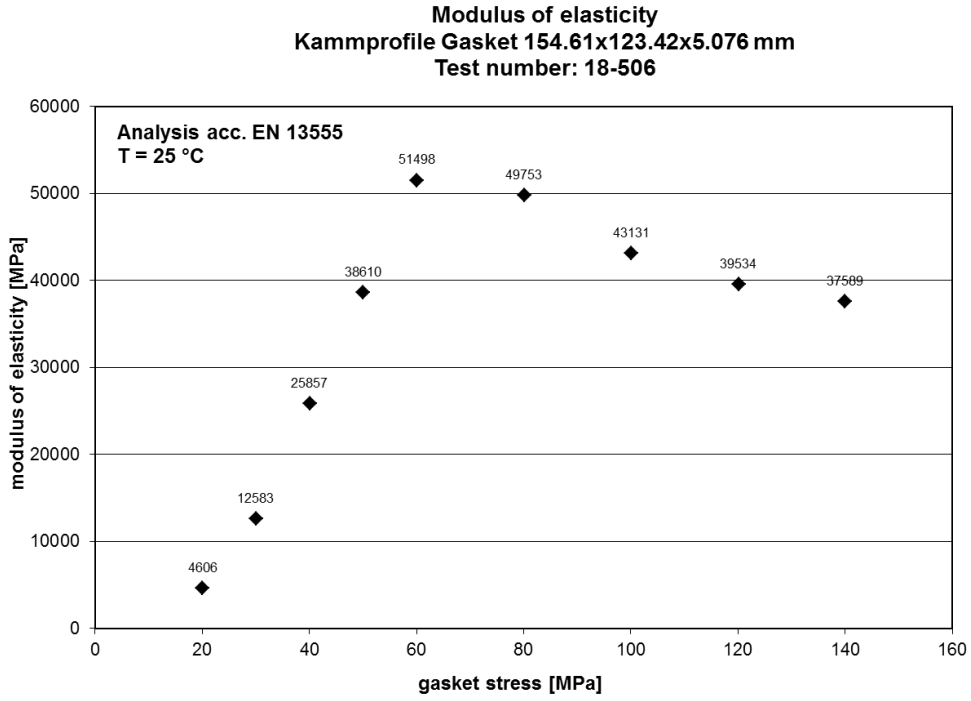
calculation of leak rate of burning period

start value scale	27.75 kg
end value scale	27.67 kg
start test	06:28:23
end test	06:58:23
test duration (min)	30.00 min
leakage	73.40 ml
leak rate burning period	0.14 ml / inch / min

calculation of leak rate of complete test

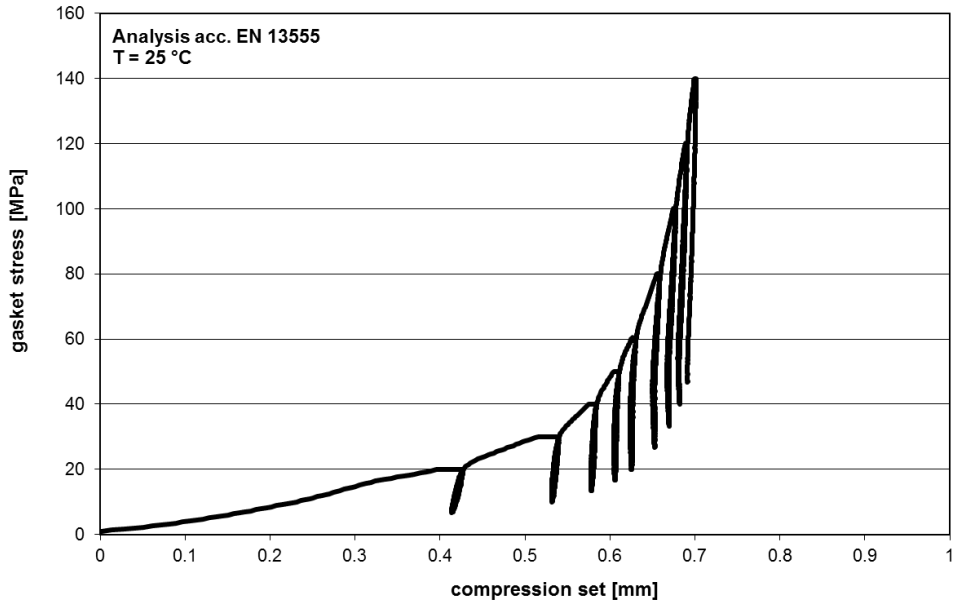
start value scale	27.75 kg
end value scale	27.67 kg
start test	06:28:23
end test	09:16:43
test duration (min)	168.33 min
leakage	73.40 ml
leak rate	**0.03 ml / inch / min**



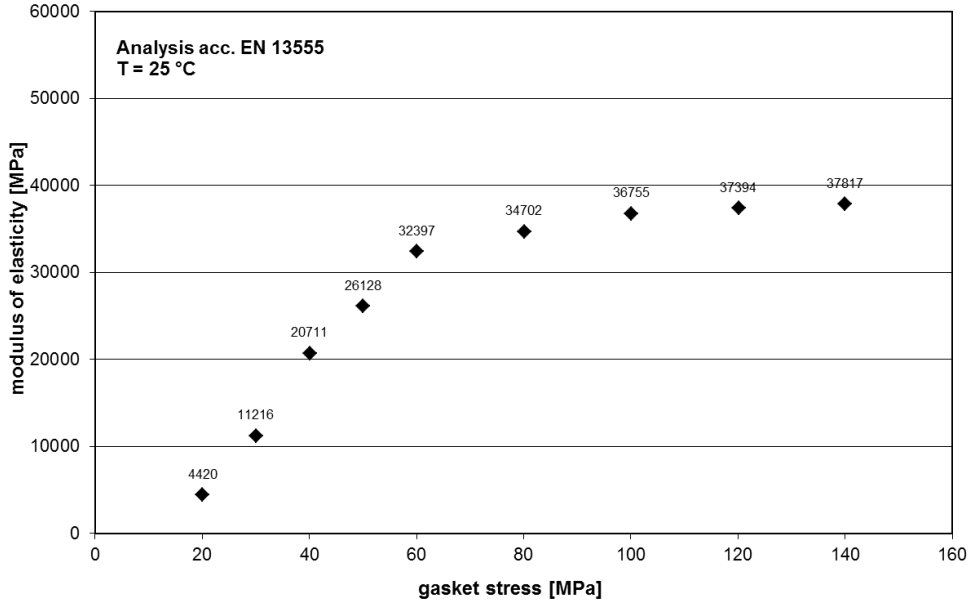


Compression test (RT) according EN 13555

Compression curve
Kammprofile Gasket 154.62x123.36x5.083 mm
Test number: 18-511

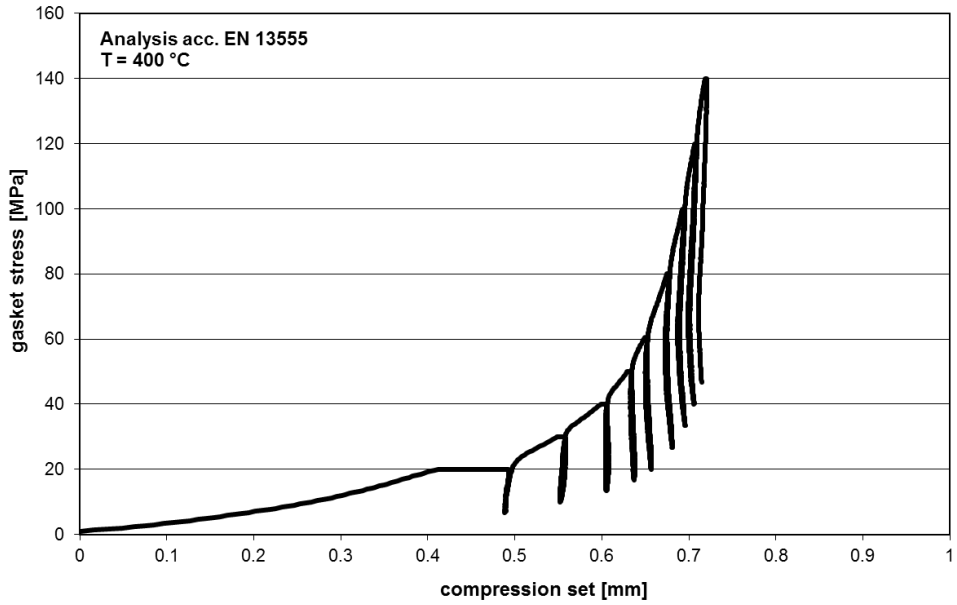


Modulus of elasticity
Kammprofile Gasket 154.62x123.36x5.083 mm
Test number: 18-511

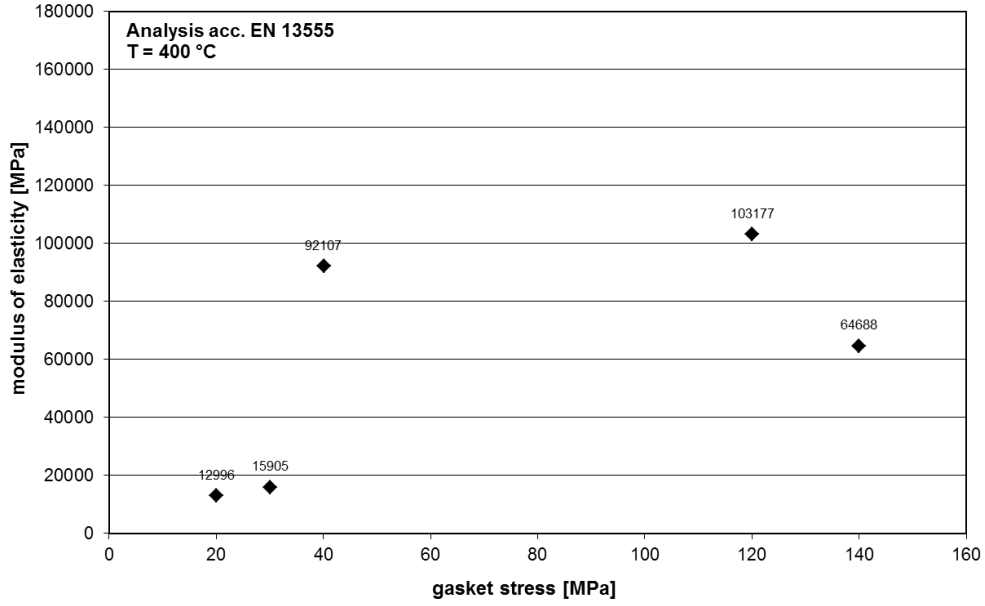


Compression test (RT) according EN 13555

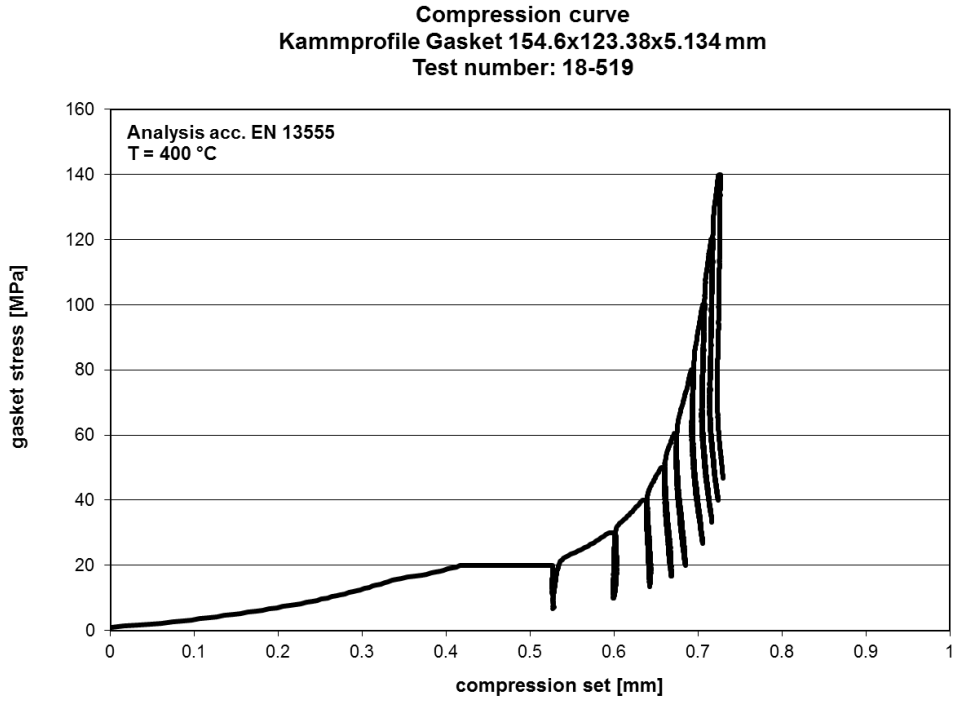
Compression curve
Kammprofile Gasket 154.62x123.35x5.094 mm
Test number: 18-517

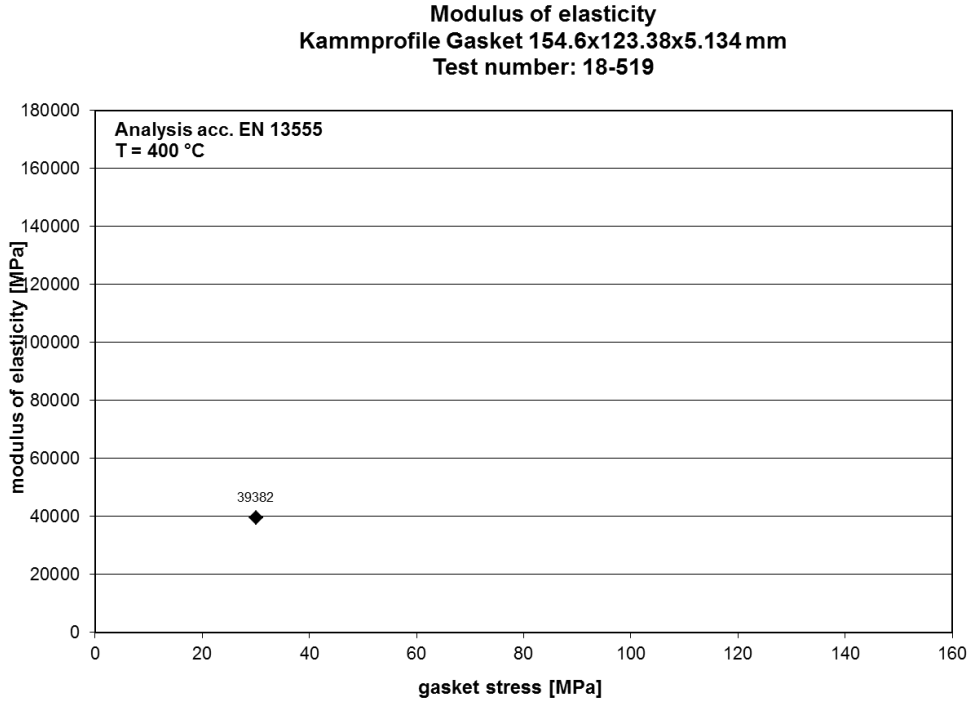


Modulus of elasticity
Kammprofile Gasket 154.62x123.35x5.094 mm
Test number: 18-517



Compression test at 400 °C according EN 13555





Compression test at 400 °C according EN 13555

Creep relaxation test (EN 13555)

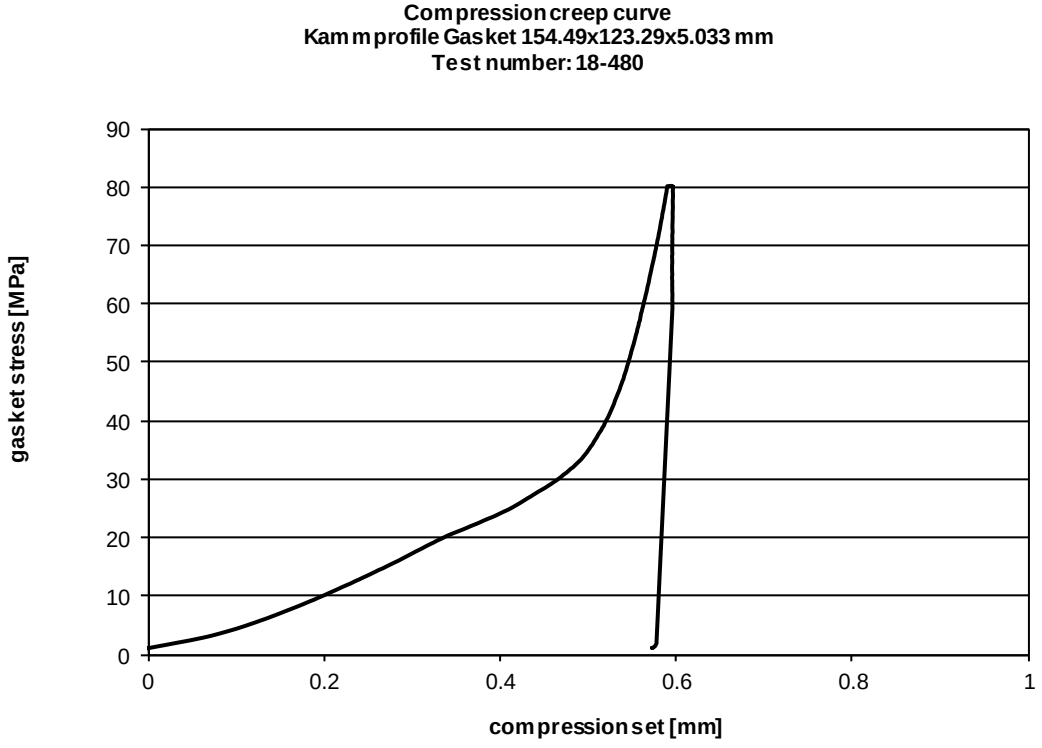
Kammprofile Gasket
154.49x123.29x5.033 mm
Test number: 18-480

Test parameters

Initial gasket stress Q_i:	80.1	MPa
Test temperature T_P:	25	°C
Time at T_P:	4:00	hh:mm
Stiffness C:	500	kN/mm

Test results

Remaining gasket stress Q_r:	80.0	MPa
Relaxation factor P_{QR} (T_P):	1.00	
Deflection Δe_{Gc}:	3	µm



Creep relaxation test (EN 13555)

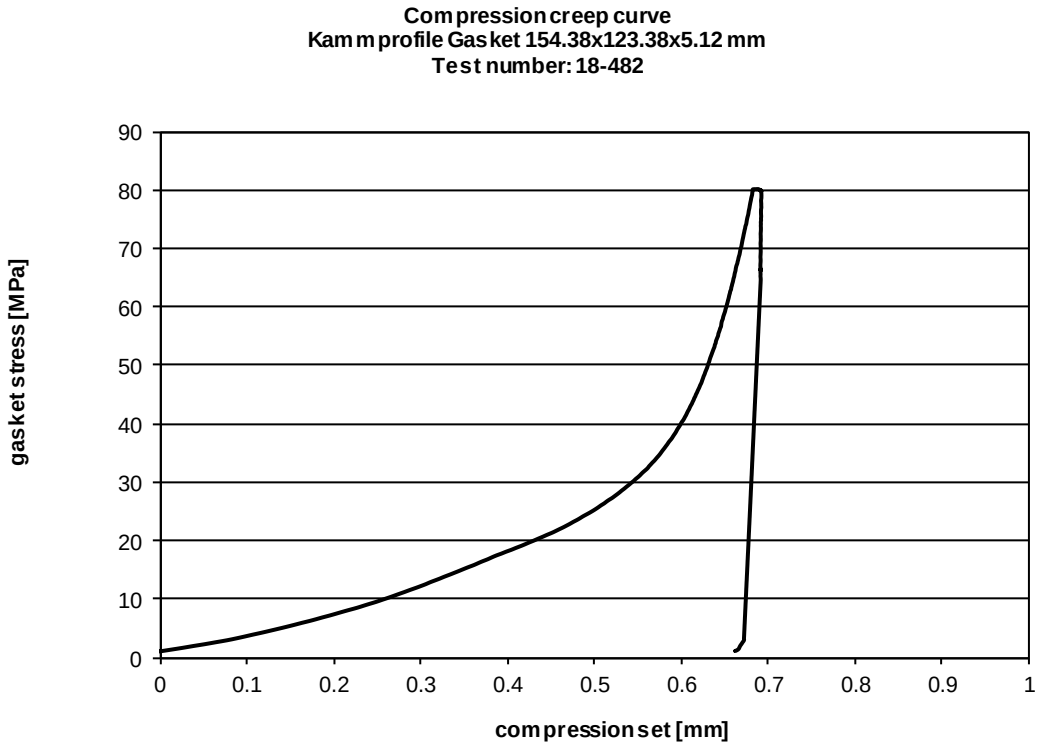
Kammprofile Gasket
154.38x123.38x5.12 mm
Test number: 18-482

Test parameters

Initial gasket stress Q_i:	80.1	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:	79.9	MPa
Relaxation factor $P_{QR}(T_P)$:	1.00	
Deflection Δe_{Gc}:	4	µm



Creep relaxation test (EN 13555)

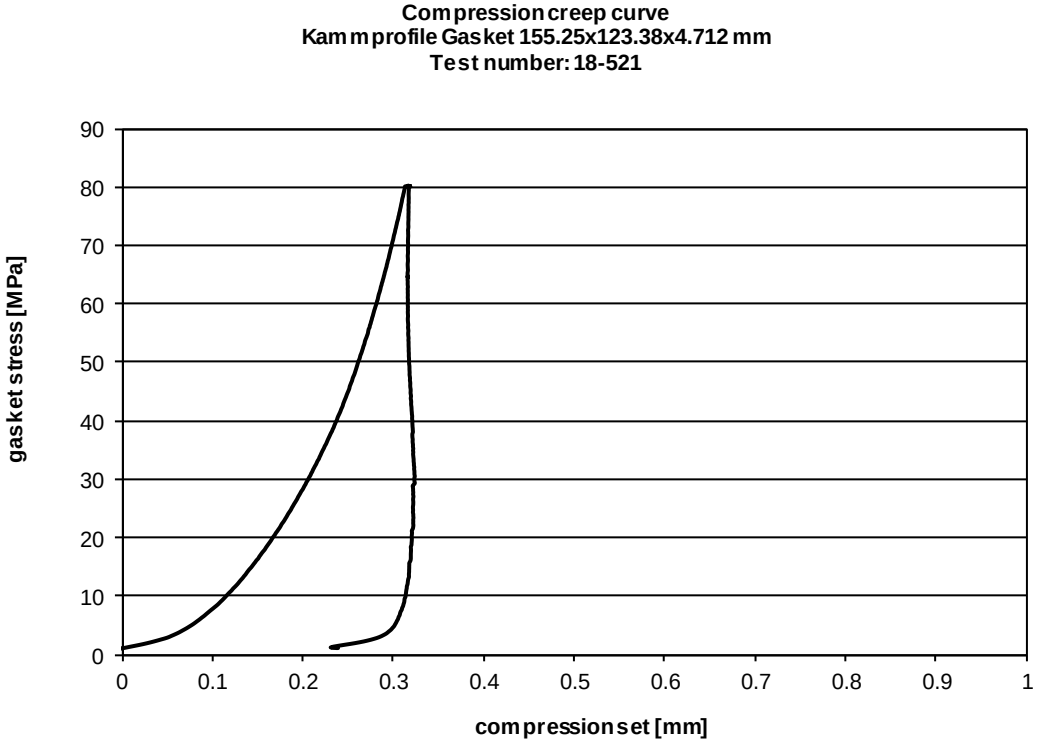
Kammprofile Gasket
155.25x123.38x4.712 mm
Test number: 18-521

Test parameters

Initial gasket stress Q_i:	80.1	MPa
Test temperature T_P:	400	°C
Time at T_P:	3:59	hh:mm
Stiffness C:	500	kN/mm

Test results

Remaining gasket stress Q_r:	79.3	MPa
Relaxation factor P_{QR} (T_P):	0.99	
Deflection Δe_{Gc}:	10	µm



Creep relaxation test (EN 13555)

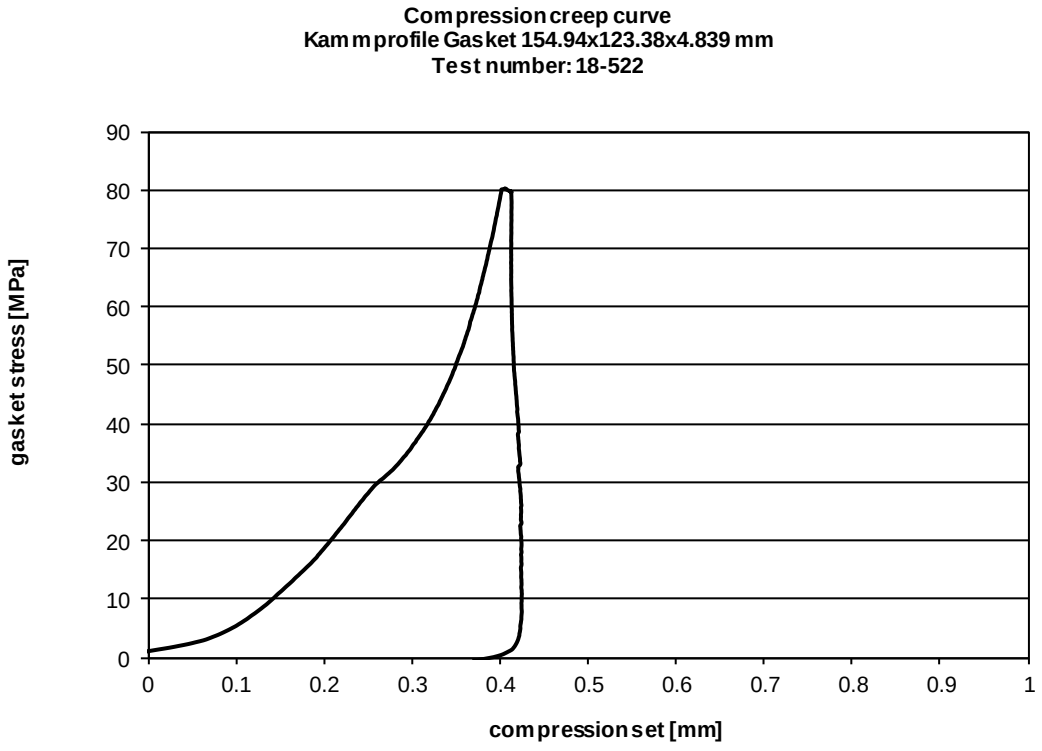
Kammprofile Gasket
154.94x123.38x4.839 mm
Test number: 18-522

Test parameters

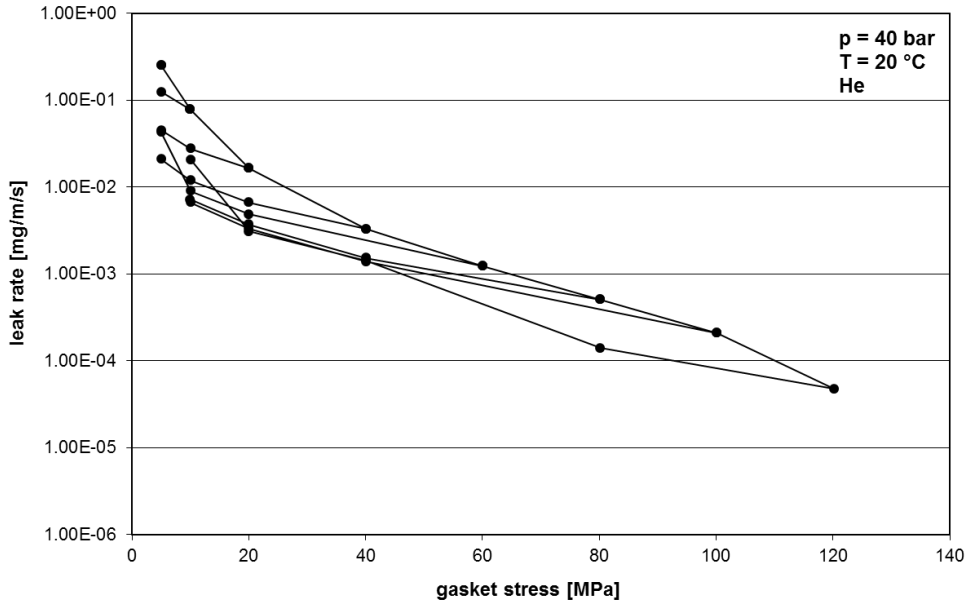
Initial gasket stress Q_i:	80.1	MPa
Test temperature T_P:	400	°C
Time at T_P:	4:00	hh:mm
Stiffness C:	500	kN/mm

Test results

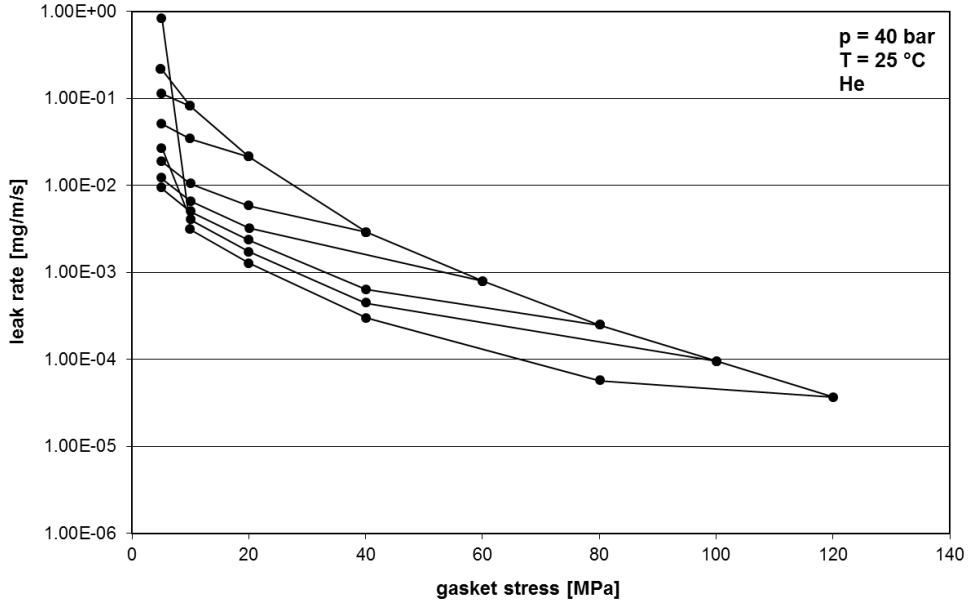
Remaining gasket stress Q_r:	79.6	MPa
Relaxation factor $P_{QR}(T_P)$:	0.99	
Deflection Δe_{Gc}:	6	µm



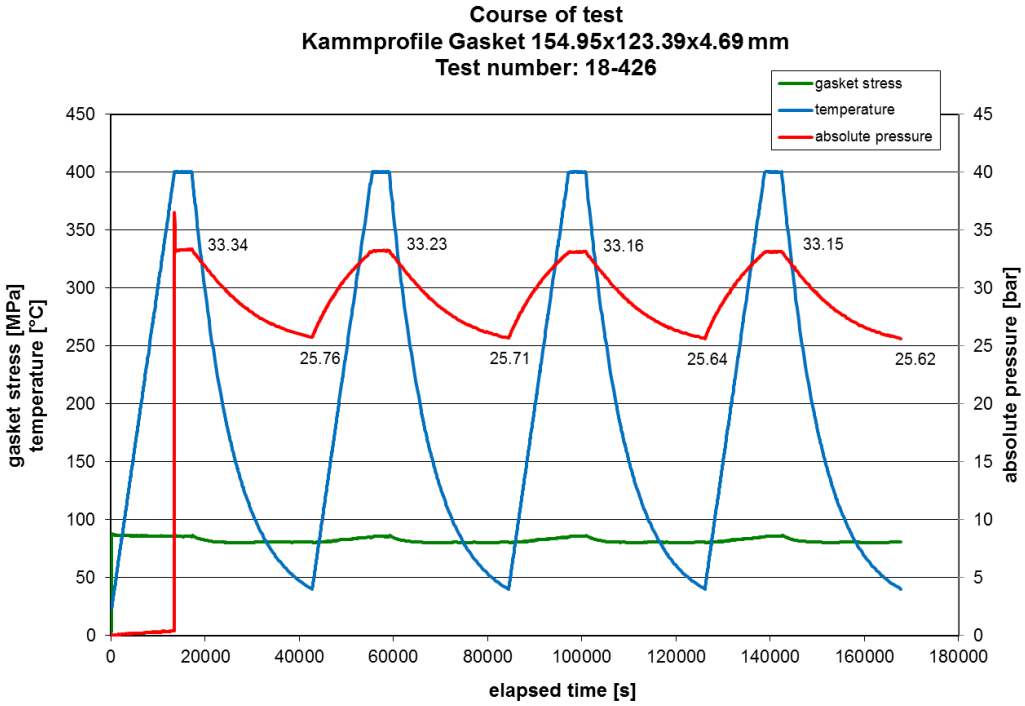
Leakage curve
Kammprofile Gasket 154.43x123.24x5.173 mm
Test number: 18-466



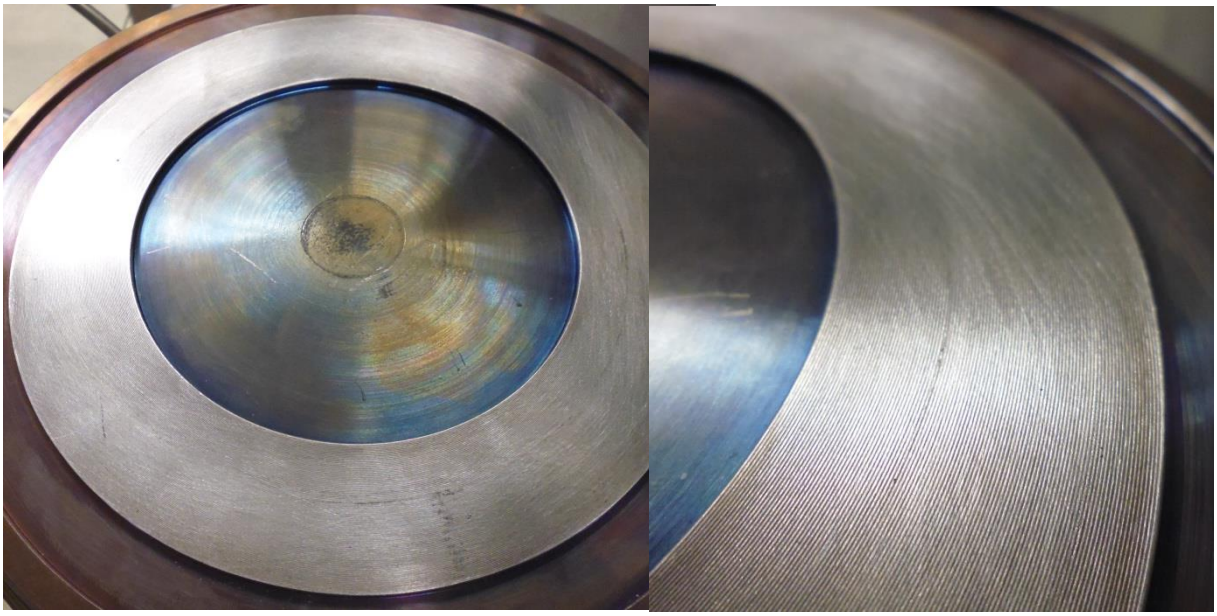
Leakage curve
Kammprofile Gasket 154.58x123.3x5.138 mm
Test number: 18-479



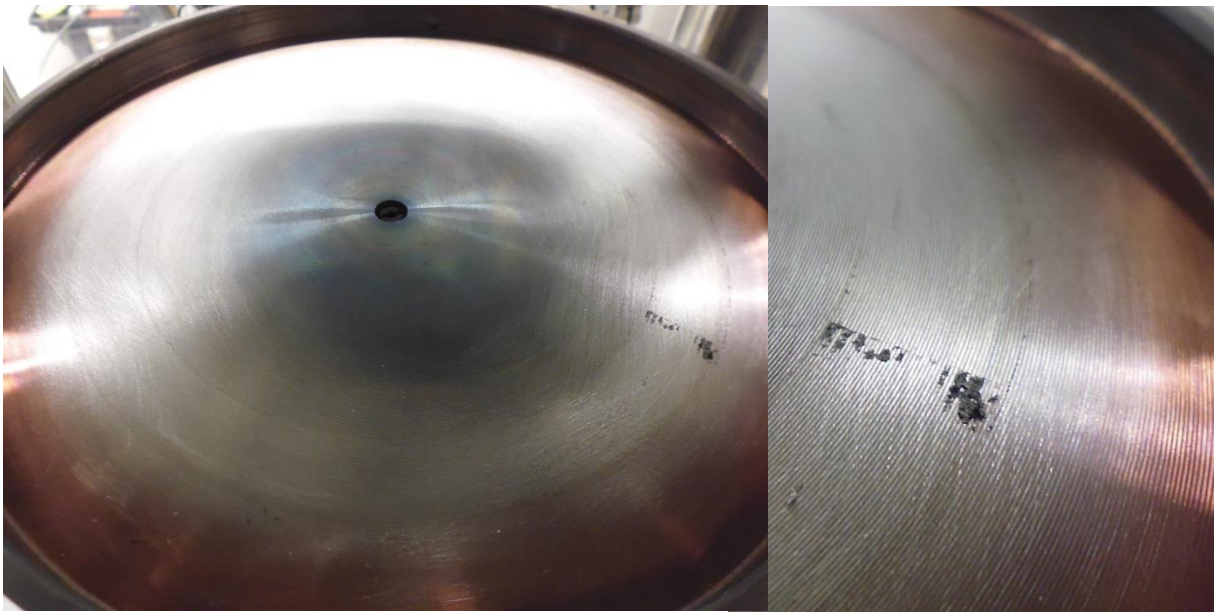
Leakage test according EN 13555



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

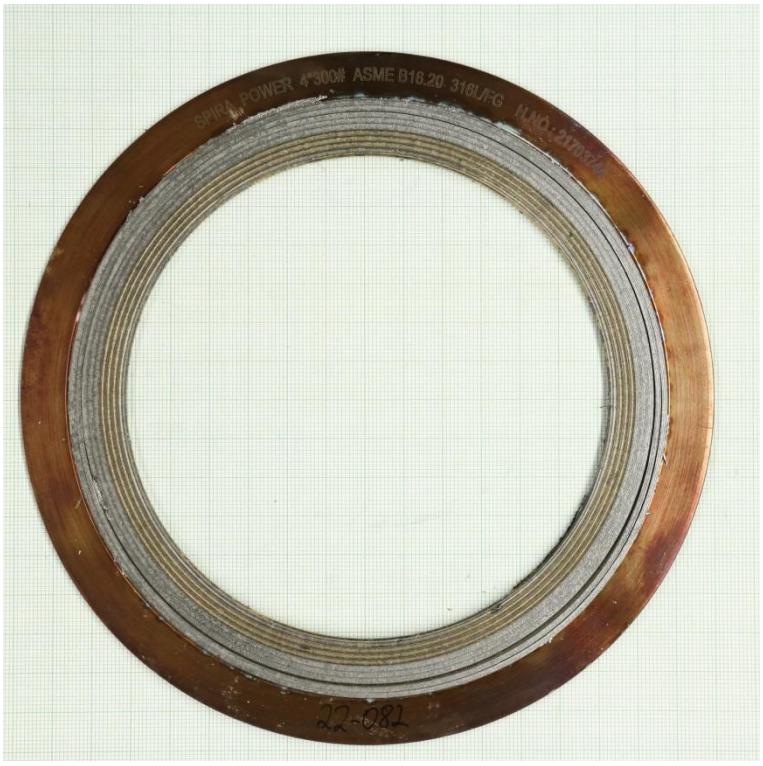


Top flange gasket adhesion



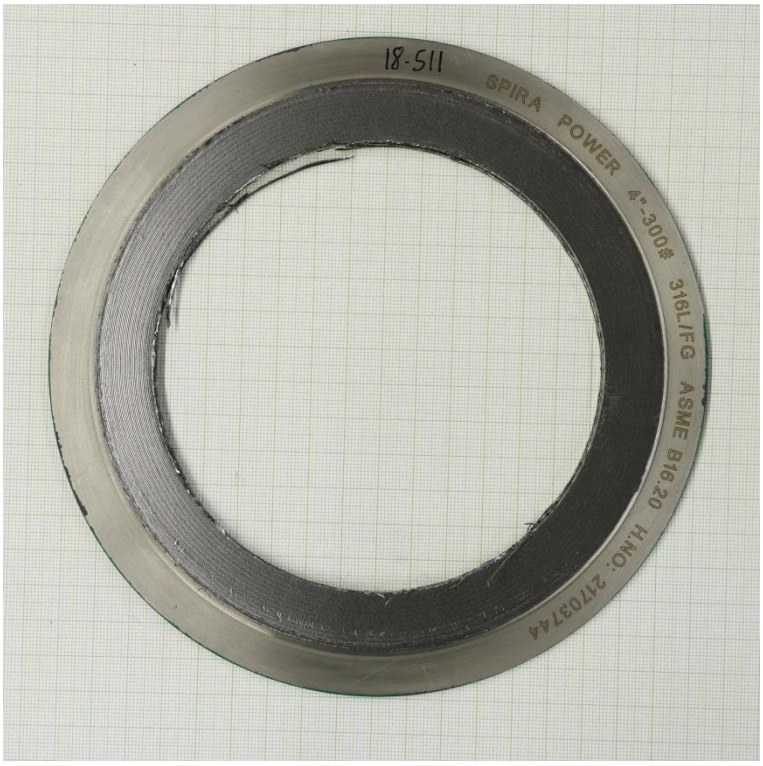
Bottom flange gasket adhesion

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

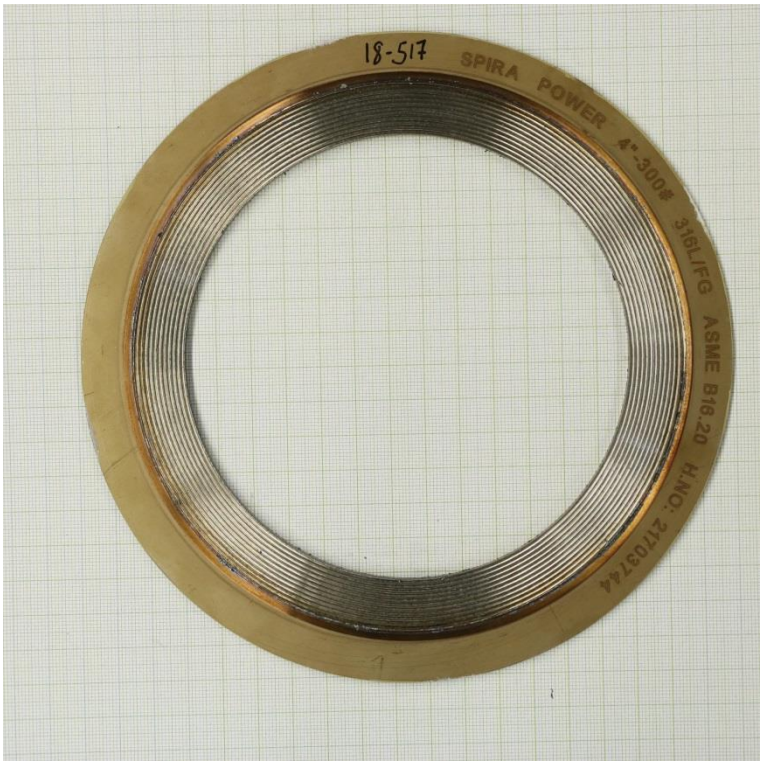


Shell leakage test (T) according MESC SPE 85/300 - 3.3.2

Compression test at RT (EN 13555)



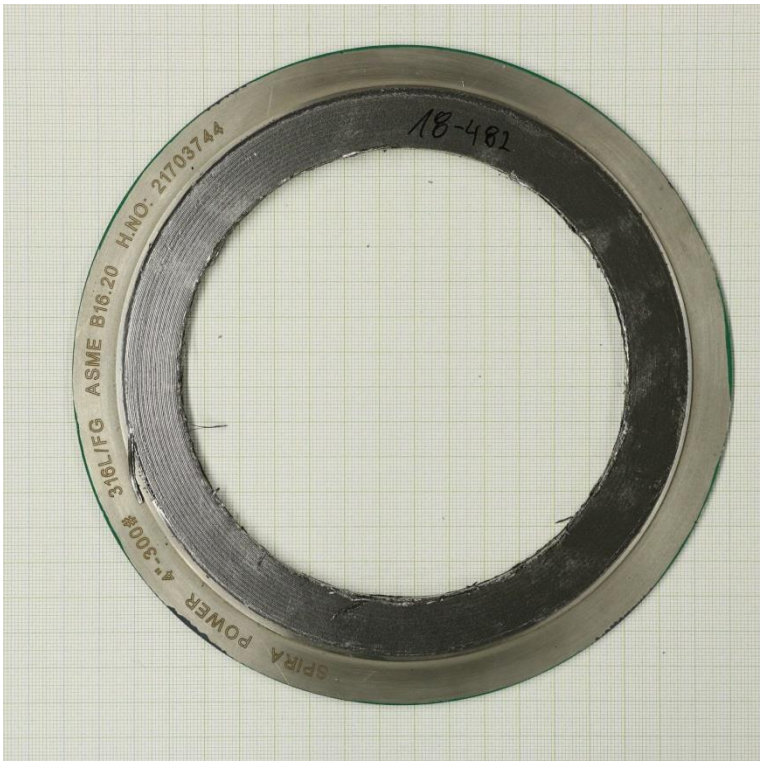
Compression test at RT (EN 13555)



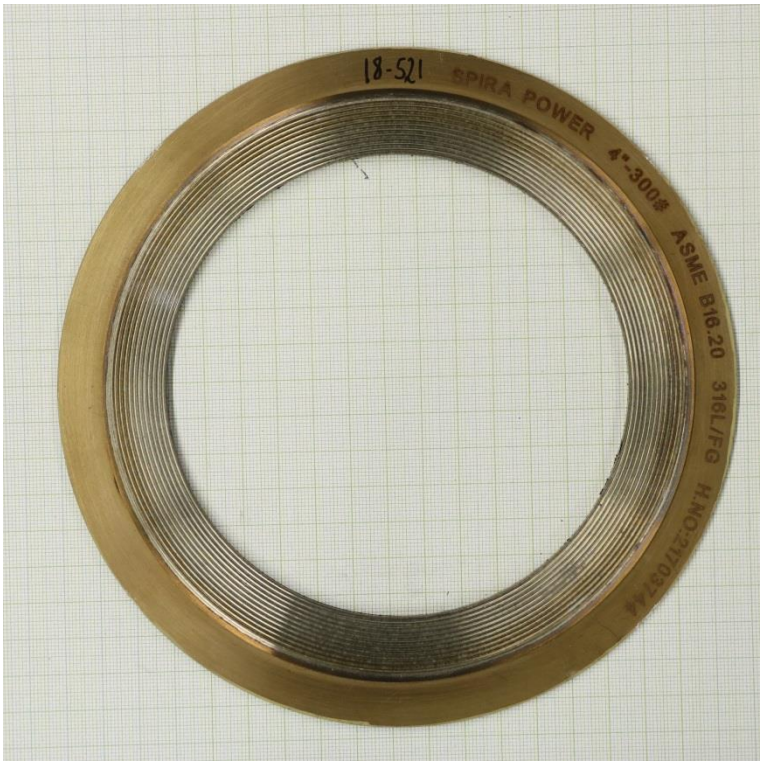
Compression test at 400 °C (EN 13555)

Compression test at 400 °C (EN 13555)

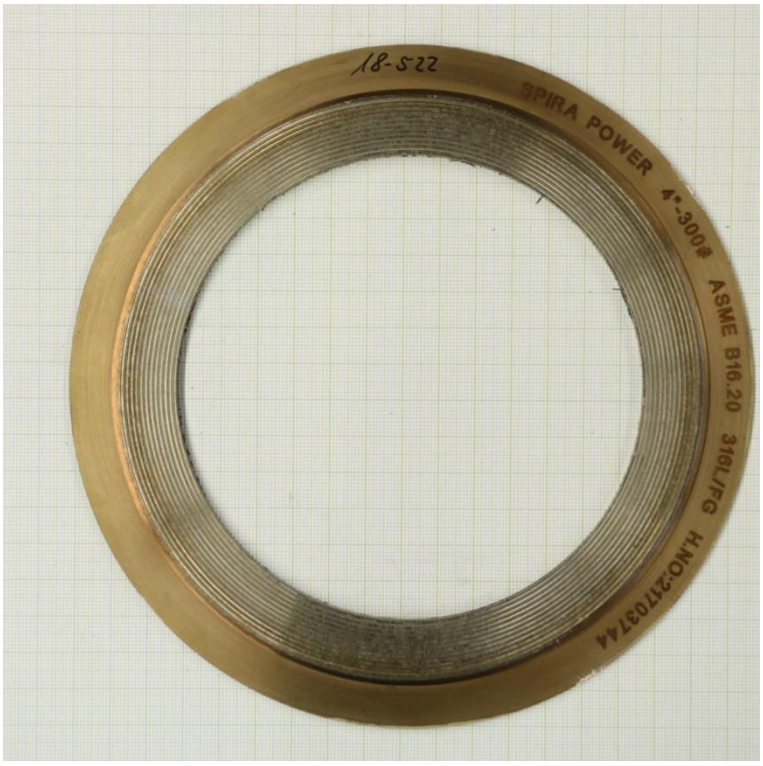
Creep relaxation test at 80 MPa - RT (EN 13555)



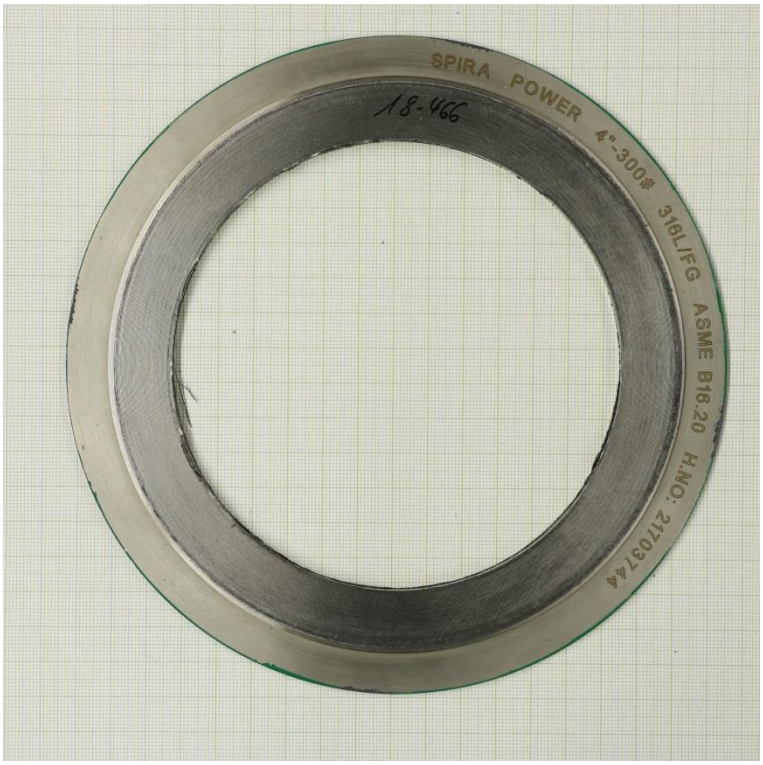
Creep relaxation test at 80 MPa - RT (EN 13555)



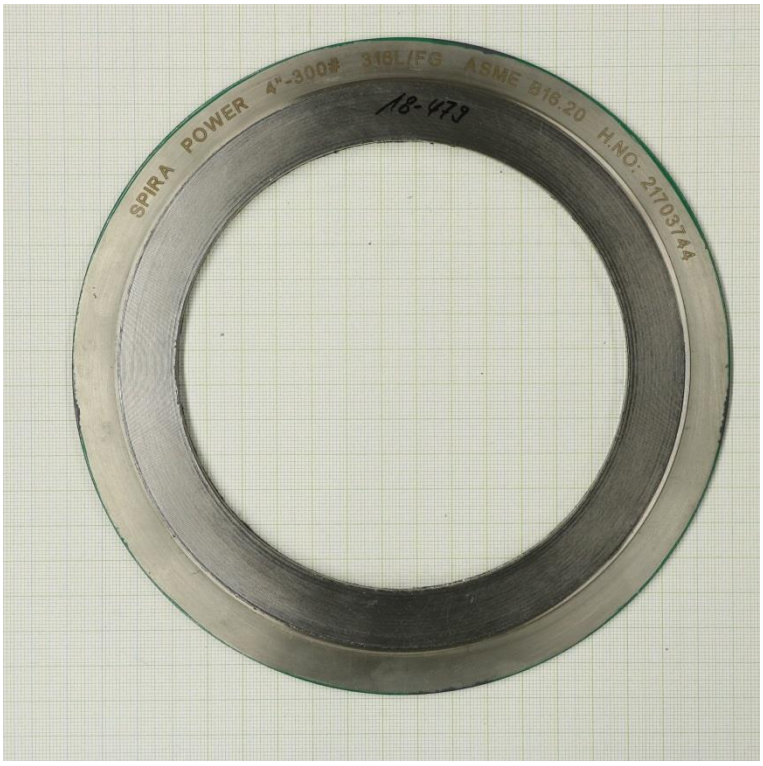
Creep relaxation test at 80 MPa - 400 °C (EN 13555)



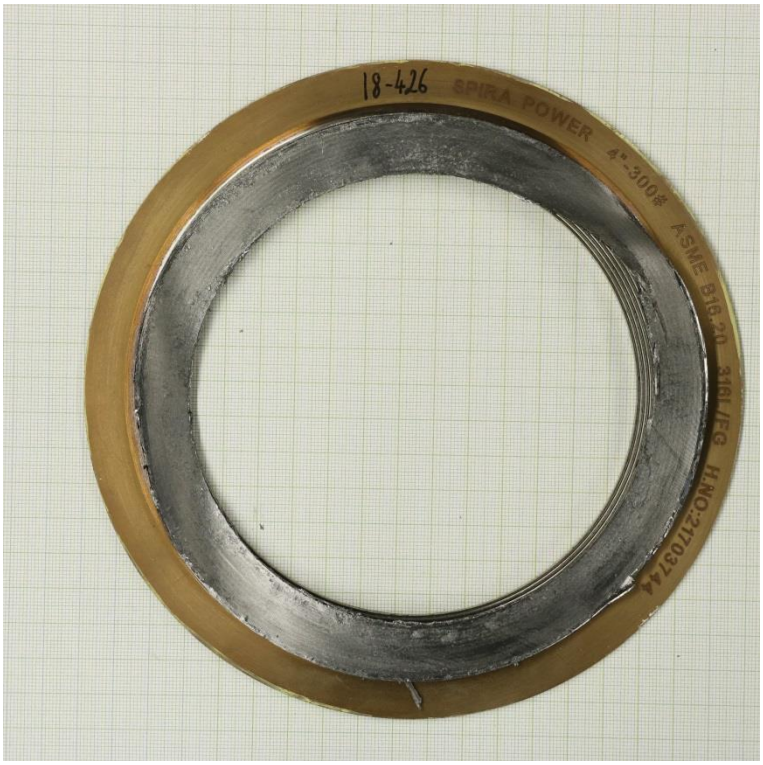
Creep relaxation test at 80 MPa - 400 °C (EN 13555)



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 Safe Test according MESC SPE 85/300 - 3.3.3