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# Test Report

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|---|---|
| Customer: | Spira Power Gasket Factory, LLC.<br>Sohar Industrial Estate,<br>311 Falaj Al Qabail<br>OM - Sultanate of Oman |
| Project number (amtec): | 304 792 |
| Report number: | 304 792 2/- |
| Test procedure: | Shell Specification MESC SPE 85/300<br>(dated February 2019) |
| Material: | 4 Inch Cl 300 Graphite SS316L Expanded Graphite Filled Spiral Wound Gasket with SS316 Inner and CS Outer Ring |
| Date: | February 24th, 2022 |
| Pages: | 13 |
| Appendices: | 28 |

| 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 spiral wound gasket manufactured by Spira Power Gasket Factory, LLC. which is customer named

- 4 Inch Cl 300 Graphite SS316L Expanded Graphite Filled Spiral Wound Gasket with SS316 Inner and CS Outer Ring.

The spiral wound gasket has an inner and outer ring according to ASME B16.20. The material of the outer ring is carbon steel and the material of the inner ring is SS316. The material of the metal strip is SS316L. Flexible graphite is the filler material.

## 2. Goal of Investigation

The goal of the investigation was the qualification of the gasket material Expanded Graphite Filled Spiral Wound 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) and
- 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.

The contact area of the gasket is OD = 149 mm and ID = 127.5 mm. The thickness of the Spiral Wound Gasket was 4.8 mm.

The thickness of the outer ring was 3.2 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).

Within this report two charges of gaskets were tested. First charge of gaskets and tests were made in 2016. 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:

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| Multifunctional test rig TEMES$_{fl.ai1}$ | No.: 010181, 010 506 and 010280 |
| Fire Safe Testing device TEMES$_{fire.safe}$ | No.: 010 595 |

Photos and the schematic view of the testing equipment TEMES$_{fl.ai1}$ and of the Fire Safe testing device 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 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 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 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 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 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 $P_{QR}$ (120 MPa – RT, 400 °C),
- Change in gasket thickness due to creep $\Delta e_{Gc}$ (120 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 $\Delta e_{Gc}$ 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 $\Delta e_{Gc}$ 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 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.
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.

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.

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: June 27th to August 8th, 2016.
Test date second charge of gaskets: January 17th to February 17th, 2022.

All test results of the gasket material Expanded Graphite Filled Spiral Wound 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 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 $6.4 \cdot 10^{-7}$ Pa·m³/(s·$mm_{dia}$), see **appendix 6**. The leak rate was decreasing with increasing gasket stress up to 160 MPa. The leak rate at a gasket stress of 118.2 MPa, which is equivalent to a bolt stress of 361 MPa, was $1.7 \cdot 10^{-7}$ Pa·m³/(s·$mm_{dia}$), which is lower than the Tightness Class BH.

For the maximum gasket surface stress of 160 MPa the leak rate was $4.9 \cdot 10^{-8}$ Pa·m³/(s·$mm_{dia}$), which is lower than the Tightness Class BH.

In the Shell leakage test at 400 °C the gasket was compressed in 10 steps from 70 MPa to 160 MPa. The leak rate at 118.2 MPa gasket stress, which is equivalent to a bolt stress of 361 MPa, at an internal pressure of 34.7 bar was $4.5 \cdot 10^{-8}$ Pa·m³/(s·$mm_{dia}$), see appendix 6.

The leak rate at all gasket stress levels was not measurable with a measuring time of 24h. Therefore the leak rate is set to $4.5 \cdot 10^{-8}$ 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 fire test API 6FB the gasket Expanded Graphite Filled Spiral Wound Gasket was mounted in a 4" Class 300 flange with hydraulic spanners to a bolt load of 68.5 kN which means a total load of 548 kN and a gasket surface stress of 114.7 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 0.12 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 gasket Expanded Graphite Filled Spiral Wound 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 Expanded Graphite Filled Spiral Wound 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 until the maximum load of the testing equipment of 200 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 200 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 200 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 200 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 $E_G$ increases nearly linear with increasing gasket stress, but at a lower level than at ambient temperature.

A very 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 $P_{QR}$ (120 MPa, RT, 500 kN/mm) and
- creep relaxation factor $P_{QR}$ (120 MPa, 400 °C, 500 kN/mm).

In total 4 creep relaxation tests were performed. The initial gasket stress level was set to 120 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 1.0 (120 MPa, RT, 500 kN/mm) and 0.97 resp. 0.98

(120 MPa, 400 °C, 500 kN/mm). The deflection $\Delta e_{Gc}$ of the gasket Expanded Graphite Filled Spiral Wound Gasket at RT is below 5 µm in both tests and 31 µm resp. 18 µm in tests at 400 °C.

A very good repeatability of the double test is noticeable.

### 6.3.3 Leakage tests

The tightness behaviour of the gasket material Expanded Graphite Filled Spiral Wound 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 31 MPa or 30 MPa, respectively. Therefore the minimum gasket stress in assembly for the tightness class $L_{0.01}$ is set to $Q_{min(0.01)}$ = 31 MPa. The lowest tightness class which could be reached was $L_{0.0001}$; therefore a gasket stress of 143 MPa resp.128 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 $4.6 \cdot 10^{-5}$ mg/m/s at 160 MPa in test 16-509.

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 $Q_{smin(0.01)}$ = 19 MPa resp. 17 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 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, no pressure drop could be recognized, see **appendix 19**.

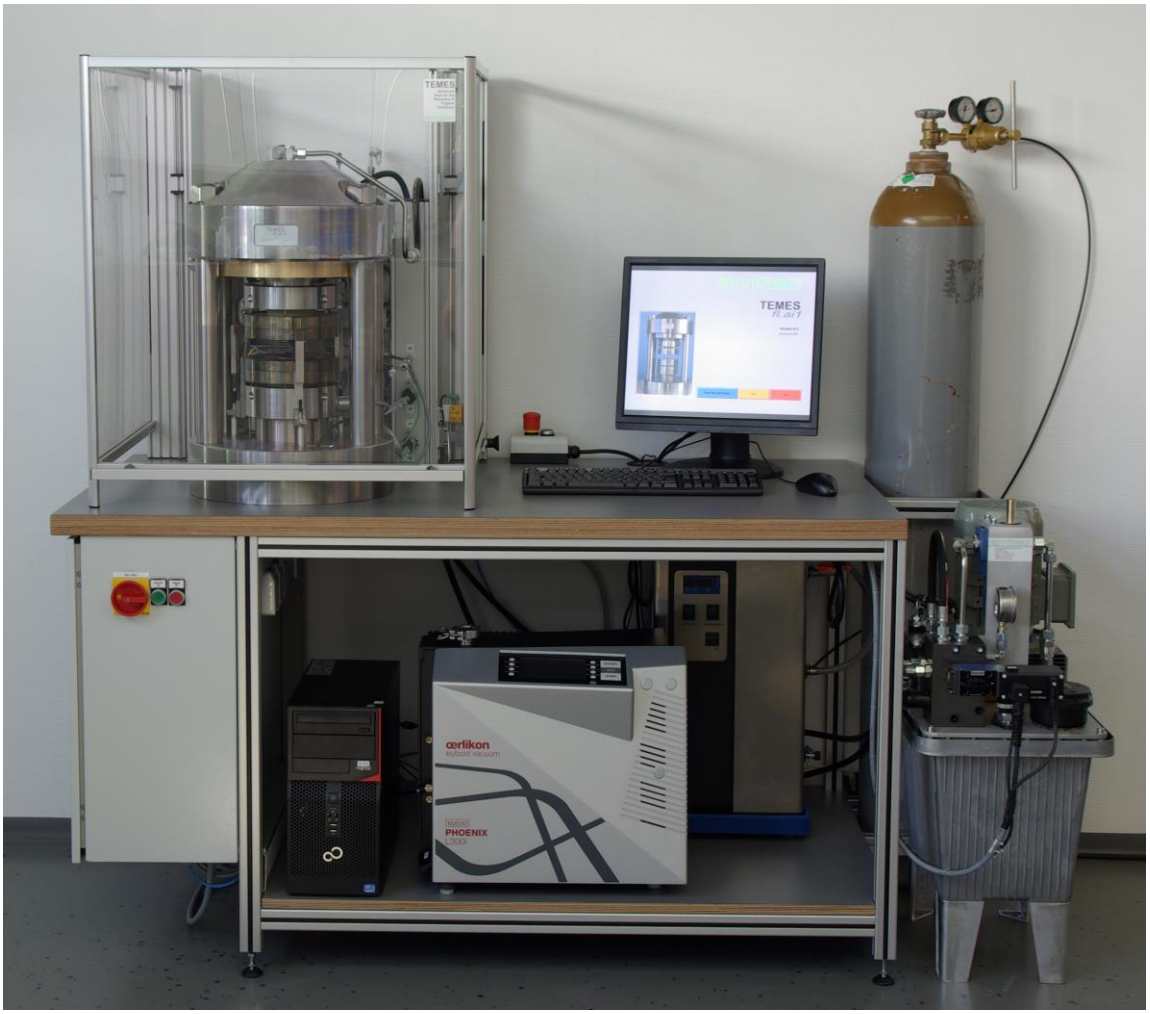
During the last thermal cycle the pressure loss is less than 0.3 bar. The gasket material Expanded Graphite Filled Spiral Wound Gasket has passed the Shell requirement of a pressure drop less than 1 bar.

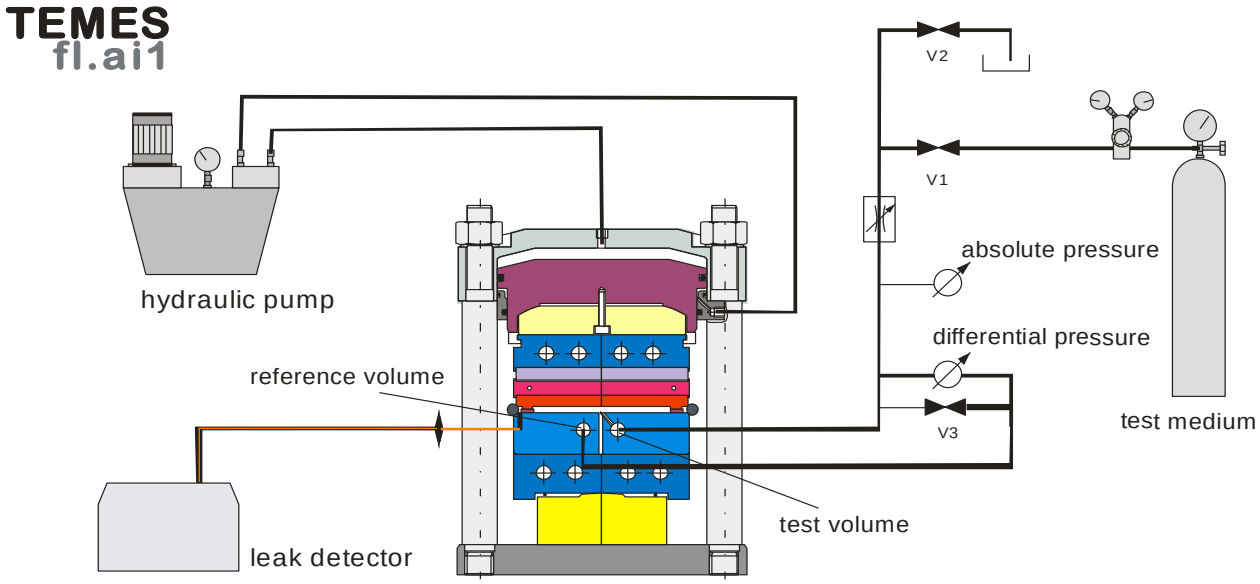
### 6.5 Gasket adhesion (MESC SPE 85/300 – 3.3.13)

In **appendices 19 and 20** photos of the adjacent flanges after tests at ambient temperature with the gasket specimens Expanded Graphite Filled Spiral Wound Gasket are represented. The gasket does not stick on the flange. Only 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 28** photos of the tested gasket specimens Expanded Graphite Filled Spiral Wound Gasket 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: Spira Power Gasket Factory, LLC.

Product: **Expanded Graphite Filled Spiral Wound Gasket**

**Maximum allowable Gasket Stress $Q_{smax}$ [MPa]**

| T [°C] | 25 | 25 | 400 | 400 |
|---|---|---|---|---|
| $Q_{smax}$ [MPa] | 200 | 200 | 200 | 200 |
| Test # | 16-456 | 16-458 | 16-468 | 16-476 |

**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 | | 4,880 | | 4,860 | | 4,860 | | 4,850 |
| 1 | | 4,822 | | 4,822 | | 4,823 | | 4,814 |
| 20 | 1128 | 4,418 | 1063 | 4,389 | 1363 | 4,150 | 1410 | 4,196 |
| 30 | 1208 | 4,203 | 1099 | 4,075 | 1585 | 3,955 | 1532 | 3,984 |
| 40 | 1290 | 3,829 | 1253 | 3,834 | 2347 | 3,785 | 2108 | 3,740 |
| 50 | 1693 | 3,694 | 1654 | 3,678 | 3245 | 3,671 | 2900 | 3,628 |
| 60 | 2219 | 3,601 | 2220 | 3,587 | 4193 | 3,589 | 3678 | 3,554 |
| 80 | 3421 | 3,466 | 3550 | 3,470 | 5723 | 3,482 | 5100 | 3,456 |
| 100 | 4679 | 3,374 | 4767 | 3,380 | 7260 | 3,409 | 6545 | 3,387 |
| 120 | 5921 | 3,301 | 5876 | 3,312 | 8845 | 3,352 | 8016 | 3,328 |
| 140 | 7501 | 3,248 | 7723 | 3,269 | 10089 | 3,300 | 9369 | 3,275 |
| 160 | 9960 | 3,221 | 10332 | 3,244 | 11167 | 3,256 | 10345 | 3,230 |
| 180 | 14313 | 3,209 | 15831 | 3,233 | 12215 | 3,219 | 11396 | 3,193 |
| 200 | 22450 | 3,203 | 25398 | 3,224 | 13097 | 3,188 | 13305 | 3,169 |
| | | | | | | | | |
| Test # | 16-456 | | 16-458 | | 16-468 | | 16-476 | |

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

**Change in gasket thickness due to creep $\Delta e_{GC}$ [µm]**

| C = 500 kN/mm | T [°C] / Q [MPa] | 25 | 25 | 400 | 400 |
|---|---|---|---|---|---|
| | 120 | 1,0 | 1,0 | 0,97 | 0,98 |
| | $\Delta e_{GC}$ [µm] | 5 | 4 | 31 | 18 |
| | Test # | 16-463 | 16-465 | 16-472 | 16-478 |

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

Manufacturer: Spira Power Gasket Factory, LLC.

Product: **Expanded Graphite Filled Spiral Wound 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 | 0,000001 | 0,0000001 |
|---|---|---|---|---|---|---|---|---|---|
| 40 | 5 | 5 | 14 | 31 | 58 | 143 | | - | - |
| Test # | 16-508 | | | | | | | | |
| 40 | 5 | 5 | 13 | 30 | 55 | 128 | - | - | - |
| Test # | 16-509 | | | | | | | | |

**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 | 0,000001 | 0,0000001 |
|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 5 | 5 | - | - | - | - | - | - | - |
| | 20 | 5 | 5 | 8 | - | - | - | - | - | - |
| | 40 | 5 | 5 | 8 | 19 | - | - | - | - | - |
| | 60 | 5 | 5 | 8 | 19 | 58 | - | - | - | - |
| | 80 | 5 | 5 | 7 | 17 | 53 | - | - | - | - |
| | 100 | 5 | 5 | 6 | 14 | 34 | - | - | - | - |
| | 160 | 5 | 5 | 5 | 10 | 28 | 107 | - | - | - |
| | Test # | 16-508 | | | | | | | | |

**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 | 0,000001 | 0,0000001 |
|---|---|---|---|---|---|---|---|---|---|---|
| | 10 | 5 | 5 | - | - | - | - | - | - | - |
| | 20 | 5 | 5 | 7 | - | - | - | - | - | - |
| | 40 | 5 | 5 | 7 | 17 | - | - | - | - | - |
| | 60 | 5 | 5 | 7 | 17 | 54 | - | - | - | - |
| | 80 | 5 | 5 | 6 | 14 | 35 | - | - | - | - |
| | 100 | 5 | 5 | 5 | 12 | 33 | - | - | - | - |
| | 160 | 5 | 5 | 5 | 8 | 24 | 100 | - | - | - |
| | Test # | 16-509 | | | | | | | | |

**Table 3: Data Sheet for Gasket Characteristics (Shell)**

Manufacturer: Spira Power Gasket Factory, LLC.

Product: **Expanded Graphite Filled Spiral Wound Gasket**

**Shell leakage test at ambient temperature**

| | | |
|---|---|---|
| Test pressure: | 51 | bar |
| Shell required gasket stresss level: | 118,2 | MPa |
| Leakage rate: | 1,66E-07 | $Pa \cdot m^3/(s \cdot mm_{dia})$ |
| Shell tightness class: | BH | |
| test no. | 22-159 | |

**Shell leakage test at 400 °C**

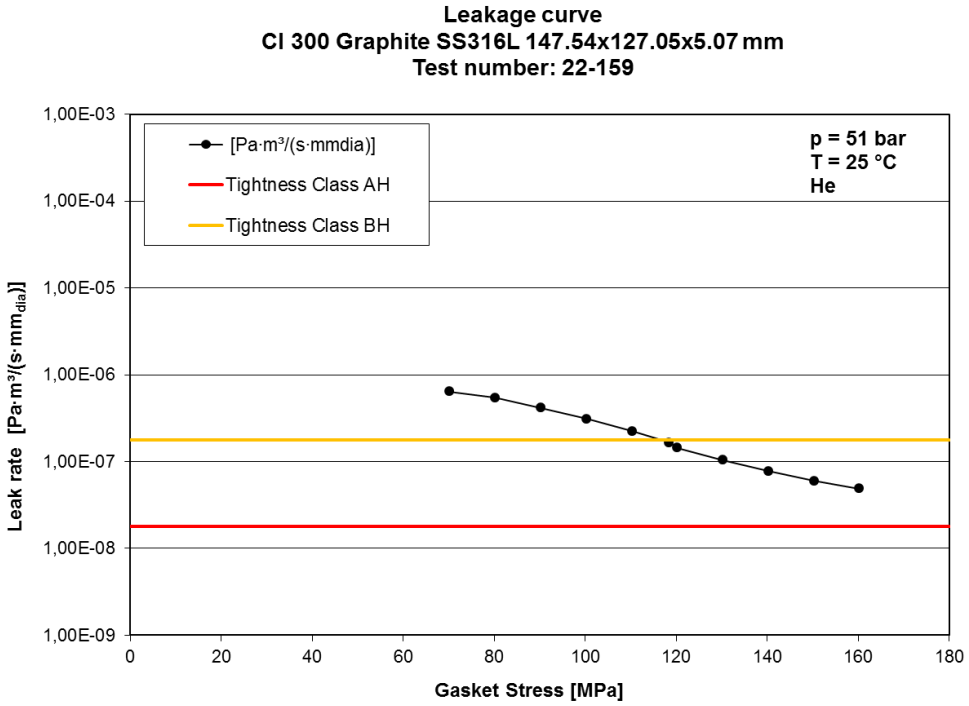
| | | |
|---|---|---|
| Test pressure: | 34,7 | bar |
| Shell required gasket stresss level: | 118,2 | MPa |
| Leakage rate: | 4,50E-08 | $Pa \cdot m^3/(s \cdot mm_{dia})$ |
| Shell tightness class: | BH | |
| test no. | 22-038 | |

**Shell cycle test at 400 °C**

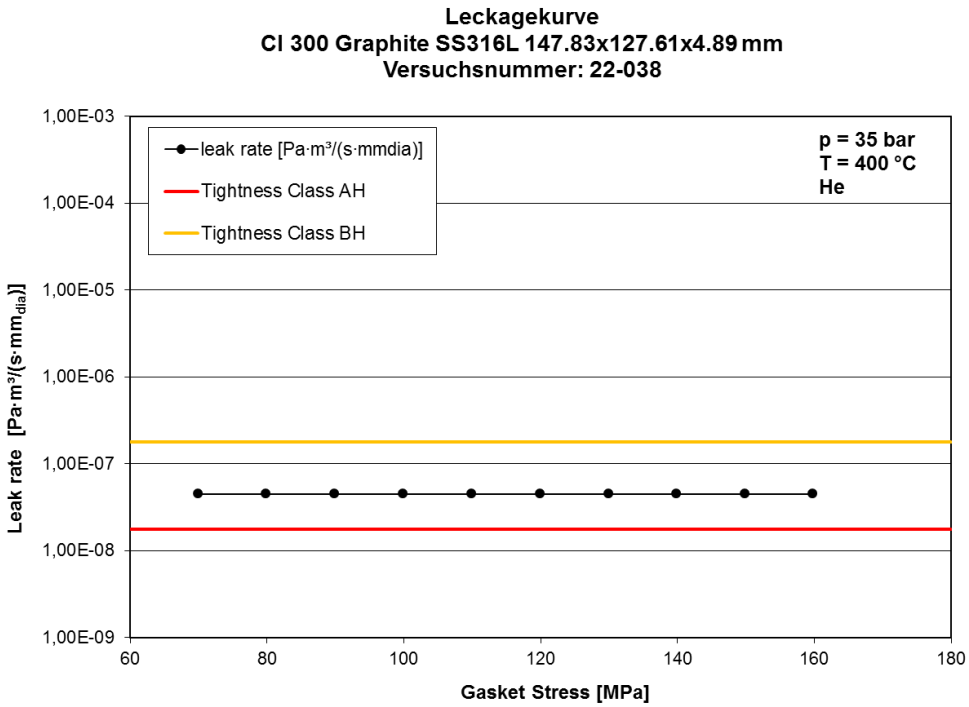
| | | |
|---|---|---|
| Test pressure: | 34,7 | bar |
| Initial gasket stress level: | 118,2 | MPa |
| Pressure drop in last cycle: | < 0.3 | bar |
| Requirements | passed | |
| test no. | 16-512 | |

**Fire test API 6FB**

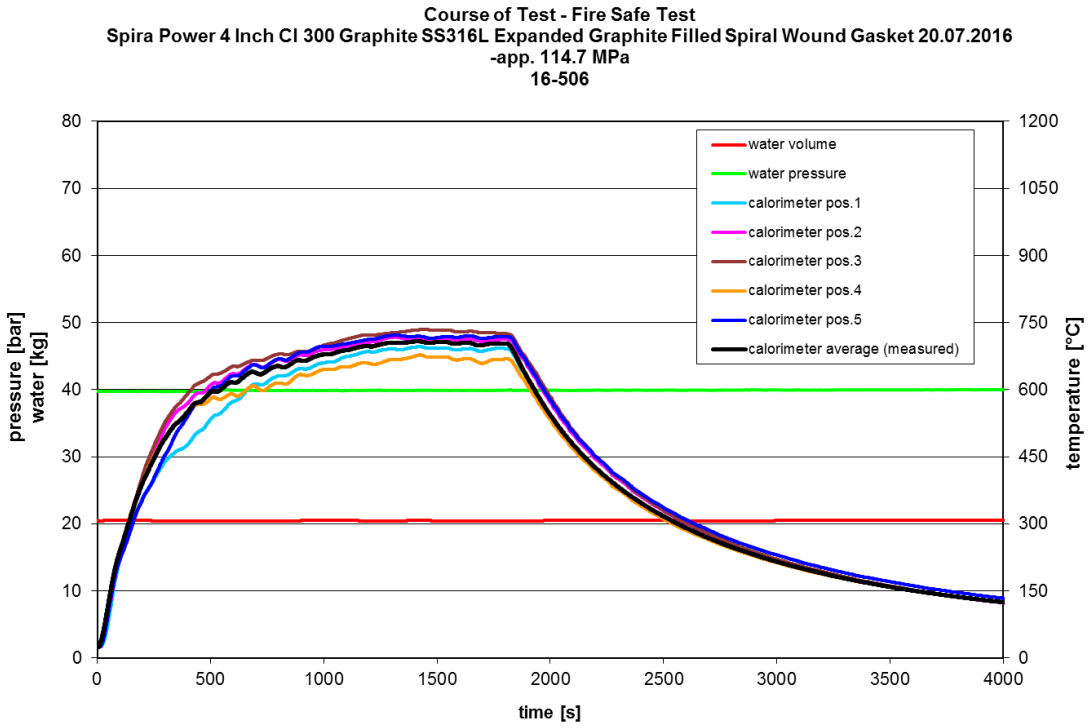
| | | |
|---|---|---|
| Test pressure: | 40 | bar |
| Initial gasket stress level: | 115 | MPa |
| Leak rate (complete test): | 0,03 | ml/inch/min |
| Requirements | passed | |
| test no. | 16-506 | |



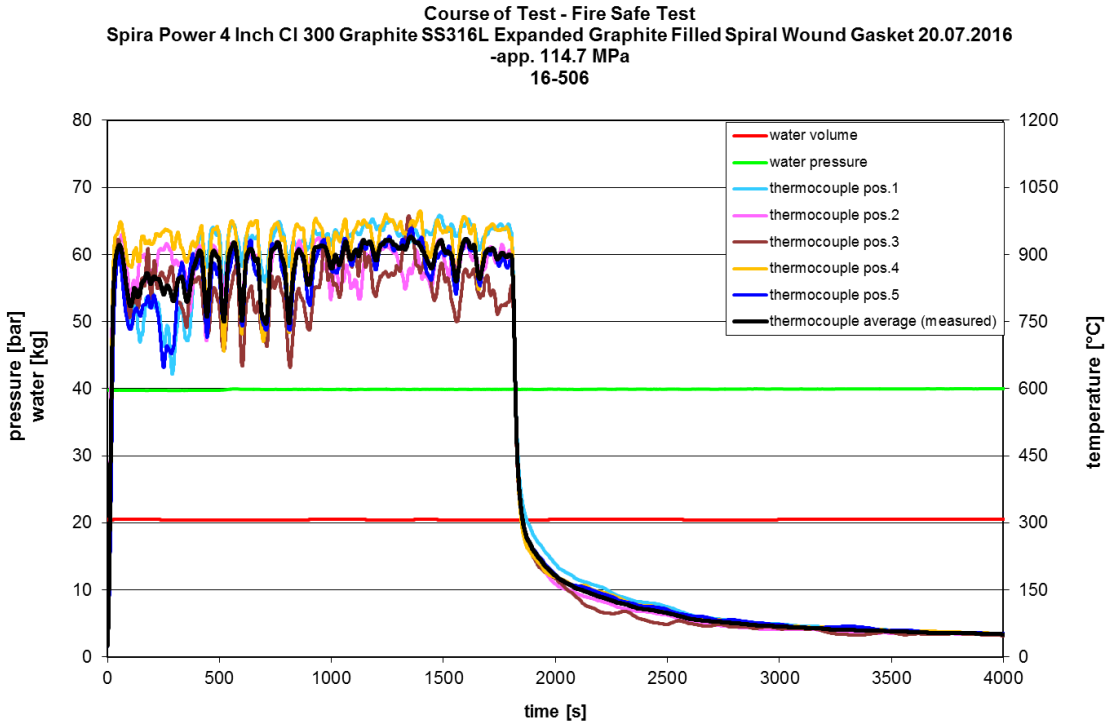

## Shell leakage test (RT) according MESC SPE 85/300 - 3.3.2



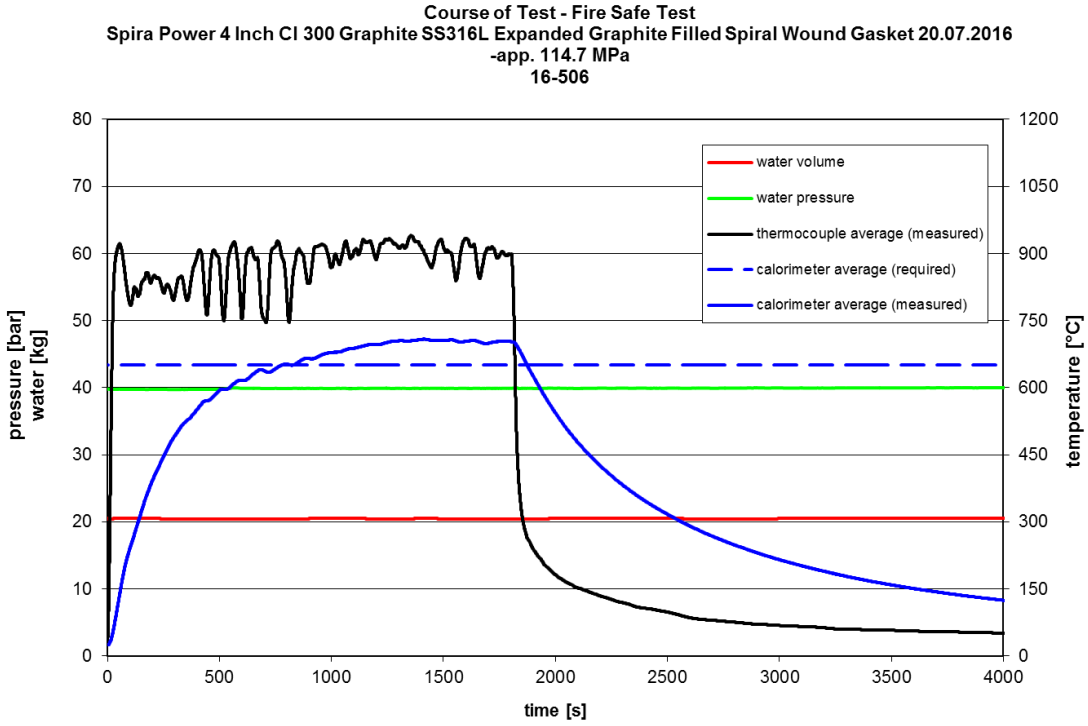

## Shell leakage test (400 °C) according MESC SPE 85/300 - 3.3.2




## 3.3.3 Fire test API 6FB - calorimeters




## 3.3.3 Fire test API 6FB – thermocouples




## 3.3.3 Fire test API 6FB

## SPIRA POWER - Expanded Graphite Filled Spiral Wound Gasket

**geometries**

| | | |
|---|---|---|
| bolts | 8 | - |
| OD gasket | 149.1 | mm |
| ID gasket | 127.1 | mm |
| mean gasket circumference contact area | 433.9 | mm |
| gasket area | 4772.4 | mm² |
| gasket contact area | 4772.4 | 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** | **512.43** | **ml** |

**calculation of gasket stress**

| | | |
|---|---|---|
| hydraulic spanners - No. | GS 3/1 | - |
| calibration factor | 0.19 | kN/bar |
| pressure | 370 | bar |
| force per bolt | 68.45 | kN |
| force total | 547.60 | kN |
| gasket stress | 114.74 | MPa |

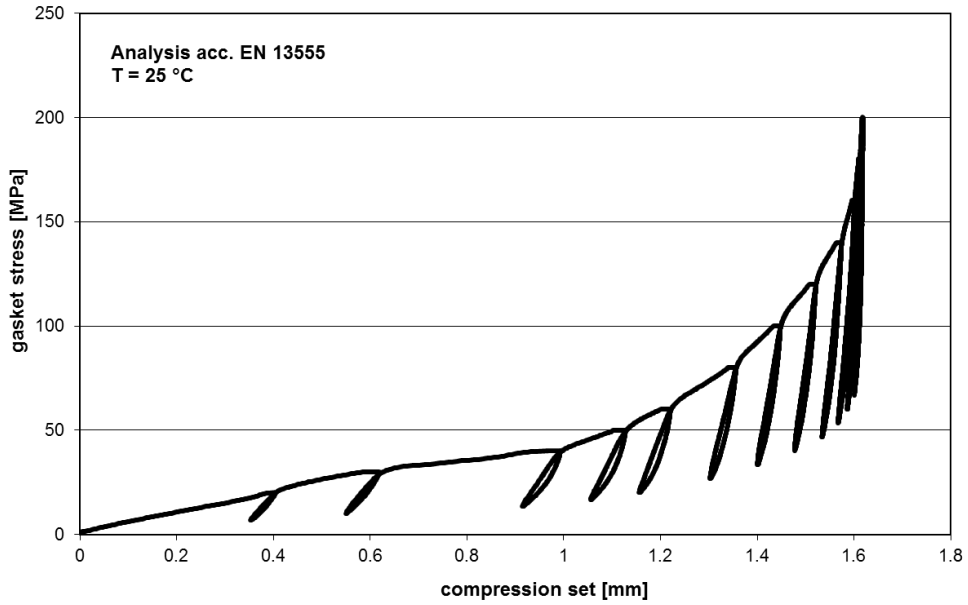
**calculation of leak rate of complete test**

| | | |
|---|---|---|
| start value scale | 20.47 | kg |
| end value scale | 20.40 | kg |
| start test | 07:31:49 | |
| end test | 10:10:32 | |
| test duration (min) | 158.71 | min |
| | | |
| leakage | 70.80 | ml |
| **leak rate** | **0.03** | **ml / inch / min** |

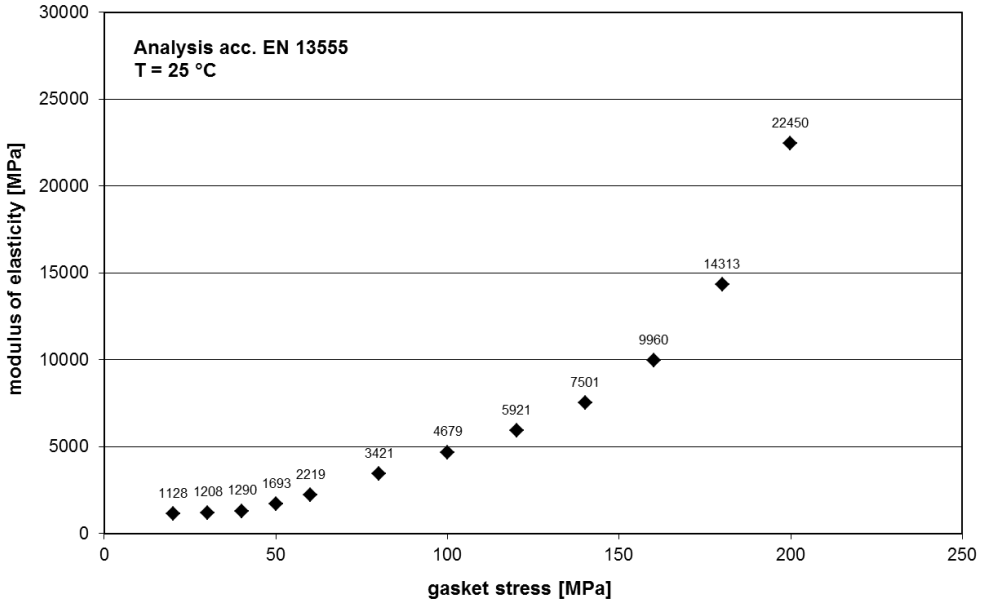
**calculation of leak rate of burning period**

| | | |
|---|---|---|
| start value scale | 20.47 | kg |
| end value scale | 20.41 | kg |
| start test | 07:31:49 | |
| end test | 08:01:49 | |
| test duration (min) | 30 | min |
| | | |
| leakage | 63.50 | ml |
| **leak rate** | **0.12** | **ml / inch / min** |

**Compression curve**
**SPIRA POWER 148.97x127.45x4.822 mm**
**Test number: 16-456**

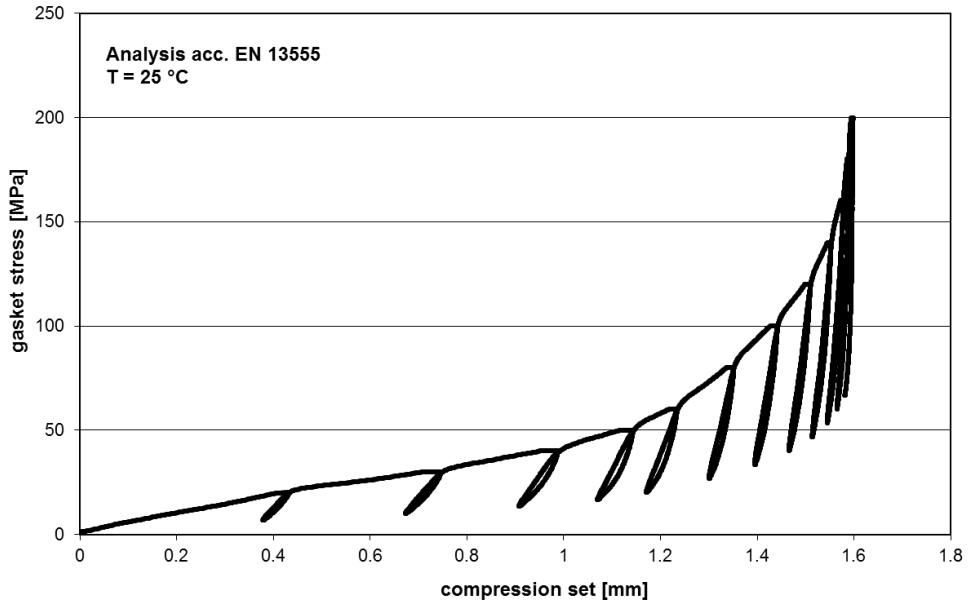



**Modulus of elasticity**
**SPIRA POWER 148.97x127.45x4.822 mm**
**Test number: 16-456**

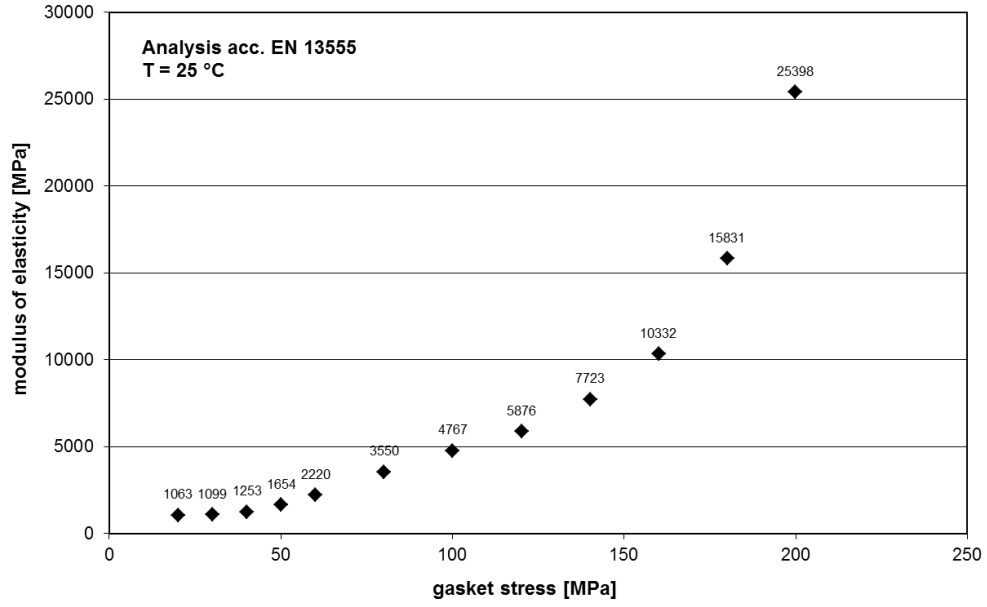



## Compression test (RT) according EN 13555

**Compression curve**
**SPIRA POWER 149.29x127.54x4.822 mm**
**Test number: 16-458**

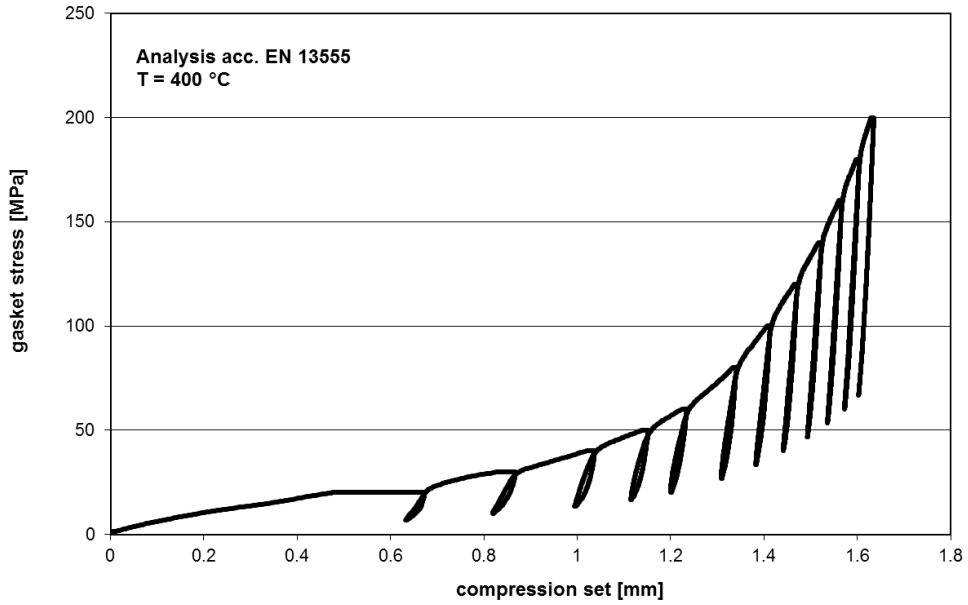



**Modulus of elasticity**
**SPIRA POWER 149.29x127.54x4.822 mm**
**Test number: 16-458**

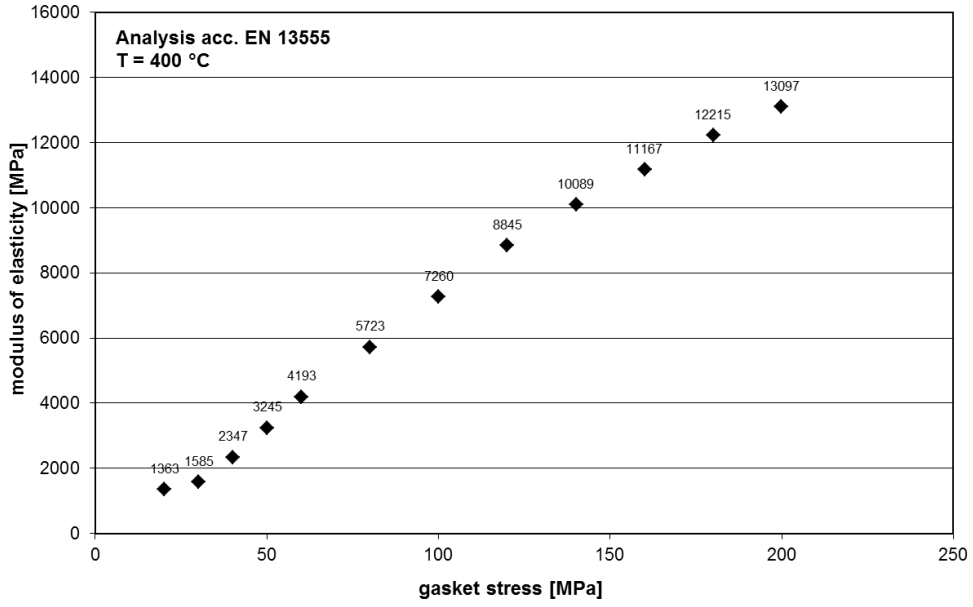



## Compression test (RT) according EN 13555

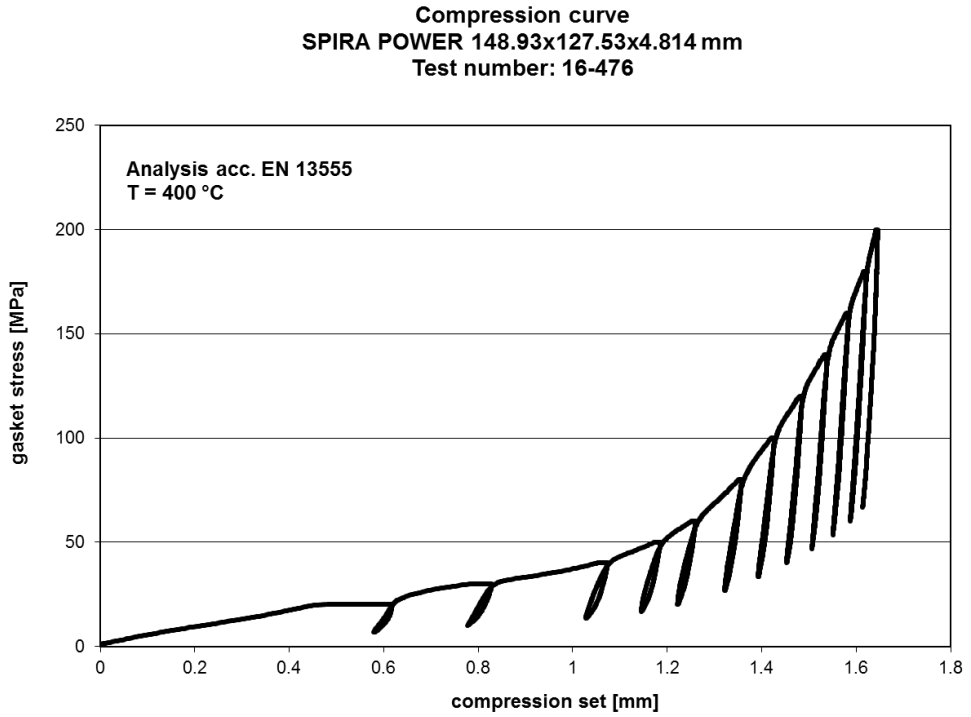
**Compression curve**
**SPIRA POWER 148.86x127.53x4.823 mm**
**Test number: 16-468**

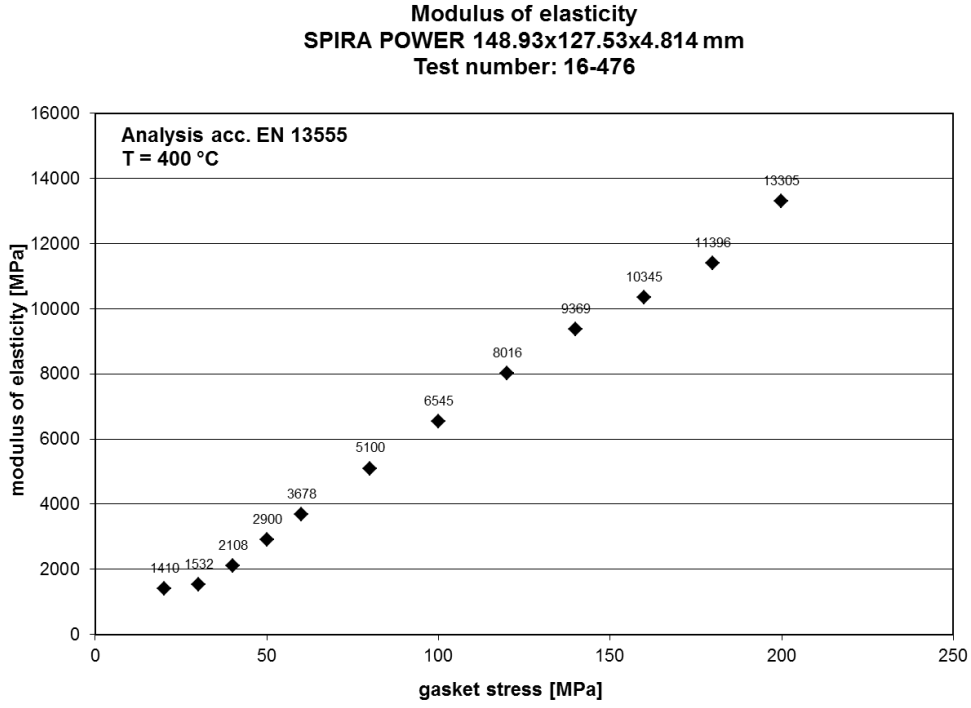



**Modulus of elasticity**
**SPIRA POWER 148.86x127.53x4.823 mm**
**Test number: 16-468**




## Compression test at 400 °C according EN 13555




## Compression test at 400 °C according EN 13555

# Creep relaxation test (EN 13555)

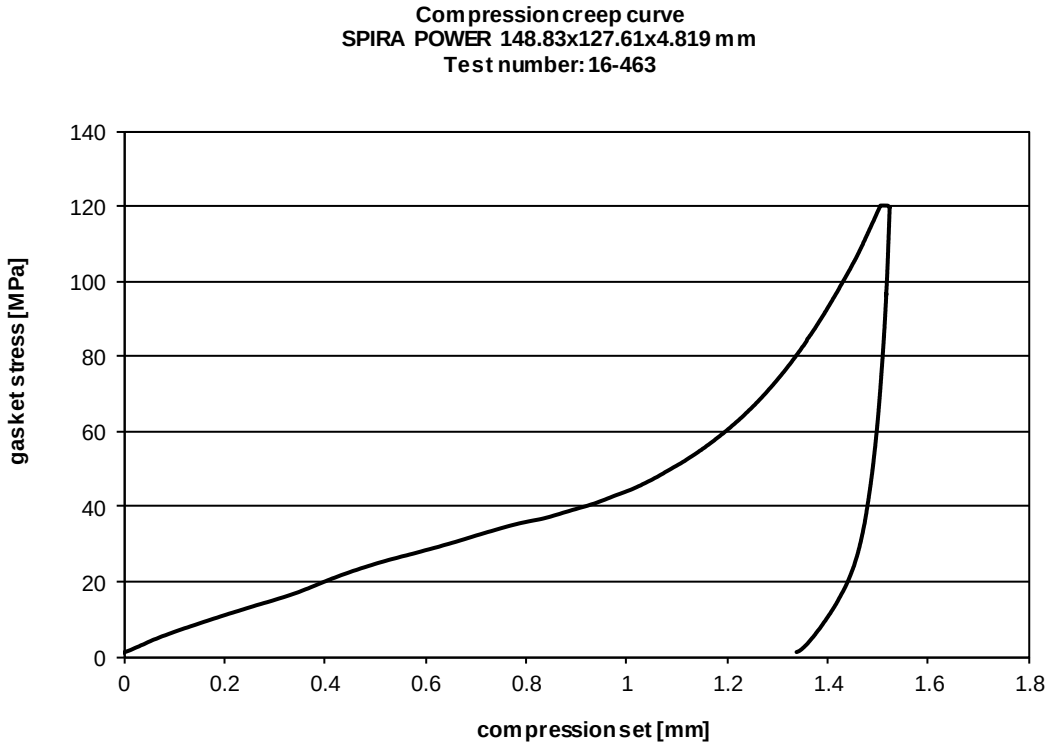
**SPIRA POWER**
**148.83x127.61x4.819 mm**
**Test number: 16-463**

## Test parameters

| | | |
|---|---|---|
| Initial gasket stress $Q_i$: | 120.1 | 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 $Q_r$: | 119.6 | MPa |
| Relaxation factor $P_{QR}(T_P)$: | 1.00 | |
| Deflection $\Delta e_{Gc}$: | 5 | µm |



# Creep relaxation test (EN 13555)

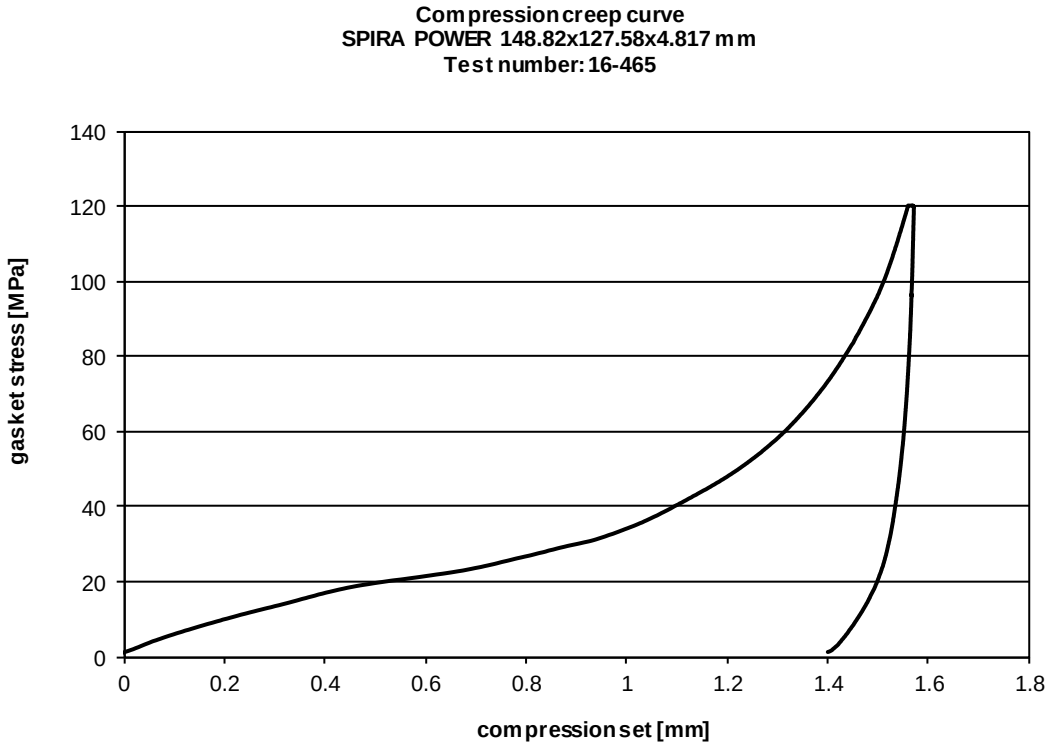
**SPIRA POWER**
**148.82x127.58x4.817 mm**
**Test number: 16-465**

## Test parameters

| | | |
|---|---|---|
| Initial gasket stress $Q_i$: | 120.1 | 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 $Q_r$: | 119.7 | MPa |
| Relaxation factor $P_{QR}$ ($T_P$): | 1.00 | |
| Deflection $\Delta e_{Gc}$: | 4 | µm |



# Creep relaxation test (EN 13555)

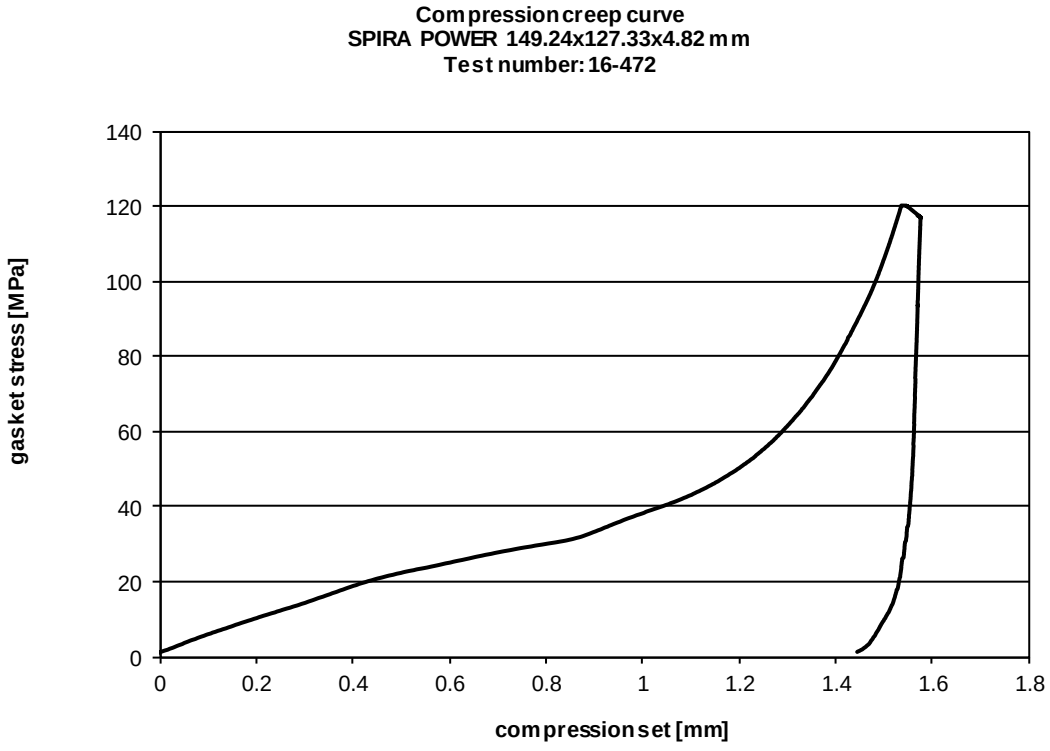
**SPIRA POWER**
**149.24x127.33x4.82 mm**
**Test number: 16-472**

## Test parameters

| | | |
|---|---|---|
| Initial gasket stress $Q_i$: | 120.1 | 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 $Q_r$: | 116.9 | MPa |
| Relaxation factor $P_{QR}$ ($T_P$): | 0.97 | |
| Deflection $\Delta e_{Gc}$: | 31 | µm |



# Creep relaxation test (EN 13555)

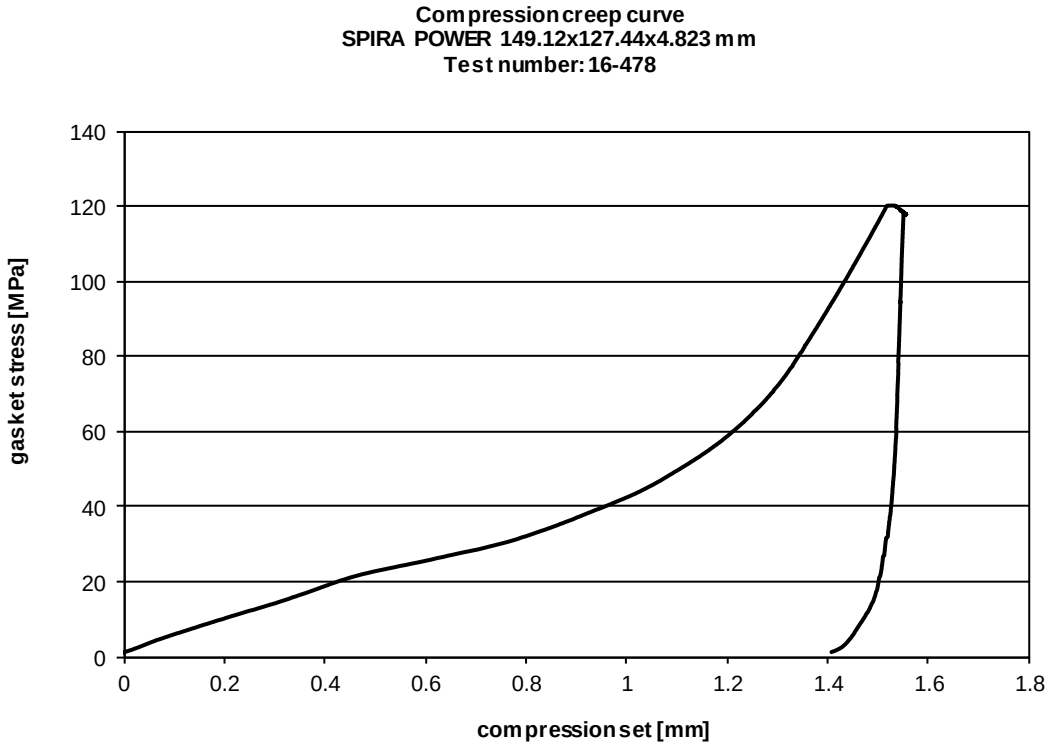
**SPIRA POWER**
**149.12x127.44x4.823 mm**
**Test number: 16-478**

## Test parameters

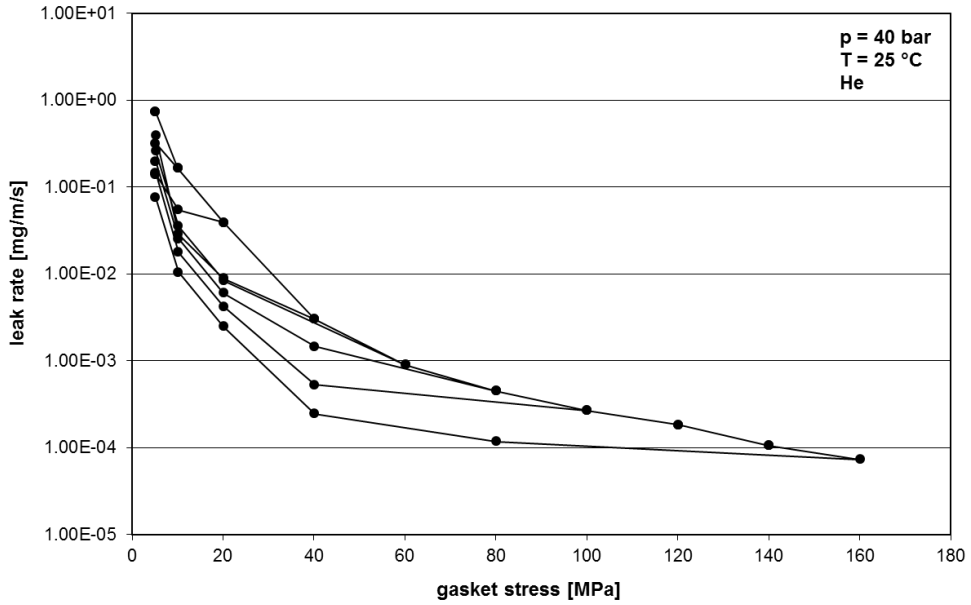
| | | |
|---|---|---|
| Initial gasket stress $Q_i$: | 120.1 | MPa |
| Test temperature $T_P$: | 400 | °C |
| Time at $T_P$: | 4:00 | hh:mm |
| Stiffness C: | 500 | kN/mm |

## Test results

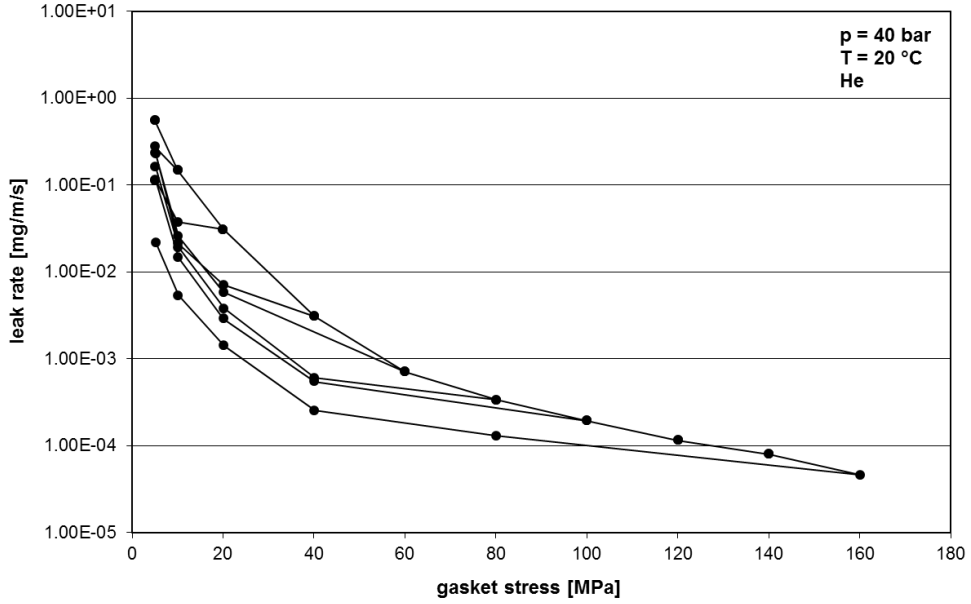
| | | |
|---|---|---|
| Remaining gasket stress $Q_r$: | 118.2 | MPa |
| Relaxation factor $P_{QR}$ ($T_P$): | 0.98 | |
| Deflection $\Delta e_{Gc}$: | 18 | µm |



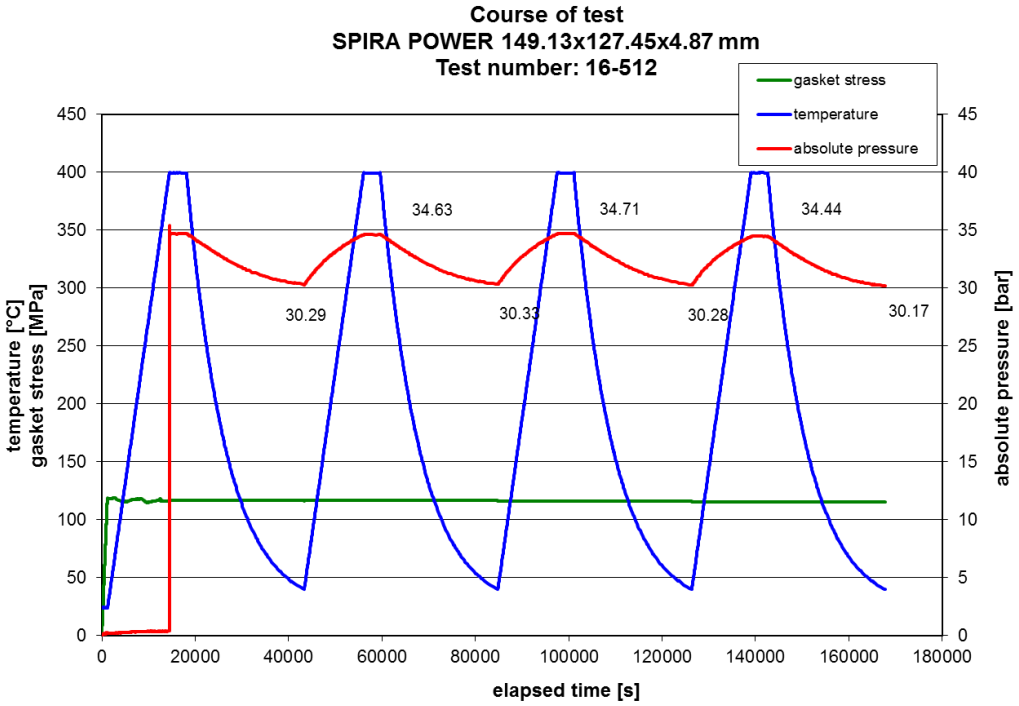
**Leakage curve**
**SPIRA POWER 148.97x127.47x4.769 mm**
**Test number: 16-508**




**Leakage curve**
**SPIRA POWER 149.3x127.57x4.78 mm**
**Test number: 16-509**



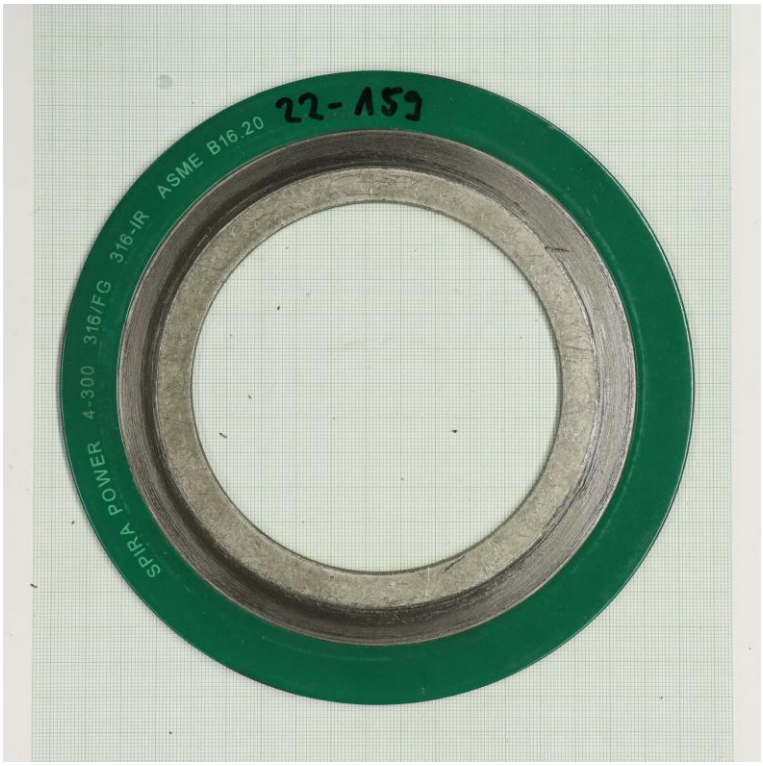

## Leakage test according EN 13555




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

**Top flange gasket adhesion**

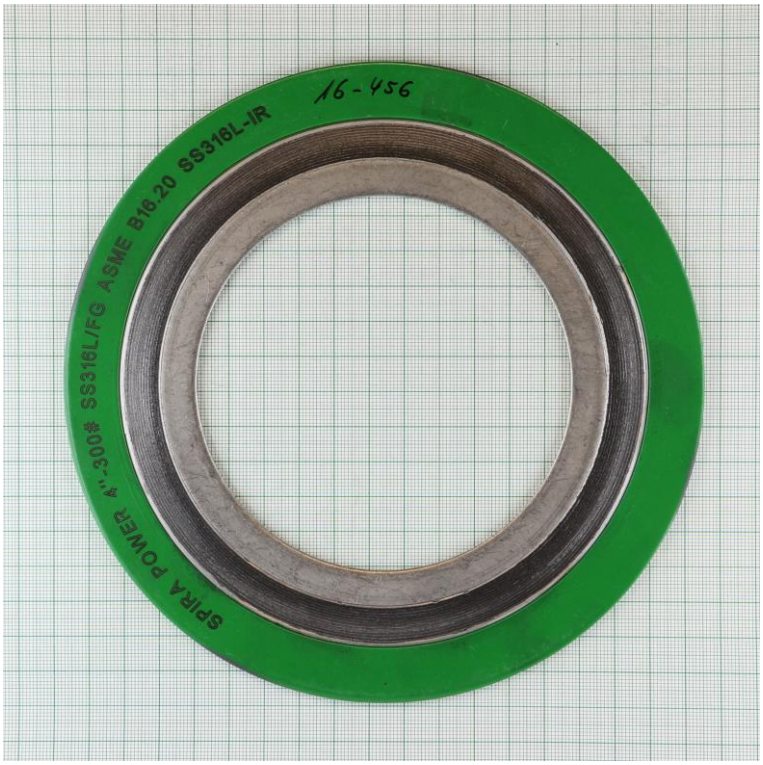
**Bottom flange gasket adhesion**



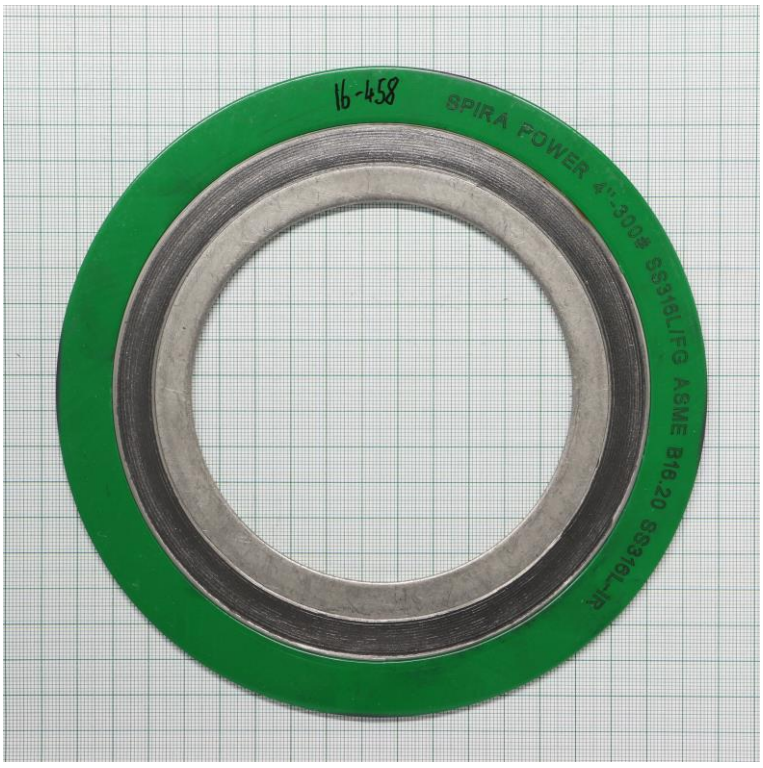

**Shell leakage test (RT) according MESC SPE 85/300 - 3.3.2**


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


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



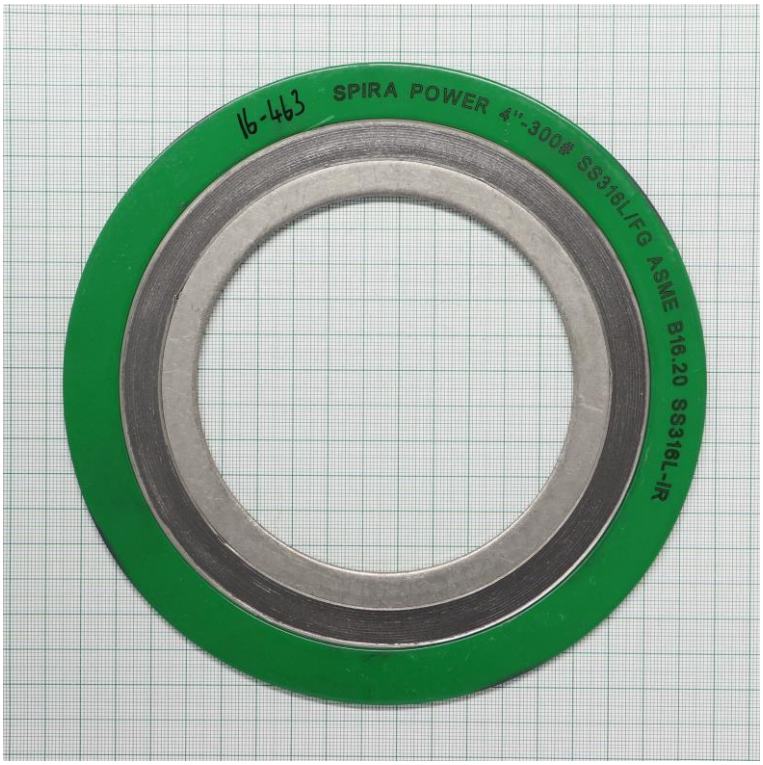

**Compression test at RT (EN 13555)**



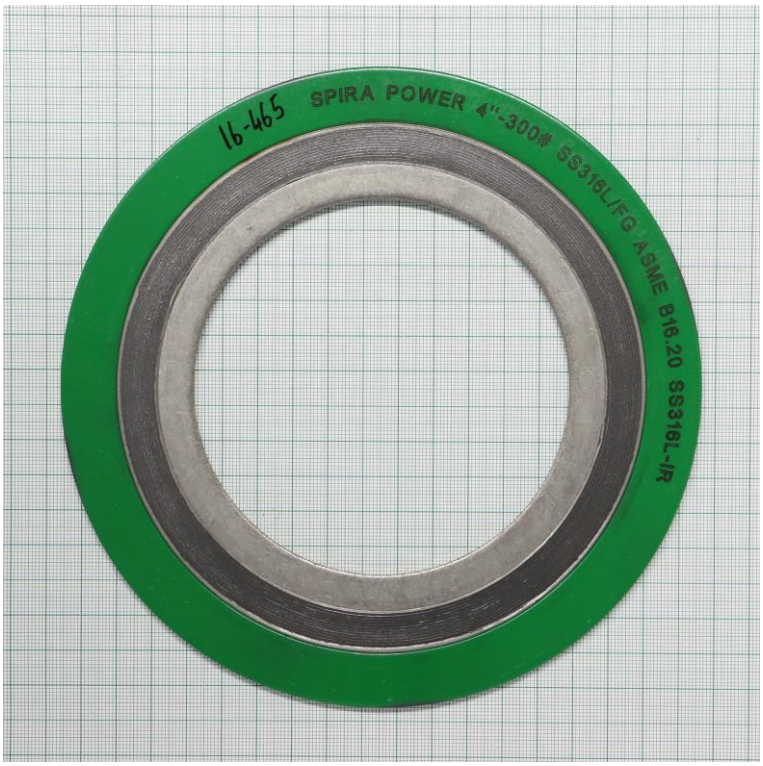

**Compression test at RT (EN 13555)**


**Compression test at 400 °C (EN 13555)**


**Compression test at 400 °C (EN 13555)**

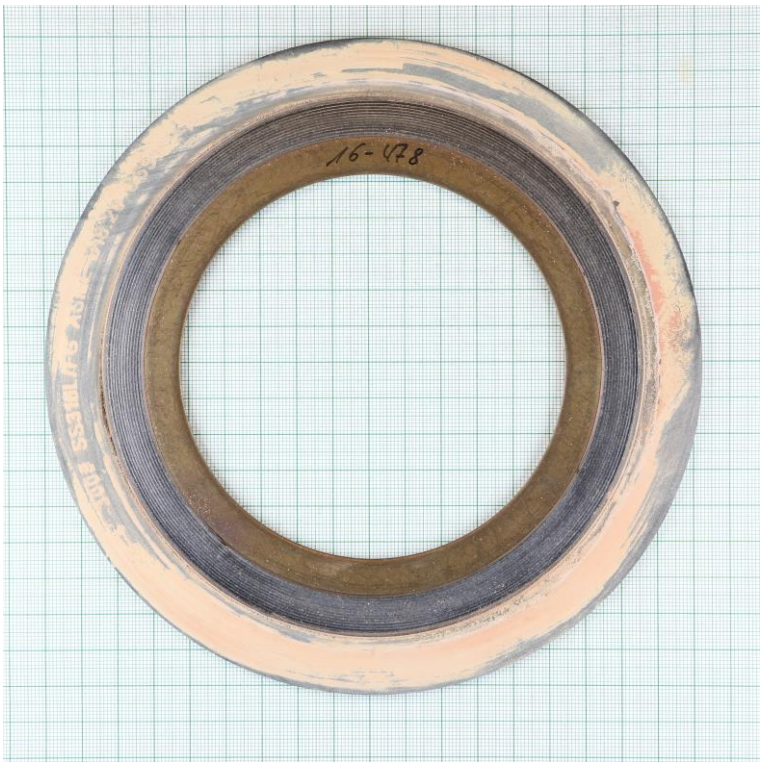



**Creep relaxation test at 120 MPa - RT (EN 13555)**

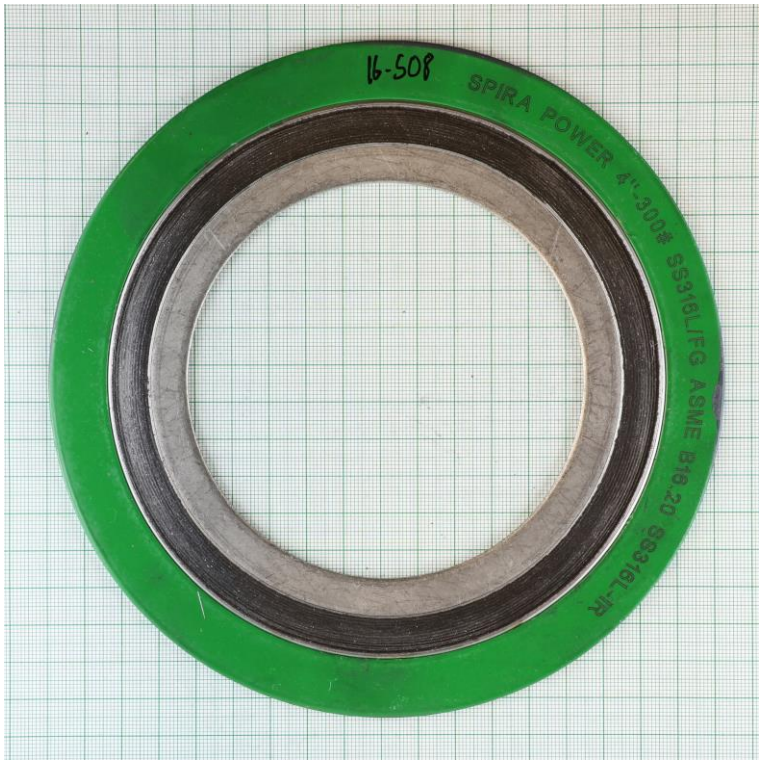



**Creep relaxation test at 120 MPa - RT (EN 13555)**

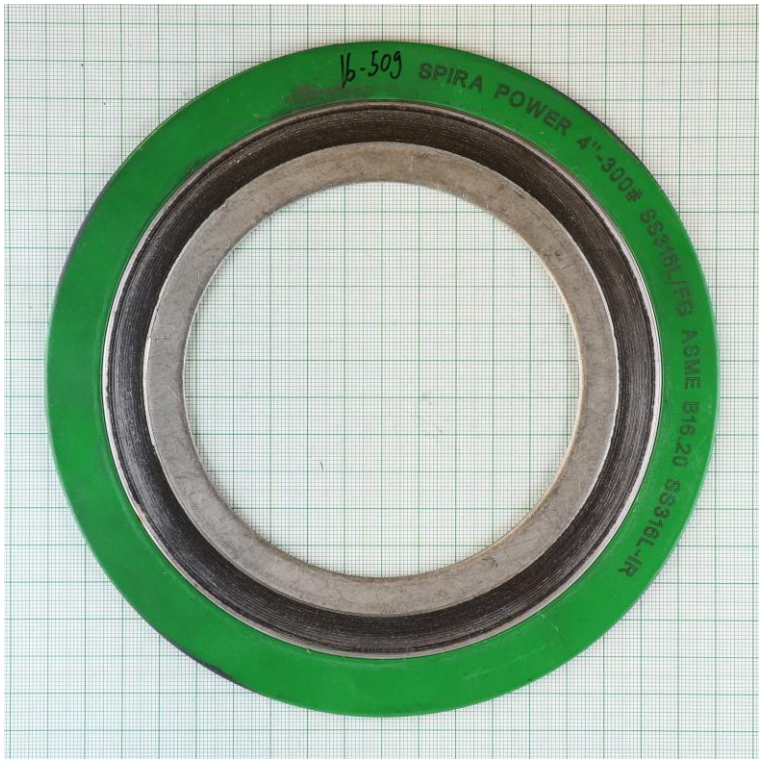

**Creep relaxation test at 120 MPa - 400 °C (EN 13555)**




**Creep relaxation test at 120 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**