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Test Report

Customer:	Kukil Inntot Co., Ltd. 17 Tapgeol-gil, KOR - 689-871 Ulsan
Project number (amtec):	303 500
Report number:	303 500 5/-
Test procedure:	Shell Specification MESC SPE 85/300 (dated February 2016)
Material:	Isolation gasket – K/# KINS-HAFS
Date:	November 22nd, 2018
Pages:	15
Appendices:	31

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Test results are only relevant to the test objects submitted.

1. Subject of Investigation

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

- K# KINS-HAFS.

The Isolation Gasket has a metallic core out of SUS316L with an insulating cover material of GRE NEMA G11. As sealing elements a spring energized PTFE ring, a metal ring and a backup ring with graphite layer on both sides are fixed in grooves which have an insulating coating.

In both tests of Fire and Electrical Isolation test the isolation kit with washers and sleeves were installed and tested.

2. Goal of Investigation

The goal of the investigation was the qualification of the gasket material K/# KINS-HAFS in accordance to the Shell Specification MESC SPE 85/300 (dated February 2016: 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 11 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 150 °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 150 °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 150 °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 150 °C (MESC SPE 85/300 - 3.3.5),

- Hot Blowout Test at 150 °C (MESC SPE 85/300 - 3.3.6) and
- Electrical Isolation test (MESC SPE 85/300 - 3.3.15).

3. Test Specimens

The geometry of the test specimens for the different tests was 4" Class 300.

Geometry of the sealing elements of the gasket:

Metal core including insulation cover	177,0 mm x 100,3 mm x 7,1 mm
Kammprofile with Graphite layer	149,7 mm x 136,8 mm x 8,5 mm
Metal ring	136.8 mm x 129.9 mm x 8.5 mm
PTFE ring	116.7 mm x 112.0 mm x 9.3 mm

Fire Test and Electrical Isolation test was done with the first charge of gaskets in 2017. All other tests were done with the second charge of gaskets in 2018.

4. Testing Equipment

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

- Multifunctional test rig TEMES$_{fl.ai1}$ No.: 010 181, 010 599 and 010 629
- Fire Safe Testing device TEMESfire.safe No.: 010 595
- Isolation test: 4″ Class 300 – pair of flanges and Insulation tester
  Megger MIT 525.: I001011

Photos and the schematic view of the testing equipment TEMES$_{fl.ai1}$, the Fire Safe and the Isolation testing device are shown in **appendices 1 to 3**.

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 $1.0 \cdot 10^{-4}$ 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 maintain 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.

For this test the following flange and bolts were used:

- Blind flanges ASME B 16.5, 4″ Class300, RF / Ra 3,2 - 6,3 µm (125-250 µin), ASTM A 105
- Studbolt, Grade 5, ASME B18.2.1,3/4 - 10 UNC x 5
- Hexagon nuts, ASME B18.2.2, 3/4 - 10 UNC

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 by a controller. 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 120 MPa at ambient and elevated temperature. After reaching the first gasket stress level the test volume is pressurised with 51 bar at ambient temperature and 45 bar at 150 °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 111 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 a gasket area of 5180 mm² of the isolation 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 4" 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, 150 °C),
- Modulus of elasticity E_G (RT, 150 °C),
- Creep relaxation factor P_{QR} (80 MPa – RT and 150 °C),
- Change in gasket thickness due to creep Δe_{Gc} (80 MPa – RT and 150 °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 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 150 °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 111 MPa. After heating up to 150 °C the specimen was pressurized with 45 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.

5.5 Hot Blowout Test (HOBT1), (MESC SPE 85/300 – 3.3.6)

The HOBT1 test can be performed in a fixture joint (NPS 3 in., ASME class 150) or in a hydraulic test rig, in which the stiffness of the flange can be simulated. In the amtec lab the HOBT1 tests are carried out in hydraulic testing equipment.

The HOBT1 test procedure consists of different steps, which may be described as follows:

1. The gasket is compressed to the required gasket stress of 34.5 MPa (5000 psi).

2. The gasket is left undisturbed for 5 minutes before it is reloaded up to 34.5 MPa (5000 psi). During this period it creeps and relaxes according to the defined stiffness of the test rig.

3. The gasket is left undisturbed for 30 minutes before the test temperature 150 °C (302 °F) is applied with an increasing rate of 1.7 K/min (3 °F/min). During this period the gasket is therefore left to creep and relax according to the defined stiffness of the test rig (780 kN/mm / 4400.00 lb/in).

4. After the 30 minutes waiting period, the specified helium pressure is applied to the test rig. Because of the increasing internal pressure, the gasket stress is decreasing. For most graphite materials, this may lead to the sudden blowout of the gasket, in which case, the blowout temperature, the actual internal pressure and the gasket stress are recorded.

For the isolation gasket – K/# KINS-HAFS the following testing parameters were chosen:

- Initial gasket stress: 34.5 MPa,
- Test temperature: 150 °C,
- Internal pressure: 67.5 bar.

5.6 Electrical Isolation Test (MESC SPE 85/300 - 3.3.15)

The Electrical Isolation Test according to MESC SPE 85/300 ensures that gasket, insulation sleeves and washer kit adhere to the requirements for AC and DC electrical isolation when installed in a flange arrangement.

In the electrical isolation test an isolation gasket with isolation sleeves and washers is mounted in a 4″ Class 300 flange.

The electrical isolation resistance is measured from every bolt to flange and from flange to flange with a voltage of 1500 V DC. There is a dwell time of one minute at each measurement point. After one minute the resistance value is taken.

The minimum resistance for the flange to flange measurement and the minimum average resistance of the bolt to flange measurement is 100 MΩ

5.7 Gasket Adhesion Test: Flange Inspection Following Ambient Temperature Fugitive Emission Test (MESC SPE 85/300 – 3.3.13)

According to Shell TAT MESC SPE 85/300, it is necessary to ensure that components or materials of the gasket do not adhere to the adjacent flanges after

disassembly. To test this, the gasket is tested in accordance to the Fugitive Emission test at ambient temperature. There must be no visible adhesion of any gasket material to any of the adjacent flanges. If an anti-stick coating is applied, the test report shall record the brand and type of that coating.

6. Results

All test results of the gasket material K/# KINS-HAFS are summarized in **appendices 4 to 6**.

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 80 MPa to 120 MPa. The detected leak rate at 80 MPa gasket stress at an internal pressure of 51 bar was $9.2 \cdot 10^{-8}$ Pa·m³/s/mm, see **appendix 7**. The leak rate was decreasing with increasing gasket stress. The leak rate at a gasket stress of 111 MPa, which is equivalent to a bolt stress of 361 MPa, was $6.9 \cdot 10^{-9}$ Pa·m³/s/mm, which is lower than the Tightness Class B.

For the maximum gasket surface stress of 120 MPa the leak rate was $4.7 \cdot 10^{-9}$ Pa·m³/s/mm, which is still lower than the Tightness Class B.

In the Shell leakage test at 150 °C the gasket was compressed in 6 steps from 80 MPa to 120 MPa. The leak rate at 80 MPa gasket stress at an internal pressure of 45 bar was $7.8 \cdot 10^{-10}$ Pa·m³/s/mm, see appendix 7. The leak rate at a gasket stress of 111 MPa, which is equivalent to a bolt stress of 361 MPa, was $6.0 \cdot 10^{-10}$ Pa·m³/s/mm, which is lower than the Tightness Class A.

For the maximum gasket surface stress of 120 MPa the leak rate was $4.5 \cdot 10^{-10}$ Pa·m³/s/mm, which is lower than the Tightness Class A.

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

In the fire test API 6FB the K/# KINS-HAFS was mounted in a 4" Class 300 flange with hydraulic spanners to a bolt load of 77.2 kN which means a total load of 618 kN and a gasket surface stress of 151.9 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 8 to 10**. 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 the burning period of 30 minutes, no leakage was measurable. The leak rate of the burning period is measured to 0.01 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 0.04 ml/inch/min and therefore below the allowable leak rate of 1 ml/inch/min.

The K/# KINS-HAFS **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 K/# KINS-HAFS were performed twice; they are listed in appendices 4 and 5. 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 4 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} (150 °C) and
- the modulus of elasticity E_G (150 °C).

Compression tests were performed at ambient temperature and at elevated temperature at 150 °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 11 to 14.**

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 150 °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 150 °C is set to 180 MPa.

The modulus of elasticity E_G at ambient temperature and at elevated temperature increases steadily with increasing gasket stress.

A good repeatability of the double test is noticeable.

6.3.2 Creep relaxation tests

In appendix 4 the gasket characteristics of the creep relaxation tests for two gasket stresses, 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, 150 °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 150 °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 15 to 18**. The creep relaxation factor P_{QR} is 0.99 (80 MPa, RT, 500 kN/mm) and 0.94 resp. 0.96 (80 MPa, 150 °C, 500 kN/mm). The deflection Δe_{Gc} of the gasket K/# KINS-HAFS at RT is 12 µm resp. 11 µm and in tests at 150 °C is 46 µm resp. 32 µm.

A good repeatability of the double test is noticeable.

6.3.3 Leakage tests

The tightness behaviour of the gasket material K/# KINS-HAFS was examined in two leakage tests at 40 bar helium. In appendix 5 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 19**. The first gasket stress level was set to 5 MPa. The tightness class $L_{0.001}$ was reached when the gasket stress was 10 MPa resp. 24 MPa. Therefore the minimum gasket stress in assembly for the tightness class $L_{0.001}$ is set to $Q_{min(0.001)} = 24$ MPa. The lowest tightness class which could be reached was $L_{0.00001}$ therefore a gasket stress of 116 MPa resp. 97 MPa is necessary.

The leak rate is decreasing with increasing gasket stress up to 160 MPa. The lowest leak rate which could be measured was $4.0 \cdot 10^{-6}$ mg/m/s at 160 MPa in test 18-907.

During the unloading cycles the leak rate is increasing. In all unloading curves no drastic increase of the leak rate (or sudden blowout) is observed.

The minimum gasket stress in service for the tightness class $L_{0.0001}$ for an initial gasket surface pressure Q_A of 60 MPa is $Q_{smin(0.0001)}$ = 15 MPa resp. 18 MPa.

6.4 HOTT: Shell cycle test at 150 °C (MESC SPE 85/300 – 3.3.5)

For the Shell cycle test at elevated temperature the isolation gasket was compressed initially with 111 MPa. After heating up to 150 °C, the specimen was pressurized with 45 bar helium. During the thermal cycles in the leakage test at 150 °C only a slight pressure drop could be measured, see **appendix 20**.

During the last thermal cycle the pressure loss is less than 0.3 bar. The gasket material K/# KINS-HAFS has **passed** the Shell requirement of a pressure drop less than 1 bar.

6.5 Hot Blowout Test (HOBT1) - (MESC SPE 85/300 – 3.3.6)

One Hot Blowout Test with the material K/# KINS-HAFS has been carried out for the measure of its margin of safety against blowout.

In **appendices 20 and 21** the results and the diagrams of the HOBT1 test of isolation gasket K/# KINS-HAFS are shown.

During heating up to 150 °C the gasket stress decreases to 30 MPa. During the pressurization with Helium to 67.5 bar the gasket stress decreases to 16 MPa. With a maximum pressure of 67.5 bar and a dwell time of 2x 15 minutes no blowout could be recognized.

The gasket material K/# KINS-HAFS has **passed** the Hot Blowout Test at a temperature of 150 °C with an initial gasket stress of 34.5 MPa and an internal pressure of 67.5 bar.

6.6 Electrical Isolation Test (MESC SPE 85/300 - 3.3.15)

In the electrical isolation test according to MESC SPE 85/300 the flange isolation gasket kit K/# KINS-HAFS was mounted in a 4″ Class 300 flange with the same conditions as in the fire test API 6FB, see appendix 10.

After that the electrical isolation resistance was measured from each bolt to the bottom flange and from top to bottom flange with a voltage of 1500 V DC for 1 minute each.

The results of the measurements with the flange isolation kit K/# KINS-HAFS are shown in **appendix 22**. The average value of the bolt to flange measurements was 1.05 TΩ. The value of the flange to flange measurement was 184 MΩ.

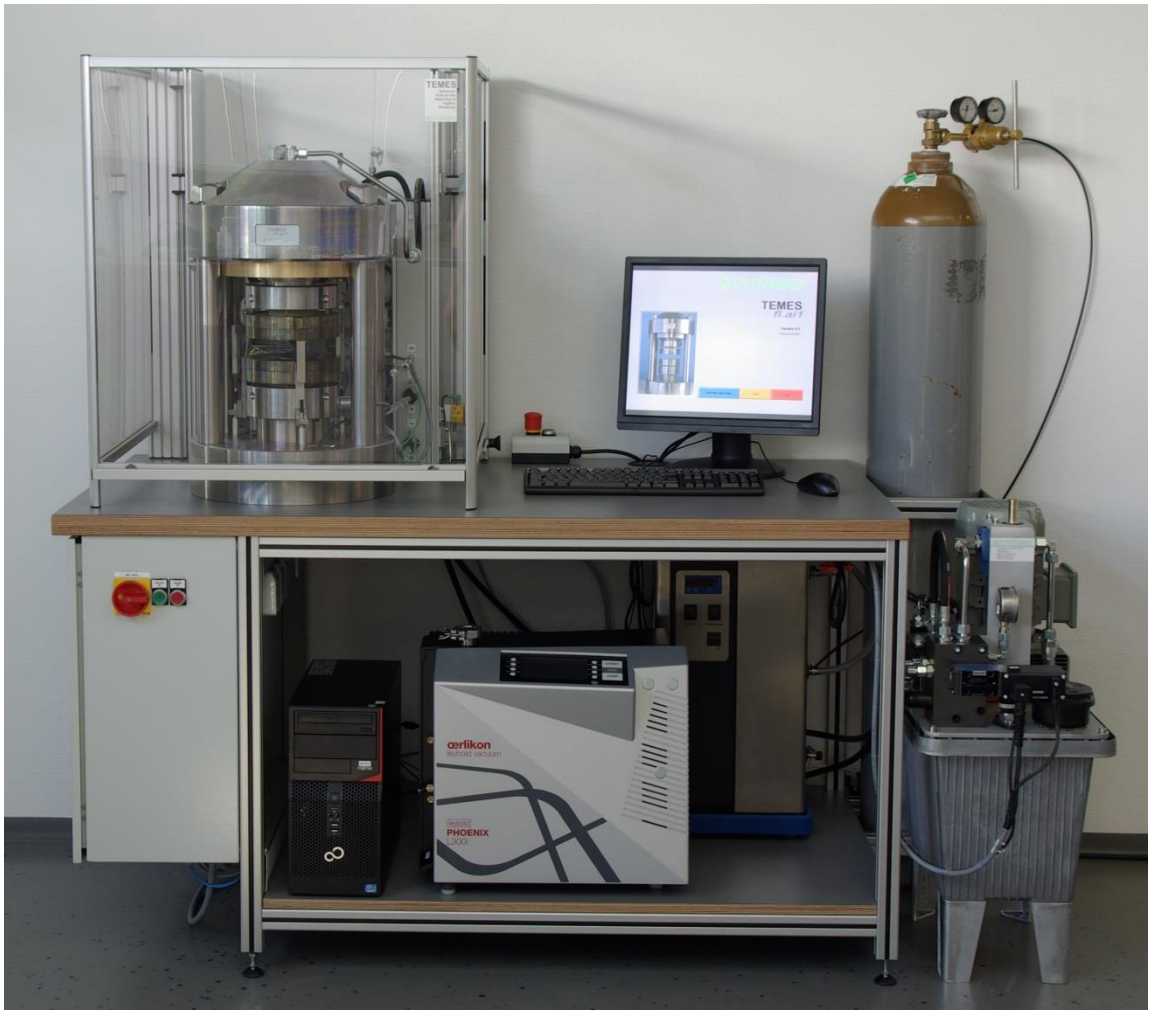
Therefore the electrical isolation resistance is higher than the minimum resistance of 100 MΩ and the Insulation Gasket K/# KINS-HAFS **passed** the electrical isolation test according to the Shell Specification MESC SPE 85/300.

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

In **appendix 23** photos of the adjacent flanges after tests at ambient temperature with the gasket specimen's K/# KINS-HAFS are represented. The gasket does not stick on the flange and slight traces of graphite are visible. The gasket adhesion could be considered as acceptable.

7. Photo documentation

In **appendices 24 to 31** photos of the tested gasket specimen's K/# KINS-HAFS for the different test procedures are presented. In tests at 150 °C the graphite layer on both sides was partly or completely peeled off.



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

Fire Safe Testing Device TEMES*fire.safe*

Isolation testing device Megger MIT 525

Table 1: Data Sheet for Gasket Characteristics (EN13555)

Manufacturer: Kukil

Product: **K/# KINS-HAFS**

Maximum allowable Gasket Stress Q_{smax} [MPa]

T [°C]	25	25	150	150
Q_{smax} [MPa]	180	180	180	180
test no.	18-906	18-910	18-913	18-914

Modulus of Elasticity E_G [MPa]

T [°C] / Q [MPa]	25		25		150		150	
	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		9.270		9.270		9.320		9.340
1		8.896		8.872		8.918		8.953
20	3486	7.982	3616	8.062	5001	7.978	3898	8.047
30	4069	7.882	4105	7.968	6313	7.896	4690	7.958
40	4503	7.795	4436	7.881	6968	7.813	5248	7.869
50	5026	7.717	4849	7.798	8077	7.743	6267	7.797
60	5506	7.640	5367	7.719	8884	7.669	7248	7.722
80	6978	7.478	6677	7.530	11514	7.542	11380	7.603
100	10170	7.396	10018	7.436	15855	7.488	17937	7.559
120	14529	7.355	14753	7.396	21363	7.451	26641	7.526
140	20220	7.325	20516	7.368	28839	7.421	34950	7.493
160	27323	7.301	27776	7.345	36325	7.391	43936	7.457
180	36053	7.277	36105	7.323	45959	7.360	53203	7.415
test no.	18-906		18-910		18-913		18-914	

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	150	150
	80	0.99	0.99	0.94	0.96
	Δe_{GC} [µm]	12	11	46	32
	test no.	18-917	18-922	18-920	18-924

Table 2: Data Sheet for Gasket Characteristics ()

Manufacturer: Kukil

Product: **K/# KINS-HAFS**

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

L / p [bar]	0.1	0.01	0.001	0.0001	0.00001	1.00E-06	1.00E-07	1.00E-08
40	5	5	10	39	116	-	-	-
test no.	18-901							
40	5	5	24	53	97	-	-	-
test no.	18-907							

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

	L / Q_A [MPa]	0.1	0.01	0.001	0.0001	0.00001	1.00E-06	1.00E-07	1.00E-08
p = 40 bar	10	5	5	-	-	-	-	-	-
	20	5	5	5	-	-	-	-	-
	40	5	5	5	33	-	-	-	-
	60	5	5	5	15	-	-	-	-
	80	5	5	5	14	-	-	-	-
	100	5	5	5	8	-	-	-	-
	160	5	5	5	5	9	-	-	-
	test no.	18-901							

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

	L / Q_A [MPa]	0.1	0.01	0.001	0.0001	0.00001	1.00E-06	1.00E-07	1.00E-08
p = 40 bar	10	5	5	-	-	-	-	-	-
	20	5	5	-	-	-	-	-	-
	40	5	5	8	-	-	-	-	-
	60	5	5	5	18	-	-	-	-
	80	5	5	5	9	-	-	-	-
	100	5	5	5	5	80	-	-	-
	160	5	5	5	5	8	-	-	-
	test no.	18-907							

Table 3: Data Sheet for Gasket Characteristics (SHELL)

Manufacturer: Kukil

Product: **K/# KINS-HAFS**

Shell leakage test at ambient temperature

Test pressure:	51	bar
Shell required gasket stress level:	111	MPa
Leakage rate:	6.84E-09	Pa·m³/s/mm
Shell tightness class:	B	
test no.	18-969	

Shell leakage test at 150 °C

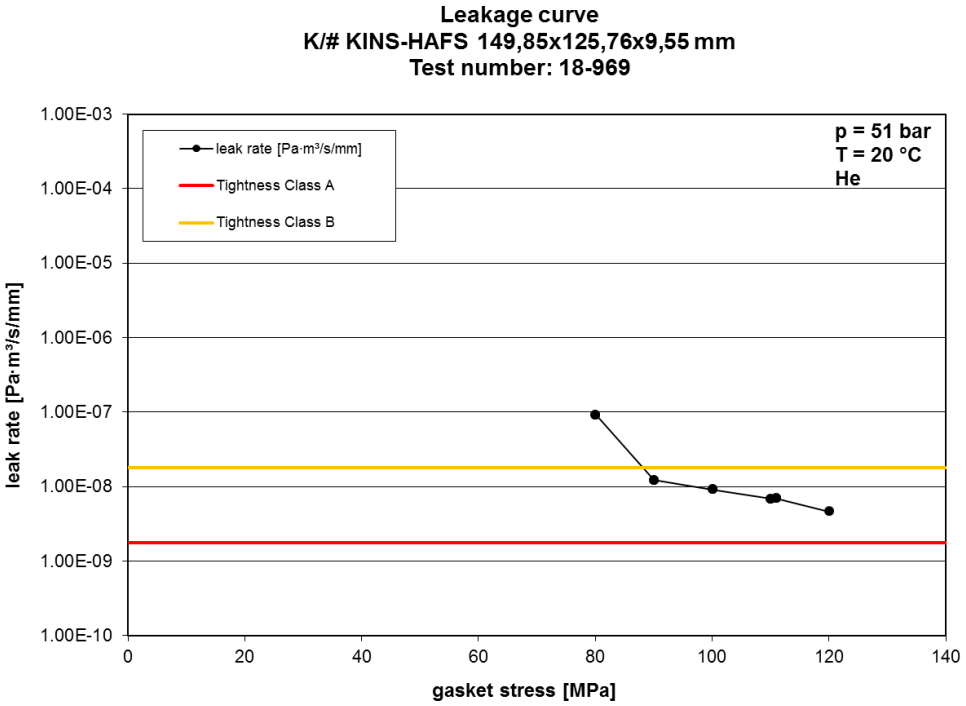
Test pressure:	45	bar
Gasket stress level:	111	MPa
Leakage rate:	6.00E-10	Pa·m³/s/mm
Shell tightness class:	A	
test no.	18-946	

Shell cycle test at 150 °C

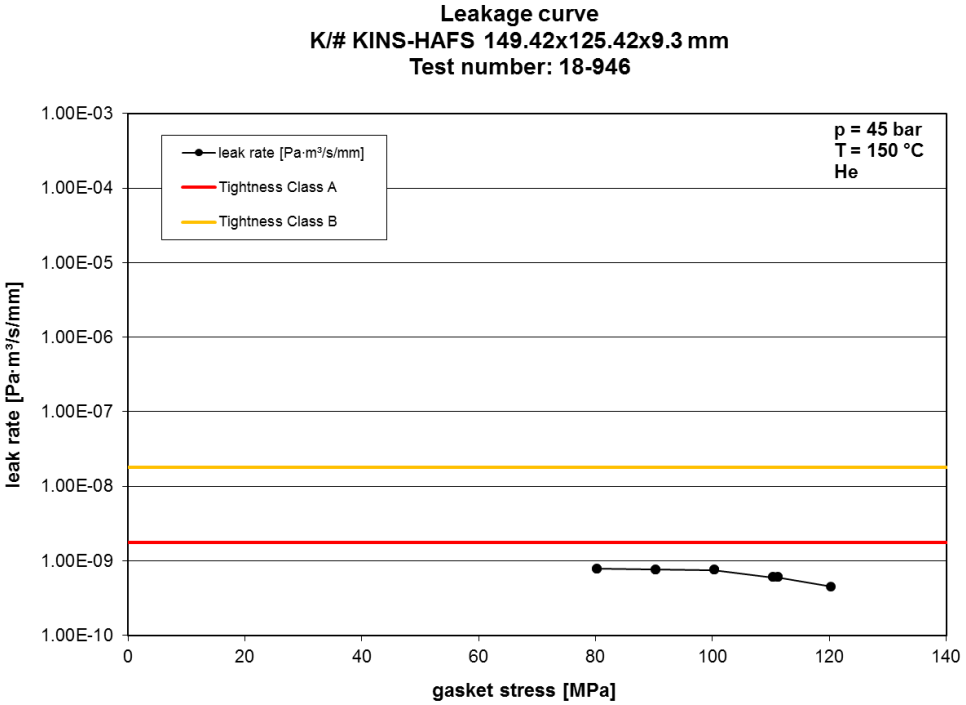
Test pressure:	45	bar
Initial gasket stress level:	111	MPa
Pressure drop in last cycle:	< 0.3	bar
Requirements:	passed	
test no.	18-902	

Hot Blowout Test (HOBT1)

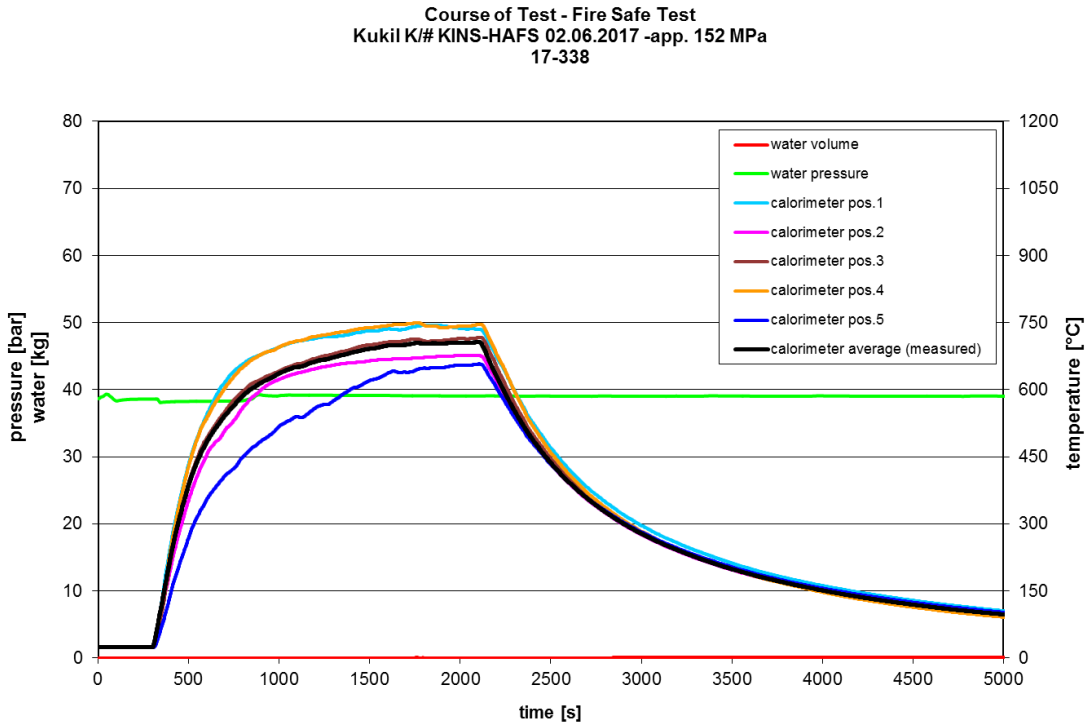
Test pressure:	67.5	bar
Gasket stress level:	34.5	MPa
Temperature:	150	°C
Requirements:	passed	
test no.	18-909	



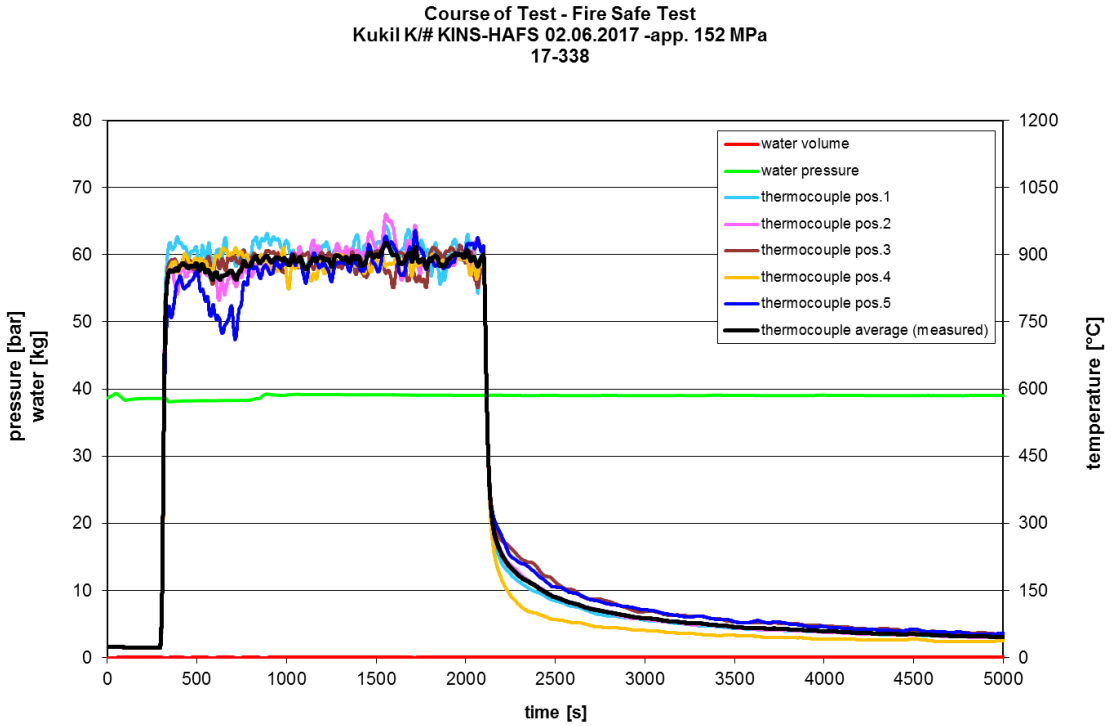
Shell leakage test (RT) according MESC SPE 85/300 - 3.3.2



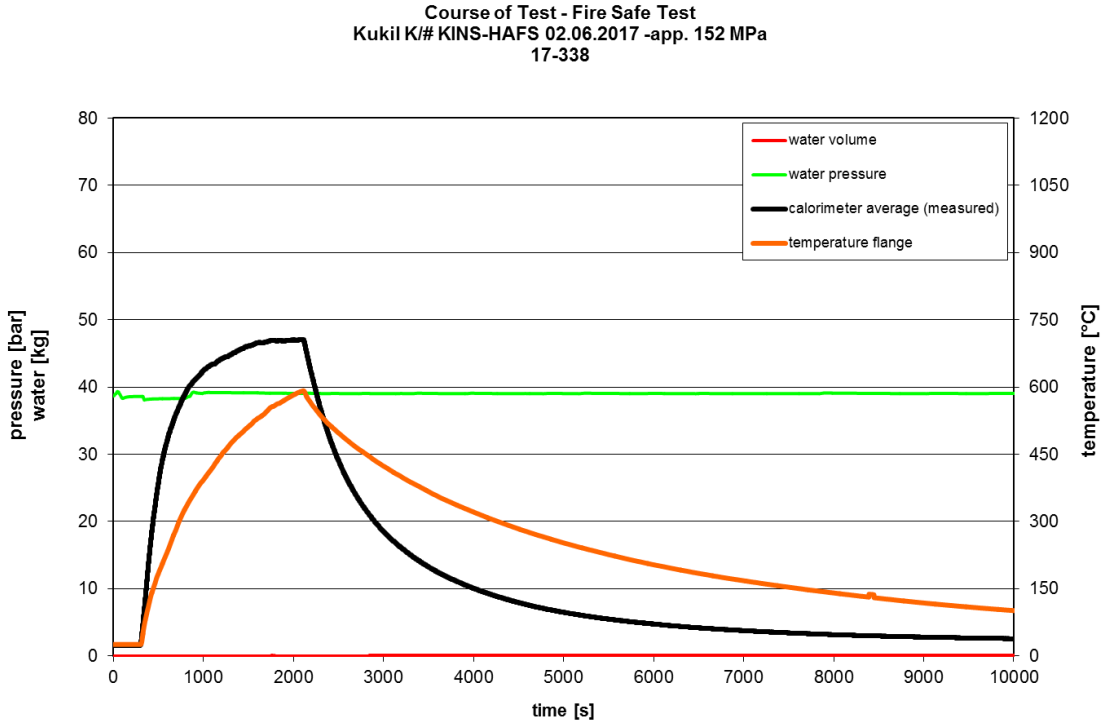
Shell leakage test (150 °C) according MESC SPE 85/300 - 3.3.2



3.3.3 Fire Test API 6FB - calorimeters



3.3.3 Fire Test API 6FB – thermocouples



3.3.3 Fire Test API 6FB

Kukil Inntot Co., Ltd. - K/# KINS-HAFS 17-338

geometries

bolts	8	-
OD gasket PTFE	117.2	mm
ID gasket PTFE	112.3	mm
OD gasket metal-ring	139.10	mm
ID gasket metal-ring	134.20	mm
OD gasket backup-ring	153.70	mm
ID gasket backup-ring	144.60	mm
mean gasket circumference contact area PTFE	360.5	mm
mean gasket circumference contact area metal-ring	429.30	mm
mean gasket circumference contact area backup-ring	468.57	mm
mean gasket circumference contact area PTFE/metal-ring/backup-ring	417.83	mm
gasket area PTFE	883.22	mm²
gasket area metal-ring	1051.78	mm²
gasket area backup-ring	2131.99	mm²
gasket area PTFE/metal-ring/backup-ring (contact area)	4067.0	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	**493.50**	**ml**

calculation of gasket stress

hydraulic spanners - No.	GS 3/1	-
calibration factor	0.16	kN/bar
pressure	495	bar
force per bolt	77.22	kN
force total	617.76	kN
gasket stress PTFE/metal-ring/backup-ring	**151.90**	**MPa**

calculation of leak rate of complete test

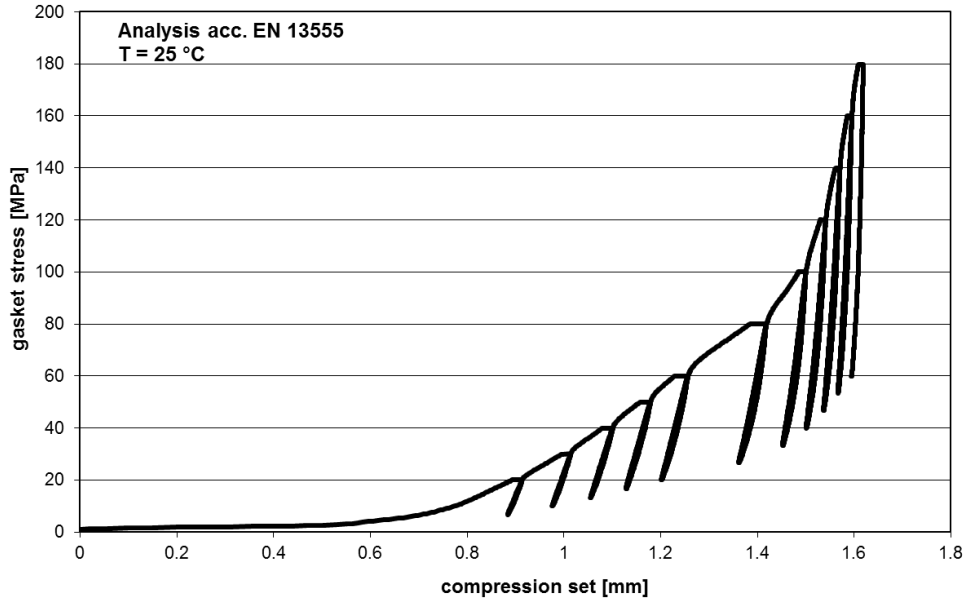
start value scale	25.85	kg
end value scale	25.74	kg
start test	08:03:23	
end test	10:50:03	
test duration (min)	166.67	min
leakage	113.00	ml
leak rate PTFE/metal-ring/backup-ring	**0.04**	**ml / inch / min**

calculation of leak rate of burning period

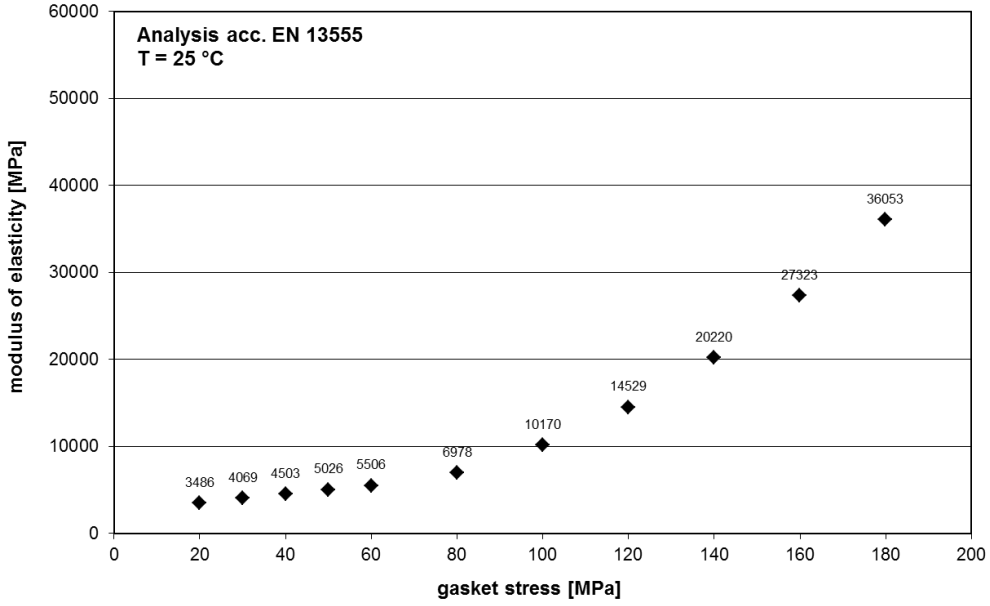
start value scale	25.86	kg
end value scale	25.85	kg
start test	08:08:17	
end test	08:38:20	
test duration (min)	30	min
leakage	4.20	ml
leak rate PTFE/metal-ring/backup-ring	**0.01**	**ml / inch / min**

Fire Test API 6FB - overview

Compression curve
K/# KINS-HAFS 149x125.54x8.896 mm
Test number: 18-906

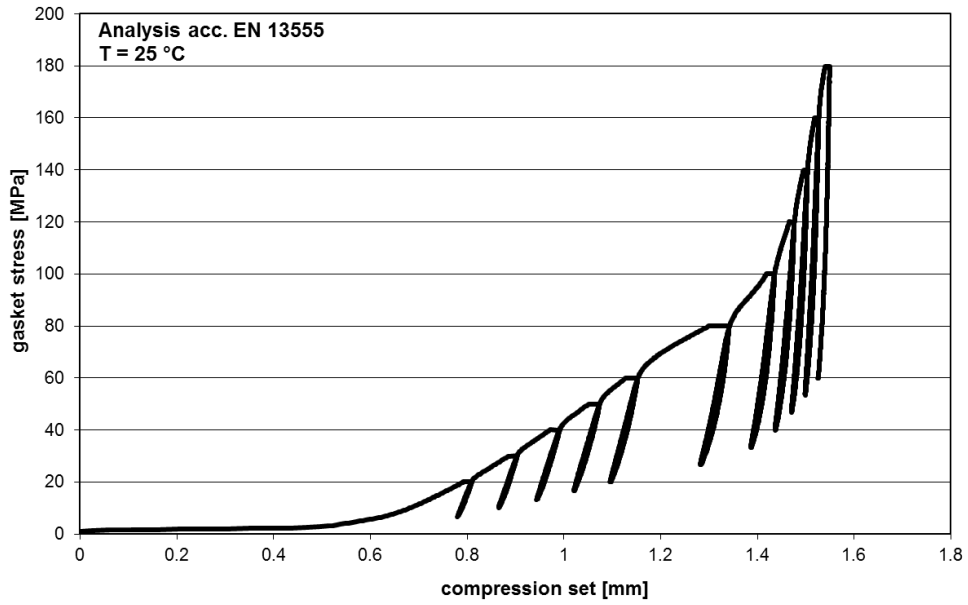


Modulus of elasticity
K/# KINS-HAFS 149x125.54x8.896 mm
Test number: 18-906

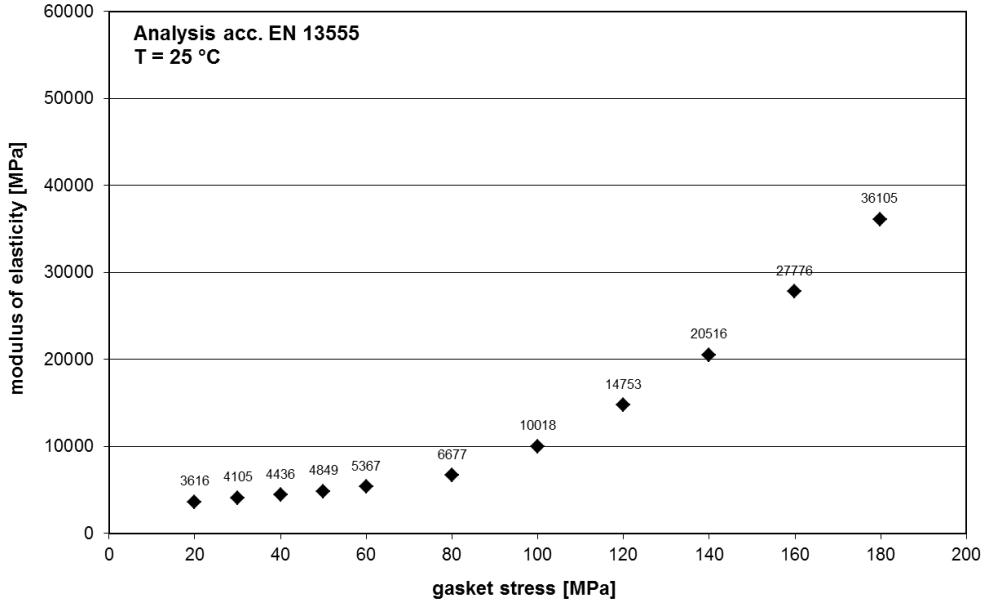


Compression test (RT) according EN 13555

Compression curve
K/# KINS-HAFS 149.41x125.51x8.872 mm
Test number: 18-910

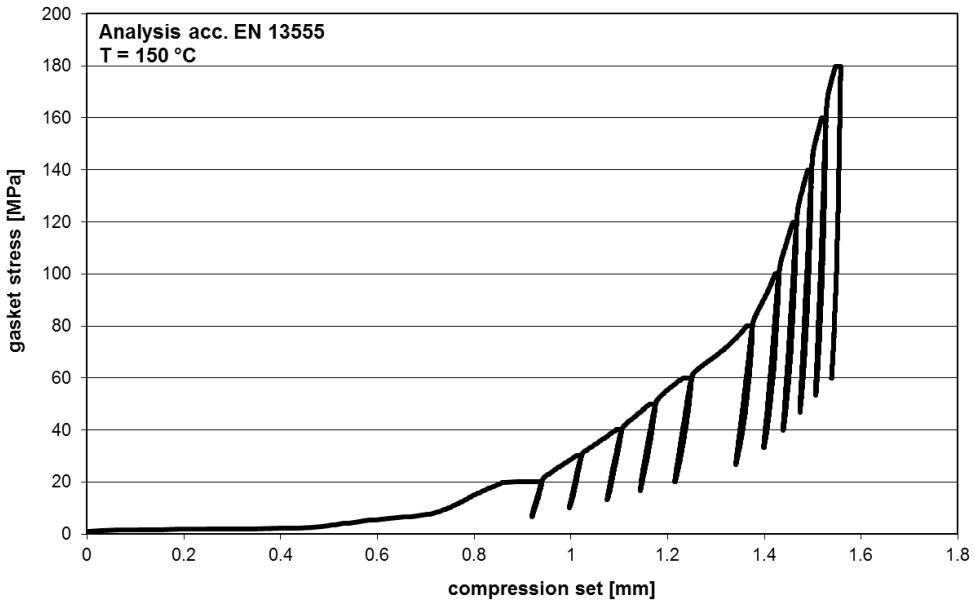


Modulus of elasticity
K/# KINS-HAFS 149.41x125.51x8.872 mm
Test number: 18-910

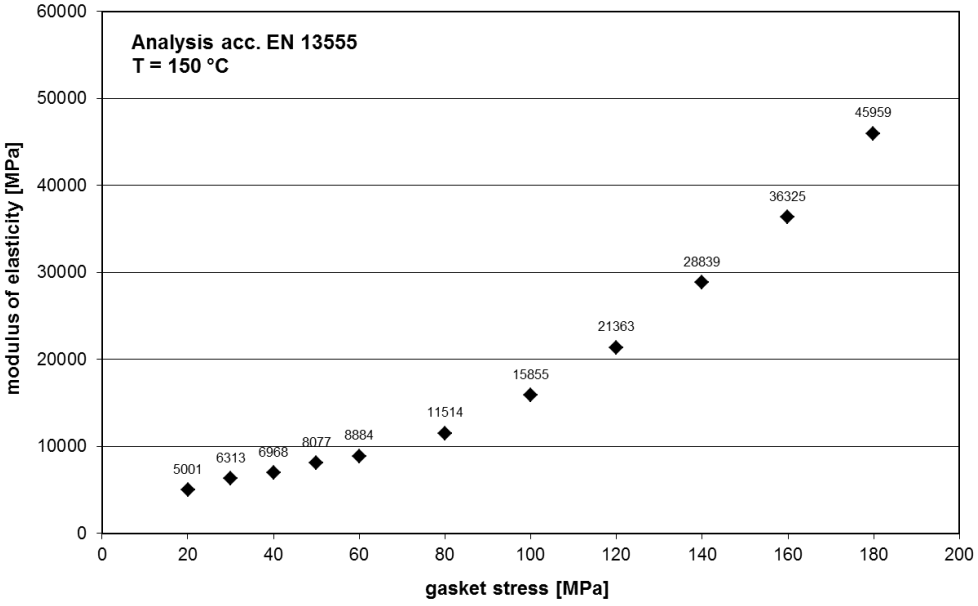


Compression test (RT) according EN 13555

Compression curve
K/# KINS-HAFS 148.97x126.44x8.918 mm
Test number: 18-913

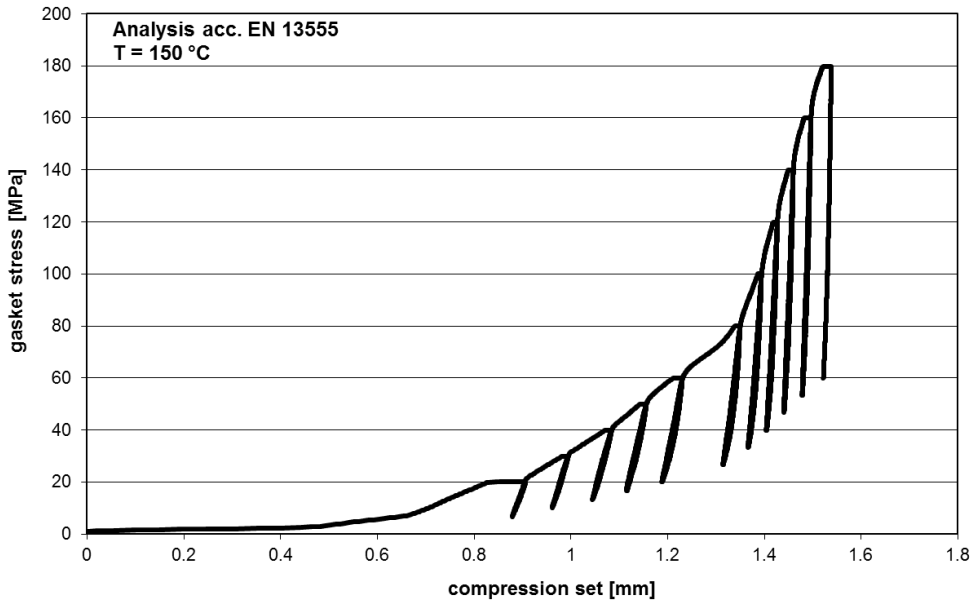


Modulus of elasticity
K/# KINS-HAFS 148.97x126.44x8.918 mm
Test number: 18-913

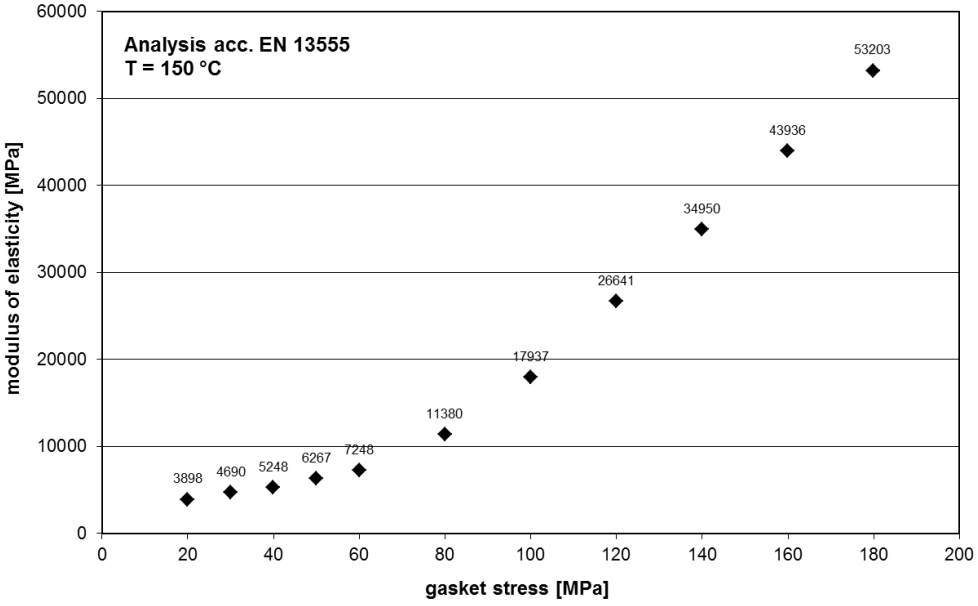


Compression test at 150 °C according EN 13555

Compression curve
K/# KINS-HAFS 149.23x125.52x8.953 mm
Test number: 18-914



Modulus of elasticity
K/# KINS-HAFS 149.23x125.52x8.953 mm
Test number: 18-914



Compression test at 150 °C according EN 13555

Creep relaxation test (EN 13555)

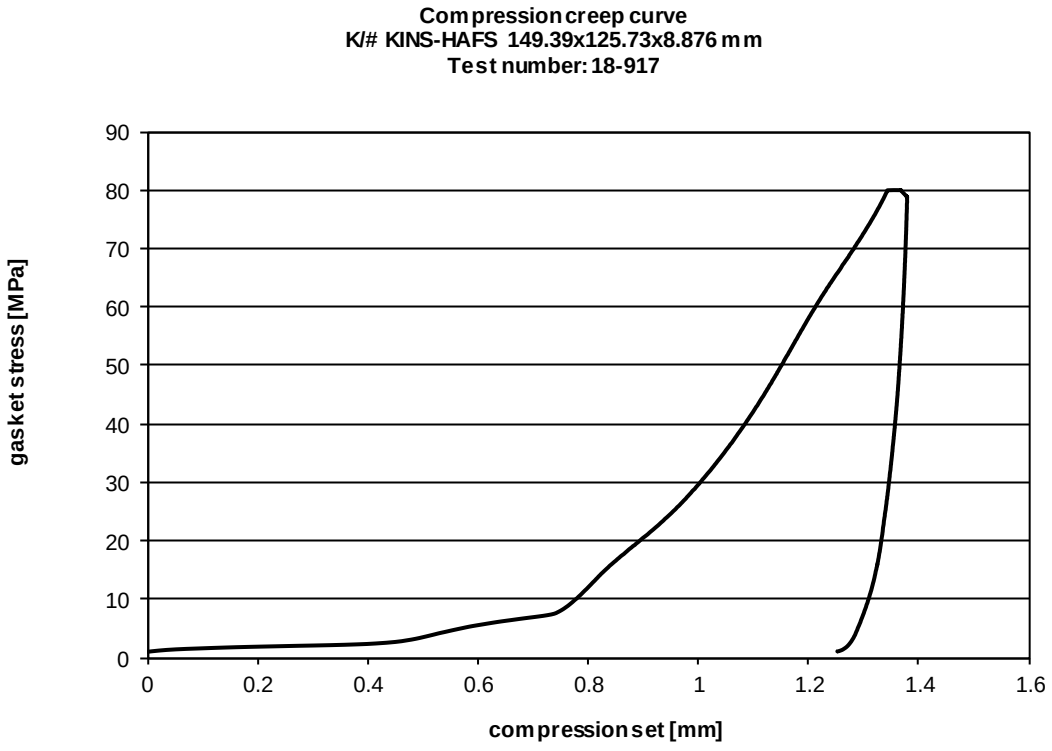
K/# KINS-HAFS
149.39x125.73x8.876 mm
Test number: 18-917

Test parameters

Initial gasket stress Q_i:	80	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:	78.8	MPa
Relaxation factor P_{QR} (T_P):	0.99	
Deflection Δe_{Gc}:	12	µm



Creep relaxation test (EN 13555)

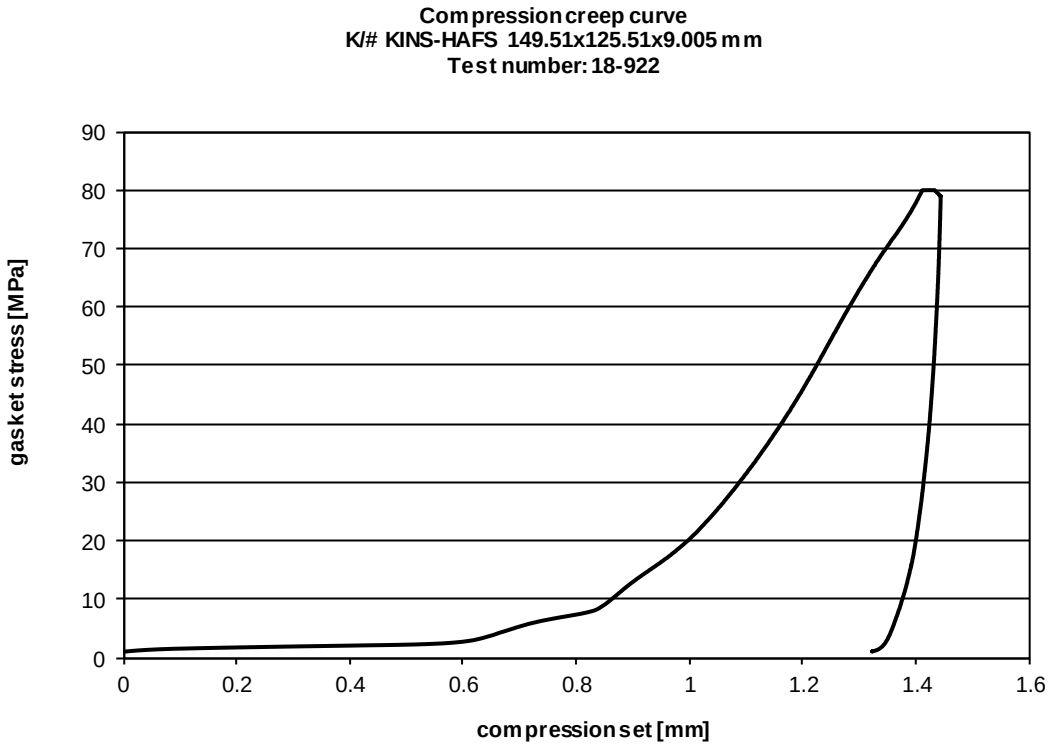
K/# KINS-HAFS
149.51x125.51x9.005 mm
Test number: 18-922

Test parameters

Initial gasket stress Q_i:	80	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:	78.9	MPa
Relaxation factor P_{QR} (T_P):	0.99	
Deflection Δe_{Gc}:	11	µm



Creep relaxation test (EN 13555)

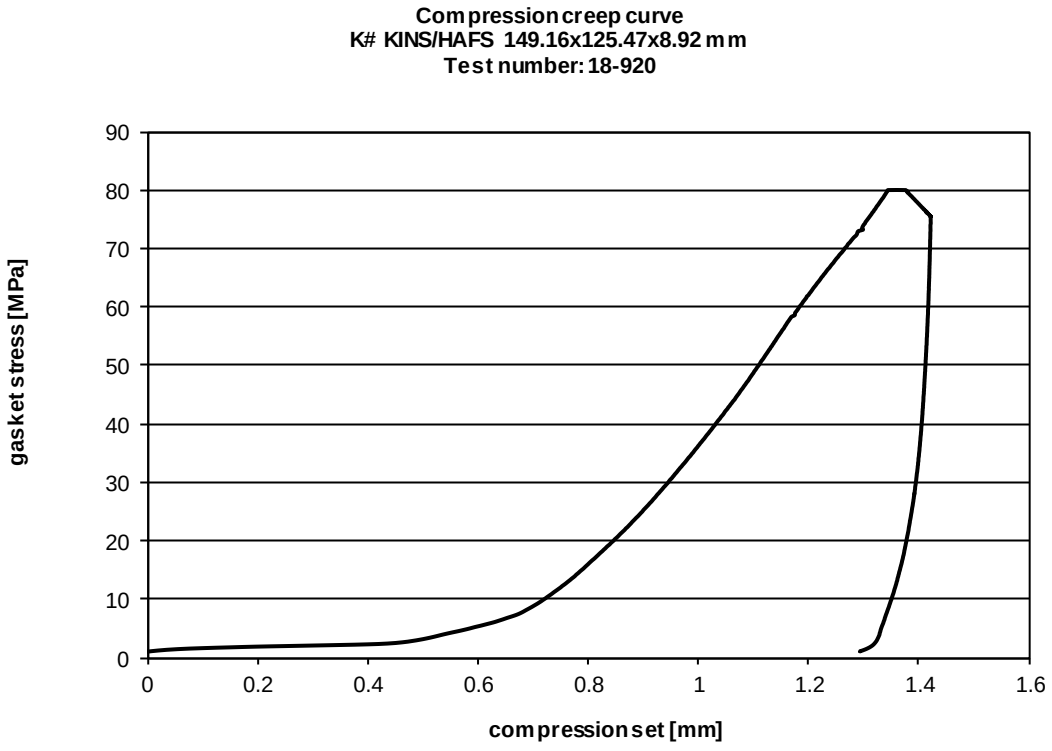
K# KINS/HAFS
149.16x125.47x8.92 mm
Test number: 18-920

Test parameters

Initial gasket stress Q_i:	80	MPa
Test temperature T_P:	150	°C
Time at T_P:	3:59	hh:mm
Stiffness C:	500	kN/mm

Test results

Remaining gasket stress Q_r:	75.5	MPa
Relaxation factor P_{QR} (T_P):	0.94	
Deflection Δe_{Gc}:	46	µm



Creep relaxation test (EN 13555)

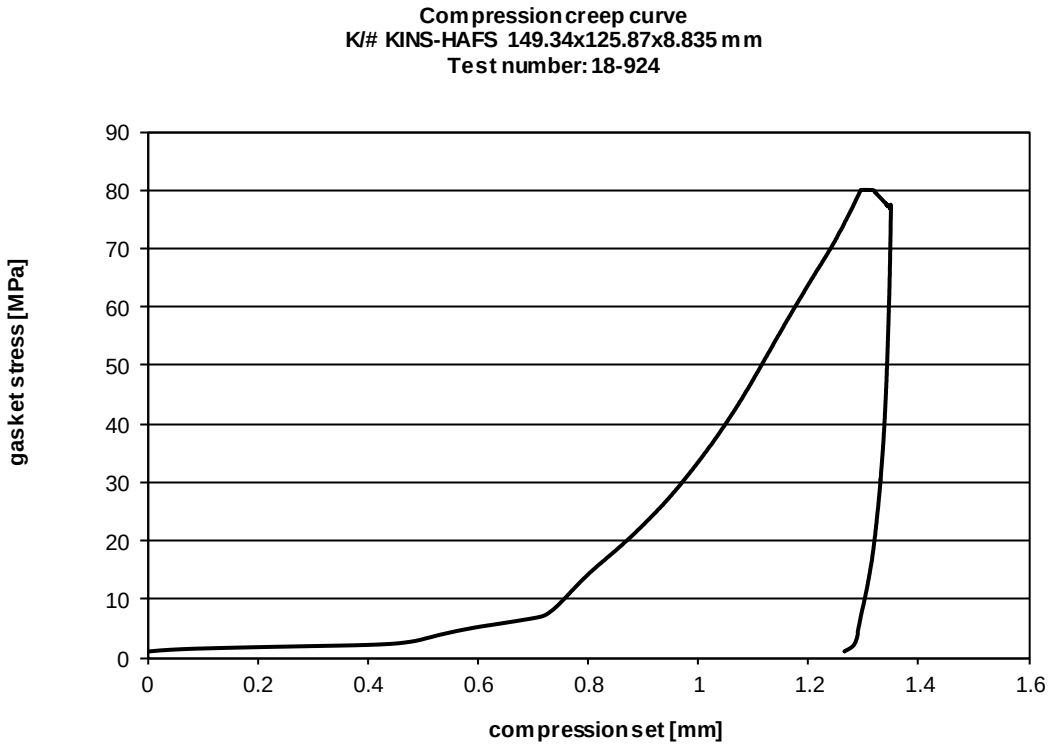
K/# KINS-HAFS
149.34x125.87x8.835 mm
Test number: 18-924

Test parameters

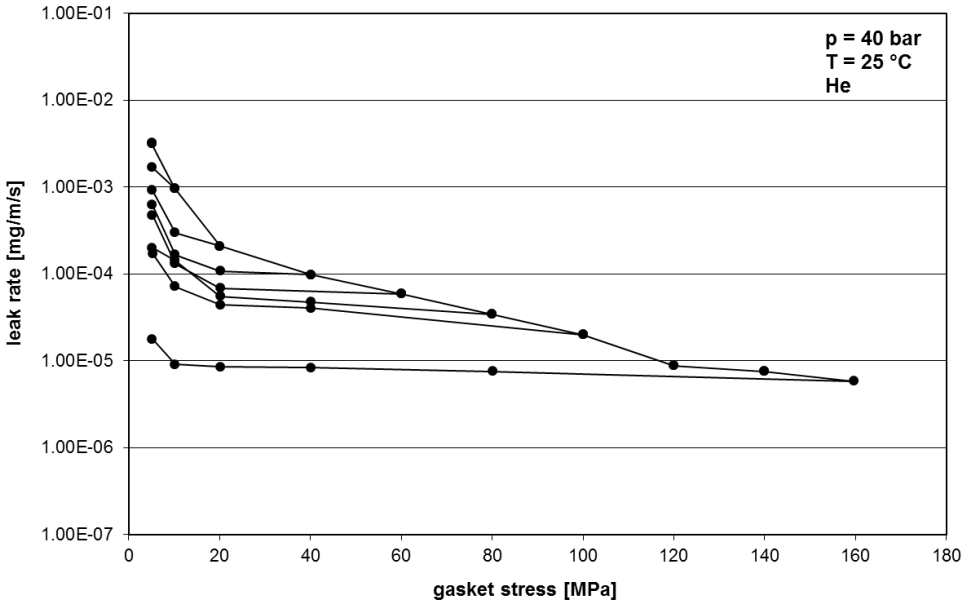
Initial gasket stress Q_i:	80	MPa
Test temperature T_P:	150	°C
Time at T_P:	3:59	hh:mm
Stiffness C:	500	kN/mm

Test results

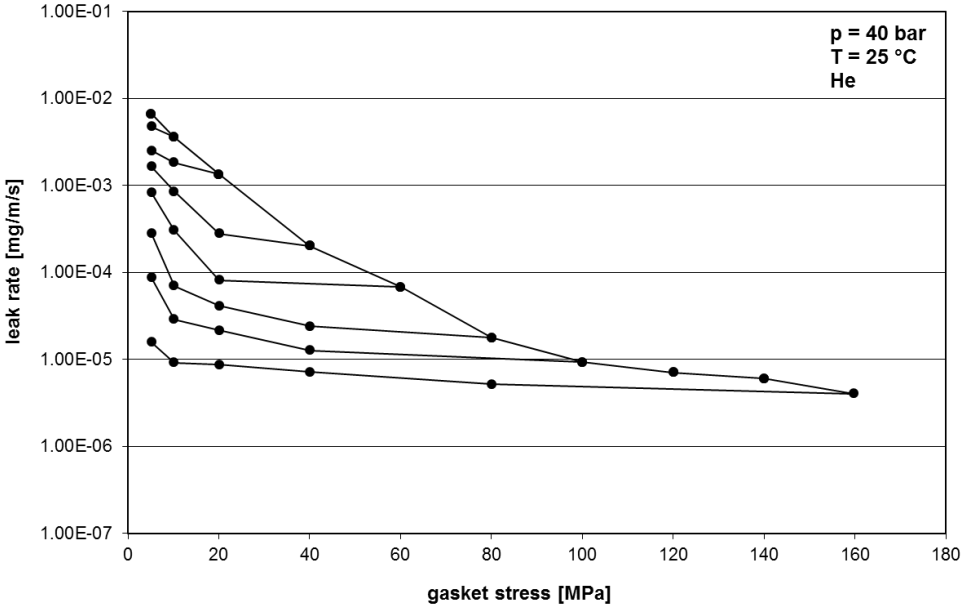
Remaining gasket stress Q_r:	76.8	MPa
Relaxation factor P_{QR} (T_P):	0.96	
Deflection Δe_{Gc}:	32	µm



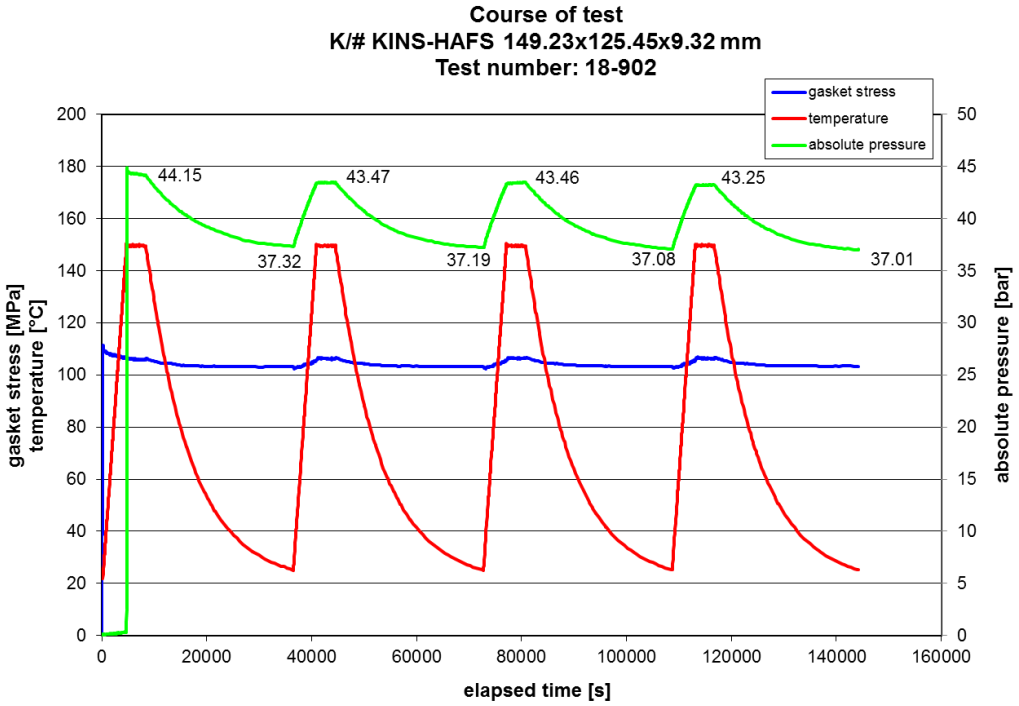
Leakage curve
K/# KINS-HAFS 149.47x124.39x8.902 mm
Test number: 18-901



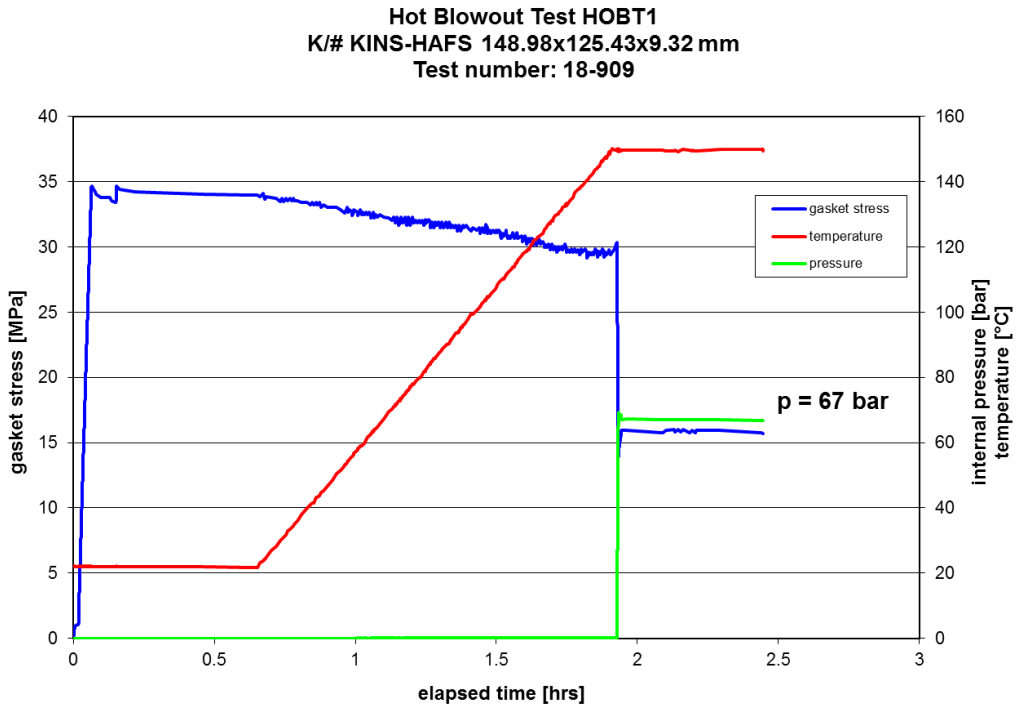
Leakage curve
K/# KINS-HAFS 149.12x125.19x8.892 mm
Test number: 18-907



Leakage test according EN 13555



Shell cycle test at 150 °C according MESC SPE 85/300 - 3.3.5



Hot Blowout Test (HOBT1) according MESC SPE 85/300 - 3.3.6

Hot Blowout Test HOBT1

K/# KINS-HAFS
148.98x125.43x9.32 mm
Test number: 18-909

Test parameters

Nominal initial gasket stress:	5000 psi	34.5 MPa
Nominal pressure:	979 psi	68 bar

Test results

Initial gasket thickness:	0.3669 in	9.32 mm
Final gasket thickness:	0.3086 in	7.84 mm
Initial gasket stress:	5020 psi	34.6 MPa
Actual test pressure:	970 psi	67 bar
Gasket stress S_g:	2314 psi	16.0 MPa
Gasket temperature T_g:	302 °F	150 °C

Hot Blowout Test (HOBT1) according MESC SPE 85/300 - 3.3.6

Kukil Insulation Kit K/# KINS-HAFS 17-342

geometries

gasket with insulation kit	K# KINS-HAFS	
manufacture	Kukil	
OD gasket PTFE	117.2	mm
ID gasket PTFE	112.3	mm
gasket thickness PTFE	9.5	mm
OD gasket metal-ring	139.1	mm
ID gasket metal-ring	134.2	mm
gasket thickness metal-ring	8.6	mm
OD gasket backup-ring	153.7	mm
ID gasket backup-ring	144.6	mm
gasket thickness backup-ring	8.5	mm
washers 1	steel washers	
number of washers	16	
washers 2	steel washers	
number of washers	16	
sleeves	G-10	
number of sleeves	8	
OD raised faces flange	155	mm
number of bolts	8	

gauge

type	Megger BM21
identification	NEWK-WA 860

isolation test

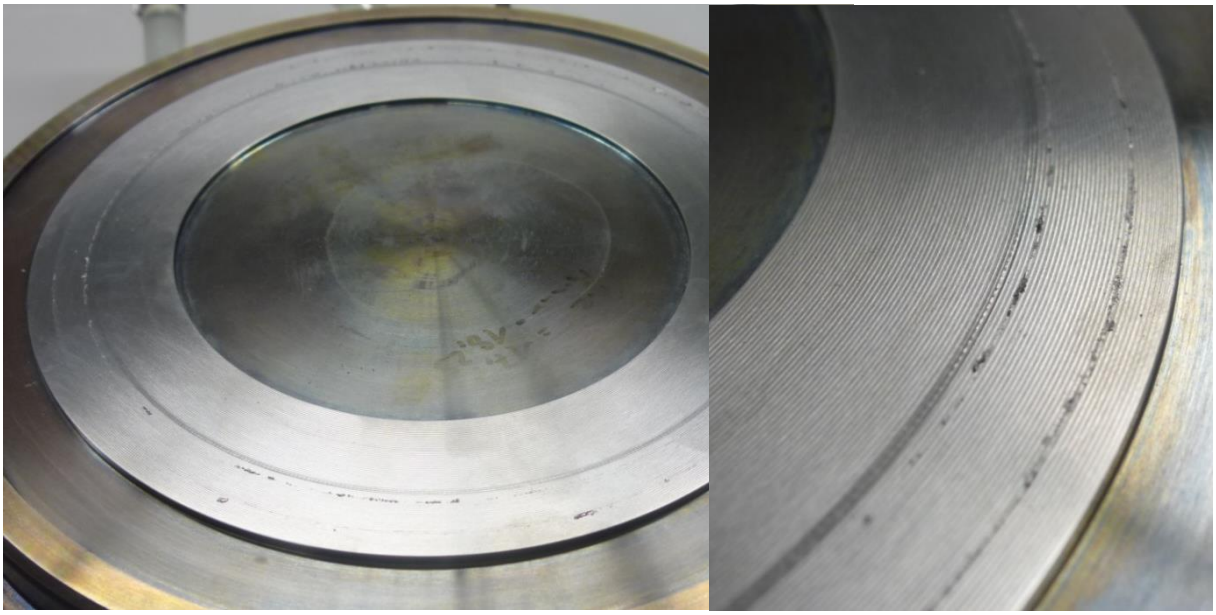
measuring time	60	s
measuring voltage	1500	VDC
minimum insulation resistance	**100**	**MΩ**

measuring data

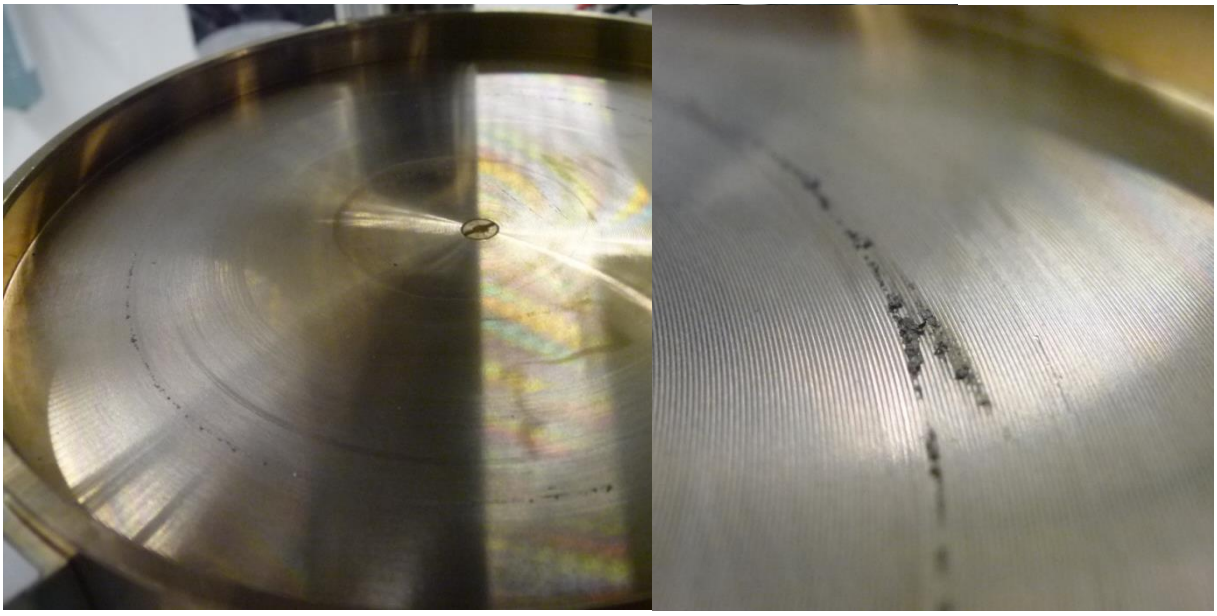
flange to bolt		
1	1.47	TΩ
2	0.965	TΩ
3	>1.52	TΩ
4	>1.52	TΩ
5	0.7	TΩ
6	>1.52	TΩ
7	>1.52	TΩ
8	>1.52	TΩ
average	**1.045**	**TΩ**
flange to flange	**184**	**MΩ**

The insulation resistance of the gasket is higher than the minimum required value and satisfies the requirements of the SPE85-300.

Electrical Isolation Test - overview



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 150 °C (EN 13555)

Compression test at 150 °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 - 150 °C (EN 13555)

Creep relaxation test at 80 MPa - 150 °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

HOBT1 according MESC SPE 85/300 - 3.3.6

Fire Test according to API 6FB (Shell Specification MESC SPE 85/300 - 3.3.3)

Electrical Isolation kit after the Fire Test (MESC SPE 85/300 - 3.3.15)