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Test Report

Customer:	Pipeline Seal & Insulator Co. Ltd. St. Neots, Cambridgeshire PE19 8HY
Project number (amtec):	301 542
Report number:	301 542 2/-
Test procedure:	Shell Specification T-2.973.758
Material:	LineBacker® G10 retainer with Teflon seal

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Pages:	9
Appendices:	16

Dipl.-Ing. F. Herkert

1. Subject of Investigation

The subject of investigation was a gasket material with sealing and electrical isolation characteristics which is named

- LineBacker®.

LineBacker consists of a G10 retainer with a Teflon quad ring sealing element.

2. Goal of Investigation

The goal of the investigation was the qualification of the gasket material LineBacker in accordance to the Shell Specification No. T-2.973.758 (September 2005).

The Shell Specification 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, 8 different tests were performed in respect of the Shell approval:

- Compression test at ambient temperature (EN 13555),
- compression test at 150 °C (EN 13555),
- relaxation test at ambient temperature (EN 13555),
- relaxation test at 150 °C (EN 13555),
- leakage test (EN 13555),
- Hot Blow-Out test (HOBT),
- Shell leakage test at ambient temperature (T-2.232.686), and
- Shell cycle test at 150 °C (T-2.232.686).

3. Test Specimens

The dimension of the test specimens was different for the 8 tests which were performed:

- Compression test (EN13555): DN40/PN40
- Relaxation test (EN 13555): DN40/PN40

- Leakage test (EN 13555): DN40/PN40
- Hot Blow-Out test (HOBT): 3" Class 150
- Shell cycle test (T-2.232.686): 4" Class 300
- Shell leakage test (T-2.232.686): 4" Class 300

4. Testing Equipment

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

Test rig:	$TEMES_{fl.ai1}$
Serial number:	010 181
Load cell:	Burster, Type 85043
Thermocouples:	kmp, Type K
Gasket deflection:	Novotechnik, Type TR 10
Absolute pressure:	HBM, Type PE 300
Differential pressure:	HBM, Type PE 300
Helium leak detector:	Leybold, Type UL 200

A photo and the schematic view of the testing equipment are shown in **appendix 1**. This servo-hydraulic press 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 using 3 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 stiffness can be realised within the equipment. In dependence on the gasket deformation the gasket surface pressure is reduced automatically.

Due to the modular design, the above test rig can be modified to perform leakage tests. The heating and cooling platens 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 measurement method, leak rates down to about 10^{-4} mg/m/s can be measured; for higher tightness classes a mass spectrometer can be used.

5. Test Procedure

5.1 Compression test (EN 13555)

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 (here: 150 °C) 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.

5.2 Creep relaxation test (EN 13555)

The creep relaxation factor P_{QR} is the ratio of the residual and the initial gasket stress from a relaxation test in a compression press used in the displacement controlled mode with a known stiffness. 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 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 after which the temperature of the test rig is raised until the test temperature is reached. Then 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 being imposed by the press is noted and P_{QR}, the ratio of the residual load to the original load, is calculated.

5.3 Leakage test (EN 13555)

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 10 MPa, holding the load and measuring the leak rate and then raising the gasket stress to 20 MPa. The load is then held whilst the leak rate is measured. In the next step the load is reduced to 10 MPa and the leak rate is measured. Then measurements are done for the next loading - unloading cycle at 40 MPa, 20 MPa and 10 MPa and so on until either the 160 MPa loading - unloading cycle is completed or the value of Q_{smax} would have been exceeded.

Deviant from the standard test procedure the lowest gasket stress level is set to 5 MPa instead of 10 MPa. The test gas used for this test is 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 Hot Blow-Out test (HOBT)

The HOBT test can be performed in a fixture joint (NPS 3 in., ASME class 150) or in a hydraulic test rig, in which the rigidity of the flange can be simulated. In the amtec lab the HOBT tests are carried out in a 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 rigidity 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 rigidity of the test rig (780 kN/mm / 4.400,00 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 PTFE based materials, this may lead to the sudden blow-out of the gasket, in which case, the blow-out temperature, the actual internal pressure and the gasket stress are recorded.

5.5 Shell leakage test at ambient temperature (T-2.232686)

In the leakage test at ambient temperature the gasket is compressed with a gasket stress between 31 and 52 MPa which is equivalent to a bolt stress between 210 and 361 MPa. After reaching the first gasket stress level the test volume is pressurized with 51 bar. 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
- Class C: $\leq 1.78 \cdot 10^{-7}$ Pa·m³/s/mm

5.6 Shell cycle test at 150 °C (T-2.232686)

In the leakage test at elevated temperature the gasket is compressed with a gasket stress of 45.6 MPa. After heating up to 150 °C the specimen was pressurized with

45.1 bar Helium (in accordance to the pressure-temperature rating in ASME B16.5), no load compensation of the internal pressure is done.

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

6. Results

All test results of the gasket material LineBacker are summarized in **appendix 2 and 3**.

6.1 Compression test (EN13555)

In appendix 2 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 modulus of elasticity for the different test temperature levels are shown in **appendix 4 and 5.**

In all compression tests performed no collapse of the gasket specimens can be recognized until the maximum load of the testing equipment is reached. Also in the diagrams of the modulus of elasticity no distinctive feature is visible which would indicate a damage of the gasket material. Therefore, the maximum allowable gasket stress Q_{smax} is set to 200 MPa (maximum load of the equipment).

In the test at ambient temperature more than 70 percent of the deformation of the gasket is found at a gasket stress level lower than 20 MPa, most of the deformation

of the gasket is found up to a gasket stress level of 50 MPa. In the test at 150 °C most of the deformation of the gasket is found at a gasket stress level lower than 20 MPa.

The modulus of elasticity E_G at ambient temperature is increasing with the gasket stress up to a gasket stress level of 140 MPa, and the modulus of elasticity at 150 °C is increasing with the gasket stress up to a gasket stress level of 120MPa. At higher gasket stress levels the modulus of elasticity is almost constant. The modulus of elasticity at 150 °C at a gasket stress lower 120 MPa is higher and at a gasket stress above 120 MPa is lower than the modulus of elasticity at ambient temperature.

6.2 Creep relaxation test (EN13555)

Two creep relaxation tests were performed at two different test temperatures with the same initial gasket stress levels and simulated stiffness of the flanges. The initial gasket stress level was set to 50 MPa, the temperature was assessed to 25 °C (RT) and 150 °C. For the stiffness the typical values for a PN designated flange (500 KN/mm) was chosen.

In appendix 2, also the gasket characteristics of the creep relaxation tests are listed:

- creep relaxation factor P_{QR} (50 MPa, 25 °C, 500 kN/mm), and
- creep relaxation factor P_{QR} (50 MPa, 150 °C, 500 kN/mm).

The results of the two creep relaxation tests are shown in **appendix 6 and 7**. The creep relaxation factors P_{QR} are both 0.99.

6.3 Leakage test (EN 13555)

The tightness behaviour of the gasket material LineBacker was examined in a leakage test at 40 bar Helium. 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 $1.0 \cdot 10^{-3}$ 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 curve is shown in **appendix 8**. The tightness class $L_{0.0001}$ has been achieved at the gasket stress level of 10 MPa. The increase of the gasket surface pressure had no influence on the tightness behaviour of the sealing material, the leakage rate was nearly constant for all gasket stress levels.

6.4 Hot Blow-Out test (HOBT)

One Hot Blow-Out test with the material LineBacker has been carried out for the measure of its margin of safety against blow-out.

In **appendix 9** the results of the HOBT test on LineBacker are listed, in **appendix 10** the diagram of the test is shown. For this material no blow-out occurred up to the maximum internal pressure of 171 bar.

6.5 Shell leakage test at ambient temperature (T-2.232686)

In the Shell leakage test at ambient temperature the gasket was compressed in 5 steps from 31 MPa to 52 MPa. In the leakage test at 31 MPa gasket stress and 51 bar internal pressure, the detected leak rate was $2.4 \cdot 10^{-4}$ mg/m/s, see **appendix 11**. The leak rate was decreasing with increasing gasket stress, for the maximum gasket surface pressure of 52 MPa the leak rate amounted to $5.6 \cdot 10^{-5}$ mg/m/s.

The leak rate at a gasket stress of 31 MPa is equivalent to $1.5 \cdot 10^{-7}$ Pa·m³/mm/s, for a gasket stress of 52 MPa the leak rate is equivalent to $4.6 \cdot 10^{-8}$ Pa·m³/mm/s which correspond to the Shell tightness Class C.

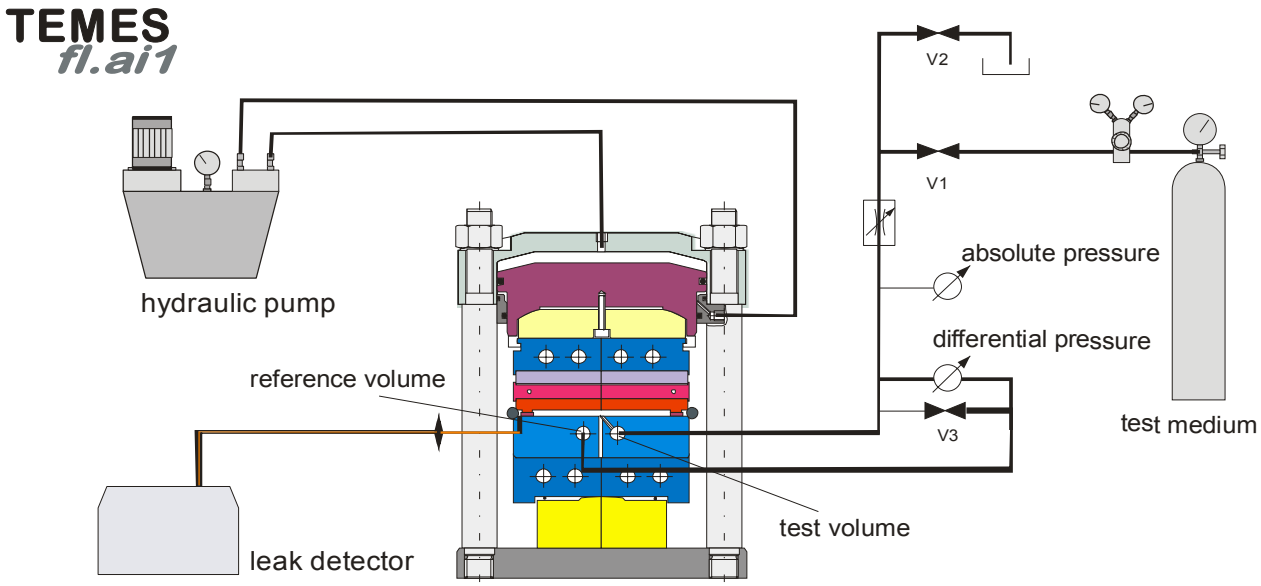
6.6 Shell cycle test at 150 °C (T-2.232686)

For the tightness test at elevated temperature the gasket was compressed initially with 45.6 MPa. After heating up to 150 °C, the specimen was pressurized with 45.1 bar Helium. During the thermal cycles in the leakage test at 150 °C, only a slight pressure drop is measured, see **appendix 12**.

During the last thermal cycle the pressure loss is 0.25 bar. The gasket material LineBacker has passed the Shell requirement of a pressure drop less than 1 bar.

7. Photo documentation

In **appendix 13 to 16** photos of the tested gasket specimens LineBacker for the 8 different test procedures are presented.



Testing Equipment TEMES*fl.ai1*

Maximum allowable Gasket Stress Q_{smax} [MPa]

T [°C]	25	150					
Q_{smax} [MPa]	> 200	> 200					
test no.	07-143	07-145					

Modulus of Elasticity E_G [MPa]

T [°C] / Q [MPa]	25	150					
20	663	887					
30	891	1326					
40	1009	1842					
50	1344	2724					
60	2281	3903					
80	3818	5175					
100	6059	6253					
120	7035	6842					
140	7726	6622					
160	7731	6208					
180	8269	6705					
200	8558	6903					
220	x	x					
240	x	x					
260	x	x					
280	x	x					
300	x	x					
test no.	07-143	07-145					

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

C = 500 kN/mm	T [°C] / Q [MPa]	25	150					
	30							
	test no.							
	50	0.99	0.99					
	test no.	07-155	07-156					
	60							
	test no.							
	80							
	test no.							
	100							
	test no.							
	120							
	test no.							
	220							
	test no.							

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
10							
test no.							
40	< 5	< 5	< 5	< 5	< 5	8	x
test no.	07-086						
80							
test no.							

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

	L / Q_A [MPa]	10	1	0.1	0.01	0.001	0.0001	0.00001
p = 40 bar	20	< 5	< 5	< 5	< 5	< 5	x	x
	40	< 5	< 5	< 5	< 5	< 5	x	x
	60	< 5	< 5	< 5	< 5	< 5	x	x
	80	< 5	< 5	< 5	< 5	< 5	x	x
	test no.	07-086						

Hot Blow-Out Test

Test pressure:	> 171	bar
Gasket blow-out stress S_{gbo}:	-	MPa
Gasket blow-out temperature T_{gbo}:	150	°C
test no.	07-079	

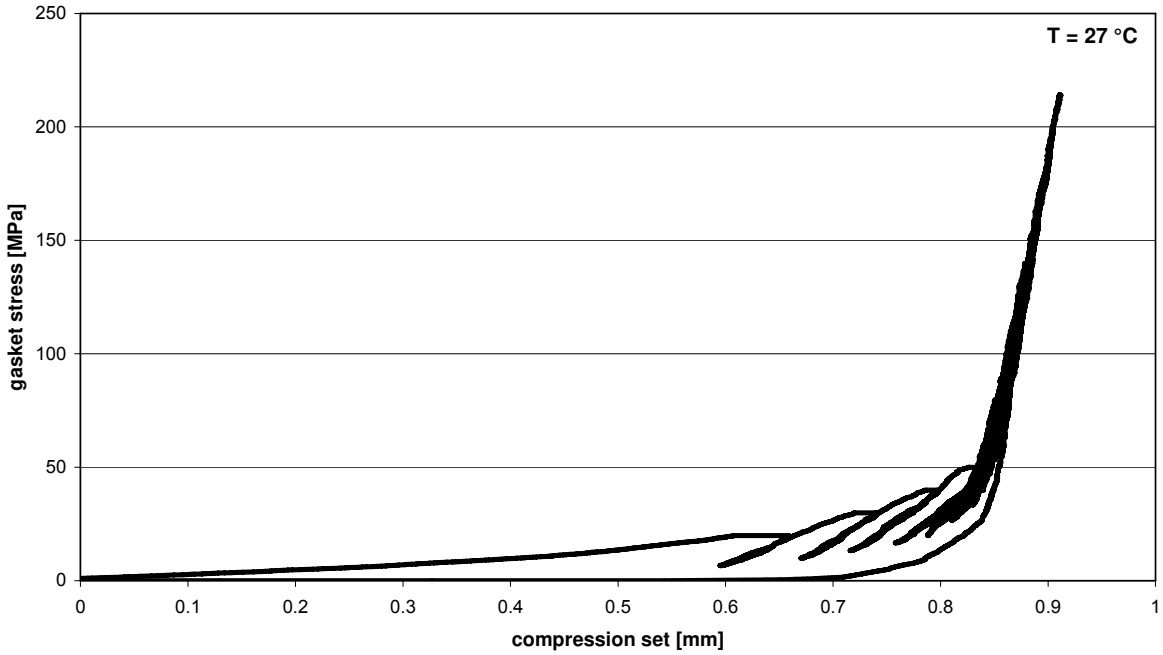
Shell leakage test at ambient temperature

Test pressure:	51	bar
Maximum gasket stress level:	52	MPa
Leakage rate:	4.60E-08	Pa.m³/s/mm
Shell tightness class:	C	
test no.	07-152	

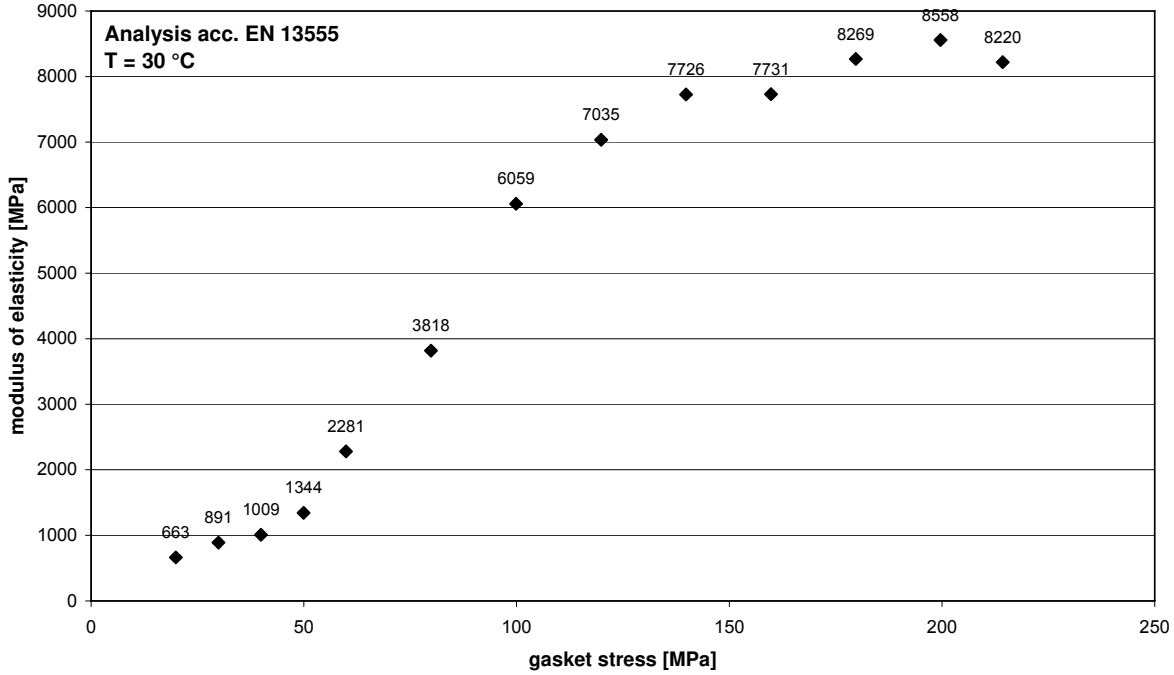
Shell cycle test at 150 °C

Test pressure:	45.1	bar
Initial gasket stress level:	45.6	MPa
Pressure drop in last cycle:	2.50E-01	bar
test no.	07-084	

Compression curve
Linebacker 91.7x43.4x4.10 mm
Test number: 07-143

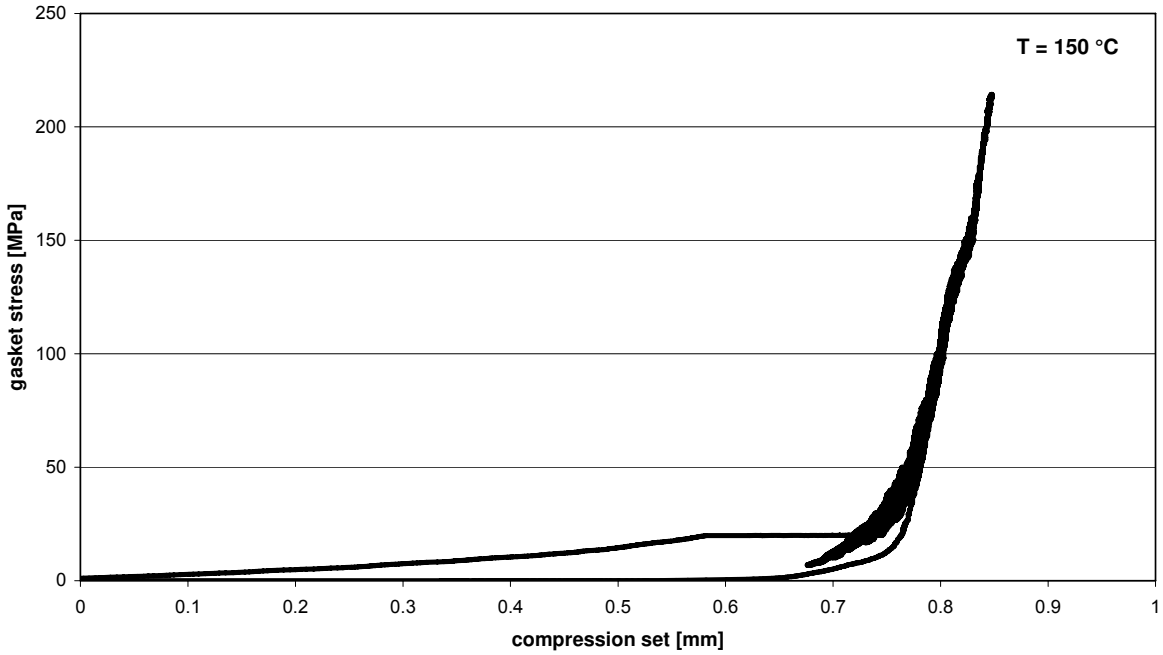


Modulus of elasticity
Linebacker 91.7x43.4x4.10 mm
Test number: 07-143

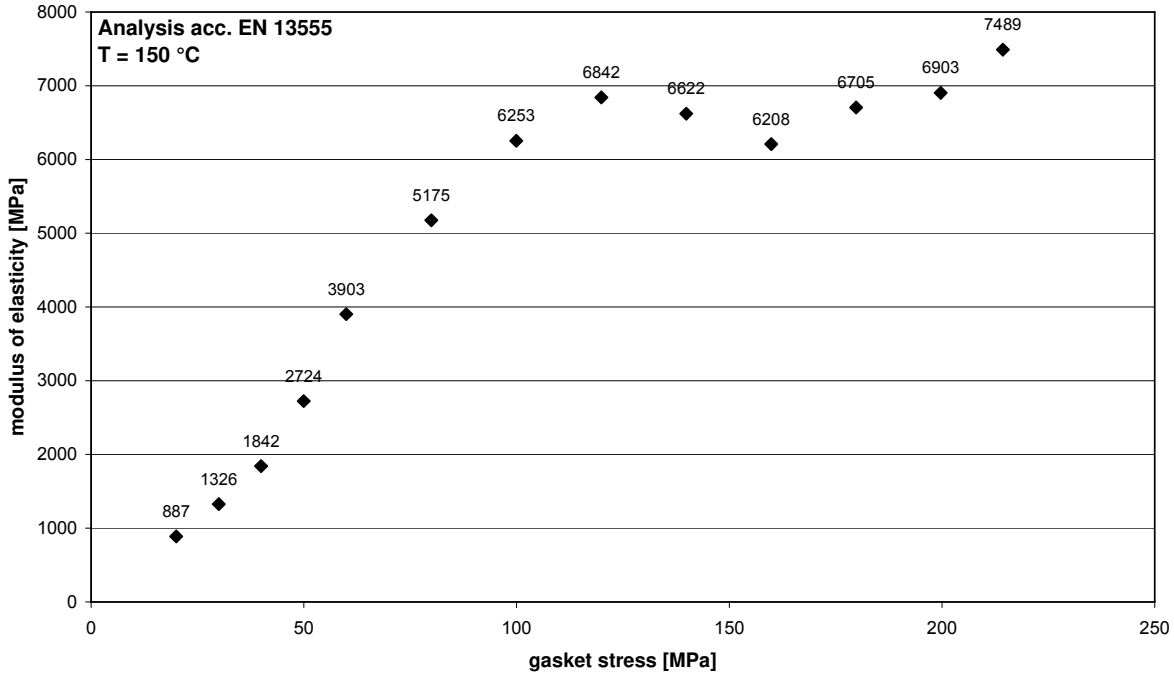


Compression test (RT) according EN 13555

Compression curve
Linebacker 91.7x43.4x4.00 mm
Test number: 07-145



Modulus of elasticity
Linebacker 91.7x43.4x4.00 mm
Test number: 07-145



Compression test at 150 °C according EN 13555

Creep relaxation test (EN 13555)

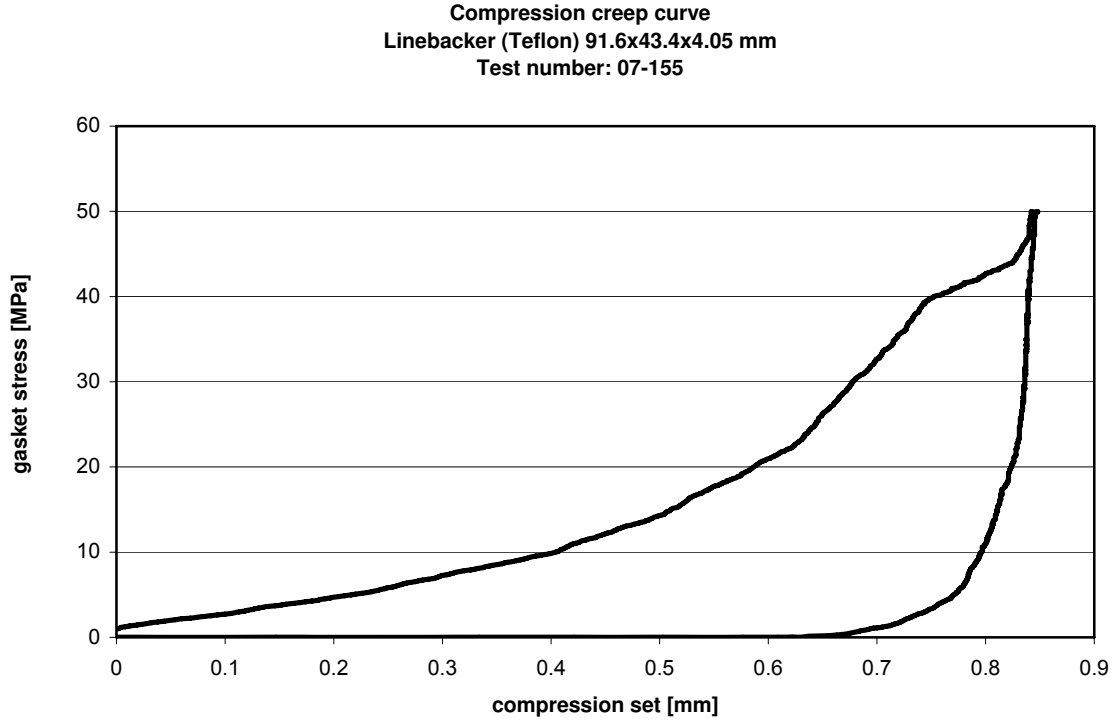
Linebacker (Teflon)
91.6x43.4x4.05 mm
Test number: 07-155

Test parameters

Inital gasket stress Q_i:	50	MPa
Test temperature T_P:	30	°C
Time at T_P:	3:58	hh:mm
Stiffness C:	500	kN/mm

Test results

Remaining gasket stress Q_r:	49.4	MPa
Relaxation factor P_{QR} (T_P):	0.99	



Creep relaxation test (EN 13555)

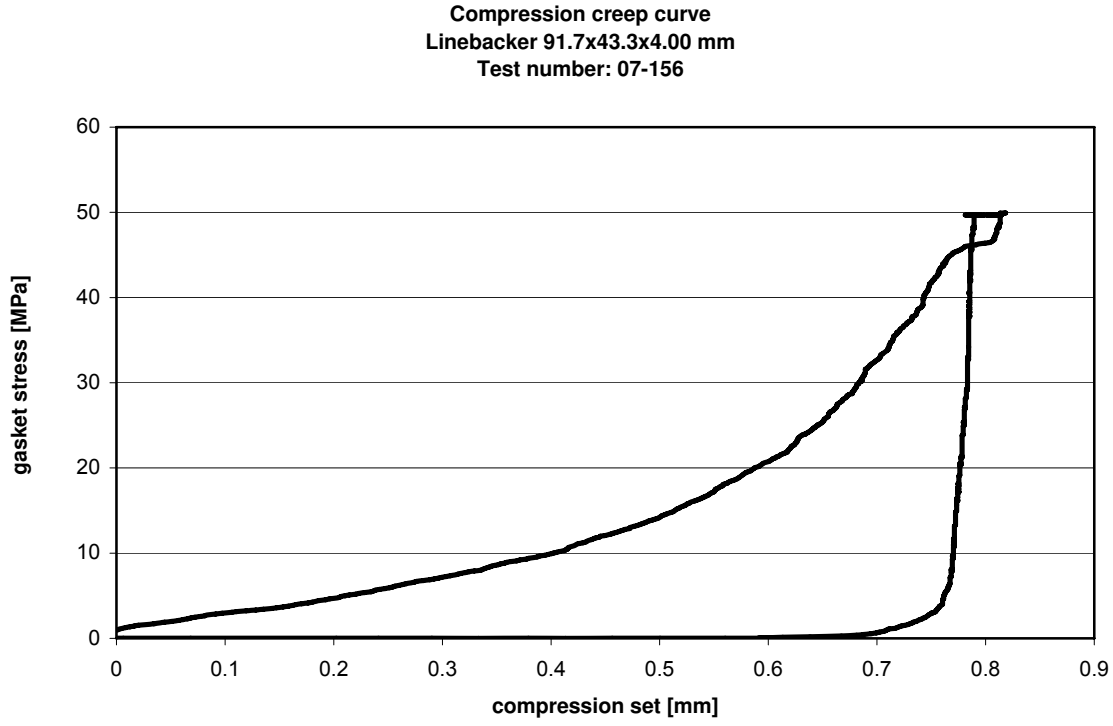
Linebacker
91.7x43.3x4.00 mm
Test number: 07-156

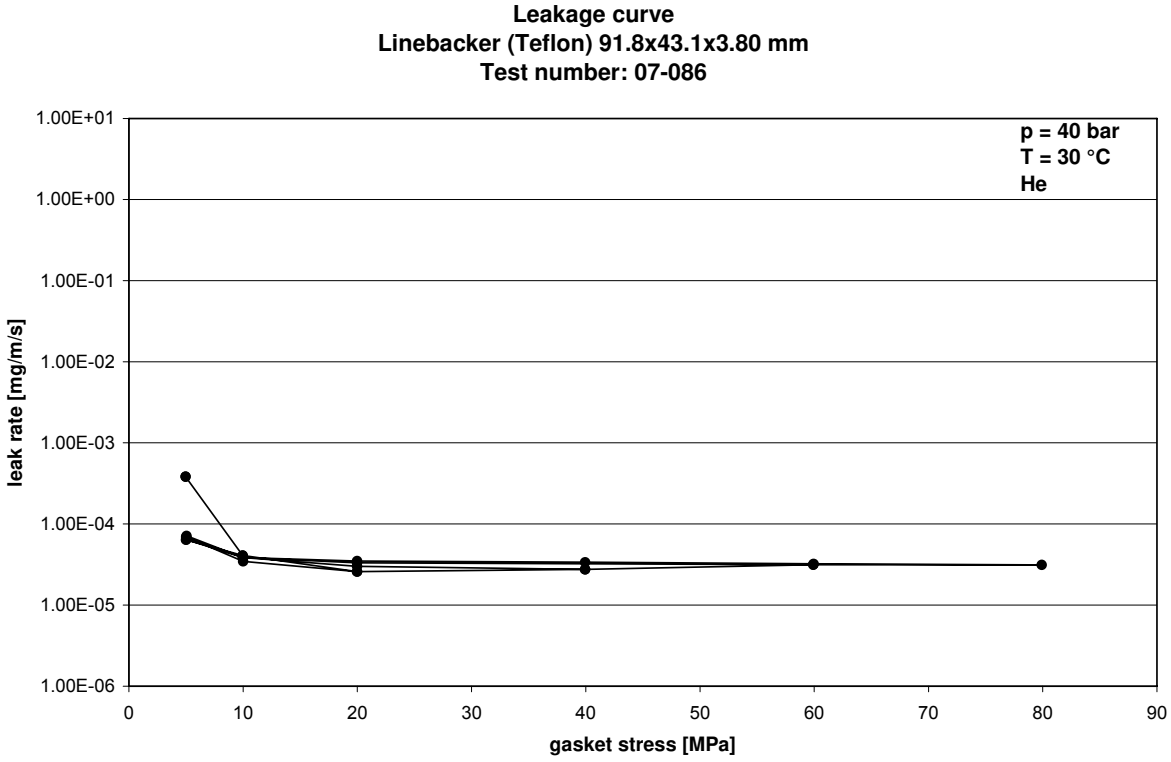
Test parameters

Inital gasket stress Q_i:	50	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:	49.7	MPa
Relaxation factor P_{QR} (T_P):	0.99	





Leakage test according EN 13555

Hot Blow-Out Test HOBT

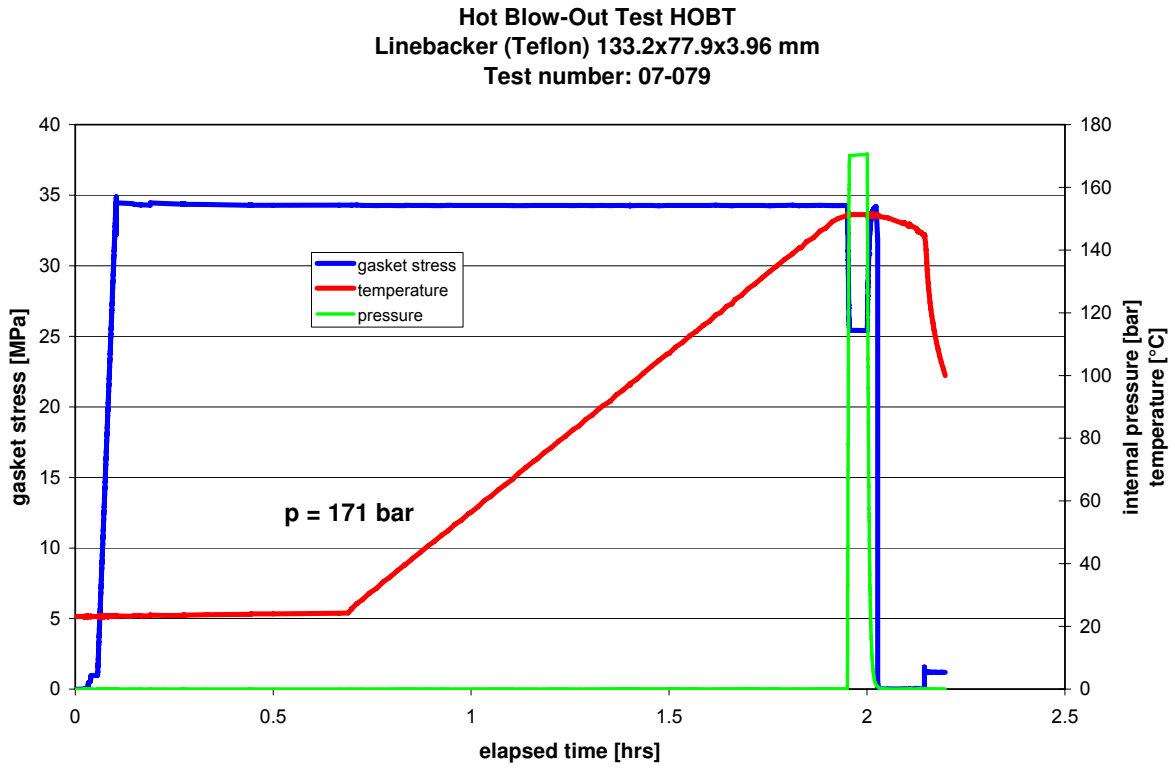
Linebacker (Teflon)
133.2x77.9x3.96 mm
Test number: 07-079

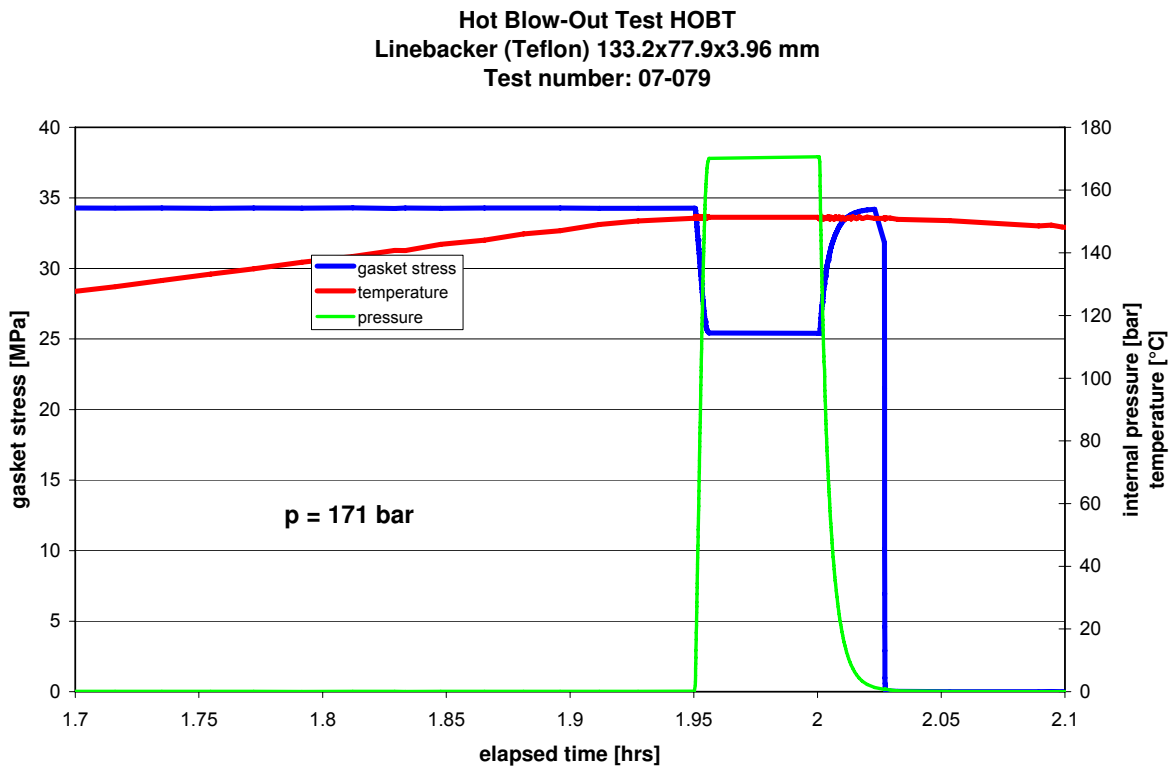
Test parameters

Nominal initial gasket stress:	5000	psi
Nominal pressure:	2321	psi

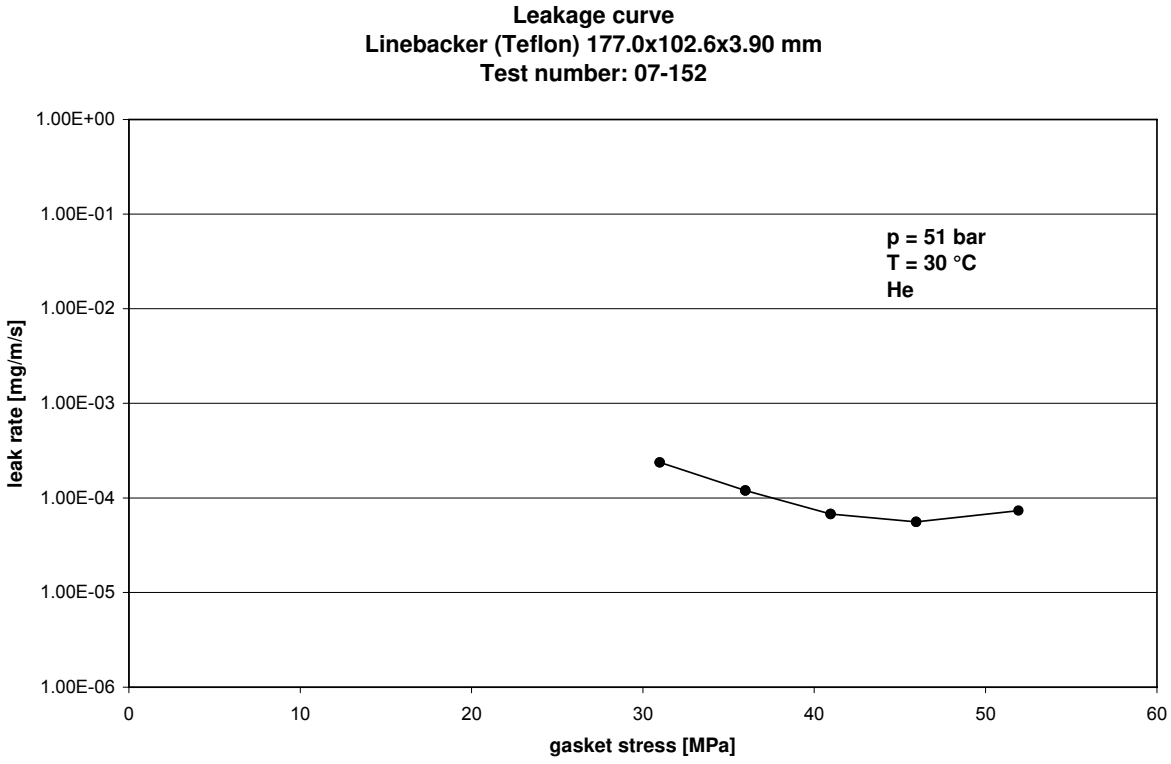
Test results

Initial gasket thickness:	0.1559	in
Final gasket thickness:	0.1205	in
Initial gasket stress:	5000	psi
Actual test pressure:	2474	psi
Gasket blow-out stress S_{gbo}:	3684	psi
Gasket blow-out temperature T_{gbo}:	303	°F

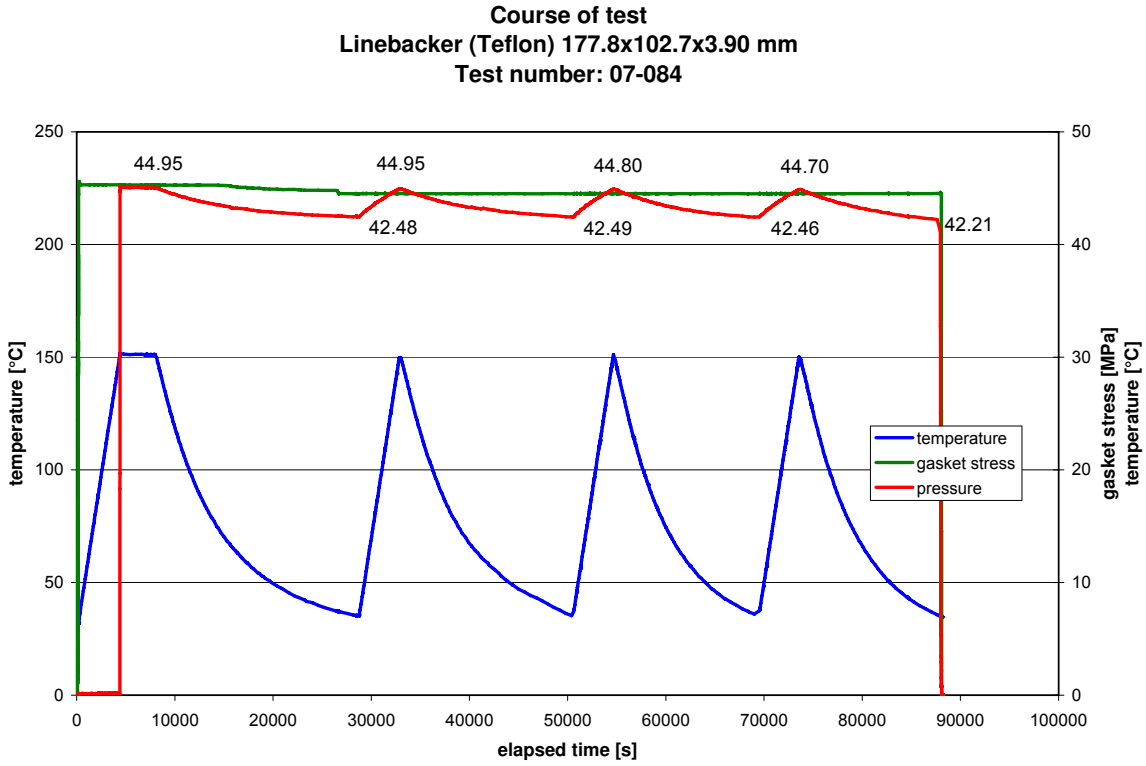




Hot Blow-Out test



Shell leakage test (RT) according T-2.232686



Shell cycle test at 150 °C according T-2.232686

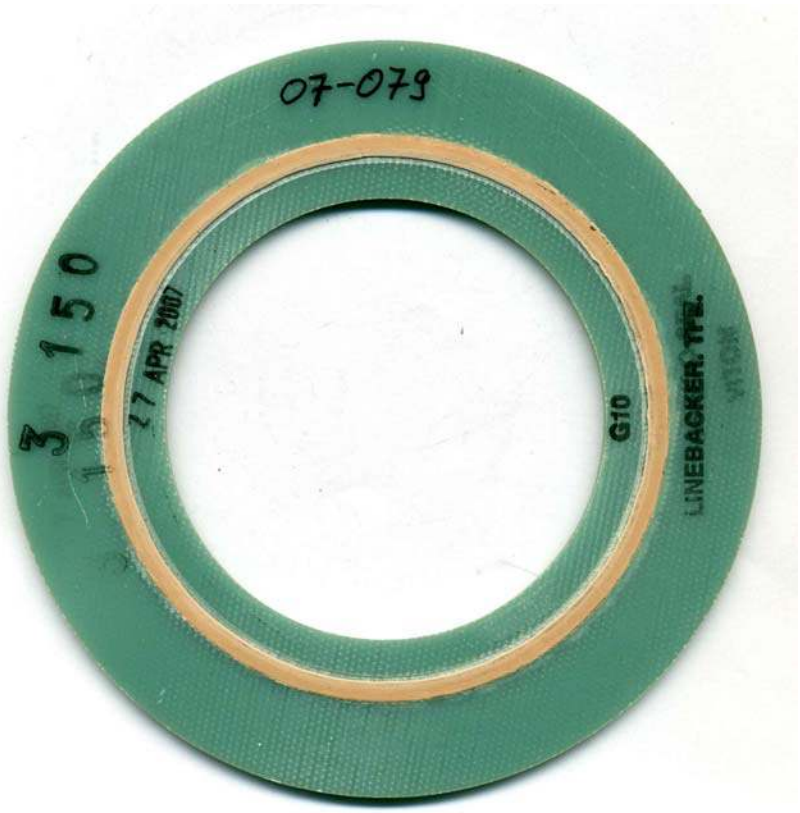
Compression test at RT (EN 13555)

Compression test at 150°C (EN 13555)

Creep relaxation test at RT (EN 13555)

Creep relaxation test at 150 °C (EN 13555)

Leakage test at RT (EN 13555)



HOBT

Shell leakage test at RT (T-2.232686)

Shell cycle test at 150 °C (T-2.232686)