LUVOCOM® EOG

High-Performance PEEK Compounds for the Energy Industry

STRUCTURAL

RESISTANT

TRIBOLOGICAL

LEHVOSS Group

LUVOCOM® EOG

Elevating Performance Over Traditional PEEK Compounds in Energy Applications

Applications in the energy industry require materials with outstanding performance. Key properties are high continuous operating temperatures, high strength to withstand pressures and loads, resistance to chemical attack and dimension stability.

In the early 1980's the high-performance polymer PEEK - today a product within the PAEK family including polymers like PEK and PEKK - was used in the first applications like back-up rings for seals because pressures in operation exceeded the capabilities of rubber and other polymers. This initial success led the expansion into further applications, which included ball valve seats, pump packing, bearings, energized seals, thrust washers, high voltage connectors and valve plates.

Innovation to drive new polymer solutions was limited by speed and resources. This was also due to limited standards in place for material selection and usage. After some catastrophic events, like the Macondo incident in 2010, the quality assurance perspective of the entire industry changed. The use of data to verify the suitability of products for particular applications took higher priority. The industry began focusing on testing standards based on quality assurance like NORSOK, ISO and API. Applications for components have become more challenging since the inception of PEEK in the 1980s.

Our response to industry's call for higher performance and lower risk in material selection

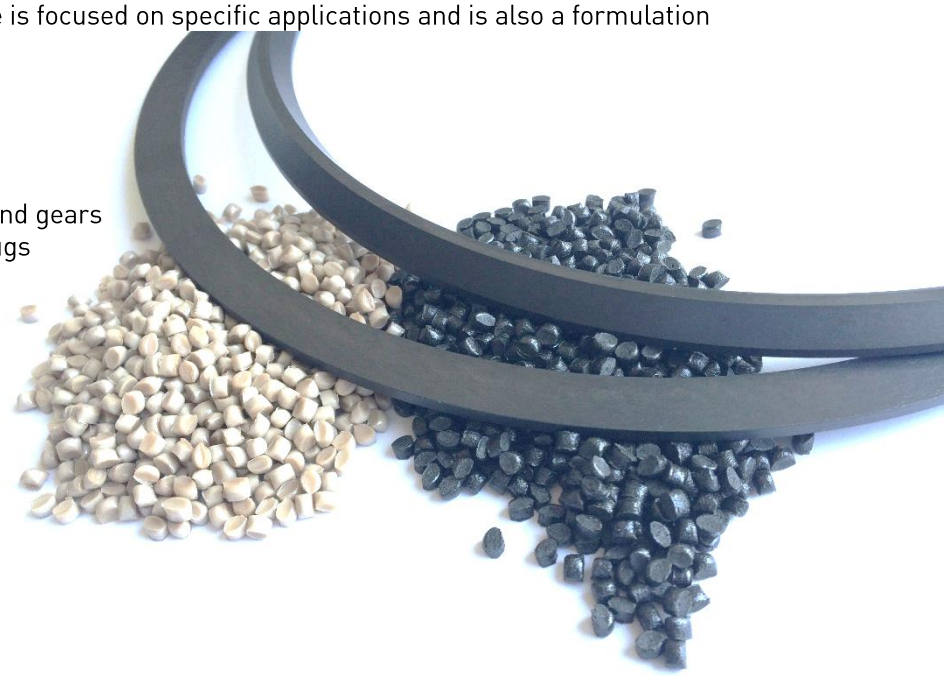
The challenges in energy applications are increasing all the time:

- Higher temperatures and pressures
- Longer service life in sour conditions
- Lower stresses in components to achieve longer service life
- Useful properties in all directions for optimum component design
- Reduced brittleness in components to reduce catastrophic breaks

This drives the need for pre-tested materials to reduce risk and time to market. LEHVOSS Group., a leading manufacturer of made-to-measure material solutions, is offering materials targeted at provide true improvements that will directly raise component performance. By including material testing according to NORSOK M710 and general material properties for historical correlation, LUVOCOM EOG is supplying the answer to these challenges. Each material grade is focused on specific applications and is also a formulation platform for future customization.

Target applications for LUVOCOM EOG

- Bearings, bushings, thrust washers and gears
- Seals, back-up rings, packers and plugs
- Electrical connectors
- Motor and pump components
- Compressor Components
- Instrument housings



LUVOCOM EOG Material Overview and Summary

LUVOCOM EOG materials are made to meet today's requirements in the energy industry. They represent a new generation of PEEK materials. On the basis of these new developments and together with experience derived from extensive testing, we can offer not only the products described but also additional tailor-made solutions. Please contact us for further information and personal support for your project.

LUVOCOM EOG-100 (unfilled modified PEEK)	
Key properties	- Enhanced for compression molding and extrusion - Shorter annealing cycles required
Main test results	- High elongation
Applications	Recommended as a neat compound in oil and gas industry applications

NORSOK M710 Certified

LUVOCOM EOG-200 (lubricated PEEK)	
Key properties	- 25% reduction in friction compared to unfilled PEEK - 60% reduction in wear compared to PEEK with PTFE
Main test results	- High elongation, reduced wear and good friction
Applications	Recommended for sealing and bearing applications in the oil and gas industry

NORSOK M710 Certified

LUVOCOM EOG-300 (glass fiber reinforced PEEK)	
Key properties	- Nearly isotropic properties - Reduced internal stress and warpage
Main test results	High elongation, shorter annealing cycles, toughness, improved isotropy
Applications	Recommended for structural applications in oil and gas industry

NORSOK M710 Certified

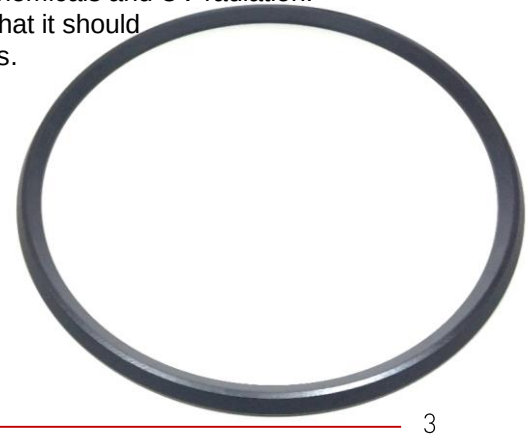
LUVOCOM EOG-400 (carbon fiber reinforced PEEK)	
Key properties	- High creep resistance while retaining ductility - Increased strain properties
Main test results	High elongation, toughness, balanced properties, improved isotropic
Applications	Recommended for structural, sealing and bearing applications in oil and gas

NORSOK M710 Certified

Form of delivery and storage

The material is delivered as 3 mm long pellets in sealed bags on pallets. Micro pellets and grit is available on request. It should be stored preferably in unopened and undamaged original containers. When the material is kept within closed rooms and under normal storage conditions, the shelf life is practically unlimited. Normal storage conditions here include protection against moisture, excessive temperatures, chemicals and UV radiation. After the material has been stored for a period of three years, we recommend that it should undergo a more precise inspection with standardized and relevant test methods.

LUVOCOM EOG for connectors and back-up rings



Material Properties

General Properties

Material			LUVOCOM			
			EOG-100	**EOG-200**	**EOG-300**	**EOG-400**
Generic formulation			PAEK unfilled **modified**	PAEK lubricated	PAEK GF 30	PAEK CF 30
Color			beige	black	black	black natural
Tensile strength (annealed)	MPa	ISO 527	95 (100)	85 (90)	135 (150)	170 (180)
Strain at break	%	ISO 527	>20	>10	>=2.8	>=2.9
Young's Modulus	MPa	ISO 527	3800	3900	10500	13500
Flex strength	MPa	ISO 527	145	140	210	260
Strain at break	%	ISO 527	na	na	>=3.1	>=2.9
Compression strength	MPa	ISO 178	130	120	205	240
MVR 380°C/10kg	cm^3/10min	ISO 1133	25	15	10	8
Density	g/cm^3	ISO 1183	1.3	1.32	1.51	1.39

Isotropic Performance – Shrinkage and Flexural Properties

LUVOCOM EOG grades are made to deliver better isotropic mechanical properties in parts. The closer the mechanical properties are in all directions of flow, the lower internal stresses tend to be; and predicting performance in final products tends to be easier. When final product performance can be predicted with more accuracy, design optimization and lower material usage can result.

Isotropy starts with material processing, and the material's shrinkage properties during processing are strong indicators of a part's predicted isotropy. The ideal ratio of in-flow shrinkage versus transfers flow shrinkage is 1. The closer the ratio is to 1, the more likely the material will process with less warpage and less internal part stress.

Shrinkage Properties

			LUVOCOM			
			EOG-100	**EOG-200**	**EOG-300**	**EOG-400**
In-flow shrinkage (3mm)	%	DIN 16901	1.5	1.4	0.5	0.2
Transverse flow shrinkage (3mm)	%	DIN 16901	1.7	1.4	0.6	0.5

Shrinkage Ratio Comparison

	LUVOCOM EOG-100	Typical PEEK unfilled	LUVOCOM EOG-200	Typical PEEK/PTFE/20	LUVOCOM EOG-300	Typical PEEK/GF/30	LUVOCOM EOG-400	Typical PEEK/CF/30
Ratio	1.1	1.3	1.0	1.4	1.2	3.0	2.5	5.0

15% better | 40% better | 150% better | 100% better

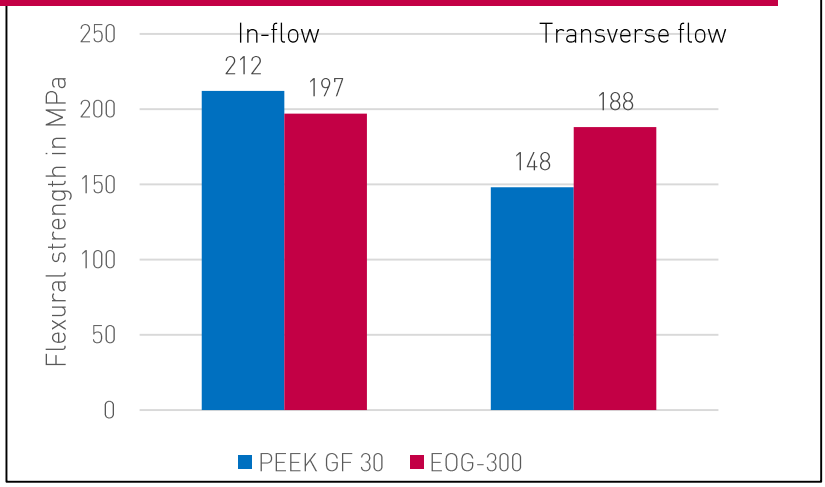
- All LUVOCOM EOG compounds show significant improvement in shrinkage ratios over typical comparable grades on the market today.
- Improved shrinkage ratios will result in lower warpage and better isotropic properties in molded parts.

Material Properties Comparison

The graphs on pages 5 and 6 compare mechanical data of standard 30% GF and CF compounds to the respective LUVOCOM EOG grades. Testing was performed on injection molded, machine-cut plates with 3 mm thickness.

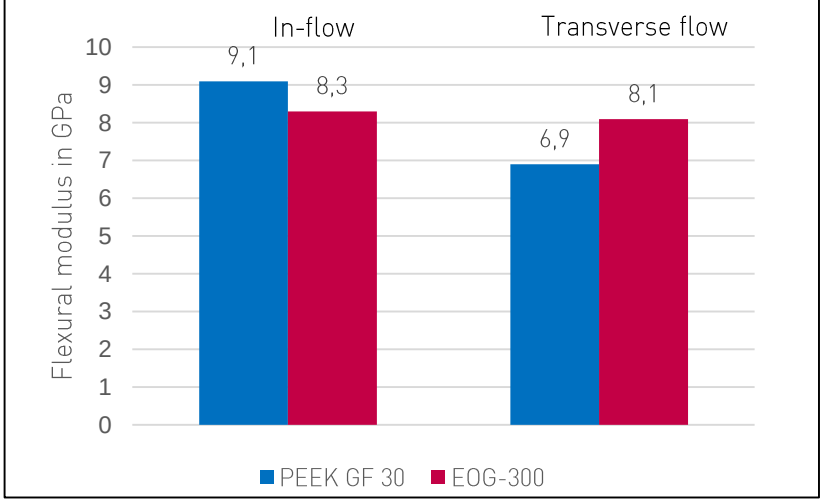
LUVOCOM EOG-300 versus PEEK GF 30

Flexural Strength - Comparison of Isotropy



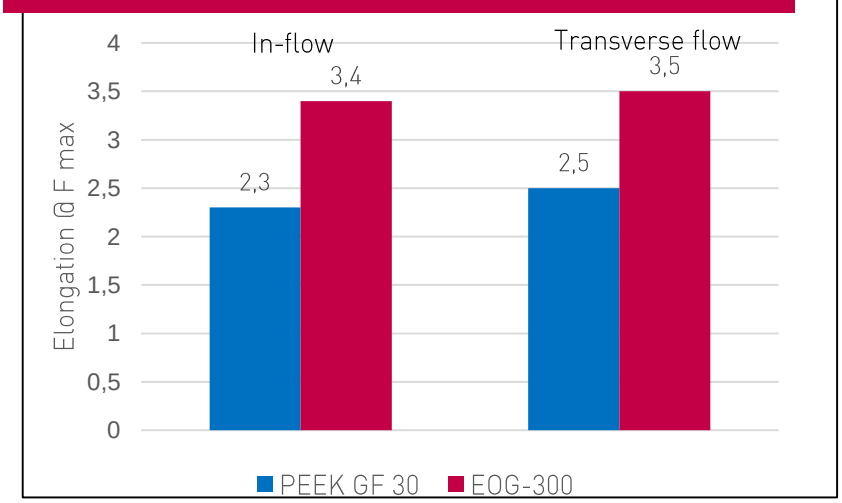
LUVOCOM EOG-300 offers
9 times better isotropy
in flexural strength than PEEK GF 30

Flexural Modulus - Comparison of Isotropy



LUVOCOM EOG-300 offers
3 times better isotropy
in elongation than PEEK GF 30

Elongation at F max - Comparison of Isotropy



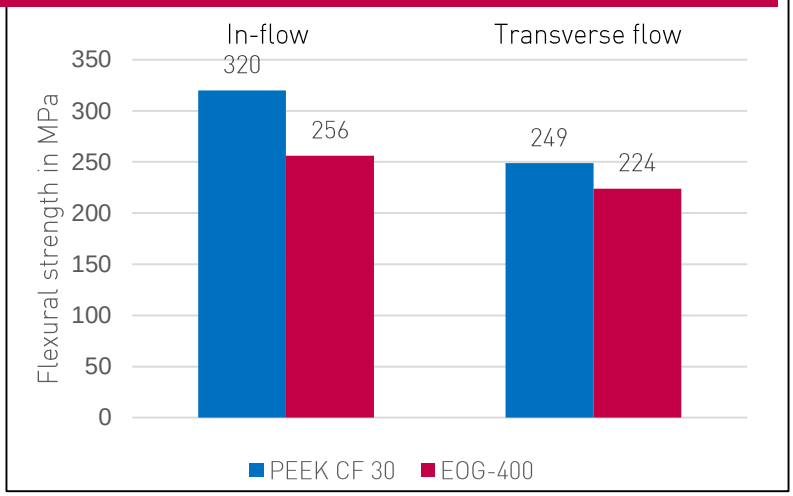
LUVOCOM EOG-300 offers
13 times better isotropy
in flexural modulus than PEEK GF 30

LUVOCOM EOG
enables lower warpage

Material Properties Comparison

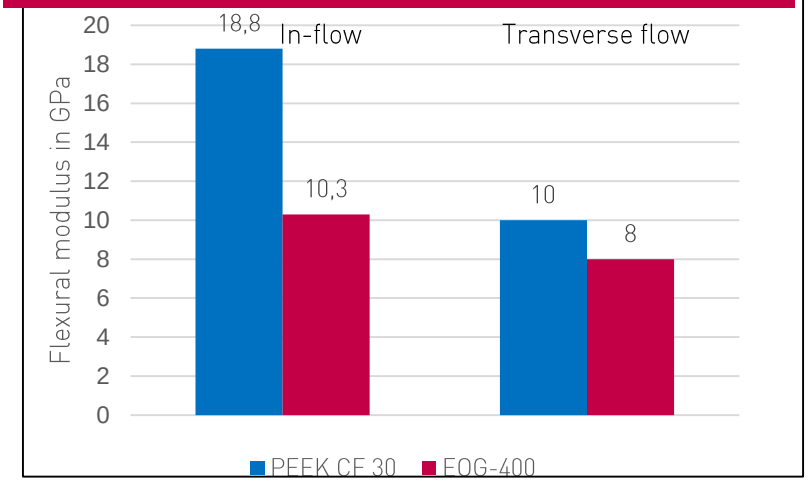
LUVOCOM EOG-400 versus PEEK CF 30

Flexural Strength - Comparison of Isotropy



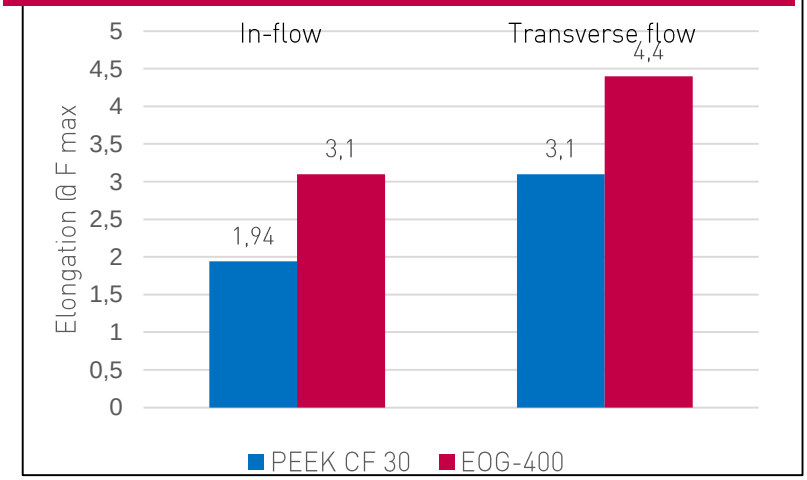
LUVOCOM EOG-400 offers
2 times better isotropy in flexural strength
than PEEK CF 30

Flexural Modulus - Comparison of Isotropy



LUVOCOM EOG-400 offers
3 times better isotropy in flexural modulus
than PEEK CF 30

Elongation @ F max - Comparison of Isotropy

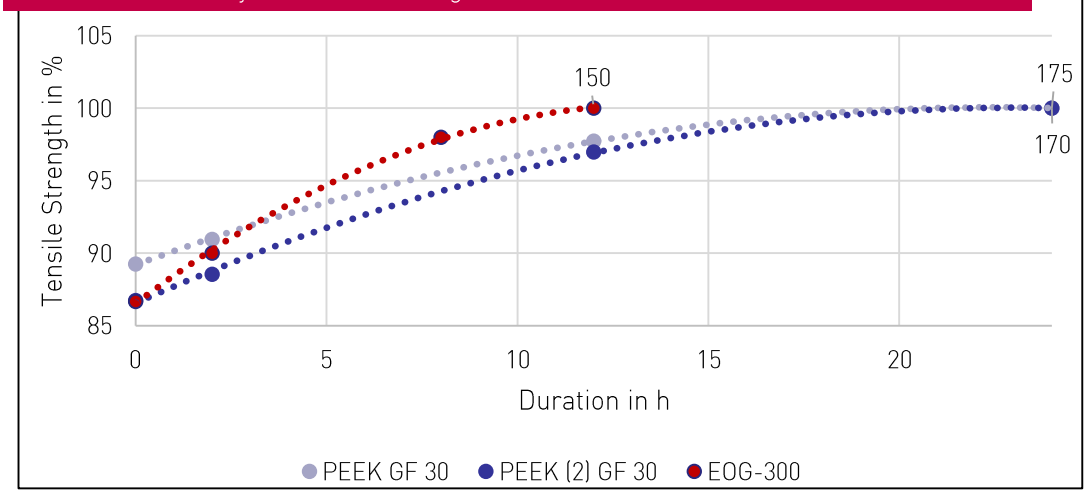


LUVOCOM EOG-400 offers
30% better isotropy in elongation
than PEEK CF 30

Material Properties Comparison

To increase the mechanical properties and to reduce stress in parts, the respective parts typically are annealed in a heat cycle process. With LUVOCOM EOG materials the 100% performance can be reached much faster compared to other typical PEEK materials.

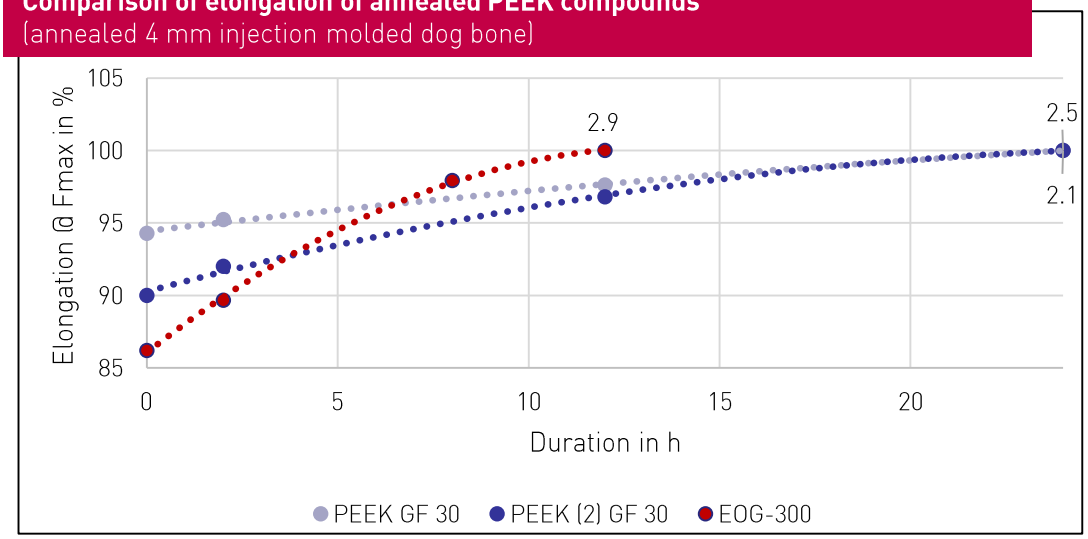
Comparison of tensile strength of annealed PEEK compounds
(annealed 4 mm injection molded dog bone)



100% achievement of annealed tensile strength:
- EOG-300 = 12 hours
- PEEK GF 30 = 20 hours
- PEEK GF 30 (2) = 20 hours

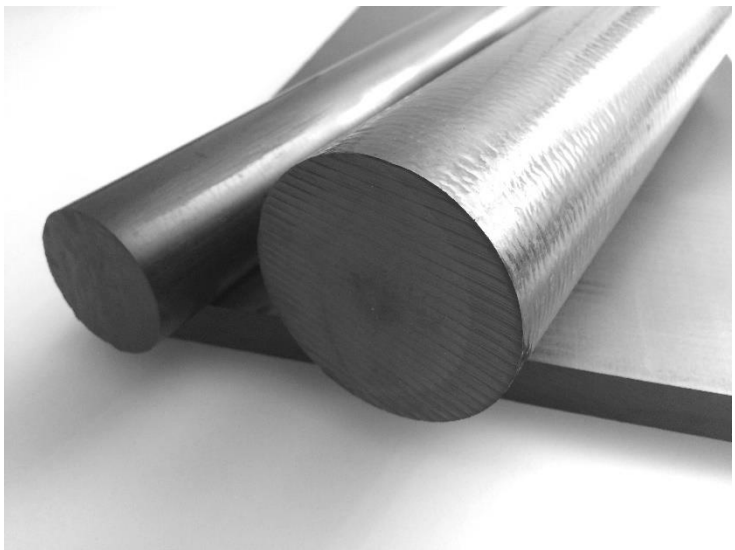
40% less time to heat treat

Comparison of elongation of annealed PEEK compounds
(annealed 4 mm injection molded dog bone)



100% achievement of annealed elongation:
- EOG-300 = 12 hours
- PEEK GF 30 = 24 hours
- PEEK GF 30 (2) = 24 hours

50% less time to heat treat

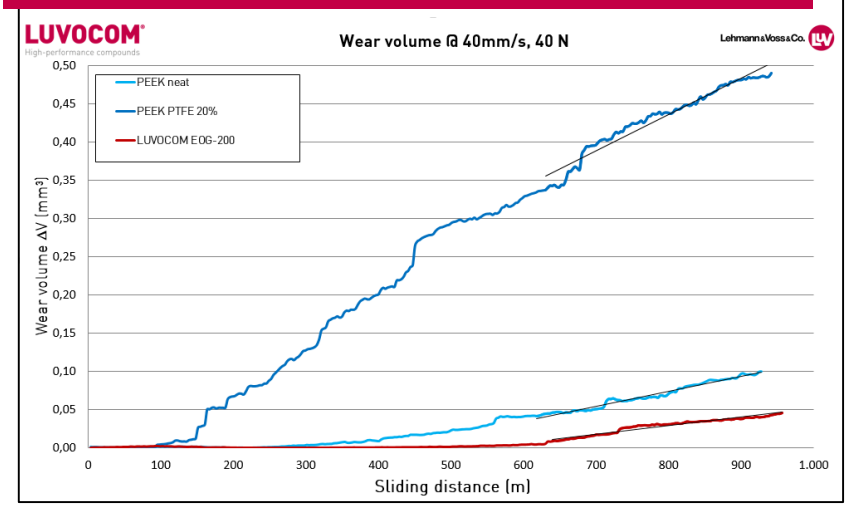


LUVOCOM EOG
for stock shapes

Tribological Properties

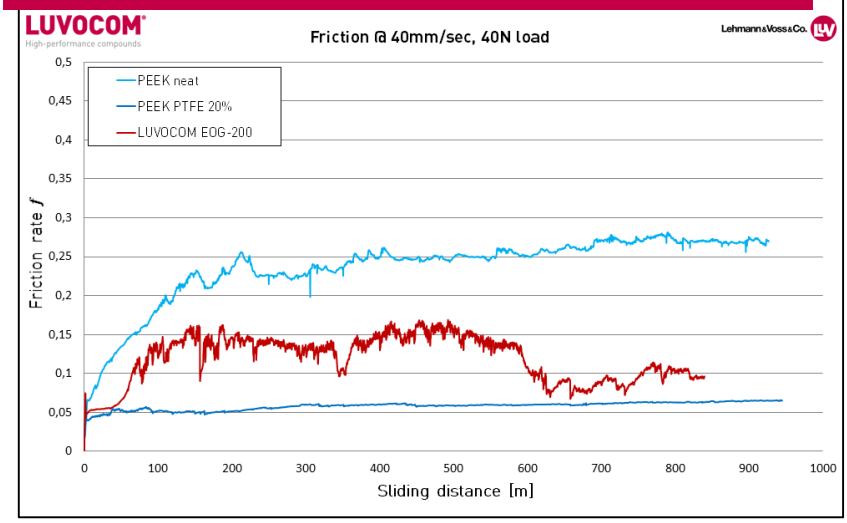
LUVOCOM EOG-200 is a dedicated tribological material and offers improved wear performance combined with low friction. PEEK polymers have inherently good tribological (friction and wear) properties. Modification with lubricants and other additives is able to further increase this performance. Applications such as bearings and seals today require improved performance from both tribological and mechanical performance. Traditional materials do not fulfill all the current requirements.

LUVOCOM EOG-200 Wear Performance
(SRV tribometer)



LUVOCOM EOG-200 shows 60% reduction in wear compared to PEEK PTFE 20

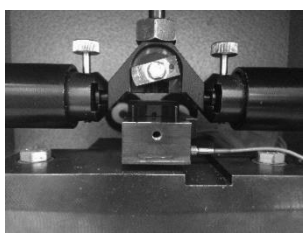
LUVOCOM EOG-200 Friction Performance
(SRV tribometer)

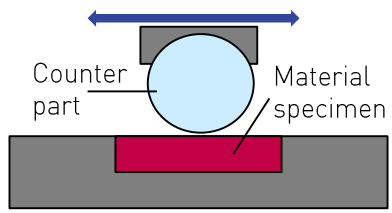


LUVOCOM EOG-200 shows 25% reduction of friction compared to neat PEEK

Test Set-up with SRV tribometer

This linear oscillating tribometer is used to characterize friction and wear behavior of materials. It represents one method for the tribology-oriented development of materials and lubricants or for quality assurance and technical service applications. This tribometer is capable of simulating short linear sliding (fretting) and a variety of field conditions.





Parameters	
Type of movement	High-frequency linear oscillation
Speed	40 mm/s
Load	40 N
Temperature	23°C
Counterpart material	100Cr6

NORSOK M710 - Objectives

Norsok M710 defines test procedures for the prediction of progressive degradation of thermoplastics exposed to fluids at elevated pressure and temperature over an extended period of time.

Objectives:

1. Assess any physical effects of the fluid on the thermoplastic and to thermally accelerate any chemical reaction between the fluid and the thermoplastic, causing tensile and related property levels to shift systematically towards a pre-defined limit of acceptability.

2. By running exposure tests with test fluids at three different elevated temperatures above the service temperature, three different times to reach the acceptance boundary will result, with the highest test temperature producing the shortest "time to failure". Plotting the log of failure times against the reciprocal of the test temperature should result in a linear trend, enabling an estimate of service life at the operating temperature. For accelerated testing, the upper test temperature should be limited to temperatures ensuring that only degradation processes relevant for the qualification range will occur.

NORSOK M710 Test Parameters

Tests performed by Alpine Polytech, Texas, USA

NORSOK M710 Qualification Parameters	
Fluid	Sour Aromatic Multiphase
Test Gas 30%	10% H2S / 5% CO2 / 85% CH4
Test Hydro 60%	70% heptane / 20% cyclohexane / 10% toluene
Test Water 10%	distilled water
Specimen	ASTM D638 Type V
Pressure	60±5 bar (870 psi) initial
Duration	42 days at each temperature
Temperature	215°C, 225°C, 240°C

ALPINE POLYTECH

NORSOK M710 Observations

1. All grades: LEHVOSS Group. and Alpine attempted to thermally accelerate chemical reaction between the PEEK and H_2S by testing at **240°C out to 42 days, but no progressive degradation of tensile properties** from thermally accelerated H_2S exposure, that could be used for life prediction, was observed.

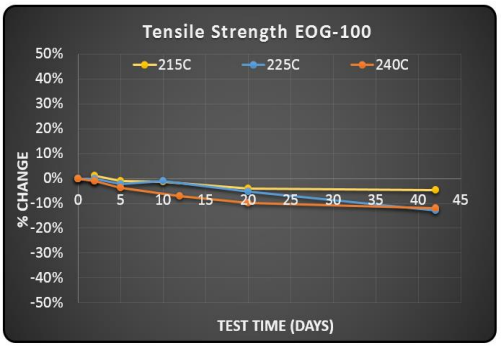
2. EOG-200 was sour aged and had 5% volume swell, 70% increase in strain at break and 10% drop in yield stress as the result of liquid absorption. The tensile strength and modulus **changes of EOG-200 did not reach the acceptance boundary (50% change)** at any time and temperature combination.

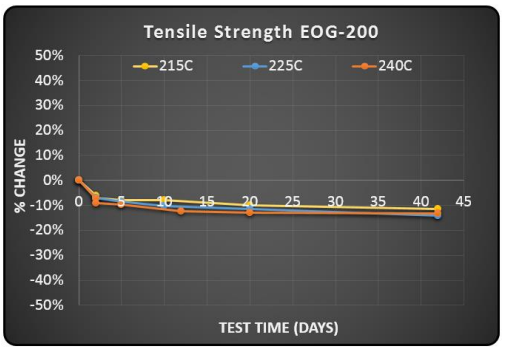
3. EOG-300 was sour aged and experienced 5% to 8% volume swell, a 600% increase in strain at break, a 40% drop in yield strength, and 25% drop in modulus as the result of initial liquid absorption. The tensile strength and modulus **changes of EOG-300 did not reach the boundary (50% change)** at any time and temp combination. The strain at break only crossed the threshold because of initial saturation.

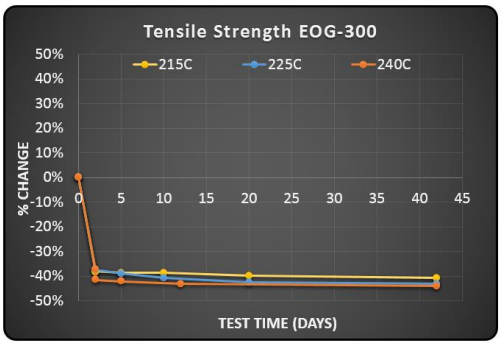
4. All grades: The changes over time also do not accurately trend towards the acceptance boundary with extrapolation confidence. Therefore, **all grades are considered stable in H_2S within these test parameters** and a "Service Life" estimation cannot be calculated using NORSOK M710 methods.

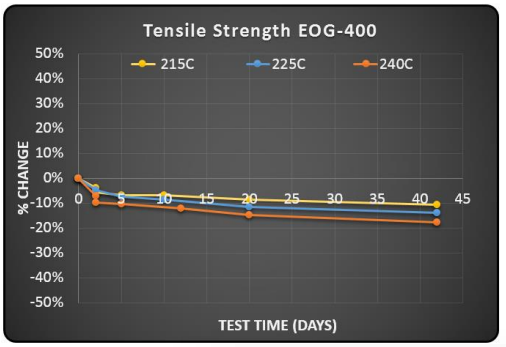
Test results – Tensile Strength

Below diagrams show the development of tensile strength of the four LUVOCOM EOG materials during NORSOK M710 testing.









ALPINE POLYTECH

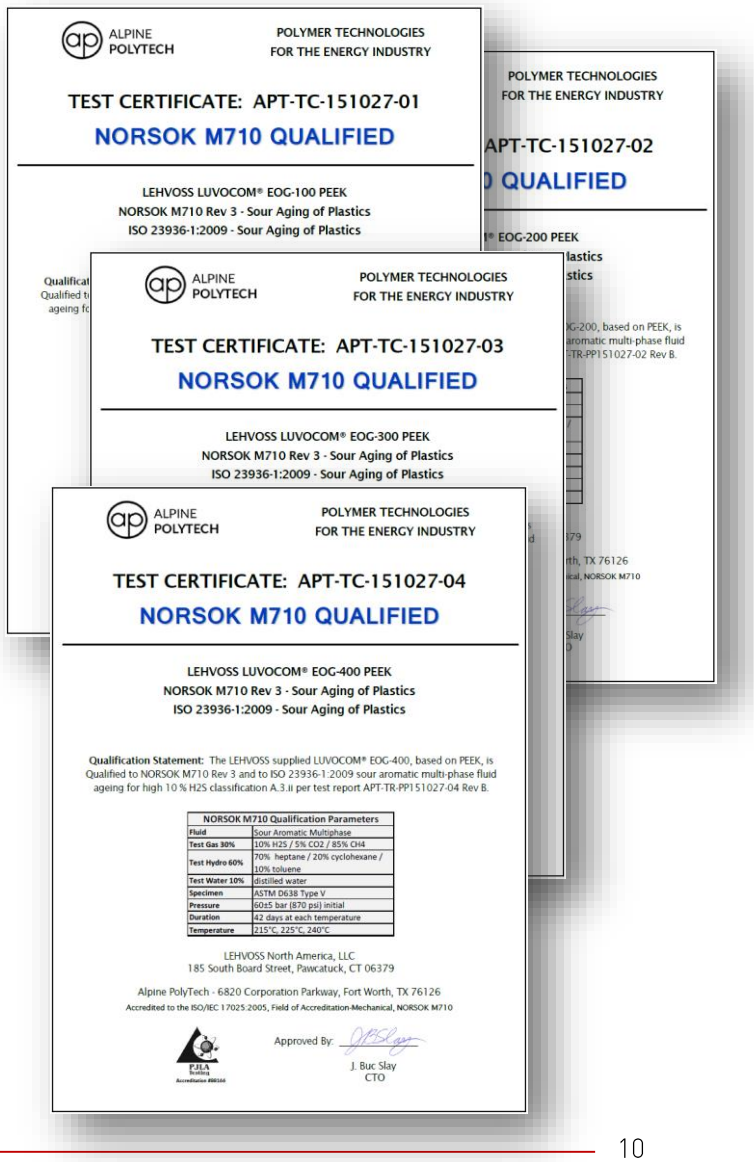
Qualification Statements

LUVOCOM® EOG-100
The supplied LUVOCOM EOG-100, based on PEEK, is Qualified to NORSOK M710 Rev 3 and to ISO 23936-1:2009 sour aromatic multi-phase fluid ageing for high 10 % H2S classification A.3.ii per test report APT-TR-PP151027-01 Rev B.

LUVOCOM® EOG-200
The supplied LUVOCOM EOG-200, based on PEEK, is Qualified to NORSOK M710 Rev 3 and to ISO 23936-1:2009 sour aromatic multi-phase fluid ageing for high 10 % H2S classification A.3.ii per test report APT-TR-PP151027-02 Rev B.

LUVOCOM® EOG-300
The supplied LUVOCOM EOG-300, based on PEEK, is Qualified to NORSOK M710 Rev 3 and to ISO 23936-1:2009 sour aromatic multi-phase fluid ageing for high 10 % H2S classification A.3.ii per test report APT-TR-PP151027-03 Rev B..

LUVOCOM® EOG-400
The supplied LUVOCOM EOG-400, based on PEEK, is Qualified to NORSOK M710 Rev 3 and to ISO 23936-1:2009 sour aromatic multi-phase fluid ageing for high 10 % H2S classification A.3.ii per test report APT-TR-PP151027-04 Rev B.


ALPINE POLYTECH
POLYMER TECHNOLOGIES FOR THE ENERGY INDUSTRY
TEST CERTIFICATE: APT-TC-151027-01
NORSOK M710 QUALIFIED
LEHVOSS LUVOCOM® EOG-100 PEEK
NORSOK M710 Rev 3 - Sour Aging of Plastics
ISO 23936-1:2009 - Sour Aging of Plastics
TEST CERTIFICATE: APT-TC-151027-03
NORSOK M710 QUALIFIED
LEHVOSS LUVOCOM® EOG-300 PEEK
NORSOK M710 Rev 3 - Sour Aging of Plastics
ISO 23936-1:2009 - Sour Aging of Plastics
TEST CERTIFICATE: APT-TC-151027-04
NORSOK M710 QUALIFIED
LEHVOSS LUVOCOM® EOG-400 PEEK
NORSOK M710 Rev 3 - Sour Aging of Plastics
ISO 23936-1:2009 - Sour Aging of Plastics
Qualification Statement: The LEHVOSS supplied LUVOCOM® EOG-400, based on PEEK, is Qualified to NORSOK M710 Rev 3 and to ISO 23936-1:2009 sour aromatic multi-phase fluid ageing for high 10 % H2S classification A.3.ii per test report APT-TR-PP151027-04 Rev B.
NORSOK M710 Qualification Parameters
Fluid: Sour Aromatic Multiphase
Test Gas 30%: 10% H2S / 5% CO2 / 85% CH4
Test Hydro 60%: 70% heptane / 20% cyclohexane / 10% toluene
Test Water 10%: distilled water
Specimen: ASTM D638 Type V
Pressure: 60±5 bar (870 psi) initial
Duration: 42 days at each temperature
Temperature: 215°C, 225°C, 240°C
LEHVOSS North America, LLC
185 South Board Street, Pawcatuck, CT 06379
Alpine PolyTech - 6820 Corporation Parkway, Fort Worth, TX 76126
Accredited to the ISO/IEC 17025:2005, Field of Accreditation-Mechanical, NORSOK M710
Approved By:
J. Buc Slay
CTO

Processing

The following processing notes for LUVOCOM EOG supplement the general notes on processing for materials based on PEEK. Please contact your local responsible LUVOCOM contact for further detailed information.

Predrying

Although PEEK molding compounds are not sensitive to hydrolysis, it is generally advisable to adjust the moisture content to 0.05% by weight or lower. Molded parts produced with excessive moisture may cause unforeseen problems when used in a hot environment at a later stage. When processing is carried out with a significantly high moisture content, we recommend evaluating the specific application. A simple hot-air oven may be used. Generally conditions ranging from 2 h at 180°C to 4 h at 150°C are sufficient.

Dwell times

To achieve optimum component quality, unnecessary dwell times should be avoided. If the process dictates times of greater than 45 min, the temperature should be reduced to 340°C intermittently. As a general rule, the higher the temperature of the material, the shorter the dwell time should be.

Injection molding

Most materials from the EOG product range are relatively viscous and therefore need higher pressures – particularly in the case of low wall thicknesses. To some extent, an increase in the material temperature is able to compensate for this. Generally a minimum of 370°C is necessary for successful plasticizing. Increasing the material temperature beyond 410°C is generally not beneficial. Similarly, a heated tool temperature is able to prevent premature freezing of the flow front and achieve an increase in strength of the joint lines. Only established special types should be processed at temperatures <170°C and >210°C.

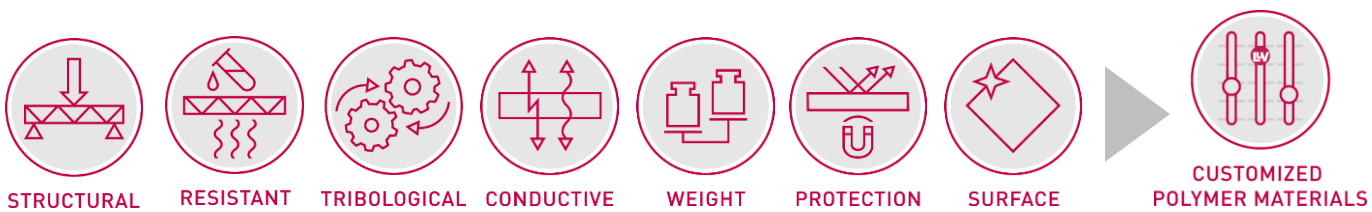
Extrusion

The extruder heating elements should be capable of maintaining a stable temperature of 400°C and be adequately protected against wear, especially for processing the EOG-300 and EOG-400 product series. The size of the machine should be designed with a view to good product quality and a sufficiently low dwell time. Dead zones should be avoided as a matter of principle. Materials from the EOG-100 family can be run with almost any screen packs; however, due to the high viscosity, high dynamic pressures result depending on the application at high mesh numbers even during start-up. This has to be taken into account in the design of the pack.
Materials of the EOG-200 family should be run with <100-mesh screen packs. Otherwise and depending on the composition of the compound, filtering out of fillers may occur. Materials of the EOG-300 and EOG-400 families should ideally not be screened at all as a disadvantageous interaction between screen and reinforcing fillers is often established. If safety reasons mean that screening is unavoidable, a screen should be selected with a maximum of 30 mesh.

Compression molding

Due to the inherent elevated dwell time, it is advisable to carry out good predrying with this process in particular. If large molded parts are to be produced, it may be helpful to prevent oxidation effects. The products of the EOG family are fundamentally suitable for forming good joint line strengths during compression. Nevertheless, plasticizing outside of the cavities may be regarded as the optimum. For smaller geometries or in order to take into account special requirements, EOG products may also be offered in different supply forms (for example: microgranulate or grit). Avoidance of monomodal particle sizes improves filling characteristics and may enhance the result. Generally, it is advisable to preheat the mold to just over > Tg in order to facilitate preforming with pressures of around 600 bar. Following this, the pressure should be reduced to the final compression temperature while the plant is heating up to the plasticizing temperature. It may take a long time to fully heat the molding compound according to the wall thickness – a rough guide value of 7 min/mm may be assumed for low wall thicknesses and up to 3 min/mm for wall thicknesses in excess of 20 mm. As material is lost particularly during mold separation and degassing, it is important to select an initial filling greater than 100% of the weight of the part. Depending on the process, loss rates of 1 to 4% should be taken into account as typical values.

Our Material Competences



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