Tecnoflon® PFR 06HC

Perfluoroelastomer

Tecnoflon® PFR 06HC is a new chemical resistant perfluoroelastomer (FFKM). Tecnoflon® PFR 06HC offers the widest range of aggressive media sealing capabilities along with excellent compression set values.

It is suitable for most applications in temperature ranging from –10 °C to 230 °C, offering outstanding resistance to aggressive media such as hot organic and inorganic acids, caustics, amines (especially hot amines, i.e. at temperature higher than 70 °C), ketones, aldehydes, esters, ethers, alcohols, fuels, solvents, sour gases, hydrocarbons, steam, hot water, ethylene and propylene oxide and mixed process streams. Moreover it can cope with a wide range of potent active pharmaceutical ingredients (API's) and aggressive cleaning agents, being especially suited to withstand steaminplace (SIP) and cleaninplace (CIP) procedures.

Moreover its structure was specifically designed to deliver enhanced extrusion resistance and rapid gas decompression (RGD or explosive decompression ED) resistance requested for many high pressure gas applications in the oil & gas industry.

Its extreme cleanliness along with its broad chemical resistance make Tecnoflon® PFR 06HC the suitable sealing material for most wet semiconductor processes (wafer cleaning, polymer removal, wet etching, polishing), for photolithography developing and stripping and for general purpose fab equipments (pumps, scrubbers, filters, chemicals delivery systems).

Tecnoflon® PFR 06HC can be combined with the cure system and other typical fluoroelastomer compounding ingredients; its mixing can be accomplished with two roll mills or internal mixers. Finished goods may be produced by a variety of rubber processing methods.

The primary use for Tecnoflon® PFR 06HC is the manufacturing of any kind of elastomeric sealing element such as Orings, gaskets, valve bodies, butterfly valves, pump housings and stators, metal bonded parts, diaphragms, profiles, etc. These sealing elements can be used in mechanical seals, pumps, compressors, valves, reactors, mixers, sprayers, dispensers, quick connect couplings, controls, instrumentation, etc. in a wide range of industrial sectors.

Tecnoflon® PFR 06HC is marketed in the form of raw polymer (1 kg box) in order to give the transformer the freedom and the opportunity to develop and fine tune compounds and items best suited to the final application.

Handling and safety

Normal care and precautions should be taken to avoid skin contact, eye contact and breathing of fumes. Smoking is prohibited in working areas. Wash hands before eating or smoking. For complete health and safety information, please refer to the material safety data sheet.

Basic characteristics of the raw polymer are as follows

Property	Typical Value	Unit	Test Method
ML (1+10') at 121 °C	75	MU	ASTM D1646
Specific gravity	2.05	g/cm^3	ASTM D792
Colour	Translucent		
Packaging / Form	1 kg / Slabs		

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Black compounds

Test Compound	Unit	70 Shore A	80 Shore A	Test Method
Tecnoflon® PFR 06HC	phr	100	100	
Luperox® 101XL-45	phr	1.5	1.5	
Drimix® TAIC (75 %)	phr	2	2	
N-990 MT Carbon Black	phr	15	25	

Property	Unit	70 Shore A	80 Shore A	Test Method
Mooney viscosity ML (1+10') at 121 °C	MU	80	85	ASTM D1646
Compound density	g/cm^3	2.00	2.01	ASTM D792
MDR 12 min at 160 °C arc 0.5 °				ASTM D6601
Minimum torque	lb · in	1.6	1.7	
Maximum torque	lb · in	22.9	28.7	
t_{s2}	s	40	38	
t'_{50}	s	60	67	
t'_{90}	s	158	200	
MDR 12 min at 150 °C arc 0.5 °				ASTM D6601
Minimum torque	lb · in	2.0	2.3	
Maximum torque	lb · in	23.0	28.3	
t_{s2}	s	71	77	
t'_{50}	s	137	150	
t'_{90}	s	315	380	
Post cure: 4 h at 230 °C				
100 % modulus	MPa	6.5	11.0	ASTM D412C
Tensile strength	MPa	19.0	19.5	
Elongation at break	%	185	160	
Hardness	Shore A	70	79	ASTM D2240
Compression set 25 % deformation, O-ring #214				ASTM D395 method B
70 h at 200 °C	%	20	23	

For additional compounds suggestion, please refer to Tecnoflon® PFR 94 technical data sheet, since its overall physical properties are very similar to PFR 06HC.

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Oil & gas compound

Test Compound	Typical Value	Unit	Test Method
Tecnoflon® PFR 06HC	100	phr	
Luperox® 101XL-45	0.9	phr	
Drimix® TAIC (75 %)	1.2	phr	
N-990 MT Carbon Black	60	phr	
PAT 777	1	phr	
Struktol® WS280	0.5	phr	

Property	Typical Value	Unit	Test Method
Compound density	1.96	g/cm^3	ASTM D792
MDR 12 min at 160 °C arc 0.5 °			ASTM D6601
Minimum torque	3.0	lb·in	
Maximum torque	40.3	lb·in	
t_{s2}	35	s	
t'_{50}	81	s	
t'_{90}	281	s	
Post cure: 4 h at 230 °C			
50 % modulus	9.0	MPa	ASTM D412C
100 % modulus	18.4	MPa	
Tensile strength	20.1	MPa	
Elongation at break	118	%	
Hardness	90	Shore A	ASTM D2240
Compression set 25 % deformation, O-ring #214			ASTM D395 method B
70 h at 200 °C	26	%	

Rapid gas decompression tests

The Tecnoflon® PFR 06HC oil & gas compound on page 3 was successfully tested in the following conditions referring to EN ISO 23936-2 standard “Petroleum, petrochemical and natural gas industries – Non-metallic materials in contact with media related to oil and gas production Part 2: Elastomers” and successfully passed the Rapid Decompression Test.

Property	Typical Value	Unit	Test Method
Gas	90/10 CH_4/CO_2	mol %	
O-ring replication	4		
Groove fill	65	%	
Temperature	100	°C	
Pressure	150	bar	
Numbers of cycles	8		
First cycle duration	minimum 68	h	
Soak time	minimum 6	h	
Hold period between cycles	1	h	
De-pressurization rate	20	bar/minute	

O-rings #312 (13.64 mm internal diameter – 5.33 mm cross-section) were submitted to testing.

All O-rings met the ISO 23936-2 acceptance criterion after the 8 cycle RGD test, since the ratings were as below:

ISO 23936 rating: 0000, 0000, 0000, 0000

Whereby the ISO 23936 rating numbers are as follows:
0: no cracks, holes or blisters; the exposed surface is intact.

Cold flexibility

Property	Typical Value	Unit	Test Method
DSC			
T_g onset	−8	°C	
T_g midpoint	−1	°C	
Retraction curve			ASTM D1329
TR_{10}	−2	°C	
TR_{30}	2	°C	
TR_{50}	4	°C	
TR_{70}	7	°C	

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Fluid resistance overview

Fluid	Volume Swelling
Inorganic acids	< 10 %
Organic acids	< 10 %
Alkalis	< 10 %
Amines (RT)	< 10 %
Hot amines (> 70 °C)	< 10 %
Water / Steam	< 10 %
Ketones	< 10 %
Esters	< 10 %
Ethers	< 10 %
Aldehydes	< 10 %
Alcohols	< 10 %
Hydrocarbons	< 10 %
Sour gas	< 10 %
Lubricants	< 10 %
Fluorinated fluids	30 – 50 %

Fluid resistance

Chemical and Process Industry (CPI)

Property	Typical Value	Unit	Test Method
Ethylenediamine, 72 h at 100 °C			
Δ Tensile strength	−35	%	
Δ Elongation at break	13	%	
Δ Hardness	−4	Shore A	
Δ Volume	6.5	%	
Ethylenediamine, 168 h at 100 °C			
Δ Tensile strength	−40	%	
Δ Elongation at break	9	%	
Δ Hardness	−7	Shore A	
Δ Volume	9	%	
2-aminoethanol (MEA – ethanolamine), 72 h at 150 °C			
Δ Tensile strength	−30	%	
Δ Elongation at break	9	%	
Δ Hardness	−9	Shore A	
Δ Volume	17	%	
NH_3, 28%, 336 h at 100 °C			
Δ Tensile strength	−19	%	
Δ Elongation at break	−16	%	
Δ Hardness	−3	Shore A	
Δ Volume	3.7	%	
2-(2-aminoethoxy) ethanol (diglycolamine), 168 h at 150 °C			
Δ Tensile strength	−35	%	
Δ Elongation at break	11	%	
Δ Hardness	−10	Shore A	
Δ Volume	20	%	
2-(2-aminoethoxy) ethanol (diglycolamine), 168 h at 200 °C			
Δ Tensile strength	−62	%	
Δ Elongation at break	3	%	
Δ Hardness	−22	Shore A	
Δ Volume	39	%	

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Property	Typical Value	Unit	Test Method
N-Methyldiethanolamine (MDEA), 168 h at 150 °C			
Δ Tensile strength	−22	%	
Δ Elongation at break	−2	%	
Δ Hardness	−2	Shore A	
Δ Volume	2	%	
N-Methyldiethanolamine (MDEA), 168 h at 200 °C			
Δ Tensile strength	−38	%	
Δ Elongation at break	−6	%	
Δ Hardness	−5	Shore A	
Δ Volume	8	%	
Dipropylamine, 168 h at 150 °C			
Δ Tensile strength	−27	%	
Δ Elongation at break	−14	%	
Δ Hardness	−4	Shore A	
Δ Volume	6.5	%	
Dipropylamine, 168 h at 200 °C			
Δ Tensile strength	−29	%	
Δ Elongation at break	−10	%	
Δ Hardness	−5	Shore A	
Δ Volume	6.9	%	
Nitric acid, 65 %, 72 h at 80 °C			
Δ Tensile strength	−30	%	
Δ Elongation at break	6	%	
Δ Hardness	−5	Shore A	
Δ Volume	5	%	
Glacial acetic acid, 336 h at 100 °C			
Δ Tensile strength	−13	%	
Δ Elongation at break	−15	%	
Δ Hardness	−5	Shore A	
Δ Volume	5	%	
Formic acid, 85 %, 168 h at 100 °C			
Δ Tensile strength	−14	%	
Δ Elongation at break	−5	%	
Δ Hardness	−5	Shore A	
Δ Volume	7	%	

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Property	Typical Value	Unit	Test Method
Water, 168 h at 220 °C			
Δ Tensile strength	−17	%	
Δ Elongation at break	23	%	
Δ Hardness	1	Shore A	
Δ Volume	2	%	
Steam, 168 h at 220 °C			
Δ Tensile strength	−29	%	
Δ Elongation at break	24	%	
Δ Hardness	1	Shore A	
Δ Volume	0	%	

For optimal acid resistance, zinc oxide and Wollastonite fillers are not recommended

Wet semiconductor

Property	Typical Value	Unit	Test Method
KOH, 50 %, 168 h at 125 °C			
Δ Tensile strength	−6	%	
Δ Elongation at break	−18	%	
Δ Hardness	−2	Shore A	
Δ Volume	0.7	%	
HNO_3 65 %/HF 49 %/water 41/13/46, 720 h at 50 °C			
Δ Tensile strength	−12	%	
Δ Elongation at break	−29	%	
Δ Hardness	0	Shore A	
Δ Volume	1.6	%	
HF, 49 %, 720 h at 23 °C			
Δ Tensile strength	−5	%	
Δ Elongation at break	−21	%	
Δ Hardness	0	Shore A	
Δ Volume	1.2	%	
APM – SC1 (NH_4OH 29 %/H_2O_2 30 %/water 1:1:5), 720 h at 23 °C			
Δ Tensile strength	−8	%	
Δ Elongation at break	−14	%	
Δ Hardness	0	Shore A	
Δ Volume	0.1	%	
HPM – SC2 (HCl 37 %/H_2O_2 30 %/water 1:1:6), 720 h at 23 °C			
Δ Tensile strength	−9	%	
Δ Elongation at break	−19	%	
Δ Hardness	1	Shore A	
Δ Volume	0	%	
SPM – Piranha fluid (H_2SO_4 96%/H_2O_2 30 % 5:1), 720 h at 23 °C			
Δ Tensile strength	1	%	
Δ Elongation at break	−19	%	
Δ Hardness	0	Shore A	
Δ Volume	0	%	

Semiconductor developing, stripping, polymer removal

In semiconductor manufacturing processes, many different specialty chemicals are used for the removal of photoresist and of post-dry etch process residue, for post-CMP cleaning as well as for edge bead removers.

They are usually either aqueous or semiaqueous or fully organic mixtures formulated to effectively remove residues or positive and negative photoresist from substrate surfaces.

The most commonly used fluids are:

- ACT® specialty chemicals by Air Products and Chemicals, Inc.
- EKC™ fluids by EKC Technology, Inc.
- PRS™, ALEG™, REZI™ product lines by Mallinckrodt Baker, Inc.

They normally contain organic solvents (like NMP, DMSO, DMAc) and organic amines (like ethanolamine, diethanolamine, hydroxylamine, diglycolamine).

Tecnoflon® PFR 06HC was tested in some of the chemical species listed above:

Property	Typical Value	Unit	Test Method
N-methyl-2-pyrrolidone (NMP), 168 h at 80 °C			
Δ Tensile strength	–17	%	
Δ Elongation at break	–18	%	
Δ Hardness	–4	Shore A	
Δ Volume	1	%	
Dimethylacetamide (DMAc), 168 h at 80 °C			
Δ Tensile strength	–16	%	
Δ Elongation at break	–12	%	
Δ Hardness	–4	Shore A	
Δ Volume	0.4	%	
2-aminoethanol (MEA – ethanolamine), 168 h at 80 °C			
Δ Tensile strength	–15	%	
Δ Elongation at break	–14	%	
Δ Hardness	–3	Shore A	
Δ Volume	0.9	%	
Dimethyl sulfoxide (DMSO), 30 %, MEA, 70 %, 336 h at 80 °C			
Δ Tensile strength	–7	%	
Δ Elongation at break	2	%	
Δ Hardness	–2	Shore A	
Δ Volume	2.2	%	

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Property	Typical Value	Unit	Test Method
Hydroxylamine, 50 %, 168 h at 80 °C			
Δ Tensile strength	–8	%	
Δ Elongation at break	–14	%	
Δ Hardness	–2	Shore A	
Δ Volume	0.1	%	
2-(2-aminoethoxy) ethanol (diglycolamine), 168 h at 80 °C			
Δ Tensile strength	–11	%	
Δ Elongation at break	–17	%	
Δ Hardness	–2	Shore A	
Δ Volume	1.2	%	
Tetramethylammonium hydroxide (TMAH), 25 %, 168 h at 90 °C			
Δ Tensile strength	–2	%	
Δ Elongation at break	–12	%	
Δ Hardness	–2	Shore A	
Δ Volume	0.5	%	

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Miscellaneous PFR properties

In general, the following properties can be considered as typical or average values for perfluoroelastomers.

Thermal expansion

Following the definition of linear coefficient of thermal expansion: $L = L_0 \cdot (1 + \alpha \cdot \Delta T)$, the average value between 80 and 250 °C is as follows:

$\alpha = 3.5 \cdot 10^{-4}$ 1/K

Specific heat

Temperature	Unit	Black Compound	White Compound	Test Method
50 °C	J/g	0.98	0.83	
100 °C	J/g	1.05	0.86	
150 °C	J/g	1.12	0.91	

Gas permeation rate

Property	Permeability (T = 30 °C)	Unit	Test Method
Nitrogen	250	$(cm^3(STP)\cdot mm/m^2\cdot atm\cdot d)$	
Oxygen	450	$(cm^3(STP)\cdot mm/m^2\cdot atm\cdot d)$	
Helium	5,400	$(cm^3(STP)\cdot mm/m^2\cdot atm\cdot d)$	

Electrical properties

Dielectric constant and loss factor at 50 Hz frequency. Volume and surface resistivity were measured applying 100 V direct tension.

Property	Typical Value	Unit	Test Method
Dielectric constant ε'	3.50		
Loss factor tan(δ)	0.030		
Surface resistivity R_s	$5.0 \cdot 10^{16}$	Ω	
Volume resistivity R_v	$6.1 \cdot 10^{16}$	Ω · cm	

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