Tecnoflon FKM and FFKM portfolio: an overview on standard grades and specialties

R. Villa

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Introduction
1892: Development of fluroalkanes (Swarts reaction)
1955: Elastomeric copolymer VDF-CTFE (M.W. Kellogg Co.-US Army)
1956: Copolymer VDF-HFP (Dupont) → improved heat stability
1960: Terpolymer VDF-HFP-TFE (Dupont) → better chemical resistance
1960s: Perfluoroelastomers - copolymers TFE/PMVE (Dupont)
1960s: Copolymers TFE-P (Dupont, Asahi Glass)
1960: Copo and terpolymers using 1HPFP instead of HFP (Montecatini-Edison SpA)
1970: Bisphenol curing chemistry (Dupont and 3M)
1970s: Terpolymers VDF/TFE/PMVE improved low T performance
Late 1970s: Peroxide curing chemistry – Br as CSM (Dupont) – I as CSM (Daikin)
Solvay Solexis: FKM and FFKM portfolio
Presentation overview

1. Introduction – Fluoroelastomers key benefits
2. Fluoroelastomers classification/performances
3. Tecnoflon® grades portfolio: fluoroelastomers
4. Perfluoroelastomers classification/performances
5. Tecnoflon® PFR grades portfolio: perfluoroelastomers

Solvay Solexis tradename for Fluoroelastomers (FKM) and perfluoroelastomers (FFKM)
Typical properties of fluoroelastomers are:

- **Excellent** chemical resistance
- **Excellent** thermal resistance
- **Very low** permeability
- **Very good** weather, O₂ and O₃ resistance
Fluorine plus

ASTM D2000/SAE J200 Spec. System

FKM and FFKM are at the top of the range!
Fluoroelastomers applications

- Automotive industry
- Aerospace industry
- Chemical & Processing industry
- Oil field / Mining
- Semicon industry
FKMs are classified according to monomer composition and ratio. FKM are manufactured by polymerization of a limited number of monomers:

- Vinylidene Fluoride (VF₂): CH₂=CF₂
- Hexafluoropropylene (HFP): CF₂=CF-CF₃
- Tetrafluoroethylene (TFE): CF₂=CF₂
- Perfluoroalkylvinylether (PAVE): CF₂=CF-OCF₃ (main monomer MVE when Rf = CF3)
- Ethylene (E): CH₂=CH₂
- Propylene (P): CH₂=CH-CH₃

FKMs can be further differentiated by curing chemistry. Two main cure systems:

- Bisphenol
- Peroxide
Fluoroelastomers (FKM) are classified according to monomer composition (ASTM D1418):

Type 1
- VF₂, HFP (Bisphenol)
  - Example: Tecnoflon® FOR 80HS

Type 2
- VF₂, HFP, TFE (Bisphenol or Peroxide)
  - Example: Tecnoflon® FOR 4391 (Bisphenol)
  - Example: Tecnoflon® P 959 (Peroxide)

Type 3
- VF₂, TFE, PMVE (Bisphenol or Peroxide)
  - Example: Tecnoflon® PL 855 (Peroxide)

Type 4
- TFE, P, VF₂ (Bisphenol)

Type 5
- TFE, HFP, VF₂, E, PMVE (Peroxide)
  - Example: Tecnoflon® BR 9151 (Peroxide)

Perfluoroelastomers (FFKM) are usually TFE / PAVE (MVE) copolymers
Fluoroelastomers (FKM) are classified according to cross-linking mechanism:

1. **Ionic** curable FKM (bisphenol – phosphonium salt)

2. **Radical** curable FKM (peroxide - TAIC)
Cross-linking mechanism

Chemical resistance is **higher** for **peroxide** curing!

**Chemical resistance** (168 h @ 150°C)

<table>
<thead>
<tr>
<th></th>
<th>Dexron III</th>
<th>ASTM 105G</th>
<th>GL-5</th>
</tr>
</thead>
<tbody>
<tr>
<td>ΔTensile</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Strength (%)</td>
<td>-15</td>
<td>-20</td>
<td>-5</td>
</tr>
</tbody>
</table>

**Thermal rating**

Thermal rating is **higher** for **bisphenol** curing!
Tecnoflon® Bisphenol Curable

- A full range of products for all kinds of items and processing technologies (compression, injection, transfer, extrusion)
- Tailor made materials for special requirements
- New copolymers with improved performances (HS grades manufactured in US plant)

For bisphenol curable FKM, Solvay Solexis supplies:

- Raw gum
- Cure incorporated materials (rubber + bisphenol + accelerator + possibly processing aids)
- Cure incorporated materials for rubber-metal bonding
## Tecnoflon® Bisphenol Curable

### Portfolio

<table>
<thead>
<tr>
<th>Material</th>
<th>%F</th>
<th>Raw Gum</th>
<th>Cure Inc.</th>
<th>Cure Inc+ Bonding promoter</th>
<th>TR$_{10}$ (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Copolymers</td>
<td>66</td>
<td>$N_{...}NH, N60HS, N90HS$</td>
<td>FOR,...FOR 80HS, FOR 501HS,</td>
<td>FOR 60K, FOR 5312K,</td>
<td>-17</td>
</tr>
<tr>
<td>Terpolymers</td>
<td>68-70</td>
<td>$T_{...}TN 50A, T 538, T 938$</td>
<td>FOR,...FOR TF, FOR 5381</td>
<td>FOR 7380K, FOR 9385F</td>
<td>-13 / -7</td>
</tr>
<tr>
<td>Low T</td>
<td>65.5-66</td>
<td>$T 636, T 636/L$</td>
<td>FOR TF 636, FOR 5361</td>
<td></td>
<td>-19</td>
</tr>
<tr>
<td></td>
<td></td>
<td>$L 636, L 636LM$</td>
<td></td>
<td></td>
<td>-21</td>
</tr>
</tbody>
</table>
Tecnoflon® Peroxide Curable

- A full range of products both for compression and injection moulding (high – low Mooney viscosity)
- Very fast curing rate
- Excellent mechanical properties
- Very low compression set
- Very low post-curing times (1 – 2 h)
- Excellent processability

For Peroxide curable FKM, Solvay Solexis supplies:

- Raw gum
## Tecnoflon® Peroxide Curable

### Portfolio

<table>
<thead>
<tr>
<th>Material</th>
<th>%F</th>
<th>%H</th>
<th>Raw Gum</th>
<th>TR10(°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>High Performance Terpolymers</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>67</td>
<td>1,7</td>
<td>P 457, P 757</td>
<td>-15</td>
</tr>
<tr>
<td></td>
<td>70</td>
<td>1,2</td>
<td>P 459, P 959</td>
<td>-7</td>
</tr>
<tr>
<td><strong>Low T</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>64</td>
<td>1,8</td>
<td>PL 455, PL 855</td>
<td>-30</td>
</tr>
<tr>
<td></td>
<td>66</td>
<td>1,6</td>
<td>PL 557</td>
<td>-29</td>
</tr>
<tr>
<td></td>
<td>66</td>
<td>1,2</td>
<td>PL 458, PI 958</td>
<td>-24</td>
</tr>
<tr>
<td><strong>Very Low T</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>66,8</td>
<td>1,05</td>
<td>VPL 85730, VPL 45730</td>
<td>-30</td>
</tr>
<tr>
<td></td>
<td>65,1</td>
<td>1,35</td>
<td>VPL 45535</td>
<td>-35</td>
</tr>
<tr>
<td></td>
<td>65,1</td>
<td>1,16</td>
<td>VPL 85540, VPL 55540</td>
<td>-40</td>
</tr>
<tr>
<td><strong>Polar Fluid Resistant</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>71</td>
<td>0,25</td>
<td>PFR 91</td>
<td>-9</td>
</tr>
</tbody>
</table>
Main features / Applications:

- **Good processability**
- **Excellent mechanical properties**
- **Permeation reduction**: automotive industry (low emissions)
- **Friction reduction**: automotive industry (shaft seals, valve stem seals)
- **Good chemical resistance**: oil industry
- **High purity**: semicon / food industry

NFT 7030  
P757/30M  
P959/30M
Solexis FFKMs: 
Tecnoflon® PFR
Perfluoroelastomers (FFKM) are basically TFE / MVE (PAVE) copolymers + CSM

FFKM: Chemical structure
FFKM: Thermal resistance

FFKM 320 °C

Their thermal resistance is the highest one among rubbers!
## FFKM: Chemical resistance

<table>
<thead>
<tr>
<th>Fluid type</th>
<th>Typical example</th>
<th>FFKM&lt;sup&gt;a&lt;/sup&gt;</th>
<th>FKM&lt;sup&gt;b&lt;/sup&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluorine Content</td>
<td>72.5%</td>
<td>66%</td>
<td></td>
</tr>
<tr>
<td>Aliphatic hydrocarbon</td>
<td>Propane</td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
<tr>
<td>Aromatic hydrocarbons</td>
<td>Benzene</td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
<tr>
<td>Organic acids</td>
<td>Acetic acid</td>
<td>Excellent</td>
<td>Fair-good</td>
</tr>
<tr>
<td>Inorganic acids</td>
<td>Sulfuric acid</td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
<tr>
<td>Alcohols</td>
<td>Methanol</td>
<td>Excellent</td>
<td>Fair-excellent</td>
</tr>
<tr>
<td>Inorganic base</td>
<td>Sodium hydroxide</td>
<td>Excellent</td>
<td>Poor-fair</td>
</tr>
<tr>
<td>Organic base</td>
<td>Aniline</td>
<td>Excellent</td>
<td>Fair</td>
</tr>
<tr>
<td>Ethers</td>
<td>MTBE</td>
<td>Excellent</td>
<td>Fair-poor</td>
</tr>
<tr>
<td>Ketones</td>
<td>Acetone</td>
<td>Excellent</td>
<td>Poor</td>
</tr>
<tr>
<td>Nitrous oxidizers</td>
<td>Ammonium nitrate</td>
<td>Excellent</td>
<td>Good</td>
</tr>
<tr>
<td>Halogen oxidizers</td>
<td>Chlorine</td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
<tr>
<td>Heat transfer fluids</td>
<td>Ethylene glycol</td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
<tr>
<td>Oils &amp; greases</td>
<td>Mineral oil</td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
<tr>
<td>Halogenated refrigerants</td>
<td>HFC-134a</td>
<td>Fair-good</td>
<td>Poor-fair</td>
</tr>
<tr>
<td>Polar solvents</td>
<td>Water</td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
</tbody>
</table>

Chemical resistance is by far improved with respect to FKM!
Differences in perfluoroelastomer performance are due to the different “weak points” nature (i.e. curing chemistry)

- Curing point: Phenoxy groups
- X-linking agent: Bisphenol AF
FFKM: Classification

Differences in perfluoroelastomer performance are due to the different “weak points” nature (i.e. curing chemistry)

Curing point: Halogen atoms (Br/I)

X-linking agent: TAIC
FFKM: Classification

Differences in perfluoroelastomer performance are due to the different “weak points” nature (i.e. curing chemistry)

Curing point: Nitrile –CN groups

X-linking reaction: Triazine formation

Curing catalyst: $R_4Sn$, etc.
Performances comparison

- **Heat Resistance**
  - Triazine: 316 °C
  - Bisphenol: 280 °C
  - Peroxide: 230 °C

- **Typical Compression Set Resistance (70 h @ 200 °C)**
  - Peroxide: 15 % (iodine)
  - Triazine: 35 %
  - Bisphenol: 50 %

- **Fluid Resistance**
  - Peroxide: the best for water & steam - strong bases
  - Triazine: poor in water & steam - strong bases

**Tecnoflon® PFR grades are peroxide curable**
## Chemical resistance

<table>
<thead>
<tr>
<th>Chemical</th>
<th>Peroxide</th>
<th>Bisphenol</th>
<th>Triazinic</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alkali</td>
<td>Excellent</td>
<td>Good</td>
<td>Poor</td>
</tr>
<tr>
<td>Amines</td>
<td>Excellent</td>
<td>Good</td>
<td>Poor</td>
</tr>
<tr>
<td>Hot water / Steam</td>
<td>Excellent</td>
<td>Good</td>
<td>Poor</td>
</tr>
<tr>
<td>Ketones</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
<tr>
<td>Solvents</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
<tr>
<td>Esters / Ethers</td>
<td>Excellent</td>
<td>Excellent</td>
<td>Excellent</td>
</tr>
<tr>
<td>Acids</td>
<td>Good</td>
<td>Poor</td>
<td>Excellent</td>
</tr>
</tbody>
</table>
# Tecnoflon® PFR grades portfolio

<table>
<thead>
<tr>
<th>Grade</th>
<th>Cross-linker</th>
<th>Feature</th>
<th>Max T (°C)</th>
</tr>
</thead>
<tbody>
<tr>
<td>PFR 91</td>
<td>TAIC</td>
<td>Not a true FFKM - Chemical Resistance</td>
<td>230</td>
</tr>
<tr>
<td>PFR 94</td>
<td>TAIC</td>
<td>Chemical Resistance</td>
<td>230</td>
</tr>
<tr>
<td>PFR 06HC</td>
<td>TAIC</td>
<td>Very high chemical resistance (strong amines)</td>
<td>230</td>
</tr>
<tr>
<td>PFR 95HT</td>
<td>Incorporated</td>
<td>Very high thermal resistance</td>
<td>320</td>
</tr>
<tr>
<td>PFR 5910M</td>
<td>Incorporated</td>
<td>High purity - low hardness</td>
<td>320</td>
</tr>
<tr>
<td>PFR 5920M</td>
<td>Incorporated</td>
<td>High purity - medium hardness</td>
<td>320</td>
</tr>
</tbody>
</table>

All are peroxide curable!
Next Generation of Low Temperature Fluoroelastomers
Overview

- History of Low Temperature Fluoroelastomers
- MOVE - new Low Temperature Monomer Technology
- Tecnoflon® VPL - a New Series of Low Temperature Grades
- Testing Data on VPL versus standard LT FKM
- Applications Examples
Could we have good low temperature properties and high chemical resistance as well?
The Fluoroelastomer Challenge

- Low temperature performance and chemical resistance are dependent upon polymer composition

<table>
<thead>
<tr>
<th>Monomer</th>
<th>TR10 Effect</th>
<th>Fluid Resistance Effect</th>
</tr>
</thead>
<tbody>
<tr>
<td>VDF CH₂=CF₂</td>
<td>Decrease</td>
<td>Decrease</td>
</tr>
<tr>
<td>HFP CF₂=CF-CF₃</td>
<td>Increase</td>
<td>Increase</td>
</tr>
<tr>
<td>TFE CF₂=CF₂</td>
<td>Increase</td>
<td>Increase</td>
</tr>
<tr>
<td>PMVE CF₂=CF-O-CF₃</td>
<td>Decrease</td>
<td>Slightly Decrease</td>
</tr>
</tbody>
</table>

The only way to improve low temperature performance is to design a new monomer.
### MOVE Monomer Solution

<table>
<thead>
<tr>
<th>Monomer</th>
<th>T&lt;sub&gt;g&lt;/sub&gt;</th>
<th>Fully Fluorinated Monomer</th>
<th>No weak point!</th>
</tr>
</thead>
<tbody>
<tr>
<td>HFP</td>
<td>T&lt;sub&gt;g&lt;/sub&gt; = 160 °C</td>
<td>CF&lt;sub&gt;2&lt;/sub&gt;=CF&lt;sub&gt;CF&lt;sub&gt;3&lt;/sub&gt;&lt;/sub&gt;</td>
<td></td>
</tr>
<tr>
<td>PMVE</td>
<td>T&lt;sub&gt;g&lt;/sub&gt; = -8 °C</td>
<td>CF&lt;sub&gt;2&lt;/sub&gt;=CF&lt;sub&gt;O&lt;/sub&gt;&lt;br&gt;CF&lt;sub&gt;3&lt;/sub&gt;</td>
<td></td>
</tr>
<tr>
<td>MOVE</td>
<td>T&lt;sub&gt;g&lt;/sub&gt; = -39 °C</td>
<td>CF&lt;sub&gt;2&lt;/sub&gt;=CF&lt;sub&gt;O&lt;/sub&gt;&lt;br&gt;CF&lt;sub&gt;2&lt;/sub&gt;&lt;br&gt;CF&lt;sub&gt;O&lt;/sub&gt;&lt;br&gt;CF&lt;sub&gt;3&lt;/sub&gt;</td>
<td></td>
</tr>
</tbody>
</table>
2. $T_g$ of copolymer lower than two homopolymers

\[ \frac{1}{T_g} = w_A P_A/T_{gA} + w_B P_B/T_{gB} + (w_A P_{AB} + w_B P_{BA})/T_{gAB} \]

Johnston eq.

$T_{gAB} = -55 \, ^\circ C$
Market Needs

**Automotive**
- Lower Sealing Temperature (cold environments)
- High pressure generates Tg shift → GDI engines require FKM with lower Tg compared to standard solutions
- Increased chemical resistance (biofuels) maintaining Low T performance

**Aerospace**
- Low T Service combined with high thermal resistance
- Low T combined with Fuels and HTS oils compatibility

**Oil & Gas**
- Drilling in cold environments
- ED Resistance
- Chemical Resistance

FKM for low Temperature Sealing

...with good process-ability as well!
**MOVE Monomer Technology**

**Tecnoflon® VPL:**
A New Series of Low Temperature Grades

<table>
<thead>
<tr>
<th>Tecnoflon®</th>
<th>VPL 85540 (45 MU)</th>
<th>VPL 85730 (45 MU)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VPL 55540 (25 MU)</td>
<td>VPL 45730 (25 MU)</td>
<td></td>
</tr>
<tr>
<td>TR10 (°C)</td>
<td>-40</td>
<td>-30</td>
</tr>
</tbody>
</table>

Beside the 2 main family of -40°C and -30°C, the new MOVE monomer technology allows us to improve other FKM in term of low T behaviour and chemical resistance.
### Rheological Properties

#### Compound recipe

<table>
<thead>
<tr>
<th>Component</th>
<th>Phr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polymer VPL</td>
<td>100</td>
</tr>
<tr>
<td>Luperox 101XL</td>
<td>45</td>
</tr>
<tr>
<td>Drimix TAIC 75</td>
<td>5</td>
</tr>
<tr>
<td>ZnO</td>
<td>5</td>
</tr>
<tr>
<td>MT N990</td>
<td>30</td>
</tr>
</tbody>
</table>

#### Polymer Viscosity

- **ML (1+10) @ 121°C**
  - Tecnoflon PL -30: 3.7 MB *in
  - VPL 85730: 4.3 MB *in
  - VPL 85540: 4.0 MB *in

#### Compound Viscosity

- **ML (1+10) @ 121°C**
  - Tecnoflon PL -30: 3.6 MB *in
  - VPL 85730: 4.3 MB *in
  - VPL 85540: 4.0 MB *in

#### MDR

- 6 minutes @ 160°C
  - Tecnoflon PL -30: 26 MB *in
  - VPL 85730: 22 MB *in
  - VPL 85540: 18 MB *in

### Observations

- **Small difference between Polymer and Compound viscosity:** excellent process-ability
- **Excellent cure profile due to Solvay’s Branching & Pseudo Living Polymerization Technology**
## Physical Properties

<table>
<thead>
<tr>
<th>Product Name</th>
<th>L.T. -30°C</th>
<th>VPL 85730</th>
<th>VPL 85540</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hardness Shore A</td>
<td>pts</td>
<td>69</td>
<td>71</td>
</tr>
<tr>
<td>Tensile Strength</td>
<td>MPa</td>
<td>20.8</td>
<td>15.8</td>
</tr>
<tr>
<td>Modulus @ 100%</td>
<td>MPa</td>
<td>4.8</td>
<td>7.5</td>
</tr>
<tr>
<td>Elongation @ Break</td>
<td>%</td>
<td>248</td>
<td>177</td>
</tr>
<tr>
<td>C-Set 70h @ 200 °C O-Rings #214, 25% def.</td>
<td>%</td>
<td>23</td>
<td>22</td>
</tr>
</tbody>
</table>

Sealing behavior has not been affected by the new monomer!!
Temperature of Retraction

Due to correct monomer sequences in the polymer chain, TR10 and TR70 values are very close.

Example of bad low T relaxation behavior.

Retention (%) vs. Temperature (°C)

- VPL 85540
- VPL 85730
- PL -30°C
- PL -24°C
Fluid Testing in Ethanol Blends

- Fuel C: 70h @ 60°C
- CE10: 70h @ 60°C
- CE22: 70h @ 60°C
- CE85: 70h @ 60°C
- Ethanol: 70h @ 60°C

- Comparable fluid resistance as 70% fluorine terpolymer

- Superior fluid resistance
Fluid Testing in Methanol Blends

- **M15**: 168h @ 23°C
- **M85**: 168h @ 40°C
- **Methanol**: 168h @ 23°C

**Volume Swell (%)**

- **Comparable fluid resistance as 70% fluorine terpolymer**

- VPL 85540
- VPL 85730
- PL -30°C
- PL -24°C
- FKM 70% F (TR10 = -7°C)
Fluid Testing in Additional Fuels

- Superior fluid resistance

<table>
<thead>
<tr>
<th>Fluid Type</th>
<th>Test Conditions</th>
<th>Volume Swell (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>VPL 85540</td>
<td>PN-180: 336h @ 60°C</td>
<td>22</td>
</tr>
<tr>
<td>VPL 85730</td>
<td>FAM B: 168h @ 60°C</td>
<td>18</td>
</tr>
<tr>
<td>PL -30°C</td>
<td></td>
<td>36</td>
</tr>
<tr>
<td>PL -24°C</td>
<td></td>
<td>20</td>
</tr>
<tr>
<td>FKM 70% F (TR10 = -7°C)</td>
<td></td>
<td>15</td>
</tr>
</tbody>
</table>

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Fluid testing in Biodiesel

- Terpolymer 68.5% Bisphenol Curable (TR10 = -13 °C)
- FKM 70%F (TR10 = -7 °C)
- PL -24
- PL -30
- VPL 85540

No problem also in Biodiesel!
Compression Set Testing for 70 hours

- Improved compression set resistance

Bar chart showing:
- VPL 85540
- VPL 85730
- L.T. -30°C
- L.T. -24°C

- 200°C
- 150°C
- 23°C
Heat Aging

Effect of heat aging @ 200°C

Retained mechanical properties vs. time (h)

- TS
- M100
- EB
- HDS
Compression Stress Relaxation

CSR via Elastocon at 150 °C

% Retained Sealing Force

Very Similar CSR to standard grades

VPL 85540  VPL 85730  PL -30°C  PL -24°C
VPL Performance in Fuel System Sealing

VPL -30 & VPL -40 versus standard PL -30°C

<table>
<thead>
<tr>
<th>Property</th>
<th>VPL 85730</th>
<th>VPL 85540</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low Temperature Performance</td>
<td>≦</td>
<td>+</td>
</tr>
<tr>
<td>Fuel resistance</td>
<td>+</td>
<td>+</td>
</tr>
<tr>
<td>Compression set</td>
<td>≦</td>
<td>≦</td>
</tr>
<tr>
<td>CSR</td>
<td>≦</td>
<td>≦</td>
</tr>
</tbody>
</table>
Conclusions

- Breakthrough Monomer Technology (MOVE)
  - Expanded low temperature performance of Fluoroelastomers
  - Superior Chemical resistance compared to standard PL -30 °C
  - Chemical Resistance comparable to 70%F PC
  - Excellent sealing behavior
  - Very good process-ability
Base resistant technology
In order to reduce “Schmiegel” Sequences we can introduce Ethylene into VDF based polymers.

- \((\text{CF}_2\text{CF})-(\text{CH}_2\text{CF}_2)-(\text{CF}_2\text{CF})-(\text{CH}_2\text{CH}_2)\) -

Protecting monomer
Base resistant materials

having all fluoro, perfluoroalkyl, or perfluoroalkoxy substituent groups on the polymer chain; a small fraction of these groups may contain functionality to facilitate vulcanization.

FKM—Fluoro rubber of the polymethylene type that utilizes vinylidene fluoride as a comonomer and has substituent fluoro, alkyl, perfluoroalkyl or perfluoroalkoxy groups on the polymer chain, with or without a cure site monomer (having a reactive pendant group).

Type 1—Dipolymer of hexafluoropropylene and vinylidene fluoride.

Type 2—Terpolymer of tetrafluoroethylene, vinylidene fluoride, and hexafluoropropylene.

Type 3—Terpolymer of tetrafluoroethylene, a fluorinated vinyl ether, and vinylidene fluoride.

Type 4—Terpolymer of tetrafluoroethylene, propylene and vinylidene fluoride.

Type 5—Pentapolymer of tetrafluoroethylene, hexafluoropropylene, vinylidene fluoride, ethylene, and a fluorinated vinyl ether.

XSBR—Carboxylic-styrene-butadiene.
XNBR—Carboxylic-acrylonitrile-butadiene.

Note 2—When designating latex or latices the terminology shall be, for example, “SBR latex” or “SBR latices.”

3.4 The “Q” class shall be defined by inserting the name of the substituent group on the polymer chain prior to the silicone designation. The following classification shall be used for members of the “Q” class.

(The M preceding the Q indicates that methyl is one of the substituent groups on the polymer chain.)
FMQ—Silicone rubber having both methyl and fluorine substituent groups on the polymer chain.
FVMQ—Silicone rubber having fluorine, vinyl, and methyl substitute groups on the polymer chain.
PMQ—Silicone rubbers having both methyl and phenyl substituent groups on the polymer chain.
PVMQ—Silicone rubbers having methyl, phenyl, and vinyl substituent groups on the polymer chain.

FKM Type 5 definition accounts for our BR technology
### BR 9151: Performance comparison

<table>
<thead>
<tr>
<th></th>
<th>FKM copo</th>
<th>FKM Terpo</th>
<th>BR 9151</th>
<th>TFE/P</th>
<th>FFKM</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aromatic Hydrocarbons</strong></td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td><strong>Fuels</strong></td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Poor</td>
<td>Good</td>
</tr>
<tr>
<td><strong>Oil</strong></td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td><strong>Methanol</strong></td>
<td>Poor</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td><strong>Hydrogen Sulfide</strong></td>
<td>Poor</td>
<td>Poor</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td><strong>Steam</strong></td>
<td>Poor</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
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<tr>
<td><strong>Amines</strong></td>
<td>Poor</td>
<td>Poor</td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
</tr>
<tr>
<td><strong>Low Temperature</strong></td>
<td>Good</td>
<td>Good</td>
<td>Good</td>
<td>Poor</td>
<td>Poor</td>
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</table>
New BR 9171

Chemical resistance

BR 9151

BR 9152
BR 4152

BR 9171

New!
A new grade with by far improved chemical resistance compared to BR 9151 was developed

Application targets:

- Axle seals: Gear oil + 6% Sturaco additive (vs TFE/P)

<table>
<thead>
<tr>
<th>C. Set O-ring #214</th>
<th>BR 9171</th>
<th>BR 9151</th>
<th>BR 9152</th>
<th>TFE/P</th>
<th>Competitor 1</th>
<th>PFR 94</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>70 h @ 200 °C %</td>
<td>37</td>
<td>42</td>
<td>43</td>
<td>54</td>
<td>48</td>
<td>21</td>
<td>~ -10</td>
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<tr>
<td>TR10 (ASTM D1329) °C</td>
<td>-9</td>
<td>-7</td>
<td>-14</td>
<td>3</td>
<td>-7</td>
<td>-2</td>
<td>~ -10</td>
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</tbody>
</table>

GL-5 + sturaco 6% - 168 h @ 150°C

<table>
<thead>
<tr>
<th></th>
<th>BR 9171</th>
<th>BR 9151</th>
<th>BR 9152</th>
<th>TFE/P</th>
<th>Competitor 1</th>
<th>PFR 94</th>
<th>Target</th>
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</thead>
<tbody>
<tr>
<td>Δ Tensile Strength %</td>
<td>-2%</td>
<td>-46%</td>
<td>-30%</td>
<td>-21%</td>
<td>-18%</td>
<td>-10%</td>
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<tr>
<td>Δ Elongation at break %</td>
<td>14%</td>
<td>-26%</td>
<td>-17%</td>
<td>7%</td>
<td>-2%</td>
<td>-2%</td>
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<tr>
<td>Δ Hardness Shore A</td>
<td>-3</td>
<td>-2</td>
<td>-1</td>
<td>-6</td>
<td>-3</td>
<td>-2</td>
<td></td>
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<tr>
<td>Δ volume %</td>
<td>1.5%</td>
<td>1%</td>
<td>1%</td>
<td>3%</td>
<td>1%</td>
<td>0%</td>
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</table>

GL-5 + sturaco 6% - 1000 h @ 150°C

<table>
<thead>
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<th></th>
<th>BR 9171</th>
<th>BR 9151</th>
<th>BR 9152</th>
<th>TFE/P</th>
<th>Competitor 1</th>
<th>PFR 94</th>
<th>Target</th>
</tr>
</thead>
<tbody>
<tr>
<td>Δ Tensile Strength %</td>
<td>-9%</td>
<td>-51%</td>
<td>-52%</td>
<td></td>
<td></td>
<td></td>
<td>&gt; -50%</td>
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<tr>
<td>Δ Elongation at break %</td>
<td>7%</td>
<td>-35%</td>
<td>-35%</td>
<td></td>
<td></td>
<td></td>
<td>&gt; -50%</td>
</tr>
<tr>
<td>Δ Hardness Shore A</td>
<td>-2</td>
<td>2</td>
<td>-1</td>
<td></td>
<td></td>
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<td></td>
</tr>
<tr>
<td>Δ volume %</td>
<td>1.6%</td>
<td>1.7%</td>
<td>1.8%</td>
<td></td>
<td></td>
<td></td>
<td></td>
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Thank you!