3M™ Dyneon™ Fluoroelastomers in Automotive Applications

Dyneon your preferred partner in Fluoropolymers
The fluoropolymer product portfolio

- PTFE
- TFM™ mod. PTFE
- Fluoro-thermoplastics (PFA, FEP, THV, PVDF, ETFE)
- Fluoroelastomers
Why using fluoropolymers in automotive applications?

- **Industry Growth**
  - Global estimate 250 Million vehicles
  - Automotive industry continues to grow – Population increase & regional expansions
  - Automobile remains our preferred mode of transportation.

- **Climate Considerations**
  - Global/Regional legislations on CO₂ emission reduction
  - Need to improve fuel economy
  - Alternative engine concepts & fuel types – Hybrid, Electric, Fuel Cell

- **Combustion Engine will remain the most popular at least for next decade.**

- Emissions targets met with combinations of alternate fuels, light weight solutions & new innovations.
Why using fluoropolymers in automotive applications?

- Good mechanical properties
- Excellent temperature resistance
- Outstanding chemical resistance
- Excellent weatherability and ozone resistance
- Very low permeation
- Good flame resistance
- Low impact resilience
Fluoropolymers by market segment - automotive

- Fuel Systems
- Air Management
- Powertrain
- Others
FKM by application segment - automotive

- O-Rings
- Hoses
- Valve Stem Seals
- Shaft Seals
- Molded Goods/Gaskets
- Fuel Injector O-Rings
- Metal Coated Gaskets
Automotive – Application Structure

Fuel Systems
- Fuel Cap
- Tank
- Fuel Transport
- Fuel Injection

Powertrain
- Engine
- Transmission

Air Management
- Air Intake Sys.
- Exhaust System
- Turbocharger

Chassis
- Suspension
- Brakes
- Wheel Steering

Electronics
- Wire & Cable

Misc.
Automotive – Application Structure

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Misc.
Fuel System – Segment Definition

- Fuel Tank
- Fuel Transport
- Fuel Injection
Fuel System – Application Overview

- **Fuel Transport**
  - 10. Fuel and Vapor Lines
  - 11. Quick connector O-rings

- **Fuel Injection (Engine)**
  - 12. Fuel Rail Seal
  - 13. Fuel Rail Crossover Line
  - 14. Fuel Injector Seals

- **Fuel Cap**
  - 1. Fuel Cap Main Seal
  - 2. Fuel Cap Pressure Relief Valve Seal

- **Fuel Tank**
  - 3. Fuel Filler Hose
  - 4. Fuel Tank Fill Limit Vent Valve Seal
  - 5. In-tank Fuel Supply Hose
  - 6. Fuel Pump Seal

- **Fuel Rail**
  - 7. Fuel Filter Seal
  - 8. Sender Seal
  - 9. Fuel Tank Rollover Valve Seal

- **Quick connect**
  - 10. Quick connect O-rings

- **Fuel Injection**
  - 11. Fuel Rail Seal
  - 12. Fuel Rail Crossover Line
  - 13. Fuel Injector Seals
Fuel System – Fuel Cap Main Seal

**Application Requirements:**
- Resistance against fuels / fuel volatiles
- Low temp performance down to -40 °C
- High temp performance not critical
- Permeation Resistance

**Trends impacting the application:**
- New fuels / biofuels
- Shift from NBR to FKM in case of direct fuel contact
- Some OEMs introduce capless systems = seal is attached to the tank lid
- Trend to higher fluorine FKM

**Relevant Specifications:**
- BMW: GS93010-1 to 3 (General Spec)
- Opel: GMW15176, GMW15983, VW: VW 2.8.1

**Material:**
- Dyneon FKM Terpolymers

**Part Function:**
- Sealing of tank cap against filler neck
Automotive – Application Structure

- Fuel Systems
  - Fuel Cap
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  - Engine
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- Air Management
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  - Exhaust System
  - Turbocharger
- Chassis
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  - Brakes
  - Wheel Steering
- Electronics
  - Wire & Cable
- Misc.
Powertrain – Segment Definition

- Combustion Engine
- Transmission
Powertrain – Application Overview

**COMBUSTION ENGINE**
- 22 Cam Shaft Seals
- 23 Crankshaft Seal
- 24 Positive Crankcase Ventilation (PCV) Hose
- 25 Oil Pump Seal

**TRANSMISSION**
- 15 Differential Shaft Seal
- 16 Wheel Shaft Seal
- 17 Transmission Seal Rings
- 18 Transmission Shaft Seal
- 19 Cylinder Head Gasket
- 20 Valve Stem Seal
- 21 Valve Cover Gasket
Application Requirements:
- Good thermal resistance up to 150 °C
- Chemically resistant against engine oils and blow by gas
- Excellent metal bonding
- Low friction / low wear
- Acceptable dry running properties

Trends impacting the application:
- Weight reduction
- Friction reduction needed for achieving CO₂ targets
- Alternative technologies in use: FKM / PTFE Compounds
- FKM > design is changing to f-less types (no spring)

Relevant Specifications:
- VW TL 52304, VW 01150-3, VW 2.8.1
- DBL 6251
- BMW: GS93010-1 to 3 (General Spec)

Material:
- Dyneon FKM Di-/Terpolymers
- Dyneon PTFE Compounds

Part Function:
- Keep oil in the engine block
New Sealing Technology

3M™ Dyneon™ Compounding Expertise

New 3M innovative filler systems

A new class of high performance 3M™ Dyneon™ Compounds

Your Benefit!
The world of fillers becomes „spheric“

Standard Glass Fillers

New Microspheric Fillers
Benefits Serving Rotary Seal Applications

<table>
<thead>
<tr>
<th>Benefit</th>
<th>Advantage</th>
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<tbody>
<tr>
<td>Optimised seal thickness</td>
<td>Higher production yield</td>
</tr>
<tr>
<td>Remarkably low leakage</td>
<td>Environmentally friendly</td>
</tr>
<tr>
<td>Optimised friction &amp; wear behaviour</td>
<td>Longer service life &amp; less fuel consumption</td>
</tr>
<tr>
<td>Improved physical properties</td>
<td>Better performance</td>
</tr>
<tr>
<td>Smoother surface finish</td>
<td>Easy to process</td>
</tr>
</tbody>
</table>

* compared to: 3M™ Dyeneon™ PTFE Compound TF 4105 freeflow 25% glass fibres
## Application properties

Rotary shaft seals with reduced thickness (> 10%)

<table>
<thead>
<tr>
<th>Friction torque</th>
<th>Wear resistance</th>
<th>Leakage</th>
</tr>
</thead>
<tbody>
<tr>
<td>25% Improvement*</td>
<td>18% Improvement*</td>
<td>70% Improvement*</td>
</tr>
</tbody>
</table>

* compared to: 3M™ Dyneon™ PTFE Compound TF 4105 freeflow 25% glass fibres
Automotive – Application Structure

- Fuel Systems
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- Powertrain
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- Air Management
  - Air Intake Sys.
  - Exhaust System
  - Turbocharger
- Chassis
  - Suspension
  - Brakes
  - Wheel Steering
- Electronics
  - Wire & Cable
- Misc.
Air Management – Segment Definition

- Exhaust System
- Air Intake Section (incl. Turbo Charger)
Air Management – Application Overview

- Turbo Charger Hose
- Turbo Charger Hose Seal
- Turbo Charger Seal
- Air Intake Manifold Gasket
- Throttle Seal
- Muffler Seal(s)
- Oxygen Sensor Seal
- SCR Injector Seal
- EGR "Stem" Seal
- EGR Flap Coating
Air Management – Turbo Charger Hose

Application Requirements:
- Good extrudability (co-extrusion)
- Excellent bonding to silicones
- Excellent resistance to fuels and oils
- Resistance to high temperatures (> 200 °C)
- Resistant to acetic acid and H₂SO₄
- Good tear propagation resistance

Trends impacting the application:
- Use of turbocharger is increasing due to downsizing of engines
- OEMs try to reduce length and thickness of TCH for cost reasons
- Integration of charge air cooler in air intake manifold

Relevant Specifications:
- VW: TL 52600A, VW 2.8.1
- Mercedes: DBL 6251

Material:
- Dyneon FKM Terpolymers (BF6 or PO cure)

Part Function:
- Connecting the turbocharger to the charge oil cooler with a flexible connection
3M™ Dyneon™ Fluoropolymers Innovations

Primer free bonding of FKM to PA46
Primer Free Overmolding

- Classic two step concept – two machine overmolding principle
- New 2K overmolding concept Stanyl® & 3M™ Dyneon™ Fluoroelastomers bonded parts can be produced in a single process (from raw materials to a finished part with one tool)

Proven by DIK (German Institute for Rubber Technology)
Your Benefits

- Weight reduction
- Time saving
- Cost reduction
- Design freedom & New functions
- Increased sustainability
- Quality improvement
Fuel Resistance of 3M™ Dyneon™ Fluoroelastomers
Fossil fuels, made from crude oil, are finite and contribute to CO₂ emissions.

Alternative fuels, like Bio-ethanol and Bio-diesel, help to reduce CO₂ emissions as well as the dependency on fossil fuels and meet legal requirements of the automotive industry.

Traditional elastomeric sealing materials (e.g. nitrile butadiene rubber) show limitations related to alternative fuels in sealing and barrier performance.

Where other elastomer products fail, 3M™ Dyneon™ Fluororubber elastomers are able to provide safer sealing solutions.
Fuel test conditions

Volume Swell (%) of FE 5640Q (66% F Dipolymer) in FAM A over time

- 23°C
- 40°C
- 60°C
- 70°C

Extrapolated
Fuel test conditions

Volume Swell (%) of FE 5840Q (70% F Terpolymer) in FAM A over time
Question: will an o-ring exposed to fuel from only one side swell as much as a fully emerged o-ring?

FC 2181
30 MT

23°C
1000 hrs

Volume Swell 17%

FAM A

Volume Swell 12%

23°C
1000 hrs

air
Fluoroelastomers are specially designed... to meet the challenges of demanding applications.

Facts:

- Volume swell in regular gasoline and biodiesel is generally low for all fluoroelastomers depending on the fluorine content.
- Permeation and volume swell in fuels reversibly change with temperature.
- The ultimate swell in regular gasoline of a fluoroelastomer sealing is achieved after:
  - >1,000 hrs at room temperature
  - or after 168 hrs at 60 °C
Fuel Resistance – Aggressive Gasoline

Volume Swell (%) after 168 hrs at 60°C

- FPO 3731: Peroxide curable, High Fluorine Content
- MIP 8740: Bisphenolic curable, Medium Fluorine Content
- FE-5530: Bisphenolic curable, Low Fluorine Content
- FE-5830Z: Bisphenolic curable, High Fluorine Content
## Chemical Resistance of Fluoroelastomers

### Physical Effects – Percent of Fluorine

<table>
<thead>
<tr>
<th>Weight % Fluorine</th>
<th>66%</th>
<th>68%</th>
<th>70%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fluid with low Physical Effects</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e.g. ASTM – oil Nr. 3</td>
<td>2,5 %</td>
<td>2 %</td>
<td>1,8 %</td>
</tr>
<tr>
<td>Volume Swell, % (72 hrs @ 150 °C)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Fluid with strong Physical Effects</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>e.g. Methanol</td>
<td>100 %</td>
<td>35 %</td>
<td>5 %</td>
</tr>
<tr>
<td>Volume Swell, % (168 hrs @ 23 °C)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>TR_{10°} °C (ASTM D – 1329)</td>
<td>-18 °C</td>
<td>-11 °C</td>
<td>- 5 °C</td>
</tr>
</tbody>
</table>
### Physical Effects – Crosslinking Density on volume swell (immersed 70 hrs @ 20°C Methanol)

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>DyneonTM Dipolymer (66% F)</strong></td>
<td>100</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td><strong>Curing Agent (Bisphenol AF)</strong></td>
<td>1</td>
<td>2</td>
<td>4</td>
</tr>
<tr>
<td><strong>Standard Formulation</strong></td>
<td>7,3</td>
<td>14,7</td>
<td>22,6</td>
</tr>
<tr>
<td><strong>ODR 177 °C, 3° ARC, Micordie, 100 CPM</strong></td>
<td>94%</td>
<td>43%</td>
<td>8%</td>
</tr>
<tr>
<td><strong>Volume Swell in Methanol</strong></td>
<td>214%</td>
<td>108%</td>
<td>70%</td>
</tr>
<tr>
<td><strong>(after 70 hrs @ 20°C)</strong></td>
<td></td>
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</tbody>
</table>
Methanol + Water vs. FKM

MeOH Volume Swell 168 hrs at 23 °C

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Methanol + Water vs. FKM

MeOH Volume Swell 168 hrs at 60 °C
Methanol + Water vs. FKM

Structure of Methanol

Solubility parameter (cal/cm³)

- Methanol as polyether structure: ~ 10
- Methanol (at elevated temp.): 14.5
- Fluoroelastomer low fluorine: 8.7
- Fluoroelastomer high fluorine: 7.1
Fluoroelastomers are specially designed... 

...to resist alternative fuels.

Facts:

- Traditional sealing materials like nitrile rubber do not fulfill the requirements and present challenges related to permeation.
- The swell of fluoroelastomers in methanol is higher at lower than at increased temperatures.
- Ethanol and butanol containing fuels (e.g. CE 22) do not reduce the sealing performance of fluoroelastomers.
- High fluorine containing fluoroelastomers resist methanol containing fuels (e.g. FAM B).
Fuel Resistance – Biodiesel (RME & SME)

Volume swell 1008 hrs @ 125 °C RME
Hardness change RME
Volume swell 1008 hrs @ 125 °C SME
Hardness change SME
Fluoroelastomers are specially designed...

...to perform in biofuels.

Facts:

- Biodiesel (RME / SME) starts to degrade under influence of temperature, air exposure and water.
- Standard fluoroelastomers show higher volume swell in contact with degraded biodiesel or fuel residuals.
- Even at elevated temperatures selected 3M™ Dyneon™ Fluoroelastomers do not compromise on sealing performance, independent if the fuel contains RME or SME.
- Fluoroelastomer formulations without acid acceptors can lead to higher volume swell of the seal in ammonia or urea solutions (e.g. ad blue).
3M™ Dyneon™ Fluoroelastomers are the right choice for demanding current and future fuel system applications.