# Vamac® Ultra

## New AEM Polymers with Extended Possibilities for Demanding Automotive Applications

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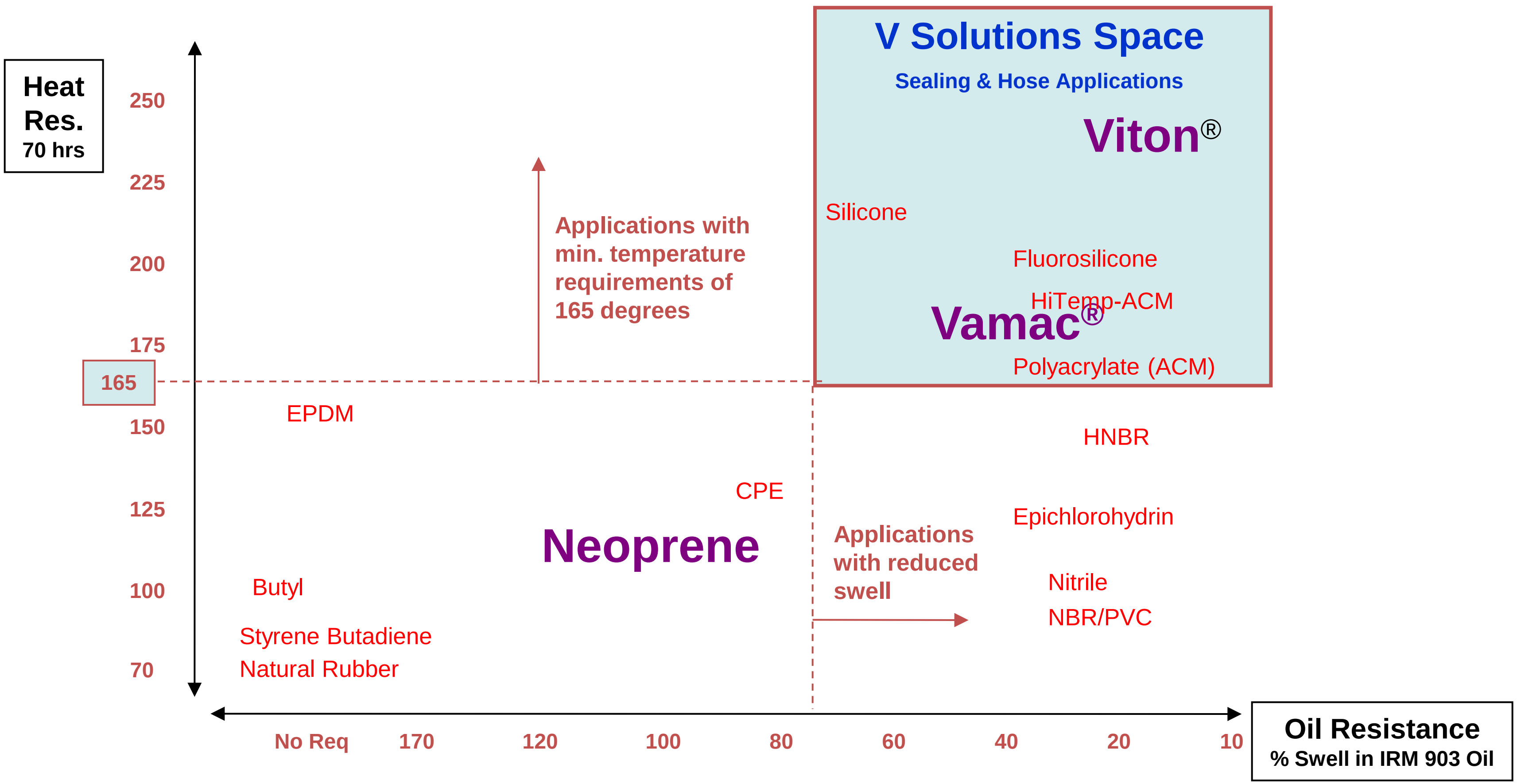
# Agenda

- Overview on Vamac® ethylene acrylic elastomer (AEM) Terpolymers
- Performance of Vamac® Ultra grades compared to standard AEM
- Heat Ageing
- Comparison to other Polymers, Compressive Stress Relaxation
- Environmental Regulations and their impact on fluids present in Modern Engines
- Test results after Immersion in Automotive fluids

# Vamac® on the Elastomer's Map

## Classification by ASTM D-2000

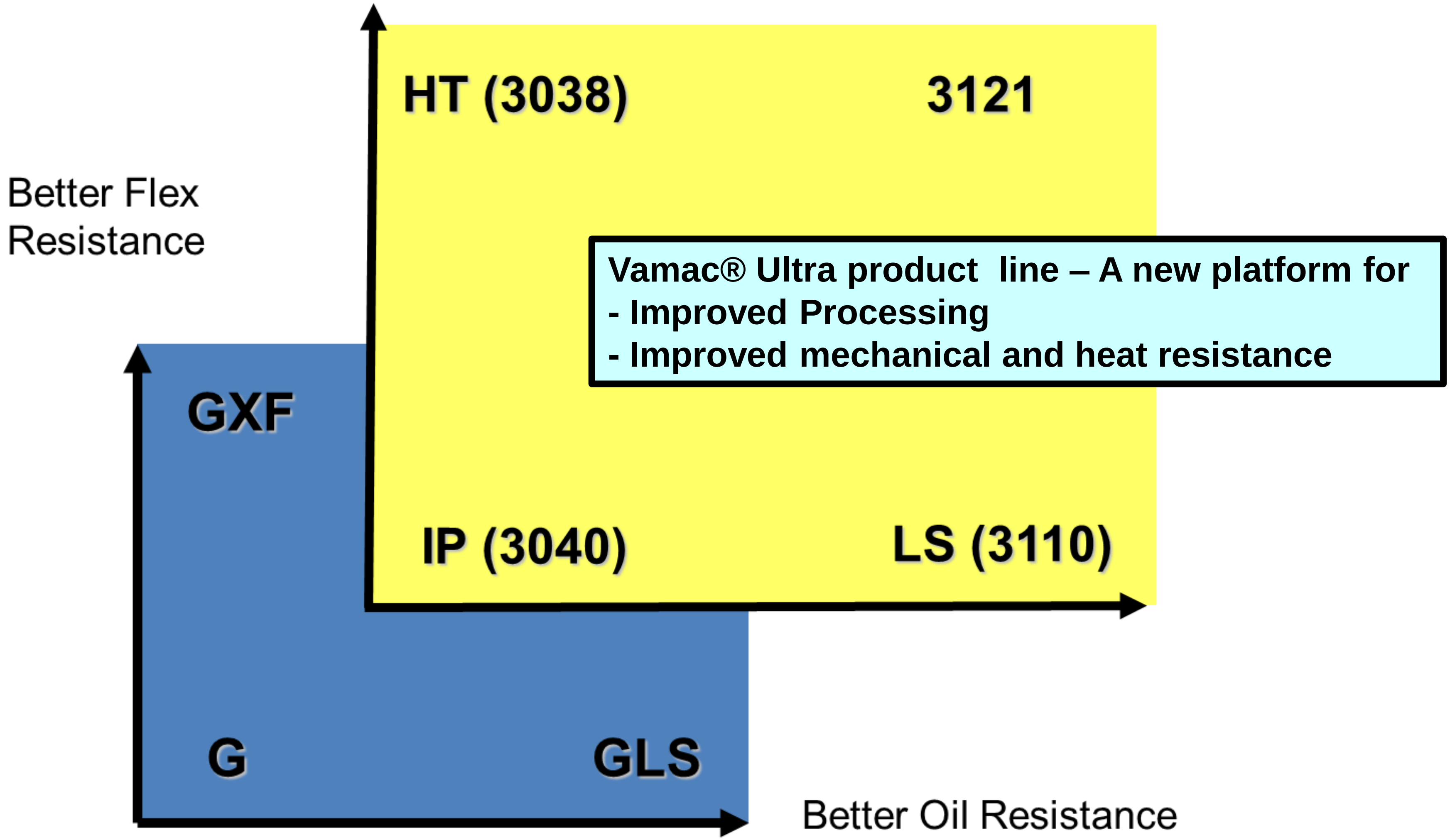


# Vamac® - Standard and High Viscosity ‘Ultra’ Grades

| | | | |
|---|---|---|---|
| Standard Grade<br>ML (1+4) 100° C, Tg | Vamac® G<br>16.5 MU, -30 ° C | Vamac® GXF<br>17.5 MU, -31 ° C | Vamac® GLS<br>18.5 MU, -24 ° C |
| High Viscosity Grade<br>ML (1+4) 100° C, Tg | Vamac® Ultra IP<br>(formerly VMX-3040)<br>29 MU, -31 °C | Vamac® Ultra HT<br>(formerly VMX-3038)<br>30 MU, -32 °C | Vamac® VMX-3110<br>30 MU, -25 °C |
| | | Vamac® VMX-3121<br>30 MU, -26 °C<br>Low oil swell version of Ultra HT | |
| Major Features<br><br>Main Application(s) | Best Compression Set, Fast Cure<br><br>Low Hardness Molded parts, Seals & Gaskets, High pressure hoses | Best Dynamic Fatigue Resistance<br><br>High Temperature Turbo Charger Hoses | Best Compression Set, Fast Cure, Low Oil swell<br><br>Molded parts with best fluid and lubricant resistance |

‚VMX‘ → developmental or experimental grades

# Product Line - Vamac® Ethylene Acrylic



# Vamac® Ultra - Compounds used for IM Tests

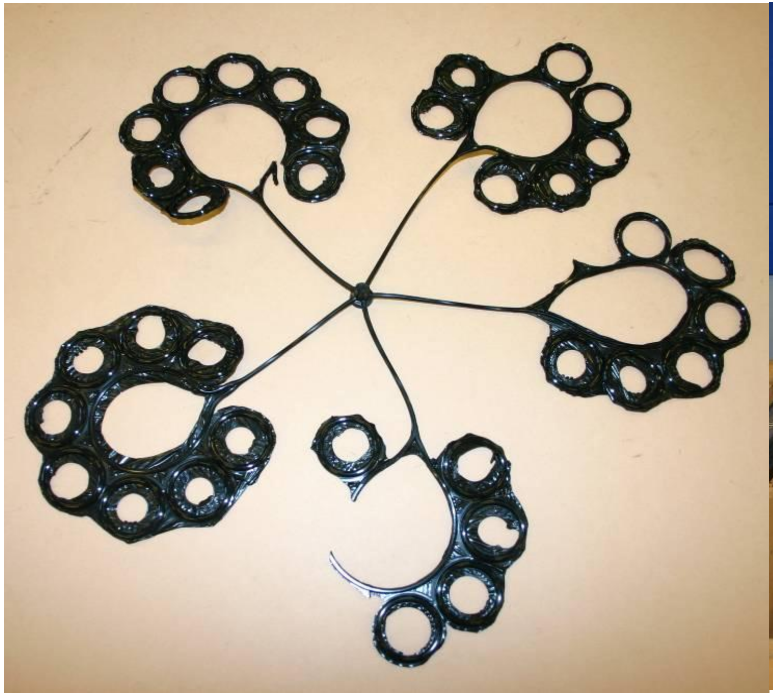
| | | |
|---|---|---|
| Vamac® G | 100 | |
| Vamac® Ultra IP | | 100 |
| Naugard® 445 | 2 | 2 |
| Vanfre® VAM | 1 | 1 |
| Armeen® 18D | 0.5 | 0.5 |
| Stearic acid | 1.5 | 1.5 |
| Spheron® SO A N-550 | 30 | 30 |
| Diak™ No 1 | 1.5 | 1.2 |
| Vulcofac® ACT 55 | 3 | 3 |
| | | |
| MDR, 15 min @ 180° C, arc 0.5° | ISO 6502 | |
| ML (dNm) | 0.3 | 0.6 |
| MH (dNm) | 10.8 | 12.0 |
| Ts2 (min) | 1.0 | 0.9 |
| Tc50 (min) | 2.1 | 2.1 |
| Tc90 (min) | 6.5 | 6.5 |

**Very sticky, non-industrial recipe with high polymer content.**

**Different levels of curative, all other ingredients identical.**

**→ At 20% lower curative level, Ultra IP compound is 11.1% higher in MH.**

# Vamac® G vs. Ultra IP, Injection Molding Test



| | |
|---|---|
| Mold Design: | O-Ring 214, 40 Cavities |
| Dimensions: | 24.99 x 3.53 mm |

# Demoulding Steps

Auto

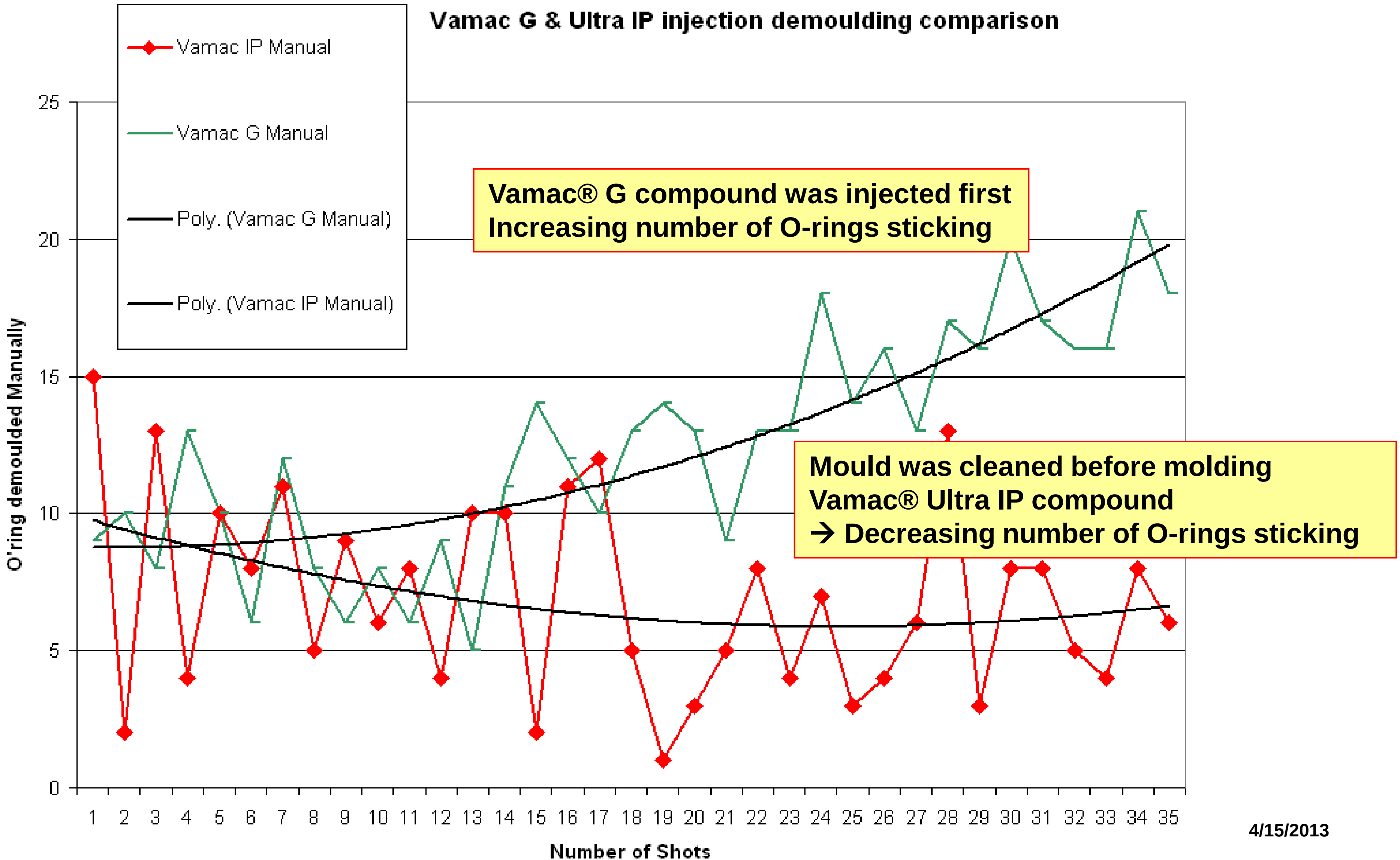
Brush

Manual

O-rings are counted

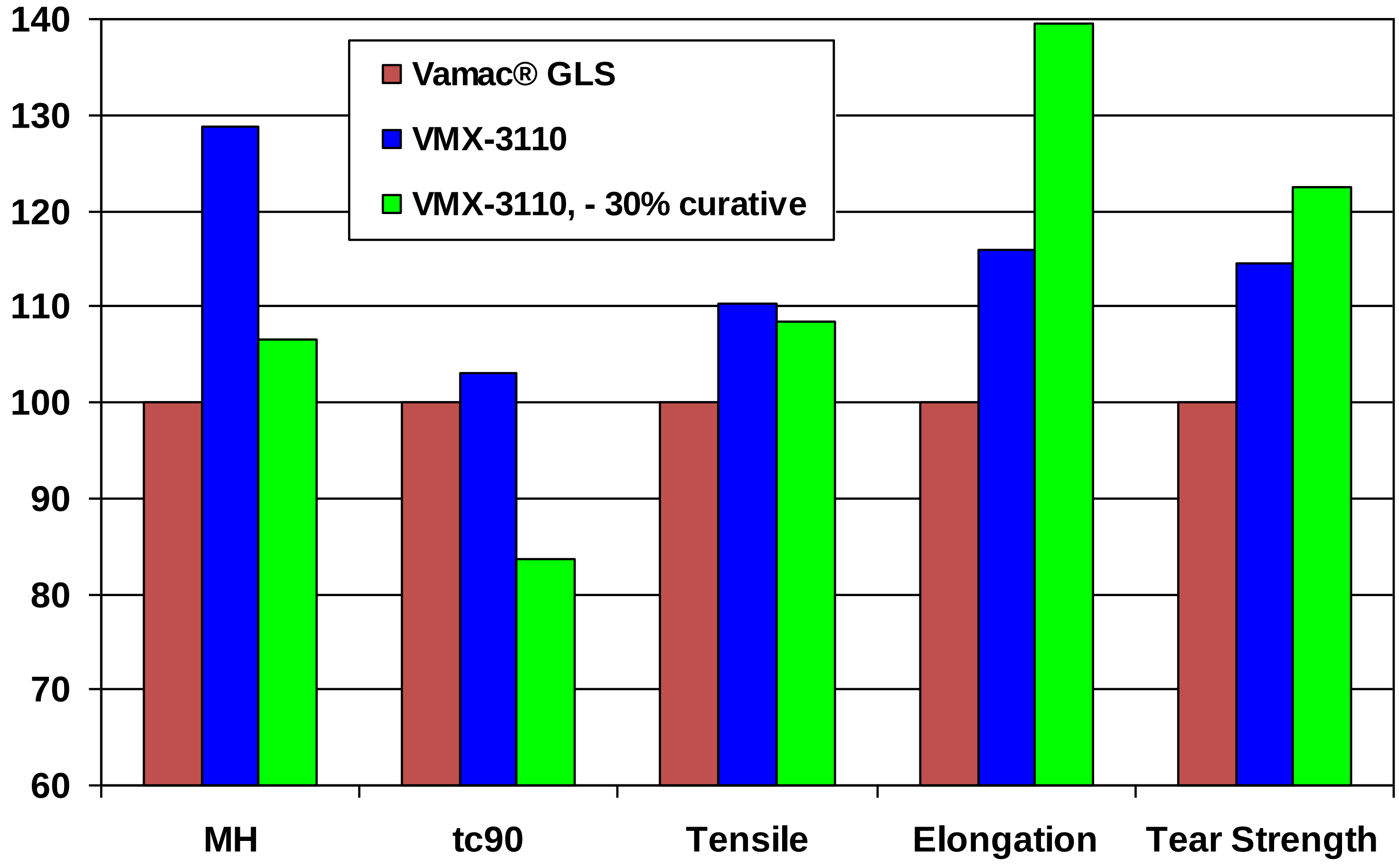
Next shot

# Vamac® G – Ultra IP, manually demolded O-rings



# Physical Properties, VMX-3110 vs. Vamac® GLS

- Properties of Vamac GLS compound =100%
- VMX-3110 was used with identical formulation and at reduced curative level (1.25 phr Diak™ No.1)



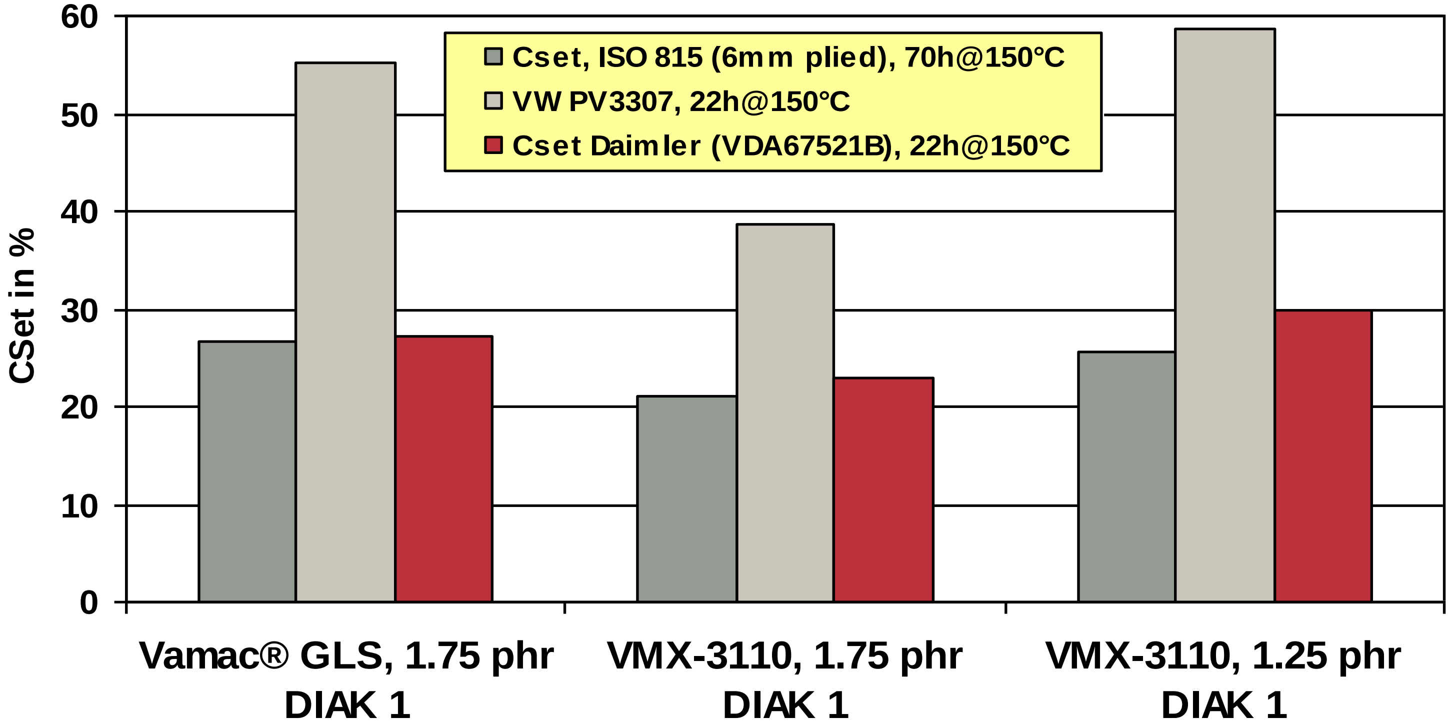

| | |
|---|---|
| Polymer | 100 phr |
| Naugard®445 | 2 |
| St. Acid | 1.5 |
| Vanfre® VAM | 1 |
| Armeen® 18 D | 0.5 |
| W759 | 10 |
| FEF-550 | 60 |
| DIAK™ No1 | 1.75 |
| ACT 55 | 2 |

→ Combination of high MH and shorter tc90 allows for much faster mold release

→ Physical properties generally improved

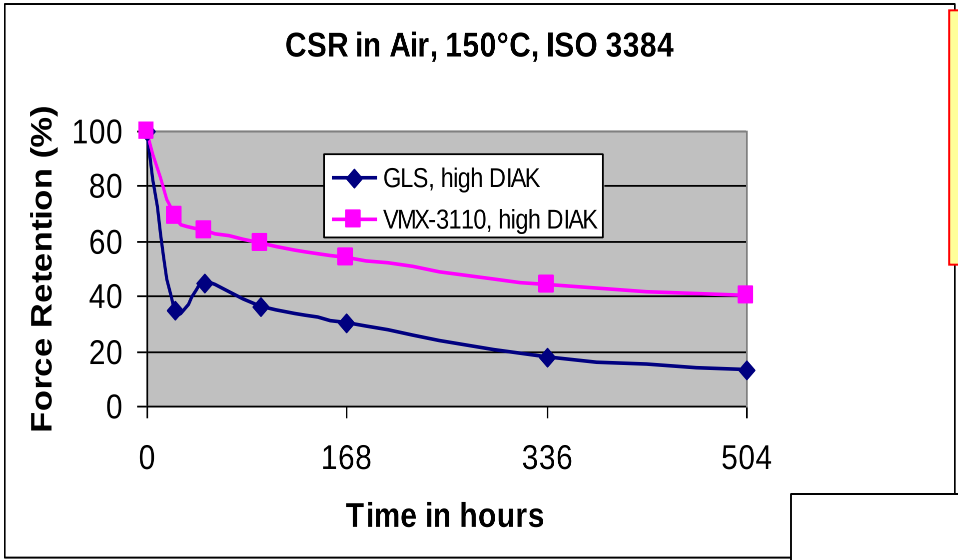
# Vamac® GLS vs. VMX-3110, Compression Set

## Diamine Curative (DIAK™ No.1) Reduction

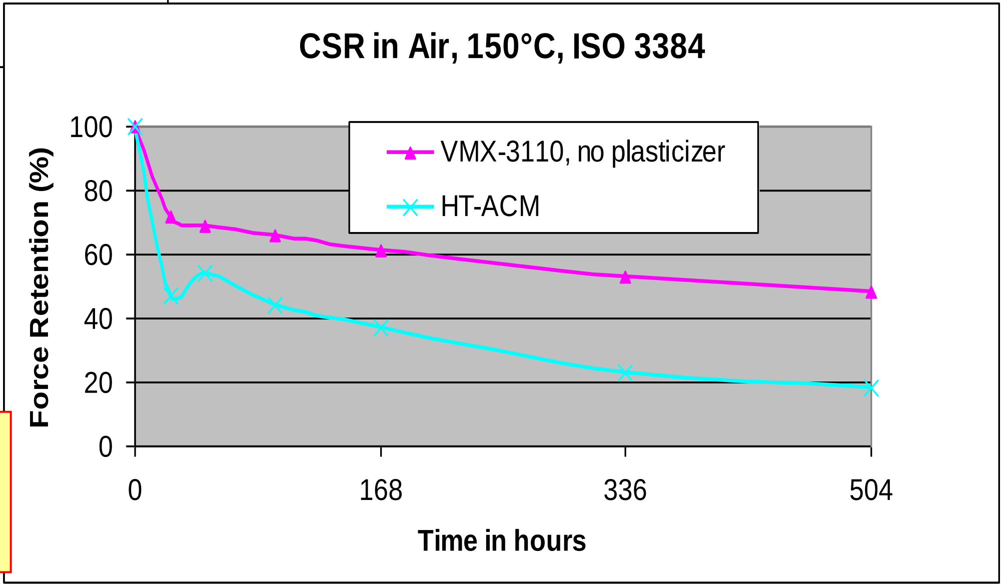



-Similar Compression Set resistance at abt. 30% Curative reduction → Compound cost reduction

# Sealing Performance - Compressive Stress Relaxation




**Vamac® GLS and VMX-3110 with identical formulations (60 Sh.A, 1.75 phr DIAK™ No1 and 20 phr of plasticiser)**
**→ VMX-3110 provides significant improvement**




**Both formulations without plasticiser**
**→ VMX-3110 significantly better than HT-ACM**

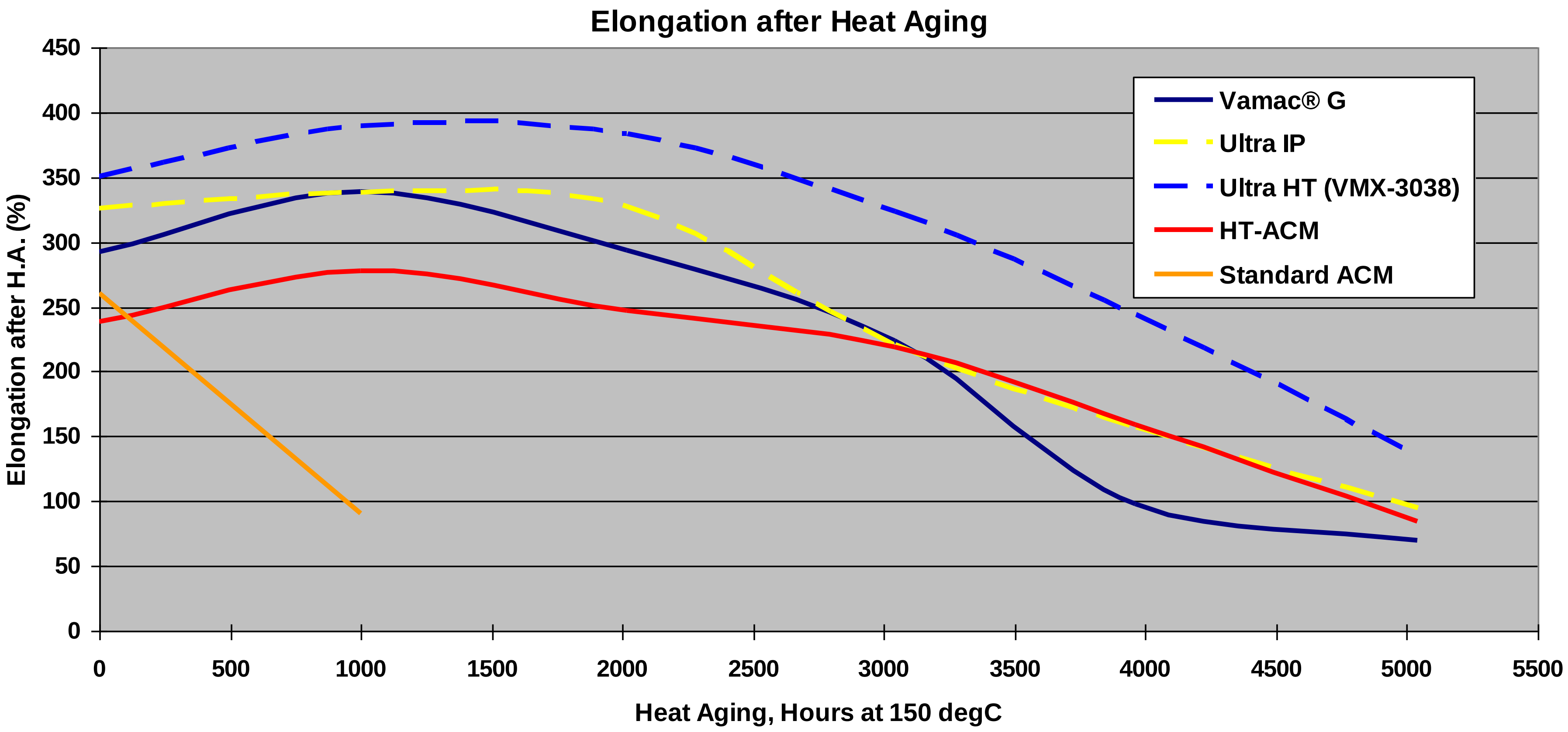
# Heat Ageing, Vamac® G vs. Ultra IP

## Compounds without plasticizer

| Heat ageing 504 h @ 175 ° C | Vamac® G | Ultra IP | Ultra IP / low DIAK™ No.1 |
|---|---|---|---|
| Hardness change (pts) | 5 | 1 | 0 |
| M 100% Change (%) | 32 | 13 | 5 |
| Tensile Strength Change (%) | -51 | -21 | -40 |
| Elongation Change (%) | -54 | -20 | -35 |
| Heat ageing 168 h @ 190 ° C | | | |
| Hardness change (pts) | 3 | -1 | -3 |
| M 100% Change (%) | 29 | 6 | 11 |
| Tensile Strength Change (%) | -30 | -21 | -34 |
| Elongation Change (%) | -40 | -24 | -35 |

**- Better property retention for Vamac® Ultra IP**
**- Little to no Hardness and Modulus Change**
**- Compounds with tighter x-link density exhibit better property retention**

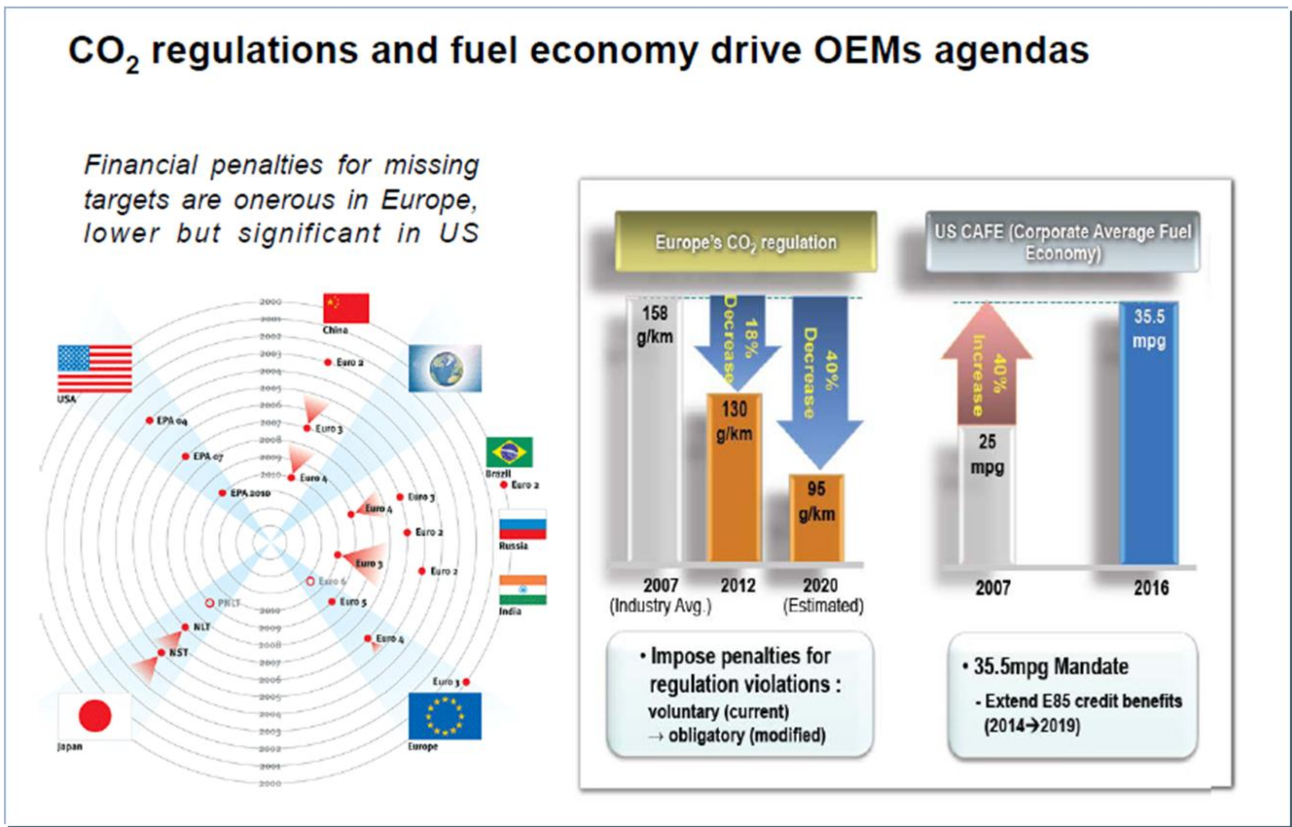
# Vamac® vs. ACM – Heat Ageing at 150° C




**- Absolute value higher for Vamac® Ultra grades compared to HT-ACM.**
**- No long-term heat ageing advantage for HT-ACM at 150° C**
**- Standard ACM (commercial compound, 55 ShA) falls below 100% remaining EaB after 1000 h at 150° C**

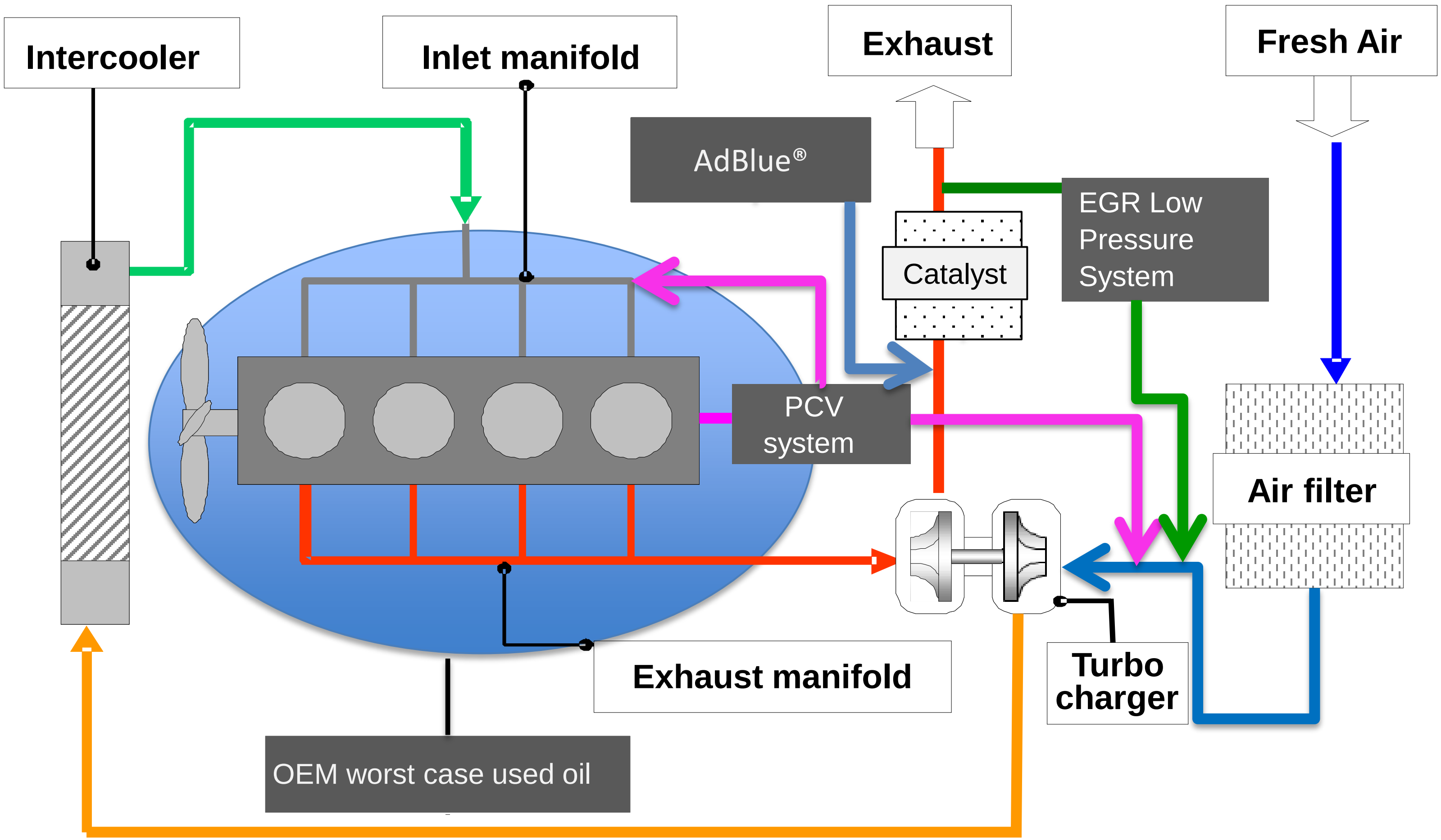
# Environmental Regulations

**Environmental regulations and the requirements to improve fuel efficiency have led to the introduction of new technologies such as Exhaust Gas Recirculation (EGR), Crankcase ventilation (PCV hose), AdBlue® system.**
**This leads to the presence of more aggressive fluids in different areas of the engine. The composition of those fluids are difficult to clearly define.**



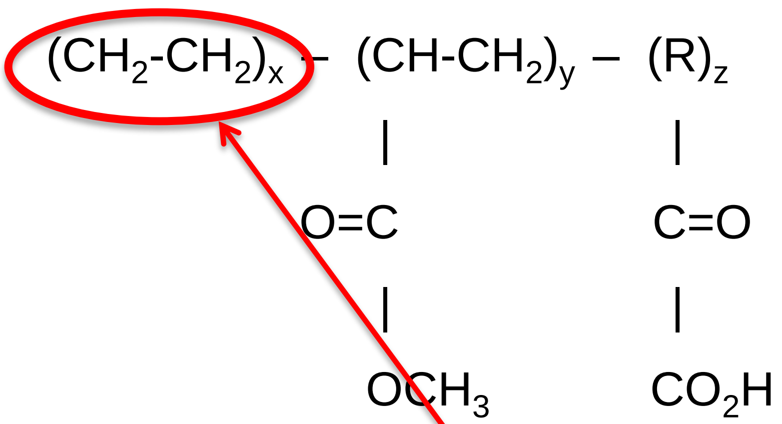
# Air Management: More Aggressive Fluids

**Turbocharger System with Recycle Loops PCV, EGR and AdBlue system**



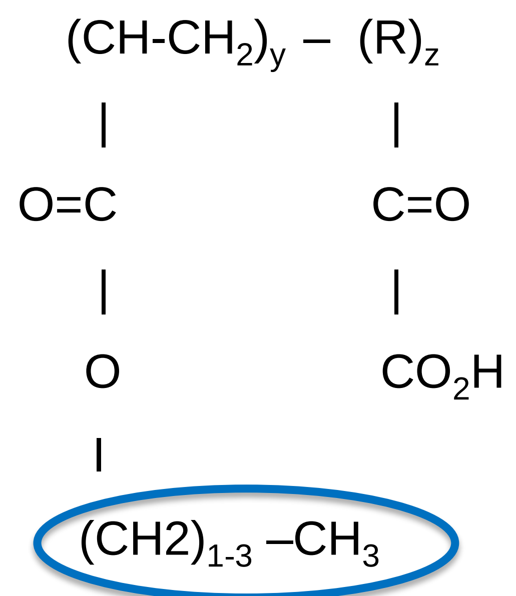
# Chemical Structure, AEM vs. ACM

**AEM (Terpolymer)**




Ethylene, Methyl Acrylate, Acidic Cure Site

**HT- ACM**




Alkyl Acrylate(s), Cure Site

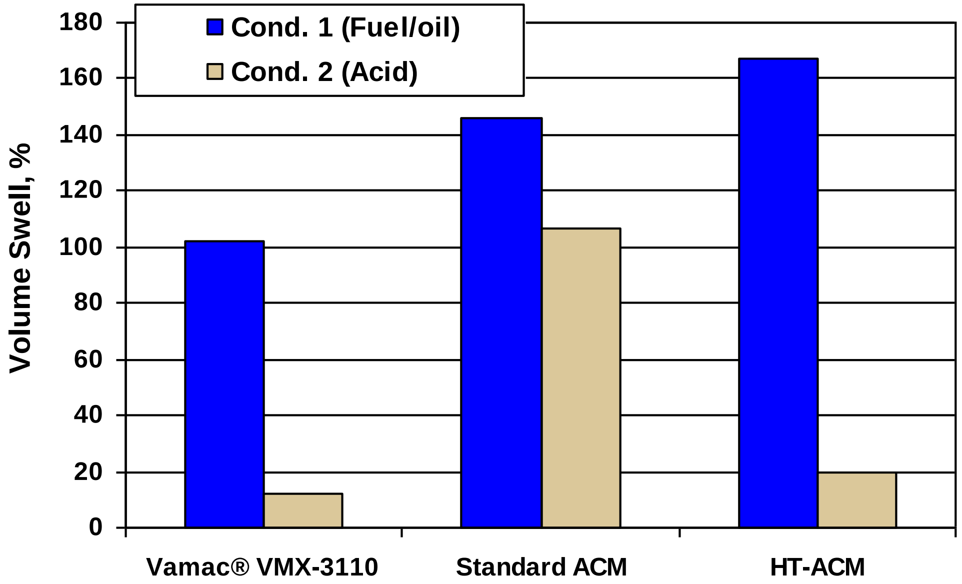
**Main difference is the high Ethylene content of AEM, resulting in better resistance to hydrolysis compared to a 100% ester like ACM.**

**Oil resistance of AEM is provided by Methyl Acrylate monomer's higher polarity compared to ACM's monomer with longer alkyl substituents**

# Blow-by : Vamac® - ACM

Blow By Gas is a leakage flow between the piston and the cylinder wall originated through the pressure difference between combustion chamber and the crankcase. Blow By Gas accumulates with oil & fuel particles.

Vamac® polymers have been used with success in PCV for many years. Below data shows results in Blow-By as defined by a German OEM, who differentiates between water-based acid condensate and oil-fuel blends (88% FAM A, 10 % Lubrizol OS206304).




All compounds have similar fillers and no plasticiser.

Tests carried out in lab autoclave, 72 h at 120° C

Results for volume change in % before drying

→ Higher swell for ACM in fuel/oil blend

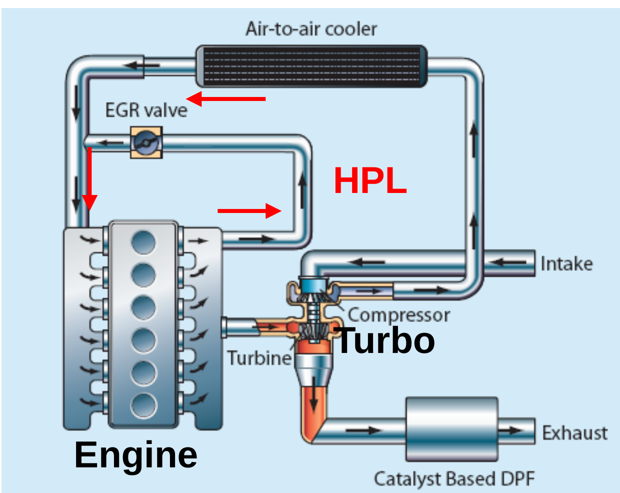
→ Higher swell of ACM in acid/water/EtOH blend

# Exhaust Gas Recirculation

**Exhaust Gas is generated from the combustion of engine and recirculated back into the engine to reduce fuel consumption or NOx formation**

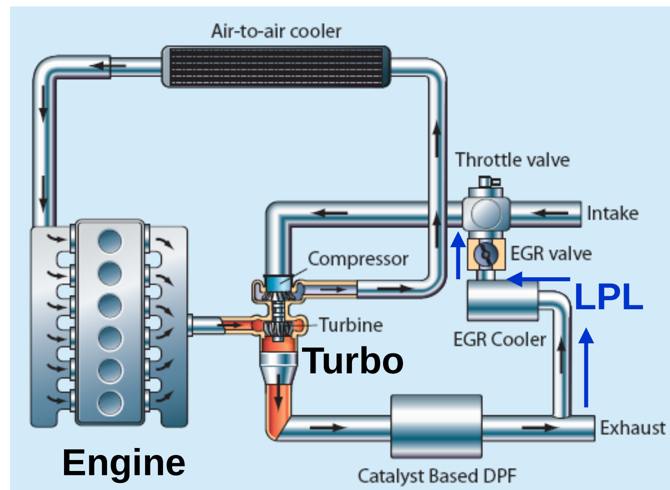
**Exhaust Gas composition : HC, $CO_2$, CO, NOx, Acids**

**High Pressure Loop (HPL)**




**High Pressure**
**High Temperature (> 200° C)**
**Mainly metal pipes**

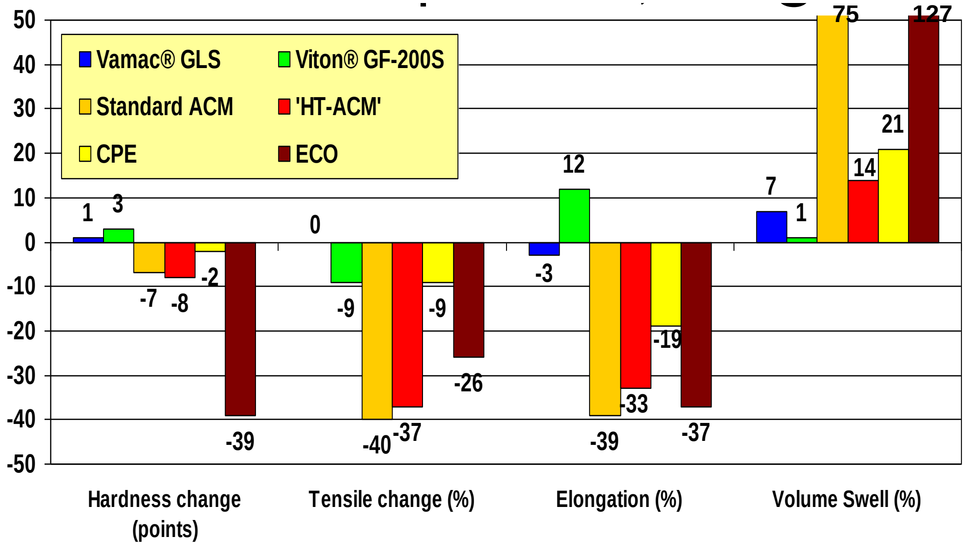
**Low Pressure Loop (LPL)**




**Low Pressure**
**Low Temperature (< 150° C)**
**Mainly flexible rubber / plastic tubes**
**+ rubber seals**

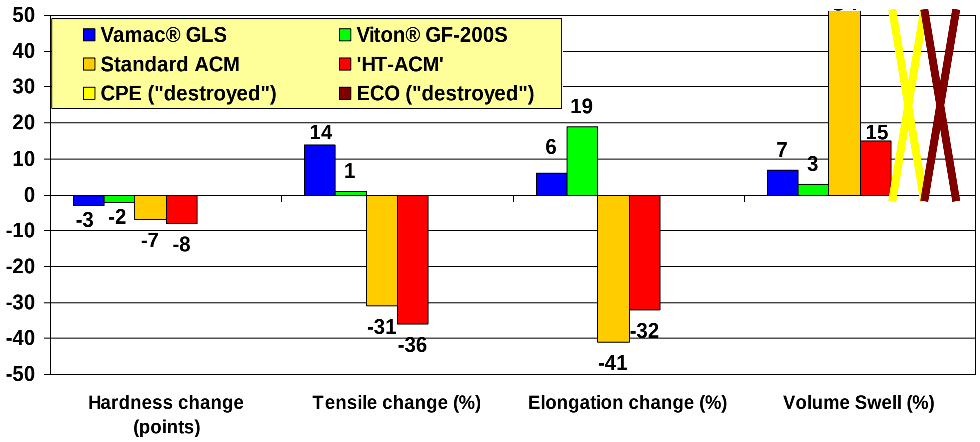
# Elastomers performances in acid condensate

## Mineral based, pH 3.3, EGR liquid contact, 168 h at 90° C




Lab tests made
with fluids
close to OEM reference

## Organic based, pH 3.0
## EGR liquid contact, 168 h at 90° C




- **Vamac® is performing well**
- **Solutions using Viton® peroxide grade without metal oxide are recommended**
- **Standard ACM , ECO & CPE: poor resistance to EGR**
- **ACM and HT-ACM have poor retention of mechanical properties vs Vamac®**

# Resistance in Acetic Acid – pH 2.5

| | Seal application | | | | Hose application | | | |
|---|---|---|---|---|---|---|---|---|
| | Vamac® Ultra IP | Vamac® Ultra IP/3110 | HT ACM 1 | HT ACM 2 | Vamac® Ultra HT | VMX 3121 | HT ACM 3 | HT ACM 4 |
| Initial properties | | | | | | | | |
| Hardness Shore A | 65 | 60 | 63 | 61 | 69 | 71 | 68 | 72 |
| Tensile (Mpa) | 16.7 | 15.6 | 10 | 10 | 20.1 | 20.1 | 9.2 | 13.1 |
| Elongation (%) | 311 | 312 | 230 | 216 | 430 | 420 | 190 | 190 |
| Fluid ageing 504 hours at 100°C in Acetic acid - pH 2.5 | | | | | | | | |
| Delta Hardness | -4 | -4 | -10 | -8 | -2 | -5 | -10 | -12 |
| Delta TS (%) | -5 | -13 | -13 | -9 | 1 | -6 | 13 | -9 |
| Delta Elongation (%) | -8 | -12 | -4 | 11 | 8 | -7 | 24 | 9 |
| Volume change (%) | 9 | 8 | 30 | 17 | 9 | 13 | 25 | 14 |
| Fluid ageing 168 hours at 150°C in Acetic acid - pH 2.5 | | | | | | | | |
| Delta Hardness | 10 | 12 | -35 | -34 | 16 | 12 | -49 | -45 |
| Delta TS (%) | 10 | 15 | -68 | -74 | 26 | 8 | -92 | -79 |
| Delta Elongation (%) | -19 | -5 | -55 | -57 | -54 | -53 | -71 | -44 |
| Volume change (%) | 2 | -2 | 219 | 212 | 5 | 4 | 343 | 161 |

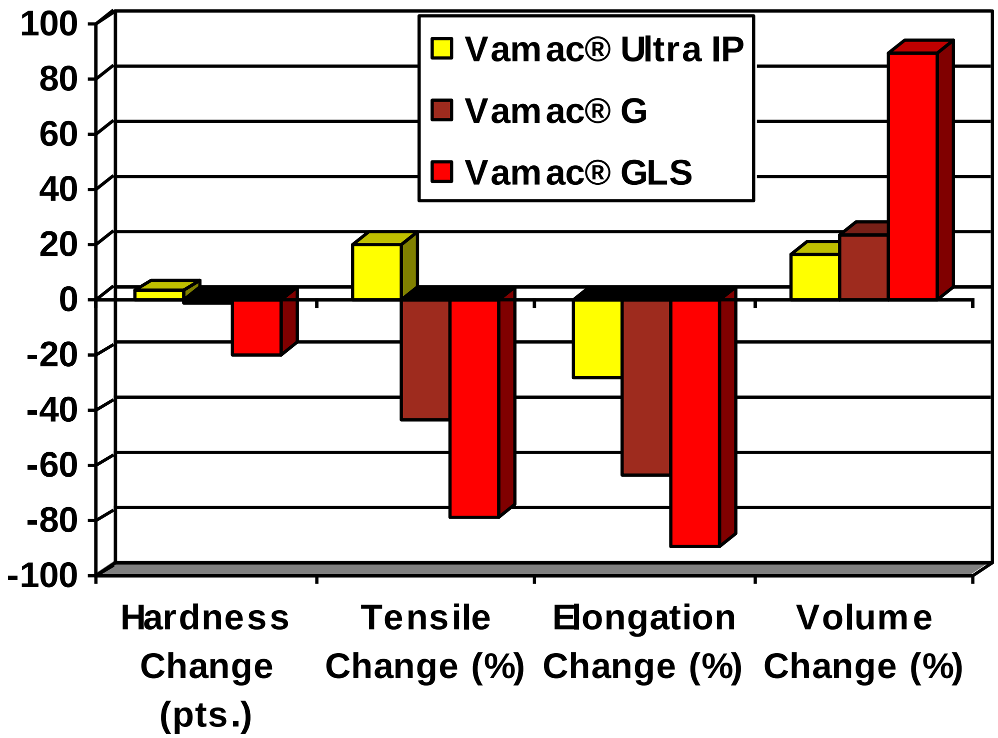
**Resistance to Acetic Acid required by major European OEM.**

- **Pure ester based polymers like ACM tend to display higher swell compared to AEM**
- **Severe impact on properties was seen on solutions using HT-ACM after fluid ageing 168 hours at 150° C in acetic acid**

# Resistance to AdBlue® Urea Solution

**Selective Catalytic Reduction systems use water based urea solutions for reduction of NOx. OEMs request very often additional resistance to Diesel fuel.**

- **Solutions using Vamac® meet existing specifications of OEMs**
- **Vamac® Ultra IP outperforms standard Vamac® grades**
- **Low MA content is recommended**




**Test conditions :**

- **Laboratory autoclave**
- **168 hours at 120° C in liquid phase**

# OEM worst case oil

- OEM has experienced field failures with cam cover gaskets used in gasoline engines
- Build-up of acids in the oil is supposed to be the reason for extreme hardening and cracks of the seals
- OEM has evaluated several used oil samples and created a “Worst Case Used Oil“ with which they were able to simulate the same hardening effects on laboratory scale
- We carried out tests in this oil as well and found the following results

# Fluid ageing 168 hours at 150° C in OEM worst case oil

Recommended Vamac® grade

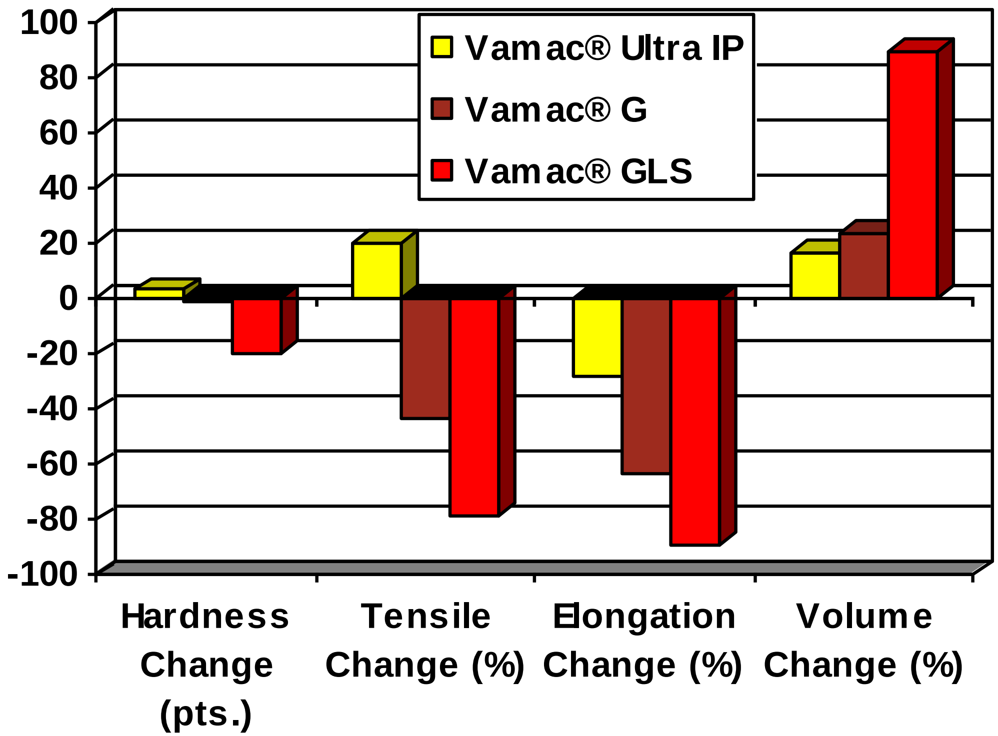
| | FKM 22294 Viton® A401C | FKM 22296 Viton® GBL200S | AEM 7226 Vamac® VMX 3110 | AEM 7227 Vamac® Ultra IP | AEM 7228 Vamac® dipolymer | ACM 89 HT-ACM 1 | ACM 90 HT-ACM 2 |
|---|---|---|---|---|---|---|---|
| **Fluid ageing 168 hours at 150°C in OEM worst case oil** | | | | | | | |
| **Autoclave - liquid phase** | | | | | | | |
| **Hardness Shore A (1 second)** | 78 | 67 | 81 | 67 | 65 | 94 | 88 |
| **Delta Hardness** | **4** | **-1** | **16** | **3** | **-5** | **31** | **31** |
| **Tensile properties (type 2) at 23°C** | | | | | | | |
| **Tensile Strength [MPa]** | 8.2 | 12.6 | 14.9 | 14.2 | 15.2 | 25.4 | 18.3 |
| **Delta TS [%]** | **-36** | **-45** | **-13** | **-18** | **7** | **149** | **65** |
| **Elongation at break [%]** | 107 | 240 | 123 | 193 | 235 | 28 | 59 |
| **Delta Elong. [%]** | **-45** | **-24** | **-61** | **-38** | **-15** | **-90** | **-77** |
| **Modulus at 100 % [MPa]** | 7.9 | 3.0 | 11.9 | 5.7 | 5.8 | - | - |
| **Delta 100% [%]** | **39** | **-4** | **184** | **41** | **19** | | **-** |
| **Weight Change [%]** | **1** | **1** | **-3** | **2** | **7** | **-8** | **-5** |
| **Volume Change [%]** | **3** | **2** | **-5** | **3** | **10** | **-14** | **-10** |

- **Solutions using Viton® peroxide witout metal oxide should be preferred for temperature above 175° C**
- **Solutions using Vamac® Ultra IP and peroxide cure Vamac® Dipolymer are performing well in the OEM worst case oil**
- **Solutions using HT-ACM are suffering with high hardness, elongation, modulus change**

# Resistance to AdBlue® Urea Solution

**Selective Catalytic Reduction systems use water based urea solutions for reduction of NOx. OEMs request very often additional resistance to Diesel fuel.**

**AEM meets existing specifications of OEMs. Vamac® Ultra IP outperforms standard Vamac® grades.**




**Test conditions:**

**- Lab autoclaves**
**- 168 hours at 120 ° C**

# Summary

- High viscosity AEM Ultra polymers offer significantly better processing and properties over standard Vamac® grades and may extend the range of applications for AEM

- Good Blow-By and Exhaust Gas Condensate Resistance make standard Vamac® and Vamac® Ultra grades a good candidate for new applications with contact to mixtures of aggressive fluids

# Thank YOU !!!

for your attention
and if you have any questions….

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