Vamac® Ethylene Acrylate Elastomer (AEM) - Possibilities for Oil & Gas Applications

Elastomers Used in the Oil and Gas Sector
Rubber in Engineering Group of IOM3
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Outline

- Vamac® Background
- Vamac® Fluid Resistance
- Comparison Vamac® vs HNBR and FKM
- Flame Retardant Vamac® Compounds for Wire & Cable Applications
- Summary
What is Vamac®?

Vamac® is an amorphous random ethylene acrylate copolymer with an acid cure-site monomer for diamine crosslinking.

- (CH₂CH₂)x -
  - (CH₂CH)y -
  - (CH₂CH)z -
  - (R) -

<table>
<thead>
<tr>
<th>Ethylene</th>
<th>Methyl Acrylate</th>
<th>Butyl Acrylate</th>
<th>Acidic cure-site</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>- C =O</td>
<td>- C =O</td>
<td></td>
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<tr>
<td></td>
<td>- O - CH₃</td>
<td>- O - C₄H₉</td>
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- (A) Polar acrylic monomer imparts fluid resistance, butyl acrylate (only in Vamac® Ultra LT) lowers Tg up to -50°C
- (E) Ethylene provides low temperature properties and good water/acid resistance, can be used for peroxide crosslinking
- (M) Saturated polymer chain for thermal stability, good ozone and UV resistance
- Halogen free

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Elastomer Performance

Classify elastomers based on their performance in various conditions.

**Oil Resistance (Volume Swell)**

- **No Req.**
- **140**
- **120**
- **100**
- **80**
- **60**
- **40**
- **20**
- **10**

**Heat Resistance**

- **SBR**
- **IR**
- **IIR**
- **EVM**
- **EPDM**
- **VMQ**
- **CR**
- **NBR**
- **ECO**
- **FVMQ**
- **FFKM**
- **HT-ACM**
- **ACM**
- **ECO**
- **NBR**

**VI %**

- **A**
- **B**
- **C**
- **D**
- **E**
- **F**
- **G**
- **J**
- **K**

**Type**

- **K** 300
- **J** 275
- **H** 250
- **G** 225
- **F** 200
- **E** 175
- **D** 150
- **C** 125
- **B** 100
- **A** 70

**Classification inspired by ASTM D2000 standard**

1. Maximum temp. at which a vulcanize can be aged for 70 hrs and still retain at least 50% of its elongation
2. % volume swell in ASTM IRM 903 Oil, 70 hrs exposure
3. % volume swell in ASTM IRM 903 Oil, 70 hrs exposure

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1 Classification inspired by ASTM D2000 standard
2 Maximum temp. at which a vulcanize can be aged for 70 hrs and still retain at least 50% of its elongation
3 % volume swell in ASTM IRM 903 Oil, 70 hrs exposure
Typical Vamac® Applications

Vamac® is widely used in automotive applications with a broad range of properties in terms of temperature, oil & grease resistance and mechanical properties e.g. air ducts, turbo charger hoses, seals & gaskets, dampers, cables, 2K parts etc.

- In Oil & Gas Applications Vamac® has so far limited use
- Compared to (F)FKM Vamac® has reduced heat and fuel resistance
- Compared to HNBR Vamac® has reduced mechanical strength and fuel resistance

However Vamac is a good ‘all-round’ elastomer which might offer some opportunities in O&G applications with cost advantage.
Vamac® Fluid Resistance

Vamac® has very good resistance to:
- Lubricating oils and greases (mineral or synthetic based)
- Transmission and power steering fluids
- Diesel fuel
- Kerosene
- Water up to 100°C
- Diluted acids and bases
- Dry and wet sour gases
- Blow-By

Fluids to avoid:
- Aromatic hydrocarbons: gasoline, benzene, toluene
- Polar organic fluids: esters, ketones, amines
- High and low pH water based solutions: risk of hydrolysis

• Vamac® strongly swells in liquid gasoline
• Only suitable in contact to some fuel fumes
• Moderate swell in Diesel
• After drying compounds show original physical properties (except for wash-out of plasticizer by gasoline)
Vamac® Steam/Coolant Resistance

- Vamac® grades with high ethylene content provide good steam and water/glycol resistance up to 100-110°C.
- At higher temperature (125°C) Vamac® is not suitable any more.
Vamac® Acid and Bases Resistance

- Vamac® shows good resistance against organic and inorganic acids up to 120°C
- Vamac® compounds show excellent resistance to exhaust and blow by gases

Solution 1 (pH~2):
- Formic Acid: 1 g/l
- Acetic Acid: 1 g/l
- Nitric Acid: 0.4 g/l
- Sulfuric Acid: 0.1 g/l
- Hydrochloric Acid: 0.1 g/l

Solution 2 (pH~3):
Same as solution 1, diluted with H₂O at a ratio of 1:10
Vamac® vs HNBR – Tensile Properties

- TS at room temperature higher for HNBR
- TS at operating temperature similar for both elastomers

**Tensile Strength at Different Temperatures**

**Elongation at Different Temperatures**

- Better elongation stability of HNBR versus Vamac® at elevated temperature
Vamac® vs HNBR – Oil Resistance

Volume Swell - IRM 902/903 and Lubrizol® 206034

- HNBR clearly performs better in IRM 903 than Vamac®
- High Methyl acrylate Vamac® grades get close to HNBR in IRM 902 and Lubrizol®
Vamac® vs HNBR – Compression Set and Heat Aging at 150°C

- Vamac® has higher heat resistance than HNBR and better compression set resistance at high temperatures.
Vamac® vs FKM – Heat Resistance

<table>
<thead>
<tr>
<th></th>
<th>Vamac® G</th>
<th>Ultra IP</th>
<th>VMX5015</th>
<th>PO FKM</th>
</tr>
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<tbody>
<tr>
<td>Vamac® G</td>
<td>100</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vamac® Ultra IP</td>
<td></td>
<td>100</td>
<td>17.5</td>
<td></td>
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<tr>
<td>Vamac® VMX 5015</td>
<td></td>
<td></td>
<td>150</td>
<td></td>
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<tr>
<td>DPA Antioxidant</td>
<td>2</td>
<td>2</td>
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<tr>
<td>Alchem 4ADA</td>
<td>1</td>
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<tr>
<td>Process Aids</td>
<td>3,5</td>
<td>3,5</td>
<td>3,5</td>
<td></td>
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<tr>
<td>FEF Black</td>
<td>50</td>
<td>50</td>
<td></td>
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<tr>
<td>MT Black</td>
<td></td>
<td></td>
<td>15</td>
<td></td>
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<tr>
<td>Plasticizer</td>
<td>5</td>
<td>5</td>
<td>5</td>
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<td>HDMC Curative</td>
<td>1,5</td>
<td>1,5</td>
<td>1,2</td>
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<tr>
<td>DBU (55%)</td>
<td>2</td>
<td>2</td>
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Heat ageing temperatures of >190°C are too high for Vamac® Standard and Ultra Grades

VMX5015 compound survives short term heat aging >190°C and 1000hrs at 175°C

Alternative for low temperature FKM replacement
CSR Test in Air – 150°C

- After 6 weeks seal force of ‘standard’ AEM compounds is <20%
- VMX5000 and FKM still show >40% seal force after 6 weeks
- FKM BP > FKM PO > VMX5020 > VMX5015 > UIP = ULS > G
Continuous temperature of 175°C is above ‘standard’ AEM use temperature.

‘Standard’ AEM is <20% seal force after 2 weeks.

VMX5000 and FKM have >20% seal force left after 6 weeks ageing.

FKM BP > FKM PO > VMX5020 > VMX5015 > UIP = ULS > G.
CSR in Pentosin® FFL-2 – 150°C

- Ageing in oil leads to better retention of seal force due to reduced oxidation
- Seal force of ‘standard’ AEM is comparable with VMX5000 and FKM
- Vamac® Ultra LS with biggest seal force reduction due to high methyl acrylate content
- In low viscosity engine oils (e.g. 0W20 – not shown) VMX5000 compounds show also excellent performance
Vamac® for Flame Retardant Applications

Vamac® is halogen free and can be compounded with large amounts of halogen free flame retardants (e.g. Al(OH)$_3$ or Mg(OH)$_2$) to achieve flame retardant, low smoke emission compounds in combination with heat/oil resistance and excellent low temperature flexibility.

<table>
<thead>
<tr>
<th>Compounds contain 150phr ATH</th>
<th>Limited Oxygen Index (LOI) [%]</th>
<th>Optical Density (25kW/m$^2$)</th>
<th>Gas Toxicity Analysis - CIT</th>
<th>Cone Calorimeter (25kW/m$^2$)</th>
<th>Total Heat Release THR [MJ/m$^2$]</th>
<th>Total smoke released TSR [m$^2$/s]</th>
<th>MARHE [kW/m$^2$]</th>
<th>UL 94 (2mm thick)</th>
<th>TG [°C]</th>
<th>IRM 902 72h@100C swell [%]</th>
<th>IRM 903 168h@70C swell [%]</th>
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<tbody>
<tr>
<td></td>
<td>IS 4589-2</td>
<td>ISO 5659-2</td>
<td>NF X 70-100-1/2</td>
<td>ISO 5660-1</td>
<td>37</td>
<td>311</td>
<td>61</td>
<td>V-0</td>
<td>-26</td>
<td>11</td>
<td>17</td>
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<tr>
<td></td>
<td>Vamac® Ultra DX</td>
<td>Ultra DX/Hytrel® 70/30</td>
<td>EVM 700</td>
<td></td>
<td>37</td>
<td>37</td>
<td>34</td>
<td>0,11</td>
<td>0,06</td>
<td>0,07</td>
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<td></td>
<td></td>
<td>38</td>
<td>295</td>
<td>67</td>
<td>V-0</td>
<td>-27</td>
<td>8</td>
<td>15</td>
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<td>35</td>
<td>791</td>
<td>51</td>
<td>V-0</td>
<td>-16</td>
<td>6</td>
<td>12</td>
</tr>
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</table>

Compounds contain 150phr ATH
### HNBR/EVM Blend vs HNBR/Vamac® Blend

<table>
<thead>
<tr>
<th></th>
<th>HNBR LT/EVM500 50/50</th>
<th>HNBR LT/DX 50/50</th>
<th>HNBR LT/DX 30/70</th>
<th>HNBR/DX/LT 30/35/35</th>
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</thead>
<tbody>
<tr>
<td>Shore A</td>
<td>69</td>
<td>64</td>
<td>64</td>
<td>67</td>
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<tr>
<td>Tensile Strength [MPa]</td>
<td>6,7</td>
<td>7,0</td>
<td>6,5</td>
<td>6,3</td>
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<tr>
<td>Elongation at break [%]</td>
<td>429</td>
<td>534</td>
<td>520</td>
<td>176</td>
</tr>
<tr>
<td>Tear Strength [kN/m]</td>
<td>25</td>
<td>25</td>
<td>27</td>
<td>35</td>
</tr>
<tr>
<td>UL94</td>
<td>V-0</td>
<td>V-0</td>
<td>V-0</td>
<td>V-0</td>
</tr>
<tr>
<td>Oxygen Concentration [%]</td>
<td>28</td>
<td>31</td>
<td>33</td>
<td>33</td>
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<tr>
<td>Fluid ageing 168 hours at 100°C in IRM 903</td>
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<tr>
<td>Hardness Change</td>
<td>-22</td>
<td>-10</td>
<td>-13</td>
<td>-11</td>
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<tr>
<td>Tensile properties (type 2) at 23°C</td>
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<td></td>
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<tr>
<td>Tensile Strength [MPa]</td>
<td>3,5</td>
<td>5,7</td>
<td>6,0</td>
<td>7,4</td>
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<tr>
<td>Delta TS [%]</td>
<td>-48</td>
<td>-18</td>
<td>-7</td>
<td>18</td>
</tr>
<tr>
<td>Elongation at break [%]</td>
<td>335</td>
<td>481</td>
<td>486</td>
<td>140</td>
</tr>
<tr>
<td>Delta Elong. [%]</td>
<td>-22</td>
<td>-10</td>
<td>-7</td>
<td>-20</td>
</tr>
<tr>
<td>Volume change [%]</td>
<td>47</td>
<td>23</td>
<td>25</td>
<td>32</td>
</tr>
</tbody>
</table>

- Substitution of EVM500 with Vamac Ultra DX in a 50/50 blend with HNBR LT gives similar physical properties and Tg with improved oil resistance.
- Increasing Ultra DX to 70phr gives similar results and leads to higher LOI but 5°C increase of Tg.
- Replacing 50% of Ultra DX in the 30/70 blend with Ultra LT (low temperature AEM) gives the same Tg as the HNBR LT/EVM500 blend with decreased Eb (interaction of Vamac LT with ATH) and improved IRM903 resistance.
Summary Vamac® Key Performance Features

- Very good chemical resistance to a variety of fluids (oils, transmission fluids, acids etc.) except fuels
- Continuous service temperature of 160°C with standard grades and 175°C with VMX5000 grades
- Short term excursions to as high as 200°C
- Excellent compressive stress relaxation (CSR) properties in sealing
- Low compression set at 150°C
- Low temperature flexibility (-35°C / -40°C)
- Halogen free polymer that can be compounded into flame retardant materials

Vamac® compounds offer an interesting set of properties that might be useful to some applications in the O&G field