

DuPont™ Vamac® VMX5000 Series

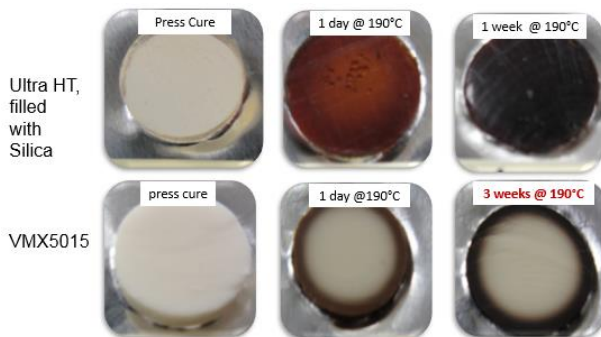
Ethylene Acrylic Elastomer (AEM) for High Temperature and Best Oil Resistant Sealing Applications

Vamac® VMX5000 - What is it?

DuPont™ Vamac® ethylene acrylic elastomers (AEM) have been successfully used for many years in sealing applications such as cam cover, oil pan gaskets, O-rings and other seals in the air and oil circuit with very good oil resistance in a temperature range between -40 and +160°C.

Standard Vamac® compounds use carbon black or inorganic fillers for reinforcement, which however accelerate oxidative degradation. The VMX5000 pre-compound series utilize a novel filler system that provide very good physical properties, comparable to Carbon Black, but do not hurt heat ageing of the final compounds.

To visualize this effect, Compression Set buttons made from a silica filled Vamac® Ultra HT and a VMX5015 based compound were submitted to different ageing conditions. There were then cut in half, please see the pictures below. Whilst the silica filled compound gets black and brittle after only 1 week at 190°C, VMX5015 was still clear white inside and flexible even after 3 weeks at 190°C.

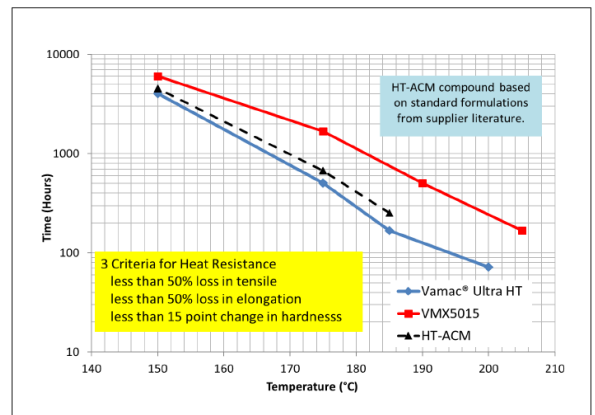


Vamac® VMX5000 Grades for Seals

| Grade | ML (1+4), 100°C | Tg by DSC °C | Density, g/cc | Key Feature |
|---------|-----------------|--------------|---------------|-------------------------------------|
| VMX5015 | 67 | -30 | 1.07 | Compression Molding, best Physicals |
| VMX5020 | 53 | -30 | 1.07 | Injection Molding |

Improved Heat Resistance

Vamac VMX5000 series pre-compounds offer by 10 to 15°C improved heat resistance over conventional carbon black filled AEM or HT-ACM. The below chart shows temperature rating based on three industry-accepted criteria: less than 50% loss in Tensile Strength and Elongation at Break, and less than 15-point change in Shore A Hardness.



Graph 1: Heat Resistance of VMX5000 vs carbon black filled AEM and ACM

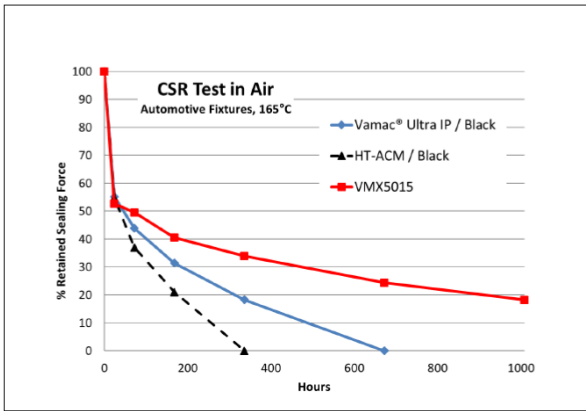
Vamac VMX5000 series pre-compounds can be seen as an interesting cost-effective alternative to FKM materials in the temperature range between -35 to +175°C, especially when good resistance to aggressive oil-acid mixtures is required.



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Improved Sealing Performance

Industry standard tests for sealing performance include compression set (CS) and compressive stress relaxation (CSR). Carbon Black filled AEM is known for its excellent performance in CSR testing vs. ACM or HT-ACM. VMX5000 based compounds offer a further improvement in long term CSR tests in air, as can be seen in Chart No.2.



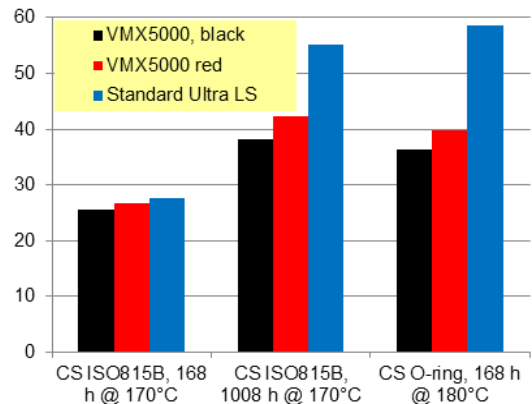
Graph 2: CSR in Air of VMX5000 vs carbon black filled AEM and ACM

Results of these tests often depend on part geometry. When tested in air or oil, a test specimen with a high surface area to volume ratio (like a D214 O-ring) experiences greater oxidation and therefore greater degradation of sealing properties than a larger specimen like an ASTM D395 type 1 button.

Three different compound have been used for a study showing effects of part shape and duration of tests.

| Formulation | VMX5015 black | VMX5015 red | Ultra LS, standard |
|-----------------------|---------------|-------------|--------------------|
| VMX5105 | 100 | 100 | |
| Vamac® Ultra LS | | | 100 |
| Vamac® Ultra IP | 50 | 50 | |
| Process aids | 1.5 | 1.5 | 2.5 |
| DPA Antioxidant | | | 2 |
| 4-ADA Antioxidant | 1.4 | 1.4 | |
| FEF N-550 | | | 10 |
| MT N-990 | 15 | | 50 |
| Aminosilane 70% | | 0.25 | |
| Silica VN2 | 15 | 10 | 50 |
| Red inorganic pigment | | 1.5 | |
| Plasticizer | 5 | 5 | 5 |
| HMDC Curative | 1.25 | 1.25 | 1.4 |
| DBU (70%) | 2 | 2 | 2 |

When comparing CS of 60 Shore A compounds, based on VMX5015 with either Carbon Black (15 phr) or silica with red pigment for colored compounds, and a traditional carbon black filled Vamac® Ultra LS compound, significant differences in CS can be found.



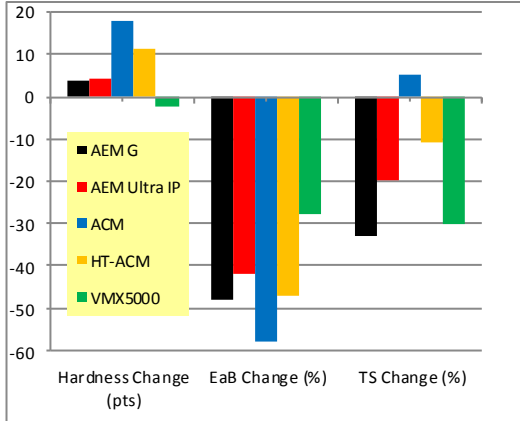
Graph 3: Compression Set VMX5000, different test conditions and specimen

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Aging and Compression Set in New Automotive Oils

New transmission and engine oils are based on synthetic, and more and more aliphatic base oils, causing lower volume swell to polar elastomers.

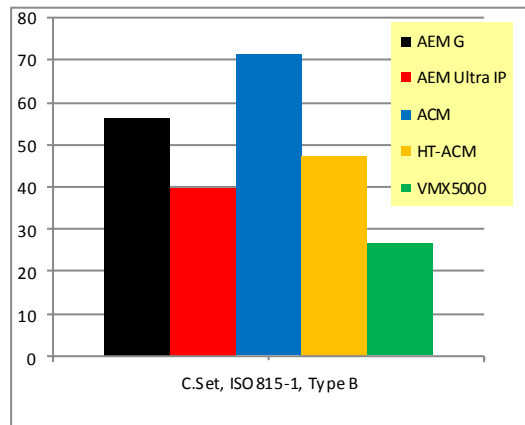
On the other side, additive packages used in these oils are becoming more and more aggressive, causing significant additional crosslinks during oil ageing tests. Five different AEM, ACM and VMX5000 compounds in the range of 60 ShA have been immersed for six weeks at 150°C in low viscosity engine oil Lukoil Genesis MC 0W-20.



Graph 4: Property Change after 1008h/150°C in Engine Oil Lukoil Genesis MC 0W-20

Carbon black filled AEM and especially ACM compounds show strong Hardness increase and loss in Elongation at Break. VMX5000 offers significant improvement in this respect. These additional crosslinks also have negative effect on long term Compression Set in such oils.

| Formulation | AEM G | Ultra IP | ACM | HT-ACM | VMX 5000 |
|---------------------|-------|----------|-----|--------|----------|
| Vamac® G | 100 | | | | |
| Vamac® Ultra IP | | 100 | | | 50 |
| ACM | | | 100 | | |
| HT-ACM | | | | 100 | |
| VMX5015 | | | | | 100 |
| Process aids | 3.5 | 3.5 | 3 | 3 | 2 |
| DPA Antioxidant | 2 | 2 | 2 | 2 | |
| 4-ADA Antioxidant | | | | | 2 |
| Plasticizer (810TM) | 15 | 15 | 5 | 5 | 7 |
| FEF N-550 | 40 | 40 | 62 | 58 | 2 |
| MT N-990 | 20 | 20 | | | 22 |
| HMDC Curative | 1.4 | 1.4 | | 0.6 | 1.25 |
| DBU (55%) | 2 | 2 | | 1 | 2 |
| NPC50 Curative | | | | 4 | |
| SR50 | | | | 4 | |
| Hardness ShA, 1s | 61 | 62 | 57 | 59 | 63 |



Graph 5: Compression Set after 1008h/150°C Lukoil Genesis MC 0W-20

Vamac® VMX5000 Benefits Summary

- ❑ **Extended Temperature Range:** -35°C to 175°C, possibility to replace FKM in some areas
- ❑ **Improved Oil Resistance:** New engine oils, transmission fluids, power steering fluids
- ❑ **Improved Sealing Performance:** In black and colored compounds



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