# Vamac® Ultra LS

Ethylene Acrylic Elastomer - Technical Data

## Description

Vamac® Ultra LS is a high viscosity version of Vamac® GLS, offering improved performance in injection molding processes compared to Vamac® GLS to reduce the frequency of mold cleaning.

Product Properties

| Property | Target Values | Method |
|---|---|---|
| Mooney Viscosity ML1+4 at 100 °C | 33 | ASTM D1646 |
| Volatiles | ≤0.6 wt % | Internal DuPont Test |
| Form (25kg nominal bale size) | 51.6 x 34.4 x 13.6 cm | Visual Inspection |
| Color | Clear to light yellow translucent | Visual Inspection |

## Major Performance Properties and Applications

The high viscosity of Vamac® Ultra LS compared to standard AEM grades results in better mixing, provided mixing conditions are adapted to requirements of polymers with higher viscosity. Increased green strength of compounds helps to avoid collapse during extrusion processes. The optimized polymer structure ensures gains in physical properties, resulting in improved performance of rubber parts such as seals, dampers and extruded hoses.

The best physical properties of Vamac® Ultra LS are obtained in rubber parts having a hardness range between 50 and 90 Shore A. Extensions to the lower hardness range may be more easily achieved with Vamac® Ultra grades than standard AEM using appropriate compounding.

Among AEM, Vamac® Ultra LS offers the best compression set and fast cure with low oil swell useful such applications as oil seals, oil cooler hose, and PCV hose.

## Handling Precautions

Because Vamac® ethylene-acrylic elastomers contain small amounts of residual methyl acrylate monomer, adequate ventilation should be provided during storage and processing to prevent worker exposure to methyl acrylate vapor. Additional information may be found in the Vamac® product Safety Data Sheet (SDS), and DuPont™ bulletin, *Safe Handling and Processing of Vamac®*.





VME-A11037-00-E0321

# Vamac® Ultra LS

Ethylene Acrylic Elastomer - Technical Data

## Mixing

Vamac® Ultra LS has higher viscosity than Vamac® GLS which permits better and faster dispersion of fillers and other compounding ingredients. Low hardness compounds or formulations with high plasticizer levels benefit most from this property. The higher viscosity of Ultra LS however results in an onset of incorporation of powdery ingredients at higher temperature than for lower viscosity Vamac® grades.

It is therefore recommended to ensure that the total time at mixing temperatures between 80 and 100°C is identical as for standard grades that processing conditions are adjusted, for example by reducing rotor speed. If the compound is discharged in relation to mass temperature at identical mixing conditions, the higher viscosity of the Ultra grades would lead to higher shear forces and faster temperature increase, followed by earlier discharge of the compound, and shorter time for dispersion of fillers and other ingredients. Bad dispersion would necessarily lead to poorer compound properties and mould fouling.

## Compounding and Physical Properties

Physical properties of the Ultra grades are known to be significantly superior to their lower viscosity reference grades at same methyl acrylate level. Both families are fully compatible to each other and can be blended at every ratio required. Ultra LS requires lower levels of diamine curative than Vamac® GLS for the same compression set levels, whilst at the same time achieving highest Elongation at Break.

Property losses, known from a replacement of formerly used coagent DOTG with alternative accelerators, can be compensated by use of Vamac® Ultra grades.

# Vamac® Ultra LS

Ethylene Acrylic Elastomer - Technical Data

Table 1 – DOTG Replacement Study: Vamac® GLS and Vamac® Ultra LS

| Compound No. | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Vamac® GLS | 100 | 100 | 50 | 50 | |
| Vamac® Ultra LS | | | 50 | 50 | 100 |
| Naugard® 445 | 2 | 2 | 2 | 2 | 2 |
| Armeen® 18D | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Vanfre® VAM | 1 | 1 | 1 | 1 | 1 |
| Stearic acid | 1.5 | 1.5 | 1.5 | 1.5 | 1.5 |
| Spheron® SO A N 550 | 60 | 60 | 60 | 60 | 60 |
| Rhenosin® W 759 | 10 | 10 | 10 | 10 | 10 |
| Diak™ No 1 | 1.75 | 1.75 | 1.5 | 1.25 | 1.25 |
| Vulcofac® ACT 55 | | 2 | 2 | 4 | 2 |
| Ekaland® DOTG C | 4 | | | | |
| | | | | | |
| Mooney Viscosity ML 1+4, 100°C, MU | 37 | 40 | 54 | 51 | 64 |
| Mooney Scorch MS 121°C (Ts5), min | 9.1 | 7.7 | 8.2 | 7.1 | 9.5 |
| | | | | | |
| MDR, 0.5°arc, 12 minutes at 180°C | | | | | |
| ML, dNm | 0.37 | 0.45 | 0.61 | 0.62 | 0.77 |
| MH, dNm | 14.46 | 14.33 | 14.62 | 13.73 | 14.68 |
| Ts2, min | 0.85 | 0.81 | 0.79 | 0.66 | 0.79 |
| T10, min | 0.72 | 0.69 | 0.67 | 0.56 | 0.67 |
| T50, min | 2.03 | 2.01 | 1.93 | 1.37 | 1.94 |
| T90, min | 6.34 | 6.62 | 6.22 | 4.54 | 6.01 |





VME-A11037-00-E0321

# Vamac® Ultra LS

Ethylene Acrylic Elastomer - Technical Data

Table 1 (continued) – DOTG Replacement Study: Vamac® GLS and Vamac® Ultra LS

| Compound No. | 1 | 2 | 3 | 4 | 5 |
|---|---|---|---|---|---|
| Original Properties (type 2) at 23°C | | | | | |
| Cure Time, 5 min at 180°C / Post-Cured, 4 hr at 175°C | | | | | |
| Hardness Shore A (1s), pts | 73 | 76 | 76 | 75 | 74 |
| Tensile Strength, MPa | 14.9 | 17.1 | 17.5 | 15.9 | 17.9 |
| Elongation at Break, % | 259 | 211 | 234 | 251 | 290 |
| 50% Modulus, MPa | 2.4 | 3.3 | 3.2 | 2.9 | 2.8 |
| 100% Modulus, MPa | 5.7 | 7.8 | 7.4 | 6.4 | 6.1 |
| Tear Die C at 23°C, N/mm | 26.7 | 23.0 | 24.8 | 26.5 | 27.0 |
| | | | | | |
| Comp Set, 70 h at 150°C (ISO815), % | 21 | 28 | 26 | 27 | 24 |
| Comp Set, 94 h at 150°C (VW PV3307), % | 49 | 57 | 71 | 77 | 49 |
| Comp Set, 22 h at 150°C, 2h cooled in clamps, % | 22 | 28 | 28 | 32 | 29 |

### Compounding Variations for Faster Cure

Vamac® Ultra grades are cleaner in injection molding and do not tend to stick to metallic surfaces of mixing or moulding equipment as much as lower viscosity AEM polymers. This can allow further optimization and variations in compounding, such as reduction of process aids. Possible advantages would be a reduced tendency to get flow lines on injection molded parts, or further acceleration of cure speed and reduction of cure cycle time, or optimization of Compression Set. Some compounding variations with 60 Shore A general purpose sealing compounds are shown in Table 2.

Further optimization of Compression Set can be achieved by using lower volatile plasticizers, as shown in Table 2, compounds No. 6 and 7. By optimizing compound formulations, cure times can be reduced by about 40 to 50%, as can be seen when comparing compound No. 6 and 11. At the same time, scorch times are reduced as well, but compound flow of 60 Shore A compound with 15 phr of plasticizer is typically sufficient to fill even molds with complex shape. Compression Set values before post-cure are reduced significantly as well. For some parts like molded air ducts, the values obtained without process aids and a more heat resistant plasticizer may be adequate even without post-cure. Outstanding Compression set values may be obtained in some cases after a very short post-cure cycle, which can be of help when post-cure oven capacities are limited.

# Vamac® Ultra LS

Ethylene Acrylic Elastomer - Technical Data

Table 2 – Vamac® Ultra LS Compounding Variations for Faster Cure and improved Comp Set

| Compound No. | 6 | 7 | 8 | 9 | 10 | 11 |
|---|---|---|---|---|---|---|
| Vamac® Ultra LS | 100 | 100 | 100 | 100 | 100 | 100 |
| Naugard® 445 | 2 | 2 | 2 | 2 | 2 | 2 |
| Vanfre® VAM | 1 | 1 | | | | |
| Armeen® 18D | 0.5 | 0.5 | 0.5 | | | |
| Stearic acid | 2 | 2 | 2 | 2 | | |
| MT Thermax® Floform N 990 | 20 | 20 | 20 | 20 | 20 | 20 |
| Regal® SRF N 772 | 45 | 45 | 45 | 45 | 45 | 45 |
| Rhenosin® W 759 | 15 | | | | | |
| Edenol® TOT stabilized | | 15 | 15 | 15 | 15 | 15 |
| Diak™ No 1 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 | 1.3 |
| Vulcofac® ACT 55 | 3 | 3 | 3 | 3 | 3 | |
| Alcanpoudre® DBU-70 | | | | | | 3 |
| | | | | | | |
| Mooney, ML1+4, 100°C, MU | 30.8 | 33.4 | 35.7 | 36.6 | 44.1 | 46.3 |
| MDR, 15 min at 180°C, arc 0.5° | | | | | | |
| ML, dNm | 0.28 | 0.29 | 0.31 | 0.34 | 0.4 | 0.37 |
| MH, dNm | 9.56 | 10.41 | 10.51 | 11.14 | 11.65 | 11.1 |
| Ts2, min | 0.97 | 0.93 | 0.87 | 0.75 | 0.72 | 0.63 |
| T50, min | 1.85 | 1.88 | 1.74 | 1.48 | 1.45 | 1.19 |
| T90, min | 6.42 | 6.62 | 6.28 | 5.41 | 5.45 | 3.58 |
| | | | | | | |
| Compression Moulding 5 min at 190°C / No Post-Cure | | | | | | |
| Comp Set, 24 h /150°C, plied, % | 56 | 54 | 50 | 46 | 50 | 45 |
| Comp Set, VW PV3307, 94 h /150°C, % | 86 | 83 | 30 | 79 | 78 | 76 |
| | | | | | | |
| Compression Moulding 1 min at 210°C / Post-Cure 30 min at 175°C | | | | | | |
| Comp Set, 24 h /150°C, plied, % | 30 | 27 | 25 | 25 | 24 | 25 |
| Comp Set, VW PV3307, 94 h /150°C, % | 71 | 64 | 65 | 65 | 64 | 62 |
| Hardness, Shore A (1s), pts | 58 | 58 | 58 | 59 | 59 | 59 |
| Tensile Strength, MPa | 14.1 | 15.3 | 15.0 | 14.9 | 15.4 | 14.1 |
| Elongation at Break, % | 368 | 386 | 370 | 338 | 330 | 330 |
| 100% Modulus, MPa | 2.5 | 2.4 | 2.6 | 2.9 | 3.0 | 3.1 |

# Vamac® Ultra LS

Ethylene Acrylic Elastomer - Technical Data

## Heat Resistance

Vamac® Ultra LS combines excellent dry heat resistance at about 170 °C over a period of 1000 h (six weeks) with very good resistance to automotive lubricants. Peak temperatures of 200°C are possible without major property changes up to four days. Sealing applications typically require resistance to upper temperature of 150°C maximum, as automotive lubricants would not withstand higher temperatures.

At the same time, Tg of -25°C of Ultra LS provides very good low temperature flexibility. The low temperature properties may be further enhanced by addition of plasticizers. In comparison to standard Vamac® grades, the high viscosity of Ultra LS permits addition of more plasticizer, while still maintaining a compound viscosity that allows good filler dispersion and good processing.

Good compression set properties make Vamac® Ultra LS an excellent choice for sealing applications. Good resistance to Blow-By (hot air, acids, oil and petrol fumes), present in automotive crankcase venting systems and air ducts combined with increased dynamic resistance are additional attributes of Vamac® Ultra LS. The resistance to water-based acids and blow-by can be further improved by blending Ultra LS with Vamac® grades with lower methyl acrylate content, such as Vamac® Ultra IP.

Heat ageing performance at elevated temperature is shown in Table 3. Compression Set is partially influenced by loss of plasticizer, as can be seen from weight loss data.

Table 3 – Heat Ageing and Compression Set of Vamac® Ultra LS at 180 °C and 165 °C

| Compound No. | 12 | 13 |
|---|---|---|
| Vamac® Ultra LS | 100 | 100 |
| Naugard® 445 | 2 | 2 |
| Armeen® 18D PRILLS | 0.5 | 0.5 |
| Vanfre® VAM | 0.5 | 0.5 |
| Stearic acid | 2 | 2 |
| Spheron® SO A N 550 | 35 | 35 |
| Nycoflex® ADB 30 | 10 | |
| Edenol® T810T stabilized | | 10 |
| Diak™ no 1 | 1.5 | 1.5 |
| Vulcofac® ACT 55 | 2 | 2 |

# Vamac® Ultra LS

Ethylene Acrylic Elastomer - Technical Data

Table 3 (continued) – Heat Ageing and Compression Set of Vamac® Ultra LS at 180 °C and 165 °C

| Compound No. | 12 | 13 |
|---|---|---|
| Original Properties (type 2) at 23ºC | | |
| Compression Moulding 10 min at 180°C / Post-cure 4 hours at 175°C | | |
| Hardness IRHD – (ISO 48, Method M /micro-test), pts | 55 | 56 |
| Tensile Strength, MPa | 17.6 | 17.8 |
| Elongation at Break, % | 350 | 343 |
| 100% Modulus, MPa | 2.78 | 2.80 |
| C. set 72 h at 180°C, (ISO 815-1, Type A /13 mm moulded buttons), % | 26 | 20 |
| C. set 1028 h at 165°C (Type A), % | 43 | 29 |
| C. set 1028 h at 165°C (Type A in Total MA4 G06190, 5W30), % | 32 | 23 |
| Heat Ageing 168 hours at 180°C | | |
| Hardness IRHD – (ISO 48, Method M /micro-test), pts | 57 | 54 |
| Delta Hardness (ISO 188), pts | 2 | -2 |
| Tensile Strength, MPa | 16.7 | 16.5 |
| Delta Tensile Strength, % | -5 | -7 |
| Elongation at Break, % | 369 | 368 |
| Delta Elongation at Break, % | 5 | 7 |
| 100% Modulus, MPa | 3.0 | 2.8 |
| Weight Change, % | -5.1 | -3.0 |
| Heat Ageing 1008 hours at 165°C | | |
| Hardness IRHD – (ISO 48, Method M /micro-test), pts | 68 | 62 |
| Delta Hardness (ISO 188), pts | 13 | 7 |
| Tensile Strength, MPa | 9.6 | 12.0 |
| Delta Tensile Strength, % | -45 | -32 |
| Elongation at Break, % | 177 | 257 |
| Delta Elongation at Break, % | -49 | -25 |
| 100% Modulus, MPa | 4.7 | 3.4 |
| Weight Change, % | -9.6 | -6.5 |

# Vamac® Ultra LS

Ethylene Acrylic Elastomer - Technical Data

**Long term sealing performance**

In Compression Set and Compressive Stress Relaxation (CSR) tests, Vamac® Ultra grades have outperformed their respective standard Vamac® grades. Table 4 shows various Compression Set results of five different 60 Shore A compounds which differ from each other in polymer type, curative level and plasticizer content. Charts 1 to 3 show CSR results of these compounds in Engine Oil, in Automatic Transmission Fluid and in Air at 150°C. Tests were conducted according to ISO3384, Type B, with 6 mm high buttons on Shawbury-Wallace testing equipment for 504 hours.

Table 4 – Comparison of Compression Set: Vamac® Ultra IP and Vamac® Ultra LS

| Compound No. | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|
| Vamac® Ultra IP | 100 | | | | |
| Vamac® Ultra LS | | 100 | 100 | 100 | 100 |
| Regal® SRF N 772 | 50 | 50 | 50 | 40 | 30 |
| MT Thermax® Floform N 990 | 20 | 20 | 20 | 20 | 20 |
| Nycoflex® ADB 30 | 20 | 20 | 20 | 10 | |
| Naugard® 445 | 2 | 2 | 2 | 2 | 2 |
| Stearic acid | 1 | 1 | 1 | 1 | 1 |
| Armeen® 18D PRILLS | 0.5 | 0.5 | 0.5 | 0.5 | 0.5 |
| Vanfre® VAM | 1 | 1 | 1 | 1 | 1 |
| Rubber chem Diak™ no 1 | 1.3 | 1.75 | 1.3 | 1.3 | 1.3 |
| Vulcofac® ACT 55 | 3 | 3 | 3 | 3 | 3 |
| | | | | | |
| Original Properties (type 2) at 23°C | | | | | |
| Compression Moulding 10 min at 180°C / Post-cure 4 hrs at 175°C | | | | | |
| Hardness Shore A (1s), pts | 60 | 63 | 61 | 61 | 63 |
| Tensile Strength, MPa | 16.0 | 15.8 | 16.0 | 16.8 | 18.5 |
| Elongation at Break, % | 363 | 313 | 346 | 352 | 356 |
| 100% Modulus, MPa | 2.7 | 3.4 | 2.9 | 2.8 | 3.2 |
| Tear Strength (type C- Crescent), kN/m | 24.1 | 21.2 | 22.6 | 23.5 | 16.7 |
| Tg by DSC (ISO 22768), °C | -44 | -40 | -40 | -33 | -23 |

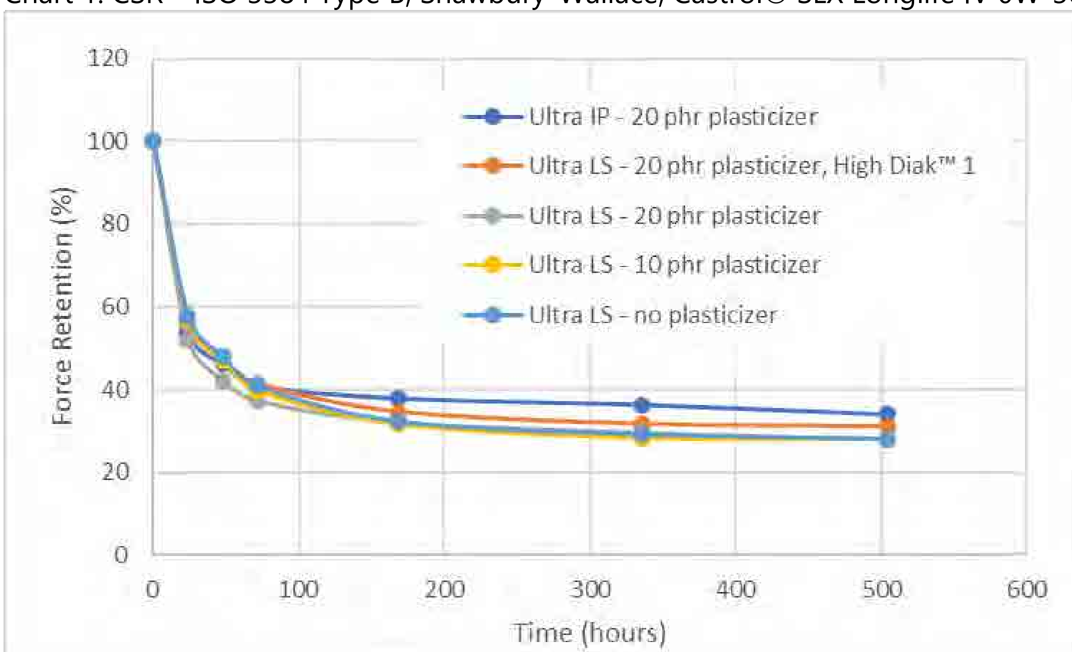
# Vamac® Ultra LS

Ethylene Acrylic Elastomer - Technical Data

Table 4 (continued) – Comparison of Compression Set: Vamac® Ultra IP and Vamac® Ultra LS

| Compound No. | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|
| Compression Set | | | | | |
| Compression Moulding 10 min at 180°C / Post-cure 4 hrs at 175°C | | | | | |
| Comp Set, VW 22 h at 150°C (VW PV 3307), % | 52 | 39 | 43 | 41 | 38 |
| Comp Set, VW 94 h at 23°C (VW PV 3307), % | 29 | 20 | 27 | 25 | 26 |
| Comp Set 70 h at 150°C (ISO 815-1, 6mm plied disks), % | 26 | 24 | 26 | 22 | 18 |
| Comp Set 70 h at 150°C (ISO 815-1, 6mm moulded buttons), % | 24 | 20 | 22 | 20 | 17 |
| Comp Set at 150°C (ISO-815-1, Type A, 13 mm buttons) | | | | | |
| 70 h, % | 16 | 14 | 15 | 13 | 12 |
| 168 h, % | 20 | 19 | 20 | 18 | 14 |
| 504 h, % | 28 | 29 | 28 | 25 | 23 |
| 1008 h, % | 34 | 37 | 34 | 33 | 30 |
| 168 h in Castrol® SLX Longlife IV 0W-30, % | 28 | 25 | 27 | 22 | 16 |

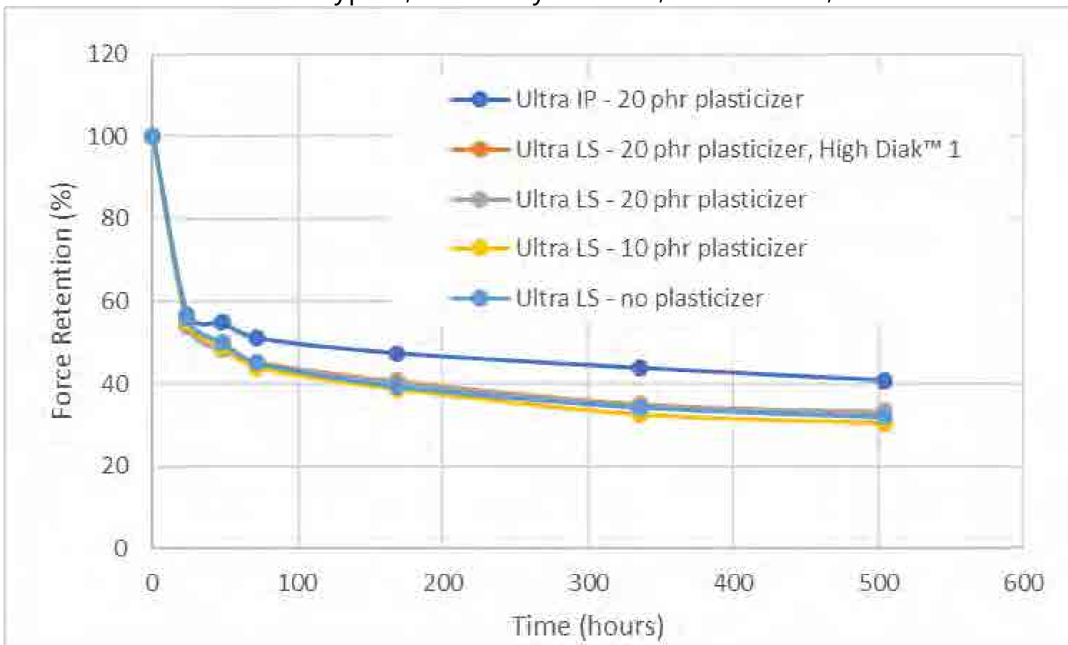
Chart 1: CSR – ISO 3384 Type B, Shawbury-Wallace, Castrol® SLX Longlife IV 0W-30, 150°C



# Vamac® Ultra LS

Ethylene Acrylic Elastomer - Technical Data

Chart 2: CSR – ISO 3384 Type B, Shawbury-Wallace, Dexron® VI, 150°C







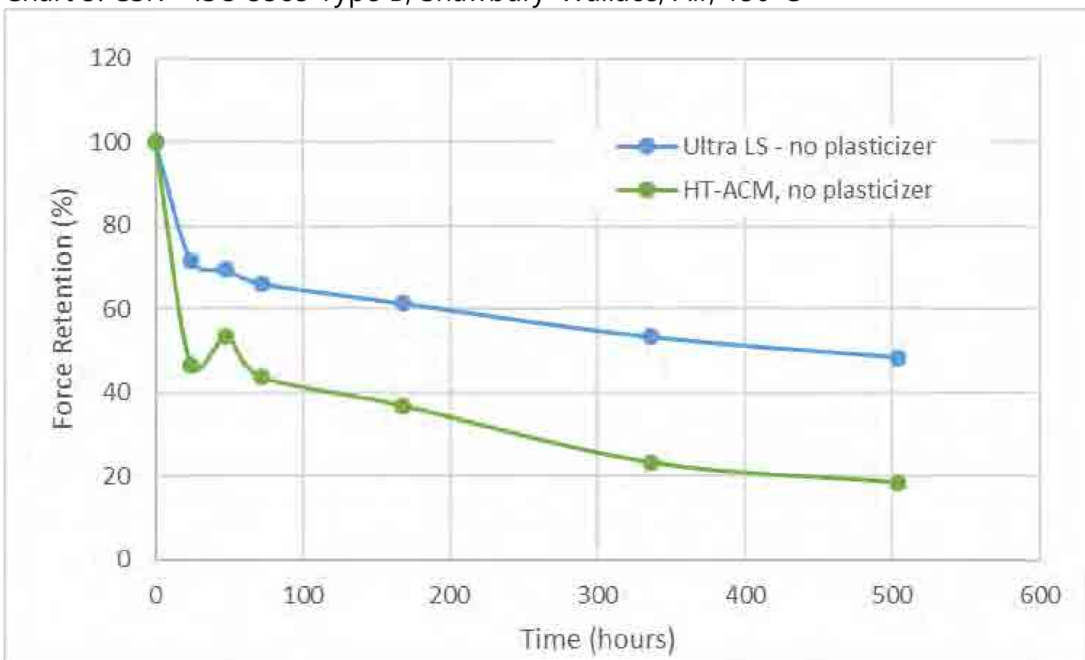

VME-A11037-00-E0321

# Vamac® Ultra LS

Ethylene Acrylic Elastomer - Technical Data

In Compressive Stress Relaxation (CSR) tests, Vamac® Ultra grades have not only outperformed their respective standard Vamac® grades, they also have increased the gap in long time sealing performance to polyacrylates. Chart 3 shows CSR test results of two 60 Shore A compounds without any plasticizer, based on both types of polymers.

Chart 3: CSR – ISO 3385 Type B, Shawbury-Wallace, Air, 150°C



# Vamac® Ultra LS

Ethylene Acrylic Elastomer - Technical Data

**Ageing in different Automotive Fluids – Oils, Oil/Fuel Blends**

Vamac® Ultra LS and Vamac® Ultra IP are both members of the higher viscosity Vamac® Ultra family. The difference between both polymers is the methyl acrylate (MA) content, which is significantly higher for Ultra LS. Whereas low MA content favours resistance to water-based fluids, high MA content provides better resistance to hydrocarbon-based fluids present in automotive engines. Compounds No. 14-18 shown in Table 4 have been aged in different fluids. Results after ageing in engine and transmission oils at 150°C and oil/fuel blends at room temperature are shown in Table 5. B-30 is a mixture of Diesel with 30% Biodiesel (RME), and E-85 is a blend of gasoline with 85% of Ethanol.

Table 5 – Fluid Ageing Results: Oils, Oil/Fuel Blends

| Compound No. | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|
| Fluid Ageing 168 h at 150°C in IRM 903 | | | | | |
| Hardness Shore A (1s), pts | 47 | 59 | 57 | 54 | 53 |
| Delta Hardness, pts | -13 | -4 | -4 | -7 | -9 |
| Tensile Strength, MPa | 11.1 | 14.9 | 14.4 | 14.6 | 14.8 |
| Delta Tensile Strength, % | -31 | -6 | -10 | -13 | -20 |
| Elongation at Break, % | 240 | 269 | 300 | 293 | 243 |
| Delta Elongation at Break, % | -34 | -14 | -13 | -17 | -32 |
| 100% Modulus, MPa | 3.4 | 4.0 | 3.4 | 3.5 | 3.5 |
| Delta 100% Modulus, % | 25 | 16 | 15 | 24 | 7 |
| Volume Change, % | 47 | 19 | 20 | 26 | 34 |
| Weight Change, % | 34 | 13 | 13 | 19 | 26 |
| Fluid Ageing 168 h at 150°C in Castrol® SLX Longlife IV, 0W-30 | | | | | |
| Hardness Shore A (1s), pts | 63 | 73 | 71 | 67 | 61 |
| Delta Hardness, pts | 4 | 10 | 10 | 6 | -2 |
| Tensile Strength, MPa | 15.2 | 15.2 | 15.1 | 16.4 | 16.2 |
| Delta Tensile Strength, % | -5 | -4 | -5 | -2 | -13 |
| Elongation at Break, % | 328 | 276 | 309 | 313 | 301 |
| Delta Elongation at Break, % | -10 | -12 | -11 | -11 | -15 |
| 100% Modulus, MPa | 3.0 | 4.2 | 3.7 | 3.5 | 3.3 |
| Delta 100% Modulus, % | 12 | 24 | 26 | 27 | 3 |
| Volume Change, % | -1 | -6 | -7 | -2 | 5 |
| Weight Change, % | -3 | -6 | -7 | -3 | 3 |

# Vamac® Ultra LS

Ethylene Acrylic Elastomer - Technical Data

Table 5 (continued) – Fluid Ageing Results: Oils, Oil/Fuel Blends

| Compound No. | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|
| Fluid Ageing 168 h at 150°C in Petro Canada Dexron® VI RDL 3434 | | | | | |
| Hardness Shore A (1s), pts | 61 | 70 | 69 | 63 | 60 |
| Delta Hardness, pts | 1 | 7 | 8 | 2 | -3 |
| Tensile Strength, MPa | 61 | 70 | 69 | 63 | 60 |
| Delta Tensile Strength, % | -4 | -2 | -6 | -2 | -12 |
| Elongation at Break, % | 304 | 229 | 247 | 283 | 242 |
| Delta Elongation at Break, % | -16 | -27 | -29 | -20 | -32 |
| 100% Modulus, MPa | 3.4 | 5.1 | 4.7 | 4.2 | 3.9 |
| Delta 100% Modulus, % | 25 | 49 | 60 | 50 | 21 |
| Volume Change, % | 8 | -1 | -1 | 5 | 11 |
| Weight Change, % | 4 | -2 | -2 | 2 | 8 |
| Fluid Ageing 168 h at 23°C in Mixture Castrol® SLX Longlife IV, 0W-30 / B-30 (90/10) | | | | | |
| Hardness Shore A (1s), pts | 59 | 62 | 60 | 59 | 59 |
| Delta Hardness, pts | -1 | -1 | -1 | -2 | -4 |
| Tensile Strength, MPa | 15.6 | 15.8 | 15.7 | 16.7 | 18.7 |
| Delta Tensile Strength, % | -3 | 1 | -1 | 0 | 1 |
| Elongation at Break, % | 372 | 318 | 360 | 362 | 352 |
| Delta Elongation at Break, % | 2 | 2 | 4 | 3 | -1 |
| 100% Modulus, MPa | 2.7 | 3.3 | 2.7 | 2.7 | 3.0 |
| Delta 100% Modulus, % | 1 | -4 | -9 | -3 | -7 |
| Volume Change, % | 1 | 0 | 0 | 0 | 0 |
| Weight Change, % | 1 | 0 | 0 | 0 | 0 |

# Vamac® Ultra LS

Ethylene Acrylic Elastomer - Technical Data

Table 5 (continued) – Fluid Ageing Results: Oils, Oil/Fuel Blends

| Compound No. | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|
| Fluid Ageing 168 h at 23°C in Mixture Castrol® SLX Longlife IV, 0W-30 / E-85 (90/10) | | | | | |
| Hardness Shore A (1s), pts | 50 | 55 | 53 | 50 | 52 |
| Delta Hardness, pts | -10 | -8 | -8 | -11 | -11 |
| Tensile Strength, MPa | 9.4 | 8.1 | 8.5 | 9.2 | 8.1 |
| Delta Tensile Strength, % | -41 | -48 | -47 | -45 | -56 |
| Elongation at Break, % | 232 | 178 | 214 | 216 | 189 |
| Delta Elongation at Break, % | -36 | -43 | -38 | -39 | -47 |
| 100% Modulus, MPa | 2.8 | 3.5 | 2.9 | 3.0 | 3.1 |
| Delta 100% Modulus, % | 3 | 3 | 0 | 7 | -3 |
| Volume Change, % | 24 | 22 | 22 | 25 | 29 |
| Weight Change, % | 15 | 13 | 13 | 16 | 19 |

## Ageing in Fuels

It is generally not recommended to use AEM in contact to liquid gasoline, as volume swell and permeation are very high. Contact to gasoline fumes however can be handled by Vamac® polymers depending on concentration. AEM compounds are not destroyed in gasoline, as physical properties after an appropriate re-drying step are nearly identical to original properties for compounds without plasticiser.

Compounds including plasticizer show weight loss after the re-drying step, which shows that the plasticizer is principally extracted by the fuel during immersion. Contact to Diesel fuel results in moderate swell of high MA Vamac® polymers like Ultra LS. Table 6 shows results after immersion in fuel.  Compounds are identical to those shown in Table 4.

# Vamac® Ultra LS

Ethylene Acrylic Elastomer - Technical Data

Table 6 – Ageing in Fuels

| Compound No. | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|
| Fluid Ageing 168 hours at 23°C in ASTM Fuel C or ISO Liquid C | | | | | |
| Hardness Shore A (1s), pts | 38 | 45 | 42 | 42 | 44 |
| Delta Hardness, pts | -22 | -18 | -19 | -19 | -19 |
| Tensile Strength, MPa | 4.4 | 5.3 | 5.0 | 4.9 | 5.1 |
| Delta Tensile Strength, % | -72 | -66 | -69 | -71 | -73 |
| Elongation at Break, % | 113 | 113 | 117 | 113 | 112 |
| Delta Elongation at Break, % | -69 | -64 | -66 | -68 | -69 |
| 100% Modulus, MPa | 3.8 | 4.5 | 3.7 | 4.1 | 4.3 |
| Delta 100% Modulus, % | 40 | 31 | 25 | 48 | 35 |
| Volume Change, % | 107 | 83 | 84 | 97 | 112 |
| Weight Change, % | 68 | 51 | 51 | 61 | 73 |
| Fluid Ageing 168 hours at 23°C in ASTM Fuel C or ISO Liquid C After re-drying 22h @ 80°C | | | | | |
| Hardness Shore A (1s), pts | 71 | 73 | 72 | 67 | 63 |
| Delta Hardness, pts | 11 | 10 | 11 | 6 | 1 |
| Tensile Strength, MPa | 17.3 | 17.7 | 17.2 | 18.8 | 18.4 |
| Delta Tensile Strength, % | 8 | 12 | 7 | 12 | -1 |
| Elongation at Break, % | 396 | 331 | 372 | 360 | 338 |
| Delta Elongation at Break, % | 9 | 6 | 7 | 2 | -5 |
| 100% Modulus, MPa | 3.1 | 3.9 | 3.4 | 3.2 | 3.0 |
| Delta 100% Modulus, % | 14 | 13 | 15 | 14 | -6 |
| Volume Change, % | -15 | -14 | -15 | -10 | -3 |
| Weight Change, % | -13 | -12 | -12 | -8 | -3 |

# Vamac® Ultra LS

Ethylene Acrylic Elastomer - Technical Data

Table 6 (continued) – Ageing in Fuels

| Compound No. | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|
| Fluid Ageing 48 hours at 23°C in DIN FAM B or ISO Liquid 2 | | | | | |
| Hardness Shore A (1s), pts | 48 | 53 | 50 | 50 | 50 |
| Delta Hardness, pts | -12 | -10 | -11 | -11 | -13 |
| Tensile Strength, MPa | 4.0 | 4.0 | 4.5 | 4.1 | 3.9 |
| Delta Tensile Strength, % | -75 | -75 | -72 | -76 | -79 |
| Elongation at Break, % | 93 | 80 | 94 | 87 | 76 |
| Delta Elongation at Break, % | -74 | -74 | -73 | -75 | -79 |
| 100% Modulus, MPa | - | - | - | - | - |
| Delta 100% Modulus, % | - | - | - | - | - |
| Volume Change, % | 159 | 134 | 150 | 154 | 176 |
| Weight Change, % | 101 | 84 | 94 | 99 | 114 |
| Fluid Ageing 48 hours at 23°C in DIN FAM B or ISO Liquid 2 After re-drying 22h @ 80°C | | | | | |
| Hardness Shore A (1s), pts | 71 | 72 | 73 | 68 | 63 |
| Delta Hardness, pts | 12 | 9 | 12 | 7 | 1 |
| Tensile Strength, MPa | 18.0 | 18.5 | 18.1 | 17.8 | 17.4 |
| Delta Tensile Strength, % | 13 | 18 | 13 | 6 | -6 |
| Elongation at Break, % | 387 | 334 | 362 | 332 | 311 |
| Delta Elongation at Break, % | 7 | 7 | 5 | -6 | -13 |
| 100% Modulus, MPa | 3.2 | 4.0 | 3.5 | 3.2 | 3.2 |
| Delta 100% Modulus, % | 16 | 16 | 19 | 16 | 0 |
| Volume Change, % | -16 | -15 | -16 | -11 | -4 |
| Weight Change, % | -14 | -12 | -13 | -9 | -4 |

# Vamac® Ultra LS

Ethylene Acrylic Elastomer - Technical Data

Table 6 (continued) – Ageing in Fuels

| Compound No. | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|
| Fluid Ageing 168 hours at 23°C in Conventional Diesel (from a Gas Station) | | | | | |
| Hardness Shore A (1s), pts | 50 | 56 | 54 | 52 | 53 |
| Delta Hardness, pts | -10 | -7 | -7 | -9 | -10 |
| Tensile Strength, MPa | 10.3 | 12.1 | 12.5 | 12.6 | 12.0 |
| Delta Tensile Strength, % | -36 | -23 | -22 | -25 | -35 |
| Elongation at Break, % | 246 | 247 | 290 | 274 | 252 |
| Delta Elongation at Break, % | -32 | -21 | -16 | -22 | -29 |
| 100% Modulus, MPa | 2.7 | 3.2 | 3.0 | 3.3 | 2.8 |
| Delta 100% Modulus, % | 1 | -5 | 3 | 17 | -14 |
| Volume Change, % | 27 | 13 | 13 | 17 | 20 |
| Weight Change, % | 17 | 8 | 7 | 11 | 14 |

## Ageing in Blow-By and EGR Condensates

AEM has been successfully used in applications which are in contact to blow-by such as positive crankcase ventilation hoses. Blow-by varies a lot depending on engine type and driving conditions, and includes fuel, engine oil and acid condensates. Exhaust gas recirculation (EGR) increases the amount of acids present in engines. Vamac® with its high ethylene monomer content, combined with highly polar MA ester monomer, offers a good combination of resistance to hydrocarbon fluids as well as to water-based acids. Compounds 14 to 18 of Table 5 have been tested in two different Blow-By condensates as defined in specification BMW GS 97018, 2010-11, and results are shown in Table 8. The tests were made with lab autoclaves that have been filled to 50% of their volume. The slabs have been hung into the liquid phase prior to ageing.

Table 7 – Condensates According to BMW GS 97018, 2010-11

| Condensate 1 (fuel/oil) | Weight % |
|---|---|
| Naphthalene | 1 |
| FAM-A (DIN51604-1) | 88 |
| Oil Lubrizol® OS206304 | 10 |
| Formaldehyde-10% | 1 |

| Condensate 2 (water/acid) | Weight % |
|---|---|
| Formaldehyde-10% | 1 |
| Deionized water | 89.7 |
| HNO3 (65%) | 0.18 |
| Formic Acid (98-100%) | 0.06 |
| Acetic Acid (96%) | 0.06 |
| Ethanol | 9 |

# Vamac® Ultra LS

Ethylene Acrylic Elastomer - Technical Data

Table 8 – Results after Ageing in BMW Condensates

| Compound No. | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|
| Fluid Ageing 70 h at 120°C in BMW Condensate 1 (fuel/oil condensate) | | | | | |
| Liquid Phase: Before re-drying | | | | | |
| Hardness Shore A (1s), pts | 43 | 47 | 44 | 45 | 47 |
| Delta Hardness, pts | -17 | -16 | -17 | -16 | -16 |
| Tensile Strength, MPa | 4.3 | 4.9 | 4.1 | 4.3 | 4.3 |
| Delta Tensile Strength, % | -73 | -69 | -74 | -74 | -77 |
| Elongation at Break, % | 107 | 119 | 110 | 116 | 114 |
| Delta Elongation at Break, % | -71 | -62 | -68 | -67 | -68 |
| 100% Modulus, MPa | 3.7 | 4.1 | 3.6 | 3.5 | 3.7 |
| Delta 100% Modulus, % | 37 | 20 | 23 | 25 | 17 |
| Volume Change, % | 136 | 72 | 113 | 88 | 102 |
| Weight Change, % | 84 | 45 | 68 | 56 | 67 |
| Fluid Ageing 70 h at 120°C in BMW Condensate 1 (fuel/oil condensate) | | | | | |
| Liquid Phase: After re-drying 22 h @ 80°C | | | | | |
| Hardness Shore A (1s), pts | 63 | 68 | 65 | 63 | 60 |
| Delta Hardness, pts | 3 | 5 | 4 | 2 | -3 |
| Tensile Strength, MPa | 15.2 | 15.7 | 15.3 | 16.9 | 17.1 |
| Delta Tensile Strength, % | -5 | -1 | -4 | 1 | -8 |
| Elongation at Break, % | 393 | 349 | 372 | 376 | 337 |
| Delta Elongation at Break, % | 8 | 12 | 7 | 7 | -5 |
| 100% Modulus, MPa | 2.9 | 3.5 | 3.0 | 3.0 | 3.0 |
| Delta 100% Modulus, % | 6 | 4 | 3 | 8 | -6 |
| Volume Change, % | -9 | -9 | -11 | -6 | 0 |
| Weight Change, % | -9 | -8 | -10 | -6 | -1 |

# Vamac® Ultra LS

Ethylene Acrylic Elastomer - Technical Data

Table 8 (continued) – Results after Ageing in BMW Condensates

| Compound No. | 14 | 15 | 16 | 17 | 18 |
|---|---|---|---|---|---|
| Fluid Ageing 70 h at 120°C in BMW Condensate 2 (acid condensate) | | | | | |
| Liquid Phase: Before re-drying | | | | | |
| Hardness Shore A (1s), pts | 61 | 63 | 62 | 59 | 57 |
| Delta Hardness, pts | 2 | 0 | 1 | -2 | -5 |
| Tensile Strength, MPa | 15.3 | 15.0 | 14.8 | 15.1 | 15.6 |
| Delta Tensile Strength, % | -4 | -5 | -7 | -10 | -16 |
| Elongation at Break, % | 393 | 347 | 387 | 358 | 361 |
| Delta Elongation at Break, % | 8 | 11 | 12 | 2 | 1 |
| 100% Modulus, MPa | 2.6 | 3.2 | 2.9 | 2.8 | 2.7 |
| Delta 100% Modulus, % | -4 | -8 | -2 | 0 | -15 |
| Volume Change, % | 2 | 1 | 1 | 6 | 12 |
| Weight Change, % | 1 | 0 | 0 | 4 | 10 |
| | | | | | |
| Fluid Ageing 70 h at 120°C in BMW Condensate 2 (acid condensate) | | | | | |
| Liquid Phase: After re-drying 22 h @ 80°C | | | | | |
| Hardness Shore A (1s), pts | 67 | 72 | 71 | 66 | 62 |
| Delta Hardness, pts | 7 | 9 | 10 | 5 | -1 |
| Tensile Strength, MPa | 16.2 | 16.2 | 16.1 | 17.5 | 18.2 |
| Delta Tensile Strength, % | 1 | 3 | 1 | 4 | -2 |
| Elongation at Break, % | 395 | 369 | 397 | 392 | 366 |
| Delta Elongation at Break, % | 9 | 18 | 15 | 11 | 3 |
| 100% Modulus, MPa | 3.1 | 3.6 | 3.2 | 3.1 | 3.0 |
| Delta 100% Modulus, % | 13 | 6 | 9 | 11 | -8 |
| Volume Change, % | -12 | -12 | -12 | -7 | -1 |
| Weight Change, % | -10 | -10 | -10 | -6 | -1 |





VME-A11037-00-E0321

# Vamac® Ultra LS

Ethylene Acrylic Elastomer - Technical Data

### Ageing in engine and transmission fluids

Volume Change in reference fluids is significant different to volume change in real automotive fluids.
New automotive lubricants show lower swell compared to older engine oils, but contain more aggressive additive packages, which could contribute to loss of properties of higher methyl acrylate grades during fluid ageing.

Blends of medium and high methyl acrylate AEM polymers are an efficient solution for fluid ageing requirements. Table 9 shows results after immersion in engine oil and ATF with compounds made of Vamac® Ultra IP, Vamac® Ultra LS and a 50/50 blend.

Table 9 - Ageing in Engine Oil and Automatic Transmission Fluid

| Compound No. | 19 | 20 | 21 |
|---|---|---|---|
| Vamac® Ultra IP | 100 | 50 | |
| Vamac® Ultra LS | | 50 | 100 |
| Stearic acid | 1 | 1 | 1 |
| Naugard® 445 | 2 | 2 | 2 |
| Armeen® 18D | 0.5 | 0.5 | 0.5 |
| Vanfre® VAM | 0.5 | 0.5 | 0.5 |
| Spheron® SOA (N 550) | 50 | 50 | 50 |
| Edenol®T810T stabilized | 17 | 17 | 17 |
| Diak™ No 1 | 1.5 | 1.5 | 1.8 |
| Vulcofac® ACT 55 | 2 | 2 | 2 |





VME-A11037-00-E0321

# Vamac® Ultra LS

Ethylene Acrylic Elastomer - Technical Data

Table 9 (continued) - Ageing in Engine Oil and Automatic Transmission Fluid

| Compound No. | 19 | 20 | 21 |
|---|---|---|---|
| Fluid Ageing 168 hours at 160°C in Lubrizol® OS 206304 | | | |
| Hardness Shore A (1s), pts | 62 | 66 | 71 |
| Delta Hardness, pts | -3 | 0 | 3 |
| Tensile Strength, MPa | 15.2 | 15.8 | 16.3 |
| Delta Tensile Strength, % | -9 | -5 | -7 |
| Elongation at Break, % | 277 | 291 | 239 |
| Delta Elongation at Break, % | -11 | -7 | -21 |
| 25% Modulus, MPa | 0.89 | 1.06 | 1.22 |
| Delta 25% Modulus, % | -7 | 5 | 17 |
| 50% Modulus, MPa | 1.7 | 2.02 | 2.24 |
| Delta 50% Modulus, % | -1 | 10 | 17 |
| 100% Modulus, MPa | 4.45 | 5.09 | 5.59 |
| Delta 100% Modulus, % | 4 | 12 | 16 |
| Volume Change, % | 11 | 6 | 1 |
| Weight Change, % | 7 | 3 | 0 |
| Fluid Ageing 168 hours at 150°C in Petro Canada Dexron® VI RDL 3434 | | | |
| Hardness Shore A (1s), pts | 64 | 68 | 73 |
| Delta Hardness, pts | -1 | 2 | 5 |
| Tensile Strength, MPa | 17.6 | 17.6 | 18.0 |
| Delta Tensile Strength, % | 5 | 5 | 3 |
| Elongation at Break, % | 274 | 271 | 240 |
| Delta Elongation at Break, % | -12 | -14 | -20 |
| 25% Modulus, MPa | 0.98 | 1.17 | 1.51 |
| Delta 25% Modulus, % | 2 | 16 | 45 |
| 50% Modulus, MPa | 1.9 | 2.12 | 2.81 |
| Delta 50% Modulus, % | 11 | 15 | 47 |
| 100% Modulus, MPa | 5.1 | 5.21 | 7.02 |
| Delta 100% Modulus, % | 20 | 15 | 46 |
| Volume Change, % | 8.8 | 3.7 | -0.5 |
| Weight Change, % | 5 | 1.5 | -1.3 |

# Vamac® Ultra LS

Ethylene Acrylic Elastomer - Technical Data

Test methods used for this bulletin:

| Test | Method |
|---|---|
| **Rheology** | |
| Mooney Viscosity | ISO 289-1:2005 |
| Mooney Scorch | ISO 289-2:1994 |
| MDR | ISO 6502:1999 |
| **Physical Properties** | |
| Hardness | ISO 868:2003 |
| Tensile Strength, Elongation, Modulus | ISO 37:1994 |
| Compression Set | ISO 815:1991 |
| Compression Set | Volkswagen PV3307 |
| Compressive Stress Relaxation (CSR) | ISO 3384 |
| Ageing in Air Oven | ISO 188:2007 |
| Fluid Ageing | ISO 1817:2005 |
| Tg by DSC | ISO 22768:2006 |
| Tear Strength Die C | ISO 34-1:2004 |





VME-A11037-00-E0321