Vamac® Ultra IP

Ethylene Acrylic Elastomer - Technical Data

Description

Vamac® Ultra IP provides improved performance in injection molding processes compared to Vamac® G to reduce the frequency of mold cleaning. The high viscosity of Vamac® Ultra IP compared to standard AEM grades results in better mixing as well as increased green strength of compounds and 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. Low abrasion values may allow extended use of Vamac® Ultra IP in dynamic seals. Vamac® Ultra IP is halogen-free.

Product Properties

Property	Target Values	Method
Mooney Viscosity ML1+4 at 100 °C	29	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 best physical properties of Vamac® Ultra IP are obtained in rubber parts having a hardness range between 50 and 90 Shore A. Extensions of this hardness range may be more easily achieved with Vamac® Ultra IP than standard AEM using appropriate compounding.

Vamac® Ultra IP combines dry heat resistance of 175 °C over a period of 1000 h (six weeks) with very good resistance to automotive lubricants. Exposure of peak temperatures of 200 °C are possible for up to four days. At the same time, the Tg (by DSC) of –31 °C provides very good low temperature flexibility.

Good compression set and compressive stress relaxation properties make Vamac® Ultra IP 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 IP.

VME-A10760-00-F0321

Vamac® Ultra IP

Ethylene Acrylic Elastomer - Technical Data

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®*.

Mixing

Vamac® Ultra IP has a higher viscosity than Vamac® G permitting better and faster dispersion of fillers and other compounding ingredients, especially in low hardness compounds or in formulations with high plasticizer levels. Black Incorporation Time (B.I.T., time between addition of the carbon black to the Banbury and peak of energy consumption) of the compounds shown in Table 1 is reduced by 17% when replacing Vamac® G with Vamac® Ultra IP.

Table 1 – Mixing Black Incorporation Time for Compounds of Vamac® G and Vamac® Ultra IP

Formulation: 100 phr of Vamac®, 65 phr Spheron® SO N550 black, 10 phr Rhenosin® W759 plasticizer, 2 phr Naugard® 445 antioxidant, 0.5 phr Armeen 18D scorch retarder, 1.5 phr stearic acid release aid, 1 phr Vanfre® VAM process aid, 1.5 phr Diak™ No. 1 curative, 2 phr Vulcofac® ACT 55 cure accelerator

Compound	Vamac® G	Vamac® Ultra IP
Francis Shaw 1.7 litre Banbury mixing		
Rotor Speed, rpm	40	40
B.I.T., sec	48	40
Temperature at B.I.T., °C	77	75
Discharge: Time, sec / Temperature, °C	180 / 95	180 / 96
Load factor, %	66	66
Polymer Mooney ML1+4, 100 °C, MU	16.8	30.1
Compound Mooney Viscosity, ML1+4, 100 °C, MU	41.8	67.4

Vamac® Ultra IP

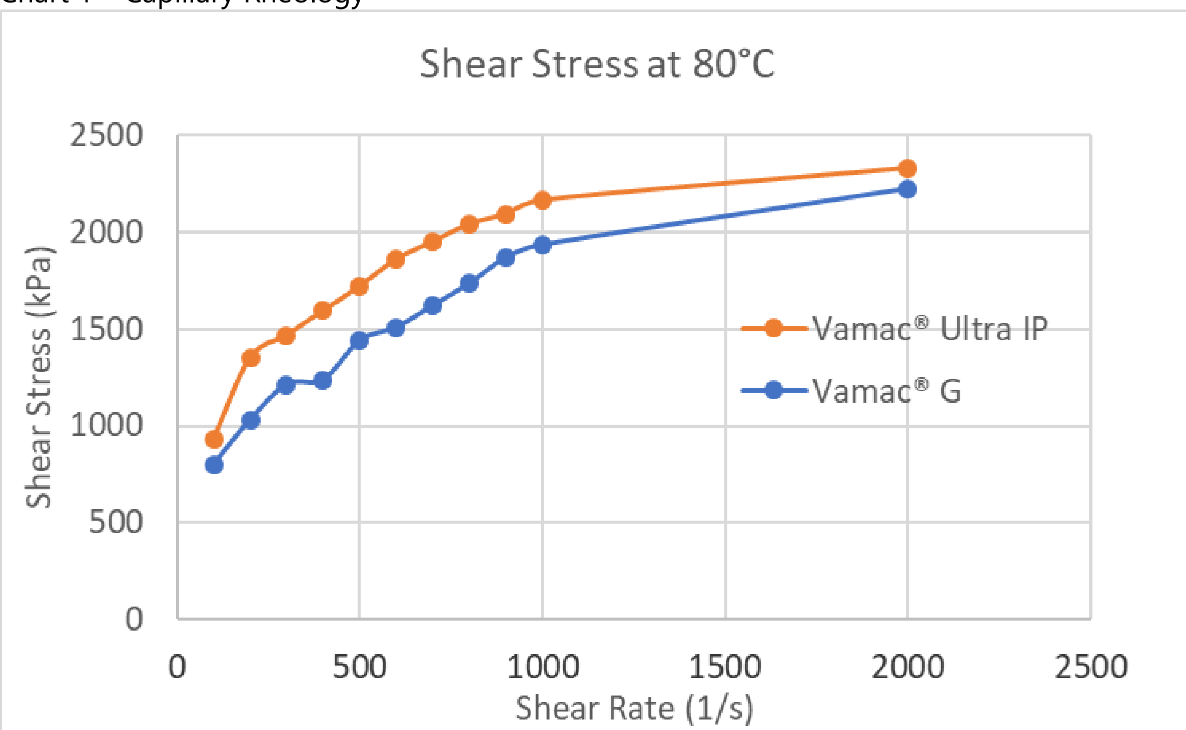
Ethylene Acrylic Elastomer - Technical Data

Processing

Standard AEM grades have Mooney viscosities ML (1+4) at 100 °C of below 20 MU, providing good compound flow and adhesion to other substrates for bonded parts. In extrusion, DuPont™ Vamac® Ultra IP provides the compound viscosity or green strength needed to avoid collapse of extruded, uncured compounds. Stickiness of the extruded compound strips for feeding to injection molding machines can also be reduced.

Vamac® Ultra IP offers significant improvements in molding processes. Higher viscosity helps reduce blistering problems in compression molding. Even with the higher Mooney viscosity, the optimized molecular weight distribution of Vamac® Ultra IP affords comparable rheology with only a modest increase in shear stress compared to the Vamac G compound for the same Shore A hardness. Such difference could be overcome by adding slightly more plasticizer and carbon black for the same Hardness and lower shear.'

Chart 1 – Capillary Rheology



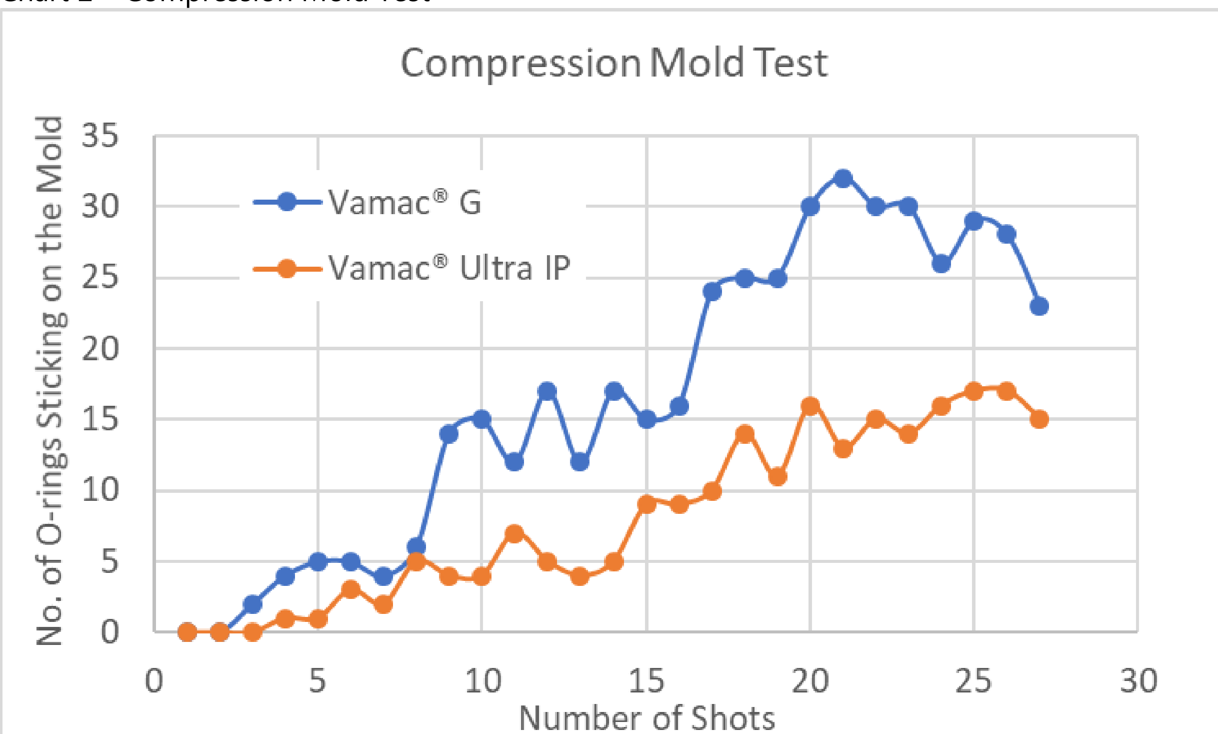
VME-A10760-00-F0321

Vamac® Ultra IP

Ethylene Acrylic Elastomer - Technical Data

Vamc® Ultra IP has lower mold fouling. An internal test is used to compare the mold-sticking characteristics of small O-rings that are compression molded. The test employs a mold with two sets of 60 cavities. After each vulcanization cycle, the O-rings are blown out by pressurized air of defined pressure under conditions of defined distance between air valve and mold. The number of O-rings sticking to the mold after each cycle is reported. Chart 2 shows a comparison between Vamac® Ultra IP and Vamac® G with identical compound formulations using this test procedure. The number of O-rings sticking to the mold is clearly decreased for Vamac® Ultra IP.

Chart 2 – Compression Mold Test



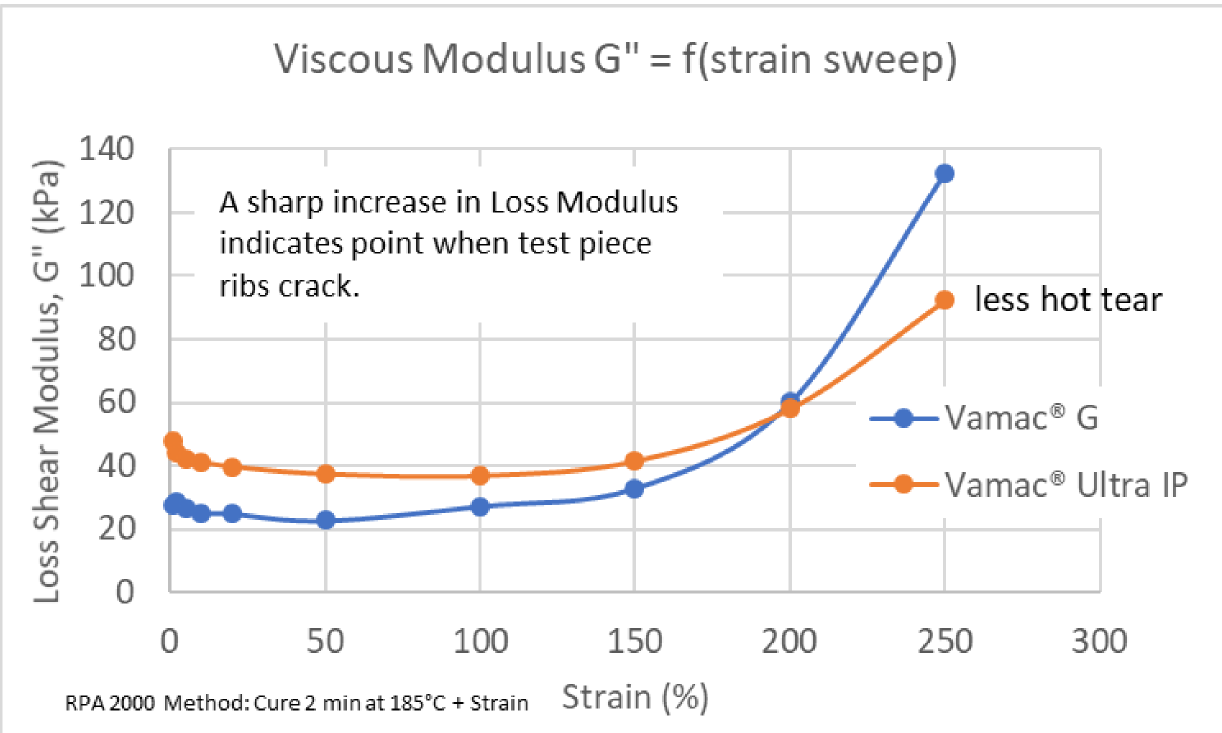
VME-A10760-00-F0321

Vamac® Ultra IP

Ethylene Acrylic Elastomer - Technical Data

Another benefit of using DuPont™ Vamac® Ultra IP in molding processes is improved hot tear strength and higher elongation-at-break at demolding temperatures. Higher elongation-at-break and hot tear properties may be demonstrated by use of RPA 2000 equipment using a cure time of 2 minutes at 185 °C, followed by a strain-sweep, as shown in Chart 3. The point at which the loss modulus shows a sharp increase is the point when ribs on the test specimen crack. This loss modulus rise occurs at lower stress levels and higher elongation for Vamac® Ultra IP compared to Vamac® G indicating better demolding characteristics. This benefit can be further improved by using a lower curative level. Higher hot tear also results in easier tear trim.

Chart 3 – RPA Test



Vamac® Ultra IP

Ethylene Acrylic Elastomer - Technical Data

Compounding and Physical Properties

Vamac® Ultra IP is formulated in a manner similar to other Vamac® terpolymers. The difference in polymer composition allows use of lower levels of diamine curative. This helps to reduce compound cost. The reduction in curative level does not adversely affect MH or compression set. MH values are equivalent to or slightly higher than those observed for Vamac® G. In addition, lower curative levels help reduce cure time and to increase maximum cure speed.

The higher viscosity of Vamac® Ultra IP also allows addition of higher levels of plasticizer and result in better low temperature flexibility while maintaining good processing behavior.

Table 2 shows rheology and physical property data for two compounds of Vamac® Ultra IP and a standard 78 Shore A hardness compound of Vamac® G. One compound of Vamac® Ultra IP includes 1.5 phr of the curative Diak™ No. 1 whereas the second compound uses a lower curative level of 1.2 phr of Diak™ No. 1. The compound Mooney Viscosity and MH of are higher for Vamac® Ultra IP compared to Vamac® G.

Table 2 – Comparison of Vamac® G with Vamac® Ultra IP and Curative Level

Compound Formulation	Vamac® G	Vamac® Ultra IP	Vamac® Ultra IP Low Diak™ No. 1
Vamac® G	100		
Vamac® Ultra IP		100	100
Naugard® 445	2	2	2
Armeen® 18D	0.5	0.5	0.5
Stearic acid	1.5	1.5	1.5
Vanfre® VAM	1	1	1
Spheron® SO N550	65	65	65
Rhenosin® W 759	10	10	10
Diak™ No.1	1.5	1.5	1.2
Vulcofac® ACT 55	2	2	2

Vamac® Ultra IP

Ethylene Acrylic Elastomer - Technical Data

Table 2 (continued) – Comparison of Vamac® G with Vamac® Ultra IP and Curative Level

Compound Rheology	Vamac® G	Vamac® Ultra IP	Vamac® Ultra IP Low Diak™ No. 1
Mooney ML(1+4) 100 °C, MU	41.8	67.4	66.4
Mooney Scorch 121 °C T5, min.	7.5	9.2	8.6
MDR 180 °C / 0.5deg / 12 min.			
ML, dNm	0.51	0.82	0.84
MH, dNm	13.2	16.7	14.6
Ts2, min	0.88	0.81	0.81
tc10, min	0.7	0.73	0.68
tc50, min	2.2	2.4	2.1
tc90, min	6.8	7.1	6.4
Peak rate, dNm/min	4.1	4.7	4.7

Physical properties such as tensile and tear strength or elongation-at-break are significantly better for Vamac® Ultra IP in comparison to Vamac® G. Standard compression set also shows advantages for Vamac® Ultra IP even at a lower curative level. However, if compression set according to Volkswagen specification PV3307 is to be optimized, higher curative levels should be considered.

Low temperature properties are substantially identical for Vamac® G and Vamac® Ultra IP. Sandpaper abrasion and resilience values indicate significant differences between the two polymers. Good abrasion results may be of interest for shaft seal or ball bearing seal applications.

Vamac® Ultra IP

Ethylene Acrylic Elastomer - Technical Data

Table 2 (continued) – Comparison of Vamac® G with Vamac® Ultra IP and Curative Level

Physical Properties	Vamac® G	Vamac® Ultra IP	Vamac® Ultra IP Low Diak™ No. 1
Cure 5 min at 180 °C / Post-Cure (4 h at 175 °C)			
Hardness, Sh. A	78	79	78
100% Modulus, MPa	8.5	7.1	6.3
Tensile Strength, MPa	16.3	18.1	17.6
Elongation at Break, %	195	261	290
Delft Tear Fmax, N/mm	21.8	23.8	26.7
Comp. Set (70 h / 150 °C), 12 mm molded disks, %	21	15	12
Comp. Set (168 h / 150 °C), 12 mm molded disks, %	23	17	19
Comp. Set (70 h / 175 °C), 12 mm molded disks, %	29	25	25
Comp. Set (1008h / 175 °C), 12 mm molded disks, %	60	54	57
Comp. Set (70 h / 190 °C), 12 mm molded disks, %	34	30	31
VW Comp. Set PV3307 (94 h / 23 °C), %	29	30	42
VW Comp. Set PV3307 (94 h / 150 °C), %	46	49	65
Tg by DSC, °C	–36	–37	–37
Sandpaper Abrasion, mm^3	164	132	133
Resiliency Test, %	38	44.4	43.6

Heat Ageing

For the following heat and oil ageing tests, compounds that do not include plasticizer were used to eliminate any effect evaporation of volatile ingredients at high temperatures. These compounds are usually not representative of Vamac® applications in the range of 150 °C. Ether-ester plasticizers or polymeric esters are used in amounts of between 10 to 20 phr for sealing applications for a good balance of low temperature flexibility and oil swell. However, for extremely high temperature requirements, such as for air ducts used in turbo charged engines, very low plasticizer levels are recommended.

Vamac® Ultra IP

Ethylene Acrylic Elastomer - Technical Data

Air oven ageing and fluid ageing results for three Shore A 55 to 60 compounds are shown in Table 3. Two of the formulations are based on Vamac® Ultra IP at two different curative levels and the third is based on Vamac® G.

Vamac® Ultra IP compounds exhibit higher initial tensile strength and elongation values compared to Vamac® G compounds. After ageing in dry heat (air), higher retention of physical properties is observed and a lower percentage change in properties is obtained for Vamac® Ultra IP. Thus, longer functionality of parts made from Vamac® Ultra IP compounds can be expected.

Table 3 – Results on Heat Ageing of Three 60 Shore A Compounds

Compound No.	Vamac® G	Vamac® Ultra IP	Vamac® Ultra IP Low Diak™ No. 1
Vamac® G	100		
Vamac® Ultra IP		100	100
Naugard® 445	2	2	2
Armeen® 18D	0.5	0.5	0.5
Stearic acid	1.5	1.5	1.5
Vanfre® VAM	1	1.5	1.5
Spheron® SO N550	30	30	30
Diak™ No.1	1.5	1.5	1.17
Ekaland DOTG	4	4	4

Vamac® Ultra IP

Ethylene Acrylic Elastomer - Technical Data

Table 3 (continued) – Air Oven Ageing of Three 60 Shore A Compounds

Compound No.	Vamac® G	Vamac® Ultra IP	Vamac® Ultra IP Low Diak™ No. 1
Original Properties			
Hardness (Sh. A, 1 sec.), 6 mm plied	55	59	57
100% Modulus, MPa	2.6	2.6	2.3
Tensile Strength, MPa	13.2	15.5	16.8
Elongation at Break, %	326	377	472
Tear Strength (ISO-34-1, Method A), N/mm	5.7	6.3	7.4
Compression set (168 h / 150 °C, 6mm plied disks), %	27	26	28
Compression set (70 h / 175 °C, 12mm molded disks), %	17	17	17
Properties After Heat ageing 504 h at 175 °C			
Hardness (Sh. A, 1 sec.), 6 mm plied	60	59	57
Delta Hardness, pts	5	0	0
100% Modulus, MPa	3.4	3.0	2.4
Delta 100% Modulus, %	32	13	5
Tensile Strength, MPa	6.5	12.2	10.1
Delta Tensile Strength, %	-51	-21	-40
Elongation at Break, %	151	302	309
Delta Elongation at Break, %	-54	-20	-35
Properties After Heat ageing 168 h at 190 °C			
Hardness (Sh. A, 1 sec.), 6 mm plied	59	58	54
Delta Hardness, pts	4	–1	–3
100% Modulus, MPa	3.3	2.8	2.5
Delta 100% Modulus, %	29	6	11
Tensile Strength, MPa	9.2	12.2	11.1
Delta Tensile Strength, %	–30	–21	–34
Elongation at Break, %	195	286	309
Delta Elongation at Break, %	–40	–24	–35

Vamac® Ultra IP

Ethylene Acrylic Elastomer - Technical Data

Ageing in Automotive Fluids

Tested in Lubrizol® OS206304 (engine oil) and Dexron® VI (transmission fluid), Vamac® Ultra IP exhibits superior overall properties after fluid ageing even with lower curative level. In applications where Vamac® is fully immersed in lubricants, such as oil seal or oil hose applications, addition of plasticizers at levels in the range of between 10 and 20 phr is recommended. Thus, a reasonable volume swell of 5 to 10% can easily be achieved. If needed, Vamac® Ultra IP can be blended at any ratio with Vamac® GLS, a standard AEM terpolymer grade that is designed for lower volume swell.

Table 3 (continued) – Fluid Ageing of Three 60 Shore A Compounds

	Vamac® G	Vamac® Ultra IP	Vamac® Ultra IP Low Diak™ No. 1
Ageing in Lubrizol® OS 206304, 5W40 (504 h at 160 °C)			
Hardness (Sh. A, 1 sec.), 6 mm plied	49	51	49
Delta Hardness, pts	–6	–8	–8
100% Modulus, MPa	2.5	2.6	2.1
Tensile Strength, MPa	8.9	11.1	11.6
Delta Tensile Strength, %	–33	–34	–26
Elongation at Break, %	242	280	338
Delta Elongation at Break, %	–26	–30	–24
Volume Change, %	23	23	24
Weight Change, %	17	17	18
Ageing in Dexron® VI (168 h at 150 °C)			
Hardness (Sh. A, 1 sec.), 6 mm plied	46	48	45
Delta Hardness, pts	–5	–6	–9
100% Modulus, MPa	2.2	2.2	1.6
Tensile Strength, MPa	11.9	12.2	14.4
Delta Tensile Strength, %	–7	–25	–13
Elongation at Break, %	265	293	391
Delta Elongation at Break, %	–39	-43	–29
Volume Change, %	21	22	22
Weight Change, %	15	16	16

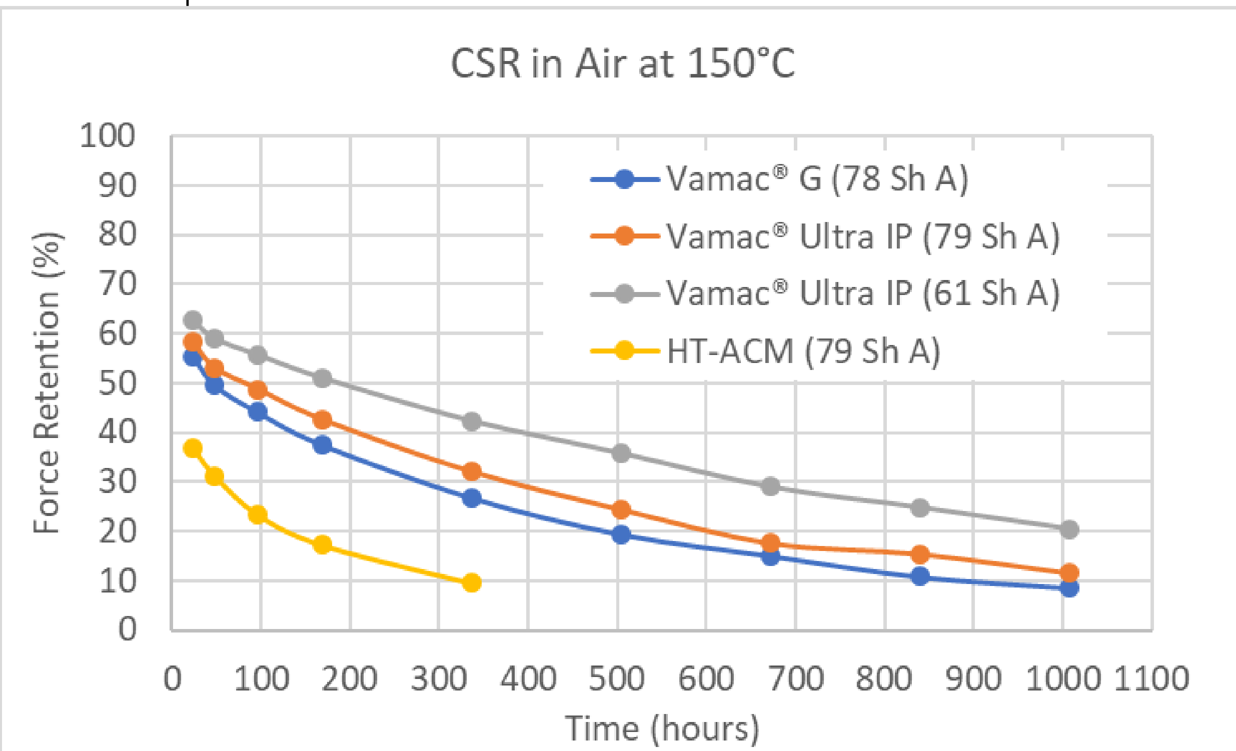
Vamac® Ultra IP

Ethylene Acrylic Elastomer - Technical Data

Compressive Stress Relaxation (CSR)

The improved ageing in dry heat and oil of Vamac® Ultra IP also results in better force retention in CSR tests in air at elevated temperature. Chart 4 shows a comparison between Vamac® and HT-ACM compounds, all diamine cured, in the range of 60 to 80 Shore A. Tests were conducted according to ASTM D6147, using a Shawbury-Wallace equipment combined with Dyneon fixtures and with cylindrical specimen (6 mm high, 13 mm diameter) at 150 °C. Vamac® clearly shows higher retention of sealing force.

Chart 4 – Compressive Stress Relaxation in Air

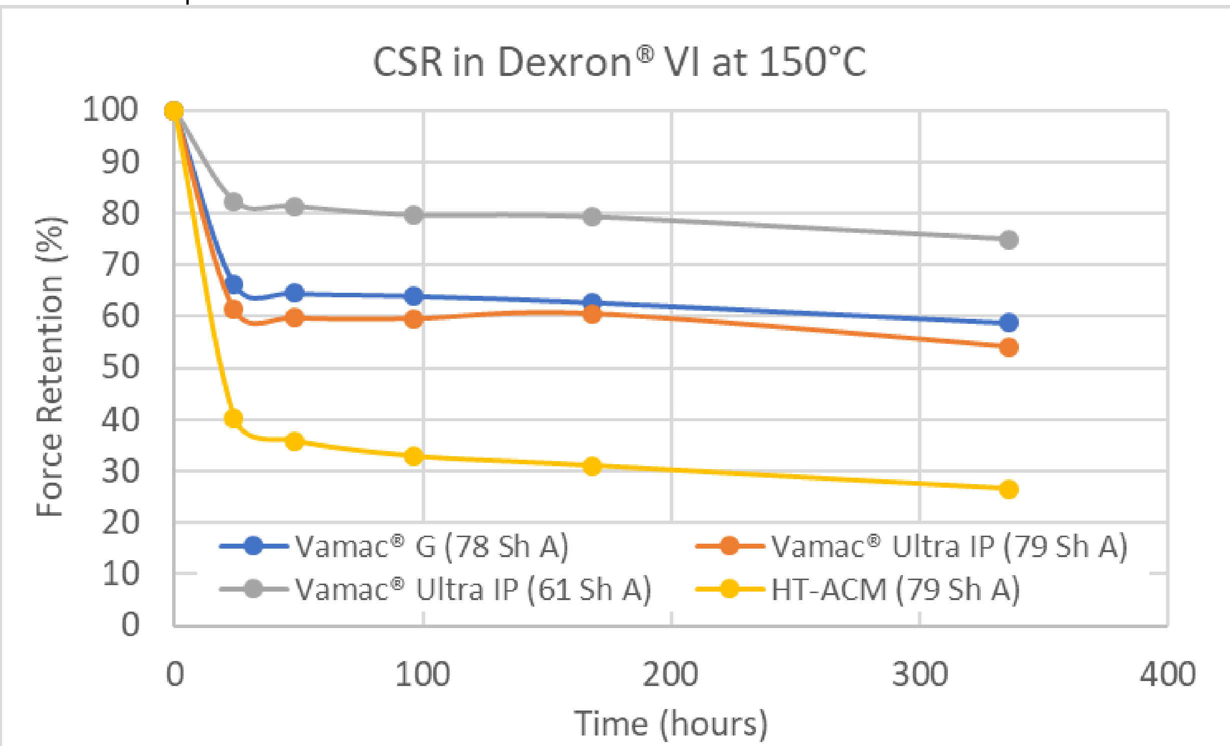


Vamac® Ultra IP

Ethylene Acrylic Elastomer - Technical Data

CSR in Dexron® VI was carried out to only 336 hours. Already from the start of the test, ACM shows a significant drop In sealing force. After two weeks, ACM shows a retention of only abt 25%, whereas all AEM compounds still show more than 50% of the initial sealing capability.

Chart 5 – Compressive Stress Relaxation in Dexron® VI Automatic Transmission Fluid



VME-A10760-00-F0321

Vamac® Ultra IP

Ethylene Acrylic Elastomer - Technical Data

Starting Point Formulations

Table 4 provides several starting point formulations based on Vamac® Ultra IP for a hardness range between 60 and 85 Shore A. Compounds are Press-Cured 5 minutes at 180 °C, and Post-Cured 4 h at 175 °C.

Table 4 - Vamac® Ultra IP Compounds Starting Formulation

Compound No.	1	2	3	4	5	6
Vamac® Ultra IP	100	100	100	100	100	100
Naugard® 445	2	2	2	2	2	2
Armeen® 18D	0.5	0.5	0.5	0.5	0.5	0.5
Stearic acid	1.5	1.5	1.5	1.5	1.5	1.5
Vanfre® VAM	1	1	1	1	1	1
Spheron® SO N550	40	52	72	65	80	
Spheron® 4000						50
Rhenosin® W 759	10	10	15	10	10	5
Diak™ No.1	1.2	1.2	1.2	1.2	1.2	1.2
Vulcofac® ACT 55	2	2	2	2	2	2
Original Properties at 23°C						
Hardness (Sh. A), pts	61	70	79	78	84	61
50% Modulus, MPa	1.3	2.0	3.3	3.0	4.6	1.3
100% Modulus, MPa	2.8	4.5	6.8	6.3	9.7	2.5
Tensile Strength, MPa	17.7	17.9	16.5	17.6	17.2	19.9
Elongation at Break, %	409	345	276	290	218	401
Delft Tear Fmax, N/mm	18.8	24.3	23.9	26.7	29.2	18.7
Comp. Set (70 h / 150 °C)*, %	12	13	14	15	18	14
Comp. Set (70 h / 190 °C)*, %	28	29	33	31	32	27
Tg by DSC, °C	-37	-37	-40	-37	-38	35
Sandpaper Abrasion, mm^3	147	132	135	133	144	167

*12 mm molded slabs

Vamac® Ultra IP

Ethylene Acrylic Elastomer - Technical Data

Test methods used for this work:

Test	Method
Rheology	
Mooney Viscosity	D1646
Mooney Scorch	D1646
MDR	D5289
Physical Properties	
Hardness	D2240
Tensile Strength, Elongation, Modulus	D412
Compression Set	D395
Compression Set	Volkswagen PV3307
Compressive Stress Relaxation (CSR)	D6147 and ISO 3384
Ageing in Air Oven	D573
Fluid Ageing	D471
Tg by DSC	D7426
Resiliency Test	ISO 4662
Sandpaper Abrasion Test	ISO 4649
Delft Tear	ISO 34-2

VME-A10760-00-F0321