

Vamac[®] HyPR 5015 / 5020

Ethylene Acrylic Elastomer Compound - Technical Data

Description

Vamac[®] HyPR 5000 Series Pre-Compounds for Improved Heat Resistance (formerly VMX5015 & VMX5020)

For demanding applications requiring high heat resistance, the HyPR 5000 series of Vamac[®] pre-compounds offer superior performance.

Until the introduction of the Vamac[®] HyPR 5000 series, AEM compounds relied on fillers like carbon black or silica to provide strength and stiffness for a finished article. These fillers, however, accelerate oxidative degradation. Vamac[®] HyPR 5000 series pre-compounds eliminate this problem by utilizing a novel filler system that actively extends the life of AEM articles exposed to hot air. As a result, finished parts based on HyPR 5000 series pre-compounds last up to three times longer at any given temperature compared to AEM compounds containing conventional fillers. Compounds based on the HyPR 5000 series are also lighter weight, with up to 15% lower specific gravity.

The improved heat ageing performance of Vamac[®] HyPR 5000 series pre-compounds benefits automotive applications such as turbocharger hose and molded air ducts, with specific advantages for seals and gaskets. Compounds made with HyPR 5000 grades exhibit significantly improved compressive stress relaxation properties in air, as well as in long term compression set.

While HyPR 5000 series pre-compounds may be extended with AEM elastomer, plasticizer or small amounts of conventional filler like carbon black, in some cases no additional filler may be required. Vamac[®] HyPR 5000 series compounds also provide a route to bright colored finished articles having superior physical properties and heat ageing resistance compared to mineral filled AEM compounds.

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 respective product Safety Data Sheet (SDS), and bulletin, *Safe Handling and Processing of Vamac[®]*.

Vamac[®] HyPR 5000 Series Product Range

Grade	ML (1+4) at 100 °C	Tg (by DSC) °C ¹	Density, g/cc	Key Feature
HyPR 5015	57	-30	1.07	Compression molding pre-compound ²
HyPR 5020	43	-30	1.07	Injection molding pre-compound ²

¹ Tg of compounds with Vamac[®] may be extended typically – 10°C lower with the addition of plasticizer.

² Not suitable for steam autoclave cure.

Vamac[®] HyPR 5000 series products are available in bale form, and the natural color is opaque creamy white to light pink. Bales are packaged in 23kg units with a blue strippable wrap in individual boxes. The strippable wrap must be completely removed prior to using the product. A full pallet will hold thirty individual boxes with a net weight of 690kg.

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Improved Heat Resistance

Vamac[®] HyPR 5000 series pre-compounds offer significantly improved heat resistance over conventional carbon black filled AEM or HT-ACM. Figure 1 shows AEM temperature rating based on three industry-accepted criteria: less than 50% loss in tensile strength and elongation, and less than 15-point change in Shore A hardness.

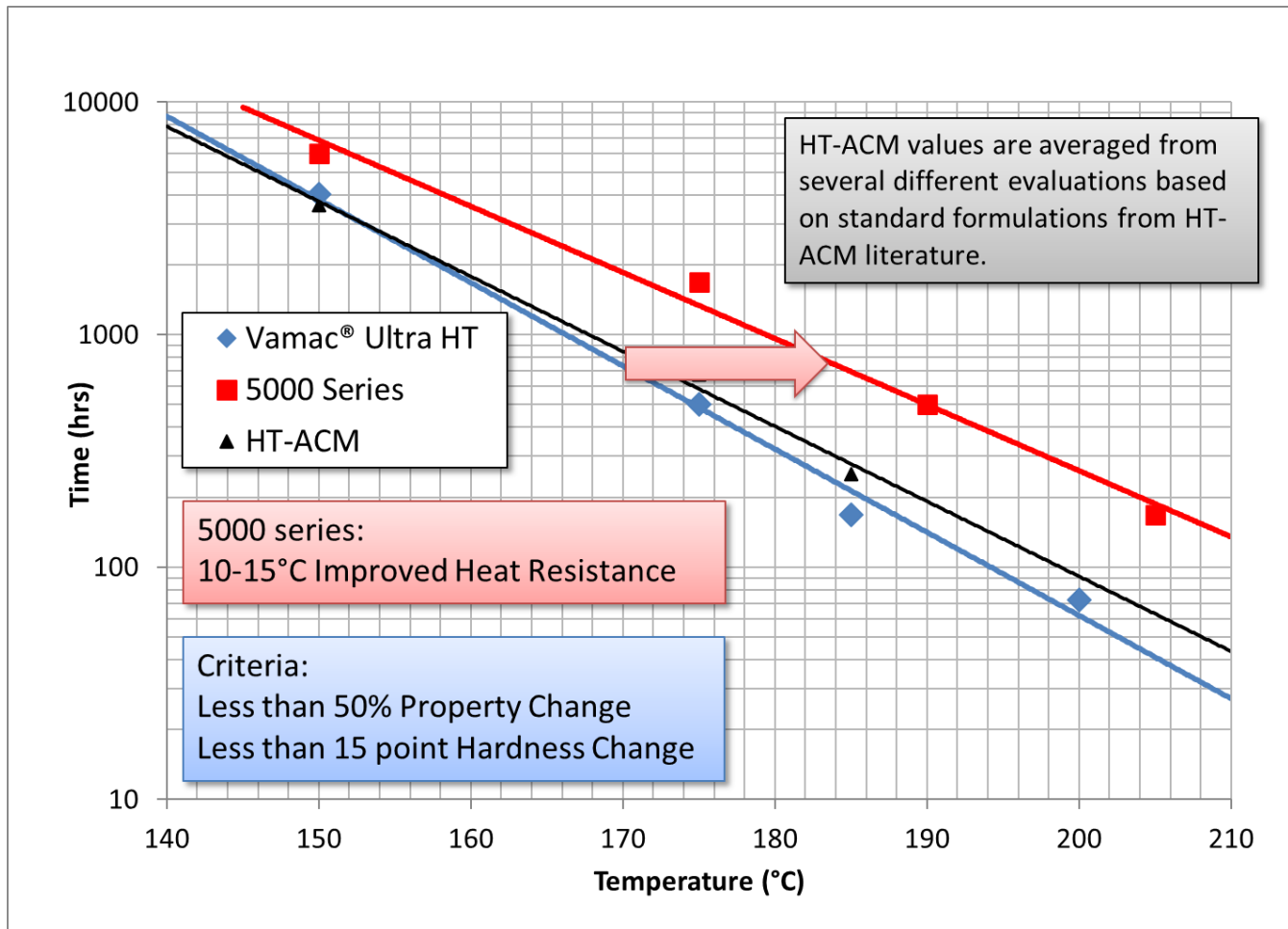
Temperature rating is improved significantly with HyPR 5000s compared to black filled AEM or HT-ACM.

at 6 weeks	from 167°C to 182°C rating	(+15°C)
at 3 weeks	from 175°C up to 190°C rating	(+15°C)
at 1 week	from 185°C up to 205°C rating	(+ 20°C)

Likewise, when the temperature is held constant there is a significant increase in performance lifetime.

at 160°C	from 1800 hours up to 3600 hours	(2 x)
at 175°C	from 504 hours up to 1680 hours	(3.3 x)
at 185°C	from 168 hours up to 750 hours	(4.5 x)

Figure 1 – Temperature Rating of Vamac[®] HyPR 5000 Series



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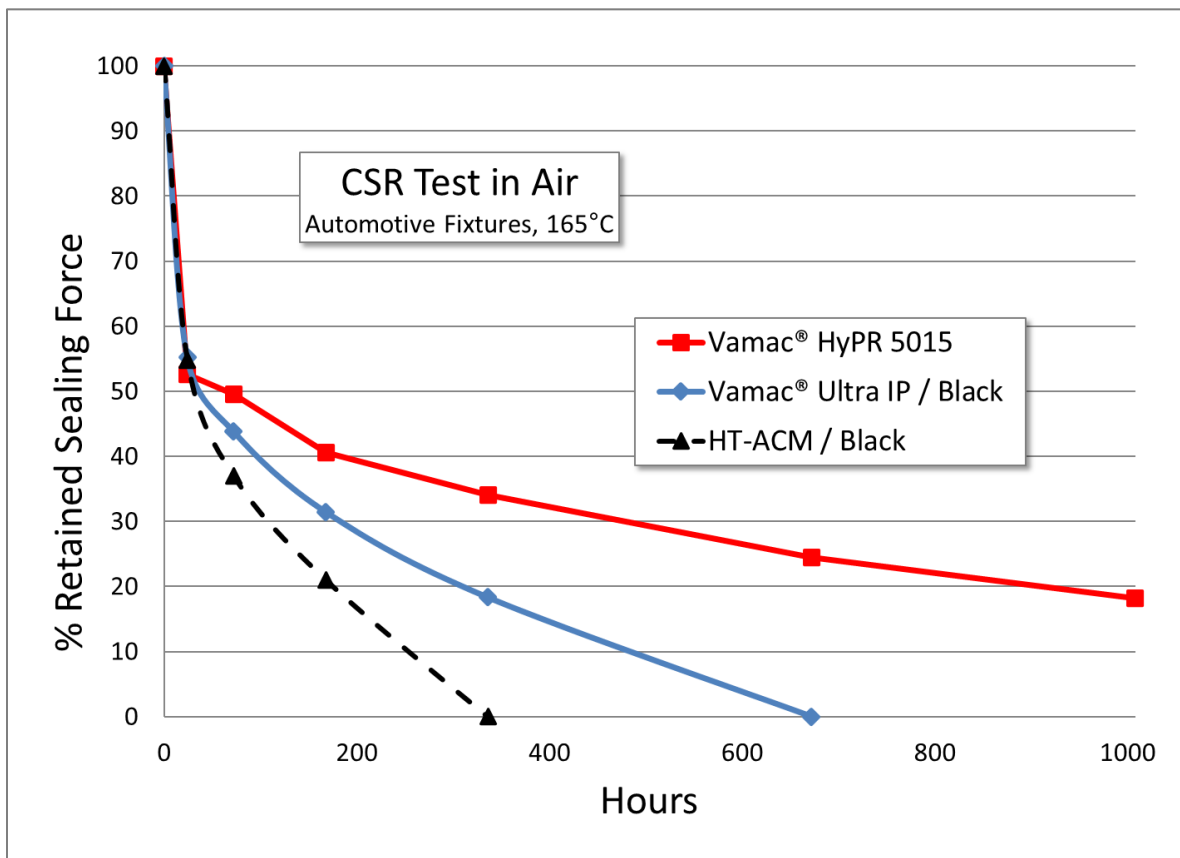
Improved Sealing Performance

Industry standard tests for sealing performance include compression set (CS) and compressive stress relaxation (CSR). Results of these tests for many elastomers, including AEM, can depend on sample geometry. When tested in air, 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. Because many seals have small sealing beads, CS and CSR tests using large specimens can mask performance issues that may arise from in-service oxidation.

The improved heat ageing performance of Vamac® HyPR 5000 pre-compounds therefore has significant benefit on long term compression set resistance, especially when tested using ISO buttons, or D214 O-rings. Figure 2 shows compression set results for 60 Shore A hardness compounds of HyPR 5020 / Ultra IP blends with either carbon black (15phr) or red pigment (for colored compound), compared to a conventional carbon black filled Vamac® Ultra LS compound.

While all the compounds perform about equally when testing ISO buttons at 168 hours/170°C, the HyPR 5000 compound outperforms the black-filled Ultra LS compound when the test time extends to 1008 hours, or when the specimen is switched to a D214 O-ring under conditions of 168 hours/180°C. Note the HyPR 5000 series compounds can tolerate small amounts of filler added for color or increasing hardness (typically by less than 10 points Shore A) without adversely affecting compression set or hot air ageing properties.

Figure 2 – Long Term Compression Set Resistance

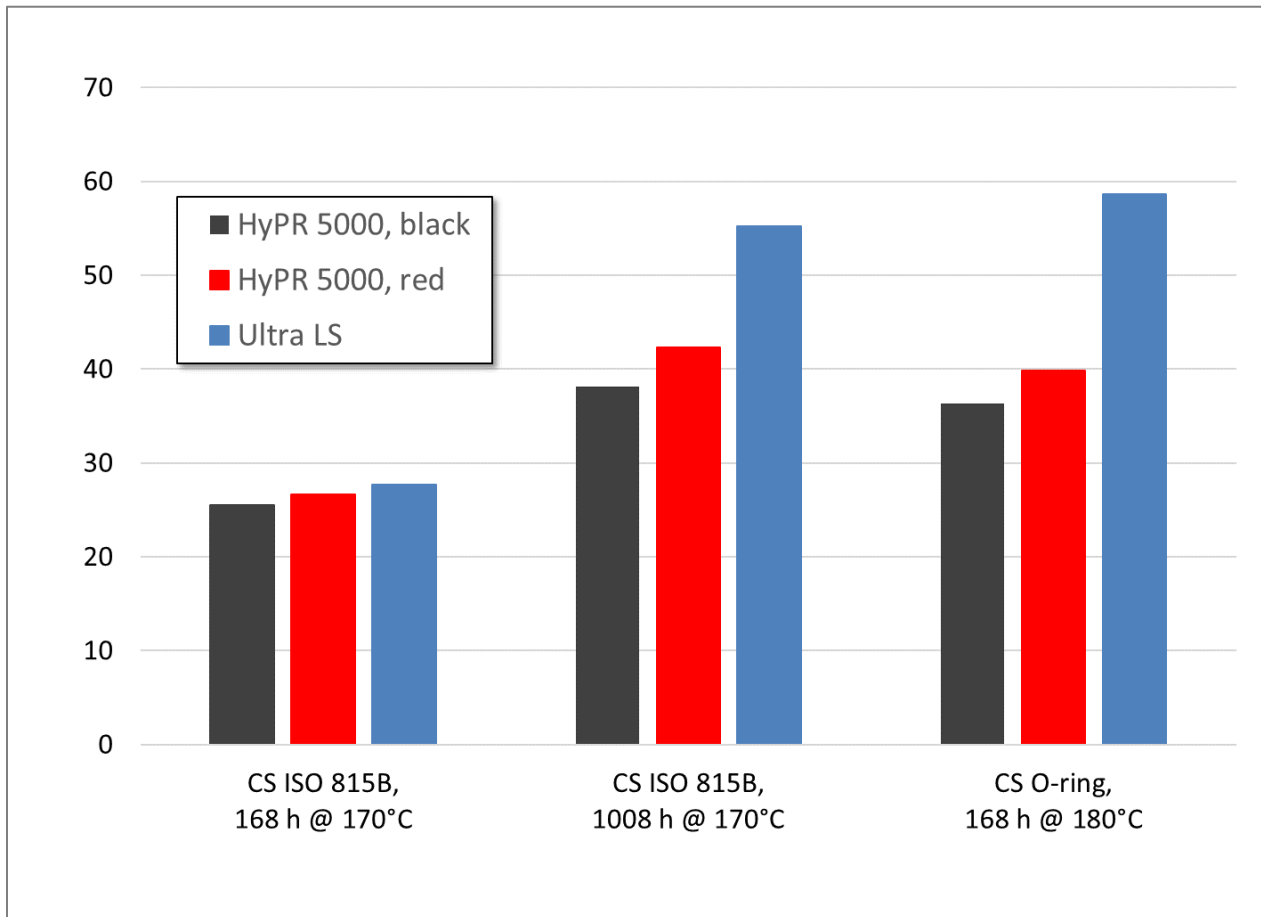


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Figure 3 shows compressive stress relaxation testing of ISO buttons in hot air for standard carbon black filled compounds of Vamac® Ultra IP, HT-ACM, and a Vamac® HyPR 5015 compound containing only 2phr N550 carbon black for color. The superior oxidative stability of the HyPR 5015 compound results in dramatically improved CSR performance.

Figure 3 – CSR in Hot Air



Compounding Vamac® HyPR 5000 Series Pre-Compounds

Vamac® HyPR 5000 series compounds optimally contain about 20% lower Diak™1 levels than conventional AEM compounds and use 4-aminodiphenylamine (ADPA) as the antioxidant. The preferred diarylamine antioxidants for carbon black or silica filled AEM compounds, like IPPD or Naugard® 445, do not perform as well in the HyPR 5000 series.

Table 2 shows starting point recipes where the amount of Vamac® HyPR 5000 series pre-compound is set so that the compound comprise 100phr total AEM. As desired, additional AEM polymer may be added along with the HyPR 5000 pre-compound to adjust hardness or cure speed. Vamac® Ultra HT, Ultra IP, and GXF are suitable diluents. Vamac® Ultra IP provides faster curing.

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Table 2 –Starting Recipes for Vamac[®] HyPR 5000 series

Ingredient (phr)	75 ShA hose	60 ShA gasket
HyPR 5000 pre-compound	181.8	118
AEM (additional)		36
Diak [™] 1	0.5 to 0.6	0.6 to 1.0
Vulcofac [®] ACT-55	1	0 to 2
Alcanpoudre [®] DBU-70		0 to 2
Armeen [®] 18D	0.5	0 to 0.5
Stearic Acid	0 to 0.5	0 to 0.5
ADPA*	0.5 to 1.5	0.5 to 1.5
Plasticizer**	2 to 5	0 to 0.5
Vanfre [®] VAM	1	1
Carbon Black	2	2

* 4-aminodiphenyl amine, is available from ChemSpec or Safic Alcan as ADPA

** Alcanplast[®] PO80, TegMer[®] 812, or similar

Compounding Tips

- Fatigue resistance is optimized at 0.55phr or less of Diak[™] 1, and ISO compression set is optimized at 0.8phr. VW compression set improves up to and beyond 1.0phr, although heat resistance worsens at Diak[™]1 levels greater than 1.0phr.
- Use at least 1phr accelerator, noting that Vulcofac[®] ACT-55 is a weaker accelerator than Alcanpoudre[®] DBU-70. Better release and faster cure may be achieved for molded compounds using 1.5 to 2phr DBU-70.
- ADPA is the preferred antioxidant for Vamac[®] HyPR 5000 series pre-compounds, and also provides added scorch protection along with Armeen[®] 18D.
- Low volatile plasticizers may be used up to 10phr, depending on the low temperature requirements.
- Low levels of carbon black (any type) may be used as a colorant without negatively impacting properties

Colored Compounds

There is a market demand for colored AEM compounds to help with product assembly. Conventional AEM compounds with mineral fillers have poor compression set properties.

Since the HyPR 5000 series pre-compounds contain a non-black filler system, and exhibit excellent properties for heat ageing, and compression set, they are particularly suitable for colored AEM parts for differentiation, and optical control.

For colored compounds, staining diarylamine antioxidant like ADPA should be avoided, and less staining Naugard[®] 445, or non-staining AO like Irganox[®] 1010 and Ultrinox[®] 626 may be used.

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Figure 4 – Vamac® HyPR 5000 series compounds with less staining Naugard® 445, 5phr TiO₂ and 2phr pigment to produce bright colors with good heat ageing

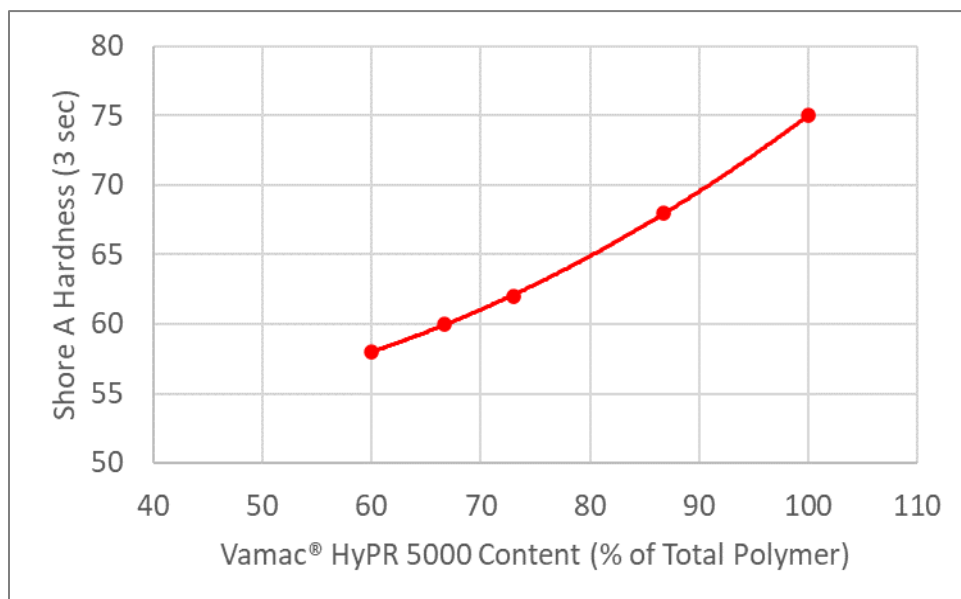


Formulating for Different Hardness Level

Vamac® HyPR 5000 series pre-compounds contain filler level for a hardness of approximately 75 Shore A after vulcanization. To achieve lower hardness levels, unfilled Vamac® AEM polymer must be added to dilute and reduce the overall filler level. Figure 4 exhibits a profile of hardness range between 55 to 75 Shore A (3 sec) for HyPR 5015 / Vamac® Ultra IP blends in a compound formulation and curative package typical for a sealing application. Further modification can be achieved by changing curative, supplemental filler, and plasticizer level. Dilution of HyPR 5000 pre-compounds may be extended to provide compounds of low hardness level (37 to 47 Shore A) with relatively good properties, and processing, which is difficult to achieve with conventional black filled compounds.

Example (%): Vamac® HyPR 5015 = 73%, Vamac® Ultra IP = 27%, ADPA = 0.93%, Vanfre® VAM = 0.67%, Stearic Acid = 0.33%, Diak™ 1 = 0.67%, Alcanpoudre® DBU-70 = 1.33% for a hardness (3s) of 62 Shore A. Higher hardness compounds (>75 Sh A) may be achieved with addition of supplemental filler.

Figure 5 – AEM Blends with Vamac® HyPR 5000 Series for Lower Hardness



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Compound Comparison of Vamac® HyPR 5000 Grades (65-70 Shore A)

The following tables compares Vamac® HyPR 5015 and 5020 versus a black filled Vamac® Ultra IP compound. Two variations of red colored compounds with HyPR 5020 are included. The later compound is a blend of HyPR 5020, and Vamac® Ultra LS with higher Diak™ 1 level.

Table 3 – Comparison of Vamac® HyPR 5000 Grades (65-70 Shore A)

Compound Formulation (phr)	Vamac® Ultra IP	HyPR 5015	HyPR 5020	HyPR 5020, red	HyPR 5020 / Ultra LS, red
Vamac® Ultra IP	100	17.5	17.5	17.5	
Vamac® Ultra LS					17.5
Vamac® HyPR 5015		150			
Vamac® HyPR 5020			150	150	150
Alcanpoudre® ADPA 75		1.5	1.5	1.5	1.5
Naugard® 445	2				
Armeen® 18D PRILLS	0.5				
Stearic Acid	2	0.5	0.5	0.5	0.5
Vanfre® VAM	1	1	1	1	1
Ultrasil® VN2				10	10
Alcanpoudre® A1100 70				0.25	0.25
Ferroxide 214 M				1.5	1.5
Spheron™ SOA (N550)	20				
Corax® N772	50				
MT Thermax® Floform N990		20	20		
Alcanplast® PO 80	10	7	7	7	7
Diak™ 1	1.4	0.9	0.9	0.8	0.9
Vulcofac® ACT-55	2	2	2	2	2

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Table 3 (continued) – Comparison of Vamac® HyPR 5000 Grades (65-70 Shore A)

Rheology	Vamac® Ultra IP	HyPR 5015	HyPR 5020	HyPR 5020, red	HyPR 5020 / Ultra LS, red
<u>Mooney Viscosity ML 1+4 at 100°C (ISO 289-1:2005)</u>					
Initial Mooney, MU	70.8	87.0	70.7	89.7	89.8
Final Mooney, MU	49.2	56.2	45.6	47.5	49.8
Slope, lg M/g s	-0.609	-0.653	-0.605	-0.667	-0.553
Intercept Mooney, MU	13.5	13.6	11.8	11.6	14.0
<u>MDR cure rate 15 minutes at 180°C, arc 0.5° (ISO 6502:1999)</u>					
ML, dNm	0.65	0.69	0.52	0.54	0.65
MH, dNm	16.45	15.03	12.40	13.28	12.19
Ts1, min	0.62	0.78	0.84	0.90	0.92
Ts2, min	0.86	1.03	1.14	1.24	1.30
T10, min	0.76	0.89	0.90	0.99	0.98
T50, min	2.46	2.58	2.56	3.00	3.10
T90, min	7.66	7.25	6.69	8.02	8.56
T95, min	9.99	9.18	8.53	10.02	10.63
Tan delta at ML	1.108	1.101	1.077	1.167	0.954
Tan delta at MH	0.009	0.045	0.047	0.047	0.049
Peak rate, dNm/min	6	6	5	5	4
<u>Mooney Scorch 45 min at 121°C (ISO 289-2:1994)</u>					
Initial Mooney, MU	27	41	30	29	32
Minimum Mooney, MU	17	20	17	17	19
Ts1, min	5.6	8.3	6.6	7.0	6.0
Ts2, min	7.0	9.9	7.8	8.2	6.9
T5, min	10.2	13.7	10.2	11.1	8.6
T10, min	13.7	17.4	12.6	14.0	10.6
T35, min	25.0	35.2	32.2	26.4	24.1
Point rise at 30 min		31.5	33.9		

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Table 3 (continued) – Comparison of Vamac[®] HyPR 5000 Grades (65-70 Shore A)

Original Properties	Vamac [®] Ultra IP	HyPR 5015	HyPR 5020	HyPR 5020, red	HyPR 5020 / Ultra LS, red
Compression molding 10 minutes at 180°C / Post-cure 4 hours at 175°C					
<u>Hardness (ISO 7619-1:2004)</u>					
Hardness Shore A (3s), pts	71.9	65.7	64.4	66.0	65.2
Hardness Shore A (1s), pts	73.5	67.9	66.2	67.7	67.2
<u>Tensile Properties (type 2) at 23°C</u>					
Tensile Strength, MPa	19.0	17.4	13.4	11.5	10.6
Elongation at Break, %	270	240	238	184	201
10% Modulus, MPa	0.67	0.58	0.52	0.56	0.55
25% Modulus, MPa	1.29	1.05	1.00	1.05	1.00
50% Modulus, MPa	2.4	2.1	1.9	1.9	1.8
100% Modulus, MPa	6.1	5.8	4.9	5.0	4.6
200% Modulus, MPa	14.8	15.1	12.0		10.7
Trouser Tear, Propagation Direction: Mill (ISO 34-1:2004)					
Tear Strength (type A), kN/m	5.5	2.6	2.9	2.6	2.8
Tg, °C	-36.0	-35.0	-34.4	-33.8	-33.9
<u>Tensile Properties T2 at 150°C (ISO 37:2005, Cor 1 2008)</u>					
Tensile Strength, MPa	6.3	6.0	5.3	3.9	3.8
Elongation at Break, %	110	179	146	112	114
10% Modulus, MPa	0.57	0.40	0.36	0.38	0.36
25% Modulus, MPa	1.17	0.82	0.74	0.77	0.73
50% Modulus, MPa	2.25	1.58	1.41	1.45	1.35
100% Modulus, MPa	5.7	3.7	3.3	3.5	3.2

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The conventional carbon black reference AEM compound exhibits more hardening, and greater loss of properties than the Vamac® HyPR 5000 series compounds.

Table 3 (continued) – Comparison of Vamac® HyPR 5000 Grades (65-70 Shore A)

Heat Ageing	Vamac® Ultra IP	HyPR 5015	HyPR 5020	HyPR 5020, red	HyPR 5020 / Ultra LS, red
<u>Heat Ageing 1008 hours at 150°C</u>					
Hardness Shore A (3s), pts	74.0	66.3	65.0	65.1	64.7
Delta Hardness, pts	2.2	0.6	0.4	-0.7	-0.7
Tensile Strength, MPa	16.6	12.4	9.3	10.1	10.1
Delta Tensile Strength, %	-12.6	-28.9	-30.8	-12.3	-5.2
Elongation at Break, %	230	216	222	217	226
Delta Elongation at Break, %	-14.8	-10.0	-6.7	17.9	12.4
50% Modulus, MPa	3.0	2.3	2.0	2.4	2.0
Delta 50% Modulus, %	23.4	11.2	4.7	25.0	8.3
100% Modulus, MPa	6.8	5.5	4.8	4.9	4.9
Delta 100% Modulus, %	11.7	-5.6	-2.3	-2.0	7.9
200% Modulus, MPa	14.9	12.0	9.2	9.9	9.6
Delta 200% Modulus, %	0.9	-20.2	-22.8		-10.5
<u>Heat Ageing 1008 hours at 175°C</u>					
Hardness Shore A (3s), pts	93.3	61.8	62.6	62.5	63.5
Delta Hardness, pts	21.4	-3.8	-1.8	-3.2	-1.9
Tensile Strength, MPa	9.4	12.1	11.4	9.9	9.1
Delta Tensile Strength, %	-50.5	-30.2	-15.0	-14.3	-13.9
Elongation at Break, %	37	175	158	140	127
Delta Elongation at Break, %	-86.3	-27.1	-33.6	-23.9	-36.8
50% Modulus, MPa		1.6	1.7	1.4	1.6
Delta 50% Modulus, %		-24.8	-13.1	-26.0	-11.1
100% Modulus, MPa		5.2	5.6	5.4	5.8
Delta 100% Modulus, %		-10.1	14.8	8.4	27.5

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Long term compression set at 160 to 170°C is lower for the HyPR 5000 compounds, and less impacted over time when cooled in the clamps compared to the black reference AEM compound. VW compression set can be made lower than what is shown for this study using higher Diak™ 1. Vamac[®] HyPR 5015 is best among the 5000 series in VW compression set.

Table 3 (continued) – Comparison of Vamac[®] HyPR 5000 Grades (65-70 Shore A)

Compression Set	Vamac [®]			HyPR 5020, red	HyPR 5020 / Ultra LS, red
	Ultra IP	HyPR 5015	HyPR 5020		
<u>Compression Set – type B (ISO 815-1:2008)</u>					
70 hours / 150°C, %	21.5	22.6	25.1	28.0	30.5
504 hours / 160°C, %	49.1	41.1	40.6	45.3	48.0
1008 hours / 160°C, %	58.0	45.0	44.8	49.3	52.9
504 hours / 170°C, %	52.3	47.9	47.1	51.3	53.9
504 hours / 180°C, %	56.3	54.2	54.0	56.0	60.5
<u>Compression Set – type B (ISO 815-1:2008), cooled in clamps for 2h</u>					
24h / 150°C, %	22.7	30.6	32.8	36.4	37.3
1008h / 150°C, %	58.7	53.6	53.5	59.0	61.5
<u>Compression Set VW (PV 3307:2004-08), 72 hours at 23°C</u>					
at 5 seconds, %	24.8	35.6	45.0	47.0	48.1
at 30 minutes, %	8.4	7.5	9.4	10.5	10.3
<u>Compression Set VW (PV 3307:2004-08), 22 hours at 150°C</u>					
at 5 seconds, %	46.2	60.5	69.7	73.8	71.8
at 30 minutes, %	30.1	32.8	40.3	46.8	45.7
Deflection, %	51	50	49	50	49

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Table 3 (continued) – Comparison of Vamac® HyPR 5000 Grades (65-70 Shore A)

Fluid Ageing:	Vamac®			HyPR 5020,	HyPR 5020 /
Engine Oil	Ultra IP	HyPR 5015	HyPR 5020	red	Ultra LS, red
<u>Ageing 1008 hours at 150°C, Aeroshell Oil Diesel Ultra, 5W-30</u>					
Compression Set – type B (ISO 815-1:2008), cooled in clamps for 2h					
CSet, (1008h / 150°C), %	46.6	48.0	51.3	52.8	58.8
Hardness Shore A (3s), pts	72.5	62.0	60.2	63.2	63.1
Delta Hardness, pts	0.8	-3.8	-4.1	-2.7	-2.1
Tensile Strength, MPa	13.5	15.3	12.2	11.8	12.5
Delta Tensile Strength, %	-28.9	-12.2	-9.1	2.5	17.6
Elongation at Break, %	139	174	173	154	154
Delta Elongation at Break, %	-48.5	-27.5	-27.3	-16.3	-23.4
25% Modulus, MPa	1.8	1.1	1.0	1.1	1.1
Delta 25% Modulus, %	37.2	1.0	3.0	1.0	13.0
50% Modulus, MPa	3.5	2.5	2.2	2.2	2.4
Delta 50% Modulus, %	44.8	18.9	13.1	15.6	31.5
100% Modulus, MPa	9.1	7.1	5.8	6.4	6.9
Delta 100% Modulus, %	49.8	22.9	19.8	26.9	49.6
Weight Change, %	3.8	5.4	4.4	5.6	3.8
Volume Change, %	6.7	7.4	6.1	7.7	5.5

Table 3 (continued) – Comparison of Vamac® HyPR 5000 Grades (65-70 Shore A)

Fluid Ageing:	Vamac®			HyPR 5020,	HyPR 5020 /
Reference Oil	Ultra IP	HyPR 5015	HyPR 5020	red	Ultra LS, red
<u>Ageing 1008 h, 150°C, Lubrizol OS 206304</u>					
Compression Set – type B (ISO 815-1:2008), cooled in clamps for 2h					
CSet, (1008h / 150°C), %	31.1	36.0	38.2	41.3	48.4
Hardness Shore A (3s), pts	67.9	58.6	57.8	59.2	59.3
Delta Hardness, pts	-3.9	-7.1	-6.6	-6.6	-5.9
Tensile Strength, MPa	17.3	15.4	12.4	10.6	11.3
Delta Tensile Strength, %	-8.8	-11.2	-7.1	-7.6	6.6
Elongation at Break, %	173	181	188	147	151
Delta Elongation at Break, %	-35.9	-24.6	-21.0	-20.1	-24.9
25% Modulus, MPa	1.4	0.8	0.9	0.9	0.9
Delta 25% Modulus, %	10.1	-20.0	-13.0	-10.5	-10.0
50% Modulus, MPa	3.1	2.0	1.9	2.1	2.0
Delta 50% Modulus, %	29.3	-2.4	1.6	7.3	11.1
100% Modulus, MPa	8.5	6.4	5.5	6.2	6.1
Delta 100% Modulus, %	40.0	11.3	12.8	22.9	33.0
Weight Change, %	9.3	11.7	11.2	11.7	9.5
Volume Change, %	13.9	14.7	14.0	14.9	12.5

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Table 3 (continued) – Comparison of Vamac[®] HyPR 5000 Grades (65-70 Shore A)

Fluid Ageing: Reference Oil + 10% FAM-B	Vamac [®]			HyPR 5020,	HyPR 5020 /
	Ultra IP	HyPR 5015	HyPR 5020	red	Ultra LS, red
<u>Fluid ageing 168 hours at 150°C in Lubrizol[®] OS 206304 +10% FAM-B (ISO 1817:2011) in Autoclave</u>					
Hardness Shore A (3s), pts	59.8	55.2	52.4	52.8	52.5
Delta Hardness, pts	-12.1	-10.6	-12.2	-12.9	-12.4
Tensile Strength, MPa	13.2	14.0	10.5	8.6	8.0
Delta Tensile Strength, %	-30.3	-19.3	-21.5	-25.2	-25.0
Elongation at Break, %	190	193	195	145	149
Delta Elongation at Break, %	-29.6	-19.6	-18.1	-21.2	-25.9
10% Modulus, MPa	0.3	0.3	0.3	0.3	0.3
Delta 10% Modulus, %	-49.3	-41.4	-44.2	-42.9	-40.0
25% Modulus, MPa	0.9	0.8	0.7	0.7	0.7
Delta 25% Modulus, %	-32.6	-28.6	-35.0	-33.3	-30.0
50% Modulus, MPa	2.1	1.7	1.4	1.6	1.5
Delta 50% Modulus, %	-13.0	-17.0	-24.6	-18.2	-17.7
100% Modulus, MPa	6.2	5.1	4.1	4.8	4.3
Delta 100% Modulus, %	2.3	-12.0	-16.1	-5.0	-6.6
200% Modulus, MPa			10.9		
Delta 200% Modulus, %			-8.7		
Weight Change, %	12.5	12.4	11.8	14.6	12.6
Volume Change, %	20.2	17.7	17.0	20.5	17.9

Table 3 (continued) – Comparison of Vamac[®] HyPR 5000 Grades (65-70 Shore A)

Fluid Ageing: Blow-By Condensate BMW GS97018	Vamac [®]			HyPR 5020,	HyPR 5020 /
	Ultra IP	HyPR 5015	HyPR 5020	red	Ultra LS, red
<u>Fluid ageing 24 hours at 120°C in Blow-By Condensate (ISO 1817:2011), in Autoclave</u>					
Hardness Shore A (3s), pts	69.1	62.8	59.8	64.6	61.8
Delta Hardness, pts	-2.6	-2.9	-4.3	-1.4	-3.4
Tensile Strength, MPa	14.5	12.9	11.6	10.8	9.5
Elongation at Break, %	253	239	238	208	194
50% Modulus, MPa	2.3	1.6	1.5	1.5	1.4
100% Modulus, MPa	5.8	3.7	3.5	3.7	3.6
Weight Change, %	0.6	5.2	5.8		
Volume Change, %	0.7	6.1	6.9		

Vamac[®] HyPR 5015 / 5020

Ethylene Acrylic Elastomer Compound - Technical Data

Table 3 (continued) – Comparison of Vamac[®] HyPR 5000 Grades (65-70 Shore A)

Fluid Ageing (after Drying): Blow-By Condensate BMW GS97018	Vamac [®]			HyPR 5020,	HyPR 5020 /
	Ultra IP	HyPR 5015	HyPR 5020	red	Ultra LS, red
Delta Hardness, pts	-1.8	1.2	-0.5	0.7	1.3
Tensile Strength, MPa	18.5	16.6	13.9	11.5	12.4
Elongation at Break, %	259	238	235	199	196
50% Modulus, MPa	2.6	2.0	1.7	1.9	2.0
100% Modulus, MPa	6.9	4.9	4.3	4.7	5.2
Weight Change, %	-0.2	0.1	0.1	-0.5	-0.6
Volume Change, %	0.0	0.0	0.2	-0.8	-0.9

Table 3 (continued) – Comparison of Vamac[®] HyPR 5000 Grades (65-70 Shore A)

Fluid Ageing: AdBlue[®] (32% Urea Solution in Water)	Vamac [®]		
	Ultra IP	HyPR 5015	HyPR 5020
Fluid ageing 168 hours at 130°C in AdBlue [®] (registered trademark of BASF) ISO 1817:2011, in Autoclave			
Hardness Shore A (3s), pts	61.8	65.4	60.9
Delta Hardness, pts	-10.1	-0.3	-3.5
Tensile Strength, MPa	18.3	12.7	11.8
Delta Tensile Strength, %	-3.3	-27.0	-11.7
Elongation at Break, %	202	343	386
Delta Elongation at Break, %	-25.2	42.9	62.2
50% Modulus, MPa	2.9	2.4	2.0
Delta 50% Modulus, %	23.0	18.0	5.2
100% Modulus, MPa	8.3	4.5	3.4
Delta 100% Modulus, %	36.7	-22.9	-29.6
Weight Change, %	33.1	25.0	29.1
Volume Change, %	35.8	24.9	29.3

Vamac® HyPR 5015 / 5020

Ethylene Acrylic Elastomer Compound - Technical Data

Higher Hardness Compounds – 70 to 80 Shore A

Formulating Vamac® HyPR 5000 series pre-compounds with additional filler allows for producing higher hardness compounds. The following study is made to further show the effect of carbon black filler type and level on HyPR 5015, and 5020 compounds, and compared with conventional black-filled AEM compounds for applications like bonded piston seals.

Table 4 – Higher Hardness Compounds with Added Carbon Black

Compound Formulation	G	G / GLS	IP / GXF	IP / GLS	IP / LS	5015, FEF	5020, FEF	5020, SRF	5020, MT	5020, low MT high Diak
Vamac® G	100	50								
Vamac® GLS		50		50						
Vamac® GXF			50							
Vamac® Ultra IP			50	50	50					
Vamac® Ultra LS					50					
Vamac® HyPR 5015						182				
Vamac® HyPR 5020							182	182	182	182
Alcanpoudre® ADPA 75						1.5	1.5	1.5	1.5	1.5
Naugard® 445	2	2	2	2	2					
Armeen® 18D PRILLS	0.8	0.8	0.8	0.8	0.8					
Stearic Acid Reagent	2	2	2	2	2					
Vanfre® VAM	1	1	1	1	1	1	1	1	1	1
Spheron™ SOA (N550)	25	25	25	25	25	15	15			
Corax® N772	60	60	60	60	60			20		
MT Thermax® N990									25	15
Alcanplast® PO 80	10	10	10	10	10	7	7	7	7	7
Diak™ no 1	1.5	1.5	1.5	1.5	1.3	0.9	0.9	0.9	0.9	1.2

Vamac® HyPR 5015 / 5020

Ethylene Acrylic Elastomer Compound - Technical Data

No scorch retarder was added to the Vamac® HyPR 5000 series compounds for this study. The addition of Armeen® 18D (stearyl amine) would reduce viscosity, lower scorch times, and slow cure speed.

Table 4 (continued) – Higher Hardness Compounds with Added Carbon Black

Rheology	G	G / GLS	IP / GXF	IP / GLS	IP / LS	5015, FEF	5020, FEF	5020, SRF	5020, MT	5020, low MT high Diak
<u>Mooney, ML 1+4 at 100°C</u>										
Initial Mooney, MU	61.7	63.1	78.6	76.3	91.9	121.3	90.9	112.1	99.9	95.4
Final Mooney, MU	42.7	41.2	55.1	54.0	62.3	76.8	60.3	60.7	58.6	53.7
<u>MDR, 12 min, 180°C, arc 0.5°</u>										
ML, dNm	0.63	0.65	0.82	0.84	0.97	1.02	0.74	0.79	0.74	0.59
MH, dNm	15.91	15.04	16.83	16.93	16.82	17.85	15.29	14.65	13.95	15.99
Ts1, min	0.58	0.56	0.64	0.55	0.58	0.76	0.80	0.82	0.81	0.90
Ts2, min	0.82	0.78	0.92	0.76	0.80	1.00	1.08	1.10	1.11	1.25
T10, min	0.70	0.66	0.81	0.68	0.71	0.94	0.94	0.92	0.91	1.09
T50, min	2.25	2.08	2.84	2.14	2.27	2.94	2.76	2.76	2.66	3.51
T90, min	6.67	6.85	8.06	6.93	7.17	8.20	6.86	7.03	6.69	8.86
Tan delta at MH	0.043	0.049	0.056	0.048	0.057	0.081	0.078	0.080	0.082	0.063
Peak rate, dNm/min	6	6	5	7	6	6	5	5	5	4
<u>Mooney Scorch 45 min at 121°C</u>										
Initial Mooney, MU	23	21	29	26	32	47	35	39	38	37
Minimum Mooney, MU	16	15	19	19	22	27	22	23	22	20
Ts1, min	4.5	4.5	5.9	4.7	5.5	7.8	5.8	6.0	5.9	7.1
Ts2, min	5.6	5.4	7.3	5.7	6.8	9.4	6.7	6.8	6.7	8.2
T5, min	7.9	7.4	10.7	7.8	9.8	13.2	8.8	8.6	8.3	10.5
T10, min	10.5	9.7	14.9	10.4	13.3	17.7	11.0	10.6	10.2	13.2

Vamac® HyPR 5015 / 5020

Ethylene Acrylic Elastomer Compound - Technical Data

Hardness of Vamac® HyPR 5000 series compounds may be adjusted by varying the addition of carbon black, and carbon black type. The HyPR 5000 series exhibit significantly lower IRHD hardness than conventional carbon black filled AEM compounds, especially HyPR 5020.

Table 4 (continued) – Higher Hardness Compounds with Added Carbon Black

Original Properties	G	G / GLS	IP / GXF	IP / GLS	IP / LS	5015, FEF	5020, FEF	5020, SRF	5020, MT	5020, low MT High Diak
Compression Molding 10 minutes at 180°C, Post-cure 4 hours at 175°C										
Initial Specific Gravity, g/cm ³	1.27	1.28	1.27	1.28	1.28	1.12	1.12	1.13	1.14	1.12
Hardness Sh A (1s), pts	80.3	81.5	81.1	80.5	80.8	79.1	73.6	74.4	72.8	72.1
Hardness Sh A (3s), pts	79.3	80.4	80.1	79.8	79.7	77.7	72.0	72.8	71.1	70.6
Hardness IRHD (Method N, ISO48:2007)	79.5	79.5	80.7	80.0	79.8	74.9	68.2	68.9	67.0	67.5
Tensile properties (type 2) at 23°C, ISO 37:2005 Cor 1 2008										
Tensile Strength, MPa	16.4	16.4	17.3	16.7	17.7	18.6	14.7	14.8	15.0	18.3
Elongation at Break, %	179	174	203	184	230	190	199	194	231	207
10% Modulus, MPa	1.2	1.1	1.0	1.2	1.1	0.9	0.8	0.8	0.7	0.7
25% Modulus, MPa	2.2	2.1	1.9	2.3	2.1	1.9	1.5	1.6	1.5	1.6
50% Modulus, MPa	4.2	4.0	3.4	4.4	3.7	4.0	3.1	3.1	2.9	3.1
100% Modulus, MPa	9.3	9.3	8.3	9.8	8.4	9.5	7.4	7.4	6.6	7.6
Tear Strength type A - Trouser test pieces (Tear propagation direction: mill), ISO 34-1:2004										
Tear Strength, kN/m	5.4	4.2	4.8	5.6	5.2	5.7	4.0	3.5	4.2	4.4
Compression Set										
Compression Set, ISO 815-1, type B										
70 h at 150°C, %	26	31	24	27	25	25	27	27	33	25
504 h at 160°C, %	49	52	49	49	50	43	44	42	42	37
504 h at 170°C, %	56	55	52	50	50	51	52	51	50	46
504 h at 180°C, %	66	69	62	62	61	61	61	60	57	57
504 h at 190°C, %	86	88	81	79	78	70	70	71	70	67
Compression Set, ISO 815-1:2008 (DBL 6038), plied – cooled in the clamps 2h										
1008 h at 150°C, %	67	69	62	64	66	48	48	47	47	40
Compression Set VW (PV 3307:2004-08), 22h at 150°C										
after 5 sec, %	41	48	43	44	41	49	62	65	59	43
after 30 min, %	31	35	29	36	28	28	38	40	33	26
Compression Set VW (PV 3307:2004-08), 72h at 23°C										
after 5 sec, %	28	32	25	28	31	36	43	45	42	26
after 30 min, %	10	11	9	10	11	8	10	10	4	7

Vamac® HyPR 5015 / 5020

Ethylene Acrylic Elastomer Compound - Technical Data

Six-week air oven ageing of Vamac® HyPR 5000 series compounds show significantly less change in hardness, and loss in elongation than carbon black filled AEM compounds.

Table 4 (continued) – Higher Hardness Compounds with Added Carbon Black

Heat Ageing	G	G / GLS	IP / GXF	IP / GLS	IP / LS	5015, FEF	5020, FEF	5020, SRF	5020, MT	5020, low MT high Diak
<u>Heat Ageing 1008 h at 150°C (ISO 188:2007)</u>										
Hardness Shore A (1s), pts	85.4	88.6	85.5	87.0	85.9	77.5	74.0	73.8	72.5	72.9
Delta Hardness, pts	5.2	6.8	4.6	6.5	5.3	-1.9	0.1	-0.7	-0.6	0.4
Tensile Strength, MPa	14.2	13.6	14.9	13.6	15.2	10.0	8.1	9.0	9.0	8.9
Delta Tensile Strength, %	-13	-17	-14	-19	-14	-47	-45	-41	-38	-52
Elongation at Break, %	145	134	163	140	178	174	213	189	192	206
Delta Elongation at Break, %	-19	-23	-20	-24	-23	-8	7	-3	-17	0
25% Modulus, MPa	3.2	3.5	2.7	3.4	2.9	1.8	1.5	1.5	1.4	1.3
Delta 25% Modulus, %	43	65	45	47	38	-6	-5	-9	-7	-17
100% Modulus, MPa	10.5	11.0	9.9	10.6	9.9	7.9	6.6	6.8	6.1	5.8
Delta 100% Modulus, %	13	19	19	8	18	-16	-10	-8	-8	-23
<u>Heat Ageing 1008 h at 175°C (ISO 188:2007)</u>										
Hardness Shore A (1s), pts	97.0	96.5	97.2	97.0	95.4	74.3	71.2	70.1	69.2	69.3
Delta Hardness, pts	16.8	14.9	16.1	16.5	14.0	-5.1	-2.3	-4.3	-3.7	-3.2
Tensile Strength, MPa	0.22	0.22	1.23	0.09	0.17	13.4	12.4	12.1	10.2	10.3
Delta Tensile Strength, %	-99	-99	-93	-100	-99	-28	-16	-18	-32	-44
Elongation at Break, %	0	0	0	0	0	144	137	128	123	129
Delta Elongation at Break, %	-100	-100	-100	-100	-100	-24	-31	-34	-47	-38
25% Modulus, MPa						1.0	0.94	1.04	0.84	0.85
Delta 25% Modulus, %						-48	-39	-36	-43	-45
100% Modulus, MPa						8.2	8.0	8.3	7.4	7.1
Delta 100% Modulus, %						-13	8	12	11	-7

Vamac[®] HyPR 5015 / 5020

Ethylene Acrylic Elastomer Compound - Technical Data

Table 4 (continued) – Higher Hardness Compounds with Added Carbon Black

Fluid Ageing	G	G / GLS	IP / GXF	IP / GLS	IP / LS	5015, FEF	5020, FEF	5020, SRF	5020, MT	5020, low MT high Diak
Fluid Ageing, 1008 h at 150°C in Petro Dextron[®] VI RDL 3434										
Hardness Shore A (1s), pts	81.5	86.9	80.1	86.3	84.1	71.7	68.4	68.1	67.2	68.1
Delta Hardness, pts	1.3	5.4	-1.0	6.3	3.3	-7.4	-5.1	-6.3	-5.5	-4.4
Tensile Strength, MPa	15.3	14.3	15.8	15.1	17.5	14.1	11.8	11.8	11.8	11.0
Delta Tensile Strength, %	-6.9	-12.8	-9.0	-9.6	-1.4	-24.5	-19.7	-20.4	-21.4	-40.0
Elongation at Break, %	93	76	118	77	121	139	140	127	153	155
Delta Elongation at Break, %	-48.0	-56.3	-41.9	-58.2	-47.4	-26.8	-29.7	-34.5	-33.8	-25.1
10% Modulus, MPa	1.3	2.0	1.2	2.0	1.7	0.6	0.5	0.5	0.5	0.5
Delta 10% Modulus, %	16.5	87.2	16.8	65.0	48.3	-38.0	-34.6	-39.0	-32.9	-33.8
100% Modulus, MPa			12.9		14.3	10.4	8.4	8.9	7.4	7.1
Delta 100% Modulus, %			54.8		71.3	9.7	14.8	20.6	10.8	-6.1
Weight Change, %	7.8	5.0	8.5	5.0	5.2	9.2	9.3	8.6	8.5	8.9
Volume Change, %	11.4	7.4	12.5	7.6	7.9	11	11.5	10.7	10.8	10.2
Fluid Ageing, 1008 h at 150°C in Pentosin[®] FFL-5 LV										
Hardness, Shore A (1s), pts	85	87.6	85.8	88.7	88.6	76.6	73.5	72.8	72.8	73.6
Delta Hardness, pts	4.5	6.0	4.7	8.2	7.9	-2.7	0	-1.4	-0.1	1.0
Tensile Strength, MPa	16.3	15.5	15.6	16.5	17.1	13.5	11.2	12.4	11.6	10.6
Delta Tensile Strength, %	-0.7	-5.5	-9.7	-0.8	-3.8	-27.5	-24.0	-16.2	-22.7	-42.0
Elongation at Break, %	83	84	102	83	108	167	184	137	178	193
Delta Elongation at Break, %	-53.6	-51.7	-49.8	-54.9	-53.0	-12.1	-7.5	-29.4	-22.9	-6.8
10% Modulus, MPa	2.3	2.5	1.9	2.8	2.2	0.7	0.7	0.8	0.6	0.6
Delta 10% Modulus, %	99.1	127.5	91.1	129.2	93.0	-19.6	-9.0	-8.5	-12.3	-16.2
100% Modulus, MPa				10.7	15.3	10.6	8.5	9.9	7.8	7.8
Delta 100% Modulus, %				9.1	83.6	11.5	15.4	33.6	18.1	2.6
Weight Change, %	4.4	2.3	4.5	2.8	1.6	5.9	4.9	6.2	5.5	6.3
Volume Change, %	6.3	3.3	6.8	3.9	2.7	7.2	6.1	7.2	6.5	7.0

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