Vamac® Ultra HT-OR

Ethylene Acrylic Elastomer - Technical Data

Description

Standard grades of DuPont™ Vamac® G and Vamac® GXF ethylene acrylic elastomer (AEM) have been widely used for some years in turbo charger hose applications and current Vamac® Ultra grades are now extending the Vamac® offering for automotive hose applications. The Ultra grades deliver improved processing, heat and oil resistance required by the market.

Vamac® Ultra HT-OR is an AEM grade that is part of the Ultra family displaying equivalent properties and processing as Vamac® Ultra HT with a clear improvement in oil resistance while maintaining a comparable resistance to acids. Vamac® Ultra HT-OR has equivalent physical, heat ageing, dynamic and sealing performances as Vamac® Ultra HT for the temperature range of 170 – 180 ˚C and is extending the oil resistance of the current portfolio. For instance, Vamac® Ultra HT-OR provides 50% improvement in volume swell in IRM 903.

Vamac® Ultra HT-OR is a terpolymer of ethylene and methyl acrylate (AEM) with an acidic cure site using a diamine-based vulcanization system delivering high mechanical properties and good low temperature flexibility. Inherently, it has a halogen free structure like other Vamac® grades, all providing superior acid resistance encountered with blow-by gas, and exhaust gas recirculation.

The Vamac® Ultra family which includes Vamac® Ultra HT-OR offers a specific polymer design with a higher viscosity improving process and properties versus standard Vamac® grades.

Vamac® Ultra HT-OR can be compounded as a DOTG free compound similar to other Vamac® terpolymer products.

Product Properties

Property	Target Values	Method
Mooney Viscosity ML1+4 at 100 °C	31	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

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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®*.

Performance & Applications

Engine downsizing and turbo charging are widely adopted by all OEMs for diesel as well as gasoline engines to reduce both fuel consumption and CO_2 emissions when compared to bigger, naturally aspirated engines, Industry leaders continue to development of cleaner vehicles to meet new, more demanding standards

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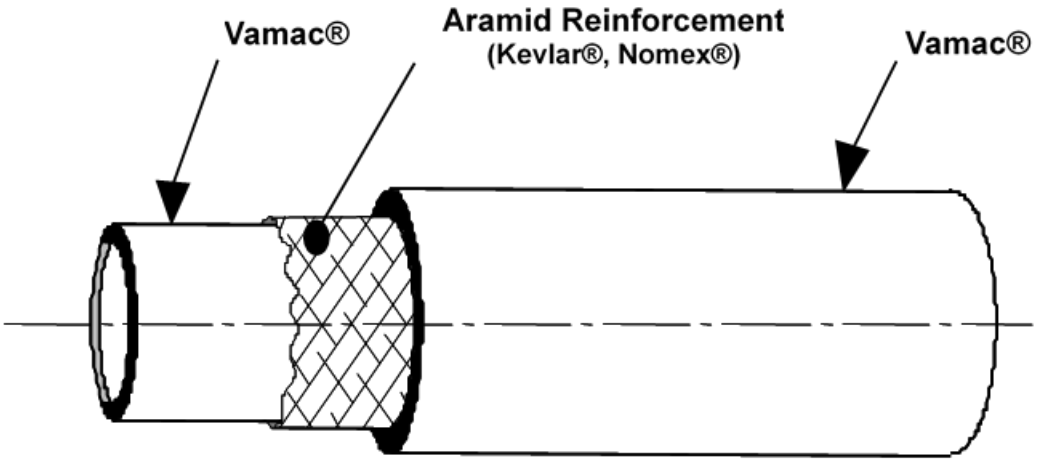
Vamac® Ultra HT-OR has been developed to meet severe fluid requirements in terms of volume swell and retention of properties after exposure in these fluids (for example IRM 903).



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Mixing

Compounds made from Vamac® Ultra HT-OR can be mixed either in an internal mixer or an open mill, with a relatively short cycle time. For internal mixers, single pass, upside-down mixing is preferred to control overheating. It is recommended for Ultra grades to use a dump temperature lower than for standard grades and to do so the rotor speed of the internal mixer can be adjusted. For more information, please refer to bulletin *Vamac® Compound Mixing Guide*, available from DuPont.

Processing

Compounds of Vamac® can be extruded using equipment commonly used to extrude thermoset elastomers. Short or moderate L/D extruders are suitable (10/1 up to 15/1). Extruded surface of Vamac® compounds are smooth and extrusion speed up to 20m/min can be achieved.

General temperature profile:

Typical starting point temperature profile for cold-feed extrusion

DIE	HEAD	ZONE 2	ZONE 1
80-90 ˚C	70-75 ˚C	60-65 ˚C	55-60 ˚C

The curing of extruded articles must be completed in an autoclave system because Vamac® will "sponge" if cured without pressure. For more information on temperature and pressure range, please refer to the *Vamac® Compounds Extrusion Guide*.

The mandrel assembly and disassembly are key points in hose manufacturing process requiring use of release agents. Various mandrel release agents are commercially available. SaficRelease RPM-V, poly(ethylene glycol adipate) by Safic Alcan was used with the compound studies that follow.

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Compounding and Physical Properties

Comparative starting point formulations for Vamac® Ultra HT and Vamac® Ultra HT-OR are shown in Table 1 that follows with 1phr of Diak™ No.1 diamine curing agent and 2phr of a cyclo-aliphatic amine accelerator, such as Vulcofac® ACT55. Compounding optimization for Vamac® Ultra HT-OR may be informed by general formulation recommendations for curative, accelerator, scorch retarder, and carbon black as given by the Technical Bulletin for Vamac® Ultra HT.

Both Vamac® Ultra HT, and Vamac® Ultra HT-OR display an equivalent set of properties for sealing performance at 175 ˚C, tear strength and tensile strength both at room and elevated temperature. A key difference is the higher glass transition temperature of Vamac® Ultra HT-OR. The higher Tg results from higher methyl acrylate monomer content, which provides improved chemical resistance in various fluids, including engine oils, grease, diesel and IRM 903.

The recommended starting point formulation for turbo charger hoses is using 1phr of Diak® N.1, 2phr of Vulcofac® ACT55, 2phr of Naugard® 445, 2 to 7phr of plasticizer, 1phr of Vanfre® VAM and stearic acid and with 45 to 50phr of FEF N550. To improve static heat ageing MT N990 carbon black can be used pure or in blends with FEF N550 filler.

Table 1 – Comparison of Vamac® Ultra HT and Vamac® Ultra HT-OR

Compound Formulation	Ultra HT	Ultra HT-OR
Vamac® Ultra HT	100	
Vamac® Ultra HT-OR		100
Naugard® 445	2	2
Stearic acid	1	1
Vanfre® VAM	1	1
Spheron® SOA (N 550)	45	45
TegMeR® 812	2	2
Rubber chem Diak™ No 1	1	1
Vulcofac® ACT 55	2	2

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Rheological Properties

Ultra HT-OR and Ultra HT have similar viscosity and rheological behavior. The cure speed and scorch safety are equivalent, and the compound viscosity displayed may be slightly higher.

Vulcanizate Properties

In general terms, Vamac® Ultra grades present high tensile strength and a broad set of properties required by automotive hose applications. Both Vamac® Ultra HT, and Vamac® Ultra HT-OR display an equivalent set of properties for sealing performance at 175 ˚C, tear strength and tensile strength both at room and elevated temperature. Improved fluid resistance with Vamac® Ultra HT-OR is balanced with higher Tg.

Dynamic properties

Vamac® Ultra HT-OR displays equivalent or slightly improved flex-fatigue properties compared to Ultra HT as indicated with De Mattia flex fatigue test results.

Table 1 (continued) – Comparison of Vamac® Ultra HT and Vamac® Ultra HT-OR

Rheology and Physical Properties	Ultra HT	Ultra HT-OR
MDR cure rate 15 minutes at 180°C, arc 0.5°		
ML, dNm	0.8	0.9
MH, dNm	13.2	12.7
Ts1, min	0.7	0.7
Ts2, min	1.0	0.9
T50, min	2.4	2.2
T90, min	7.1	7.7
Mooney Scorch 45 minutes at 121 °C		
Ts1, min	5.8	5.9
Ts2, min	7.1	7.0
T5, min	9.8	9.6
Mooney Viscosity ML 1+4 at 100 °C		
Final Mooney, MU	66	73

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Table 1 (continued) – Comparison of Vamac® Ultra HT and Vamac® Ultra HT-OR

Physical Properties	Ultra HT	Ultra HT-OR
Press-cure 10 minutes at 180 °C / Post-cure 4 hours at 175 °C		
Original Properties (type 2) at 23 °C		
Hardness Shore A (1s), pts	69	71
Tensile Strength, MPa	20.1	20.1
Elongation at Break, %	430	420
50% Modulus, MPa	1.9	2.0
100% Modulus, MPa	4.1	4.0
Tear Strength (type C, Crescent), kN/m	29.3	27.6
Tensile Properties (type 2) at 175 °C		
Tensile Strength, MPa	5.7	6.7
Elongation at Break, %	130	150
50% Modulus, MPa	1.7	1.7
100% Modulus, MPa	3.9	3.9
Tear Strength (type C, Crescent), kN/m	10.1	10.6
Compression Set (70h / 175 °C, plied), %	30	30
VW Comp Set PV3307 (22h / 175 °C, 5 seconds), %	65	62
VW Comp Set PV3307 (22h / 175 °C, 30 minutes), %	43	45
Glass Transition Temperature (Tg) by DSC, °C	-31	-24
Mandrel Bend Test at -35 °C		
(DuPont Method: 24h conditioning)	No Cracks	No Cracks
De Mattia at 150˚C, after ageing 94hrs / 200 ˚C		
Cycles (Median of 5 Samples)	155	635
Cycles (Average of 5 Samples)	335	1499

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Heat ageing

Physical property testing is shown for a range of ageing conditions (175 ˚C, 190 ˚C and 200 ˚C) relating to continuous and peak service temperatures for turbo charger hose, automotive hose and air duct applications.

Table 1 (continued) – Comparison of Vamac® Ultra HT and Vamac® Ultra HT-OR

Heat Ageing at 190 and 200 °C	Ultra HT	Ultra HT-OR
Heat Ageing 94 hours at 200 °C		
Tensile properties (type 2) at 23 °C		
Hardness Shore A (1s), pts	71	76
Delta Hardness, pts	2	5
Tensile Strength, MPa	12.6	12.3
Delta Tensile Strength, %	-37	-39
Elongation at Break, %	301	309
Delta Elongation at Break, %	-30	-26
50% Modulus, MPa	2.0	2.3
Delta 50% Modulus, %	6	18
100% Modulus, MPa	3.8	4.1
Delta 100% Modulus, %	-8	3
Heat Ageing 168 hours at 190 °C		
Tensile properties (type 2) at 23 °C		
Hardness Shore A (1s), pts	73	76
Delta Hardness, pts	4	5
Tensile Strength, MPa	12.2	11.2
Delta Tensile Strength, %	-39	-44
Elongation at Break, %	292	294
Delta Elongation at Break, %	-32	-30
50% Modulus, MPa	2.3	2.4
Delta 50% Modulus, %	17	23
100% Modulus, MPa	3.6	4.2
Delta 100% Modulus, %	-12	5

Vamac® Ultra HT-OR

Ethylene Acrylic Elastomer - Technical Data

Table 1 (continued) – Comparison of Vamac® Ultra HT and Vamac® Ultra HT-OR

Heat Ageing at 175 °C	Ultra HT	Ultra HT-OR
Heat Ageing 168 hours at 175 °C		
Tensile properties (type 2) at 23 °C		
Hardness Shore A (1s), pts	69	73
Delta Hardness, pts	0	2
Tensile Strength, MPa	16.4	16.4
Delta Tensile Strength, %	-18	-18
Elongation at Break, %	450	460
Delta Elongation at Break, %	5	9
50% Modulus, MPa	1.7	2.0
Delta 50% Modulus, %	-12	1
100% Modulus, MPa	3.4	3.7
Delta 100% Modulus, %	-16	-8
Heat Ageing 504 hours at 175 °C		
Tensile properties (type 2) at 23 °C		
Hardness Shore A (1s), pts	72	74
Delta Hardness, pts	3	3
Tensile Strength, MPa	12.4	11.3
Delta Tensile Strength, %	-38	-44
Elongation at Break, %	311	292
Delta Elongation at Break, %	-28	-30
50% Modulus, MPa	2.0	2.3
Delta 50% Modulus, %	4	18
100% Modulus, MPa	3.8	4.2
Delta 100% Modulus, %	-8	5

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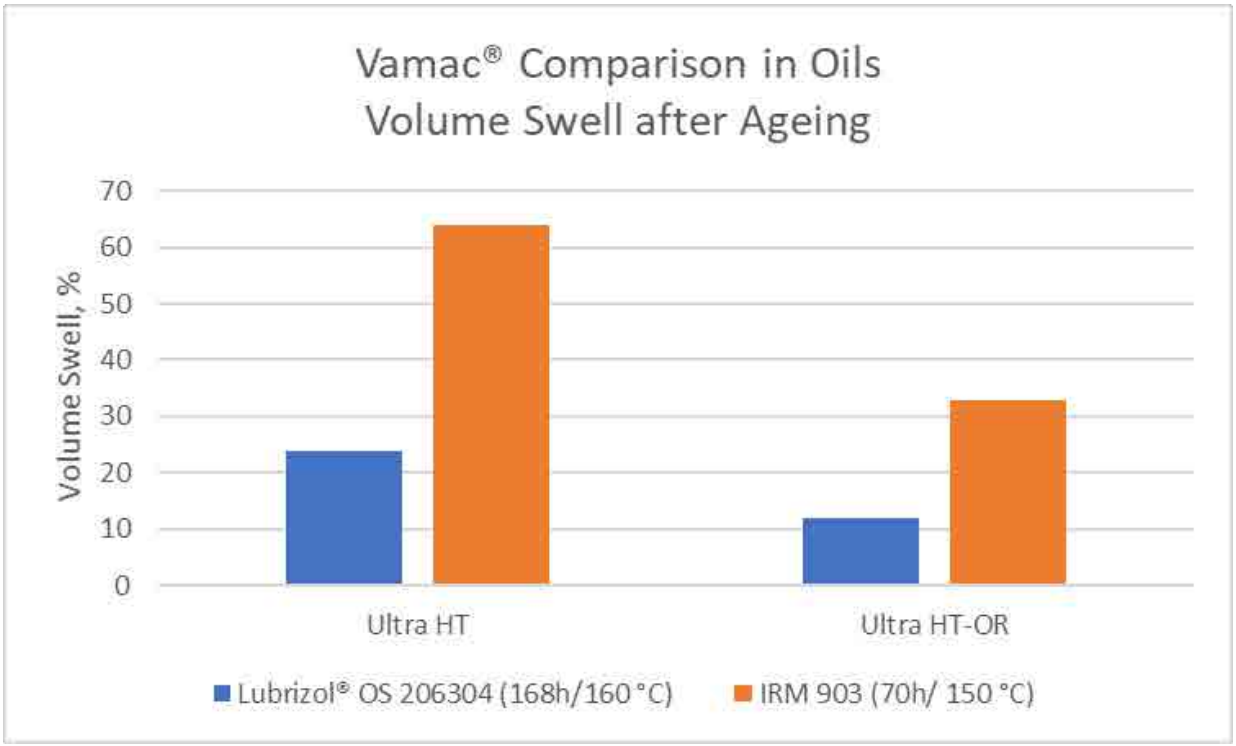
Fluid Ageing

Fluid ageing tests clearly show the improved oil resistance of Vamac® Ultra HT-OR over Vamac® Ultra HT. Vamac® Ultra HT-OR shows a 50% improvement in volume swell compared to Vamac® Ultra HT.



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Ethylene Acrylic Elastomer - Technical Data

Table 1 (continued) – Comparison of Vamac® Ultra HT and Vamac® Ultra HT-OR

Fluid Ageing	Ultra HT	Ultra HT-OR
Fluid Ageing 168 hours at 160 °C in Lubrizol® OS 206304		
Tensile properties (type 2) at 23 °C		
Hardness Shore A (1s), pts	57	66
Delta Hardness, pts	-12	-5
Tensile Strength, MPa	17.0	18.3
Delta Tensile Strength, %	-16	-9
Elongation at Break, %	360	370
Delta Elongation at Break, %	-16	-11
50% Modulus, MPa	1.5	1.8
Delta 50% Modulus, %	-23	-6
100% Modulus, MPa	3.7	4.1
Delta 100% Modulus, %	-10	4
Volume Change, %	24	12
Fluid Ageing 168 hours at 150 °C in IRM 903		
Tensile properties (type 2) at 23 °C		
Hardness Shore A (1s), pts	50	56
Delta Hardness, pts	-20	-15
Tensile Strength, MPa	14.3	17.9
Delta Tensile Strength, %	-29	-11
Elongation at Break, %	300	390
Delta Elongation at Break, %	-30	-8
50% Modulus, MPa	1.3	1.5
Delta 50% Modulus, %	-30	-25
100% Modulus, MPa	4.1	3.8
Delta 100% Modulus, %	-1	-5
Volume Change, %	64	33

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Ethylene Acrylic Elastomer - Technical Data

Table 1 (continued) – Comparison of Vamac® Ultra HT and Vamac® Ultra HT-OR

Fluid Ageing	Ultra HT	Ultra HT-OR
Fluid Ageing 54 hours at 100 °C in Acetic Acid (2.5 pH) EGR Solution, liquid phase		
Tensile properties (type 2) at 23 °C		
Hardness Shore A (1s), pts	67	66
Delta Hardness, pts	-2	-5
Tensile Strength, MPa	20.3	18.9
Delta Tensile Strength, %	1	-6
Elongation at Break, %	390	390
Delta Elongation at Break, %	-8	-7
50% Modulus, MPa	2.0	2.0
Delta 50% Modulus, %	3	0
100% Modulus, MPa	4.4	4.4
Delta 100% Modulus, %	7	10
Volume Change, %	9	13

Vamac® Ultra HT-OR Compounding Filler Study

Vamac® Ultra HT-OR is well suited for turbo charger hose and automotive hose applications for the class temperature of 170 – 180 °C. The following study explores carbon black filled compound formulations to demonstrate additional improvement in heat ageing for Vamac® Ultra HT-OR.

The use of carbon black MT N990 has already proven some advantage for Vamac® Ultra HT for high temperature long term heat ageing, maintaining hardness stability, while reducing the loss in elongation. Other advantages of MT carbon black are the reduction of Mooney viscosity of the Ultra grade compound and the improvement of the compression set.

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Table 2 - Vamac® Ultra HT-OR Compound Filler Study

Compound Formulation & Rheology	Ultra HT-OR 50phr N550 Endenol® T810T	Ultra HT-OR 45phr N550 TegMer® 812	Ultra HT-OR 90phr N990 TegMer® 812
Vamac® Ultra HT-OR	100	100	100
Naugard® 445	2	2	2
Stearic acid	1	1	1
Vanfre® VAM	0.5	1	1
Spheron™ SOA (N 550)	50	45	
MT Thermax® Floform N990			90
TegMeR® 812		2	2
Edenol® T810T stabilized	5		
Rubber chem Diak™ No. 1	1	1	1
Vulcofac® ACT 55	2	2	2
MDR cure rate 15 minutes at 180 °C, arc 0.5°			
ML, dNm	0.9	0.9	0.7
MH, dNm	13.4	12.7	13.2
Ts1, min	0.6	0.7	0.6
T50, min	2.1	2.2	2.2
T90, min	7.1	7.7	7.4
Mooney Scorch 45 minutes at 121 °C			
Ts1, min	5.3	5.9	5.6
Ts2, min	6.4	7.0	6.6
T5, min	8.9	9.6	8.9
Mooney Viscosity ML 1+4 at 100 °C			
Final Mooney, MU	69	73	63

Vamac® Ultra HT-OR

Ethylene Acrylic Elastomer - Technical Data

Table 2 (continued) - Vamac® Ultra HT-OR Compound Filler Study

Original Properties	Ultra HT-OR 50phr N550 Endenol® T810T	Ultra HT-OR 45phr N550 TegMer® 812	Ultra HT-OR 90phr N990 TegMer® 812
Press-cure 10 minutes at 180 °C / Post-cure 4 hours at 175 °C			
Original Properties (type 2) at 23 °C			
Hardness Shore A (1s), pts	73	71	69
Tensile Strength, MPa	19.7	20.1	15.2
Elongation at Break, %	390	420	360
50% Modulus, MPa	2.2	2.0	1.8
100% Modulus, MPa	4.6	4.0	3.8
Tear Strength (type C, Crescent), kN/m	28.0	27.6	25.4
Original Properties (type 2) at 175 °C			
Tensile Strength, MPa	5.9	6.7	3.9
Elongation at Break, %	130	150	130
50% Modulus, MPa	1.8	1.7	1.5
100% Modulus, MPa	4.2	3.9	3.0
Tear Strength (type C, Crescent), kN/m	10.7	10.6	8.3
Compression Set (70h / 175 °C, plied), %	28	30	27
VW Comp Set (22h / 175 °C, 5 sec), %	71	62	59
VW Comp Set (22h / 175 °C, 30 min), %	46	45	37
Glass Transition Temp (Tg) by DSC, °C	-25	-24	-24
Mandrel Bend Test at -35 °C			
(DuPont Method: 24h conditioning)	Pass	Pass	Pass

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Table 2 (continued) - Vamac® Ultra HT-OR Compound Filler Study

Heat Ageing at 190 and 200 °C	Ultra HT-OR 50phr N550 Endenol® T810T	Ultra HT-OR 45phr N550 TegMer® 812	Ultra HT-OR 90phr N990 TegMer® 812
Heat Ageing 94 hours at 200 °C			
Tensile properties (type 2) at 23 °C			
Hardness Shore A (1s), pts	78	76	67
Delta Hardness, pts	6	5	-2
Tensile Strength, MPa	11.7	12.3	9.0
Delta Tensile Strength, %	-41	-39	-41
Elongation at Break, %	290	309	272
Delta Elongation at Break, %	-26	-26	-24
50% Modulus, MPa	2.6	2.3	1.6
Delta 50% Modulus, %	21	18	-12
100% Modulus, MPa	4.4	4.1	3.0
Delta 100% Modulus, %	-4	3	-20
Heat Ageing 168 hours at 190 °C			
Tensile properties (type 2) at 23 °C			
Hardness Shore A (1s), pts	76	76	67
Delta Hardness, pts	4	5	-2
Tensile Strength, MPa	11.2	11.2	9.5
Delta Tensile Strength, %	-43	-44	-37
Elongation at Break, %	301	294	296
Delta Elongation at Break, %	-23	-30	-18
50% Modulus, MPa	2.5	2.4	1.5
Delta 50% Modulus, %	16	23	-15
100% Modulus, MPa	4.5	3.6	2.9
Delta 100% Modulus, %	-2	-10	-23

Vamac® Ultra HT-OR

Ethylene Acrylic Elastomer - Technical Data

Table 2 (continued) - Vamac® Ultra HT-OR Compound Filler Study

Heat Ageing at 175 and 180 °C	Ultra HT-OR 50phr N550 Endenol® T810T	Ultra HT-OR 45phr N550 TegMer® 812	Ultra HT-OR 90phr N990 TegMer® 812
Heat Ageing 504 hours at 180 °C			
Tensile properties (type 2) at 23 °C			
Hardness Shore A (1s), pts	83	84	71
Delta Hardness, pts	11	13	2
Tensile Strength, MPa	7.3	6.2	6.3
Delta Tensile Strength, %	-63	-69	-59
Elongation at Break, %	122	92	146
Delta Elongation at Break, %	-69	-78	-59
50% Modulus, MPa	4.0	4.2	2.1
Delta 50% Modulus, %	86	115	16
100% Modulus, MPa	6.8		4.2
Delta 100% Modulus, %	49		12
Heat Ageing 504 hours at 175 °C			
Tensile properties (type 2) at 23 °C			
Hardness Shore A (1s), pts	75	74	66
Delta Hardness, pts	3	3	-3
Tensile Strength, MPa	10.6	11.3	9.9
Delta Tensile Strength, %	-46	-44	-35
Elongation at Break, %	290	292	256
Delta Elongation at Break, %	-26	-30	-29
50% Modulus, MPa	2.4	2.3	1.8
Delta 50% Modulus, %	12	18	-1
100% Modulus, MPa	4.2	4.2	3.5
Delta 100% Modulus, %	-8	5	-7

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Table 2 (continued) - Vamac® Ultra HT-OR Compound Filler Study

Fluid Ageing	Ultra HT-OR 50phr N550 Endenol® T810T	Ultra HT-OR 45phr N550 TegMer® 812	Ultra HT-OR 90phr N990 TegMer® 812
Fluid Ageing 168 hours at 160 °C in Lubrizol® OS 206304			
Tensile properties (type 2) at 23 °C			
Hardness Shore A (1s), pts	68	66	63
Delta Hardness, pts	-5	-5	-6
Tensile Strength, MPa	17.9	18.3	15.2
Delta Tensile Strength, %	-9	-9	0
Elongation at Break, %	360	370	350
Delta Elongation at Break, %	-6	-11	-1
50% Modulus, MPa	2.0	1.8	1.6
Delta 50% Modulus, %	-7	-6	-13
100% Modulus, MPa	4.5	4.1	3.3
Delta 100% Modulus, %	-3	4	-12
Volume Change, %	10	12	10
Fluid Ageing 168 hours at 150 °C in IRM 903			
Tensile properties (type 2) at 23 °C			
Hardness Shore A (1s), pts	58	56	55
Delta Hardness, pts	-14	-15	-14
Tensile Strength, MPa	17.0	17.9	13.9
Delta Tensile Strength, %	-14	-11	-8
Elongation at Break, %	350	390	340
Delta Elongation at Break, %	-11	-8	-6
50% Modulus, MPa	1.6	1.5	1.3
Delta 50% Modulus, %	-27	-25	-30
100% Modulus, MPa	4.1	3.8	3.1
Delta 100% Modulus, %	-11	-5	-18
Volume Change, %	30	33	29

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Table 2 (continued) - Vamac® Ultra HT-OR Compound Filler Study

Fluid Ageing	Ultra HT-OR 50phr N550 Endenol® T810T	Ultra HT-OR 45phr N550 TegMer® 812	Ultra HT-OR 90phr N990 TegMer® 812
Fluid Ageing 54 hours at 100 °C in Acetic Acid (2.5 pH) EGR Solution, liquid phase			
Tensile properties (type 2) at 23 °C			
Hardness Shore A (1s), pts	69	66	64
Delta Hardness, pts	-4	-5	-5
Tensile Strength, MPa	19.4	18.9	13.6
Delta Tensile Strength, %	-2	-6	-11
Elongation at Break, %	350	390	390
Delta Elongation at Break, %	-9	-7	9
50% Modulus, MPa	2.1	2.0	1.5
Delta 50% Modulus, %	-3	0	-16
100% Modulus, MPa	4.7	4.4	3.1
Delta 100% Modulus, %	4	10	-18
Volume Change, %	10	13	12

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ISO testing methods were used to produce this technical bulletin and the ASTM are shown in the below table only for comparison purpose.

Rheology	ISO Method	ASTM Standard
Mooney Viscosity	ISO 289-1:2005	D1246
Mooney Scorch	ISO 289-2:1994	D1246
MDR	ISO 6502:1999	D5289
Physicals		
Hardness	ISO 7619-1:2004	D2240
Tensile, elongation	ISO 37:2005	D412
Fluid ageing	ISO 1817:2005	D471
Heat ageing	ISO 188:2007	D573
Compression set	ISO 815-1:2008	D395
Compression set VW	VW PV 3307:2004-08	
Tg by DSC	ISO 22768:2006	D7426
Tear strength	ISO 34	D624
De Mattia	ISO 132:2005	D430

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