Vamac® Ultra HT

Ethylene Acrylic Elastomer - Technical Data

Description

DuPont™ Vamac® G has been widely used for a number of years in turbo charger hose applications. Vamac® GXF was developed to improve heat resistance and dynamic properties and these properties have now been further enhanced with the development of Vamac® Ultra HT (high temperature).

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Vamac® Ultra HT has been developed to extend heat resistance and the dynamic performance of the standard Vamac® portfolio to a temperature range of 170 -180 °C, suitable for demanding applications such as turbo hoses and air ducts.

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

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

Vamac® Ultra HT 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	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

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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®*.

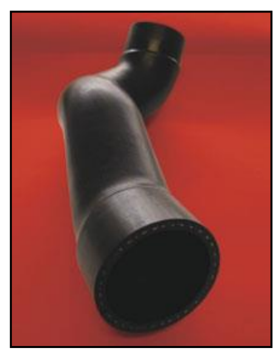
Performance & Applications

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

Vamac® Ultra HT has been developed to answer this automotive market trend and extend the Vamac® product range in terms of high temperature performance combined with flex fatigue resistance. This set of properties is further associated with oil resistance, tear resistance and sealing performance making it a material of choice especially for automotive turbo charger hoses.

Its continuous service temperature is 170 °C – 180 °C with peaks up to 190 °C – 200 °C are suitable especially for the latest diesel and gasoline turbo engines. A typical turbo hose construction recommendation follows: Vamac® Ultra HT / DuPont™ Nomex® aramid fibre / Vamac® Ultra HT.

At higher specified temperature, rubber multilayer structures are used such as FKM/VMQ construction or FKM/Vamac®/Nomex® aramid fibre/Vamac® construction



The main automotive applications targeted are:

- Turbo charger hoses
- Other hoses / air ducts
- Torsional dampers

Although most applications are found in automotive, industrial applications can also benefit when a good extrusion process, heat resistance and improved flex fatigue resistance are required in addition to Vamac® typical properties.

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Mixing

Compounds made from Vamac® Ultra HT 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. For more information, please refer to bulletin, *Vamac® Compound Mixing Guide*, available from DuPont.

Formulation

Example compounds are shown in the tables that follow for various formulations with Vamac® Ultra HT polymer using a diamine curing agent and accelerators based on DPG and DBU. Cure accelerator Rhenogran® DPG 80 is a diphenylguanidine and Vulcofac® ACT55 is a cycloaliphatic amine (DBU). The DBU based accelerator has been used in recent years to replace DOTG due to the implementation of REACH legislation and provide similar vulcanizates properties. DPG can be used in combination with DBU to improve properties such as the elongation at break and the flex fatigue resistance.

The recommended starting point formulation is the DPG-free compound with 1 or 0.9phr of DuPont™ Diak™ No.1, and 2phr of Vulcofac® ACT 55.

The formulations do not contain any scorch retarder, like Armeen® 18D, commonly used in compounds with Vamac®. For a demanding manufacturing process with higher shear speeding up the reaction, 0.5phr of Armeen® 18D is recommended to minimize scorch.

A low level of plasticiser should be used in formulations for elevated service temperatures. At higher temperatures of 190 – 200 °C, most of the plasticiser can be lost from the elastomer. The recommended use is 1 to 3phr of a polymeric ether/ester plasticiser with low volatility at elevated temperature.

In certain applications where heat resistance is critical it is suggested that a maximum of 50 phr of N550 is used. Additionally, other types of carbon black with larger particle size can be used to further extend the upper temperature limit.

The curative level of Diak™ No.1 can be adjusted in the formulation related to the final requirements in terms of compression set and flex fatigue performance.

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Rheological properties

A significant viscosity increase at equal formulation can be realized from Vamac® GXF to Vamac® Ultra HT. The higher viscosity improves processability and provides higher green strength. Vamac® Ultra HT cured with DBU provides a higher cross-link density compared to GXF or to Vamac® Ultra HT cured with a combination of DBU and DPG. Additionally, the cure speed is faster which can provide reduced cycle time.

Vulcanizate properties

A broad set of properties is required in automotive hose applications to insure the function of the final part. The key properties are heat and oil resistance induced by the engine environment itself. Vamac® Ultra HT delivers increased mechanical properties, tear strength and heat resistance compared to Vamac® GXF.

Vamac® Ultra HT displays a stable modulus after ageing and even measured at elevated temperature with an elongation above 120%. In addition, the hardness change is minimal after heat exposure. The ISO compression sets are all in line with specification but vary depending on the type of formulation. Effectively, the level of Diak™ No.1 is important to obtain the desired balance of properties between sealing and dynamic performance.

Dynamic properties

The DeMattia flex-fatigue and crack growth tests display the crack initiation to failure resistance at elevated temperature and the crack propagation resistance at room temperature.

The cross-linking density and the curing package have an important influence over this flex fatigue property. The DPG / DBU blend formulation with 1.25 phr of Diak™ No.1 will show, superior fatigue and crack resistance, when properly formulated, compared to formulations containing only DBU, but compromise will be made on compression set.

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Heat ageing

Table 1 shows heat ageing values at 200 °C which is the maximum peak service temperature advised for the material. The hardness change is very low with values below 5 points and the tensile properties maintain a high level with elongation still above 350% for the DBU cure package.

A complete ageing set of data is displayed in the second study (Table 2) with longer term ageing conditions at temperature from 175 °C to 190 °C

Fluid ageing

The second study also compares Vamac® GXF and Vamac® Ultra HT for fluid ageing performance in two engine oils and the reference fluid, IRM 903. The test fluid IRM 903 is not representative of the engine oil effect on elastomers. Effectively, the results provided showing both engine oils, are clearly better compared to IRM 903 which demonstrate a more aggressive effect.

Vamac® Ultra HT provides an improvement in fluid ageing compared to GXF with higher absolute properties after fluid ageing and similar properties change.

Conclusions

Vamac® Ultra HT provides better compound properties and higher heat resistance over Vamac® GXF as follows:

- Higher elongation at break before and after heat ageing
- Higher tear resistance
- Very low hardness and modulus change after heat ageing
- Better flex fatigue resistance after ageing.
- 170 – 180 °C continuous temperature resistance on hoses (with Nomex® textile reinforcement)

These properties make Vamac® Ultra HT the product of choice for turbo charger hoses in the 170 °C- 180 °C temperature range. The recommended starting point formulation for Vamac® Ultra HT for turbo charger hoses is using 1 phr of Diak™ and 2 phr of Vulcofac® ACT55 or equivalent.

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Table 1 - Vamac® Ultra HT Formulations & Comparison with GXF

	Vamac® GXF	Vamac® Ultra HT			
Diak™ No 1	1.1phr	1.1phr	1phr*	0.9phr	1.25phr
Vulcofac® ACT 55	2phr	2phr	2phr	2phr	1phr
Rhenogran® DPG 80					2.5phr
Vamac® GXF	100				
Vamac® Ultra HT		100	100	100	100
Naugard® 445	2	2	2	2	2
Vanfre® VAM	1	1	1	1	1
Stearic acid	1	1	1	1	1
Spheron® SO A N 550	45	45	45	45	45
Alcanplast® PO 80	2	2	2	2	2
Diak™ No.1	1.1	1.1	1	0.9	1.25
Vulcofac® ACT 55	2	2	2	2	1
Rhenogran® DPG 80					2.5
Mooney Viscosity ML 1+4 at 100°C					
Final Mooney [MU]	46	66	66	65	63
MDR cure rate 15 min at 180°C, arc 0.5°					
ML, dNm	0.5	0.8	0.8	0.8	0.7
MH, dNm	11.1	13.6	12.9	11.7	10
Ts1, min	0.7	0.7	0.6	0.6	0.8
T50, min	2.2	2.2	2.0	1.8	2.3
T90, min	6.8	6.8	6.1	5.5	7.0

*starting formulation

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Table 1 (continued) - Vamac® Ultra HT Formulations & Comparison with GXF

	Vamac® GXF	Vamac® Ultra HT			
Diak™ No 1	1.1phr	1.1phr	1phr	0.9phr	1.25phr
Vulcofac® ACT 55	2phr	2phr	2phr	2phr	1phr
Rhenogran® DPG 80					2.5phr
Mooney Scorch 45 minutes at 121°C					
Ts1, min	5.5	5.4	5.1	5.2	6.9
Ts2, min	6.5	6.3	6.0	6.1	8.4
T5, min	8.9	8.5	8.1	8.2	11.8
Compression molding 10 minutes at 180°C, Post-cure 4 hours at 175°C					
Original Properties (type 2) at 23°C					
Hardness Shore A (1s), pts	67	67	67	67	66
Tensile Strength, MPa	18	19.6	20.3	19.5	18.8
Elongation at Break, %	380	395	420	425	440
50% Modulus, MPa	1.7	1.7	1.6	1.6	1.6
100% Modulus, MPa	3.3	3.8	3.3	3.0	3.1
Tensile properties (type 2) at 175°C					
Tensile Strength, MPa	4.8	5.5	5.5	5.4	4.9
Elongation at Break, %	135	120	130	145	135
50% Modulus, MPa	1.4	1.8	1.6	1.5	1.5
100% Modulus, MPa	3.2	4.1	3.7	3.3	3.3
Compression set 70 hours at 150 °C - plied					
Compression set, %	26	23	24	26	30
Compression set VW 22 hours at 175°C					
Measured at 5 sec, %	64	55	65	72	75
Measured at 30 min, %	43	35	42	46	54

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Table 1 (continued) - Vamac® Ultra HT Formulations & Comparison with GXF

	Vamac® GXF	Vamac® Ultra HT			
Diak™ No 1	1.1phr	1.1phr	1phr	0.9phr	1.25phr
Vulcofac® ACT 55	2phr	2phr	2phr	2phr	1phr
Rhenogran® DPG 80					2.5phr
Heat ageing 94 hours at 200 °C					
Tensile properties (type 2) at 23 °C					
Hardness Shore A (1s), pts	70	70	69	69	70
Delta Hardness, pts	3	3	2	2	4
Tensile Strength, MPa	13.2	15.3	14.6	12.8	12.2
Delta Tensile Strength, %	-26	-22	-28	-34	-35
Elongation at Break, %	325	350	375	385	310
Delta Elongation at Break, %	-14	-12	-11	-9	-29
50% Modulus, MPa	1.9	1.9	1.8	1.6	1.8
Delta 50% Modulus, %	14	11	7	0	14
100% Modulus, MPa	3.6	3.8	3.5	2.8	3.5
Delta 100% Modulus, %	7	-1	5	-5	13
DeMattia crack growth at 23ºC (samples pre-heat aged 94 hours at 200 °C), cycles					
4.5 mm	99	19	35	202	249
8.5 mm	2427	1835	3515	4731	2171
12.5 mm	5338	4670	8677	11793	4336
De Mattia Flex Cracking at 150 °C, cycles					
Median	15	75	155	155	1275
Average	23	343	323	187	891

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Table 2 - Vamac® GXF & Vamac® Ultra HT Ageing Study

Formulation & Rheology	Vamac® GXF Diak™: 1.1phr DBU: 2phr	Vamac® Ultra HT Diak™: 1.1phr DBU: 2phr
Vamac® GXF	100	
Vamac® Ultra HT		100
Naugard® 445	2	2
Ofalub® SEO	1	1
Stearic acid	1	1
Spheron® SO A N 550	45	45
Alcanplast® PO 80	2	2
Rubber Chem Diak™ no 1	1.1	1.1
Vulcofac® ACT 55	2	2
<u>MDR cure rate 15 minutes at 180 °C, arc 0.5°</u>		
ML, dNm	0.4	0.8
MH, dNm	9.6	13.4
Ts2, min	1.2	1
T50, min	2.5	2.4
T90, min	8.1	7.4
<u>Differential Scanning Calorimetry (DSC)</u>		
Tg by DSC, °C	-31	-31

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Table 2 (continued) - Vamac® GXF & Vamac® Ultra HT Ageing Study

Original Properties & Heat Ageing	Vamac® GXF Diak™: 1.1phr DBU: 2phr	Vamac® Ultra HT Diak™: 1.1phr DBU: 2phr
Compression moulding 10 minutes at 180 °C, Post-cure 4 hours at 175°C		
Original Properties (type 2) at 23 °C		
Hardness Shore A (1s), pts	66	67
Tensile Strength, MPa	18.3	19.8
Elongation at Break, %	360	380
50% Modulus, MPa	1.7	1.9
100% Modulus, MPa	3.8	4.2
Tear strength type C - Crescent test pieces at 23 °C		
Tear Strength, kN/m	23	25
Heat ageing 504 hours at 175 °C		
Tensile properties (type 2) at 23 °C		
Hardness Shore A (1s), pts	70	70
Delta Hardness, pts	4	3
Tensile Strength, MPa	12.2	14
Delta Tensile Strength, %	-34	-29
Elongation at Break, %	280	325
Delta Elongation at Break, %	-22	-15
50% Modulus, MPa	2	2
Delta 50% Modulus, %	16	4
100% Modulus, MPa	4.1	4.0
Delta 100% Modulus, %	8	-5

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Table 2 (continued) - Vamac® GXF & Vamac® Ultra HT Ageing Study

Heat Ageing	Vamac® GXF Diak™: 1.1phr DBU: 2phr	Vamac® Ultra HT Diak™: 1.1phr DBU: 2phr
Heat ageing 336 hours at 180 °C		
Tensile properties (type 2) at 23 °C		
Hardness Shore A (1s), pts	69	70
Delta Hardness, pts	3	2
Tensile Strength, MPa	10.7	13.2
Delta Tensile Strength, %	-42	-33
Elongation at Break, %	240	300
Delta Elongation at Break, %	-33	-22
50% Modulus, MPa	1.9	1.9
Delta 50% Modulus, %	8	4
100% Modulus, MPa	3.9	4.1
Delta 100% Modulus, %	4	-3
Heat ageing 168 hours at 190 °C		
Tensile properties (type 2) at 23 °C		
Hardness Shore A (1s), pts	71	71
Delta Hardness, pts	5	4
Tensile Strength, MPa	10.3	12.7
Delta Tensile Strength, %	-44	-36
Elongation at Break, %	220	275
Delta Elongation at Break, %	-39	-28
50% Modulus, MPa	2	1.9
Delta 50% Modulus, %	14	3
100% Modulus, MPa	4.1	4.0
Delta 100% Modulus, %	8	-5

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Table 2 (continued) - Vamac® GXF & Vamac® Ultra HT Ageing Study

Fluid Ageing	Vamac® GXF Diak™: 1.1phr DBU: 2phr	Vamac® Ultra HT Diak™: 1.1phr DBU: 2phr
Fluid ageing 94 hours at 175 °C in Lubrizol® OS 206304		
Hardness Shore A (1s), pts	56	58
Delta Hardness, pts	-10	-9
Tensile Strength, MPa	14.7	16.2
Delta Tensile Strength, %	-20	-18
Elongation at Break, %	285	310
Delta Elongation at Break, %	-22	-20
100% Modulus, MPa	4.0	4.1
Delta 100% Modulus, %	7	-4
Volume Change, %	25	24
Weight Change, %	17	17
Fluid ageing 94 hours at 175 °C in Castrol SLX Long Life III, 5W30		
Hardness Shore A (1s), pts	59	61
Delta Hardness, pts	-7	-6
Tensile Strength, MPa	15.7	17.5
Delta Tensile Strength, %	-14	-12
Elongation at Break, %	315	320
Delta Elongation at Break, %	-14	-16
100% Modulus, MPa	4.0	4.5
Delta 100% Modulus, %	6	6
Volume Change, %	18	17
Weight Change, %	12	12

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Table 2 (continued) - Vamac® GXF & Vamac® Ultra HT Ageing Study

Fluid Ageing	Vamac® GXF Diak™: 1.1phr DBU: 2phr	Vamac® Ultra HT Diak™: 1.1phr DBU: 2phr
Fluid ageing 70 hours at 150 °C in IRM 903		
Hardness Shore A (1s), pts	46	50
Delta Hardness, pts	-20	-17
Tensile Strength, MPa	11.2	13.0
Delta Tensile Strength, %	-39	-34
Elongation at Break, %	200	210
Delta Elongation at Break, %	-45	-46
50% Modulus, MPa	1.6	1.9
Delta 50% Modulus, %	-10	3
100% Modulus, MPa	4.5	5.5
Delta 100% Modulus, %	19	30
Volume Change, %	66	62
Weight Change, %	51	48

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Test Methods

Rheology

Mooney Viscosity	ISO 289-1:2005
Mooney Scorch	ISO 289-2:1994
MDR	ISO 6502:1999

Physicals

Hardness	ISO 7619-1:2004
Tensile, elongation	ISO 37:2005
Fluid ageing	ISO 1817:2005
Heat ageing	ISO 188:2007
Compression set	ISO 815-1:2008
Compression set VW	VW PV 3307:2004-08
Tg by DSC	ISO 22768:2006
De Mattia	ISO 132:2005

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