DuPont™ Vamac® Ultra HT

Technical Information — Rev. 2, December 2013

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),formerly known as VMX 3038.

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 resistance (acid presents in 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.

For more information, please contact your DuPont technical representative

Typical Product Properties

Requirements

Properties	Target Values	Test Method
Mooney Viscosity, ML 1+4 at 100 °C (212 °F)	29	ASTM D1646
Volatiles, wt%	≤0.6	Internal DuPont Test
Form, mm (in)	Bale size is nominally: 560 x 370 x 165 (22 x 15 x 7)	Visual Inspection
Color	Clear to light yellow translucent	Visual Inspection

Packaging

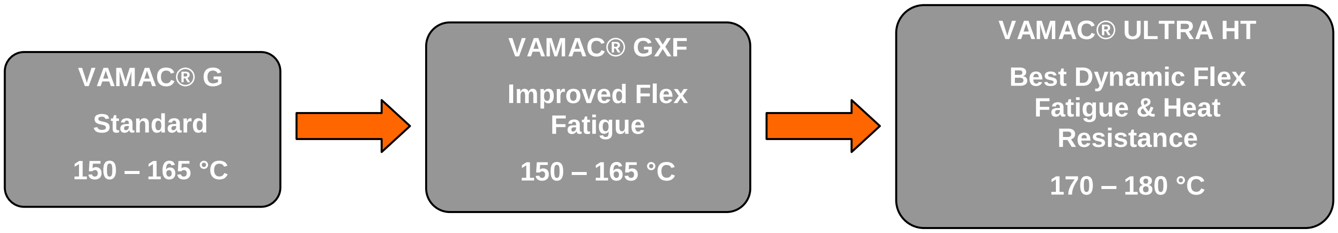
25 kg bales with blue strippable wrap in individual boxes that contain one bale. A full pallet will hold thirty individual boxes with a net weight of 750 kg.

Note: Blue strippable wrap must be completely removed before using the product.

Handling and Precautions

Because Vamac® Ultra HT contains small amounts of residual methyl acrylate monomer, adequate ventilation should be provided during mixing and processing to prevent worker exposure to methyl acrylate vapour. Additional information may be obtained in the 'Material Safety Data Sheet' (MSDS), and the "Safe Handling and Processing Guide of Vamac®" available from **vamac.dupont.com**.

Vamac® grades for automotive hoses



Performances & 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 emission when compared to bigger engines naturally aspirated, and contribute to develop cleaner vehicles.

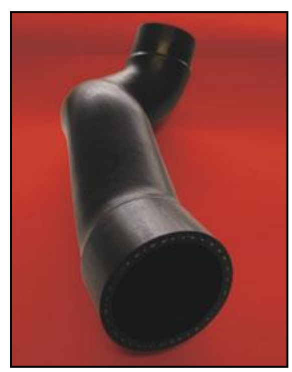
Vamac® Ultra HT has been developed to answer this automotive market trend and extend the Vamac® product range in terms of high temperature performance combined with flex fatigue resistance. This set of properties is further associated with oil resistance, tear resistance and sealing performance making 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 is: Vamac® Ultra HT / Nomex® aramid fibre / Vamac® Ultra HT

At higher specified temperature, rubber multilayer structures are used such as DuPont™ Viton® / VMQ construction or newly proposed Viton® / Vamac® / DuPont™ 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.

Compounding and Vulcanizate properties

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 the "Vamac® Compound Mixing Guide" available on line at **www.vamac.dupont.com**.

Formulation

Studies shown in Tables 1 and 2 details various formulations with Vamac® Ultra HT polymer using a diamine curing agent and accelerators based on DPG and DBU. Rhenogran® DPG 80 used in this study is a diphenylguanidine and Vulcofac® ACT55 a cycloaliphatic amine (DBU) accelerator. 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. The DPG can be used in association 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 2 phr of Vulcofac® ACT 55.

The formulations do not contain any retarder, Armeen® 18D, usually used in Vamac® compound. For a demanding manufacturing process in terms of 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. Effectively at 190 – 200 °C, most of the plasticiser can be extracted out of the elastomer. The recommended use is 1 to 3 phr 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.

Rheological properties

A significant viscosity increase at equal formulation can be realized from Vamac® GXF to Vamac® Ultra HT (Table 1). 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 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 in order 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 compressions 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 balanced 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 (Table 2) at room temperature.

The cross-linking density and the curing package have an important influence over this flex fatigue property as illustrated in Table 2. The DPG / DBU blend formulation with 1.25 phr of Diak™ No.1 will show, superior fatigue and crack resistance, when properly formulated, than formulations containing only DBU, but compromise will be made on compression set.

Heat ageing

Table 2 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 (Tables 3 to 4) with longer term ageing conditions at temperature from 175 °C to 190 °C

- Heat ageing 504 hrs at 175 °C
- Heat ageing 336 hrs at 180 °C
- Heat ageing 168 hrs at 190 °C

Fluid ageing

The second study (Table 5) 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. The formulation is highlighted in the study presented on following pages.

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

	Vamac® GXF	Vamac® Ultra HT			
	Diak™: 1.1phr ACT 55: 2phr	Diak™: 1.1phr ACT 55: 2phr	Start point Diak™: 1phr ACT 55: 2phr	Diak™: 0.9phr ACT 55: 2phr	Diak™: 1.25phr DPG 80: 2.5phr ACT 55: 1phr
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
Rubber chem 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	1.8	2.3
T90 [min]	6.8	6.8	6.1	5.5	7
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	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					
Tensile properties (type 2) at 23°C					
Tensile Strength [MPa]	18.0	19.6	20.3	19.5	18.8
Elongation at break [%]	380	395	420	425	440
Modulus at 50 % [MPa]	1.7	1.7	1.6	1.6	1.6
Modulus at 100 % [MPa]	3.3	3.8	3.3	3.0	3.1
Hardness Shore A (1 second)					
Shore A	67	67	67	67	66

Table 2 - Vamac® Ultra HT Comparison with GXF

	Vamac® GXF	Vamac® Ultra HT			
	Diak: 1.1phr DBU: 2phr	Diak: 1.1phr DBU: 2phr	Diak: 1phr DBU: 2phr	Diak: 0.9phr DBU: 2phr	Diak: 1.25phr DPG: 2.5phr DBU: 1phr
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
Modulus at 50 % [MPa]	1.4	1.8	1.6	1.5	1.5
Modulus at 100 % [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
Heat ageing 94 hours at 200 °C					
Tensile properties (type 2) at 23 °C					
Tensile Strength [MPa]	13.2	15.3	14.6	12.8	12.2
Delta TS [%]	-26	-22	-28	-34	-35
Elongation at break [%]	325	350	375	385	310
Delta Elong. [%]	-14	-12	-11	-9	-29
Modulus at 50 % [MPa]	1.9	1.9	1.8	1.6	1.8
Delta 50% [%]	14	11	7	0	14
Modulus at 100 % [MPa]	3.6	3.8	3.5	2.8	3.5
Delta 100% [%]	7	-1	5	-5	13
Hardness Shore A (1 second)					
Shore A	70	70	69	69	70
Points change	3	3	2	2	4
Samples pre-Heat aged 94 hours at 200 °C					
DeMattia crack growth at 23°C					
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					
Median	15	75	155	155	1275
Average	23	343	323	187	891

Table 3 - Vamac® GXF & Vamac® Ultra HT Ageing Study: Formulation

	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
MDR cure rate 15 minutes at 180 °C, arc 0.5°		
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
Compression moulding 10 minutes at 180 °C		
Post-cure 4 hours at 175°C		
Tensile properties (type 2) at 23 °C		
Tensile Strength [MPa]	18.3	19.8
Elongation at break [%]	360	380
Modulus at 50 % [MPa]	1.7	1.9
Modulus at 100 % [MPa]	3.8	4.2
Hardness Shore A (1 second)		
Shore A	66	67
Tear strength type C - Crescent test pieces at 23 °C		
Tear Strength [kN/m]	23	25
Differential Scanning Calorimetry (DSC)		
Tg by Dsc, °C	-31	-31

Table 4 - Vamac® GXF & Vamac® Ultra HT Heat Ageing Study: Properties

	Vamac® GXF Diak™: 1.1phr DBU: 2phr	Vamac® Ultra HT Diak™: 1.1phr DBU: 2phr
Heat ageing 504 hours at 175 °C		
Hardness Shore A (1 second)	70	70
Delta hardness	4	3
Tensile properties (type 2) at 23 °C		
Tensile Strength [MPa]	12.2	14.0
Delta TS [%]	-34	-29
Elongation at break [%]	280	325
Delta Elong. [%]	-22	-15
Modulus at 50 % [MPa]	2.0	2.0
Delta 50% [%]	16	4
Modulus at 100 % [MPa]	4.1	4.0
Delta 100% [%]	8	-5
Heat ageing 336 hours at 180 °C		
Hardness Shore A (1 second)	69	70
Delta hardness	3	2
Tensile properties (type 2) at 23 °C		
Tensile Strength [MPa]	10.7	13.2
Delta TS [%]	-42	-33
Elongation at break [%]	240	300
Delta Elong. [%]	-33	-22
Modulus at 50 % [MPa]	1.9	1.9
Delta 50% [%]	8	4
Modulus at 100 % [MPa]	3.9	4.1
Delta 100% [%]	4	-3
Heat ageing 168 hours at 190 °C		
Hardness Shore A (1 second)	71	71
Delta hardness	5	4
Tensile properties (type 2) at 23 °C		
Tensile Strength [MPa]	10.3	12.7
Delta TS [%]	-44	-36
Elongation at break [%]	220	275
Delta Elong. [%]	-39	-28
Modulus at 50 % [MPa]	2.0	1.9
Delta 50% [%]	14	3
Modulus at 100 % [MPa]	4.1	4.0
Delta 100% [%]	8	-5

Table 5 - Vamac® GXF & Vamac® Ultra HT Fluid Ageing: Properties

	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 (1 second)	56	58
Delta hardness	-10	-9
Tensile Strength [MPa]	14.7	16.2
Delta TS [%]	-20	-18
Elongation at break [%]	285	310
Delta Elong. [%]	-22	-20
Modulus at 100 % [MPa]	4.0	4.1
Delta 100% [%]	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 (1 second)	59	61
Delta hardness	-7	-6
Tensile Strength [MPa]	15.7	17.5
Delta TS [%]	-14	-12
Elongation at break [%]	315	320
Delta Elong. [%]	-14	-16
Modulus at 100 % [MPa]	4.0	4.5
Delta 100% [%]	6	6
Volume Change (%)	18	17
Weight Change (%)	12	12
Fluid ageing 70 hours at 150 °C in IRM 903		
Hardness Shore A (1 second)	46	50
Delta hardness	-20	-17
Tensile properties (type 2) at 23 °C		
Tensile Strength [MPa]	11.2	13.0
Delta TS [%]	-39	-34
Elongation at break [%]	200	210
Delta Elong. [%]	-45	-46
Modulus at 50 % [MPa]	1.6	1.9
Delta 50% [%]	-10	3
Modulus at 100 % [MPa]	4.5	5.5
Delta 100% [%]	19	30
Volume Change (%)	66	62
Weight Change (%)	51	48

Material used in formulations and test fluids – general composition and suppliers

Material	Chemical Composition	Supplier
Polymer		
DuPont™ Vamac® GXF	Ethylene Acrylic Elastomer	DuPont Performance Polymers
DuPont™ Vamac® Ultra HT	Ethylene Acrylic Elastomer	DuPont Performance Polymers
Release Aids		
Armeen® 18D	Octadecyl Amine	Akzo Nobel
Vanfre® Vam	Complex Organic phosphate ester	R.T. Vanderbilt
Stearic Acid	Carboxylic acid	Sigma-Aldrich
Ofalub SEO	Phosphoric acid ester	Safic Alcan
Anti-oxidant		
Naugard® 445	Diphenyl Amine	Chemtura
Plasticiser		
Rhenosin® W759	Mixed Ether/Ester Plasticizer	Rhein Chemie
Alcanplast® PO 80	Ether/Ester Plasticizer	Safic Alcan
Filler		
Spheron® SO N550	Carbon Black	Cabot
Curatives		
DuPont™ Diak® No. 1	Hexamethylene Diamine Carbamate	DuPont Performance Poymers
Accelerator		
Vulcofac® ACT 55	Amine derivative	Safic Alcan
Rhenogran® DPG 80%	Diphenyl guanidine	Rhein Chemie
Test Fluids		
IRM 903	Test Fluid	
Long life III 5W30	5W30 engine oil	Castrol Limited
Lubrizol OS 206304	5W40 engine oil	Lubrizol Ltd

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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(09/10) Reference No. VME-A10877-00-E1213

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