



# DuPont™ Vamac®

## Formulating and Compounding Overview

Technical Information — Rev. 2, July 2010

The principles of compounding are similar to conventional technology in that curatives, fillers, antidegradants, plasticizers and process aids all are used. As with other high-performance, heat-resistant elastomers, the choice of potential additives tends to be smaller, and their selection more specific. Equal attention must be given to avoid ingredients that could give detrimental effects.

### **Polymer Selection**

DuPont™ Vamac® terpolymers are the most widely used grades of Vamac®. However, the terpolymers and dipolymer are similar in major properties such as heat and oil resistance. There are some differences in processing characteristics.

Vamac® G, the general-purpose terpolymer, has a higher-viscosity variant, Vamac® HVG, which can be considered for applications requiring increased green strength or generous loadings of plasticizer. Vamac® GLS, a higher methylacrylate grade, offers improved oil resistance, in exchange for slightly reduced low-temperature flexibility. Vamac® GXF improves the elevated temperature tensile properties and dynamic fatigue resistance while exhibiting a longer cure and higher compression set.

Vamac® DP is a dipolymer analog of Vamac® G. Compared with the diamine-cured terpolymer, it contains no reactive cure site and must be cured via a peroxide/coagent system.

The following table summarizes the most important differences between the terpolymers and dipolymer.

**Table 1. Vamac® Polymer Selection**

		Nominal ML 1+4 100 °C
<b>Terpolymers</b>		
<ul style="list-style-type: none"> <li>• Good physicals/compression set</li> <li>• Good metal bonding</li> <li>• Low hardness compounds possible</li> <li>• Good flex resistance</li> <li>• Moderate scorch times</li> <li>• Need post-curing</li> </ul>		
	Vamac® G	16.5
	Vamac® HVG	26
	Vamac® GLS	18.5
	Vamac® GXF	17.5
<b>Dipolymer</b>		
<ul style="list-style-type: none"> <li>• Minimized need for post-cure to attain low compression set</li> <li>• Long scorch times</li> <li>• Less affected by oil additives</li> </ul>		
	Vamac® DP	22

### Antidegradants

DuPont™ Vamac® terpolymers, G, GLS, GXF and HVG, require the addition of two parts of a semi-staining diphenylamine antioxidant in black formulations. Only one part is used in Vamac® dipolymer compounds, because the antioxidant interferes with the peroxide cure. If ultimate aging performance is necessary in the dipolymer, then the level of diphenylamine antioxidant can be increased to two parts, with a slight increase in the peroxide level to minimize the effect on cure state and compression set. Two parts of a nonstaining phenolic antioxidant, such as Santowhite powder, can be used in nonblack compounds.

Contact with zinc (e.g., hose couplings) catalyzes heat aging in Vamac®, including dipolymer compounds. Hydrazine antioxidants are effective in preventing the zinc-catalyzed attack. One part of ADK STAB CDA-6 or two parts of inhibitor OABH are suggested. No antiozonants are necessary in any Vamac® formulation.

### Fillers

Carbon black is the preferred filler for Vamac®. It has no effect on its heat aging properties, and is beneficial to compression set and flex resistance. The majority of Vamac® compounds contain N762 or N774 SRF blacks, or N550 FEF black. All give good reinforcement with or without plasticizer. High-structure blacks such as N-683 or Spheron® 5000 also are suitable. Highly reinforcing blacks such as ISAF tend to respond best without accompanying plasticizer, probably due to the limited shear dispersion available from the polymer during mixing. Low-structure blacks also can be difficult to disperse. MT black may be used as a filler and diluent.

Mineral fillers should be selected with care. For high physical properties, tensile and tear, a fumed silica is most effective and has the least effect on heat aging properties. Fumed silica significantly increases compound viscosity and increases compression set, and therefore is normally incorporated at moderate levels of up to 25 parts. Surface-treated talc also is reinforcing, with much less effect on compression set compared with fumed silica.

Calcium carbonate may be used at quite high levels without too much effect on heat aging; the best reinforcement comes from the precipitated form. Barium sulfate also is suitable as a high-level filler.

Aluminum hydroxide is used frequently as a flame-retarding filler in Vamac<sup>®</sup>. However, it should be recognized that ultimate heat aging performance will be sacrificed when this filler is used. Compound modulus will usually increase with time as ionic crosslinks form in the terpolymer under the influence of aluminum hydroxide. This effect is not present in dipolymer compounds.

Magnesium hydroxide can only be used in Vamac<sup>®</sup> dipolymer. Other active metal oxides should be avoided in terpolymer, although low levels of iron and chrome oxides may be used as pigments. Limited amounts of antimony trioxide can also be tolerated in flame retarded compounds. Metal stearates, present in some grades of calcium carbonate, can affect heat aging.

Zinc compounds are harmful to all Vamac<sup>®</sup> types.

**Table 2. Reinforcing Agents/Fillers**

Preferred	Unsuitable	Permissible
Carbon blacks	Metal oxides	Titanium dioxide (to 5 parts)
Fumed Colloidal silica (up to 25 parts)	Metal stearate coated fillers	Chromium oxide (to 5 parts)
Uncoated calcium carbonate	Clay	Antimony trioxide (to 5 parts)
Blanc fixe	High levels of silica	Iron oxide (to 3 parts)
Coated talc		

**Table 3. Plasticizers**

For Vamac <sup>®</sup> Dipolymer:	
Linear trimellitate	-45 to 155 °C trioctyl trimellitate
Low volatility alkyl trimellitate	-40 to 170 °C Bisoflex <sup>®</sup> T810T, Pasthall 810TM
Tri isononyl trimellitate	-40 to 170 °C ADK cizerC-9N
Polyester	-30 to 170 °C Plasthall <sup>®</sup> 670
For Vamac <sup>®</sup> Terpolymers:	
Linear polyester types	Best heat stability (-25 °C to 180 °C)
Mixed ether/ester types	Optimum balance of low and high-temperature properties -45 °C to 160 °C Thiocol TP 759/Nycoflex ADB30 -40 °C to 175 °C ADK Cizer RS735
Monomeric esters	-55 °C to 125 °C dioctyl sebate

### Plasticizers

A frequent cause of poor aging performance is a poor choice of plasticizer. It is important that the selected plasticizer be nonvolatile and stable at the highest expected service temperature. For the best high-temperature performance, polyester plasticizers are recommended. Most polyesters are effective up to or over 180°C. However, this class of plasticizer is not very useful for improving low-temperature flexibility. Standard monomeric ester plasticizers such as DOS produce the best low-temperature flexibility, but are limited to 125 °C to 135 °C in continuous use.

The most useful plasticizer and best compromise for high- and low-temperature performance is the mixed ether/ester type such as Nycoflex ADB 30, Thiocol TP 759 and ADK Cizer RS 735. An approximate temperature range of -40 °C to 170 °C can be covered with these materials, depending upon final choice and mode of test.

The ether/ester types are unsuitable for Vamac<sup>®</sup> dipolymer, because they retard the peroxide cure. Trimellitate types are more suitable with Bisoflex<sup>®</sup> T8 10T, ADK Cizer C-9N and Plasthall<sup>®</sup> 670 having the lowest volatility. Trioctyl trimellitate is a good general-purpose example. The level of plasticizer is normally 5-15 parts for dipolymer, but terpolymer types can tolerate much higher loadings.

## Cure Systems

Most articles made from Vamac<sup>®</sup> terpolymer are cured with a combination of a guanidine and a blocked primary diamine (Diak<sup>™</sup> No. 1). Permanent cross-links are formed by reaction with the carboxylic sites on the polymer backbone. This system gives a good blend of cure rate and physical properties. Small variations in diamine level and selection of guanidine type can effectively highlight certain performance features such as compression set and flex resistance. Other curatives known to be reasonable substitutes for Diak<sup>™</sup> No. 1 are triethylene tetramine, and methylene dianiline (MDA). Some of these materials may be preferred in dispersed form to reduce handling hazards. MDA may not be permitted in some countries.

Peroxide systems may be used in Vamac<sup>®</sup> terpolymer, particularly for cable applications where fast cures under continuous pressurized vulcanization are desired. Peroxides are not recommended for molded articles where poor hot tear strength and mold sticking may cause difficulties.

Compression set may be poor when peroxide cures are used with terpolymers. Best results are obtained from DOTG/Diak<sup>™</sup> No. 1 combinations and DPG/Diak<sup>™</sup> No.1 combinations.

**Table 4. DuPont<sup>™</sup> Vamac<sup>®</sup> Cure Systems**

<b>For Terpolymers</b>			
<b>General Purpose</b>	<b>Cure System</b>	<b>Parts</b>	<b>Cure Rate</b>
<b>Diak<sup>™</sup> No. 1 Guanidine</b>			
For compression set	Diak <sup>™</sup> No. 1	1.5	Fast
	DOTG	4	
For flex resistance	Diak <sup>™</sup> No. 1	1.25	Medium
	DPG	4	
<b>Diak<sup>™</sup> No. 1 Alternatives</b>			
High modulus	Triethylene tetramine		Fast
Safe scorch	Methylene dianiline		Slow
<b>Thick Sections (Guanidine Substitution)</b>			
Diak <sup>™</sup> No.1	1.25		1.5
Secondary amine	6 (Armeen <sup>®</sup> 2C)		4
<b>Cables (fast continuous cure)</b>			
Peroxide	7.5 (Perkadox 14/40)		
HVA-2	2		
<b>For Dipolymer</b>			
<b>Moldings and Best Properties</b>			
Peroxide	5 (Di-Cup <sup>®</sup> or Vul-Cup <sup>®</sup> 40%)		
HVA-2	2		
<b>Hose/General Purpose</b>			
Varox <sup>®</sup> 50% DBPH	5		
TAC	2		

Vamac<sup>®</sup> dipolymer may only be cured with peroxides. Because no acid cure site monomer is present, mold release is easier than with peroxide-cured terpolymer. The level of peroxide should be moderate to help demolding elongation and suppress blisters. Compression set resistance is good without post-curing and rivals that of post-cured terpolymer.

HVA-2 is a good all-around coagent, giving fast cures and optimized physical properties. However, the lower-cost, triallylcyanurate often can be substituted. Zinc methacrylates should be avoided.

Very thick molded articles can be made from Vamac<sup>®</sup> terpolymer, but require a special variation on the guanidine/DIAK<sup>™</sup> No. 1 system, where the guanidine is replaced by a secondary amine, Armeen<sup>®</sup> 2C.

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(01/08) Reference No. VME-A10652-00-B0710



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