Vamac® Ultra DX

Ethylene Acrylic Elastomer - Technical Data

Description

Vamac® Ultra DX peroxide curable ethylene-methyl acrylate dipolymer grade provides improved mold release, comparable to Vamac® Ultra terpolymers. Increased green strength of compounds produced with Vamac® Ultra DX helps to avoid collapse during extrusion processes and may help in applying reinforcement layers without cutting the inner tube by filaments. The optimized polymer structure ensures gains in physical properties, resulting in improved performance of rubber parts such as cables, seals, gaskets or extruded hoses.

The best physical properties of Vamac® Ultra DX are obtained in rubber parts having a hardness range between 50 and 90 Shore A. Compounds may be peroxide or e-beam cured, and like other Vamac® grades, Ultra DX is halogen-free.

Product Properties

Property	Target Values	Method
Mooney Viscosity ML1+4 at 100 °C	26	ASTM D1646
Volatiles	≤0.4 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

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®*.

Mixing

Vamac® Ultra DX has higher viscosity than Vamac® DP which permits better and faster dispersion of fillers and other compounding ingredients. Vamac® Ultra DX also showed reduced sticking to mixing equipment in lab tests compared to Vamac® DP. Due to the general good scorch safety of peroxide cured compounds, changes in mixing cycle due to higher viscosity are not considered necessary.

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Compounding and Physical Properties- Wire & Cable

Table 1 shows a comparison of Vamac® Ultra DX to Vamac® DP in identical formulations, which can be used as a starting point for halogen-free, flame retardant Wire & Cable applications.

Table 1 - Compound Properties, HFFR W&C Compound

Compound No.	1	2
Vamac® Polymer	DP	Ultra DX
Vamac® DP	100	
Vamac® Ultra DX		100
Naugard® 445	1	1
Armeen®18 D	0.5	0.5
Stearic Acid	1.5	1.5
Martinal® OL-111 LE	160	160
Dynasylan® 6490	1	1
Perkadox® 14-40B-GR	4.5	4.5
Rubber chem HVA-2	1	1
Total PHR	269	269
Mooney Viscosity ML 1+4, 100°C, MU - Polymer	22	28
Mooney Viscosity ML 1+4, 100°C, MU - Compound	41	51
MDR, 0.5°arc, 12 minutes at 180°C		
ML, dNm	0.44	0.48
MH, dNm	16.3	17.6
Ts2, min	0.48	0.49
T10, min	0.45	0.47
T50, min	1.36	1.34
T90, min	4.41	4.26

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Table 1 (continued) - Compound Properties, HFFR W&C Compound

Compound No.	1	2
Original Properties (Press-Cure 15 minutes at 180°C)		
Hardness Shore A (1 s), pts	76	79
Tensile Strength, MPa	9.8	11.5
Elongation at Break, %	261	267
100% Modulus, MPa	6.6	7.0
Tear Die C at 23°C, N/mm	39	38
Trouser Tear Die A at 23°C, N/mm	5.5	6.5
Tg by DSC, °C	-29	-28
Heat ageing 168 hours at 160°C		
Hardness Shore A (1 s), pts	82	82
Delta Hardness, pts	7	4
Tensile Strength, MPa	11.4	12.3
Delta Tensile Strength, %	16	7
Elongation at Break, %	209	241
Delta Elongation at Break, %	-20	-10
100% Modulus, MPa	8.3	8.6
Delta 100% Modulus, %	26	23
Heat ageing 168 hours at 175°C		
Hardness Shore A (1 s), pts	82	83
Delta Hardness, pts	6	5
Tensile Strength, MPa	10.8	11.7
Delta Tensile Strength, %	10	2
Elongation at Break, %	170	184
Delta Elongation at Break, %	-35	-31
100% Modulus, MPa	9.2	9.4
Delta 100% Modulus, %	39	34

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Table 1 (continued) - Compound Properties, HFFR W&C Compound

Compound No.	1	2
Fluid ageing 168 h at 150°C in IRM 903		
Hardness Shore A (1 s), pts	62	65
Delta Hardness, pts	-14	-13
Tensile Strength, MPa	10.3	11.8
Delta Tensile Strength, %	5	3
Elongation at Break, %	163	181
Delta Elongation at Break, %	-38	-32
100% Modulus, MPa	7.1	7.2
Delta 100% Modulus, %	8	3
Volume Change, %	29	27
Weight Change, %	17	16

Polymer and Compound Mooney are higher for Vamac® Ultra DX. The tighter crosslink network and faster cure lead to slightly higher Hardness, with higher Tensile Strength, and still slightly higher Elongation at Break. After Heat Ageing, Vamac® Ultra DX maintains its properties better than Vamac® DP

Compounding and Physical Properties – Carbon Black Filled Compounds

The major difference between compounds based on diamine cured Vamac® Terpolymers and peroxide cured Dipolymers is that process aids and plasticizers have to be kept at a minimum needed for good low temperature performance and good mold release, as they significantly impact the cure speed and crosslink density of peroxide cure systems. However, addition of small amounts of Vanfre® VAM process aid showed positive impact on heat ageing in our lab tests.

In simple Carbon Black filled compounds shown in Table 2, Vamac® Ultra DX showed slightly faster cure, higher MH, along with significant better combination of tensile and Elongation and Break compared to Vamac® DP, whilst Compression Set was slightly inferior for Vamac® Ultra DX.

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Table 2 - Compound Properties, 70 Shore A Carbon Black Filled Compounds

Compound No.	3	4	5	6
Vamac® Polymer	DP	Ultra DX	Ultra DX	Ultra DX
Co-Agent	TRIM	TRIM	TAIC	HVA-2
Vamac® DP	100			
Vamac® Ultra DX		100	100	100
Vanfre® VAM	0.75	0.75	0.75	0.75
Naugard® 445	1	1	1	1
Stearic Acid Reagent (95%)	0.5	0.5	0.5	0.5
Spheron® SOA (N 550)	50	50	50	50
Luperox® DC 40 P	8	8	8	8
Rubber chem HVA 2				3
Sartomer® SR 350 (TRIM)	3	3		
Diak™ No. 7 (TAIC)			3	
Mooney Viscosity ML 1+4, 100°C, MU	30	38	43	46
MDR, 0.5°arc, 15 minutes at 180°C				
ML, dNm	0.44	0.52	0.55	0.66
MH, dNm	10.16	10.74	16.47	12.79
Ts2, min	0.94	0.93	0.91	0.36
T10, min	0.68	0.68	0.83	0.32
T50, min	1.54	1.55	1.91	0.61
T90, min	3.29	3.19	4.23	1.97

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Table 2 (continued) - Compound Properties, 70 Shore A Carbon Black Filled Compounds

Compound No.	3	4	5	6
Original Properties at Room Temperature (Press-Cure 10 minutes at 185°C)				
Hardness Shore A (1 s), pts	67	66	71	68
Tensile Strength, MPa	15.9	17.8	19.3	14.4
Elongation at Break, %	337	371	185	207
100% Modulus, MPa	4.0	3.7	8.5	5.3
C. set, 70 h at 150°C (ISO 815), %	24	29	17	22
C. set, 168 h at 150°C (SO 815), %	32	36	28	32
C. set, 94 h at 150°C (ASTM D1414*), %	24	31	11	29
C. set, 22 h at 150°C (VW PV 3307, 5 sec), %	84	86	48	80
Tensile Properties (type 2) at 150°C				
Tensile Strength, MPa	5.0	5.0	4.2	3.5
Elongation at Break, %	142	148	75	90

*o-ring size: AS-214

Replacing TRIM as coagent by TAIC or HVA-2 results in much higher MH and better Compression Set, but properties measured at room temperature and 150°C are low, which may result in problems during molding or in the final application.

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Optimization of Properties and Compression Set

To obtain a good combination of Compression Set resistance and physical properties, Table 3 shows possibilities with combinations of coagents and alternative peroxide with higher decomposition temperature.

Table 3 – Optimizing Compression Set and Physical Properties – Coagent Level and Type

Compound No.	7	8	9	10
Vamac® Ultra DX	100	100	100	100
Naugard® 445	1	1	1	1
Stearic acid	0.5	0.5	0.5	0.5
Vanfre® VAM	0.5	0.5	0.5	0.5
Spheron® SOA N550	50	50	50	50
Rubber chem HVA 2	3	1.5		3
Sartomer® SR 350 (TRIM)			1.5	
Diak™ No. 7 (TAIC)		1.5	1.5	
Luperox® 101 XL 45				8
Luperox® DC 40 P	8	8	8	
MDR, 0.5°arc, 15 minutes at 180°C				
ML, dNm	0.45	0.53	0.48	0.57
MH, dNm	12.32	14.35	13.31	13.25
Ts2, min	0.38	0.42	0.74	0.37
T10, min	0.34	0.37	0.61	0.34
T50, min	0.68	1.18	1.57	0.79
T90, min	2.07	3.09	3.66	3.41
Original Properties (Press-Cure 5 minutes at 185°C)				
Hardness Shore A (1 s), pts	68	69	68	68
Tensile Strength, MPa	16.2	17.9	19.1	16.0
Elongation at Break, %	266	228	252	232
100% Modulus, MPa	4.3	5.6	5.2	5.1
C. set, 70 h at 150°C (ISO 815), %	44	28	27	67

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Table 3 (continued) – Optimizing Compression Set and Physical Properties – Coagent Level and Type

Compound No.	7	8	9	10
Original Properties (Press-Cure 10 minutes at 185°C)				
Hardness Shore A (1 s), pts	67	69	68	67
Tensile Strength, MPa	15.5	17.6	18.4	15.4
Elongation at Break, %	245	217	248	204
100% Modulus, MPa	4.5	6.1	5.2	5.6
C. set, 70 h at 150°C (ISO 815), %	22	16	16	21

A combination of TAIC with either HVA-2 or TRIM offers good combinations of physical properties and Compression Set, as well as options for reduced cure times. Dicumyl peroxide provided better Compression Set, but results must be taken with care, as active oxygen index at same phr levels are different for both peroxides used.

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Another study, shown in Table 4, looked at different peroxide levels to those typically used for Vamac® DP

Table 4 – Optimizing Compression Set and Physical Properties – Peroxide Level

Compound No.	11	12	13	14	15
Vamac® DP	100				
Vamac® Ultra DX		100	100	100	100
Naugard® 445	1	1	1	1	1
Stearic Acid Reagent (95%)	0.5	0.5	0.5	0.5	0.5
Vanfre® VAM	1.25	0.75	0.75	0.75	0.75
Spheron® SOA (N 550)	50	50	50	50	50
Sartomer® SR350 (TRIM)	1.5	1.5	1.5	1.5	1.5
Rubber chem Diak™ no 7	1.5	1.5	1.5	1.5	1.5
Luperox® DC 40 P	8	8	6.5	5	4
Luperox® 230 XL 40 SP					2.5
Mooney Viscosity ML 1+4, 100°C, MU	34	45	42	44	39
MDR, 0.5°arc, 15 minutes at 180°C					
ML, dNm	0.43	0.61	0.54	0.56	0.46
MH, dNm	14.49	15.32	12.39	9.93	11.06
T10, min	0.64	0.60	0.63	0.64	0.61
T50, min	1.67	1.58	1.72	1.84	1.62
T90, min	4.22	3.64	4.05	4.49	4.40
Original Properties (Press-Cure 5 minutes at 185°C)					
Hardness Shore A (1 s), pts	68	70	68	67	67
Tensile Strength, MPa	17.0	18.2	16.7	15.8	16.1
Elongation at Break, %	225	238	282	370	309
100% Modulus, MPa	6.1	6.3	4.7	3.6	3.8
C. set, 70 h at 150°C (ISO 815), %	26	27	23	31	42

Vamac® Ultra DX provided best Compression Set resistance at levels of about 6.5 phr Dicumyl peroxide. This level also provides significant better Elongation at Break.

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Injection Molding Performance

Vamac® Terpolymers are usually material of choice for parts that are produced in Injection, Transfer or Compression Molding. Dipolymers historically have been chosen rarely due to stickiness of peroxide cured AEM compounds. Vamac® Ultra DX showed excellent properties in demolding in lab trials, reaching performance levels comparable to Vamac® Ultra IP.

The procedure used in DuPont labs to determine mold release uses a horizontal injection molding machine, and a mold with 40 cavities of O-rings, Size AS-214. Cold runners are used, and central single point injection. The mold is cleaned according to the same procedure before a new compound is tested. Mold temperature has been set at 185°C. Cure time has been set at 30 seconds, where blister-free O-rings have been obtained. After mold opening, a brush is removing most of the O-rings from the mold. The number of O-rings sticking to the mold after brushing is counted.

Table 5 – Compounds used for Injection Moulding Tests

Compound No.	16	17	18	19	20
	DP	Ultra DX	Ultra DX: Reduced Process Aid	Ultra DX: TRIM	Ultra DX: Plasticizer
Vamac® DP	100				
Vamac® Ultra DX		100	100	100	100
Naugard® 445	1	1	1	1	1
Stearic Acid Reagent (95%)	0.5	0.5	0.5	0.5	0.5
Vanfre® VAM	1.25	1.25	0.75	0.75	0.75
Spheron® SOA (N 550)	50	50	50	50	60
Alcanplast PO 80					10
Rubber chem HVA 2	2	2	2		2
Sartomer® 350 (SR 350)				3	
Luperox® DC 40 P	8	8	8	8	8

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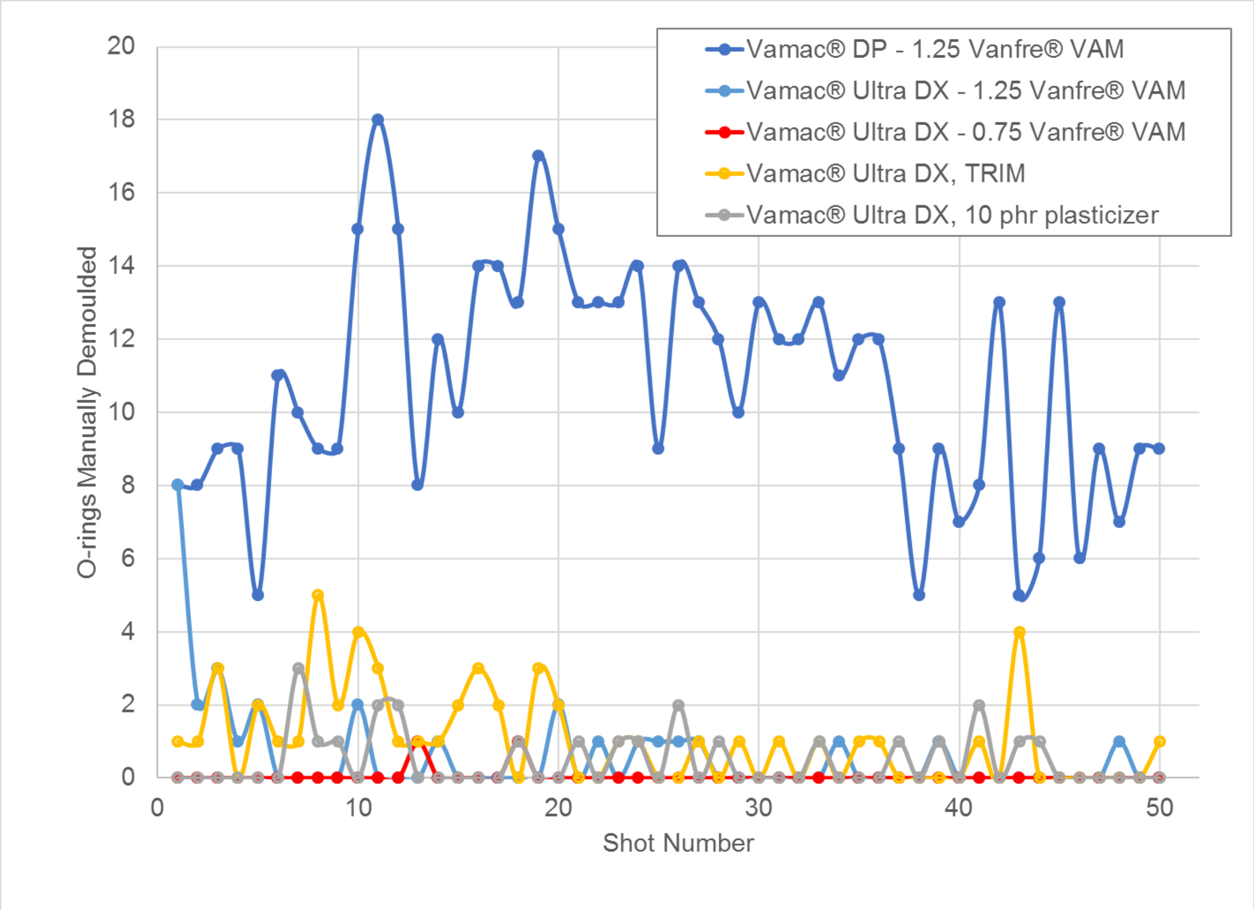
Chart 1 shows the protocol of the injection moulding trials, reporting the number of O-rings that had to be removed from the mold manually throughout the 50 shots that have been made with each of the compounds shown in **Table 5**. Whilst the compound based on Vamac® DP could not be well demolded, nearly all the O-rings based on Vamac® Ultra DX were released either automatically or by brushing, requiring reduced manual demoulding.

Chart 1 – Injection Moulding Trial: Number of O'rings Manually Demoulded



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Fluid Resistance, Comparison to AEM Terpolymers

Vamac® terpolymers are known for their excellent sealing capabilities and are extensively used for seals such as cam cover gaskets, oil pan gaskets or transmission seals in harsh automotive environments. Newer oils contain significant levels of additives that may promote additional crosslinking effects of AEM terpolymers during ageing. Vamac® Ultra DX dipolymer shows much less tendency to form such crosslinks during fluid ageing and maintains its original Elongation at Break much better, as shown in **Table 6**. Exxon MB Formula 5W30 is used as first fill oil for truck diesel engines, Fuchs Titan 5W30 as a first fill oil for passenger car gasoline engines by a well-known German OEM. Pentosin® FFL-4 is a lubricant used in automatic transmissions.

Table 6 – Comparison to Vamac® Terpolymers, Engine Oil Ageing

Compound No.	21	22	23	24
Vamac® GLS	100			
Vamac® Ultra LS		100		
Vamac® Ultra IP			100	
Vamac® Ultra DX				100
Naugard® 445	2	2	2	1
Vanfre® VAM	1	1	1	
Armeen® 18D PRILLS	0.5	0.5	0.5	
Stearic Acid Reagent (95%)	2	2	2	0.5
MT Thermax® Floform N 990	30	30	30	
Spheron® SOA (N 550)				25
Regal® SRF N 772	45	45	45	40
Alcanplast 810 TM	15	15	15	5
Rubber chem Diak™ no 1	1.3	1.3	1.3	
Alcanpoudre DBU-70	3	3	3	
Luperox® DC 40 P				8
Rubber chem HVA 2				2

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Table 6 – Comparison to Vamac® Terpolymers, Engine Oil Ageing

Compound No.	21	22	23	24
Original Properties (Press-Cure 5 minutes / 190°C, Post-Cure 4 h / 175°C)				
Hardness Shore A (1 s), pts	64	65	64	70
Tensile Strength, MPa	14.7	17.1	17.4	14.2
Elongation at Break, %	262	314	310	276
100% Modulus, MPa	4.1	4.2	4.1	4.9
C.set, 24 h at 150°C (ISO 815), %	16.3	13.5	11.4	14.5
C.set, 94 h at 150°C (VW PV3307), %	67.9	56.8	52.2	89.3
C.set, 22 h at 150°C (plied, ISO 815-B), %	26.9	23.0	20.8	46.3
Fluid ageing 1008 h at 150°C in Exxon Mobil, MB Formula 225.18, 5W-30				
Hardness Shore A (1 s), pts	75	72	65	68
Delta Hardness, pts	10	7	2	-3
Tensile Strength, MPa	7.1	9.6	10.2	12.0
Delta Tensile Strength, %	-52	-44	-41	-15
Elongation at Break, %	101	118	136	185
Delta Elongation at Break, %	-61	-62	-56	-33
100% Modulus, MPa	7.1	8.0	6.3	5.5
Delta 100% Modulus, %	73	91	55	13
Volume Change, %	-4	-2	6	9
Weight Change, %	-3	-2	4	6
Fluid ageing 1008 h at 150°C in Fuchs Titan, EM 225.16 (HTHS 3,5), 5W-30				
Hardness Shore A (1 s), pts	73	71	63	67
Delta Hardness, pts	9	6	-1	-3
Tensile Strength, MPa	9.4	13.2	16.0	12.6
Delta Tensile Strength, %	-36	-23	-8	-11
Elongation at Break, %	120	169	235	208
Delta Elongation at Break, %	-54	-46	-24	-25
100% Modulus, MPa	8.0	6.3	5.0	5.0
Delta 100% Modulus, %	95	50	23	3
Volume Change, %	-4	-3	4	8
Weight Change, %	-3	-3	2	5

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Table 6 (continued) – Comparison to Vamac® Terpolymers, Engine Oil Ageing

Compound No.	21	22	23	24
Fluid ageing 1008 h at 150°C in Pentosin® FFL-4				
Hardness Shore A (1 s), pts	76	75	66	70
Delta Hardness, pts	12	9	3	0
Tensile Strength, MPa	13.6	15.4	16.7	13.4
Delta Tensile Strength, %	-8	-10	-4	-6
Elongation at Break, %	124	166	193	176
Delta Elongation at Break, %	-53	-47	-38	-36
100% Modulus, MPa	10.1	8.1	5.8	6.4
Delta 100% Modulus, %	146	93	43	31
Volume Change, %	-2	-1	6	10
Weight Change, %	-1	-1	4	7

Continuous Vulcanization without external Pressure (UHF, Salt Bath)

Vamac® Terpolymers are used as standard material for hoses, due to good physical properties and excellent green strength of compounds for extrusion. Dipolymer compounds typically have had lower green strength. Vamac® Ultra DX offers higher green strength and better properties compared to Vamac® DP and can meet existing AEM specifications.

Straight tubes can be cured in pressureless, continuous systems like UHF ovens or salt baths. Suitable compounds need Calcium Oxide (CaO) as absorbent for moisture which is always present in any rubber compounds. CaO would react with the acidic cure sites of Vamac® Terpolymers, for which reason these polymers cannot be used for such cost-effective continuous vulcanization processes. Vamac® Dipolymers can be used along with CaO, and some compounding possibilities have been developed in the past to produce compounds fit for use in pressureless cure processes. Vamac® Ultra DX has shown improvements over Vamac® DP in lab trials. Optimization, including use of a combination of two peroxides with lower and higher decomposition temperatures may be employed, but was not used in this study. **Table 7** gives some indications of the range of pressureless cure, and more information can be provided on request.

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These compounds were extruded through a Garvey Die and then cured in a standard heat ageing oven without pressure. Compounds 25 and 27 of Table 7 showed significant blistering, with Vamac® Ultra DX being significantly better. The blends with 15 phr of Vamac® Ultra LS were significantly lower in blistering, whereas the blend with 25 phr of Vamac® Ultra LS along with Vamac® Ultra DX was principally free of blisters. The compound with lower reinforcing N990 carbon black resulted in higher blistering, and lower hardness.

Table 7 – Compounds for Pressureless Cure Processes

Compound No.	25	26	27	28	29	30
Vamac® DP	100	85				
Vamac® Ultra LS		15		15	25	25
Vamac® Ultra DX			100	85	75	75
Naugard® 445	1	1	1	1	1	1
Armeen® 18D PRILLS	0.5	0.5	0.5	0.5	0.5	0.5
Stearic Acid Reagent (95%)	1	1	1	1	1	1
Struktol® WS 180	0.5	0.5	0.5	0.5	0.5	0.5
Kezadol GR (CaO desiccant)	10	10	10	10	10	10
Spheron® SOA (N 550)	65	65	65	65	65	20
MT Thermax® Floform N 990						80
Luperox® DC 40 P	8	8	8	8	8	8
Sartomer® SR350 (TRIM)	2	2	2	2	2	2
Mooney Viscosity ML 1+4, 100°C, MU	54	65	69	84	92	62
<u>MDR, 0.5°arc, 12 minutes at 190°C</u>						
ML [dNm]	0.78	1.13	1.02	1.27	1.61	0.76
MH [dNm]	12.40	13.39	13.21	14.27	15.01	10.18
Ts1 [min]	0.45	0.45	0.43	0.41	0.39	0.45
T50 [min]	0.87	0.88	0.82	0.82	0.80	0.77
T90 [min]	1.81	1.90	1.60	1.72	1.74	1.78
Tan delta at MH	0.094	0.115	0.098	0.138	0.154	0.133
Peak rate [dNm/min]	14	15	16	16	17	14

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Table 7 (continued) – Compounds for Pressureless Cure Processes

Compound No.	25	26	27	28	29	30
Original Properties (Cure Time: 5 minutes at 190°C)						
Hardness Shore A (1 s), pts	72	75	75	79	80	71
Tensile Strength, MPa	12.4	14.0	13.9	14.3	15.8	12.3
Elongation at Break, %	283	258	312	275	278	306
100% Modulus, MPa	4.7	6.6	5.4	7.0	8.2	4.7
Trouser Tear, Type A (ISO 34-1), N/mm	7.4	6.1	8.6	6.9	9.9	7.8
C.set 70 h at 150°C (ISO 815 type B), %	53	68	52	71	82	81
C.set 70 h at 150°C (ISO 815 type B plied), %	46	64	49	68	78	72
Fluid ageing 168 h at 150°C in Lubrizol® OS 206304						
Hardness Shore A (1 s), pts	59	63	63	69	69	62
Delta Hardness, pts	-13	-12	-13	-10	-11	-9
Tensile Strength, MPa	10.2	11.8	10.9	12.7	13.2	11.2
Delta Tensile Strength, %	-18	-16	-22	-11	-16	-9
Elongation at Break, %	261	242	302	274	243	271
Delta Elongation at Break, %	-8	-6	-3	0	-13	-11
100% Modulus, MPa	4.0	5.4	4.3	5.6	6.4	4.3
Delta 100% Modulus, %	-15	-18	-20	-20	-22	-9
Volume Change, %	11	16	12	14	9	14
Weight Change, %	11	10	10	9	9	8

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Test methods used for this work:

Test	Method
Rheology	
Mooney Viscosity	ISO 289-1:2005
Mooney Scorch	ISO 289-2:1994
MDR	ISO 6502:1999
Physical Properties	
Hardness	ISO 868:2003
Tensile Strength, Elongation, Modulus	ISO 37:1994
Compression Set	ISO 815:1991
Compression Set	Volkswagen PV3307
Compressive Stress Relaxation (CSR)	ISO 3384
Ageing in Air Oven	ISO 188:2007
Fluid Ageing	ISO 1817:2005
Tg by DSC	ISO 22768:2006
Tear Strength, Die C	ISO 34-1:2004

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