Viton™ B-135C and B-435C

Fluoroelastomers

Improved Processing Viton™ Terpolymer Precompounds for Bonded Metal Insert Applications (e.g., Crank Shaft, Cam Shaft, and Valve Stem Seals)

Introduction

Viton™ B-135C and Viton™ B-435C are two Viton™ precompounds intended for use in molding applications that require bonding to metal inserts. Viton™ B-135C and Viton™ B-435C have a nominal Mooney viscosity (ML 1+10 at 121 °C [250 °F]) of 10 and 40, respectively. Both precompounds are based on 68.5% fluorine gums and have the excellent heat and fluid resistance associated with other 68.5% fluorine Viton™ terpolymers.

These precompounds contain a proprietary cure system, bonding promoter, and process aid package that has been developed to impart improved processing characteristics over existing terpolymer precompounds like Viton™ B-651C. They are designed to provide a wide processing window combined with easy mold release and low mold fouling.

Typical applications for these materials are valve stem, cam shaft, and crank shaft seals, as well as other metal bonded components requiring the heat and fluid resistance of a 68.5% fluorine Viton™ terpolymer. By blending Viton™ B-135C with Viton™ B-435C, full compounds may be tailored to give the viscosity most appropriate for the production equipment in use (compression, transfer, or injection molding) and tooling geometry.

Product Description

Chemical Composition	Terpolymer of hexafluoropropylene, vinylidene fluoride, and tetrafluoroethylene with cure chemicals
Physical Form	Slab
Color	Off-white
Odor	None
Specific Gravity	1.85
Solubility	Low molecular weight esters and ketones
Fluorine Percent	~67%
Storage Stability	Excellent
Mooney Viscosity (ML 1+10 at 121 °C [250 °F])	Viton™ B-135C: 10 Viton™ B-435C: 40

Chemours™

Some of the advantages that can be realized by using these materials are:

- Calcium hydroxide is not required during final compounding; although, if added, it will increase cure rate as with other bisphenol-cured Viton™ types. The many problems related to calcium hydroxide (e.g., hygroscopy and dispersion) can be totally eliminated.
- Safe, scorch-free molding when processed at traditional mold temperatures (e.g., 190 °C [374 °F]). This can help to reduce/eliminate scorch-related rejects in cases where flow paths are relatively long and tortuous.
- Fast cure cycles and, hence, improved productivity when processed at higher mold temperatures would be possible using precompounds like Viton™ B-651C (e.g., >200 °C [392 °F]).
- Parts can be demolded at lower crosslink densities without the risk of mold fouling. Because Viton™ is less fragile at lower crosslink densities, this can result in fewer rejects (e.g., spring groove tearing in the case of shaft seal or valve stem seal production).

These precompounds have been designed to provide more efficient, cost-effective processing. Shorter cycle times, reduced rejects, and longer periods between mold cleaning all contribute to effectively lowering the cost per part. Apart from reducing the cost per part, improved productivity may have far more important implications. An example might be elimination of the need for capital investment for additional injection molding machines.

The following technical data is presented in two parts:

- Recipes Not Containing Calcium Hydroxide
- Recipes Containing Calcium Hydroxide

Safety and Handling

Before handling or processing Viton™ B-135C or Viton™ B-435C, read and follow the recommendations in Chemours bulletin, "Handling Precautions for Viton™ and Related Chemicals".

Viton™ B-135C and Viton™ B-435C should be handled like other types of Viton™. For the safe handling of other compounding ingredients, please refer to the respective manufacturers.

Compound Testing (Recipes Not Containing Calcium Hydroxide)

The properties of Viton™ B-435C have been measured in typical shaft seal formulations and are compared to those of Viton™ B-651C in Tables 1 to 8. Compounds 1A and 1B are carbon black filled, while compounds 1C and 1D contain a mixed carbon black/mineral filler system.

The properties of Viton™ B-135C, the lower viscosity blend partner, in the same shaft seal formulations are also given. Compound 1G is carbon black filled and compound 1H contains a mixed carbon black/mineral filler system. Compounds 1E and 1F are based on blends of Viton™ B-135C and Viton™ B-435C and included to illustrate the effect of blending to make intermediate viscosity compounds.

The Mooney Viscosity results for compounds 1A to 1D show that for a given recipe, compounds based on the precompounds will have a somewhat lower viscosity. This is an advantage of the curing and process aid systems used and will provide improved mold flow. It should be noted that the scorch measurements on these compounds have been made at temperatures of 135 °C (275 °F) and 160 °C (320 °F), which is somewhat higher than normal.

Table 1. Compounds of Viton™ B-435C, Viton™ B-135C, and Viton™ B-651C

Compound	1A	1B	1C	1D	1E	1F	1G	1H
Precompound	Viton™ B-435C	Viton™ B-651C	Viton™ B-435C	Viton™ B-651C	Viton™ B-435C/B-135C		Viton™ B-135C	Viton™ B-135C
Filler System	Black	Black	Mixed	Mixed	Mixed	Mixed	Black	Mixed
Viton™ B-435C	100	—	100	—	80	60	—	—
Viton™ B-135C	—	—	—	—	20	40	100	100
Viton™ B-635C	—	100	—	100	—	—	—	—
MT Thermax FF N 990	30	30	10	10	10	10	30	10
Nyad 400	—	—	25	25	25	25	—	25
Maglite DE	6	6	6	6	6	6	6	6
Calcium Hydroxide	—	2	—	2	—	—	—	—
VPA No. 2	0.5	0.5	0.5	0.5	0.5	0.5	0.5	0.5

Table 2. Mooney Scorch and Viscosity

Compound	1A	1B	1C	1D	1E	1F	1G	1H
Precompound	Viton™ B-435C	Viton™ B-651C	Viton™ B-435C	Viton™ B-651C	Viton™ B-435C/B-135C		Viton™ B-135C	Viton™ B-135C
Filler System	Black	Black	Mixed	Mixed	Mixed	Mixed	Black	Mixed
Mooney Viscosity								
ML 1+4 at 100 °C (212 °F)	114	140	118	145	105	95	64	69
Mooney Scorch at 135 °C (275 °F)								
Minimum	32	39	36	42	30	25	13	14
5 pt Rise Time, min	12.1	18.0	17.4	20.7	21.2	23.6	21.2	37.5
Mooney Scorch at 160 °C (320 °F)								
Minimum	25	28	26	30	21	17	8	7
5 pt Rise Time, min	4.6	5.7	4.9	5.8	5.2	5.5	6.6	7.4

Table 3. Monsanto ODR and MDR Test Results

Compound	1A	1B	1C	1D	1E	1F	1G	1H
Precompound	Viton™ B-435C	Viton™ B-651C	Viton™ B-435C	Viton™ B-651C	Viton™ B-435C/B-135C		Viton™ B-135C	Viton™ B-135C
Filler System	Black	Black	Mixed	Mixed	Mixed	Mixed	Black	Mixed
Monsanto ODR, 180 °C (356 °F), 1° arc, 12 min								
ML, dN·m	3.7	8.6	3.8	8.9	3.5	2.7	1.9	1.7
MH, dN·m	36	49	36	48	35	36	35	35
t_{s2}, min	2.06	1.58	1.77	1.67	1.72	1.91	2.50	2.50
t_{50}, min	3.19	2.51	2.72	2.43	2.50	2.67	3.22	3.17
t_{90}, min	4.23	2.85	3.24	2.72	2.89	3.00	3.66	3.49
Monsanto ODR, 190 °C (374 °F), 1° arc, 12 min								
ML, dN·m	3.22	7.82	3.50	8.33	3.25	2.43	1.75	1.49
MH, dN·m	35.96	46.34	35.33	44.76	33.99	34.07	32.48	33.00
t_{s2}, min	1.43	1.19	1.34	1.25	1.37	1.43	1.85	1.80
t_{50}, min	2.16	1.81	2.00	1.79	1.93	1.96	2.32	2.24
t_{90}, min	2.51	2.03	2.32	1.99	2.19	2.19	2.57	2.44
Monsanto ODR, 200 °C (392 °F), 1° arc, 12 min								
ML, dN·m	3.00	7.61	3.28	8.25	2.99	2.28	1.79	1.47
MH, dN·m	34.57	44.70	34.32	44.61	33.12	33.18	30.14	31.55
t_{s2}, min	1.17	0.92	1.07	0.97	1.04	1.12	1.72	1.42
t_{50}, min	1.72	1.37	1.56	1.38	1.46	1.53	2.05	1.72
t_{90}, min	1.98	1.54	1.80	1.53	1.65	1.70	2.22	1.85
Monsanto ODR, 180 °C (356 °F), 0.5° arc, 12 min								
ML, dN·m	0.64	1.93	0.65	1.92	0.58	0.43	0.47	0.33
MH, dN·m	13.21	18.86	12.34	17.27	11.79	11.50	11.98	11.22
t_{s2}, min	1.52	1.10	1.32	1.11	1.25	1.39	1.92	1.82
t_{50}, min	2.00	1.53	1.71	1.43	1.52	1.63	2.22	2.09
t_{90}, min	2.74	1.94	2.23	1.79	1.94	2.05	2.61	2.42
Monsanto ODR, 190 °C (374 °F), 0.5° arc, 12 min								
ML, dN·m	0.55	1.69	0.56	1.69	0.49	0.36	0.39	0.26
MH, dN·m	12.25	17.66	11.55	15.97	10.92	10.98	11.10	10.26
t_{s2}, min	1.05	0.75	0.93	0.74	0.86	0.93	1.22	1.21
t_{50}, min	1.33	0.97	1.15	0.91	1.01	1.08	1.39	1.34
t_{90}, min	1.73	1.20	1.42	1.10	1.23	1.30	1.61	1.53
Monsanto ODR, 200 °C (392 °F), 0.5° arc, 12 min								
ML, dN·m	0.49	1.62	0.50	1.54	0.44	0.32	0.33	0.24
MH, dN·m	11.54	16.83	10.73	15.26	10.20	10.04	10.57	9.76
t_{s2}, min	0.79	0.55	0.70	0.52	0.65	0.72	0.83	0.79
t_{50}, min	0.97	0.68	0.84	0.61	0.76	0.82	0.94	0.88
t_{90}, min	1.21	0.81	1.02	0.78	0.91	0.97	1.16	1.01

The ODR and MDR test results show that compounds based on the precompounds were designed to be somewhat slower than those based on Viton™ B-651C, and they contain relatively low levels of accelerator to impart improved processing safety. The precompounds also yield lower values of MH. Because physical properties (before and after post-cure) are unaffected by this implied lower state of cure, it may be considered an advantage. Stresses caused by part deformation during demolding are the root cause of splitting and tearing, and the lower MH will result in lower stresses (and a reduced tendency to tear) for a given deformation. Figures 1 and 2 illustrate the retarded cure responses of the technology (compound 1A) versus the old technology (compound 1B).

Figure 1. Comparison of t_{s2} (ODR, 1° arc) for Viton™ B-435C and Viton™ B-651C

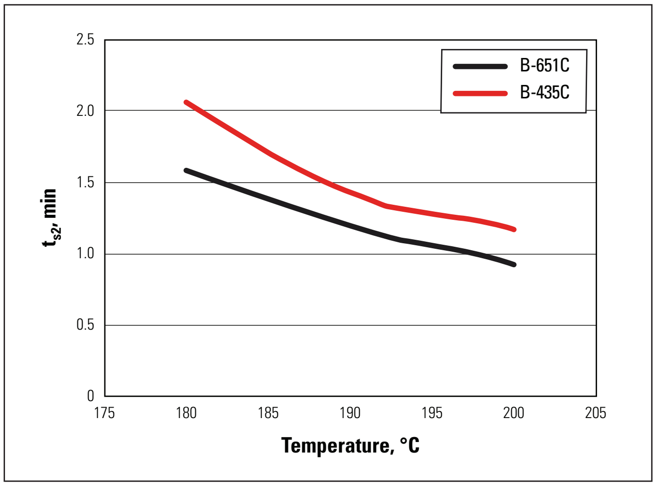
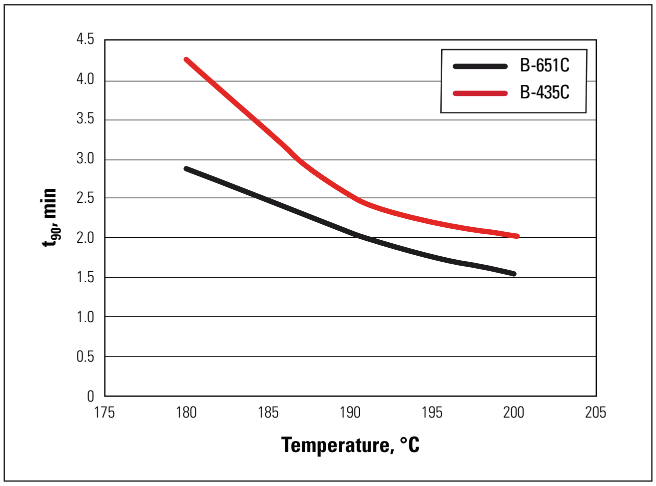


Figure 2. Comparison of t_{90} (ODR, 1° arc) for Viton™ B-435C and Viton™ B-651C



The Gottfert Rheovulkameter is an excellent indicator of flowability during processing because it combines the effects of viscosity and cure response. Scorchy compounds, or those with poor flow characteristics, will be highlighted by this test. The results of compounds 1A and 1B (and 1C and 1D) in Table 4 show that compounds based on Viton™ B-435C flow consistently better than compounds based on Viton™ B-651C. This supports the results of molding trials using Viton™ B-435C. The flow length results are illustrated graphically for compounds 1A and 1B in Figure 3.

Figure 3. Comparison of Rheovulkameter Flow Length for Viton™ B-435C and Viton™ B-651C

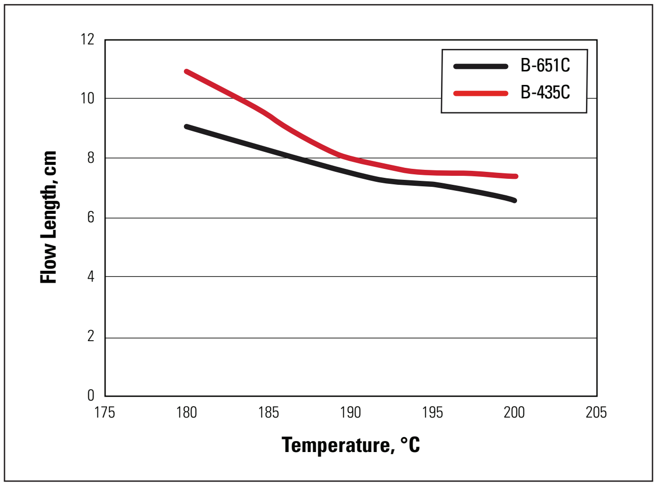


Table 4. Gottfert Rheovulkameter Test Results

Compound	1A	1B	1C	1D	1E	1F	1G	1H
Precompound	Viton™ B-435C	Viton™ B-651C	Viton™ B-435C	Viton™ B-651C	Viton™ B-435C/B-135C		Viton™ B-135C	Viton™ B-135C
Filler System	Black	Black	Mixed	Mixed	Mixed	Mixed	Black	Mixed
Rheovulkameter at 180 °C (356 °F)								
Volume, cm^3	1.21	0.93	0.86	0.82	1.13	1.49	2.99	2.87
Flow Rate, cm^3/sec	0.042	0.027	0.030	0.022	0.035	0.045	0.074	0.083
Length, cm	10.7	9.0	8.6	8.3	11.2	14.0	27.2	25.8
Weight, g	2.2	1.9	1.9	1.9	2.5	3.1	5.5	5.6
Rheovulkameter at 190 °C (374 °F)								
Volume, cm^3	0.84	0.8	0.81	0.72	1.07	1.3	2.71	2.49
Flow Rate, cm^3/sec	0.039	0.031	0.040	0.027	0.048	0.053	0.104	0.085
Length, cm	8.0	7.5	7.5	7.0	9.8	12.4	24.5	23.3
Weight, g	1.7	1.6	1.7	1.6	2.2	2.7	4.9	5
Rheovulkameter at 200 °C (392 °F)								
Volume, cm^3	0.77	0.68	0.72	0.65	0.93	1.19	2.46	2.27
Flow Rate, cm^3/sec	0.044	0.034	0.041	0.032	0.048	0.058	0.111	0.097
Length, cm	7.4	6.6	6.8	6.2	8.8	11.5	22.7	21.4
Weight, g	1.6	1.4	1.6	1.5	2	2.5	4.5	4.5

The results given in Table 5 simply illustrate that, for a given recipe, there are no significant differences between the properties of Viton™ B-135C, Viton™ B-435C, and Viton™ B-651C.

The results given in Table 6 again show that there are no significant differences between the precompounds and Viton™ B-651C in terms of bonding to metal and low temperature properties. The good bonding results achieved with the precompounds indicate that the incorporated process aid system does not detract from the bonding performance of these materials.

Table 5. Physical Properties (ISO 37)

Compound	1A	1B	1C	1D	1E	1F	1G	1H
Precompound	Viton™ B-435C	Viton™ B-651C	Viton™ B-435C	Viton™ B-651C	Viton™ B-435C/B-135C		Viton™ B-135C	Viton™ B-135C
Filler System	Black	Black	Mixed	Mixed	Mixed	Mixed	Black	Mixed
Initial Physical Properties, Cured at 180 °C (356 °F), No Post-Cure								
Tensile Strength, MPa	9.1	9.5	9.7	10.1	9.4	9.7	7.9	8.1
Elongation at Break, %	463	411	462	421	451	423	410	401
100% Modulus, MPa	2.9	3.3	2.4	2.9	2.2	2.3	2.9	2.2
200% Modulus, MPa	5.2	5.5	3.7	4.6	3.7	3.7	5.0	3.6
300% Modulus, MPa	6.2	7.6	5.5	6.7	5.6	5.6	6.6	5.6
Hardness, Shore A	68	72	68	68	70	66	68	73
Post-Cured 24 hr at 200 °C (392 °F)								
Tensile Strength, MPa	12.8	12.3	11.0	12.1	11.1	11.3	12.9	11.0
Elongation at Break, %	355	361	380	348	361	368	361	346
100% Modulus, MPa	3.6	3.8	3.7	5.3	3.7	3.6	3.3	3.4
Hardness, Shore A	75	76	70	71	70	70	77	71
Compression Set (%)—Small Pips								
70 hr at 200 °C (392 °F)	35	35	34	28	36	34	42	42
22 hr at 150 °C (302 °F) (2 hr Cool in Clamps)	45	48	37	36	38	39	51	41

Table 6. Other Properties

Compound	1A	1B	1C	1D	1E	1F	1G	1H
Precompound	Viton™ B-435C	Viton™ B-651C	Viton™ B-435C	Viton™ B-651C	Viton™ B-435C/B-135C		Viton™ B-135C	Viton™ B-135C
Filler System	Black	Black	Mixed	Mixed	Mixed	Mixed	Black	Mixed
Bonding to Metal — Chemosil 512								
Force Max., N/mm	15.5	15.2	19.4	11.2	13.2	6.9	10.3	8.8
Bonding to Metal — Megum 3290/1								
Force Max., N/mm	13.6	8.3	13.7	4.9	12	8.8	9.5	7.1
Low Temperature Testing								
TR-10, °C	−13	−13	−13	−13	−13	−13	−14	−13

The test results given in Table 7 indicate that there are no significant differences between the oil resistance of compounds based on the precompounds versus Viton™ B-651C.

The test results given in Table 8 indicate that there are no significant differences between the heat resistance of compounds based on the precompounds versus Viton™ B-651C.

Table 7. Aging in Hot Oil

Compound	1A	1B	1C	1D	1E	1F	1G	1H
Precompound	Viton™ B-435C	Viton™ B-651C	Viton™ B-435C	Viton™ B-651C	Viton™ B-435C/B-135C		Viton™ B-135C	Viton™ B-135C
Filler System	Black	Black	Mixed	Mixed	Mixed	Mixed	Black	Mixed
Aged 168 hr at 150 °C (302 °F) in RL-138 Oil								
Tensile Strength, MPa	9.7	7.8	8.5	10.4	8.2	7.5	8.9	7.1
△ Tensile Strength, %	−24	−37	−23	−14	−26	−34	−31	−35
Elongation at Break, %	135	152	126	144	123	116	109	122
△ Elongation at Break, %	−62	−58	−67	−59	−66	−68	−70	−65
Hardness, Shore A	78	75	73	71	71	74	80	73
△ Hardness, pt	2.8	−0.6	3	0.6	0.8	3.8	2.2	2.8
Volume Swell, %	0.4	1.1	0.3	0.5	0.2	2.2	0.5	0.4
Aged 168 hr at 150 °C (302 °F) in Shell Helix 10W40 Oil								
Tensile Strength, MPa	10.6	10.8	10.3	11.5	10.7	10.6	10.7	10.5
△ Tensile Strength, %	−17	−12	−6	−5	−4	−6	−17	−5
Elongation at Break, %	296	337	208	252	267	274	265	248
△ Elongation at Break, %	−17	−7	−45	−28	−26	−26	−27	−28
Hardness, Shore A	74	73	72	69	71	70	75	70
△ Hardness, pt	−1	−3	1	−1	0.4	−0.2	−2	−0.2
Volume Swell, %	0.0	0.4	0.1	0.2	0.0	0.0	0.1	0.1

Table 8. Aging in Hot Air

Compound	1A	1B	1C	1D	1E	1F	1G	1H
Precompound	Viton™ B-435C	Viton™ B-651C	Viton™ B-435C	Viton™ B-651C	Viton™ B-435C/B-135C		Viton™ B-135C	Viton™ B-135C
Filler System	Black	Black	Mixed	Mixed	Mixed	Mixed	Black	Mixed
Aged 168 hr at 200 °C (392 °F) in Hot Air								
Tensile Strength, MPa	16.2	15.3	11.4	12.3	11.3	11.4	13.2	11.2
△ Tensile Strength, %	21	20	3	2	2	1	1	1
Elongation at Break, %	315	310	261	227	260	259	298	247
△ Elongation at Break, %	−12	−16	−45	−53	−39	−42	−21	−40
Hardness, Shore A	72	73	70	73	69	69	72	69
△ Hardness, pt	−2.8	−2.8	−0.8	2.0	−1.0	−1.4	−4.8	−1.8
Aged 168 hr at 230 °C (446 °F) in Hot Air								
Tensile Strength, MPa	12.6	16.2	9.7	12.2	10.0	10.1	13.8	10.5
△ Tensile Strength, %	−2	24	−13	1	−11	−12	6	−5
Elongation at Break, %	356	317	342	263	340	329	322	300
△ Elongation at Break, %	0.2	−14.0	−11.2	−32.3	−6.2	−11.9	−12.3	−15.0
Hardness, Shore A	75	75	69	70	69	70	79	71
△ Hardness, pt	0.	−1.0	−0.8	0.0	−0.6	−0.4	2.2	0.2

Compound Testing (Recipes Containing Calcium Hydroxide)

The properties of Viton™ B-435C and blends of Viton™ B-435C with Viton™ B-135C have been measured in typical shaft seal formulations containing calcium hydroxide and are compared to those of Viton™ B-651C in Tables 9 to 15. Compound 2A uses a mixed mineral/black filler system based on Viton™ B-651C and is included for control purposes. Compounds 2B, 2C, and 2D, based on Viton™ B-435C, contain a mixed mineral/black filler system and are included to show the effect of adding different levels of calcium hydroxide in the precompound. Compounds 2E and 2F also use a mixed carbon black/mineral filler system and are blends of Viton™ B-435C and Viton™ B-135C. Compounds 2G and 2H are carbon black filled compounds of Viton™ B-651C and Viton™ B-435C.

The Mooney Viscosity results show that for a given recipe, compounds based on the precompounds will have a somewhat lower viscosity when compounded using calcium hydroxide. This is an advantage of the curing and process aid systems used and will provide improved mold flow.

The ODR and MDR test results indicate that, when compounded using calcium hydroxide, Viton™ B-435C is faster than Viton™ B-651C. At higher temperatures (200 °C [392 °F]) the differences become small and Viton™ B-435C approaches the cure rate of Viton™ B-651C.

Table 9. Aging in Hot Air

Compound	2A	2B	2C	2D	2E	2F	2G	2H
Precompound	Viton™ B-651C	Viton™ B-435C	Viton™ B-435C	Viton™ B-435C	Viton™ B-435C/B-135C		Viton™ B-651C	Viton™ B-435C
Filler System	Black	Black	Mixed	Mixed	Mixed	Mixed	Black	Mixed
Calcium Hydroxide, phr	2	2	1	3	2	2	2	2
Viton™ B-651C	100						100	
Viton™ B-135C					20	40		
Viton™ B-435C		100	100	100	80	60		100
MT Thermax FF N 990	10	10	10	10	10	10	30	30
Nyad 400	25	25	25	25	25	25		
Elastomag 170	6	6	6	6	6	6	6	6
Rhenofit CF	2	2	1	3	2	2	2	2
VPA No. 2	0.50	0.50	0.50	0.50	0.50	0.50	0.50	0.50

Table 10. Mooney Scorch and Viscosity

Compound	2A	2B	2C	2D	2E	2F	2G	2H
Precompound	Viton™ B-651C	Viton™ B-435C	Viton™ B-435C	Viton™ B-435C	Viton™ B-435C/B-135C		Viton™ B-651C	Viton™ B-435C
Filler System	Black	Black	Mixed	Mixed	Mixed	Mixed	Black	Mixed
Calcium Hydroxide, phr	2	2	1	3	2	2	2	2
Mooney Viscosity								
ML 1+4 at 100 °C (212 °F)	145.8	129.4	125.2	132.2	119.7	105.6	144.1	126.1
Mooney Scorch at 121 °C (250 °F)								
Minimum	54.2	47.7	46.9	49.3	43.5	36.6	52.9	46.6
5 pt Rise Time, min	>45	26.1	>45	20.4	>45	27.6	27.6	17.1

Table 11. Monsanto ODR and MDR Test Results

Compound	2A	2B	2C	2D	2E	2F	2G	2H
Precompound	Viton™ B-651C	Viton™ B-435C	Viton™ B-435C	Viton™ B-435C	Viton™ B-435C/B-135C		Viton™ B-651C	Viton™ B-435C
Filler System	Black	Black	Mixed	Mixed	Mixed	Mixed	Black	Mixed
Calcium Hydroxide, phr	2	2	1	3	2	2	2	2
Monsanto ODR, 180 °C (356 °F), 1° arc, 12 min								
ML, dN·m	9.06	7.42	7.22	8.46	6.72	5.31	9.16	8.40
MH, dN·m	34.74	30.50	35.00	34.87	36.95	36.30	46.15	39.49
t_{s2}, min	1.98	1.39	1.61	1.19	1.42	1.48	1.52	1.22
t_{50}, min	2.85	2.08	2.54	1.78	2.13	2.19	2.60	2.00
t_{90}, min	3.42	2.55	3.24	2.20	2.56	2.60	3.25	2.47
Monsanto ODR, 190 °C (374 °F), 1° arc, 12 min								
ML, dN·m	8.63	7.88	7.17	8.72	6.45	5.29	8.61	7.95
MH, dN·m	44.40	37.98	40.11	36.67	37.14	35.20	44.78	37.80
t_{s2}, min	1.22	1.04	1.12	1.04	1.08	1.27	1.18	0.98
t_{50}, min	1.81	1.55	1.75	1.48	1.59	1.77	1.90	1.54
t_{90}, min	2.14	1.84	2.12	1.73	1.86	2.03	2.29	1.86
Monsanto ODR, 200 °C (392 °F), 1° arc, 12 min								
ML, dN·m	8.66	7.71	7.02	9.37	6.29	4.96	8.38	7.85
MH, dN·m	37.39	32.40	34.20	31.92	32.84	32.75	41.78	35.49
t_{s2}, min	1.10	0.92	0.99	1.06	0.87	0.93	0.93	0.81
t_{50}, min	1.59	1.32	1.49	1.41	1.28	1.32	1.46	1.24
t_{90}, min	1.95	1.57	1.81	1.61	1.51	1.52	1.75	1.50
Monsanto ODR, 180 °C (356 °F), 0.5° arc, 12 min								
ML, dN·m	1.79	1.62	1.47	1.69	1.30	0.98	1.93	1.75
MH, dN·m	16.19	13.72	14.12	12.81	13.02	12.35	17.51	14.14
t_{s2}, min	1.05	0.86	1.07	0.79	0.97	1.03	1.07	0.87
t_{50}, min	1.43	1.15	1.54	1.00	1.28	1.31	1.64	1.22
t_{90}, min	2.08	1.50	2.07	1.27	1.66	1.65	2.26	1.62
Monsanto ODR, 190 °C (374 °F), 0.5° arc, 12 min								
ML, dN·m	1.61	1.50	1.32	1.57	1.15	0.88	1.76	1.59
MH, dN·m	15.42	13.09	13.35	12.35	12.23	11.75	16.48	13.44
t_{s2}, min	0.69	0.66	0.70	0.60	0.72	0.75	0.74	0.64
t_{50}, min	0.94	0.83	1.05	0.74	0.90	0.92	1.05	1.11
t_{90}, min	1.25	1.05	1.36	0.91	1.13	1.14	1.42	1.20
Monsanto ODR, 200 °C (392 °F), 0.5° arc, 12 min								
ML, dN·m	1.49	1.38	1.24	1.50	1.09	0.81	1.61	1.53
MH, dN·m	14.43	12.19	12.71	11.70	11.66	10.98	15.38	12.96
t_{s2}, min	0.56	0.52	0.59	0.48	0.56	0.58	0.57	0.52
t_{50}, min	0.68	0.64	0.77	0.57	0.68	0.69	0.75	0.66
t_{90}, min	0.88	0.79	0.97	0.69	0.83	0.84	0.96	0.83

The ODR and MDR test results indicate that, when compounded using calcium hydroxide, Viton™ B-435C is faster than Viton™ B-651C. At higher temperatures (200 °C [392 °F]), the differences become small and Viton™ B-435C approaches the cure rate of Viton™ B-651C.

Figure 4. Comparison of t_{s2} (ODR, 1° arc) for Viton™ B-435C (with various levels of calcium hydroxide) and Viton™ B-651C

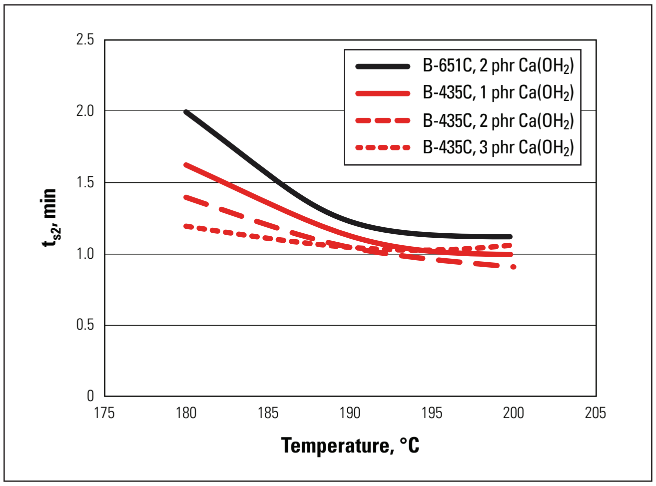


Figure 5. Comparison of t_{90} (ODR, 1° arc) for Viton™ B-435C (with various levels of calcium hydroxide) and Viton™ B-651C

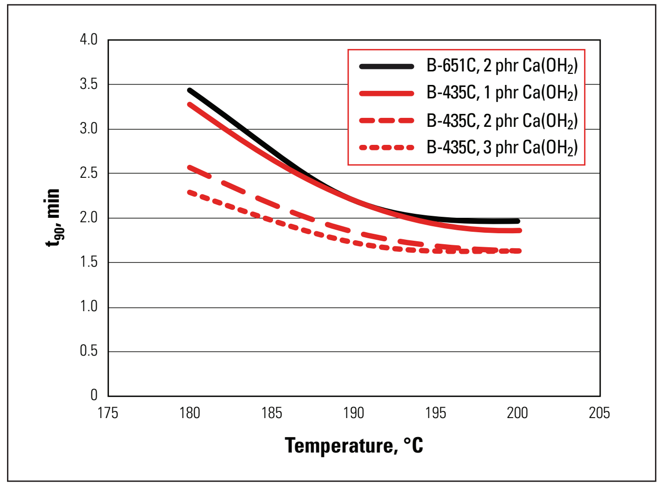


Table 12. Gottfert Rheovulkameter Test Results

Compound	2A	2B	2C	2D	2E	2F	2G	2H
Precompound	Viton™ B-651C	Viton™ B-435C	Viton™ B-435C	Viton™ B-435C	Viton™ B-435C/B-135C		Viton™ B-651C	Viton™ B-435C
Filler System	Black	Black	Mixed	Mixed	Mixed	Mixed	Black	Mixed
Calcium Hydroxide, phr	2	2	1	3	2	2	2	2
Rheovulkameter at 180 °C (356 °F)								
Volume, cm^3	1.46	1.27	1.16	0.92	1.09	1.35	1.63	1.24
Flow Rate, cm^3/sec	0.050	0.063	0.058	0.054	0.051	0.058	0.074	0.082
Length, cm	11.6	12.2	10.6	7.7	9.4	11.9	14.6	11.3
Weight, g	2.6	2.5	2.3	1.8	2.2	2.6	3	2.4
Rheovulkameter at 190 °C (374 °F)								
Volume, cm^3	0.81	0.72	0.88	0.7	0.9	1.14	0.77	0.96
Flow Rate, cm^3/sec	0.040	0.041	0.046	0.040	0.046	0.065	0.038	0.055
Length, cm	7.5	6.9	7.8	6.0	7.9	9.8	7.1	7.1
Weight, g	1.8	1.6	1.8	1.4	1.8	2.2	1.6	1.6
Rheovulkameter at 200 °C (392 °F)								
Volume, cm^3	0.65	0.68	0.83	0.61	0.82	0.99	0.71	0.71
Flow Rate, cm^3/sec	0.035	0.042	0.046	0.041	0.050	0.061	0.037	0.045
Length, cm	6.3	6.3	7.3	5.6	7.3	8.8	6.3	6.2
Weight, g	1.5	1.5	1.7	1.3	1.7	2	1.4	1.4

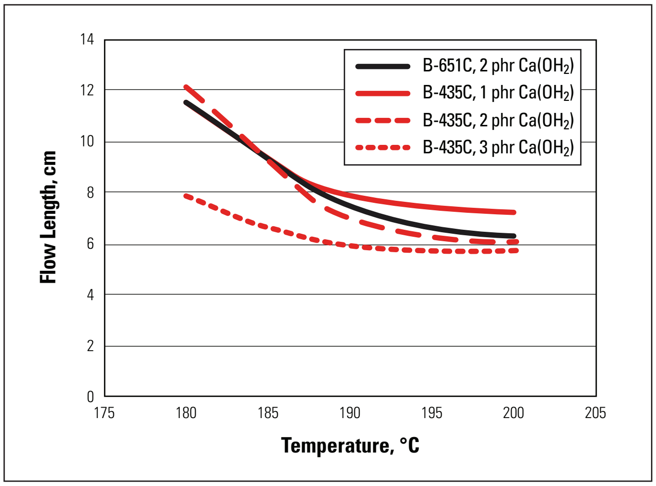
The Gottfert Rheovulkameter results indicate that the flow/cure behavior of Viton™ B-435C is similar to that of Viton™ B-651C.

The results given in Table 13 indicate that there is little difference between the physical properties of Viton™ B-435C and Viton™ B-651C.

Table 13. Physical Properties

Compound	2A	2B	2C	2D	2E	2F	2G	2H
Precompound	Viton™ B-651C	Viton™ B-435C	Viton™ B-435C	Viton™ B-435C	Viton™ B-435C/B-135C		Viton™ B-651C	Viton™ B-435C
Filler System	Black	Black	Mixed	Mixed	Mixed	Mixed	Black	Mixed
Calcium Hydroxide, phr	2	2	1	3	2	2	2	2
Initial Physical Properties, Cured at 180 °C (356 °F), No Post-Cure								
Tensile Strength, MPa	10.3	8.9	9.7	9.5	9.5	8.9	10.3	8.3
Elongation at Break, %	441.5	452.7	470.3	524.5	481.5	467.9	473.9	455.6
100% Modulus, MPa	2.8	2.4	2.2	2.4	2.5	2.4	2.8	2.8
Hardness, Shore A	69.3	68.5	68.1	68.5	67.9	68.3	72.9	71.7
Post-Cured 24 hr at 200 °C (392 °F)								
Tensile Strength, MPa	11.8	11.5	11.4	11.1	10.4	10.4	13.6	13.9
Elongation at Break, %	345.9	398.6	375.5	386.0	389.5	368.6	383.7	395.2
100% Modulus, MPa	4.9	4.3	4.3	4.0	3.4	3.9	3.6	3.6
Hardness, Shore A	70.1	69.5	69.5	70.3	69.9	69.9	74.5	72.7
Compression Set (%)—Small Pips								
70 hr at 200 °C (392 °F)	23	33	29	35	33	34	27	36
22 hr at 150 °C (302 °F) (2 hr Cool in Clamps)	41	49	43	54	48	50	51	59

Figure 6. Comparison of Rheovulkameter Flow Length for Viton™ B-435C (with various levels of calcium hydroxide) and Viton™ B-651C



The results given in Table 14 indicate a tendency for better bonding performance with Viton™ B-435C.

The results given in Table 15 show that there are no major differences in the oil resistance of Viton™ B-435C and Viton™ B-651C. Viton™ B-435C has a tendency to give slightly higher hardness change in RL-138 oil.

Table 14. Other Properties

Compound	2A	2B	2C	2D	2E	2F	2G	2H
Precompound	Viton™ B-651C	Viton™ B-435C	Viton™ B-435C	Viton™ B-435C	Viton™ B-435C/B-135C		Viton™ B-651C	Viton™ B-435C
Filler System	Black	Black	Mixed	Mixed	Mixed	Mixed	Black	Mixed
Calcium Hydroxide, phr	2	2	1	3	2	2	2	2
Bonding to Metal — Megum 3290/1								
Force Max., N/mm	8	10.3	9.5	11.8	12.2	9.8	9.3	10.3

Table 15. Aging in Hot Oil

Compound	2A	2B	2C	2D	2E	2F	2G	2H
Precompound	Viton™ B-651C	Viton™ B-435C	Viton™ B-435C	Viton™ B-435C	Viton™ B-435C/B-135C		Viton™ B-651C	Viton™ B-435C
Filler System	Black	Black	Mixed	Mixed	Mixed	Mixed	Black	Mixed
Calcium Hydroxide, phr	2	2	1	3	2	2	2	2
Aged 168 hr at 150 °C (302 °F) in RL-138 Oil								
Tensile Strength, MPa	11.3	10.1	9.6	10.8	10.7	9.8	8.9	10.0
△ Tensile Strength, %	−4.2	−12.2	−15.8	−2.7	2.9	−5.8	−34.6	−28.1
Elongation at Break, %	113.9	114.6	105.9	119.3	116.1	114.2	134.5	128.9
△ Elongation at Break, %	−67.1	−71.2	−71.8	−69.1	−70.2	−69.0	−64.9	−67.4
Hardness, Shore A	72.7	74.1	74.1	74.1	74.1	74.3	76.1	77.5
△ Hardness, pt	2.6	4.6	4.6	3.8	4.2	4.4	1.6	4.8
Volume Swell, %	1.5	0.0	0.1	0.1	0.0	0.0	0.0	0.1
Aged 168 hr at 150 °C (302 °F) in Shell Helix 10W40 Oil								
Tensile Strength, MPa	12.5	11.7	11.8	12.0	11.5	11.5	10.2	11.5
△ Tensile Strength, %	5.9	1.7	3.5	8.1	10.6	10.6	−25.0	−17.3
Elongation at Break, %	251.0	269.4	266.2	260.8	249.4	264.1	293.2	292.3
△ Elongation at Break, %	−27.4	−32.4	−29.1	−32.4	−36.0	−28.4	−23.6	−26.0
Hardness, Shore A	69.7	70.1	69.1	70.7	70.3	69.5	72.9	73.3
△ Hardness, pt	−0.4	0.6	−0.4	0.4	0.4	−0.4	−1.6	0.6
Volume Swell, %	0.85	1.23	0.29	3.13	0.36	0.34	0.27	0.30

Processing Viton™ B-135C and Viton™ B-435C

A combination of short cycle times and a low number of rejects provides a route to increased productivity; these precompounds are designed to achieve this goal.

The physical properties needed for many sealing applications dictate that a relatively high molecular weight polymer be used (e.g., Viton™ B-651C). It is generally true that such polymers also have a relatively high viscosity at normal processing temperatures, which can sometimes cause problems during processing.

Defects generally result from one of the following:

- Premature cure and scorch during mold filling.
- Defects related to high viscosity (surface flow marks and poor filling).
- At the demolding stage due to poor tear strength at processing temperatures (splitting and tearing).
- Surface defects due to a build-up of deposit on the mold surface (fouling).

To achieve short cycle times, it is desirable to raise processing temperatures; but, this practice will often lead to premature cure and scorch. Even if scorch does not occur, high process temperatures can result in other problems associated with hot tear strength (splitting and tearing during demolding). Reducing the processing temperature will alleviate the tendency for scorch and splitting, but can eventually lead to flow marks at the part surface, which are due to the high polymer viscosity (also a cause for rejects). If process temperatures are lowered then, to maintain short cycle times, the parts must be demolded at lower states of cure that generally go hand in hand with mold fouling and sticking. Somewhere in between lies the good processing window; depending on the part design and compound recipe, this window may be very restricted.

The precompounds were developed to avoid this type of scenario. The cure system is designed to be safe enough to allow processing at relatively high temperatures (>200 °C [392 °F]) and, thus, take advantage of the viscosity thinning effect. The chemical nature of the cure system is such that parts can be demolded at much lower states of cure without the risk of mold fouling. At low states of cure, fluoroelastomers are less fragile; problems of splitting and tearing are much less likely to occur. The proprietary process aid package contains components that help during mixing, mold flow, and mold release with no negative effect on bonding performance.

Below are some hints that may prove useful in compounding and processing to get the full advantage from these materials:

Formulation and Mixing

- In many cases, a blend of Viton™ B-135C and Viton™ B-435C should be used in order to ensure the optimum compound viscosity for a particular molding process.
- Because compounds based on these materials do not need calcium hydroxide to initiate the cure system, it is suggested that the only metal oxide in the formulation should be 6 phr magnesium oxide (required as an acid acceptor).
- The precompounds already contain a process aid package. If these precompounds are being used to replace another polymer (e.g., Viton™ B-651C), then any process aids in the existing formulation should be removed. It may be desirable to include 0,5 phr wax (either Viton™ Process Aid No. 2 or Carnauba Wax) in the final formulation to further assist in mold release.
- It is not appropriate to try to match existing curves (e.g., ODR) when replacing older polymers (e.g., Viton™ B-651C) with these precompounds. The materials are designed to be processed under completely different conditions. The addition of calcium hydroxide or other accelerators (e.g., Viton™ Curative No. 20) will probably not be beneficial and may negate the benefits of the curing technology.
- Because the materials are designed to have a wide operating window, adjustment of processing temperature can, to a large extent, replace the older practice of adjustment of the compound recipe.

Injection Molding

Given that the optimum processing temperature for a particular compound will largely depend on the geometry of the part being made, it is suggested that the mold temperature be set 10–15 °C (18–27 °F) higher than for a traditional formulation (200–210 °C [392–410 °F] might be typical).

The higher mold temperature will allow easy injection (temperature reduction of viscosity) and compensate for the slower curing speed of the formulation. It should also be remembered that the materials can be demolded at relatively low states of cure without the risk of mold fouling.

During setup, cure cycles should be progressively reduced to avoid demolding at a high state of cure where fluoroelastomers become fragile and problematic. It should be noted that if the mold temperature is too high, the bonding reaction may be compromised. In practice, this may be the determining factor for the mold temperature setting.

Although the precompounds have excellent processing safety, increasing the barrel temperature is probably not advisable. It is usually beneficial to retract the nozzle after the pressure hold on period, and nozzle drool may be a problem if the barrel temperature is set too high.

Screw speed, back pressure, and barrel temperature all have an effect on the temperature of the compound on exit from the nozzle. It is suggested that the combined effect should be to achieve a "melt" temperature in the region of 100–110 °C (212–230 °F), measured at the nozzle when injecting into air.

Cold Runner Blocks

Cold runner blocks are becoming more popular as a means of eliminating runner scrap. While this is a very cost-effective means of avoiding material waste, care must be taken in the design of the cold runner system in the case of bonded metal parts. Cold runner blocks are generally set to a relatively low temperature (e.g., <100 °C [212 °F]) to minimize heat history in the material. If the flow path connecting the cold runner block to the cavities is not designed to increase the compound temperature to around 130–140 °C (266–284 °F) during injection, it is likely that bonding problems will occur. If the temperature of the Viton™ compounds at the metal bonded inteface is too low, then the bonding reaction is inefficient and bond failures will result.

Transfer Molding

The same basic principles apply for transfer molding in that the process may be run hotter without the risk of scorch. The transfer pot can generally be set at a temperature 10–15 °C (18–27 °F) higher than for a traditional formulation that will aid in material flow. It is again essential, for efficient bonding, that the temperature of the Viton™ compound at the metal bonded interface reaches the temperature necessary for an efficient bonding reaction. Cure cycles should be adjusted to allow demolding at relatively low states of cure (compared to traditional formulations), in order to take advantage of improved hot tear strength.

Compression Molding

When using modern electrically heated compression molding presses, molds should again be relatively hot (10–15 °C [18–27 °F] hotter than for traditional formulations). Cure cycles should be adjusted to demold at relatively low states of cure, in order to minimize molding cycle time and take advantage of the better hot tear strength at low cure states.

When using steam heated compression molding presses, it may not be possible to achieve these higher process temperatures (typical temperatures are 185–190 °C [365–374 °F]). Even so, because these materials can be demolded at a relatively low state of cure without the risk of mold fouling, cycle times should still be short.

The addition of calcium hydroxide is not desirable; but, if desired, a small amount of calcium hydroxide may be added to accelerate steam compression molding formulations.

For more information, visit Viton.com

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