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Compounding Guide

3M™ Dyneon™ Fluoroelastomers

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Compounding Fluoroelastomers

Introduction

Components created with 3M™ Dyneon™ Fluoroelastomer compounds have the potential to increase the durability, reliability, and safety of your products – provided that they are made using the proper materials and processes for the application at hand. Variations in the ratios of inorganic bases, filler systems and cure systems used in compounding can yield significant control over the physical and rheological properties of the resulting compounds – including properties such as mold flow and mold release that are critical for many applications.

This manual provides general guidelines that can be used as reference in compounding fluoroelastomers. In addition to data regarding the physical properties yielded by various compounds and processes, the effects of potential contamination and the general requirements of certain types of applications (such as O-rings, molded goods, and extruded compounds) are also discussed. For more specific guidelines for the materials used in specific applications, refer to the 3M™ Dyneon™ Fluoroelastomer Recipe Book.

Note: The purpose of this guide is to provide basic information to product users for use in evaluating, processing, and troubleshooting their use of certain 3M products. The information provided is general or summary in nature and is offered to assist the user. The information is not intended to replace the user's careful consideration of the unique circumstances and conditions involved in its use and processing of 3M products. The user is responsible for determining whether this information is suitable and appropriate for the user's particular use and intended application. The user is solely responsible for evaluating third party intellectual property rights and for ensuring that user's use and intended application of 3M product does not violate any third party intellectual property rights.

General Compounding

The basics of choosing the polymer and cure system and compounding those systems with the proper acid acceptors and fillers to fulfill the rheological, physical and processing requirements are, in general, relatively simple. This is due to the limited number of ingredients that are able to withstand the harsh chemical or thermal environments that fluoroelastomers are exposed to.

General Compounding Ingredients (PHR)*

Fluoroelastomer	100
Acid Acceptor(s)	6-20
Filler	0-80
Processing Aids	0-2
Curatives (May be incorporated in polymer)	1-4

Bases

(Acid Acceptors)

Inorganic bases commonly used in compounding fluoroelastomers include the following:

CaO Calcium Oxide, HP-XL HallStar®

$Ca(OH)_2$ Calcium Hydroxide, HP-XL HallStar®

MgO Magnesium Oxide, Elastomag® 170

MgO Magnesium Oxide, Maglite Y HallStar®

MgO Magnesium Oxide, Maglite D HallStar®

ZnO Zinc Oxide, USP #1

Inorganic bases affect both the rheological and the physical properties. The best balance of properties will be achieved by using a combination of calcium hydroxide and magnesium oxide. The following tables illustrate the change in properties resulting from variations in the ratio of calcium hydroxide and magnesium oxide.

The general compounding data was generated in our Application and Product Development Laboratory and should be used only as a guide for compounding. Potential differences may arise due to differences in raw materials and processing techniques. Materials should be processed and evaluated in the consumer's facility to verify the properties.

*Parts per Hundred Rubber

Changes in Properties with Varying Ratios of $Ca(OH)_2$ and MgO and Levels of Carbon Black N990 Using FE 5640Q

(Dumbbell Test Specimens)

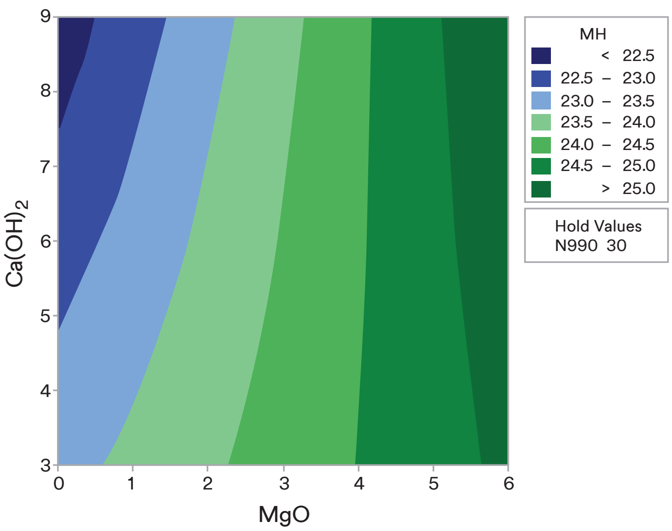
Compound Formulations, phr (Effect of $Ca(OH)_2$/MgO Ratios and N990 level using FE 5640Q)										
FE 5640Q	100	100	100	100	100	100	100	100	100	100
MT Black (N990)	55	5	5	30	55	5	55	5	55	30
$Ca(OH)_2$ HP-XL HallStar®	9	3	3	6	9	9	3	9	3	0
MgO, Elastomag® 170	0	0	6	3	6	6	0	0	6	18
Total Parts	**164**	**108**	**114**	**139**	**170**	**120**	**158**	**114**	**164**	**148**
MDR, 12 minutes @ 177°C (350°F)										
ML, in-lbs	2.1	0.7	0.9	1.4	2.9	1.1	1.9	0.8	2.2	2.0
MH, in-lbs	34.2	11.1	13.4	24.2	39.4	13.8	37.8	12.5	39.0	19.6
ts2, minutes	1.6	7.6	3.8	2.4	1.1	2.1	3.5	3.1	1.9	1.8
t'50, minutes	2.4	8.3	4.3	3.0	1.8	2.3	6.1	3.3	3.5	3.2
t'90, minutes	3.5	11.4	6.4	4.5	2.9	3.2	8.9	4.8	5.4	5.9
Press Cure, 10 minutes @ 177°C (350°F)										
		15 Min								
Tensile, psi	1416	1039	1343	1547	1505	1629	1268	1318	1514	1717
Elongation, %	271	318	315	295	214	326	319	312	320	412
Modulus 100%, psi	948	186	237	623	1027	296	812	226	948	580
Hardness, Type A, pts	88	53	57	76	89	60	87	56	88	75
Post Cure, 16 hours @ 232°C (450°F)										
Tensile, psi	2237	1069	1745	2303	1748	2180	2050	1606	2466	2473
Elongation, %	184	292	289	235	125	280	203	275	186	250
Modulus 100%, psi	1223	188	249	758	1394	314	1126	252	1271	739
Hardness, Type A, pts	91	54	58	76	91	61	91	58	91	79
Specific Gravity	1.84	1.85	1.90	1.88	1.90	1.90	1.84	1.86	1.87	1.91
Tear Die C on Post Cure, 16 hours @ 232°C (450°F)										
Tear, ppi	199	98	114	172	186	136	198	123	201	187
Compression Set, 70 hours @ 200°C (392°F), ASTM D1414										
Compression Set, %, 0.139" O-ring	24	13	12	15	24	13	19	12	17	18
Air Aging, 70 hours @ 270°C (518°F), ASTM D573										
Tensile, % change	-27	-6	-14	-23	-24	-25	-19	-17	-30	-33
Elongation, % change	7	21	31	22	11	13	3	24	17	40
Modulus 100%, psi	-28	-27	-34	-27	-28	-14	-26	-29	-30	-27
Hardness, Type A, pts change	1	-6	-6	2	2	-1	1	-5	1	1

Note: MgO, $Ca(OH)_2$ and N990 in phr

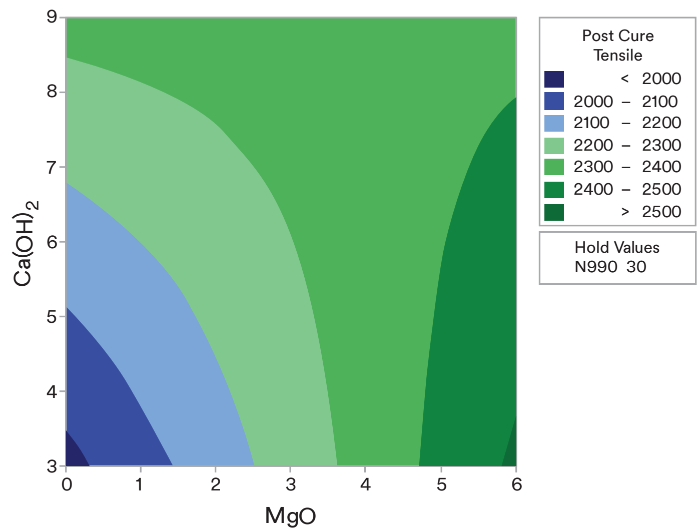
FE 5640Q Contour Plots

3M™ Dyneon™ Fluoroelastomer FE 5640Q is a 66% Fluorine dipolymer of vinyline fluoride and hexafluoropropylene. A design of experiments (DOE) was run using FE 5640Q varying the levels of carbon black MT N990, $Ca(OH)_2$ HP-XL and MgO Elastomag® 170. The levels of these variables range as: carbon black MT N990, from 5 to 55 phr, $Ca(OH)_2$ HP-XL, from 3 to 9 phr and MgO Elastomag 170, from 0 to 6 phr. Data collected during the experiment included: cure rheology and physical properties on press (10 minutes @ 177°C) and post cure (16 hours @ 232°C) test sheets, Die C tear strength after post cure (16 hours @ 232°C), compression set after post cure (70 hours @ 200°C, 0.139′ O-rings) and air aging (70 hours @ 270°C). Contour plots were generated holding the carbon black level constant at 30 phr.

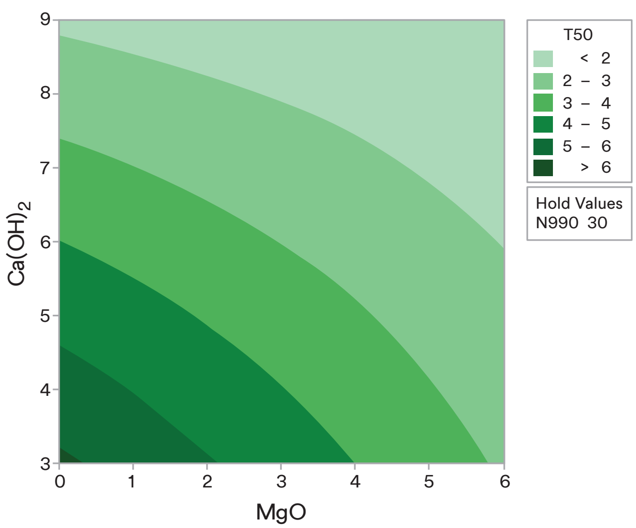
MH (in-lb) vs Levels of Metal Oxide



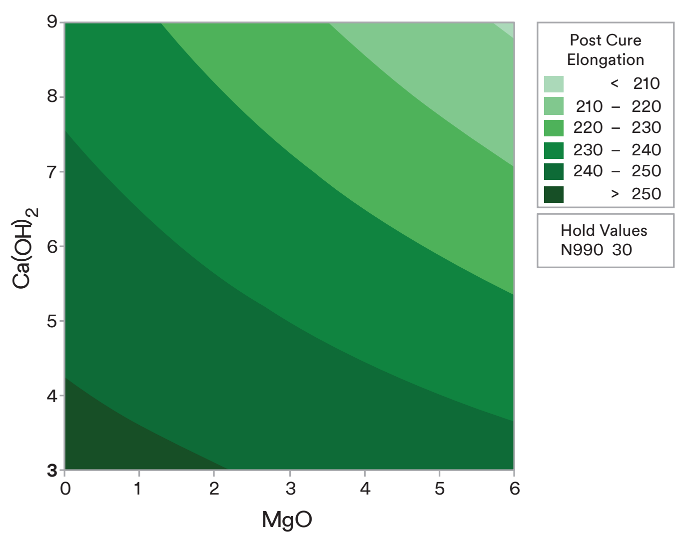
Post Cure Tensile (psi) vs Levels of Metal Oxide



t'50 (min) vs Levels of Metal Oxide



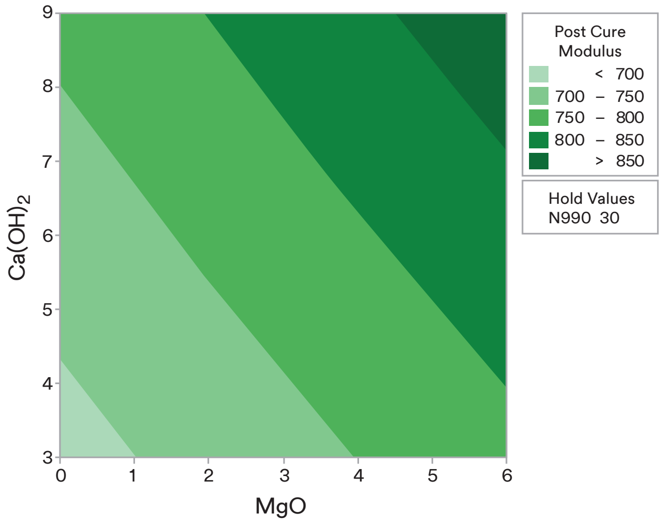
Post Cure Elongation (%) vs Levels of Metal Oxide



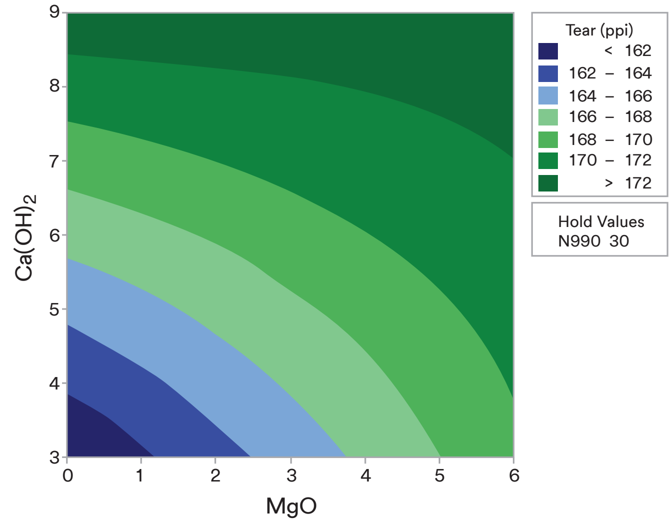
Note: MgO, $Ca(OH)_2$ and N990 in phr

FE 5640Q Contour Plots

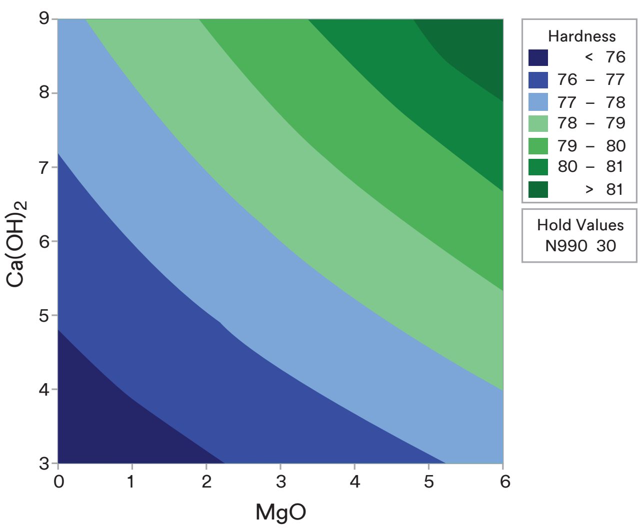
Post Cure Modulus (psi) vs Levels of Metal Oxide



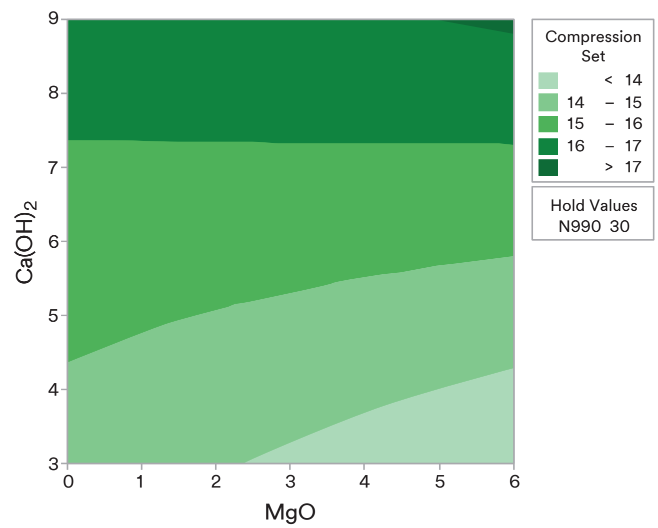
Tear (ppi) vs Levels of Metal Oxide



Hardness vs Levels of Metal Oxide



Compression Set (%) vs Levels of Metal Oxide



Note: MgO, $Ca(OH)_2$ and N990 in phr

Changes in Properties with Varying Ratios of $Ca(OH)_2$ and MgO Using FE 5840Q

(Dumbbell Test Specimens)

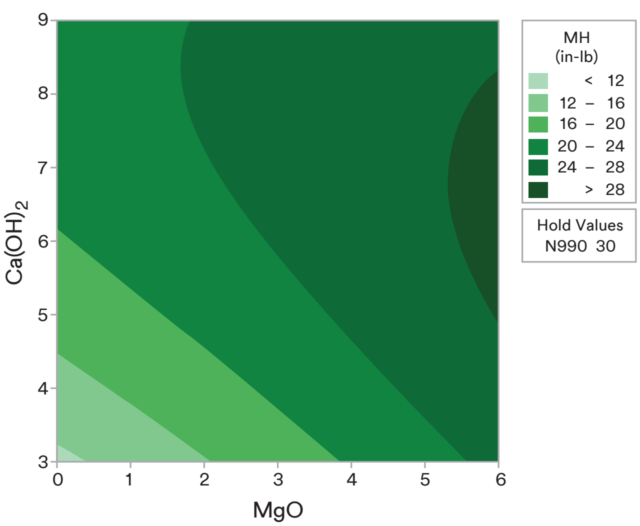
Compound Formulations, phr (Effect of $Ca(OH)_2$/MgO Ratios Using FE 5840Q)					
FE 5840Q	100	100	100	100	100
MT Black (N990)	30	30	30	30	30
$Ca(OH)_2$ HP-XL, HallStar®	3	6	9	9	3
MgO, Elastomag® 170	0	3	6	0	6
Total Parts	**133**	**139**	**145**	**139**	**139**
MDR, 12 minutes @ 177°C (350°F)					
ML, in-lbs	0.6	1.0	1.4	1.0	0.9
MH, in-lbs	11.1	24.3	27.2	22.6	25.0
ts2, minutes	4.4	2.3	1.4	2.0	2.3
t'50, minutes	5.2	2.8	1.7	2.4	2.9
t'90, minutes	7.1	3.9	2.3	3.3	3.8
Press Cure, 10 minutes @ 177°C (350°F)					
Tensile, psi	1173	1420	1343	1248	1345
Elongation, %	625	412	254	387	338
Modulus 100%, psi	394	658	849	626	711
Hardness, Type A, pts	74	82	81	81	79
Post Cure, 16 hours @ 232°C (450°F)					
Tensile, psi	1521	2222	2188	1964	1952
Elongation, %	402	302	229	285	256
Modulus 100%, psi	490	774	932	770	770
Hardness, Type A, pts	81	88	88	88	84
Tear Die C on Post Cure, 16 hours @ 232°C (450°F)					
Tear, ppi	194	191	189	191	170
Compression Set, 70 hours @ 200°C (392°F), ASTM D1414					
Compression Set, %, 0.139" O-ring	60	36	39	39	36
Air Aging, 70 hours @ 270°C (518°F), ASTM D573					
Tensile, % change	-54	-52	-48	-52	-54
Elongation, % change	73	56	44	69	87
Modulus 100%, % change	-34	-39	-38	-42	-47
Hardness, Type A, pts change	-1	-1	0	-1	-2

Note: MgO, $Ca(OH)_2$ and N990 in phr

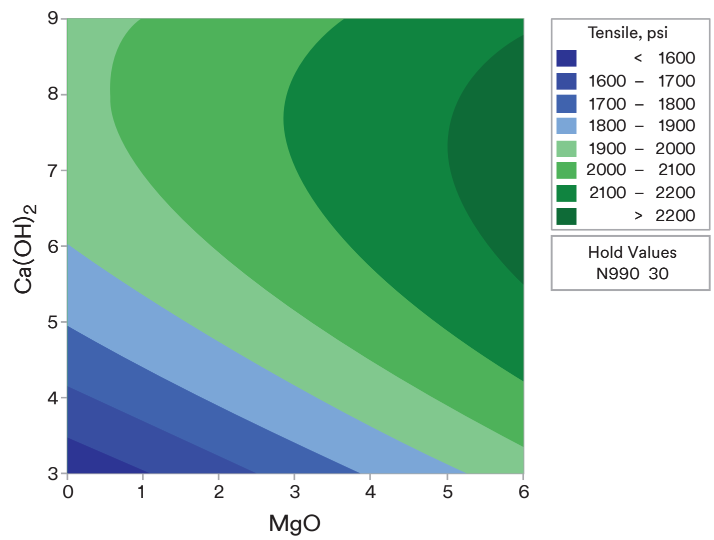
FE 5840Q Contour Plots

3M™ Dyneon™ Fluoroelastomer FE 5840Q is a 70% Fluorine terpolymer of vinyline fluoride, hexafluoropropylene and tetrafluoroethylene. A design of experiments (DOE) was run using FE 5840Q varying the levels of $Ca(OH)_2$ HP-XL and MgO Elastomag® 170. The levels of these variables range as: $Ca(OH)_2$ HP-XL from 3 to 9 phr and MgO Elastomag 170 from 0 to 6 phr, holding the carbon black (N990) level constant at 30 phr. Data collected during the experiment included: cure rheology and physical properties on press (10 minutes @ 177°C) and post cure (16 hours @ 232°C) test sheets, Die C tear strength after post cure (16 hours @ 232°C), compression set after post cure (70 hours @ 200°C, 0.139′ O-rings) and air aging (70 hours @ 270°C). Contour plots were generated holding the carbon black level constant at 30 phr.

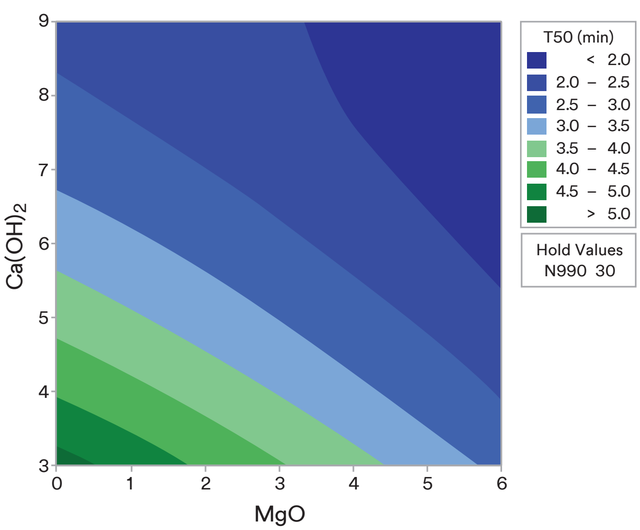
MH (in-lb) vs Levels of Metal Oxide



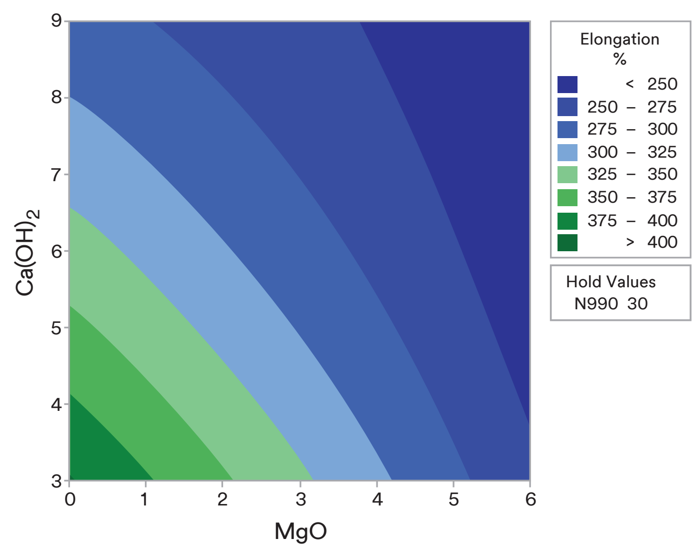
Post Cure Tensile (psi) vs Levels of Metal Oxide



t'50 (min) vs Levels of Metal Oxide



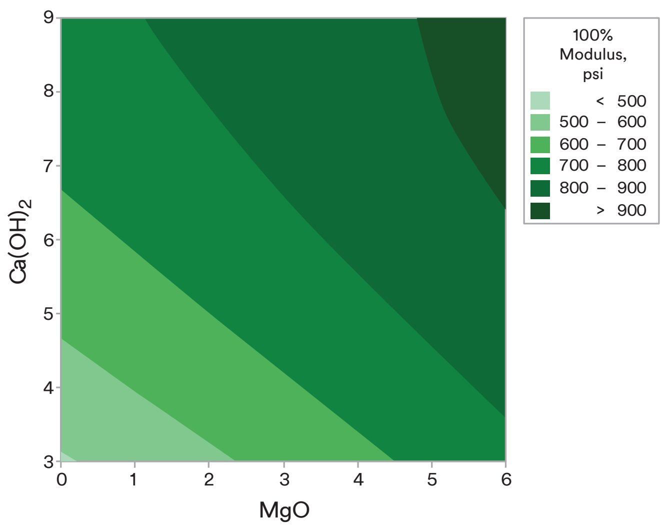
Post Cure Elongation (%) vs Levels of Metal Oxide



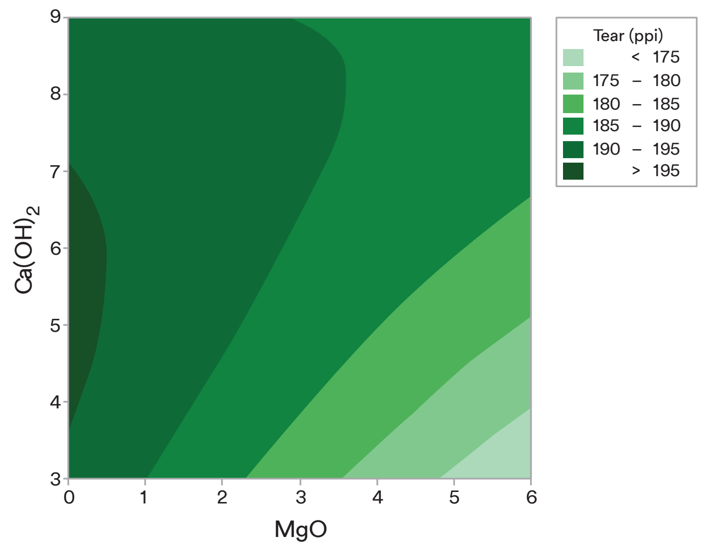
Note: MgO, $Ca(OH)_2$ and N990 in phr

FE 5840Q Contour Plots

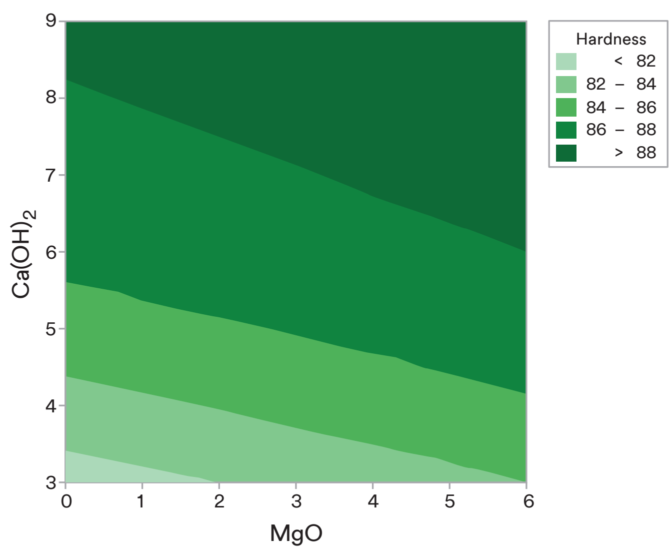
Post Cure Modulus (psi) vs Levels of Metal Oxide



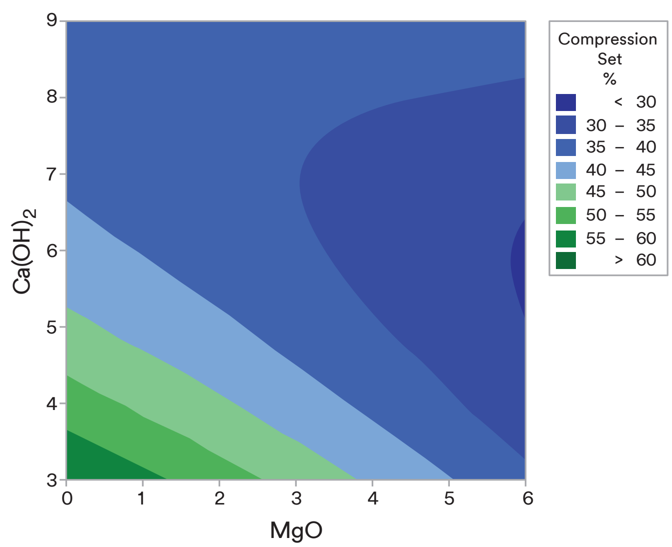
Tear (ppi) vs Levels of Metal Oxide



Hardness vs Levels of Metal Oxide



Compression Set (%) vs Levels of Metal Oxide



Note: MgO, $Ca(OH)_2$ and N990 in phr

Filler Systems

Black	ASTM Code
MT Medium Thermal	N990
SRF Semi-Reinforcing Furnace	N774 and N762
HAF High Abrasion Furnace	N326 and N330

Carbon Black Comparison Table (for equivalent hardness)	
1 part N330	2.5 parts N990
1 part N550	2.4 parts N990
1 part N660	2.0 parts N990
1 part N774	1.9 parts N990
1 part N762	1.6 parts N990

Non-Black (Mineral)	Common Trade Names
Fine Ground Silica	Min-U-Sil® (5 micron)
Oxides	Mapico® Tan-10 (Fe_2O_3• ZnO)
Calcium Carbonate, $CaCO_3$	Albacar® 5970
Barium Sulfate, $BaSO_4$	Huberbite® 10
Calcium Metasilicate	NYAD® 400
Zinc Oxide, ZnO	USP #1
Titanium Dioxide, TiO_2	Sakai Chemical A-110
Mistron CB	Cyprubond
Silicone Dioxide	Aerosil® R972
Zinc Sulfide, ZnS	Sachtolith L

Effect of Filler Level (Non-Black)

3M™ Dyneon™ Fluoroelastomer FE 5642 formulated to various durometers with various non-black fillers.

	55±5 Durometer						60±5 Durometer					
Compound Recipe	**1**	**2**	**3**	**4**	**5**	**6**	**1**	**2**	**3**	**4**	**5**	**6**
FE 5642	100	100	100	100	100	100	100	100	100	100	100	100
$Ca(OH)_2$ HP-XL, Hallstar®	6	6	6	6	6	6	6	6	6	6	6	6
MgO, Elastomag® 170	3	3	3	3	3	3	3	3	3	3	3	3
Min-U-Sil® (5 microns)	10						20					
Zinc Oxide, USP #1		25						45				
NYAD® 400			10						22			
Calcium Carbonate, Albacar® 5970				10						22		
Mapico® Tan 10A					15						25	
Barium Sulfate, Huberbrite® 10						20						40
Post cure, 16 hours @ 232°C (450°F)												
Tensile, psi	1565	2160	1265	1185	1605	1560	1885	2275	1415	1445	2035	1810
Elongation, %	225	345	285	280	290	320	275	330	255	310	305	325
Modulus 100%, psi	260	240	250	220	245	235	370	320	430	335	390	345
Hardness, Type A, pts	56	56	56	54	56	57	60	63	61	60	62	62
Air aging, 70 hours @ 270°C (518°F), ASTM D573												
Tensile, % change	-41	-4	-13	-11	-20	-19	-43	-5	-21	-2	-31	-22
Elongation, % change	38	-10	13	-5	19	13	7	-14	18	-10	15	6
Hardness, Type A, pts change	-6	2	-4	-1	-4	-4	-2	3	-3	-1	-3	-1
Compression Set, 70 hours @ 200°C (392°F), ASTM D1414												
Compression Set, %, 0.139" O-ring	16	18	16	20	16	16	Not Run					
Specific Gravity, ASTM D297												
	1.90	2.17	1.94	1.93	2.03	2.06	1.97	2.34	1.98	1.99	2.13	2.22

Note: MgO, $Ca(OH)_2$ and N990 in phr

Effect of Filler Level (Non-Black) continued

3M™ Dyneon™ Fluoroelastomer FE 5642 formulated to various durometers with various non-black fillers.

	70±5 Durometer						80±5 Durometer						90±5 Durometer					
Compound Recipe	1	2	3	4	5	6	1	2	3	4	5	6	1	2	3	4	5	6
FE 5642	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
$Ca(OH)_2$ HP-XL, Hallstar®	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
MgO, Elastomag® 170	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3
Min-U-Sil® (5 microns)	40						62						85					
Zinc Oxide, USP #1		75						100						155				
NYAD® 400			45						70						95			
Calcium Carbonate, Albacar® 5970				45						70						95		
Mapico® Tan 10A					45						72						100	
Barium Sulfate, Huberbrite® 10						60						85						120
Post cure, 16 hours @ 232°C (450°F)																		
Tensile, psi	2360	2620	1735	1405	2200	1865	2280	2630	1870	1530	2465	1850	2265	2100	1920	1575	2320	1575
Elongation, %	240	305	205	280	300	350	180	300	160	220	310	300	165	215	125	150	260	225
Modulus 100%, psi	810	510	1130	615	480	450	1220	655	1465	970	860	585	1405	1075	1615	1265	1125	810
Hardness, Type A, pts	72	69	73	70	69	69	80	79	81	78	79	79	88	93	86	85	89	86
Air aging, 70 hours @ 270°C (518°F), ASTM D573																		
Tensile, % change	-47	-20	-26	8	-32	-24	-49	-29	-29	3	-45	-17	-43	-37	-28	3	-52	-17
Elongation, % change	4	-16	15	-25	8	-9	14	-32	16	-41	-8	-3	12	-33	4	-33	-10	-9
Hardness, Type A, pts change	-3	6	-2	2	0	0	1	2	-1	4	5	1	1	2	2	3	5	0
Compression Set, 70 hours @ 200°C (392°F), ASTM D1414																		
Compression Set, %, 0.139" O-ring	18	27	17	21	22	18	Not Run						27	53	22	25	38	27
Specific Gravity, ASTM D297																		
	2.03	2.62	2.10	2.07	2.31	2.36	2.11	2.91	2.20	2.14	2.55	2.53	2.17	3.20	2.28	2.20	2.74	2.70

Note: MgO, $Ca(OH)_2$ and N990 in phr

3M™ Dyneon™ Fluoroelastomer FE 5642 formulated to various durometers with various non-black fillers.

Test Formulation, PHR	N990 MT Black	NYAD® 400	Celite® 350	Min-U-Sil® 5µ	Aerosil® R972	Mistron® CB (Cyprubond)	Austin Black®	TiO_2 A-110 Sakai Chemical	$BaSO_4$ Huberbrite® 10	Mapico® Tan 10A	Albacar® 5970 Cal $CaCO_3$	Zinc Oxide USP #1
FE 5642	100	100	100	100	100	100	100	100	100	100	100	100
MgO, Elastomag® 170	3	3	3	3	3	3	3	3	3	3	3	3
$Ca(OH)_2$ HP-XL, Hallstar®	6	6	6	6	6	6	6	6	6	6	6	6
Filler Level	30	45	20	35	10	25	25	60	65	50	45	80
Total Parts	**139**	**154**	**129**	**144**	**119**	**134**	**134**	**169**	**174**	**159**	**154**	**189**
MDR, 6 minutes @ 177°C (350°F)												
ML, in-lbs	1.4	1.5	1.6	1.5	1.1	1.3	1.6	2.0	1.8	1.6	2.3	1.9
MH, in-lbs	17.5	15.6	14.5	14.4	8.5	9.8	11.8	18.4	14.0	14.6	18.0	12.0
ts2, minutes	1.7	1.3	1.8	1.3	2.1	4.4	3.2	0.9	1.1	1.6	1.0	1.3
t'50, Minutes	2.2	1.5	2.1	1.6	2.5	6.1	5.3	1.3	1.4	2.0	1.2	1.6
t'90, Minutes	3.5	2.4	3.3	2.4	3.6	9.8	9.6	2.3	2.2	3.3	1.9	2.9
Press Cure, 10 minutes @ 177°C (350°F)												
Tensile, psi	1674	1030	1742	1299	2542	2203	1198	1717	1490	2306	1722	2290
Elongation, %	420	311	436	360	602	462	621	482	438	520	416	593
Modulus 50%, psi	283	303	286	262	182	521	235	355	241	301	288	267
Modulus 100%, psi	462	470	506	432	242	980	324	486	374	511	543	393
Hardness, Type A, pts	72	70	69	69	60	73	67	78	68	70	72	71
Post Cure, 16 hours @ 232°C (450°F)												
Tensile, psi	2356	1845	2395	2614	3014	2504	1824	2477	2136	2756	2552	2480
Elongation, %	285	211	255	250	434	277	351	280	321	256	234	286
Modulus 50%, psi	315	365	354	344	205	621	263	502	276	352	371	339
Modulus 100%, psi	561	882	783	763	292	1235	442	745	505	720	800	571
Hardness, Type A, pts	73	72	71	71	64	73	70	85	69	74	74	74
Specific Gravity	1.8	2.1	1.9	2.0	1.9	2.0	2.1	2.3	2.3	2.4	2.0	2.6
Air Aging, 70 hours @ 270°C (518°F), ASTM D573												
Tensile, % change	-30	-34	-37	-45	-33	-34	-29	Too Brittle	-29	-49	-30	-12
Elongation, % change	31	15	65	46	66	51	-3		47	45	-25	37
Modulus 50, % change	-20	-21	-26	-30	-8	-22	-23		-22	-6	44	3
Modulus 100%, % change	-35	-35	-44	-47	-17	-33	-29		-35	-30	26	-9
Hardness, Type A, pts	1	1	-1	-1	1	1	-2		1	3	8	6
Compression Set, 70 hours @ 200°C (392°F), ASTM D1414												
Compression Set, %, 0.139" O-ring	18	17	20	17	31	24	16	29	19	25	21	30

Note: MgO, $Ca(OH)_2$ and N990 in phr

Before specifying a low durometer compound, you might consider one with a higher durometer rating that offers similar performance characteristics. For more information on the effect of durometer ratings in specific applications, contact your 3M Technical Representative.

Low Durometer Compounds

A Type A durometer rating between 45 and 60 is considered low for fluoroelastomers.

Some of the interest in low durometer fluoroelastomers is a result of upgrading from silicones to fluoroelastomer. In doing this, consideration should be given to the fact that some compromises are made in properties as the fluoroelastomer durometer is reduced. These compromises include:

Lower physical properties – In general, the lower the durometer below 55, the lower the properties. However, the differences are not always great.

Less compression set resistance – The result of lower crosslink densities and process aids/plasticizers.

Slower cures – This can be increased using small amounts of accelerator, such as 3M™ Dynamar™ FC 2172 or 3M™ Dynamar™ FX 5166.

Higher cost – In comparing compounds above the 45-55 durometer range, the higher level of fillers required at 55 durometer may be partially offset by diluting with lower cost raw gum. In 45 durometer stocks, plasticizers can aid processability and also help keep costs down.

Guidelines

The following guidelines can be used to produce low durometer fluoroelastomer compounds.

1. Use high crosslink density (FE 5640Q, FC 2174, FC 2152, FE 5641Q) incorporated cure polymers to blend 50/50 with low to medium viscosity raw gum polymers (FC 2145, FC 2230).
2. Use medium viscosity (FE 5640Q, FC 2174, FE 5641Q, FC 2230) polymers for compression molding. Lower viscosities may be used for transfer or injection molding.
3. Use 1-2 phr FC 2172 if necessary to accelerate the cure.
4. Use 3 phr each MgO and $Ca(OH)_2$.
5. Use 1-3 phr filler.
6. Use 0.5 to 1 phr Carnauba wax if release or tearing during molding is a problem. Mix well or blistering may occur.

Low Durometer Compounds

Outlined below are typical compounds of this type:

	A	B
3M™ Dyneon™ FC 2174	100	50
3M™ Dyneon™ FC 2145		50
3M™ Dyneon™ FC 2172	–	1
MT Black (N990)	3	2
$Ca(OH)_2$ HP-XL, Hallstar®	6	3
MgO (Maglite® D)	3	3
Carnauba Wax	0.5	0.5

Typical Rheological Properties

Cure ODR, 177°C (350°F)		
Minimum	11.0	9.0
Time to 1 pt. Rise	4.6	4.2
Time to 30 in-lb torque	6.2	6.1
Torque at 12 minutes	77	41

Typical Physical Properties

Press Cure, 10 minutes @ 177°C (350°F)		
Tensile, psi	1000	1000
Elongation, %	275	480
Modulus 100%, psi	258	163
Hardness, Type A, pts	55	47
Post Cure, 16 hours @ 232°C (450°F)		
Tensile, psi	1450	1300
Elongation, %	250	430
Modulus 100%, psi	265	148
Hardness, Type A, pts	55	47
Tear Strength, Die C ppi	77	91
Heat Aging, 70 hours @ 270°C (518°F), ASTM D573		
Tensile, psi	1150	840
Elongation, %	255	420
Modulus 100%, psi	229	115
Hardness, Type A, pts	53	45
Compression Set, %, 0.139" O-ring, ASTM D1414		
22 hours @ 200°C (392°F)	7	12
70 hours @ 200°C (392°F)	15	25
70 hours @ 149°C (300°F)	1	8

Note: MgO, $Ca(OH)_2$ and N990 in phr

Cure Systems

Diamine – Added by molder

Dicinnamylidene hexane diamine, Diak® No. 3
Hexamethylene diamine carbamate, Diak® No. 1

Dihydroxy – Incorporated by manufacturer in most cases

Hexafluoropropylidene diphenol (Bisphenol AF; crosslinker)/ Triphenylbenzylphosphonium chloride (accelerator)

Peroxide – Added by molder

2,5-dimethyl-2,5 Di(t-butyl-peroxy) hexane/ Triallyl Isocyanurate (coagent)

Each cure system has advantages and disadvantages.

Effects of Cure Systems

Typical Properties of Vulcanized Compound.

Compound Formulations, phr	Diamine A	Dihydroxy B	Peroxide C	Peroxide D
3M™ Dyneon™ FC 2260	100	100	100	100
MT Black (N990)	30	30	30	30
MgO, Maglite® Y	10	–	–	–
MgO, Elastomag® 170	–	3	–	–
$Ca(OH)_2$ HP-XL, Hallstar®	–	6	–	3
Varox® DBPH-50 HP	–	–	2.5	2.5
TAIC	–	–	3	3
Diamine, Diak® No. 3	2.5	–	–	–
Dihydroxy	–	1.8	–	–
Accelerator	–	0.6	–	–
ZnO	–	–	5.0	–

Original Properties

Mooney Scorch, 30 minutes, MS250, ASTM D1646				
Minimum Viscosity, MU	90.5	66.7	48.1	53.9
t_3, minutes	5.61	11.00	>30	>30
t_{10}, minutes	7.22	16.44	>30	>30
t_{18}, minutes	8.71	19.60	>30	>30
MDR, 12 minutes @ 177°C (350°F), 0.5°arc, ASTM D5289				
Minimum Torque, ML, in-lb	2.7	2.8	2.2	2.3
Maximum Torque, ML, in-lb	18.0	20.7	12.6	14.6
ts2, minutes	1.8	1.3	1.0	0.9
t'50, minutes	4.4	2.2	1.6	1.6
t'90, minutes	9.2	3.9	4.0	4.6
Press Cure, 15 minutes @ 177°C (350°F)				
Tensile, psi	1440	1295	1605	1790
Elongation, %	220	235	295	270
Modulus 100%, psi	660	650	450	505
Hardness, Type A, pts	71	74	69	71
Post Cure, 16 hours @ 232°C (450°F)				
Tensile, psi	1960	1980	2185	2230
Elongation, %	160	200	270	245
Modulus 100%, psi	915	890	570	595
Hardness, Type A, pts	75	74	72	72
Compression Set, 70 hours @ 200°C (392°F), ASTM D1414				
Compression Set, %, 0.139" O-ring	53	17	34	32

Note: MgO, $Ca(OH)_2$ and N990 in phr

Processing Aids

Type	Example	Effect	Recommended Loading
Waxes	Carnauba Wax	Improved release, good flow/surface, most common	0.5-2.0 phr
Plasticizers	DBS/DOP	Lowers viscosity, increased shrinkage	1.0-3.0 phr
Stearates	Zinc Stearate, Aflux 54	Improved release	0.5-3.0 phr
Polyethylene	AC 1702	Improved release and flow	0.5-3.0 phr
Organosilicones	WS 280	Improved release, good flow/surface	0.5-2.0 phr
Fatty Acid Esters	WB 222, HT 290	Improved release, good flow/surface	0.5-2.0 phr
Siloxane Elastomer	3M™ Dynamar™ RA 5300	Improved release, good flow/surface, minimized impact on physical properties and shrinkage	0.5-1.0 phr

Pigments

Color	Common Trade Names
Red	Harwick Stan-tone® D-2000, D-2503 Bayferrox® 160M
Yellow	Harwick Stan-tone® DC-445, Bayferrox® 1420M
Green	Harwick Stan-tone® D-5005; Akrochem® 414
Blue	Harwick Stan-tone® D-4006, D-4900, Akrochem® 626
Brown	Harwick Stan-tone® D-8300, D-8301
Orange	Harwick Stan-tone® D-1504, Akrochem® 870

Key Considerations for Pigments

- Inorganic based pigments are preferred due to the high temperatures needed to post cure fluoroelastomers. Organic based pigments tend to degrade at high temperatures leading to inconsistent colors and color variation.
- Use with non-black fillers ZnS or ZnO, depending on filler choice the final color will vary.
- Use ZnS, ZnO or TiO_2 for brighter, more vibrant, colors.
- Minimize use – too much negatively affects shrinkage, physical properties, and/or adhesion.

Blending Fluorocarbon Elastomers

The blending or dilution of an incorporated cure polymer with that of a raw gum polymer will change certain physical properties and flow characteristics. The most common reasons for blending a raw gum polymer with an incorporated cure gum would be to:

- Increase elongation
- Lower modulus
- Improve tear strength
- Increase or lower compound viscosity (depending on which polymers are involved)
- Adjust level of curatives

Blending 3M™ Dyneon™ Incorporated Cure Gums with Raw Gum

Compound Formulations, phr	A	B	C	D	E	F	G
FE 5640Q	100	80	60	80	60	80	60
FC 2145	–	20	40	–	–	–	–
FC 2230	–	–	–	20	40	–	–
FC 2178	–	–	–	–	–	20	40
MT Black (N990)	30	30	30	30	30	30	30
$Ca(OH)_2$ HP-XL, Hallstar®	6	6	6	6	6	6	6
MgO, Elastomag® 170	3	3	3	3	3	3	3
MDR, 12 minutes @ 177°C (350°F)							
ML, in-lb	2.0	1.0	1.0	1.0	1.0	2.0	3.0
MH, in-lb	25.0	18.0	11.0	18.0	11.0	18.0	14.0
ts2, minutes	2.5	2.5	2.8	2.3	2.5	2.1	1.9
t'50, minutes	3.4	3.4	4.0	3.1	3.5	2.9	2.8
t'90, minutes	4.7	4.8	6.8	4.2	5.7	3.9	4.4
Press Cure, 10 minutes @ 177°C (350°F)							
Tensile, psi	1425	1415	1360	1415	1420	1550	1580
Elongation, %	280	380	495	310	515	350	505
Modulus 100%, psi	610	440	305	485	300	475	355
Hardness, Type A, pts	76	72	69	72	68	71	69
Press Cure Tear Die C							
Tear, ppi	117	139	145	130	145	133	148
Post Cure, 16 hours @ 232°C (450°F)							
Tensile, psi	2080	2180	2055	2110	2105	2160	2305
Elongation, %	215	275	350	250	340	255	330
Modulus 100%, psi	770	605	370	560	365	585	425
Hardness, Type A, pts	77	75	70	70	71	72	71
Post Cure Tear Die C							
Tear, ppi	136	142	153	142	155	151	160
Heat Aging, 70 hours @ 270°C (518°F), ASTM D573							
Tensile, psi	2045	1900	1770	1745	1710	2035	1820
Elongation, %	205	250	370	240	370	260	335
Modulus 100%, psi	705	510	360	470	320	515	365
Hardness, Type A, pts	77	75	70	74	72	73	71
Compression Set, 70 hours @ Room Temperature, ASTM D1414							
Compression Set, %, 0.139" O-ring	9	16	33	16	31	14	26
Compression Set, 70 hours @ 200°C (392°F), ASTM D1414							
Compression Set, %, 0.139" O-ring	15	18	32	17	28	16	25

Note: MgO, $Ca(OH)_2$ and N990 in phr

Blending 3M™ Dyneon™ Peroxide Curable Fluoroelastomers with Synthetic Elastomers

Peroxide Curable Fluorelastomers can be blended with:

- Fluorosilicones
- Nitriles
- EPDM
- Silicones
- Epichlorohydrin

Blending Fluorocarbon/Fluorosilicone Elastomers

Compound Formulations, phr	A (80/20)	B (60/40)	C (60/40)
3M™ Dyneon™ FC 2260	80	60	60
Fluorosilicone (Dow Corning® LS-420)	20	40	40
Iron Oxide (Bayferrox® 110M)	–	–	2.5
Silicon Dioxide (Aerosil® R-972)	20	20	15
Fumed Silica (Cab-O-Sil® HS-5)	6.5	6.5	–
$Ca(OH)_2$ HP-XL, Hallstar®	3	3	–
Peroxide (Luperco 101 XL)	1.3	1.3	1.4
TAIC (Diak® No. 7)	1.1	1.2	1.6
Typical Rheological Properties – 12 minutes ODR @ 177°C (350°F), 100 CPM, 3° Arc			
Minimum torque, in-lb	39	23	12
Time to 1 in-lb rise, minutes	3.0	2.2	2.7
Time to 80 in-lb torque, minutes	4.2	4.2	8.1
Maximum torque, 12 minutes, in-lb	95	81	53
Typical Physical Properties Cure, 15 minutes @ 177°C (350°F) Post Cure, 16 hours @ 200°C (392°F)			
Specific Gravity	1.73	1.66	1.63
Tensile, psi	2160	1580	1390
Elongation, %	290	235	330
Modulus 100%, psi	740	660	320
Hardness, Type A, pts	83	79	63
Compression Set, 0.139' O-ring, %, ASTM D1414			
70 hours @ 149°C (300°F)	28	25	18
70 hours @ 200°C (392°F)	50	50	54
Low Temperature Properties			
TR_{10}, °C (°F)	-21 (-6)	-24 (-11)	-24 (-11)
Brittleness Point, °C (°F)	-30 (-22)	-43 (-45)	-53 (-63)
Torsional Modulus, psi × 10^4			
-20°C (-4°F)	1.6	0.4	0.3
-30°C (-22°F)	4.9	1.7	1.3
-40°C (-40°F)	7.6	2.7	2.1
-50°C (-58°F)	9.7	3.0	2.7
-60°C (-76°F)	11.0	4.8	3.6

Note: MgO, $Ca(OH)_2$ and N990 in phr

Effects of Crosslink Density on Bisphenol Cure Fluoroelastomer

Typical Properties of Vulcanized Compound

Compound Formulations, phr	Low	Medium	High
3M™ Dyneon™ FC 2230	100	100	100
Bisphenol-AF	0.95	1.26	1.89
FX 5166	0.21	0.29	0.43
$Ca(OH)_2$ HP-XL, HallStar®	6	6	6
MgO, Elastomag® 170	3	3	3
MT Black (N990)	30	30	30
Total Parts	**140.2**	**140.6**	**141.3**
MDR, 12 minutes @ 177°C (350°F), 0.5°arc			
ML, in-lb	1.2	1.2	1.2
MH, in-lb	11.0	14.9	22.9
ts2, minutes	1.4	1.2	1.2
t'50, minutes	1.9	1.5	1.5
t'90, minutes	2.9	2.2	2.1
Tand @ML	0.96	0.99	0.99
Tand @MH	0.11	0.07	0.04
Press Cure, 10 minutes @ 177°C (350°F) Post Cure, 16 hours @ 232°C (450°F)			
Tensile, psi	2046	2412	2448
Elongation, %	310	264	194
Modulus 100%, psi	447	597	911
Hardness, Type A, pts	68	71	77
Compression Set, 70 hours @ 200°C (392°F), ASTM D395 (buttons)			
Compression Set, %	27	21	20

Increasing the crosslink density while maintaining the cure rate typically leads to the following:

- An increase in MH
- An increase in modulus @100% strain
- A decrease in elongation
- An increase in hardness
- Lower compression set

Note: MgO, $Ca(OH)_2$ and N990 in phr

- FC 2260 and FLS 2650 products require ZnO to achieve ultimate cure state.
- FPO products can be cured with or without ZnO depending on application needs.
- ZnO promotes property retention after heat aging, however, will negatively affect volume swell with water, acids and steam.
- Addition of ZnO may increase hardness, decrease elongation, and increase modulus.

Effects of Zinc Oxide on Various Peroxide Cure Fluoroelastomers

3M™ Dyneon™ Peroxide Cure FKM	FC 2260		FPO 3520		FPO 3630		FPO 3740		FLS 2650	
	66%		66%		68%		69.5%		70%	
	Dipolymer		Terpolymer		Terpolymer		Terpolymer		Terpolymer	
3M™ Dyneon™ Peroxide Cure FKM	100	100	100	100	100	100	100	100	100	100
TAIC 100%	3	3	3	3	3	3	3	3	3	3
DBPH 100%	2	2	2	2	2	2	2	2	2	2
ZnO		3		3		3		3		3
MT Black (N990)	30	30	30	30	30	30	30	30	30	30
MDR, 6 minutes @ 177°C (350°F)										
ML, in-lb	2.2	2.3	0.7	0.7	0.8	0.8	0.7	0.7	1.5	1.6
MH, in-lb	4.7	12.2	13.0	17.2	16.1	18.2	15.2	18.1	3.8	11.5
ts2, minutes	2.5	0.6	0.5	0.5	0.4	0.4	0.5	0.5	2.5	0.6
t'50, minutes	1.1	0.9	0.7	0.6	0.6	0.6	0.6	0.7	0.9	0.9
t'90, minutes	3.6	2.3	1.8	1.5	1.4	1.3	1.1	1.7	2.6	2.2
Press Cure, 10 minutes @ 177°C (350°F)										
Tensile, psi	NA	1474	2300	2075	2105	2320	2225	2360	NA	1460
Elongation, %		325	315	215	265	230	250	235		320
Modulus 100%, psi		325	360	625	520	685	575	649		410
Hardness, Type A, pts		66	61	66	68	70	66	67		68
Post Cure, 16 hours @ 232°C (450°F)										
Tensile, psi	NA	2930	3040	3500	3270	3450	3150	3530	NA	2675
Elongation, %		290	245	195	260	200	240	210		215
Modulus 100%, psi		600	720	1150	920	1120	710	960		910
Hardness, Type A, pts		72	67	72	72	75	71	72		74
Compression Set, % 70 hours @ 200°C (392°F), 0.139' O-ring, ASTM 1414										
Press Cure	NA	59	47	50	40	47	51	48	NA	67
Post Cure		41	46	50	42	38	49	40		44
Acetic Acid Immersion - 1.0M Solution @ 100°C, %Volume Swell										
48 hours	NA	47	0.1	27	-0.1	23	-0.3	21	NA	34
168 hours		73	1.1	54	0.8	53	0.6	48		75
504 hours		59	1.3	71	1.2	81	1.0	68		115

Note: MgO, $Ca(OH)_2$ and N990 in phr

Increasing the level of peroxide, Varox DBPH-50, typically increases the cure speed.

Increasing levels of TAIC:

- Increases MH
- Increases modulus @ 100% strain
- Increases tensile strength
- Lowers elongation and compression set

Effects on Varying Levels of Co-Agents on Peroxide Cure Fluoroelastomer FPO 3730

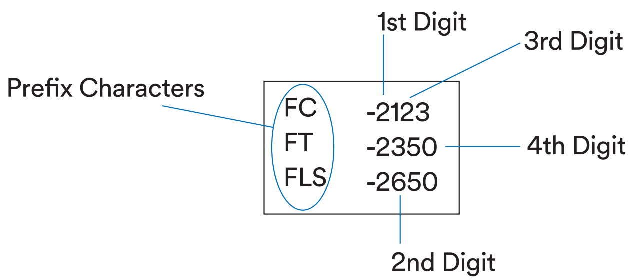
Typical Properties of Vulcanized Compound

	TAIC Constant				DBPH-50 Constant			
Compound Formulations, phr	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**
Dyneon FPO 3730	100	100	100	100	100	100	100	100
MT Black (N990)	30	30	30	30	30	30	30	30
TAIC 100%	2	2	2	2	1.0	1.5	2.0	2.5
Varox DBPH-50	1	2	3	4	1.5	1.5	1.5	1.5
ZnO	3	3	3	3	3	3	3	3
Mooney Scorch @ 121°C (250°F)								
Minimum Viscosity, MU	not tested	26.8	25.8	not tested	30	29.7	29.4	28.5
t_3, minutes	not tested	>30	22.8	not tested	>30	>30	>30	>30
t_{10}, minutes	not tested	>30	25.6	not tested	>30	>30	>30	>30
MDR, 0.5° Arc 12 minutes @ 177°C (350°F)								
ML, in-lbs	0.9	1.0	1.0	1.0	0.9	0.9	0.8	0.8
MH, in-lbs	17.4	17.7	17.0	16.7	14.0	15.8	17.0	18.4
ts2, minutes	0.7	0.5	0.5	0.4	0.6	0.6	0.6	0.6
t'50, minutes	1.1	0.7	0.6	0.6	0.8	0.9	0.9	0.9
t'90, minutes	2.9	1.8	1.4	1.1	2.3	2.2	2.3	2.4
Press Cure, 10 minutes @ 177°C (350°F)								
Tensile, psi	2218	2329	2434	2412	1664	1912	2185	2414
Elongation, %	249	236	231	231	312	277	277	249
Modulus 100%, psi	696	637	633	608	396	487	474	610
Hardness, Type A, pts	67	68	65	65	65	66	66	68
Specific Gravity	1.90	1.89	1.88	1.88	1.89	1.89	1.89	1.88
Post Cure, 16 hours @ 232°C (450°F)								
Tensile, psi	3449	3557	3548	3368	3228	3484	3423	3563
Elongation, %	227	201	199	187	251	223	218	207
Modulus 100%, psi	912	1068	1033	1096	692	852	916	1125
Hardness, Type A	71	71	71	71	68	69	70	71
Specific Gravity	1.90	1.90	1.90	1.90	1.90	1.91	1.90	1.90
Heat Age, 70 hours @ 250°C (482°F)								
Tensile, psi	3520	3552	3452	3527	3349	3467	3432	3570
Elongation, %	260	252	238	231	272	240	235	231
Modulus 100%, psi	720	764	785	928	737	838	943	964
Hardness, Type A, pts	70	70	70	71	68	69	70	71
Tensile Change %	2	0	-3	5	4	0	0	0
Elongation Change %	15	25	20	24	8	8	8	12
Modulus Change %	-21	-28	-24	-15	7	-2	3	-14
Hardness Change, pts	-1	0	-1	0	0	0	0	0
Compression Set %, 70 hours @ 200°C, 0.139' O-ring, ASTM 1414								
Press Cure	49	48	49	49	58	51	45	43
Post Cure	38	39	40	41	46	39	36	33

Note: MgO, $Ca(OH)_2$ and N990 in phr

Product Numbering System Codes

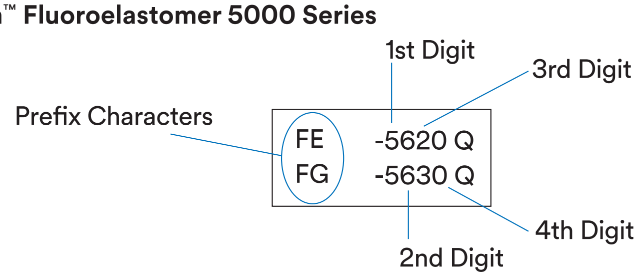
3M™ Dyneon™ Fluoroelastomer 2000 Series



Code	Property
Prefix Characters	Represents Fluorine Content (FC:65.6 to 67.9% F; FT: 68.0 to 69.9% FLS:70% F and above; FX: Precommercial product)
1st Digit	Always “2”
2nd Digit	Distinguishes cure type (even numbers – raw gum; odd numbers – incorporated cure)
3rd Digit	Mooney Viscosity range [ML1 + 10 @ 121° C] (1 = 0 to 19; 2=20 to 29; 3 = 30 to 39; 4 = 40 to 49; 5 = 50 to 59; 6 = 60 to 69; 7 = 70 to 79; 8 = 80 to 89; 9 = 90 to 99; 0 = 100 and above)
4th Digit	Sequential number: (0-9)

Notes: FC-2145, FC-2174, FC-2176, FC-2177, FC-2178, FC-2180, FC-2181, FC-2182 and FLS-2530 do not conform to this system. The products were introduced prior to the development of the current numbering system.

3M™ Dyneon™ Fluoroelastomer 5000 Series



Code	Property
Prefix Characters	"FE or "FG"
1st and 2nd Digit	Represents Fluorine Content (56 = 65.6 to 67.9% F; 57 = 68.0 to 69,9% F; 58 = 70.0% F and above)
3rd Digit	Mooney Viscosity range [ML1 + 10 @ 121° C] (1 = 0 to 19; 2=20 to 29; 3 = 30 to 39; 4 = 40 to 49; 5 = 50 to 59; 6 = 60 to 69; 7 = 70 to 79; 8 = 80 to 89; 9 = 90 to 99; 0 = 100 and above)
4th Digit	Sequential number: (0-9)

Compounding for O-Ring Applications

Simple parts such as O-rings can be made via injection or compression molding.

Polymer Selection:

- Polymer with high crosslink density (low compression set)
- Polymer must have good mold release characteristics

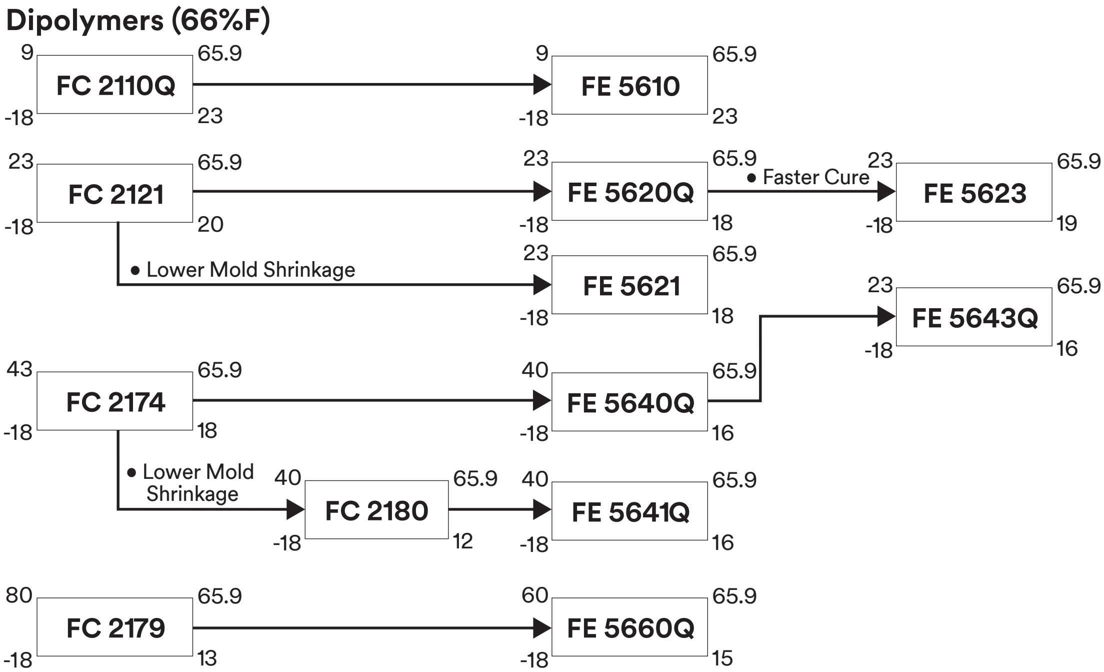
Filler Selection:

- Black or non-black
- MT Black and Austin Black® yield best compression set resistance

FE Products Compared to FC Products

- Cleaner running
- Better flow
- Excellent mold release
- Improved scorch resistance @ higher molding temperatures >200°C (392°F)
- More consistent cycle-to-cycle part dimensions

Suggested O-Ring Polymers:



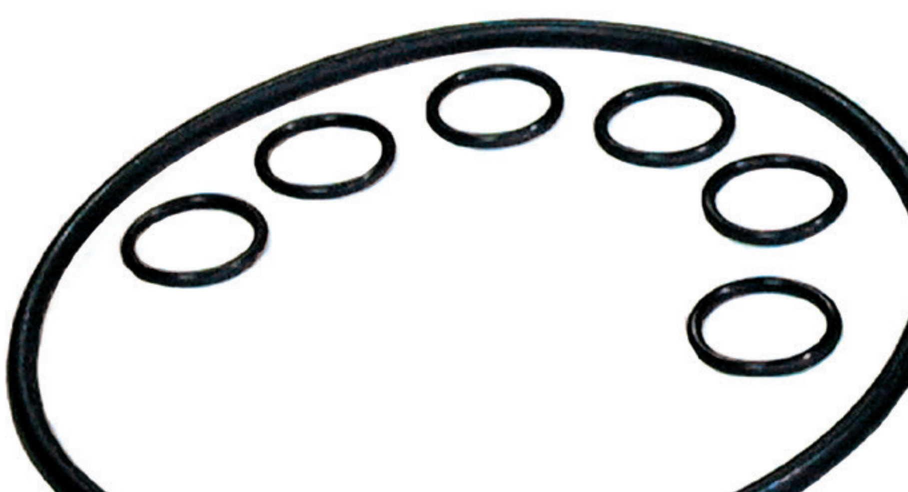
Product Legend

A. Mooney Viscosity (Mu) ML 1+10 @ 121°C
B. Fluorine Content (%)
C. TR10 (°C)
D. Compression Set 70 hours @ 200°C. ASTM 395, method B, 214 O-rings

All properties listed are based on a test compound containing:

Polymer	100
N990 Carbon Black	30
MgO	3
Ca(OH)	6

Data not for specification purposes.



Compounding for Molded Goods Applications

Molded goods are typically parts that require improved mold flow, mold release characteristics and a specific state of cure in the polymer. These parts commonly have complex shapes that may include undercuts or ribbed sections that cause demolding problems, i.e. tearing, if the proper compound is not used. Successful molding techniques consist of injection, transfer or compression molding.

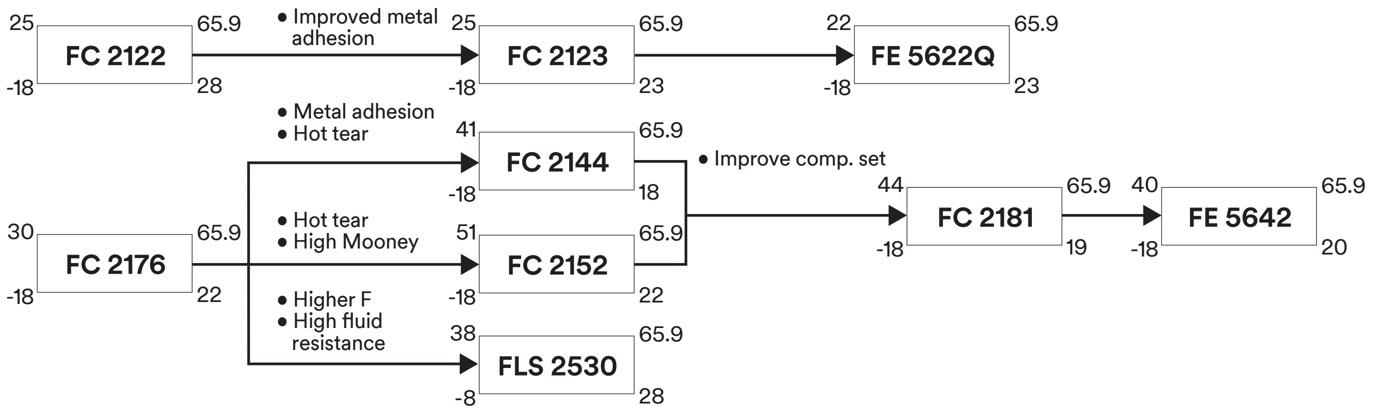
FE Products Compared to FC Products
- Cleaner running
- Better flow
- Better release
- Improved metal adhesion
- Improved scorch resistance

Polymer Selection:
- Polymer with low crosslink density (high elongation)
- Polymer must have good mold release characteristics

Filler Selection:
- Black or non-black
- SRF and HAF blacks yield the best hot tear strength
- High ratio of MgO to $Ca(OH)_2$ improves tear strength

Suspected Molded Goods Polymers:

Dipolymers (66%F)



Terpolymers (~70%F)

Product Legend

A. Mooney Viscosity (Mu) ML 1+10 @ 121°C
B. Fluorine Content (%)
C. TR10 (°C)
D. Compression Set 70 hours @ 200°C. ASTM 395, method B, 214 O-rings

All properties listed are based on a test compound containing:

Polymer	100
N990 Carbon Black	30
MgO	3
$Ca(OH)_2$	6

Data not for specification purposes.

Compounding for Extrusion Processes

Compound Considerations:

- Extrudate surface requirements
- Configuration of finished part
- Temperature capabilities of processing equipment (choose process aid that will be effective).

Typical Recommendations:

- Medium to low viscosity gum
- 1-2 phr process aid (DBS/Polyethylene/Wax /RA 5300 see Processing Aid Table on page 17)
- Barrel and die temperatures at 65 to 104°C (150 to 220°F)

FE Products Compared to FC Products

- Produce smooth extrudates without process aids
- Can be compounded to pass -40°C mandrel flex test

Suggested Extrusion Formulations	O-ring Cord	Hose/Tubing
3M™ Dyneon™ FE 5620Q, FE 5640Q	100	-
3M™ Dyneon™ FE 5620Q, FE 5640Q	-	100
Magnesium Oxide, MgO	3	3
Calcium Hydroxide, $Ca(OH)_2$	6	6
MT Black (N990)	10-50	-
SRF (N-762)	-	10-20
$BaSO_4$ or $CaCO_3$	-	20-40
Carnauba Wax	0.5-1.0	0.5-1.5
Poly AC 6A	-	0-0.5

Suggested Extrusion Grade Polymers:

Dipolymers (66%F)

23 **FC 2120** 65.9
-18 22

30 **FC 2182** 65.9
-18 22

Terpolymers (68%-71%F)

28 **FX 11818** 68.6
-14 34

23 **FT 2320** 69
-12 30

→
- 69.2% F
- Good permeation resistance to automotive fuels

36 **FE 5730** 69.2
-12 45

→
- 70.5% F
- Excellent permeation resistance to automotive fuels

33 **FE 5830Q** 70.5
-7 50

Product Legend

A. Mooney Viscosity (Mu) ML 1+10 @ 121°C
B. Fluorine Content (%)
C. TR10 (°C)
D. Compression Set 70 hours @ 200°C. ASTM 395, method B, 214 O-rings

All properties listed are based on a test compound containing:

Polymer	100
N990 Carbon Black	30
MgO	3
$Ca(OH)_2$	6

Data not for specification purposes.

A **FE 5620Q** B
C D

Compounding for Calendering Processes

Limiting Factors on Compound:

- Intended end-use of calendered sheet (i.e. die cut gaskets, fabric lamination, sheet stock)
- Temperature range of calender
- Thickness of stock

Suggested Calendering Formulations	PHR
Low/Medium Viscosity inc. cure polymer	100
Magnesium Oxide, MgO	3
Calcium Hydroxide, $Ca(OH)_2$	6
MT Black (N990)	10-60
Carnauba Wax	1
Polyethylene	1

Compounding for Metal Adhesion

Acid Acceptors:

- Higher levels of metal oxides, e.g. MgO, promotes better adhesion.
- Addition of 3-5 phr calcium oxide (CaO) improves adhesion.

Fillers:

- Black/non-black used in fluoroelastomers that do not adversely affect cure speed or aging properties.
- Process aids are only used if necessary.

Recommended Formulations	PHR
3M™ Dyneon™ FE 5642, FE 5622Q, FC 2123	100
Magnesium Oxide, MgO	3
Calcium Hydroxide, $Ca(OH)_2$	6
Calcium Oxide, CaO	0-5
MT Black (N990)	5-50

Higher durometers are harder to bond.

Safety and Toxicology

Before processing 3M™ Dyneon™ Fluoroelastomers, read and follow all precautions and directions for use contained in the product label and Safety Data Sheet (SDS). General handling precautions and directions for use include: (1) Store and use all Dyneon fluoroelastomers only in well ventilated areas; (2) Do not smoke in areas contaminated with dust from fluoroelastomers; (3) Avoid eye contact; (4) After handling Dyneon fluoroelastomers wash any contacted skin with soap and water.

Potential hazards, including evolution of toxic vapors, can occur during compounding or processing under excessively high temperature conditions. Appropriate local exhaust ventilation such as vapor extractor units should be installed above compounding or processing equipment. When compounding, be sure to read and follow all precautions and directions for use from other compound ingredient suppliers.

References

ASTM D297: Standard Test Methods for Rubber Products—Chemical Analysis

ASTM D412: Standard Test Methods for Vulcanized Rubber and Thermoplastic Elastomers—Tension

ASTM D573: Standard Test Method for Rubber—Deterioration in an Air Oven

ASTM D1329: Standard Test Method for Evaluating Rubber Property—Retraction at Lower Temperatures (TR Test)

ASTM D1414: Standard Test Methods for Rubber O-Rings

ASTM D1646: Standard Test Methods for Rubber—Viscosity, Stress Relaxation, and Pre-Vulcanization Characteristics (Mooney Viscometer)

ASTM D1765: Standard Classification System for Carbon Blacks Used in Rubber Products

ASTM D2240: Standard Test Method for Rubber Property—Durometer Hardness

ASTM D5289: Standard Test Method for Rubber Property—Vulcanization Using Rotorless Cure Meters

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