Viton™ Fluoroelastomers

Oven Post-Curing of Parts

Technical Information

Introduction

Compounds based on Viton™ fluoroelastomers are commonly subjected to a two-stage cure cycle, in order to optimize physical properties. Compression set and tensile strength are two of the properties most often improved by an oven post-cure cycle.

Initial curing is typically completed under pressure in a mold or autoclave to prevent porosity, splitting, or rupturing of the part, due to gas evolution from by-products of the cross-linking reactions. A secondary cure, called a post-cure, is accomplished in an air circulating oven. Typical post-cure cycles may be as short as 2 hr or as long as 24 hr. Post-cure oven temperatures typically range from a low of 150 °C (302 °F) to as high as 250 °C (482 °F), although temperatures between 200–232 °C (392–450 °F) are more common.

The optimal post-cure time and temperature will vary depending on the specific formulation, cure system type, and required performance in the application. The majority of improvement in properties is typically obtained after the first 2–4 hr in the oven, with smaller incremental improvements after longer post-cure times.

Post-Curing General Practices and Precautions

Parts to be post-cured should be de-flashed prior to post-curing, and care should be taken to ensure that all loose particles of flash are removed from the parts. Small pieces of flash falling onto the heating elements in the oven can be a source of fire.

Post-cure ovens must be equipped to provide adequate (fresh) airflow. Generally, a minimum of 0.14–0.20 m^3 (5.0–7.0 ft^3) of air per minute should be introduced on a continuous basis into an oven having interior dimensions of approximately 0.23 m^3 (8 ft^3).

Parts to be post-cured must be placed evenly throughout the oven. The parts must not be piled too deeply, thus preventing adequate air circulation around the parts.

Adequate airflow around the individual parts is critical, not only to obtain consistent physical properties within a given batch of parts, but also to help prevent oven fires.

High levels of hydrocarbon process aids, such as carnauba wax, or low molecular weight polyethylene in fluoroelastomer compounds can be volatilized out of the compounds during the oven post-cure cycle and condense or collect on the inside of the oven venting pipe. This can increase the likelihood of an oven fire. Post-cure oven temperatures should also be monitored and verified. It is critical that an even temperature be maintained throughout the entire oven, and temperature differences between the center of the oven and any corner area not exceed 5° C (10 °F). Regular periodic inspection and maintenance of post-cure ovens is suggested.

Fluoroelastomer parts should not be placed in a post-cure oven with other parts made from different elastomers. In particular, parts made with silicone rubber should not be post-cured with a fluoroelastomer. Chemical interactions between silicone rubber and the small amounts of hydrogen fluoride generated during the post-curing of the fluoroelastomer compound can damage or destroy parts.

Please refer to the "Handling Precautions for Viton™ and Related Chemicals" technical bulletin for additional important information on potential hazards and best practices for handling, processing, curing, and post-curing Viton™ fluoroelastomer parts.

Large Parts

Molded parts having cross-sectional thicknesses in excess of 5 mm (0.20 in) should be "step" post-cured. A suggested "step" post-cure cycle would start at 90 °C (194 °F) for 2–4 hr. The oven temperature can then be increased in increments of 25–40 °C (45–72 °F) each hour, until the desired final temperature is reached. The remaining time can be run at the final temperature. The "step" post-cure cycle is critical in particular for large parts utilizing a bisphenol AF (BpAF)-based curing system to allow generated by-product moisture from the cross-linking reaction to gradually volatilize.

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Bonded Parts

Parts of Viton™ fluoroelastomer bonded to substrates, such as metal, polyamide resins, and other elastomers, require additional considerations. Parts bonded to metal inserts and polyamide resins are typically post-cured at temperatures no higher than 200 °C (392 °F), in order to prevent degradation of the primer and subsequent loss of the bond. Some applications do not require post-curing for part performance. In the case of fuel hose, for example, a post-cure may be detrimental to the part, because other layers in the hose construction, such as NBR and ECO, are not sufficiently resistant to allow a high temperature post-cure.

Effect of Post-Cure Time and Oven Temperature on Properties

Formulations

Oven post-cure cycles are known to have significant effects on properties in formulations utilizing BpAF curing systems; but, effects are also seen in formulations utilizing peroxide curing systems. Formulations of each were tested to quantify post-cure effects at oven temperatures of 200 °C and 232 °C (392 °F and 450 °F) for up to 24 hr exposure (Table 1).

Three BpAF-cured formulations based upon Viton™ A-401C fluoroelastomer were evaluated. Formulation 1 contains a standard metal oxide system without process aids. Formulation 2 includes a VPA No. 2 process aid. Formulation 3 uses a high magnesium oxide system (no calcium hydroxide) with no process aids.

Three peroxide-cured formulations based upon Viton™ GF-600S fluoroelastomer were also evaluated. Formulation 4 is a standard peroxide and coagent-cured formulation containing no process aids and a no-metal oxide (NMO) formulation. Formulation 5 includes a metal oxide, zinc oxide as a heat stabilizer, and is also without process aids. Formulation 6 is a NMO formulation and includes a process aid.

It should be noted that all of the test formulations in this study are reinforced with carbon black. Experience has shown that mineral-filled Viton™ fluoroelastomer formulations typically require longer post-cure cycles to obtain optimal properties.

Compression Set

The majority of improvement in compression set is obtained in the first 4 hr of post-curing at both 200 °C and 232 °C (392 °F and 450 °F) (Table 3). BpAF-cured formulations benefit from longer cure cycles at higher post-cure temperatures. However, peroxide-cured formulations reach their optimal compression set after 24 hr at 200 °C (392 °F) and 8 hr at 232 °C (450 °F). Longer post-cure cycles at 232 °C (450 °F) result in increased compression set results (Figures 1 and 2). The lowest compression set is obtained in formulations without process aids, regardless of cure system or post-cure cycle.

Tensile Strength

The majority of improvement in tensile strength is obtained in the first 4 hr of post-curing at 200 °C (392 °F) in peroxide-cured formulations, while BpAF-cured formulations see continual improvement out to 24 hr (Table 4, Figure 3). Post-curing at 232 °C (450 °F) provides the majority of improvement after 8 hr in both peroxide- and BpAF-cured formulations (Figure 4). Process aid addition appears detrimental only when post-curing BpAF-cured formulations at 200 °C (392 °F).

Additional Properties

Elongation, hardness, and modulus are also effected by post-cure cycles. The higher strain modulus (stress at 100% strain) is significantly affected. Large increases of M100 are observed in the longer post-cure cycles (Table 7), particularly in formulations containing process aids. The increase in low strain modulus (stress at 25% strain) due to post-cure conditions is somewhat less (Table 8). The change in hardness due to post-curing is relatively small with typically less than four Shore A points increase.

Figure 1. Compression Set After 200 °C (392 °F) Post-Cure

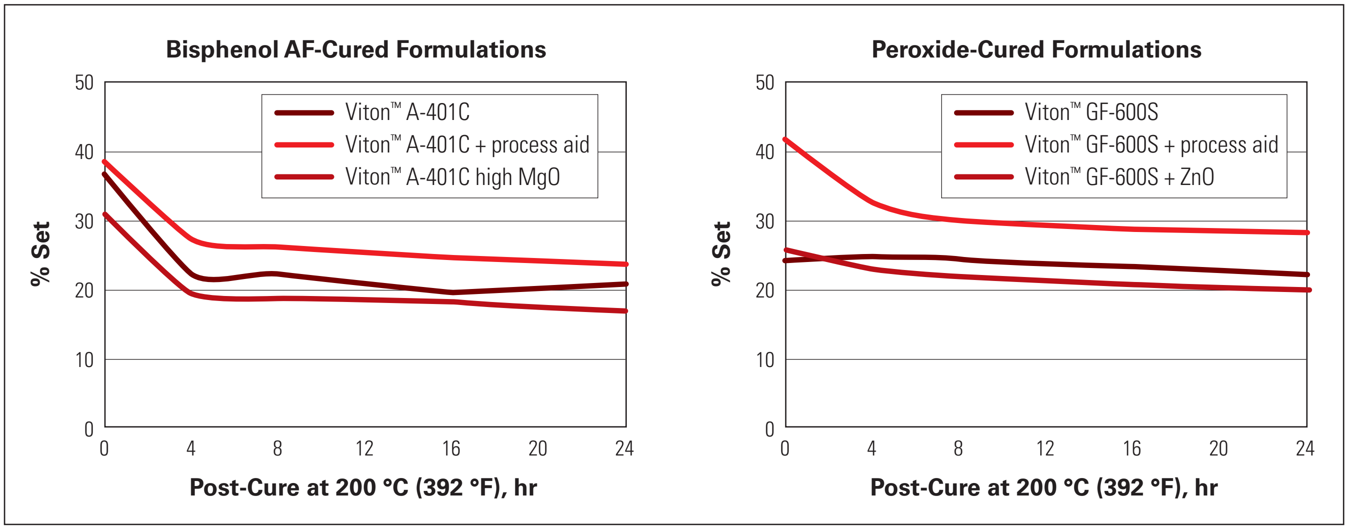

Figure 2. Compression Set After 232 °C (450 °F) Post-Cure

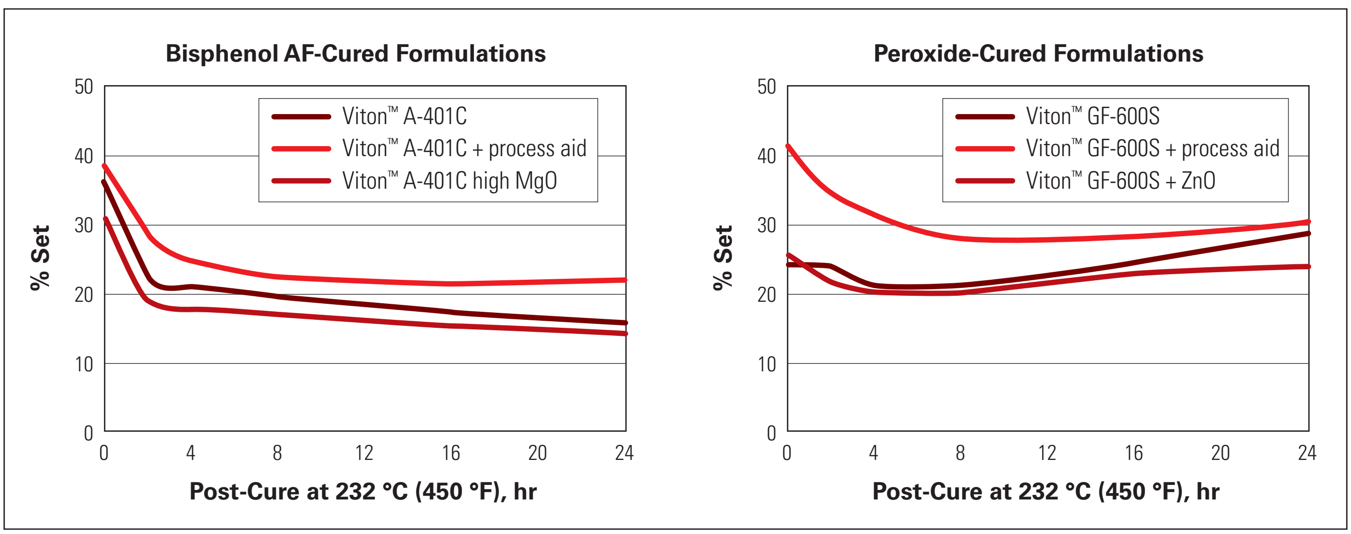

Figure 3. Tensile Strength After 200 °C (392 °F) Post-Cure

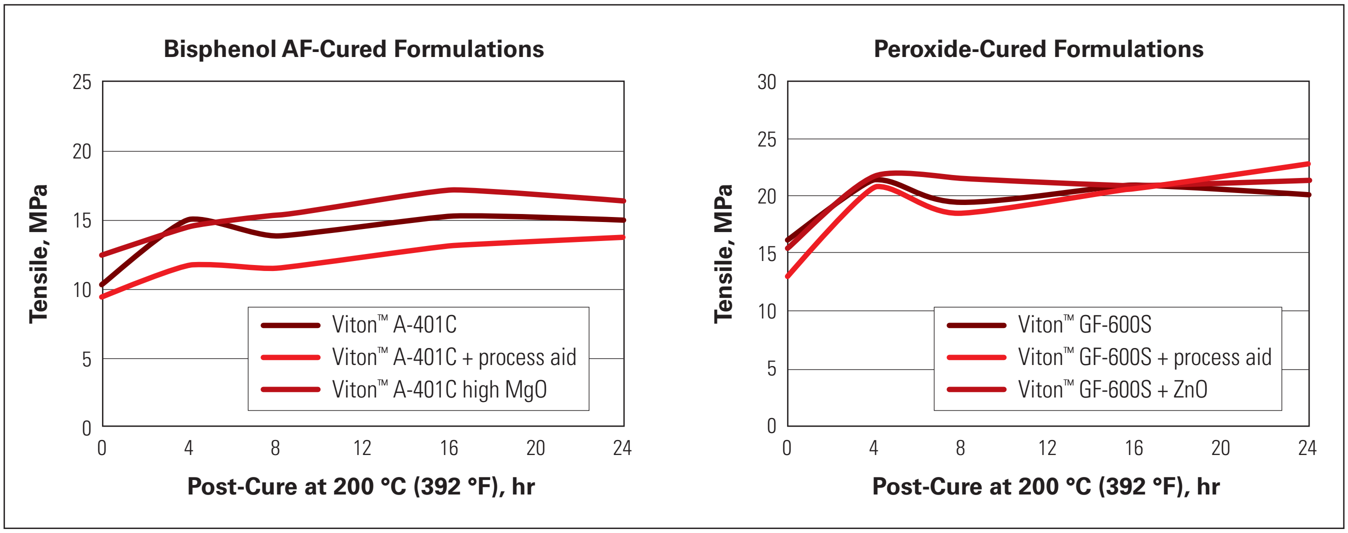

Figure 4. Tensile Strength After 232 °C (450 °F) Post-Cure

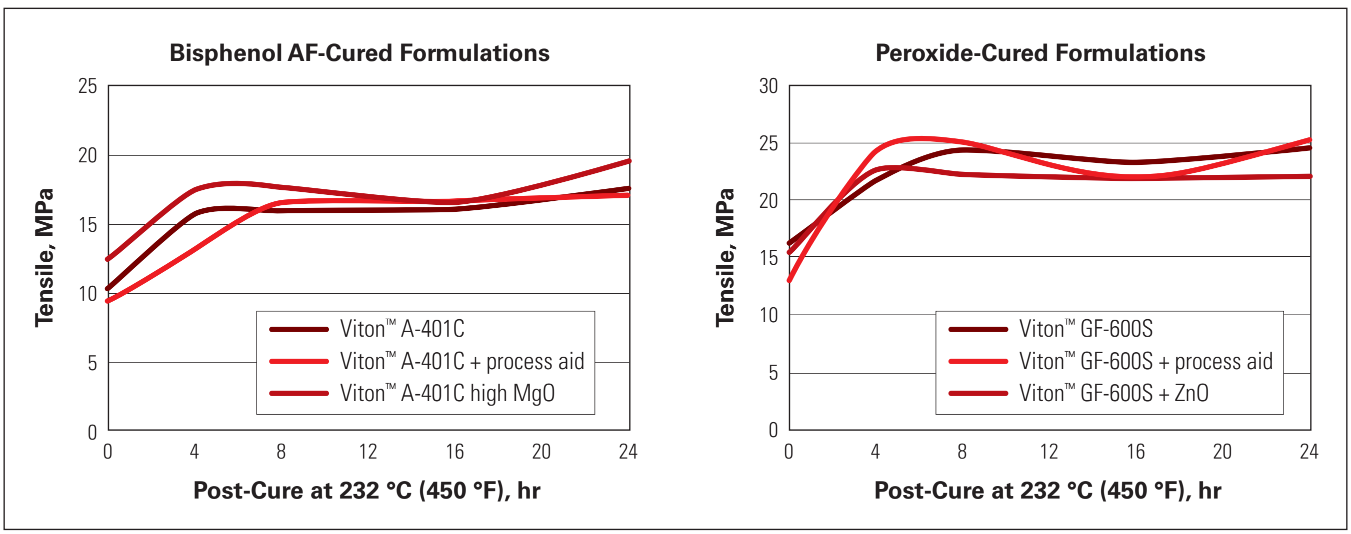

Table 1. Formulations

	Viton™ A-401C	Viton™ A-401C + Process Aid	Viton™ A-401C High MgO	Viton™ GF-600S	Viton™ GF-600S + Process Aid	Viton™ GF-600S + ZnO
Viton™ A-401C	100	100	100			
Viton™ GF-600S				100	100	100
N990 Carbon Black	30	30	30	30	30	30
Calcium Hydroxide	6	6				
MgO High Activity	3	3	9			
Zinc Oxide						3
Viton™ Curative No. 7 (VC-7)				2.5	2.5	2.5
Varox® DBPH-50				1.5	1.5	1.5
VPA No. 2		0.75				
Struktol® HT-290					0.75	
Total phr	139.00	139.75	139.00	134.00	134.75	137.00

Table 2. Compound Rheology

MDR 10 min, 177 °C (350 °F), 0.5° arc	Viton™ A-401C	Viton™ A-401C + Process Aid	Viton™ A-401C High MgO	Viton™ GF-600S	Viton™ GF-600S + Process Aid	Viton™ GF-600S + ZnO
ML (dNm)	2.0	2.0	2.1	2.2	1.9	2.2
MH (dNm)	33.1	33.7	29.7	33.9	29.7	33.8
ts2 (min)	0.9	0.9	1.1	0.4	0.4	0.4
t'50 (min)	1.2	1.2	2.2	0.8	0.8	0.7
t'90 (min)	1.8	2.0	3.8	1.6	1.4	1.3
t'95 (min)	2.2	2.5	5.0	2.1	1.9	1.7

Table 3. Compression Set, %—Aged 70 hr at 200 °C (392 °F)

Post-Cure Conditions		Viton™ Formulations					
Temperature, °C (°F)	Time, hr	A-401C	A-401C + Process Aid	A-401C High MgO	GF-600S	GF-600S + Process Aid	GF-600S + ZnO
No Post-Cure		37	39	31	24	41	26
200 (392)	4	22	28	20	25	33	23
200 (392)	8	22	26	19	24	30	22
200 (392)	16	20	25	18	23	29	21
200 (392)	24	21	24	17	22	28	20
232 (450)	4	21	25	18	21	32	20
232 (450)	8	20	23	17	21	28	20
232 (450)	16	18	22	15	25	28	23
232 (450)	24	16	22	14	29	30	24

Table 4. Tensile Strength, MPa

Post-Cure Conditions		Viton™ Formulations					
Temperature, °C (°F)	Time, hr	A-401C	A-401C + Process Aid	A-401C High MgO	GF-600S	GF-600S + Process Aid	GF-600S + ZnO
No Post-Cure		10.3	9.3	12.3	16.2	13.3	15.3
200 (392)	4	14.8	11.6	14.5	21.1	20.4	21.5
200 (392)	8	13.9	11.6	15.2	19.4	18.6	21.6
200 (392)	16	15.2	13.1	17.1	20.8	20.6	20.9
200 (392)	24	14.9	13.7	16.3	20.2	22.8	21.2
232 (450)	4	15.6	13.0	17.4	21.4	23.9	22.3
232 (450)	8	15.9	16.4	17.6	24.2	24.9	22.2
232 (450)	16	16.1	16.5	16.5	23.2	21.9	21.8
232 (450)	24	17.4	17.1	19.5	24.3	24.9	22.0

Table 5. Elongation, %

Post-Cure Conditions		Viton™ Formulations					
Temperature, °C (°F)	Time, hr	A-401C	A-401C + Process Aid	A-401C High MgO	GF-600S	GF-600S + Process Aid	GF-600S + ZnO
No Post-Cure		252	257	314	285	380	272
200 (392)	4	237	248	250	283	369	301
200 (392)	8	207	233	264	243	303	315
200 (392)	16	231	234	274	247	287	286
200 (392)	24	232	230	259	239	308	278
232 (450)	4	224	199	249	241	323	294
232 (450)	8	208	207	244	276	290	290
232 (450)	16	202	190	221	269	250	270
232 (450)	24	200	186	236	310	304	282

Table 6. Hardness, Shore A pts

Post-Cure Conditions		Viton™ Formulations					
Temperature, °C (°F)	Time, hr	A-401C	A-401C + Process Aid	A-401C High MgO	GF-600S	GF-600S + Process Aid	GF-600S + ZnO
No Post-Cure		74	74	71	71	70	72
200 (392)	4	75	75	73	74	75	75
200 (392)	8	76	76	73	74	75	75
200 (392)	16	76	77	71	75	77	75
200 (392)	24	75	76	73	75	77	75
232 (450)	4	77	76	72	74	77	75
232 (450)	8	77	77	72	74	78	75
232 (450)	16	76	79	74	75	77	76
232 (450)	24	77	78	73	73	75	76

Table 7. Stress at 100% Strain, MPa

Post-Cure Conditions		Viton™ Formulations					
Temperature, °C (°F)	Time, hr	A-401C	A-401C + Process Aid	A-401C High MgO	GF-600S	GF-600S + Process Aid	GF-600S + ZnO
No Post-Cure		4.86	4.68	4.33	4.68	3.48	4.52
200 (392)	4	6.13	5.20	4.81	5.88	4.70	5.56
200 (392)	8	6.01	5.41	4.82	6.20	5.11	5.58
200 (392)	16	6.39	5.78	5.32	6.27	5.78	5.91
200 (392)	24	6.32	5.96	5.18	6.17	6.36	5.89
232 (450)	4	6.34	6.07	5.16	6.28	5.55	5.59
232 (450)	8	6.77	7.14	5.57	6.66	6.31	5.99
232 (450)	16	7.03	7.66	5.83	6.54	7.08	6.29
232 (450)	24	7.50	7.97	5.65	6.35	6.56	5.97

Table 8. Stress at 25% Strain, MPa

Post-Cure Conditions		Viton™ Formulations					
Temperature, °C (°F)	Time, hr	A-401C	A-401C + Process Aid	A-401C High MgO	GF-600S	GF-600S + Process Aid	GF-600S + ZnO
No Post-Cure		1.87	1.78	1.65	1.34	1.29	1.28
200 (392)	4	1.86	1.84	1.67	1.49	1.64	1.58
200 (392)	8	1.93	1.94	1.64	1.61	1.75	1.61
200 (392)	16	1.99	1.93	1.69	1.57	1.82	1.59
200 (392)	24	2.07	1.94	1.71	1.58	1.92	1.62
232 (450)	4	1.95	1.90	1.67	1.52	1.72	1.59
232 (450)	8	2.10	1.98	1.71	1.58	1.84	1.59
232 (450)	16	2.04	2.22	1.83	1.65	1.93	1.58
232 (450)	24	2.08	2.13	1.68	1.63	1.93	1.62

For more information, visit Viton.com

Replaces: K-28395
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