Viton® fluoroelastomer

# Electrical Properties of Viton®

This technical information addresses the concept of electrical insulation and jacketing for service in environments exposed to high temperatures and corrosive fluids.

Viton fluoroelastomers are a unique family of elastomers that provide a combination of heat and fluid resistance far beyond the range of other synthetic elastomers. In addition, vulcanizates of Viton exhibit excellent resistance to ozone, oxidation, abrasion, and weathering, while maintaining mechanical properties of the same order of magnitude as conventional synthetic rubbers. This technical information summarizes and compares the electrical properties of five Viton fluoroelastomers, Viton E-60C, Viton B-910, and Viton A, Viton B, and Viton B-50 with Diak™ No. 3 as a curative. It should be noted that properties equivalent to those obtained with Viton E-60C and Viton B-910 can also be obtained with Viton E-60 plus Viton Curative Nos. 20 and 30 or Viton B plus Viton Curative Nos. 20 and 30. (Refer to DuPont Dow Elastomers technical information H-73596-01, "Compounding with Viton® Curative Masterbatches," for specific formulations.) Where lower viscosity compounds are desired, Viton E-45 can be substituted for Viton E-60.

### Advantages (versus plastic types)

- Excellent heat and fluid resistance
- Flexibility with reduced knot sensitivity and improved kink resistance
- Improved distortion and cold-flow resistance
- Improved abrasion, tear, and cut-through resistance

### Uses

- Primary insulation for low-voltage, low-frequency applications
- Jacketing material for improved heat and fluid resistance

## Handling Precautions

Using recommended handling procedures, Viton fluorelastomer polymers and products based on them present no health hazards of which DuPont Dow Elastomers is aware. Toxic vapors, which may include hydrogen fluoride,* may be liberated from products based on Viton during cure, post-cure, or service at temperatures above 200°C (393°F). Adequate ventilation should be provided in work areas where compounds of parts of Viton are being processed or are likely to be exposed to temperatures in this range. Avoid breathing vapors or dusts from such operations. If vapors or dust are inhaled, remove to fresh air. By following these precautions, there should be no problem in staying within the limits set by OSHA. Before handling or processing Viton, be sure to read and be guided by suggestions in DuPont Dow Elastomers technical information H-71129-02, "Handling Precautions for Viton® and Related Chemicals."

It has been found that some metal oxides in a dispersion at high levels in Viton will undergo an exothermic decomposition when heated to a temperature in the range of 200°C (392°F). For example, a blend of litharge/Viton (80/20) was found to decompose exothermically when heated above 200°C (392°F). Metallic lead was one of the products produced. Some decomposition has also been noted in high viscosity compounds of Viton containing 10–20 phr of metal oxide where high frictional heat can be developed during molding. The same sort of exothermic decomposition takes place with litharge and other fluoro-

*Hydrogen fluoride is regulated as an air contaminant in the United States under the Occupational Safety and Health Act (refer to CFR Title 29 1910.1000). This sets the 8-hr time-weighted average in any 8-hr work shift of a 40-hr work week at 3 ppm.

elastomers, as well as with other types of elastomers such as natural rubber, SBR, polychloroprene, and ethylenepropylene copolymers. This effect is not fully understood.

Lead and lead oxides (litharge) are regulated in the United States under the Occupational Safety and Health Act (29 CFR 1910.1025, Subpart Z—Toxic and Hazardous Substances). The permissible exposure limit (PEL) is 50 µg/m$^3$ of air average over an 8-hr period. However, an action level of 25 µg lead/m$^3$ of air requires special procedures (refer to the OSHA Regulation cited above).

Other compounding ingredients that are used with Viton® to prepare finished products may present hazards in handling and use. Before proceeding with any compounding or processing work, consult and follow label directions and handling precautions from suppliers of all ingredients.

## Electrical Properties

The electrical properties of Viton fluoroelastomer are compiled in *Tables 1* through *4*. In general, the data indicate that compounds of Viton fluoroelastomer are suitable as insulative materials for low-voltage, low-frequency applications and as jacketing materials for improved heat and fluid resistance.

Physical properties of vulcanized slabs are also presented for reference (*Table 1*). Tensile and modulus of press-cured materials are generally higher than those of steam-cured samples. Compression set properties of compounds based on Viton E-60C and Viton B-910 are superior to those based on Viton A and Viton B with Diak™ No. 3 as curative.

Electrical properties on cured slabs indicate that insulative materials based on Viton A or Viton B/ Diak No. 3 have marginally better electrical properties than those based on Viton E-60C or Viton B-910. Electrical properties on No. 12 AWG aluminum wire further emphasize the superiority of materials cured with Diak (*Table 2)*. In all cases, air-aging of samples at high temperatures improves electrical properties, while testing at high temperatures or aging of samples in water reduces electrical properties (*Tables 2* and *3*). Compounds containing non-black fillers have better electrical properties than those containing carbon black (*Table 4*).

## Processing

In general, compounds based on Viton E-60C and Viton B-910 are safer processing and cure more rapidly than those based on diamine (Diak) cures. They are, therefore, more compatible with continuous vulcanization (CV) cure cycles.

Compounds of Viton may be crosshead-extruded on metal conductor using conventional wire extrusion techniques. Processing aids such as pentaerythritol tetrastearate (PET) and carnauba wax No. 3 NC may be used to improve extrusion smoothness. They have no effect on electrical properties. Recommended extruder conditions are:

| | **Viton E-60C and Viton B-910** | **Viton A and B Diak No. 3 Cure** |
|---|---|---|
| Feed | Cold | Cold |
| Screw | Cold | Cold |
| Barrel | 66°C (150°F) | 66°C (150°F) |
| Fixed Head | 104°C (220°F) | 93°C (200°F) |
| Cross Head | 129°C (265°F) | 104°C (220°F) |

Compounds of Viton may be CV-cured for 60–90 sec in steam at 1.59 MPa (230 psi). For more information on processing, see DuPont Dow Elastomers technical information "A Capsule View of the A, B, and E Types of Viton®."

**Table 1**
**Electrical and Physical Properties of Viton® E-60C and Viton B-910 Compared with Those of Viton A and Viton B**

| Compound | 1A | 1B | 1C | 1D |
|---|---|---|---|---|
| Viton E-60C | 100 | — | — | — |
| Viton B-910 | — | 100 | — | — |
| Viton A | — | — | 100 | — |
| Viton B | — | — | — | 100 |
| Blanc Fixe | 30 | 30 | 30 | 30 |
| High-Activity MgO | 3 | 3 | — | — |
| Low-Activity MgO | — | — | 15 | 15 |
| Calcium Hydroxide | 6 | 3 | — | — |
| Diak™ No. 3 | — | — | 3.0 | 3.0 |
| **Stock Properties** | | | | |
| **Mooney Scorch, MS at 121°C (250°F)** | | | | |
| Minimum viscosity, units | 34 | 62 | 30 | 54 |
| Time to 10-unit rise, min | 0 units in 45 min | 35 | 44 | 39 |
| **Vulcanizate Properties** | | | | |
| **Slabs*, Press-Cured 15 min at 177°C (350°F)** | | | | |
| **Stress/Strain and Hardness at 24°C (75°F)** | | | | |
| **Original** | | | | |
| 100% Modulus, MPa (psi) | 3.6 (525) | 2.8 (400) | 2.2 (325) | 2.2 (325) |
| Tensile Strength, MPa (psi) | 11.0 (1,600) | 11.2 (1,625) | 11.2 (1,625) | 15.2 (2,200) |
| Elongation at Break, % | 210 | 290 | 410 | 450 |
| Hardness, Durometer A | 68 | 72 | 68 | 70 |
| **After Oven Cure—24 hr at 232°C (450°F)** | | | | |
| 100% Modulus, MPa (psi) | 4.6 (675) | 3.2 (475) | 3.6 (525) | 3.0 (425) |
| Tensile Strength, MPa (psi) | 13.0 (1,900) | 12.0 (1,750) | 16.0 (2,325) | 19.0 (2,750) |
| Elongation at Break, % | 210 | 270 | 340 | 460 |
| Hardness, Durometer A | 68 | 71 | 75 | 71 |
| **Electrical Properties** | | | | |
| **Specific Inductive Capacity (1,000 Hz)** | | | | |
| Original | 10.05 | 9.51 | 10.71 | 9.60 |
| After Oven Cure—24 hr at 232°C (450°F) | 9.91 | 8.81 | 9.96 | 9.20 |
| **Power Factor, % (1,000 Hz)** | | | | |
| Original | 6.70 | 9.22 | 4.55 | 3.48 |
| After Oven Cure—24 hr at 232°C (450°F) | 4.70 | 4.14 | 2.87 | 2.57 |
| **Volume (DC) Resistivity, Ω·cm** | | | | |
| Original | $1.06 \times 10^{11}$ | $5.79 \times 10^{10}$ | $4.47 \times 10^{11}$ | $1.92 \times 10^{12}$ |
| After Oven Cure—24 hr at 232°C (450°F) | $3.06 \times 10^{14}$ | $3.28 \times 10^{11}$ | $1.17 \times 10^{13}$ | $7.01 \times 10^{13}$ |
| **Dielectric Strength, kV/mm (V/mil)** | | | | |
| Original | 23.1 (586) | 16.5 (420) | 20.9 (530) | 20.8 (528) |
| After Oven Cure—24 hr at 232°C (450°F) | 20.4 (517) | 19.2 (488) | 22.4 (568) | 20.2 (513) |
| **Slabs* Steam-Cured, sec at 1.59 MPa (230 psi)** | 60 | 60 | 90 | 90 |
| **Stress/Strain and Hardness at 24°C (75°F)** | | | | |
| **Original** | | | | |
| 100% Modulus, MPa (psi) | 2.8 (400) | 2.0 (300) | 1.8 (250) | 2.0 (300) |
| Tensile Strength, MPa (psi) | 10.2 (1,475) | 10.0 (1,450) | 10.4 (1,500) | 9.8 (1,425) |
| Elongation at Break, % | 250 | 350 | 590 | 570 |
| Hardness, Durometer A | 63 | 66 | 71 | 71 |
| **After Oven Cure—24 hr at 232°C (450°F)** | | | | |
| 100% Modulus, MPa (psi) | 3.8 (550) | 2.6 (375) | 4.0 (575) | 3.2 (475) |
| Tensile Strength, MPa (psi) | 9.4 (1,375) | 10.4 (1,500) | 14.6 (2,125) | 17.6 (2,550) |
| Elongation at Break, % | 190 | 280 | 290 | 390 |
| Hardness, Durometer A | 64 | 68 | 57 | 74 |
| **Electrical Properties** | | | | |
| **Volume (DC) Resistivity, Ω·cm** | | | | |
| Original | $2.61 \times 10^{11}$ | $5.82 \times 10^{10}$ | $1.81 \times 10^{13}$ | $1.66 \times 10^{13}$ |
| After Oven Cure—24 hr at 232°C (450°F) | $3.54 \times 10^{15}$ | $1.56 \times 10^{12}$ | $4.74 \times 10^{14}$ | $2.14 \times 10^{14}$ |
| **Dielectric Strength, kV/mm (V/mil)** | | | | |
| Original | 12.2 (309) | 12.2 (311) | 18.0 (456) | 16.7 (423) |
| After Oven Cure—24 hr at 232°C (450°F) | 20.2 (514) | 12.4 (316) | 15.7 (398) | 16.4 (416) |

* Stress/strain properties obtained on 1.9 mm (0.075 in) thick dumbbells.
Electrical properties obtained on slabs 0.635 x 152 x 152 mm (0.025 x 6 x 6 in).

**Table 2**
**Electrical Properties of Compounds of Viton® on Wire**

| Compound | 2A | 2B | 2C |
|---|---|---|---|
| Viton E-60C | 100 | — | — |
| Viton B | — | 100 | — |
| Viton B-50 | — | — | 100 |
| Blanc Fixe | 30 | 30 | 30 |
| Litharge | 15 | 15 | 15 |
| Diak™ No. 3 | — | 3 | 3 |
| **Vulcanizate Properties** | | | |
| Insulated wire—1.2 mm (3/64 in) insulation on No. 12 AWG aluminum wire, steam-cured, sec at 1.59 MPa (230 psi) | 60 | 90 | 90 |
| **Electrical Properties*** | | | |
| **Original—After immersion in water for 5 min at 15.6°C (60°F)** | | | |
| Insulation Resistance, MΩ/km (MΩ/1,000 ft) | 0.10 (0.33) | — | 1.12 (3.66) |
| Specific Inductive Capacity (60 Hz) | 10.91 | — | 9.51 |
| Power Factor, % (60 Hz) | 7.46 | — | 6.90 |
| **After Air-Aging 24 hr at 232°C (450°F)** | | | |
| Insulation Resistance, MΩ/km (MΩ/1,000 ft) | 10.8 (35.5) | — | 458 (1,502) |
| Specific Inductive Capacity (60 Hz) | 7.12 | — | 8.28 |
| Power Factor, % (60 Hz) | 6.59 | — | 6.26 |
| **After Air-Aging 70 hr at 276°C (528°F)** | | | |
| Insulation Resistance, MΩ/km (MΩ/1,000 ft) | 775 (2,542) | — | 1 988 (6,522) |
| Specific Inductive Capacity (60 Hz) | 10.16 | — | 9.76 |
| Power Factor, % (60 Hz) | 7.58 | — | 6.64 |
| **Original—After immersion in water for 16 hr at 15.6°C (60°F)** | | | |
| Insulation Resistance, MΩ/km (MΩ/1,000 ft) | 0.07 (0.22) | 1.14 (3.73) | 1.14 (3.73) |
| Specific Inductive Capacity (60 Hz) | 11.56 | 10.19 | 9.74 |
| Power Factor, % (60 Hz) | 10.0 | 7.77 | 7.47 |
| **After Air-Aging 24 hr at 232°C (450°F)** | | | |
| Insulation Resistance, MΩ/km (MΩ/1,000 ft) | 0.05 (0.17) | 1.09 (3.57) | 1.19 (3.90) |
| Specific Inductive Capacity (60 Hz) | 14.82 | 10.91 | 10.23 |
| Power Factor, % (60 Hz) | 15.32 | 10.25 | 9.36 |
| **After Air-Aging 70 hr at 276°C (528°F)** | | | |
| Insulation Resistance, MΩ/km (MΩ/1,000 ft) | 226 (741) | 405 (1,327) | 532 (1,744) |
| Specific Inductive Capacity (60 Hz) | 10.33 | 9.85 | 9.30 |
| Power Factor, % (60 Hz) | 10.26 | 9.01 | 6.34 |

*After steam curing, samples are tested for electrical properties either without air-aging or after air-aging for times and temperatures indicated. Either aged or unaged.

**Table 3**
**Electrical Properties of Wire Insulated with Viton®**

| Compound | |
|---|---|
| Viton A | 90 |
| Viton LM | 10 |
| Low-Activity MgO | 15 |
| Super Multifex (replaced by Multifex® MM) | 30 |
| Diak™ No. 3 | 2.5 |

**Vulcanizate Properties**

Insulated wire—0.79 mm (2/64 in) insulation on No. 14 AWG 7 strand copper conductor
Cure: Steam—1 hr at 0.55 MPa (80 psi)
Oven—24 hr at 177°C (350°F)

| Electrical Properties | Insulation Resistance, MΩ/km (MΩ/1,000 ft) | Power Factor, % (1,000 Hz) | Specific Inductive Capacity (1,000 Hz) | Dielectric Strength, kV/mm (V/mil) |
|---|---|---|---|---|
| **Tested in Air** | | | | |
| At 24°C (75°F) | 13.7 (45.0) | 3.4 | 4.2 | — |
| At 90°C (194°F) | 0.04 (0.14) | 4.7 | 7.6 | — |
| At 125°C (257°F) | 0.009 (0.03) | 15.2 | 7.0 | — |
| At 150°C (302°F) | 0.006 (0.02) | 27.3 | 7.1 | — |
| At 200°C (392°F) | 0.002 (0.008) | 80 | 9.1 | — |
| **Tested in Air at 24°C (75°F)** | | | | |
| After 3 days at 150°C (302°F) | 27.1 (89) | 1.8 | 6.8 | 34.1 (865) |
| After 7 days at 150°C (302°F) | 28.4 (93) | 1.6 | 7.2 | 34.2 (869) |
| After 3 days at 200°C (392°F) | 228 (748) | 1.4 | 5.9 | 35.7 (908) |
| After 7 days at 200°C (392°F) | 598 (1,963) | 1.6 | 5.7 | 35.6 (905) |

**Table 4**
**Effect of Fillers on Electrical Properties of Viton**

| Compound | | | | | | |
|---|---|---|---|---|---|---|
| Viton B | 100 | | | | | |
| Low-Activity MgO | 15 | | | | | |
| Filler | As indicated | | | | | |
| Diak No. 3 | As indicated | | | | | |
| | **No Filler** | **MT Black** | **MT Black** | **FEF Black** | **Precipitated Whiting*** | **Blanc Fixe** |
| Filler | — | 20 | 60 | 20 | 30 | 45 |
| Diak No. 3 | 3 | 3 | 3 | 3 | 4 | 4 |

**Vulcanizate Properties**

Cure: Press, 30 min at 149°C (300°F)
Oven Step-Cure to 205°C (400°F), then 24 hr at 205°C (400°F)
Slabs: 0.635 x 152 x 152 mm (0.025 x 6 x 6 in)

| Electrical Properties at 24°C (75°F) | | | | | | |
|---|---|---|---|---|---|---|
| Volume (DC) Resistivity, Ω·cm | $2.9 \times 10^{13}$ | $1.5 \times 10^{13}$ | $6.6 \times 10^{11}$ | $7.1 \times 10^{12}$ | $1.4 \times 10^{14}$ | $1.1 \times 10^{13}$ |
| Specific Inductive Capacity (1,000 Hz) | 9.26 | 17.34 | 355.8 | 34.22 | 8.53 | 7.68 |
| Power Factor, % (1,000 Hz) | 3.0 | 3.1 | 26.4 | 7.3 | 2.5 | 2.5 |

*Super Multifex (replaced by Multifex MM)