DuPont Films

High Performance Films

# Kapton®

polyimide film

# Corona Resistant Kapton® CR Takes Electrical Insulation Design and Reliability to New Levels

## Improved Margin of Operational Safety

DuPont Kapton® CR polyimide film was developed specifically to withstand the damaging effects of "corona," which can cause ionization and eventual breakdown of an insulation material or system when the voltage stress reaches a critical level.

In development and testing by DuPont with ABB Industrie AG Switzerland (a subsidiary of the multinational ABB group) and Siemens AG, two of the world's foremost traction motor manufacturers, Kapton® CR shows corona resistance or voltage endurance of greater than 100,000 hr at 20 kV/mm (500 V/mil) at 50 Hz. Kapton® CR also provides twice the thermal conductivity (0.385 W/m·K) of standard Kapton®. These substantial property improvements increase the margin of operational safety and open the door to new electrical design possibilities in traction motors, transformers, and electrical rotating machines.

**Table 1** shows the properties of Kapton® CR and **Table 2** shows the properties of the heat-sealable version, Kapton FCR®, which is laminated to DuPont Teflon® FEP film. As you can see, these next-generation insulation materials retain all the other excellent electrical, thermal, mechanical, and physical properties for which standard Kapton® is known.

## Excellent Results in Corona Resistance Testing

**Figure 1** compares the corona resistance of Kapton® CR to that of standard Kapton® HN. At a voltage stress of 20 kV/mm (500 V/mil) AC at 50 Hz, for example, Kapton® CR has a life endurance in excess of 100,000 hr (11½ yr), compared to 200 hr for Kapton® HN. Similar substantial improvements in corona resistance are seen at other voltages as well. Testing was performed independently by DuPont, ABB Industrie AG Switzerland, and Siemens AG according to IEC 343.

**Figure 1. Comparison of Corona Resistance of Kapton® 100 CR versus Kapton® 100 HN. Based on measurements performed by DuPont, ABB Industrie AG Switzerland, and Siemens AG according to IEC 343.**

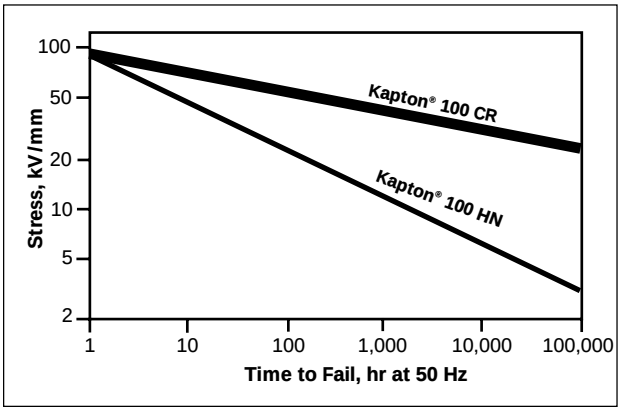


**Table 1**
**Typical Properties of Kapton® Type 100 CR Polyimide Film, 25 μm (1 mil)**

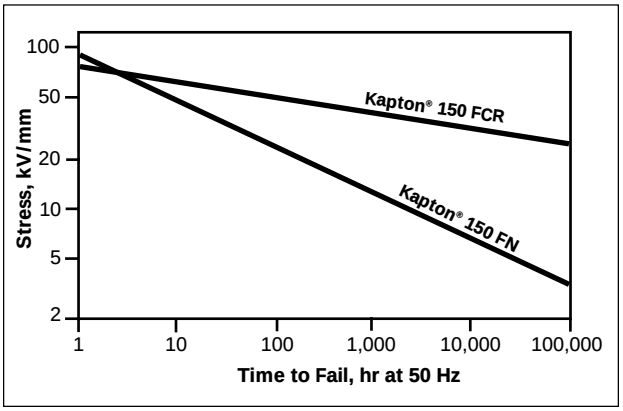
| Property | Typical Value at 23°C (73°F) | Test Method |
|---|---|---|
| ***Electrical*** | | |
| Corona Resistance, hr at 20 kV/mm at 50 Hz | >100,000 | IEC-343 |
| Dielectric Strength, kV/mm (V/mil) | 291 (7,400) | ASTM D-149-81 |
| Dielectric Constant | 3.9 | ASTM D-150-81 |
| Dissipation Factor | 0.003 | ASTM D-150-81 |
| Volume Resistivity, ohm·cm | $2.3 \times 10^{16}$ | ASTM D-257-78 |
| Surface Resistivity, ohm/sq | $3.6 \times 10^{16}$ | ASTM D-257-78 |
| ***Mechanical*** | | |
| Ultimate Tensile Strength, MPa (psi) | 152 (22,100) | ASTM D-882-91 |
| Yield Point at 3%, MPa (psi) | 66 (9,500) | ASTM D-882-91 |
| Stress to Produce 5% Elongation, MPa (psi) | 86 (12,500) | ASTM D-882-91 |
| Ultimate Elongation, % | 40 | ASTM D-882-91 |
| Tensile Modulus, GPa (psi) | 3.2 (463,000) | ASTM D-882-91 |
| Tear Strength—Propagating, N (lbf) | 0.03 (0.007) | ASTM D-1922 |
| Tear Strength—Initial, N (lbf) | 11 (2.5) | ASTM D-1004-90 |
| Density, g/cm³ | 1.54 | ASTM D-1505-90 |
| Yield, m²/kg (ft²/lb) | 25.5 (125) | — |
| ***Thermal*** | | |
| Coefficient of Thermal Conductivity, W/m·K | 0.385 | Univ. of Delaware Method |
| Flammability | 94 V-0 | UL-94 (Tested by DuPont) |
| Shrinkage, % at 150°C (302°F) | 0.2 | ASTM D-5214-91 |
| 400°C (752°F) | 0.6 | |

**Table 2**
**Typical Properties of Kapton® Type 150 FCR 019 Polyimide Film, 37.5 μm (1.5 mil)**

| Property | Typical Value at 23°C (73°F) | Test Method |
|---|---|---|
| ***Electrical*** | | |
| Corona Resistance, hr at 20 kV/mm at 50 Hz | >100,000 | IEC-343 |
| Dielectric Strength, kV/mm (V/mil) | 173 (4,400) | ASTM D-149-81 |
| Dielectric Constant | 2.9 | ASTM D-150-81 |
| Dissipation Factor | 0.001 | ASTM D-150-81 |
| Volume Resistivity, ohm·cm | $5.3 \times 10^{16}$ | ASTM D-257-78 |
| Surface Resistivity, ohm/sq | $1.6 \times 10^{15}$ | ASTM D-257-78 |
| ***Mechanical*** | | |
| Ultimate Tensile Strength, MPa (psi) | 117 (17,000) | ASTM D-882-91 |
| Yield Point at 3%, MPa (psi) | 48 (7,000) | ASTM D-882-91 |
| Stress to Produce 5% Elongation, MPa (psi) | 62 (9,000) | ASTM D-882-91 |
| Ultimate Elongation, % | 43 | ASTM D-882-91 |
| Tensile Modulus, GPa (psi) | 2.4 (348,000) | ASTM D-882-91 |
| Tear Strength—Propagating, N (lbf) | 0.05 (0.012) | ASTM D-1922 |
| Tear Strength—Initial, N (lbf) | 5.3 (1.2) | ASTM D-1004-90 |
| Density, g/cm³ | 1.72 | ASTM D-1004-90 |
| Yield, m²/kg (ft²/lb) | 15.79 (77.4) | — |
| ***Bonding, N/cm (lb/in)*** | | |
| Teflon® FEP to Kapton® CR | 7.7 (4.4) | DuPont Test |
| Teflon® FEP to Copper | 7.9 (4.5) | DuPont Test |
| Laminate Bond as Received | 1.2 (0.7) | DuPont Test |

**Figure 2** compares the corona resistance of Kapton® FCR, a heat-sealable version laminated to Teflon® FEP film, with that of standard Kapton® FN, which is also laminated to Teflon®. As expected, the corona resistance of Kapton® FCR is substantially more than that of standard, laminated Kapton® FN.

**Figure 2. Comparison of Corona Resistance of Kapton® 150 FCR 019 versus Kapton® 150 FN 019. DuPont testing performed according to IEC 343.**




## Excellent Insulating Properties for Magnet Wire

Throughout the development program, Swiss Insulating Works performed a series of magnet wire tests comparing next-generation to standard Kapton®. These results are summarized in **Table 3**. Kapton® FCR exhibits properties almost identical to those of Kapton® FN, both of which are well in excess of typical specifications.

**Table 3**
**Comparison of Magnet Wire Insulating Properties for Kapton® Type 150 FCR 019 Polyimide Film and Kapton® Type 150 FN 019 Polyimide Film***

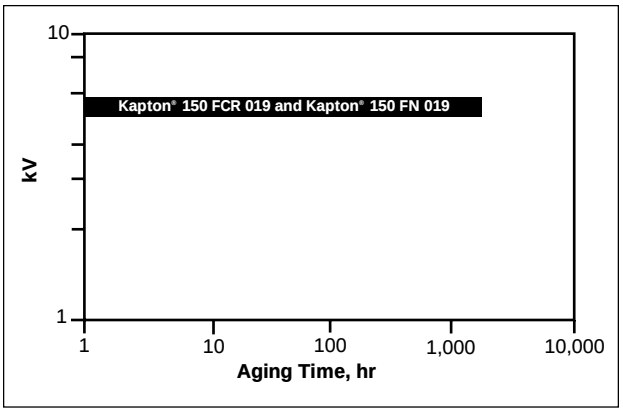
| Property | Kapton® 150 FN 019 | Kapton® 150 FCR 019 | Kapton® 150 FN 019 | Kapton® 150 FCR 019 |
|---|---|---|---|---|
| Number of Wraps | 1 | 1 | 1 | 1 |
| Lapping, % | 50 | 50 | 53 | 53 |
| Insulation Increase, mm | 0.15 | 0.15 | 0.21 | 0.21 |
| Breakdown Voltage, Straight, IEC 851-5, kV | | | | |
| Min. | 4.5 | 4.0 | 6.0 | 6.0 |
| Avg. | 6.0 | 5.5 | 7.0 | 7.0 |
| Bend Test, IEC 851-3 | | | | |
| 2× Width Edgewise, kV | | | | |
| Min. | 4.5 | 4.0 | 5.0 | 5.0 |
| Avg. | 5.5 | 5.0 | 6.0 | 6.0 |
| 2× Thickness Flat, kV | | | | |
| Min. | 4.5 | 4.0 | 5.0 | 5.0 |
| Avg. | 5.5 | 5.0 | 6.0 | 6.0 |
| Bend Test After Heat Shock (30 min at 220°C [428°F]), IEC 851-6, kV | | | | |
| Min. | 4.5 | 4.0 | 5.0 | 4.5 |
| Avg. | 5.5 | 5.0 | 6.0 | 5.5 |

*Data provided by Swiss Insulating Works.

## Excellent Resistance to Voltage Breakdown

Using magnet wire prepared by Swiss Insulating Works, Siemens AG compared the voltage breakdown of Kapton® FCR versus standard Kapton® FN in a shot bath according to IEC 251-3. The magnet wire was aged at 250°C (482°F), placed in a lead shot bath, and a voltage was applied. The results in **Figure 3** show that even after 2,000 hr at 250°C (482°F), there is no degradation for either Kapton® FCR or Kapton® FN.

**Figure 3. Comparison of Voltage Breakdown of Kapton® 150 FCR 019 and Kapton® 150 FN 019 in a Shot Bath (IEC 251-3). Magnet wire was immersed in lead beads and thermally aged at 250°C (482°F) by Siemens AG. No degradation was seen up to 2,000 hr for either Kapton® FCR or Kapton® FN. Both magnet wires gave excellent results within the band shown in the chart.**




## Applications and Availability

Traction motor manufacturers are in the process of evaluating Kapton® CR, and it has already been adopted by ABB Industrie AG Switzerland for use in its Veridur®-Plus insulating system. It can also be used in transformers, electrical rotating machines (for example, in generators), and any other insulation application where corona is a concern.

Kapton® CR is available in a variety of widths, 3.0 mm to 1,200 mm, in 25 µm thickness. Thicker versions are planned and custom gauges can be discussed. A heat-sealable version, consisting of 25 µm Kapton® CR laminated to 12.5 µm Teflon® FEP film, is also available.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