



# THE GUND COMPANY

Manufacturers & fabricators of engineered material solutions

|                   |                                                                                                                                                                                                                                                                                                                                                                               |                      |                              |
|-------------------|-------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|----------------------|------------------------------|
| Item:             | NEMA Grade FR4 Glass Epoxy Laminate                                                                                                                                                                                                                                                                                                                                           |                      |                              |
| Description:      | NEMA Grade FR4 materials are glass fabric reinforced laminates, bonded with flame resistant epoxy resin. The material has the ability to maintain excellent mechanical, electrical and physical properties at elevated temperature to 130 °C. FR4 from The Gund Company is UL, RoHS, and REACH certified to ensure reliability, safety, and consistency (UL File No. E339275) |                      |                              |
| Standards:        | NEMA LI-1: Grade FR4                                                                                                                                                                                                                                                                                                                                                          | MIL-I-24768/27 GEE-F | IEC 60893: EP GC 202 (sheet) |
| Availability:     |                                                                                                                                                                                                                                                                                                                                                                               |                      | English Units (in)           |
|                   |                                                                                                                                                                                                                                                                                                                                                                               |                      | SI Units (mm)                |
|                   | Laminate Sheets:                                                                                                                                                                                                                                                                                                                                                              | Thickness:           | 0.010 to 5.0                 |
|                   |                                                                                                                                                                                                                                                                                                                                                                               | Standard Sheet Size  | 48 x 120                     |
| Convolute Tubing: | FR4 convolute tubes are available from The Gund Company in nearly any custom size of inside and outside diameter, per customer requirements                                                                                                                                                                                                                                   |                      |                              |
| Fabricated Parts: | The Gund Company custom fabricates insulation material to the exact specifications and drawings of our customers.                                                                                                                                                                                                                                                             |                      |                              |

| Key Characteristics | Units - English (SI)      | Typical Values     |
|---------------------|---------------------------|--------------------|
| Standard Color      | --                        | Green <sup>1</sup> |
| Density             | lb/in <sup>3</sup> (g/cc) | 0.067 (1.85)       |

<sup>1</sup> Custom colors are available upon request

## NEMA LI-1 FR4 Required Properties

| Key Characteristics                                                     | Test Method | Units               | NEMA Required                    | Typical Values               |
|-------------------------------------------------------------------------|-------------|---------------------|----------------------------------|------------------------------|
| Breakdown Voltage (0.062")<br>Condition A<br>Condition D-48/50          | ASTM D-149  | kV                  | 45 min<br>40 min                 | 66<br>65                     |
| Permittivity @ 1 MHz (0.062")<br>Condition A<br>Condition D-48/50       | ASTM D-150  | --                  | 5.2 max<br>5.4 max               | 4.4<br>4.5                   |
| Dissipation Factor @ 1 MHz (0.062")<br>Condition A<br>Condition D-48/50 | ASTM D-150  | --                  | 0.025 max<br>0.035 max           | 0.014<br>0.015               |
| IZOD Strength (0.062")<br>Length-Wise<br>Cross-Wise                     | ASTM D-229  | ft-lb/in<br>Notched | 7.0 min<br>5.5 min               | 13<br>12                     |
| Flexural Strength (0.062")<br>Length-Wise<br>Cross-Wise                 | ASTM D-790  | ksi (MPa)           | 60.0 (414) min<br>50.0 (345) min | 80 (552)<br>70 (483)         |
| Bonding Strength (0.500")<br>Length-Wise<br>Cross-Wise                  | ASTM D-229  | Lb (kg)             | 2000 (907) min<br>1600 (725) min | 2,500 (1,133)<br>1,900 (862) |
| Moisture Absorption (0.125")                                            | ASTM D-570  | %                   | 0.15 max                         | 0.10                         |
| Flammability Rating                                                     | UL94        | Class               | V-I                              | V-0                          |

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Material Data Sheet

NEMA Grade FR4

## IEC 60893-3-2 EPGC 202 Required Properties

| Key Characteristics                                        | Test Method | Units             | IEC Requirement    | Typical Values   |
|------------------------------------------------------------|-------------|-------------------|--------------------|------------------|
| Flexural Strength                                          | ISO 179     | MPa               | 340 min            | 560              |
| Charpy Impact Strength                                     | ISO 179     | kJ/m <sup>2</sup> | 33 min             | 49               |
| Perpendicular Electric Strength<br>(90 oC in Oil, 1.5mm)   | IEC 60243-1 | kV/mm             | 13 min             | 25               |
| Parallel Breakdown Voltage<br>(Stepped, 90 oC in Oil, 3mm) | IEC 60243-1 | kV                | 35 min             | >45              |
| Insulation Resistance<br>(After Water Immersion)           | --          | MΩ                | 5(10) <sup>4</sup> | >10 <sup>7</sup> |
| Flammability Rating                                        | UL94        | Class             | V-0                | V-0              |
| Moisture Absorption (1.5mm)                                | --          | mg                | 19 max             | 13               |

## Additional Engineering Properties

| Key Characteristics                                 | Test Method    | Units - English (SI)   | Typical Values           |
|-----------------------------------------------------|----------------|------------------------|--------------------------|
| Tensile Strength (0.125") Length-Wise               | ASTM D-638     | ksi (MPa)              | 62 (430)                 |
| Compressive Strength, Flat-Wise (0.500")            | ASTM D-695     | ksi (MPa)              | 66 (455)                 |
| Flexural Modulus (0.062") Length-Wise<br>Cross-Wise | --             | ksi (GPa)              | 2,900 (20)<br>2,600 (18) |
| Shear Strength (punch type, 0.062")                 | ASTM D-732     | psi (MPa)              | 21,500 (148)             |
| Coefficient of Thermal Expansion                    | ASTM E-228     | "/"°Cx10 <sup>-6</sup> | 15                       |
| Temperature Index                                   | ASTM D-2304    | °C                     | 130                      |
| Glow Wire Flame Index & Ignition Temperature        | IEC 60695-2-12 | °C                     | 960                      |
| Hot Wire Ignition                                   | UL 746A        | Sec                    | 120                      |
| High Current Arc Ignition (3mm)                     | UL 746A        | Arcs                   | 120                      |
| Arc Resistance (0.125")                             | ASTM D-495     | Sec                    | 140                      |
| Comparative Tracking Index (0.125")                 | ASTM D-3638*   | V                      | 230                      |
| Dielectric Strength (Condition A)                   | ASTM D-149     | V/mil                  | 635                      |
| Volume Resistivity (0.062")                         | ASTM D-257     | Ω - cm                 | 3(10) <sup>15</sup>      |
| High Voltage Arc Resistance                         | UL 746A        | Sec                    | 300                      |
| High Voltage Arc Tracking Rate                      | UL 746A        | mm/min                 | 0                        |

\*ASTM D-3638 & IEC 112 are the same test method - IEC 60112 is slightly different, but the results are similar.