



**Micarta ® Laminates – Various Grades Technical Information**

Phenolic sheet is a hard, dense material made by applying heat and pressure to layers of paper or glass cloth impregnated with synthetic resin. These layers of laminations are usually of cellulose paper, cotton fabrics, synthetic yarn fabrics, glass fabrics or unwoven fabrics. When heat and pressure are applied to the layers, a chemical reaction (polymerization) transforms the layers into a high-pressure thermosetting industrial laminated plastic.

<b><u>PROPERTIES</u></b>	<b><u>APPLICATIONS</u></b>
Excellent dielectric strength	Terminal boards
Good machinability	Switches
Light weight	Bearings
Heat and wear resistant	Gears
Resists corrosion and chemicals	Wear strips
Good mechanical strength & dimensional stability	Gaskets
Low moisture absorption	Washers
	Transformers
	Machining components
	Industrial laminates

**PAPER REINFORCED PHENOLIC**

NEMA XX per MIL-I-24768 PBG

Normal electrical applications, moderate mechanical strength, continuous operating temperature of 250°F.

**CANVAS REINFORCED PHENOLIC**

NEMA C per MIL-I-24768 TYPE FBM

NEMA CE per MIL-I-24768 TYPE FBG

Good mechanical and impact strength with continuous operating temperature of 250°F.

**LINEN REINFORCED PHENOLIC**

NEMA L per MIL-I-24768 TYPE FBI

NEMA LE per MIL-I-24768 TYPE FEI

Good mechanical & electrical strength. Recommended for intricate high strength parts. Continuous operating temperature 250°F.

**NYLON REINFORCED PHENOLIC**

NEMA N-1 per MIL-I-24768 TYPE NPG

Superior electrical properties under humid conditions, fungus resistant, continuous operating temperature of 160°F.

**Phenolic Resin - Paper Substrates**

**NP600** is paper phenolic product designed for use as drill entry material for the manufacture of printed circuit boards. A non-NEMA economy grade, the product is used in jigs and templates. It has a hard, flat surface for good drill starts, as well as sufficient strength to maintain hole positions.

**NP602** is a paper-based laminate with low phenolic resin content. A non-NEMA economy grade, NP602 is typically hot punched for numerous low voltage electrical applications. NP602 offers fair electric properties in dry conditions, but the product is not suitable for applications that require resistance to high humidity.

**NP605** is a paper phenolic sheet used as a drill-backer material. A non-NEMA economy grade, the product is

used in jigs and templates. Its hard, flat surface and low sheet thickness variance facilitate superior drilling by helping to maintain the vertical axis. It is also frequently used as a replaceable tabletop for milling, drilling, and other machining applications.

**NP610** (NEMA X) is a phenolic paper material for mechanical applications. Primarily a machining material, NP610 can be hot punched in thicknesses up to 0.093 inch. Offering good tensile, flexural, and compressive strength, this mechanical grade is UL listed (File Number E-187147). Applications include panels, washers, switch bases, terminal boards, and structural parts. NP610 complies with the requirements of MIL-I-24768/12, Type PBM.

**NP611** (NEMA XP) is a hot-punching, paper based phenolic grade. With mechanical properties approaching those of NP610, NP611 also offers improved electrical and punching characteristics. NP611 is a warm to hot punching grade, used for switch parts and other applications that need good moisture resistance, such as switch bases, terminal boards, insulating washers, and other intricate punched parts. NP611 complies with the requirements of MIL-I-24768/19, Type PBM-P.

**NP612** (NEMA XPC) is a paper based phenolic grade, which is suitable for room temperature punching and shearing in thicknesses up to 0.125 inch. Though its mechanical properties do not equal those of NP611, NP612 offers greater flexibility. This mechanical grade is UL listed (File Number E-187147) and meets the requirements of MIL-I-24768/20, Type PBM-PC. Suitable for intricate punched parts, the product is designed for applications in which electrical and moisture requirements are of secondary importance.

**NP625** (NEMA XPC) is a paper based phenolic grade, which is suitable for punching and shearing in thicknesses up to 0.125 inch and at temperatures slightly higher than room temperature. NP625 is designed for applications in which electrical and moisture characteristics better than NP612's are required.

**NP629** (NEMA XX) is a paper based phenolic that is a machining grade with less robust electrical properties than those of NP630. This product meets the requirements of MIL-I-24768/11, Type PBG. Designed for electrical insulation, the product can be used in dry or high humidity conditions. Applications include barriers, breaker arms, switch panel boards, and relay and switch bases.

**NP630** (NEMA XXX) is a machining grade with very good electrical properties and excellent resistance to moisture and splitting. NP630 is UL listed (File Number E-187147) and meets the requirements of MIL-I-24768/10, Type PBE. Applications include high-voltage switch gear and radio and television panels.

**NP631** is a hot-punching thermoset composite material offering excellent electrical properties and low moisture absorption. NP631 is used for punched parts for high-voltage switches, gears, and other insulation applications requiring high electrical strength in areas of high humidity and moisture.

**NP639** is an economical paper-reinforced laminate that can withstand temperatures up to 150°C without blistering. Besides high-temperature resistance, this non-NEMA grade offers good compressive strength and low moisture absorption. Typical applications involve high temperatures, compression, and wear resistance.

**NP660** (NEMA XP) is an economy version of NP611. This product is made of natural kraft paper without pigmented cover sheets. This low-cost paper phenolic is suitable for warm to hot punching. NP660 is UL listed (File Number E-187147) and complies with the requirements of MIL-I-24768/19, Type PBM-P.

**NP664** (NEMA XPC) is a composite made from unbleached kraft paper with pigmented cover plies on the surface. This low-cost paper phenolic is a room temperature punching grade with high flexural strength and mechanical and electrical properties similar to NP612. NP664 is UL listed (File Number E-187147). NP664 complies with the requirements of MIL-I-24768/20, Type PBM-PC.

**NP680** (NEMA XP) is a hot-punching grade with electrical properties between those offered by NP611 and NP631. NP680 complies with the requirements of MIL-I-24768/19, Type PBM-P.

**NP691** (NEMA FR-1) is a flame-resistant, room temperature punching grade is similar to NP612 in electrical

properties and mechanical strength, but offers improved moisture resistance. NP691 is UL listed (File Number E-187147). NP691 complies with the requirements of MIL-I-24768/24, Type PBM-PF.

**NP843** is made from kraft paper and phenolic resin system. The cover plies use a semi-conductive phenolic resin, while the core is insulating. Applications include X-ray tables in operating rooms and other applications where X-ray clarity is required.

**SP3000 - SkatePlate 3000™** is composed of a phenolic resin system combined with a mechanical grade of kraft paper. It is designed for the wear surfaces in roller skate and skateboard parks. Primarily a machining material, SkatePlate 3000 offers good tensile, flexural, flatwise impact, and compressive strength. Additionally, it does not splinter like plywood surfaces. Thus, the material can be used to produce a tough, non-splintering surface that offers excellent wear resistance. While it is suitable for the surfaces of indoor sports facilities, SkatePlate 3000 also holds up well to the weather in outdoor environments.

### **Epoxy Resin – Paper Substrates**

**NP613** is constructed from electrical grade of kraft paper and a specially modified thermoset epoxy resin system. The product offers good dimensional and thermal stability, as well as a low power factor. NP613 is designed to be used in tap changers, coil support plates, and terminal panels for transformers and their accessories.

**NP643** is a thermoset material constructed from electrical grade kraft paper and a specially modified high temperature epoxy resin system. The product offers good dimensional and thermal stability, electrical insulation, and a low power factor. NP643 is designed to be used in tap changers, coil support plates, and terminal panels for transformers and their accessories.

**NP670** is composed of an epoxy resin system combined with a cotton linter paper for form a low-cost alternative to NEMA CEM-1 materials. A non-NEMA grade, this paper epoxy composite offers properties similar to those of NEMA FR-3, but does not meet permittivity, water absorption, and dissipation factor requirements. The product can be punched at room temperature at thicknesses up to 0.093 inch.

### **Melamine Resin – Various Substrates**

**ES-1** is a melamine laminate composed of a white melamine paper core and various pigmented cover sheets. The three-ply material comes in a standard sheet size of 36 inches  $\pm$  1.00 x 39 inches  $\pm$  1.00, with standard thicknesses of 1/16, 3/32, and 1/8 inch. Standard finish options are polished, or P (highly polished and shiny), and Lamicaid satin, or LS (non-brushed and dull). A textured suede finish is also available.

**ES-2** consists of three internal layers (two colored decorative surfaces, two white sub-cores just below the surfaces, and a black core centered in the thermoset composite material). ES-2 is a five-ply material, which comes in a standard sheet size of 36 inches  $\pm$  1.00 x 39 inches  $\pm$  1.00, with standard-thicknesses of 3/32 and 1/8 inch. Weights of the three standard-thickness sheets are approximately 7.0, and 9.3 lb., respectively. Standard finish options are polished, or P (highly polished and shiny), or LS (non-brushed and dull). A textured suede finish is also available at an additional cost.

**ES-3** consists of a black phenolic paper core and two colored decorative surfaces impregnated with melamine resin. The three-ply, high performance material comes in a standard sheet size of 36 inches  $\pm$  1.00 x 39 inches  $\pm$  1.00, with standard thicknesses of 1/16, 3/32, and 1/8 inch. Standard finish options are polished, or P (highly polished and shiny), or LS (non-brushed and dull). A textured suede finish is also available.

**ES-4** is composed of layers of a pigmented paper melamine resin inner cores and white, black, or colored cover sheets. The main difference between this product and ES-1 is that the ES-4 core is colored rather than white. The material comes in a standard sheet size of 36 inches  $\pm$  1.00 x 39 inches  $\pm$  1.00, with standard thicknesses of 1/16, 3/32, and 1/8 inch. Standard finish options are polished, or P (highly polished and shiny), and Lamicaid satin, or LS (non-brushed and dull). A textured suede finish is also available.

**NP329** combines bleached linen with a melamine resin system. It provides better arc resistance than NP320E, holds up to ammonia-based refrigerants, and meets UL94, V-0 requirements. A hard material compared to phenolic linen, this durable product should be heated to be punched. Nevertheless, it machines very well with standard machining equipment. The product is sometimes chosen for decorative parts because of its white color.

## Phenolic Resin – Cotton Fabric Substrates

**BR60** consists of multiple plies of heavy-weight canvas cloth saturated with phenolic resin system, modified with molybdenum disulfide, which provides internal lubrication to reduce frictional heat generation and wear of metal shafts on the bearing. The pre-preg (b-stage) plies are then laminated under heat and pressure to produce a thermoset composite material. BR60 laminates offer load-bearing capacities equivalent to those of brass and bronze, but will not seize to metal shafts, speeding up bearing replacement and reducing equipment downtime. Compared to thermoplastics, BR60 provides superior load-bearing properties and has a Coefficient of Thermal Expansion that more closely matches the CTE of metal shafts. BR60 is used to make water-cooled propeller stave bearings on ships. In addition, steel and aluminum rolling mills prefer BR60 bearings because they last longer than metal and thermoplastic bearings in many applications and can be replaced quickly during overhauls.

**BR70** consists of multiple plies of heavy-weight canvas cloth saturated with phenolic resin system modified with alumina, which adds hardness to the bearing to reduce wear. The pre-preg (b-stage) plies are then laminated under heat and pressure to produce a thermoset composite material. Similar in construction to BR30, this product is colored red for easier inspection of bearing surfaces. BR70 laminates offer load-bearing capacities equivalent to those of brass and bronze, but will not seize to metal shafts, speeding up bearing replacement and reducing equipment downtime. Compared to thermoplastics, BR70 provides superior load-bearing properties and has a Coefficient of Thermal Expansion that more closely matches the CTE of metal shafts. BR70 is used to make water-cooled propeller stave bearings on ships. In addition, steel and aluminum rolling mills prefer BR70 bearings to metal and thermoplastic bearings because they last longer in many applications and can be replaced quickly during overhauls.

**MC223** is a medium-weave cotton phenolic composite specifically formulated to meet MIL-P-18324 requirements. Easy to machine, this product offers superior load-bearing properties and a low coefficient of friction. Known in the shipbuilding industry as “Marine Micarta”, MC223 has long been used in the industry to make dry, water-cooled, and lubricated bearings. Applications include pintle and stave-type bearings for rudder shafts. The product is also suitable for heavy equipment applications that require finer machining profiles than those provided by bearing-grade laminates.

**MC320LE** (NEMA LE) is composed of a fine-weave bleached cotton fabric combined with a phenolic resin system. This composite provides medium strength and excellent wear and electrical characteristics. MC320LE offers the best qualities of a woven cloth with a uniformly tight weave for excellent machining. It is suitable for terminal boards in the marine industry, and bearing retainers and other frictional wear applications.

**MC330** combines a cotton canvas fabric with a phenolic resin system. It is specially processed to enhance its properties for use in cryogenic applications. MC330 is easy to machine and is commonly used to make spacers for installation of liquid oxygen apparatus where temperatures reach minus 320°F,

**NP310** (NEMA C) consists of a cotton canvas fabric and general-purpose phenolic resin. The product is easy to machine and operates with less noise than metal. In addition, this material is not as abrasive as fiberglass alternatives when used in wear applications. Since it does not spark when struck, NP310 can be used in explosion-proof environments. The material is commonly used to make gears, pulleys, rollers, and guides. NP310 is a mechanical grade and does not have electrical properties comparable to NP310E. NP310 complies with the requirements of MIL-I-24768/16, Type FBM.

**NP310BW** is composed of a cotton fabric combined with a phenolic resin system, in which a metallic screen is placed to better dissipate heat than standard cotton phenolic composite by itself. This product is designed for devices that generate large amounts of heat but cannot be externally cooled using liquids. Applications include trunion wheels, wire strander rolls, and pile driver head cushions.

**NP310E** (NEMA CE) consists of a cotton canvas type fabric and electrically insulating phenolic resin system. NP310E is easy to machine and operates with less noise than metal. In addition, this material is not as abrasive as fiberglass alternatives when used in wear applications. NP310E can be used in explosion-proof environments. This material is commonly used to make gears, pulleys, rollers, and guides, as well as electrically insulated parts such as control boards. NP310E complies with the requirements of MIL-I-24768/14, Type FBG.

**NP310HT** combines a cotton canvas fabric with general-purpose phenolic resin. The product is heat treated in phenolic sheet form to reduce dimensional changes as it ages in use. NP310HT is easy to machine and operates with less noise than metal. In addition, this material is not abrasive in wear applications. NP310HT can be used in explosion-proof environments and is commonly used to make gears, pulleys, rollers, and guides.

**NP310U** is a utility grade made of low-cost materials consisting of a cotton canvas fabric and a general-purpose phenolic resin. This material is commonly used to make gears, pulleys, rollers, and guides.

**NP313** is composed of cotton fabric combined with a phenolic resin system that has been enhanced with a molybdenum disulfide powder to reduce wear. NP313 is easy to machine and operates with less noise than metal. In addition, this material is not as abrasive as fiberglass alternatives when used in wear applications. Applications include a variety of parts subject to wear and yet, NP313 maintains most of its electrical insulation properties. NP313 has better wear properties than NP310 and is used where additional lubrication is very low or non-existent.

**NP313HT** is composed of cotton canvas fabric and phenolic resin enhanced with a molybdenum disulfide lubricant to reduce wear. The product is also heat treated to reduce dimensional changes as it ages. NP313HT is easy to machine and operates with less noise than metal. Applications include a variety of parts subject to wear.

**NP315** consists of cotton canvas fabric combined with a phenolic resin enhanced with a solid graphite lubricant to reduce wear. The product is easy to machine and operates with less noise than metal. In addition, this physical material is not as abrasive as fiberglass alternatives when used in wear applications. Applications include a variety of parts subject to wear. This material can conduct electricity and it should not be used where this could cause a safety hazard.

**NP318** (NEMA CF) is a post-forming canvas phenolic material, which is composed of a cotton fabric and a modified phenolic resin system that allows the material to be heated, formed into a specific shape, and then cooled under restraint to hold the newly formed shape. NP318 does not meet the NEMA requirement for non-afterglow for Grade CF, but is used for applications by Boeing Aircraft, with exemption of the non-afterglow requirement.

**NP319** is a bleached canvas phenolic laminate with graphite added as a solid lubricant. This material has improved wear properties under certain conditions. The moisture absorption and machinability are improved when compared to NP315. NP319 is conductive to electricity and should not be used where this is detrimental to the application.

**NP320** (NEMA L) is used where better machining is needed compared to that offered by canvas grades. This product consists of a fine-weave linen fabric and general-purpose phenolic resin. Besides easy machining, NP320 operates with less noise than metal. In addition, this physical material is not as abrasive as fiberglass alternatives when used in wear applications. NP320 can be used in explosion-proof environments. It is suitable for smaller and more intricate shapes than those made with NP310, and is commonly used to make gears, pulleys, rollers, and guides.

**NP320E** (NEMA LE) is used where better machining is needed compared to that offered by canvas grades. This product consists of a fine-weave linen fabric and electrical grade of phenolic resin. Besides easy machining, NP320E operates with less noise than metal. In addition, this physical material is not as abrasive as fiberglass alternatives when used in wear applications. Since it does not spark when struck, NP320E can be used in explosion-proof environments. Suitable for smaller and more intricate shapes than those made with NP310, this product is commonly used to make gears, pulleys, rollers, and guides, as well as electrical insulating parts.

**NP320U** is a utility grade made of low-cost materials. For better machining than that offered by canvas grades, this product consists of a fine-weave linen fabric and general-purpose phenolic resin. Besides easy machining, NP320U operates with less noise than metal. NP320U can be used in explosion-proof environments, and is suitable for smaller and more intricate shapes than those made with NP310, and is

commonly used to make gears, pulleys, rollers, and guides.

**NP322** is a combination of a linen substrate and a phenolic resin binder in which a solid lubricant, molybdenum di-sulfide, is suspended. It is used when better machining than that offered by canvas grades and non-conducting internal lubrication are needed. NP322 operates with less noise than metal and can be used in explosion-proof environments. It is suitable for smaller and more intricate shapes than those made with NP313. This product is commonly used to make a variety of parts that are subject to wear.

**NP322HT** is the heat-treated version of NP322 and is used when a smoother finish and a more thermally stable part in many applications. NP322HT can be used in explosion-proof environments. It is more suitable for smaller and more intricate shapes than can be made with NP313. This product is commonly used to make a variety of parts subject to repeated wear cycling.

**NP325** is used when better machining is needed than that offered by the comparable canvas grade NP315. This product consists of a linen fabric and phenolic resin enhanced with a graphite lubricant to reduce wear. It is suitable for smaller and more intricate shapes than those made with NP315 and is commonly used to make a variety of parts subject to wear. This material is more prone to conduct electricity and it should not be used in applications where this attribute is a potential safety hazard.

**NP342** (NEMA C) consists of cotton sheeting and general-purpose phenolic resin. In terms of price and quality of machining, this material is an intermediate option between canvas and linen grades. The product is easy to machine and operates with less noise than metal. In addition, this material is not as abrasive as fiberglass alternatives when used in wear applications.

**NP342LS** consists of cotton sheeting combined with a general-purpose phenolic resin system. In terms of price and quality of machining, this material is an intermediate option between canvas and linen grades. NP342LS includes additives and heat treating prior to shipment, which reduces shrinkage when the product is in use. NP342LS is approved for use in air motor vane applications.

**NP344** is composed of cotton sheeting and phenolic resin system enhanced by a molybdenum disulfide lubricant that reduces wear. The product is easy to machine and operates with less noise than metal. In addition, this physical material is not as abrasive as fiberglass alternatives when used in wear applications. The machining quality is between NP313 and NP347. NP344 is commonly used to make a variety of parts subject to wear.

**NP347** is composed of a bleached cotton canvas combined with a phenolic resin system enhanced by a molybdenum disulfide lubricant that reduces wear. NP347 is easy to machine and operates with less noise than metal equivalents. NP347 uses a finer fabric than NP313 and therefore, can be machined with a smoother finish for better fit and less exposed fibers. It also has better machining characteristics than the non-bleached version, NP344. It is used to make a variety of parts subject to wear, which also require the smoother final finish.

### **Epoxy Resin – Glass Fabric Substrates**

**MC511A** (NEMA G-11) is a high performance thermoset epoxy fiberglass composite that provides higher strength than MC511AF. The product offers excellent physical, mechanical, and electrical properties at both room temperature and elevated temperatures. MC511A is chosen over high-temperature mat glass thermoset composites and high performance glass-filled thermoplastics because of its excellent machining characteristics, outstanding dimensional stability, superior creep resistance, and excellent high-temperature and performance characteristics. In use, the product is often exposed to continuous temperatures as high as 155°C for up to a decade. And in short-term applications such as insulation in aerospace and defense systems, the material withstands temperatures in excess of 300°C. Halogen free to conform to European restrictions, MC511A is specially formulated to meet exacting power generation standards requiring higher strength at elevated temperatures. The product is considered the premier material for use as Class F insulation in electrical power generation and transmission equipment.

**MC511AF** (NEMA G-11) is a high strength medium weight fiberglass epoxy resin composite that offers excellent physical, mechanical, and electrical properties at both room temperature and elevated temperatures. The product retains at least 50 percent of its room-temperature flexural strength at 150°C (E-1/150, T-150).

MC511AF is chosen over high temperature glass mat composites and high-performance glass-filled thermoplastics because of its excellent machineability, outstanding dimensional stability, superior creep resistance, and overall endurance over long periods of time in the application. In use, the product is often exposed to continuous temperatures as high as 155°C for up to a decade. And in short-term applications such as insulation in aerospace and defense systems, the material withstands temperatures in excess of 300°C. Halogen free to conform to European restrictions, MC511AF is specially formulated to meet exacting power generation standards requiring higher strength at elevated temperatures. The product is considered the standard material for use as Class F insulation in electrical power generation and transmission equipment.

**MC511FR** (NEMA FR-5) is a high strength medium weight glass epoxy composite that offers excellent physical, mechanical, and electrical properties at both room temperature and elevated temperatures. It is similar to MC511AF but also has a UL 94 flammability rating of V-1. The product retains at least 50 percent of its room-temperature flexural strength at 150°C (E-1/150, T-150).

**MC511SN - StatNot™** is a composite consisting of woven glass and a static-dissipative epoxy resin system. It offers electrostatic dissipative properties ( $10^6$  to  $10^{10}$  Ω/Sq). This material is used when static dissipation is required from surface to surface of the composite in the X, Y, and Z directions. The product can serve as corona discharge and static dissipative slot filler material in structural applications. Other applications include PCB test fixtures and tabletops used for testing and repair of military and civilian electronics.

**NP130** (NEMA FR-4) consists of a woven glass fabric substrate combined with a halogenated epoxy resin system. It is produced to printed circuit board quality standards, is flame retardant and meets UL-94 flammability classification V-0. NP130 meets or exceeds the requirements of MIL-I-24768/27, Type GEE-F, and IPC 4101, sheet 21.

**NP130HF** (NEMA FR-4) is a glass fabric epoxy composite that is a lower resin content version of NP130. NP130HF is engineered to provide higher flexural strength, higher flexural modulus (stiffness), and resistance to warp and twist than other NEMA Grade FR-4 products. The product is also more dimensionally stable than some similar offerings. Users give the product high marks for its performance in applications such as printed circuit board testing. NP130HF meets or exceeds the requirements of MIL-I-24768/27, Type GEE-F.

**NP500A** (NEMA G-10) is a glass fabric combined with a halogen-free epoxy resin system. The product offers a combination of excellent electrical characteristics and superior physical properties. In addition, it is not flame retardant and meets NEMA G-10 requirements. NP500A is used for structural support and insulation properties. It is also suitable for pipe shoes and vacuum applications. NP500A complies with the requirements of MIL-I-24768/2, Type GEE, and IPC 4101, sheet 20.

**NP500CR** (NEMA G-10) is composed of a woven glass fabric combined with a halogen-free epoxy resin system. The product also offers superior physical properties and excellent electrical characteristics that are maintained in high-humidity conditions. In addition, it is not flame retardant and meets NEMA G-10 requirements. Designed to withstand absolute zero temperatures, the product is manufactured to the NIST G-10CR process specification for materials used in deep space and cryogenic applications. NP500CR complies with the requirements of MIL-I-24768/2, Type GEE.

**NP510A** (NEMA FR-4) combines a woven glass fabric and an epoxy resin laminate ( $T_g$  approximately 130°C) that contains bromine. The product provides consistent quality and good electrical properties under dry and humid conditions, as well as high flexural, impact, and bond strength at room temperatures. This product is suitable for a variety of structural, high humidity, and electrical insulation applications, which include terminal boards, lapping carriers, and disc and microelectronics polishing. NP510A complies with the requirements of MIL-I-24768/27, Type GEE-F.

**NP511** (NEMA G-11) combines a woven glass fabric and a high temperature epoxy resin system ( $T_g$  over 180°C) that is non-brominated. The product provides consistent quality and good electrical properties under dry and humid conditions, as well as high flexural, impact, and bond strength at room and elevated temperatures. This product is suitable for a variety of structural, high humidity, and electrical insulation applications, which include cryogenic applications and many other applications for which very high or very low temperatures are part of the environmental requirement of the application. NP511 meets or exceeds the requirements of MIL-I-24768/3, Type GEB.

**NP511EM** (NEMA G-11) is very much like NP511 with the exception that it is easier to machine. It has the same thermal and electrical characteristics, meets all of the physical and electrical properties of NEMA G-11 and has higher arc resistance than NP511. NP511EM can be used in most applications where NP511 is used, but it is not recommended for cryogenic applications.

**NP512** combines a woven glass fabric and an epoxy resin system. The product provides high flexural, impact, and tensile strength at room temperatures along with a very high flexural modulus. NP512 is suitable for applications requiring enhanced flexural modulus and physical strength beyond the conventional characteristics of NEMA FR-4.

**NP571** is a high performance composite providing superior mechanical strength at continuous operating temperatures of 210°C and above. The high temperature characteristics make the NP571 ideal for numerous uses in power generation, oil & gas seals and gaskets, and aerospace applications. In addition to superior strength, NP571 also provides excellent machining characteristics, outstanding dimensional stability, and superior creep resistance. In use, this product maintains its physical, mechanical, and electrical properties for up to a decade.

**SP525M - WaveMax 5000™** is a combination of a non-woven random glass mat substrate combined with a high temperature, static dissipative epoxy resin system. Offering superior machining properties, WaveMax 5000 “cuts like butter.” In the production of finely machined parts, the product can be used to machine strong but very thin walls without breakout. WaveMax 5000 provides excellent mechanical strength at a continuous operating temperature of 190°C. In addition, short exposures to temperatures approaching 360°C (such as those produced during wave soldering and IR reflow) will not adversely affect the life of the material.

**SP526M - WaveMax 6000™** is a combination of a non-woven random glass mat substrate combined with a high temperature, static dissipative epoxy resin system. In the production of finely machined parts, WaveMax™ can be used to machine strong but very thin walls without breakout. WaveMax 6000 provides excellent mechanical strength at a continuous operating temperature of 250°C. In addition, short exposures to temperatures approaching 360°C (such as those produced during lead free wave soldering) will not adversely affect the life of the material.

#### **Various Resins – Glass Fabric Substrates**

**MC504BR - ShotBlocker™** is the only commercially available Class 1-A fire-rated projectile resistant building material. Lighter than steel, ricochet-resistant, and readily installed with ordinary power hand tools, ShotBlocker is the ideal reinforcing substrate for ballistic resistant architectural and building projects. ShotBlocker consists of woven glass fabric impregnated with a high temperature phenolic resin system. This product offers good flexural, compressive, and impact strength at elevated temperatures, as well as excellent creep resistance provided by the phenolic resin system. Unlike some competitive ballistic products, it does not require a messy and labor intensive wet lay-up process. From government facilities to bank teller stations, armored vehicles, and commercial aircraft, ShotBlocker provides far greater security and protection in walls, doors, and counters than similar polyester-based anti-ballistic laminates. ShotBlocker also complies with several federal and state flame and smoke protection regulations.

**MC507U** consists of multiple plies of woven fiberglass impregnated with silicone resin and laminated under heat and pressure to produce a high temperature thermoset composite. This silicone resin woven glass composite material offers excellent mechanical characteristics and electrical insulation, as well as thermal insulation properties equivalent or superior to those of expensive engineering thermoplastics. The product is mainly used as high temperature electrical insulation or thermal insulation in applications such as oven, welding, and plasma-cutting insulators. In these applications, this fiberglass composite can withstand short-term exposure to temperatures as high as 600°C, as well as continuous exposure to temperatures up to 220°C for periods as long as several years.

**MC514MG** is a high performance thermoset composite which is manufactured using an electrical grade of woven fiber glass, combined with a high temperature phenolic resin system. The resin system has a specially milled graphitic carbon additive which eliminates stray electrical potentials which can damage insulation in generators. The graphitic carbon additive in the resin system enables lubrication for easy installation in the slots.

**NP504** (NEMA G-3) is a high performance composite manufactured from a woven glass fabric with high-



temperature phenolic resin system. NP504 offers high temperature resistance, as well as good flexural, compressive, and impact strength at elevated temperatures. In addition, the phenolic resin system gives the product excellent creep resistance. This thermoset composite does not melt or become soft with heat, and therefore can be used for seals, acid-resistant gaskets, oven internals, and various structural applications. NP504 complies with the requirements of MIL-I-24768/18, Type GPG.

**NP509** (NEMA G-9) consists of woven glass fabric combined with a melamine resin system. The product is a very hard and flame resistant machining grade with excellent electrical properties in low humidity conditions. It also offers high physical strength and excellent arc resistance, while meeting UL flammability requirement, 94 V-0 or better. Applications include switchboard panels, arc barriers, circuit breaker parts, and structural/electrical components. NP509 complies with the requirements of MIL-I-24768/1, Type GME, and MIL-I-24768/8, Type GMG.

**NP515LS** (NEMA G-3) is a high performance composite manufactured from a woven glass fabric with high-temperature phenolic resin system. It is engineered to provide superior shrink characteristics at elevated temperatures, making it an ideal material for insulating gaskets. NP515LS complies with the requirements of IEC 60893-3-4 PF GC 201.

**NP522** is a high performance composite manufactured from OCV Technical Fabrics ShieldStrand™ reinforcement with a high-temperature phenolic resin system. It was developed to comply with stringent Military requirements as a ballistic resistant material. As such NP522 complies with MIL-DTL-64154B, Class B, Code 2. It is typically used as armor on vehicles required by the United States Department of Defense.

**NP523** is a high performance composite manufactured from AGY S-2 Glass® with a high-temperature phenolic resin system. It was developed to comply with stringent Military requirements as a ballistic resistant material. As such NP523 complies with MIL-L-64154 and MIL-DTL-64154B, Class A, Code 1. It is typically used as armor on vehicles required by the United States Department of Defense.

**P95** consists of woven glass fabric with polyimide resin. The product is engineered to maintain excellent physical properties at 240°C, making it suitable for high temperature applications. It offers a low coefficient of thermal expansion, as well as high mechanical strength and consistent quality. It can be used for structural components, thermal insulators, PCB manufacture and assembly, and high temperature gaskets in petrochemical plants and other applications requiring excellent compressive strength, low moisture absorption, and excellent chemical resistance.

### **Various Resins - Synthetic Substrates**

**Specialty Kevlar™ Reinforcement:** Norplex-Micarta offers customized Kevlar substrates that are combined with epoxy resin, phenolic resin, or polyimide resin systems.

**Specialty Nomex™ Reinforcement:** Norplex-Micarta offers customized Nomex products that are combined with epoxy, phenolic, or polyimide resin systems.

**NP101** (NEMA N-1) uses a modified phenolic resin on a woven nylon fabric substrate. The product offers good impact strength and excellent electrical properties under high humidity conditions. NP101 meets the requirements of MIL-I-24768/9, Type NPG.

**NP193E** is a combination of aramid and glass fibers woven into a fabric, impregnated with a high temperature epoxy resin. NP193E offers high wear resistance and long life in compressor applications. It can also take the place of asbestos in the vane industry, where it is considered a low-cost alternative to vanes made entirely of an aramid fabric.

**NP193M** is a combination of aramid and glass fibers woven into a fabric and impregnated with a melamine resin system. Melamine is highly resistant to anhydrous ammonia; therefore, the vanes produced with this material replace asbestos in refrigeration compressors.

**NP193P** combines woven aramid fiber/glass fabric combined with a high temperature phenolic resin system. The product offers excellent mechanical strength at elevated temperatures and in adverse environments. Applications include aircraft brakes, wear plates for conveyor systems, and vanes in compressors and pumps.

NP193P features high wear resistance and long life in compressor applications. It can also take the place of asbestos in the vane industry.

**NP193PM** is composed of a texturized aramid and "soft glass" fibers which are combined to make a fabric that is stronger than pure aramid and less abrasive than glass fabrics. This material is impregnated with a high temperature phenolic resin system which includes a non-conducting solid lubricant. This high performance composite has excellent mechanical strength at elevated temperatures and in adverse chemical environments. Applications include wear plates for conveyor systems, valve plates, and compressor and pump vanes.

### **Composite Combinations**

**MC450SB - StormBlocker™** is a high strength composite panel composed of a woven fiberglass surface combined with a proprietary core which was developed to withstand 250mph winds and the flying debris generated by F-5 tornadoes and CAT-5 hurricanes. A potential life and property saver. The *StormBlocker* Shelter System is constructed as an above-ground storm shelter within a home.

**NP424** (NEMA CEM-1) is a composite material composed of an epoxy resin system, combined with woven glass fabric surfaces and paper core. Initially designed as a low-cost alternative to NEMA Grade FR-4 products, NP424 offers easy punching, excellent mechanical and electrical properties, and higher flexural strength than paper-based grades. NP424 is mainly used in the printed circuit board industry, but can be used for any application that requires higher performance than a phenolic paper-based product. It offers higher strength, better moisture absorption, and better electrical properties than all of the paper and canvas phenolic systems. NP424 complies with the requirements of MIL-I-24768/29, Type CEM-1.

**NP615** combines a NP612 core with high resin content melamine impregnated surfaces for improved arc resistance. NP615 is a room temperature shearing and punching grade in thicknesses up to 0.125 inch. Compared to NP611, the product is more flexible but provides less robust mechanical properties. Applications include switch backs where arcing may be present during opening and closing of switch contacts.

**NP634** is a combination of a NP611 core combined with phenolic glass cover plies. A non-NEMA grade, NP634 provides higher mechanical strength and dimensional stability than NP611.

**NP900** consists of a core made from paper and a phenolic resin system that is combined with rubber on one side and frequently a fiber cover opposite the rubber. A non-NEMA grade, NP900 is typically used to produce gaskets or washers.

MADE WITH	USED IN	FEATURES	NEMA GRADE	COLOR
PAPER PHENOLIC	Mechanical grade, intricate punch parts, insulating washers, switch bases, terminal boards	Requires little to no preheating. good cold shearing, cold punch	XP	Tan
			XP	Black
			XP	Chocolate
PAPER PHENOLIC	Mechanical grade, intricate punch parts	Excellent cold punch and cold shearing	XPC	Chocolate
			XPC	Tan
			XPC	Black
PAPER PHENOLIC	Mechanical grade, punch parts 3/32" max thickness	Non Nema, warm punch		Tan Chocolate Black
PAPER PHENOLIC	Mechanical grade	Non Nema, warm punch		Tan Chocolate Black
PAPER PHENOLIC	Mechanical grade, terminal boards, structural parts, switch bases, washers, panels	General purpose. high mechanical strength, electrical properties are secondary	X	Natural
PAPER PHENOLIC	Electrical grade, switch board panels, relay and switch bases, breaker arms, barriers	Electrical insulation in dry or humid conditions, good machining, fair mechanical strength	XX	Natural
			XX	Black
PAPER PHENOLIC	Electrical grade, panel boards, high voltage switch, gear, radio, television panels	Electrical insulation, high humidity resistance, good dimensional stability, excellent resistance to splitting	XXX	Natural
			XX	
PAPER PHENOLIC	Mechanical grade, intricate punch parts, insulating washers, switch bases, terminal boards	Solid black color throughout, requires little to no preheating, good cold shear and punch	XP	Black
PAPER PHENOLIC	Mechanical grade, thick punch parts 3/32" through 1/4"	Ultra Soft punch plate, cold punch. Solid black color throughout	XPC	Natural
			XPC	Black
PAPER PHENOLIC	Electrical grade, punch parts, electronic equipment, insulating washers and spacers	Electrical insulation, low dielectric losses in severe humidity, warm punch	XXP	Tan
PAPER PHENOLIC	Electrical grade, punch parts, radio & TV terminal boards, panels, U.L. listed as 65M03 unclad	Cold punch and shearing, high insulation resistance and low dielectric losses under severe humidity	XXXPC	Natural
FINE WEAVE COTTON CLOTH PHENOLIC	Mechanical grade, fine tooth gears, radio parts, terminal boards	High mechanical strength, good appearance, good machining qualities	L	Natural
FINE WEAVE COTTON CLOTH PHENOLIC	Electrical - mechanical grade, marine relay bases, terminal bases and strips, radio parts, high humidity applications	Electrical and mechanical strength, moisture resistance	LE	Natural
			LE	Black
FINE WEAVE COTTON CLOTH PHENOLIC	Mechanical grade - for fine machined parts, gears, radio parts, terminal boards	Fine weave canvas where better than CE machining characteristics are required & grade L cannot be justified		Natural
MEDIUM WEAVE COTTON CLOTH PHENOLIC	Mechanical grade, gears, pinions, spacers, structural applications	Economy grade, high impact strength, good mechanical properties	C	Natural

<b>MEDIUM WEAVE COTTON CLOTH PHENOLIC</b>	Mechanical - electrical grade, small gears, pinions, radio parts, marine switch board panels	Economy grade, good acid resistance, low voltage, low frequency electrical performance	CE	Natural
<b>MEDIUM WEAVE COTTON CLOTH PHENOLIC</b>	Mechanical grade, marine bearings, piston and packing rings, pump valve, doctor blades, marine Phenolic	Low moisture absorption, dimensional stability		Natural
<b>MEDIUM WEAVE COTTON CLOTH PHENOLIC</b>	Mechanical grade, valves, plating tanks	Low moisture absorption, good dimensional stability, good resistance to acids and alkalies		Natural
<b>MEDIUM WEAVE COTTON CLOTH PHENOLIC</b>	Mechanical grade, support blocks, spacers for liquid oxygen tanks	Special formulation for cryogenic applications, property retention at extremely low temperatures		Natural
<b>MEDIUM WEAVE COTTON CLOTH PHENOLIC</b>	Mechanical grade, packing rings, pistons, bearings	Canvas with molybdenum disulfide, low coefficient of friction		Green
<b>MEDIUM WEAVE COTTON CLOTH PHENOLIC</b>	Mechanical grade, wire stranders, heat dissipation applications	Canvas with copper screen		Natural
<b>MEDIUM WEAVE COTTON CLOTH PHENOLIC</b>	Mechanical grade, pistons, packing rings, textile mill bearings	Canvas with graphite, self-lubricating, low coefficient of friction		Black
<b>GLASS CLOTH MELAMINE</b>	Electrical - mechanical grade, switch board panels, arc barriers, circuit breaker parts, structural electrical parts	High mechanical strength high arc and heat resistance, self-extinguishing, excellent electrical properties under dry conditions	G-5	Gray
<b>GLASS CLOTH MELAMINE</b>	Electrical - mechanical grade, marine switch board panels, structural parts	High mechanical strength, high arc and heat resistance, self-extinguishing, excellent electrical properties under dry and humid conditions	G-9	Gray
<b>GLASS CLOTH SILICONE</b>	Electrical grade, class H insulation, heating-appliance insulation	Good electrical properties under humid conditions, excellent heat and arc resistance, self-extinguishing	G-7	White
<b>GLASS CLOTH EPOXY</b>	Electrical - mechanical grade, terminal boards, high humidity applications, U.L. listed as 65M38 unclad	High flexural, impact and bond strength at room temperatures, good electrical properties under dry and humid conditions	G-10	Green
<b>GLASS CLOTH EPOXY</b>	Electrical - mechanical grade, rotor slot insulation, structural members at elevated temperatures	High mechanical strength at temperatures up to 150°C, retains 50% of its flexural strength at elevated temperatures	G-11	Green

### Typical properties of phenolics

ASTM or UL test	Property	General purpose	Impact	Non bleeding	Electrical	Heat resistant	Glass reinforced	Chemical resistant compound
<b>PHYSICAL</b>								
D792	Specific gravity	1.35- 1.46	1.36- 1.41	1.37- 1.38	1.36- 1.75	1.41- 1.84	1.7- 2.0	1.37- 1.75
D570	Water absorption, 24 hours, 1/8 inch thick (%)	0.6-0.7	0.6-0.9	0.8-0.9	0.05- 0.20	0.30- 0.35	0.05- 0.2	0.20- 0.40
<b>MECHANICAL</b>								
D651	Tensile strength (psi)	6,500- 7,000	6,000- 7,000	6,000- 7,000	5,000- 7,000	5,000- 6,000	6,000- 12,000	7,000- 9,000
D790	Flexural modulus (105 psi)	11-13	12	10	17-25	14	20-30	10
D790	Flexural strength (psi)	9,000- 11,000	10,000	10,000	9,000- 11,000	10,000	12,000- 24,000	9,500

D256	Impact strength, izod (ft-lb/in. of notch)	0.30- 0.35	0.6- 1.05	0.28	0.28- 0.45	0.26	0.4-1.5	0.50
D785	Hardness, Rockwell E	70-95	82	82	75-88	94	92-104	76
<b>THERMAL</b>								
C177	Thermal conductivity (104 cal - cm/sec- cm <sup>2</sup> - °C)	7.1	7.9	-	16.0	-	-	8.8
D696	Coefficient of thermal expansion (105 in./in.-°C)	3.95	3.56	4.40	2.60	2.80	1.80	3.60
D648	Deflection temperature (°F) At 264 psi	275-360	270-500	370	310-400	330-380	370-550	360-430
UL94	Flammability rating 1/8 inch	V-1	HB	-	V-0	V-0	V-0	HB
<b>ELECTRICAL</b>								
D149	Dielectric strength (V/mil) short time, 1/8 in. thick	350	350-400	200	400	170	400	175
D150	Dielectric constant At 1kHz	5.2-5.3	5.2-5.4	-	4.9-6.5	11.7	4.4	7.8
D150	Dissipation factor At 1kHz	0.04- 0.05	0.04- 0.06	-	0.025- 0.10	0.15	0.03	0.12
D257	Volume resistivity (ohm-cm) At 73°F, 50% RH	1011- 1012	1011- 1012	1012	1011- 1013	1012	1012	1011
D495	Arc resistance(s)	100	50	-	184	181	181	-

### **Thermoset Plastic Laminate.**

Thermoset Plastic Laminate is a uniformly dense and structurally strong material that will not soften appreciably under the reapplication of heat. It is an extremely durable plastic that is lightweight and moisture resistant. Industrial laminates are thermoset resin impregnated reinforcing materials (paper, cotton fabric, glass fabric, etc.) that are cured under heat and pressure to form solid shapes having high mechanical and electrical insulating properties. Laminates are available in sheet, rod, tube, and angle. Since laminates are comprised of a combination of materials, they are also referred to as composites.

### **Standard stock grades include:**

**G10/FR4 Glass Reinforced Epoxy** - natural (yellowish to light green) The most versatile all around laminate, this grade is a continuous glass woven fabric base impregnated with an epoxy resin binder. It has extremely high mechanical strength, good dielectric loss properties, and good electric strength properties, both wet and dry. Certifies to Mil-I-24768/27 GEE-F

**G11/FRS Glass Reinforced Epoxy** - natural (yellow green to amber) This grade is similar to G10/FR4, with the addition of a higher operating temperature and some improved mechanical strength at elevated temperatures. Certifies to Mil-I-24768/28 GEB -F

**G5/G9 Class Reinforced Melamine** - natural (grayish brown) This grade is composed of a continuous glass woven cloth base impregnated with a melamine resin binder. Melamines are the hardest of all laminates, exhibiting good dimensional stability and are resistance. It is also caustic resistant. Certifies to Mil-I-24768/1 CME

**G7 Glass Reinforced Silicone** - natural (cream to white) Composed of a continuous glass woven cloth base impregnated with a silicone resin binder, this grade has excellent heat and are resistance. It has extremely good dielectric loss properties under dry conditions and good electrical properties under humid conditions, although the percentage of change is high. Certifies to Mil-I-24768/17 GSG

**X/XX/XXX Paper Reinforced Phenolic** - natural (tan) This grade is composed of a paper base impregnated with a phenolic resin binder. It has good electric strength properties with fair mechanical strength. Outstanding for use as template material and or backup material. Certifies to Mil-I-24768/112 PBM, I11 PBG and /10 PBE

**C/CE Cotton Fabric Reinforced Phenolic** - natural (light tan to brown) This grade is composed of a continuous cotton woven cloth impregnated with a phenolic resin binder. This grade contains a medium weave canvas and is known primarily for it's mechanical properties. This grade is not recommended for primary insulation. Certifies to Mil- I-24768/14 FBG

**Linen L/LE Cotton Fabric Reinforced Phenolic** - natural (light tan to brown) This grade is composed of a continuous cotton woven cloth impregnated with a phenolic resin binder. This grade contains a fine weave linen and, like the canvas phenolic, is known for it's

mechanical properties. The finer weave allows for machining more intricate details than Canvas, like gear teeth. This grade is not recommended. for primary insulation. Certifies to Mil-I-24768/13 FBE

**Mat Glass Reinforced Polyester** - GPO-1 (tan) and GPO-3 (red) These grades are composed of random mat (non-woven) fiberglass reinforcement held together by a polyester resin binder. GPO-3 offers superior arc and track resistance.

**THERMOSET SHEET TOLERANCES**  
All measurements are in inches

THICKNESS Decimal Inches	ALL Glass Grades	ALL GPO Grades	ALL Paper Grades	C Canvas Grade	CE Canvas Grade	L Linen Grade	LE Linen Grade
.005	±.001	-	-	-	-	-	-
.010	±.002	-	±.002	-	-	±.003	±.003
.015	±.003	-	±.0025	-	-	±.0035	±.0035
.020	±.004	-	±.003	-	-	±.004	±.004
.025	±.0045	-	±.0035	-	-	±.004	±.004
.031	±.0065	±.0075	±.0035	±.0065	±.0065	±.005	±.005
.047	±.0075	-	±.0045	±.0075	±.0075	±.0055	±.0055
.062	±.0075	±.0075	±.005	±.0075	±.0075	±.006	±.006
.093	±.009	±.009	±.007	±.009	±.009	±.007	±.007
.125	±.012	±.010	±.008	±.010	±.010	±.008	±.008
.156	±.015	±.011	±.009	±.011	±.011	±.009	±.009
.187	±.019	±.0125	±.010	±.0125	±.0125	±.010	±.010
.250	±.022	±.015	±.012	+0.30	±.015	+0.24	±.012
.312	±.026	-	±.0145	+0.35	±.0175	+0.29	±.0145
.375	±.030	±.020	±.017	+0.40	±.020	+0.34	±.017
.437	±.033	-	±.019	+0.44	±.022	+0.38	±.019
.500	±.036	±.024	±.021	+0.48	±.024	+0.42	±.021
.625	±.040	±.027	±.024	+0.53	±.027	+0.53	±.024
.750	±.043	±.029	±.027	+0.58	±.029	+0.54	±.027
.875	±.046	-	±.030	+0.62	±.031	+0.60	±.030
1.000	±.049	±.033	±.033	+0.65	±.033	+0.65	±.033
1.250	±.055	-	±.037	+0.73	±.037	+0.73	±.037
1.500	±.061	-	±.041	+0.81	±.041	+0.81	±.041
1.750	±.067	-	±.045	+0.89	±.045	+0.89	±.045
2.000	±.073	-	±.049	+0.97	±.049	+0.97	±.049

Sheet tolerance thickness - At least 90% of the sheet will measure within the tolerance given in the above table.

Sheet tolerance Length and Width - The tolerance in length and width of standard sheet sizes will be plus or minus 1" from standard.

Thickness range " from - to	Percentage warp & twist allowed	36" width warp (" ) allowed	48" length warp (" ) allowed
.031 - .062	5.0%	1.800	2.400

<b>.063 - .125</b>	<b>2.5%</b>	<b>.900</b>	<b>1.200</b>
<b>.126 - 2.50</b>	<b>1.0%</b>	<b>.360</b>	<b>.480</b>
<b>.251 - .750</b>	<b>0.5%</b>	<b>.180</b>	<b>.240</b>
<b>.750 - max</b>	<b>0.25%</b>	<b>.090</b>	<b>.120</b>

Sheet tolerance Warp and Twist - In the case of warp, this percentage is stated in terms of the lateral dimensions (length or width); in the case of twist, one corner to the diagonally opposite corner.

\*\* The value for grade G-7 is 1.5 percent

Note 1- These values do not apply to cut pieces but only to sheet sizes manufactured.

Note 2- For method of measuring warp and twist, see ASTM-D-709

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