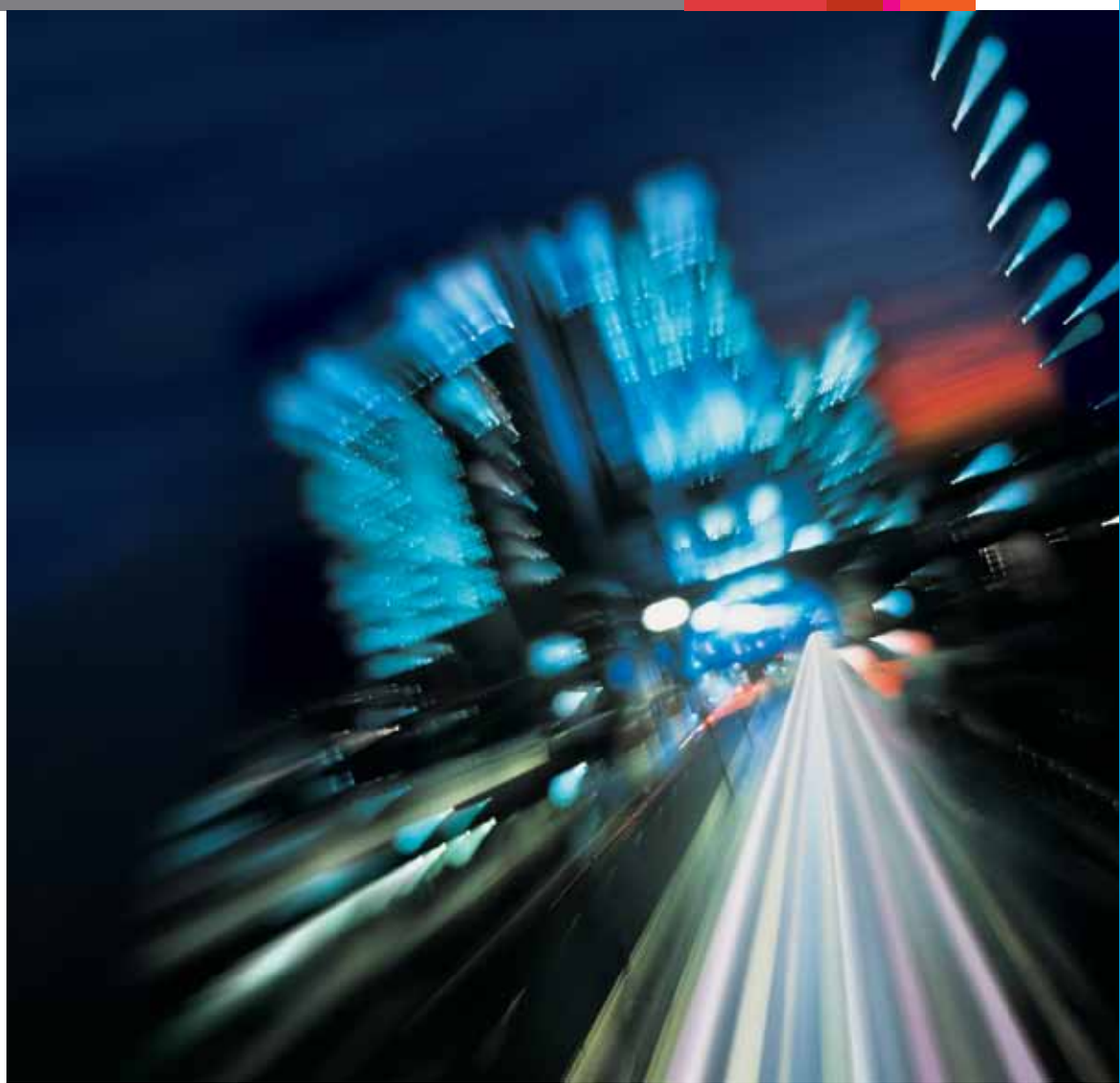
Setting the Standard for Electrical Insulation

PERFORM WHEN THE HEAT IS ON



DUPONT®

Nomex®

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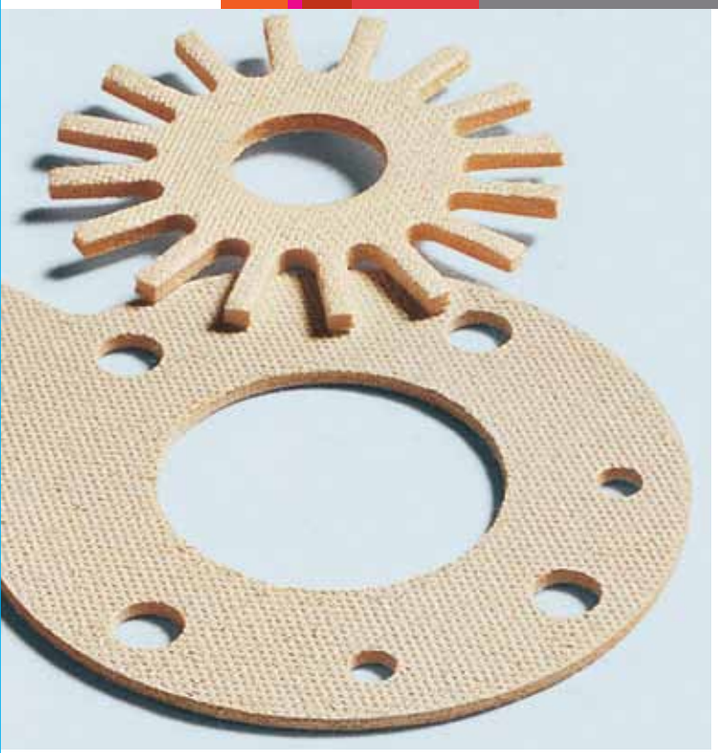


Proven Reliability

Nomex® thermal technology performs in the most demanding electrical applications

Wherever there's a need for electrical insulation, there are usually Nomex® brand products to fill it. In its various forms – primarily papers and pressboards – Nomex® has a unique balance of properties for use in transformers, motors, generators and other electrical equipment. This unique balance of properties has helped provide reliability to manufacturers for over 40 years. Nomex® is a synthetic aromatic polyamide polymer that provides high levels of electrical, chemical and mechanical integrity, when converted into its various sheet forms. Used properly, Nomex® products help extend the life of electrical equipment and reduce premature failures.

Nomex® products have characteristics which make them ideally suited for electrical insulation applications. These characteristics may vary slightly, depending on the form and type of Nomex®. The following pages provide a comprehensive look at Nomex® and explain the advantages of using it in a broad range of electrical applications. Within the family of Nomex® products – papers, pressboards, non-wovens, fabricated parts and specialized forms such as laminates and creped papers – there is a solution to help you meet your particular requirements. Contact a DuPont representative for more information and assistance.

Superior Characteristics

A unique combination of properties gives Nomex® superior characteristics

Inherent dielectric strength
In densified form, Nomex® products withstand short-term electrical stresses of 18 to 40 kV/mm (457 to 1015 V/mil), depending on product type and thickness.

Mechanical toughness
Densified Nomex® products are strong, resilient and (in the thinner grades) flexible, with good resistance to tearing and abrasion.

Thermal stability
Temperatures up to 200°C have little or no effect on the electrical and mechanical properties of Nomex® products, and useful values are retained at considerably higher temperatures. Furthermore, these useful properties are maintained for at least 10 years of continuous exposure at 220°C.

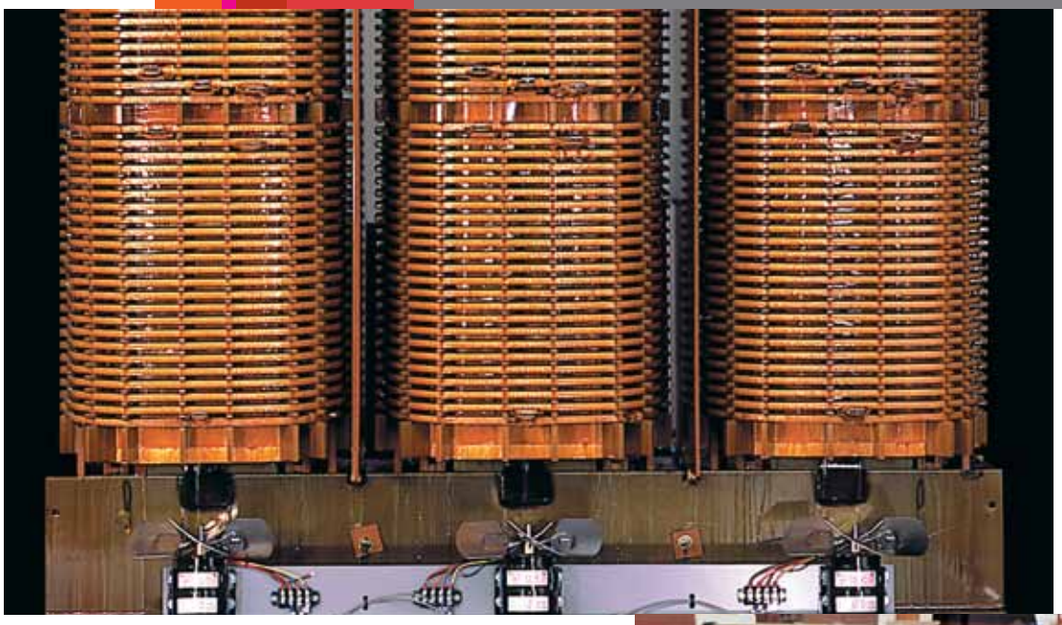
Non-toxic/flame resistant
Nomex® products do not produce any known toxic reactions in humans or animals. Nomex® products do not melt and, with a limiting oxygen index (LOI) at 220°C above 20.8 (the critical value for combustion in air), they do not support combustion. A safety information brochure (MSDS) is available upon request. Nomex® products fulfilling UL 94V-0 requirements are available, and a data sheet detailing UL ratings for our products is also available.

Chemical compatibility
Nomex® is essentially unaffected by most solvents, and is unusually resistant to attacks by acids and alkalis. It is compatible with all classes of varnishes and adhesives, transformer fluids, lubricating oils and refrigerants. Since Nomex® products are not digestible, they are not attacked by insects, fungi or mold.

Moisture insensitivity
In equilibrium at 95 percent relative humidity, densified Nomex® papers and pressboards maintain 90 percent of their bone-dry dielectric strength, while many of their mechanical properties are actually improved.

Cryogenic capabilities
Nomex® has found acceptance in a variety of cryogenic applications due to its unique polymeric structure. At the boiling point of nitrogen (77 K), Nomex® Type 410 paper and Nomex® Type 993 and Nomex® Type 994 pressboards have tensile strengths in excess of room temperature values.

Radiation resistant
Nomex® is essentially unaffected by 800 megarads (8 Mgy) of ionizing radiation and still retains useful mechanical and electrical properties after eight times this exposure.



Nomex® papers and pressboards in dry-type transformers provide many benefits, including proven performance, enhanced safety and low transmission losses.

Short and Long Term Benefits

Nomex® papers and pressboards provide short and long term benefits in dry-type transformers

Dry-type transformers, ranging in size from electronic power supplies and lighting ballasts to 19 MVA/35 kV distribution transformers, have been benefiting from the superior performance of Nomex® paper and pressboard insulation for more than 40 years.

Nomex® offers proven performance in dry-type transformers
Ventilated dry-type transformers (VDT) and cast resin transformers are growing in popularity worldwide. Nomex® papers and pressboards permit major design improvements in these types of transformers. For example, transformers insulated with Nomex® offer the following advantages to end users:

Safety
There are no fluids to spill, explode or burn, and Nomex® does not support combustion in air. In the case of a building fire, Nomex® products do not produce significant amounts of toxic smoke or dangerous particles. For this reason, among others, Nomex® is used extensively in honeycomb structures for aircraft interiors.

Low transmission losses
Since dry-type transformers insulated with Nomex® can be located close to their loads – inside factories, schools, hospitals and apartments – low-voltage lines can be shortened with a consequent reduction of the related losses.

Help reduce cost, size and weight
Dry-type transformers insulated with Nomex® can be designed with temperature rise up to 150K, requiring less conductor and core steel, and resulting in lower initial cost. This reduced size and weight contributes to ease of installation, especially since no vaults or catch basins are required. Smaller cores also mean lower no-load losses.

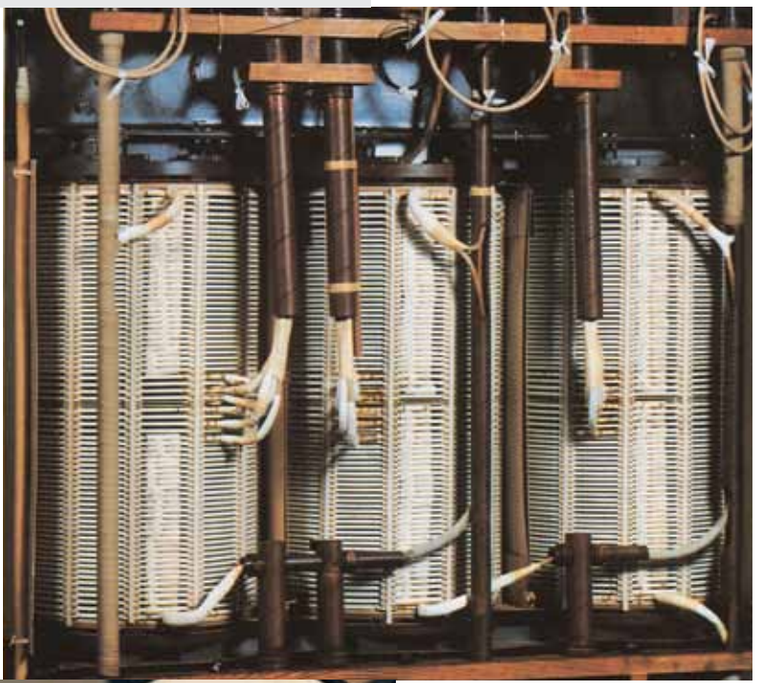
Capability for harmonic loading
Transformers supplying loads with heavy harmonic content frequently see high hot spot temperatures. Standard transformers typically reduce the increase in base temperature to compensate, which raises the size of the unit. Dry-type and fluid-filled transformers designed with Nomex® still have a large reserve temperature capability to accommodate these hot spots.

Reserve capacity
If transformers are to be operated continuously at or near their rated loads, efficiency is of prime importance. In this case, one could select 80K rise VDT units insulated with Nomex®, allowing these units to operate continuously at 133 percent of rated load.

Proven reliability
Surveys published by IEEE show failure rates of modern, open-ventilated, dry-type transformers equivalent to conventional fluid-filled units in the same power and voltage classes. Repair time for dry-type units is also considerably shorter.

Resistance to humidity
Since the properties of densified Nomex® papers and pressboards are insensitive to moisture, transformers insulated with Nomex® perform satisfactorily in humid environments. This allows the placement of VDT or cast coil units in many locations not considered in the past.

Nomex® offers benefits, including proven performance and reliability in fluid-filled transformers.



Proven Performance

Nomex® offers proven performance in fluid-filled transformers

Fluid-filled transformers

Nomex® paper and pressboard in fluid-filled transformers offer the potential for a variety of economic and safety benefits, including light weight, small size, reduction in fluids, safety, low flammability, capacity and low energy losses. These advantages contribute to:

Reduced size and weight

While maintaining top oil temperatures at constant levels with only modest increases in average oil temperatures, the weight of a transformer can be reduced by as much as 25 percent for a given kVA output. Conversely, the kVA rating can be increased by up to 50 percent for a given size and weight.

This weight reduction allows mobile substations and railway traction transformers, for example, to be designed with operating capabilities larger than before. More compactly designed transformers are revolutionizing the wind-generator marketplace in a similar manner. Use of high temperature fluids like silicone oil or ester fluids permit even greater savings in size and weight.

Excellent characteristics

Insulation systems based on Nomex® maintain excellent electrical and mechanical characteristics over a transformer's service life. Negligible aging, resistance to shrinkage and compression, and the superior resilience of Nomex® help to assure coil structures will remain tight and able to withstand short circuit forces even after years of service.

Reserve capacity

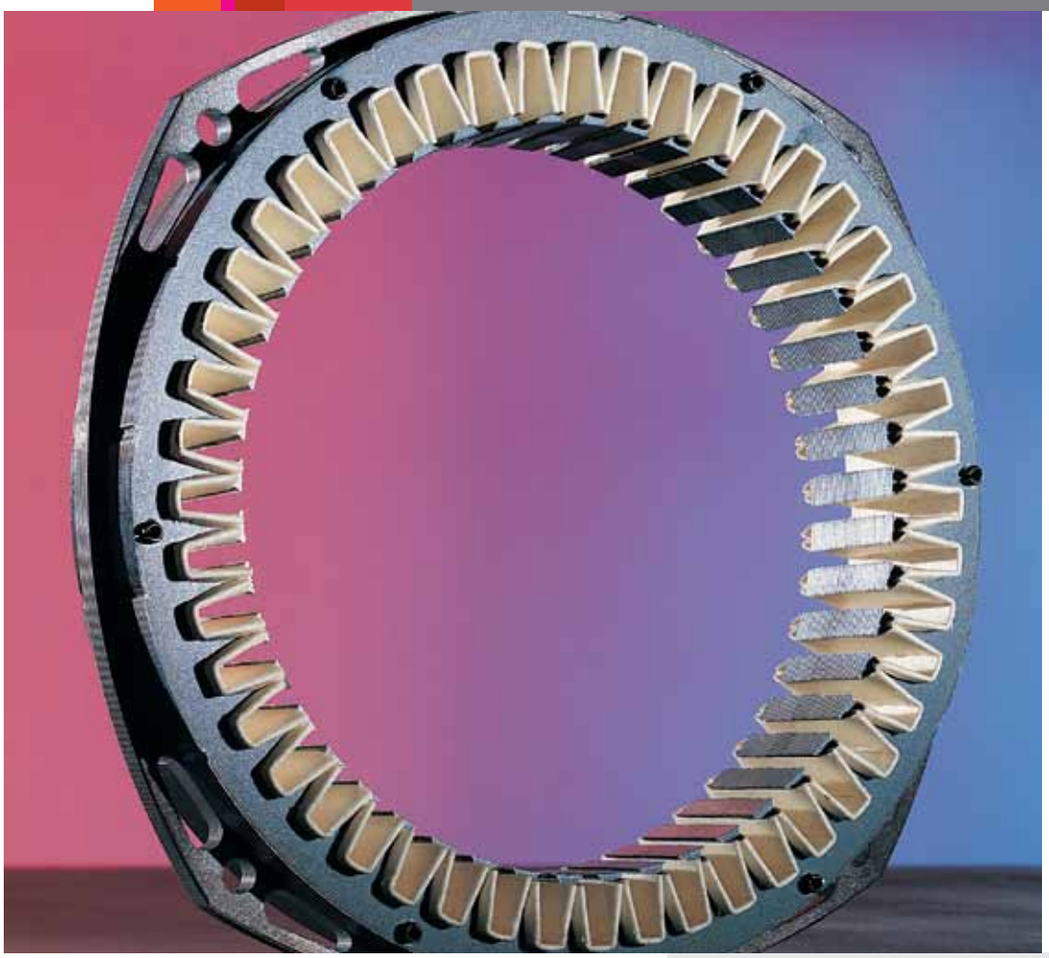
Transformers insulated with Nomex® can be designed to have extra power capacity for emergency peak load situations. This can result in substantial savings in redundancy planning.

Standardization

Customers for transformers insulated with Nomex® have included users in the power utility, industrial and railway markets. IEEE Guide 1276 and IEC Technical Specification 60076-14 provide guidance to manufacturers and users regarding the production and application of some of these transformers.

Specific applications in fluid-filled transformers where Nomex® is used, include:

- Mobile Transformers
- Traction Transformers
- Wind Turbine Transformers
- Repaired Transformers
- Utility Substations
- Unit Substations
- Rectifier Transformers
- Furnace Transformers
- Pole Top Distribution Transformers
- Pad Mounted Distribution Transformers



Rotating machines made with Nomex® papers and pressboards offer proven performance.

Extending Life

Nomex® papers and pressboards help increase reliability to users and help extend the lives of motors and generators

Nomex® papers and pressboards have numerous applications in motors, generators and transformers. Nomex® is used in all types of rotating equipment, from AC and DC to random and form wound, in sizes from miniature servo motors to 13.6 kV industrial drives and 150 MW steam-turbine generators. Additionally, Nomex® papers and pressboards provide significant advantages to users of motors and generators.

Thermal protection

The use of Nomex® for ground insulation can help prevent premature motor failure and equipment downtime. This is because Nomex® does not shrink, embrittle, soften or melt during short-term exposure to temperatures as high as 300°C, and because it maintains good insulating properties continuously at 220°C for 10 years.

Motors may encounter temperatures considerably above their design ratings due to:

- Overloads caused by reduced speeds or stalled rotors
- Restricted cooling (especially in dirty environments)
- Reduced line voltage or unbalanced phases
- Frequent starts and stops
- Unusually high ambient temperatures

Because of its superior thermal properties and mechanical strength, Nomex® can help enhance motor performance and reliability.

Boosted mechanical toughness

The strength and resilience of Nomex® papers and pressboards help extend rotating equipment life in severe operating conditions. These conditions include the severe shock and vibration seen in steel mill drives and railway traction motors, as well as the abrasion caused by thermal expansion and centrifugal forces in standby gas-turbine generators.

A family of products for motor applications

With a broad spectrum of application needs and requirements, motors and generators come in all shapes and sizes, each with its own unique technical specifications. From servo motors to turbine generators, these specifications dictate a vast assortment of thermal, electrical and mechanical requirements for the motor designer to meet. DuPont provides critical solutions for this range of needs. The graphic on Page 16 shows the breadth of products from DuPont, by application and temperature class, available to help the motor designer.

Nomex® papers and pressboards provide many advantages to manufacturers of motors and generators.

Many Advantages

Nomex® papers and pressboards offer manufacturers of motors and generators many advantages

One product line for all needs

The flexibility and formability of Nomex® Type 410 and 414 papers (0.18 to 0.38 mm) (7 to 15 mil) facilitate their insertion (automatic or manual) as slot liners. Their resilience holds them in the slot. The stiffness of thick grades of Nomex® papers (0.51 to 0.76 mm) (20 to 30 mil) makes them especially useful as slot wedges, topsticks and midsticks, inserted by machine or by hand. Thicker Nomex® papers are routinely hot-formed into permanent shapes such as slot wedges and V-ring segments. Additionally, Nomex® pressboards can be cut and shaped into sticks and other, more complex shapes. The high dielectric strength and cut-through resistance of Nomex® papers may permit replacement of thicker materials, thereby gaining additional space in the slot.

Reduced slot liner damage

The tear resistance of Nomex® papers help reduce slot liner damage during winding and shaping of the coils in random-wound motors. Under more severe conditions, two- and three-ply laminates of Nomex®/Mylar®/Nomex® and Nomex®/Kapton®/Nomex® can help provide a superior slot insulation barrier.

Reduced tooling cost

End-laminations of Nomex® pressboards can be punched using the same die sets used for metal laminations.

Specific insulating parts in which Nomex® is used in rotating equipment

Some examples of how Nomex® papers and pressboards are used in rotating equipment include:

- Slot liners
- Wedges, midsticks and topsticks
- Phase insulation
- Conductor wrap
- Coil wrap and interleaving
- End-laminations
- Lead insulation
- Pole pieces and coil supports
- Crossover tubing and end caps
- Commutator V-rings
- Bushings (for double insulation)

Other applications of Nomex® products

Other electrical applications include fire-resistant wrapper and marker tapes for cables, appliance switch covers, shields for printed circuit boards, thermal and static barriers, and speaker coils.

Diverse Materials

Nomex®, a family of insulation materials engineered to help meet the diverse demands of the electrical industry

Nomex® – quality runs through our entire line

Whether your electrical insulation needs demand creped papers, laminates or pressboard, DuPont™ Nomex® offers you a complete portfolio of high-performance insulation solutions engineered for outstanding performance and reliability.

Nomex® papers and pressboards

Nomex® papers and pressboards are made entirely of synthetic aromatic polyamide polymer. Paper and pressboard are the most widely used forms of Nomex®.

Nomex® papers

Type 410 is the original form of Nomex® paper, and is widely used in a majority of electrical equipment applications. It is produced in thickness from 0.05 to 0.76 mm (2 to 30 mil) with specific gravities from 0.7 to 1.2. As a high-density product, it has high inherent dielectric strength, mechanical toughness, flexibility and resilience. Nomex® Type 410 is used in almost every known sheet insulation application.

Type 411 is a lower-density version of Nomex® paper. It is available in thicknesses from 0.13 to 0.58 mm (5 to 23 mil), with a specific gravity of 0.3 and correspondingly lower electrical and mechanical properties. It is used in applications such as motor phase insulation and transformer coil end filler, where high bulk and conformability are of prime importance, along with increased impregnability and saturability.

Type 414 is electrically and thermally similar to Nomex® Type 410, but it is processed to produce a strong but more flexible and conformable sheet with an open surface. It is produced in thicknesses from 0.09 to 0.38 mm (3.4 to 15 mil), with specific gravities from 0.9 to 1.0. It is designed for use as slot insulation in hand-wound motors, for linear wrapping of wire, and as main insulation for fluid-filled and dry-type transformers, where conformability and impregnability are required.

Type 418 is produced by incorporating mica platelets. It is available in thicknesses from 0.08 to 0.36 mm (3 to 14 mil), and is designed for high-voltage applications, including motor conductor and coil wrap, and transformer ground and layer insulation. Nomex® Type 418 has high inherent dielectric strength (30 to 40 kV/mm) (760 to 1015 V/mil), but can also be readily impregnated with varnishes when desirable. Nomex® Type 418 offers increased voltage endurance compared to Nomex® Type 410.

Type 419 is a lower-density version of Nomex® Type 418. It is available in two thicknesses, 0.18 mm (7 mil) and 0.33 mm (13 mil), with a specific gravity of 0.5 for applications where conformability and saturability are required.

Type E56 is a medium-density paper (specific gravity 0.7) produced in thicknesses from 0.13 to 0.51 mm (5 to 20 mil). This paper has mechanical and electrical properties that fall between Nomex® Type 410 and Nomex® Type 411. It offers a higher yield and therefore, economically, a more attractive solution in applications where it is not critical to use to the full extent of the mechanical or electrical properties of Nomex® Type 410.

Nomex® pressboards

Increased thickness and rigidity set Nomex® pressboards apart from the other forms of Nomex®. They are used for spacers and barriers in transformers, both fluid-filled and dry-type, and as end-laminations in motors. This family of products offers a range of mechanical properties that help ensure design flexibility in a variety of applications.

Type 992 is a low-density pressboard produced in two thicknesses 1.6 and 3.2 mm (63 and 125 mil), with a specific gravity of 0.5. This material's low density allows easy formation of complex shapes and provides the highest saturability of the pressboard products.

Type 993 is a medium-density pressboard produced in thicknesses from 1.0 to 4.0 mm (40 to 160 mil), with specific gravities of 0.7 to 0.9. This material provides a balance of rigidity and conformability, along with outstanding saturability and excellent properties in oil.

Type 994 is a high-density pressboard, available in thicknesses from 1.0 to 9.6 mm (40 to 380 mil), with specific gravities from 1.1 to 1.2. It provides superior stability under compressive loads. Nomex® Type 994 will also absorb oils and other fluids, but not as readily as Nomex® Types 992 and 993.

Laminates based on Nomex® brand paper
Ideally suited to a variety of temperature ranges and applications, and commercially available, products include:

NM – Two-ply laminate of Nomex® and polyester film. Cost-effective, thin and slick laminates that are outstanding alternatives to those that are all polyester-based.

NMN – Three-ply laminate with polyester film between two layers of Nomex® brand paper. Broadly used in the manufacture and remanufacture of medium and large Class F and Class H motors.

NMNM – Four-ply laminate, similar to NMN, with a thin polyester film on one side to improve insertion characteristics. Most often used in applications that require extra slickness and stiffness.

NK and NKN – Two- and three-ply laminates similar to NM and NMN with polyimide film rather than polyester film. Typically found in motors and generators that operate in excess of Class H temperature requirements.

Spunlaced fabrics
Nomex® brand spunlaced fabrics Type E88C are designed for uses that require a high degree of saturability and yet must withstand severe thermal or chemical requirements. Such uses include motor phase insulation, saturable facing plies on laminates as well as saturable conductor wrap. These nonwoven sheets have an open and porous structure that allows easy saturation by resins and varnishes. Nomex® Type E88C spunlaced fabrics are available in two forms, moderate density (Styles 309A, 320A and 326A) and higher density (Styles 309B and 320B). These products are produced in thicknesses from 0.05 mm to 0.15 mm (2 to 6 mil). The higher-density form offers a higher modulus for those applications requiring increased resistance to deformation.

Nomex® brand spunlaced fabrics Type E88 are also available in a variety of weights and thicknesses for applications requiring more bulk and conformability. These products also offer excellent saturability. Information about these products is available upon request.

Fabricated parts
Nomex® products are also commercially available in a wide range of coated, laminated, formed, creped, punched and prefabricated parts for specific applications. DuPont can provide source lists of companies that provide these parts, as well as technical information on methods for cutting, forming, coating and laminating Nomex®.

Nomex® in other forms
The unique thermal, chemical and physical properties of Nomex® can be obtained in many forms. Trade-produced variations include: B-stage coated Nomex® brand papers; needle-punched felts; quilts and woven fabrics of Nomex® brand fibers; tie cords and sleeving of continuous filament Nomex® spun yarns; and many others. If your insulation needs include these or any other variations, DuPont can help you with your application and provide source lists for these materials, upon request.

Continuous Development

Creating innovative products to help meet the demands of a changing world

Pioneers. Innovators. Experts.

Nomex® paper has been available for over 40 years, since DuPont developed this unique form of electrical insulation. Many of the insulation materials were invented by DuPont. These inventions include Kapton® polyimide film, Mylar® polyester film and Voltron™ wire enamel, as well as Teflon®, Rynite® and Zytel® resins. While many of the original versions of these products have been around for over 30 years, each business continues to utilize DuPont technology and expertise to develop innovative products. With over 200 years of DuPont history, we look forward to always bringing you the most reliable, innovative and high-performing products, well into the future.

New product development

DuPont is committed to continuously developing and commercializing new and modified products to satisfy increasing needs for the electrical industry. In many arenas, DuPont personnel are involved with customers to better understand their needs and help them design improved product solutions. Continuously expanding process capability allows DuPont to develop new product variations, as well as new sheet constructions. Please share your needs with your local DuPont representative to allow us to help you identify or to develop a suitable product to match your specific requirements.

Nomex®, proven performance worldwide

International recognition

Nomex® papers have been in use for more than 40 years in electrical equipment around the world. Nomex® pressboards and nonwoven products have also received worldwide acceptance. Nomex® paper is officially recognized as a 220°C insulating material by:

IEC 60819-3-3
UL plastics component file (QMFZ2) – E34739
NEMA/ANSI Standard – FI-3

Rating organizations in England, France, Germany, Italy and Japan recognize Nomex® papers as being in their highest temperature class for insulating materials. Other than films, there are no insulating materials that are recognized by UL as 220°C component materials for electrical and mechanical uses.

Support services for users of Nomex®

Underwriters Laboratories Systems

UL has recognized over 1,400 systems based on Nomex® paper in conjunction with other components (wire enamels, sleevings, spacers, tapes, tie cords, varnishes and encapsulating compounds) that are required for motor or transformer applications. These systems are in OBJS2 files developed by a variety of materials suppliers of the above insulating components. DuPont has developed over 500 such systems in their UL files E57692 and E69939, which cover temperatures from 130° to 240°C and voltages up to 34.5 kV, and are freely available to users of DuPont materials. DuPont has established a website, www.e-insulationsys.com, to provide more information on these systems. Use of these OBJS2 systems often enables a manufacturer to obtain UL listings of their products without the lengthy and costly heat aging procedures normally required to demonstrate the chemical compatibility and thermal stability of the combined insulations. Of course, the manufacturer must still obtain UL approval of the specific electrical and mechanical design.

Brochures listing the UL-recognized insulation systems involving DuPont materials, with information on how to use them, may be obtained upon request from DuPont.

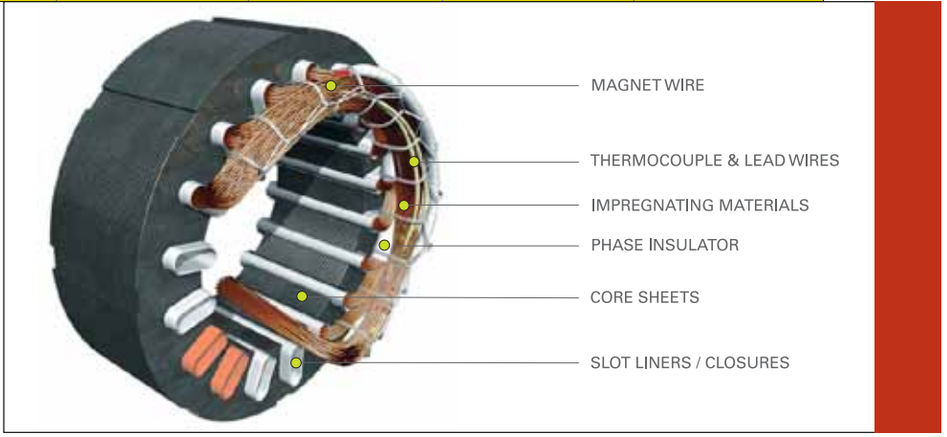
Technical assistance

Our staff of technical specialists is available to answer questions or help assist you with your technical problems related to the use of Nomex® papers or pressboards. You may reach us through your authorized distributor of Nomex® or by contacting us directly.

When needed, a DuPont representative will visit your site to become thoroughly acquainted with your operating conditions, in order to help you decide on your effective course of action.

DuPont technologies for your motors

	130° C	155° C	180° C	200° C	220° C
MAGNET WIRE ENAMELS	Herberts® Electro	Herberts® Electro	Herberts® Electro / Voltron®	Herberts® Electro / Voltron®	Herberts® Electro
MAGNET WIRE WRAP			Kapton® or Nomex®	Kapton® or Nomex®	Kapton® or Nomex®
SLOT LINER MATERIALS	Mylar®	Teonex®	Nomex®	Nomex®	Nomex®
	Melinex®	Mylar® / Nomex®	Kapton® / Nomex®	Kapton® / Nomex®	Kapton® / Nomex®
IMPREGNATING RESINS	Herberts® Electro	Herberts® Electro	Herberts® Electro	Herberts® Electro	
PHASE INSULATOR	Mylar® / Nomex®	Mylar® / Nomex®	Nomex®	Nomex®	Nomex®
CORE SHEET VARNISHES	Voltatex®	Voltatex®	Voltatex®	Voltatex®	Voltatex®
THERMOCOUPLE AND LEAD WIRE INSULATION	Tefzel®	Tefzel®	Teflon® FEP	Teflon®	Teflon® PFA



Meeting Standards

State-of-the-art quality control helps assure uniformity and reliable performance of Nomex®

A sophisticated system of checks and balances

DuPont has developed an advanced, statistically based system of quality controls for Nomex® products. The main elements are:

- Written definition and routine monitoring of all process conditions. Process conditions are computer-controlled, utilizing feedback of process and quality measurements, and are continuously monitored on the machine.
- Routine testing of statistically selected samples of all products in standardized, state-of-the-art laboratories.
- Visual inspection, with both reflected and transmitted light, which supplements automatic, online inspection of all finished products to detect and remove or correct defects caused during paper manufacture.
- Product specifications for all property and quality standards must be met before any Nomex® product can be shipped.
- Complete records of all process conditions and test results, identifiable by package number, to facilitate the traceability of any shipped product.
- Our quality systems comply with international standards and have been certified to ISO 9002 since 1991. We also upgraded our certification to the ISO 9001:2000 standards in 2002.

Additional information

Please do not hesitate to contact your local authorized distributor or us directly to obtain more detailed information about the behavior of the Nomex® products in specific conditions or to obtain advice or additional literature on:

- Processing of Nomex® products (cutting, slitting, folding, forming, coating, bonding, wrapping).
- Design guidelines for dry-type or fluid-filled transformers.
- Computerized thermal simulations for fluid-filled transformer designs enhanced with Nomex®.
- Safety data sheets (MSDS).
- Case histories of applications using Nomex® papers and pressboards.
- Moisture effects on Nomex®.
- Info on non-electrical applications using Nomex®.

To contact us about Nomex®, or for global product support, consult the information below.

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