

DuPont™
NOMEX®



SETTING THE STANDARD FOR ELECTRICAL INSULATION

PERFORM WHEN THE HEAT'S ON



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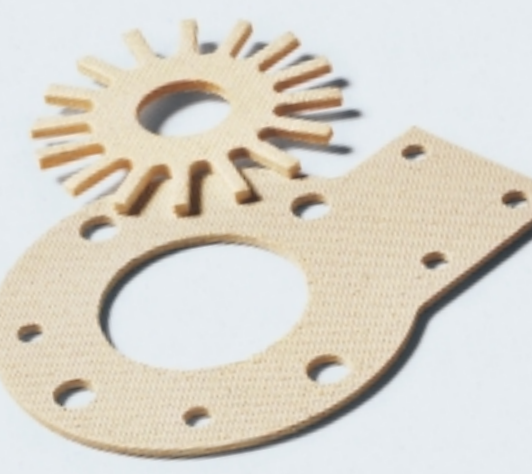
PROVEN RELIABILITY

NOMEX® thermal technology provides reliability 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 the right balance of properties for use in transformers, motors, generators and other electrical equipment. This unique balance of properties has been providing reliability to manufacturers for over 35 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 can extend the life of electrical equipment, reduce premature failures and repairs, and act as a safeguard in unforeseen electrical stress situations.

NOMEX® products have characteristics which make them ideally suited for electrical insulation applications. These characteristics may vary slightly in the different forms and types of NOMEX®. The following pages provide a comprehensive look at NOMEX® and explain the advantages of specifying it in a broad range of electrical applications. Within the family of NOMEX® products – papers, pressboards, non-wovens, fabricated parts and specialised forms – there is a solution to meet your particular requirements. Contact a DuPont representative for more information and assistance.



SUPERIOR CHARACTERISTICS

A unique combination of properties give 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, with no need for further treatment with varnishes or resins.

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.

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 mould.

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 as well as NOMEX® Type 993 and NOMEX® Type 994 pressboards have tensile strengths in excess of room temperature values.

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 mechanical properties are actually improved.





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.

NON-TOXIC/FLAME RESISTANT

NOMEX® products will 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. A data sheet detailing UL Ratings for our products is available.

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 35 years.

NOMEX® OFFERS IMPROVED 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:

ENHANCED 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.

REDUCED COST, SIZE AND WEIGHT

Dry type transformers insulated with NOMEX® can be designed with temperature rise up to 150°C requiring less conductor and core steel, 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.

IMPROVED CAPABILITY FOR HARMONIC LOADING

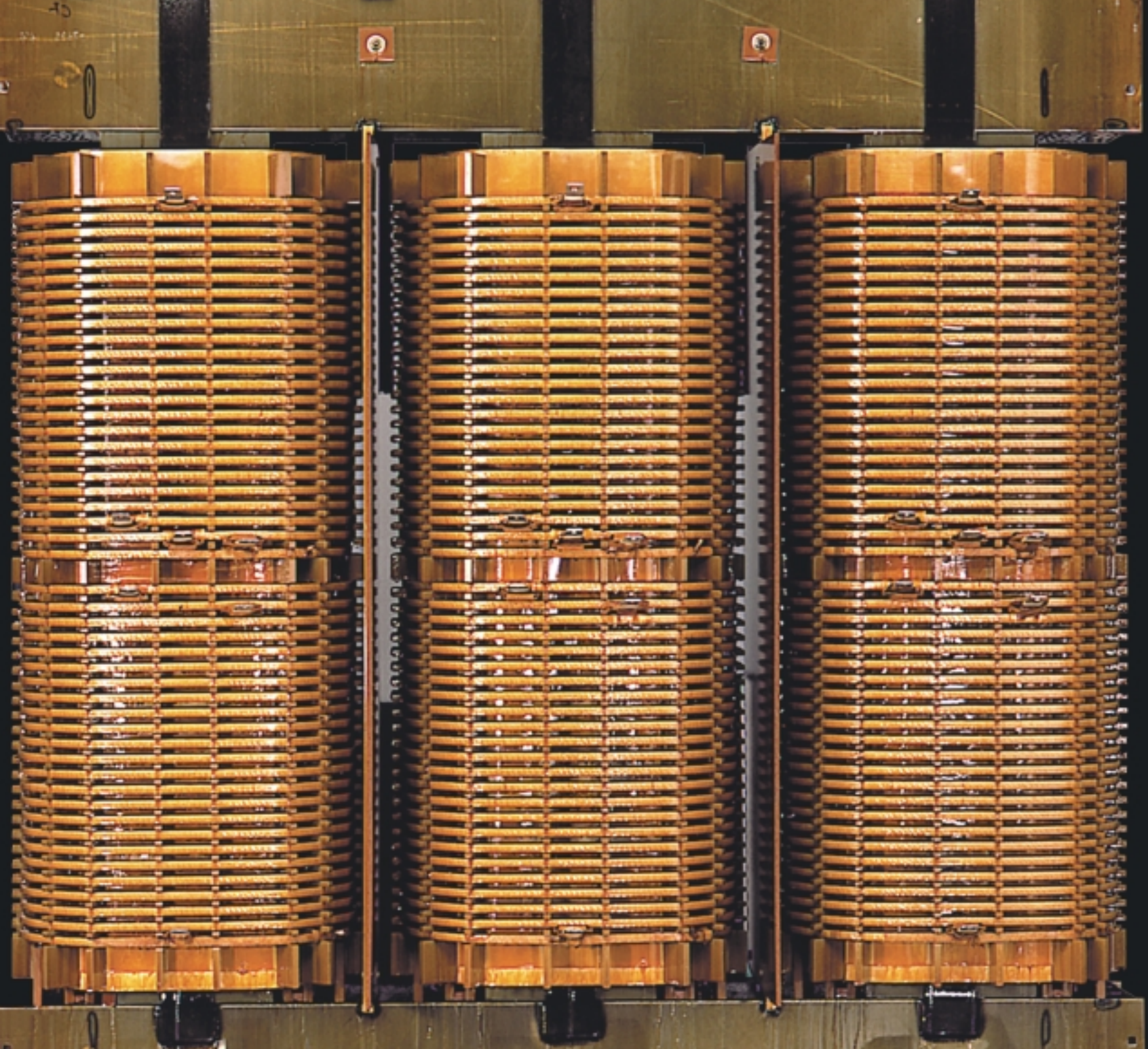
Transformers supplying loads with heavy harmonic content frequently see high hot spot temperatures. Standard transformers typically reduce the increase in base-temperature to compensate, which raises the size of the unit. Dry type and fluid-filled transformers designed with NOMEX® still have a large reserve temperature capability to accommodate these hot spots, with no loss of life.

INCREASED 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 80°C-rise VDT units insulated with NOMEX®, allowing these units to operate continuously at 133 percent of rated load (if needed, for example, due to unplanned expansions) at a much lower cost than that associated with adding an additional transformer.



Dry type transformers



IMPROVED 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. Whenever necessary, 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 the most humid environments. This allows the placement of VDT or cast coil units in many locations not considered in the past.

FRIENDLY TO THE ENVIRONMENT

At the end of their useful life, VDT units can easily be dismantled, and the copper (or aluminium) conductors recovered, along with the steel core.

IMPROVED PERFORMANCE

NOMEX® offers improved performance in fluid-filled transformers

FLUID-FILLED TRANSFORMERS

NOMEX® paper and pressboard in fluid-filled transformers offer the potential for a variety of economic, environmental and safety benefits to the user, including: lighter weight, smaller size, reduction in fluids, improved safety, less flammable transformers, more capacity and lower energy losses. These advantages can...

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 permits even greater savings in size and weight.

INCREASE RESERVE CAPACITY

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

IMPROVE RELIABILITY

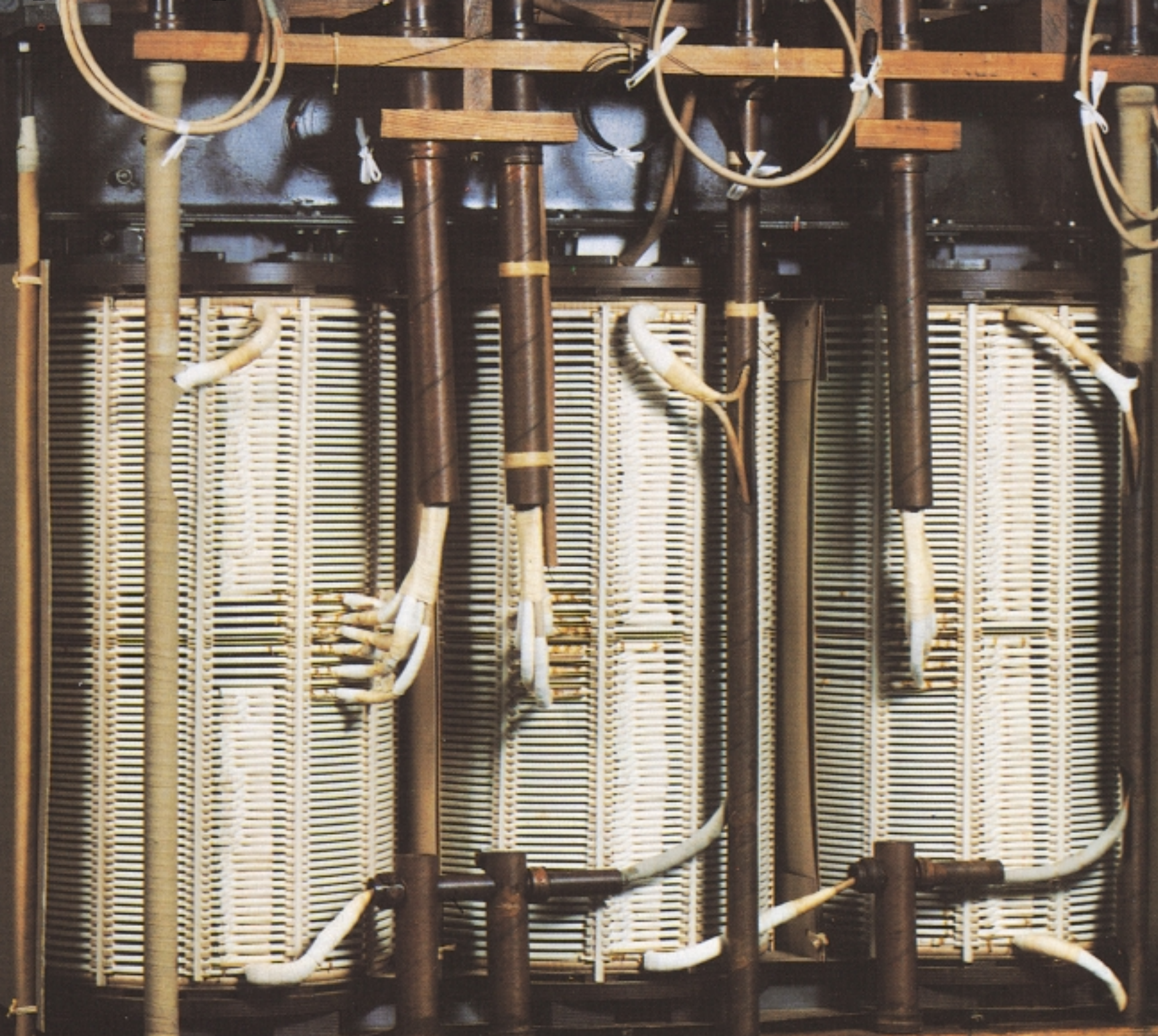
Insulation systems based on NOMEX® maintain excellent electrical and mechanical characteristics over a transformer's service life. Negligible aging, resistance to shrinkage and compression, and the superior resilience of NOMEX® help to assure coil structures will remain tight and be able to withstand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

STANDARDIZATION

Customers for NOMEX® insulated transformers have included users in the Power Utility, Industrial and Railway markets. An IEEE Guide provides guidance to manufacturers and users regarding the production and application of some of these transformers.



Fluid-filled transformers



Specific applications in fluid-filled transformers where NOMEX® is used

- Mobile Transformers
- Traction Transformers
- Repaired Substations
- Utility Substations
- Unit Substations
- Rectifiers
- Furnace Transformers
- Pole Top Distribution Transformers

EXTENDING LIFE

NOMEX® papers and pressboards offer increased reliability to users and extended life of motors and generators

NOMEX® papers and pressboards find numerous applications in motors and generators. 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. The use of NOMEX® papers and pressboards provides significant advantages to users of motors and generators.

BETTER THERMAL PROTECTION

Use of NOMEX® for ground insulation can 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 maintains good insulating

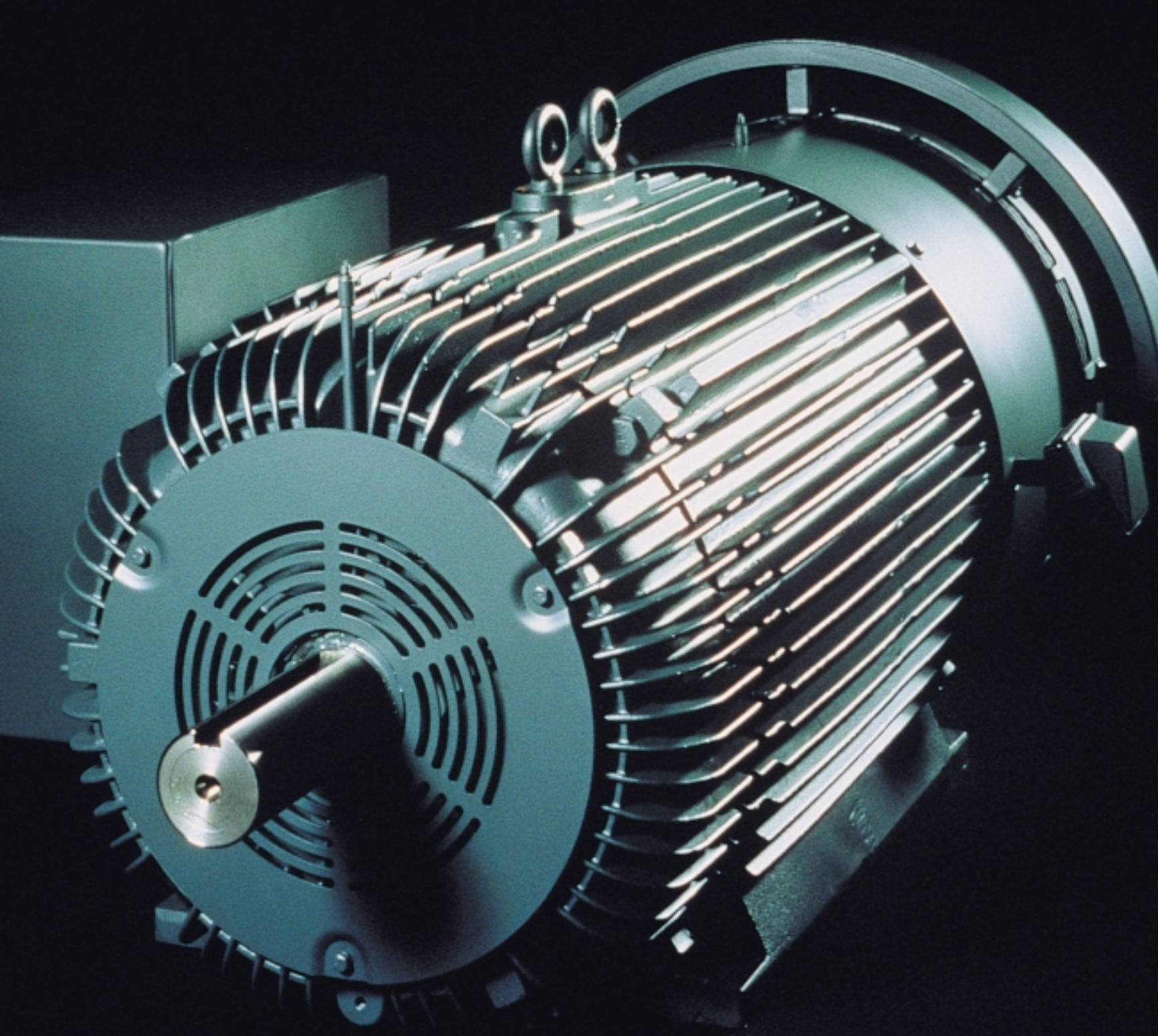
properties continuously at 220°C for 10 years. Motors may encounter temperatures considerably above their design ratings due to:

- 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, NOMEX® can enhance motor performance and reliability.



Rotating machines



BOOSTED MECHANICAL TOUGHNESS

The strength and resilience of NOMEX® papers and pressboards help extend rotating equipment life in severe operating conditions. These conditions include 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 stand-by gas-turbine 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) facilitates 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 reduces 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 be counted on to 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.

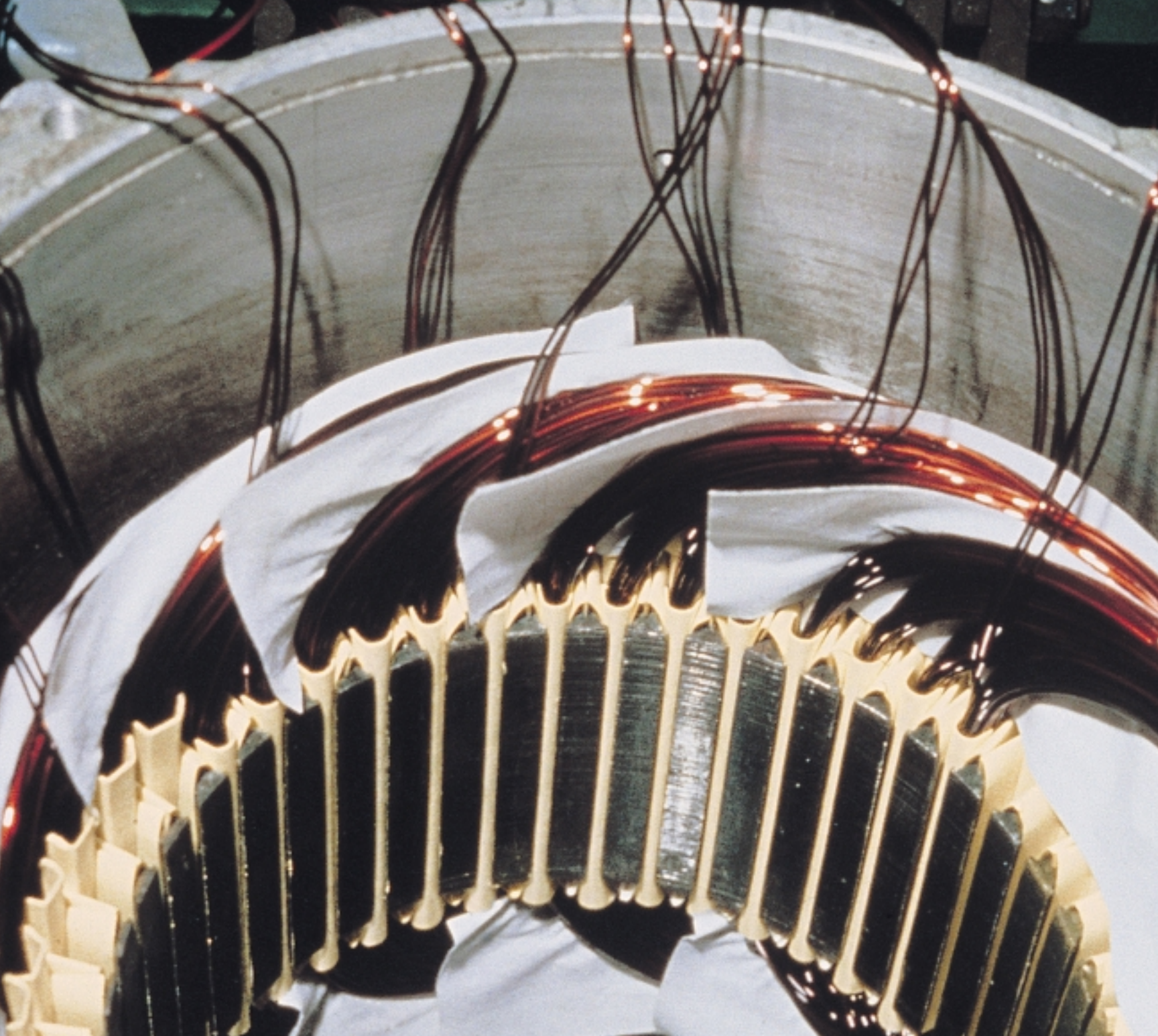
Specific insulating parts where NOMEX® is used in rotating equipment

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

- Conductor wrap
- Coil wrap and interleaving
- Slot liners



Rotating machines



- Wedges, mid-sticks and top-sticks
- Phase insulation
- End-laminations
- Pole pieces and coil supports
- Cross-over tubing and end caps
- Commutator V-rings
- Bushings (for double insulation)
- Lead 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 meet the diverse demands of the electrical industry

NOMEX® papers and pressboards

NOMEX® papers and pressboards are made entirely of synthetic aromatic polyamide polymer in two forms:

- Floc: short fibers that provide mechanical strength.
- Fibrids: microscopic filmy particles that provide dielectric strength and act as a binder.

The floc and fibrids are combined to form sheet structures by specialized paper or board-making methods. During each process the fibrids join to form filmy webs between the fibers. In most cases, the paper sheet is then densified – or calendered – at high temperature and pressure to permanently lock the components together and produce a relatively impermeable structure with high levels of electrical and mechanical integrity. Paper and pressboard are the most widely used forms of NOMEX®. There is an appropriate type and thickness for each electrical insulation application.

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 thicknesses from 0.05 to 0.76 mm (2 to 30 mil) with specific gravities from 0.7 to 1.2. As a calendered 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 the uncalendered precursor of NOMEX® Type 410. 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 is calendered under different conditions which 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 of fluid-filled and dry type transformers where conformability and impregnability are required.

TYPE 418

is produced by adding 50 percent mica platelets, intimately blended with the floc and fibrils during papermaking. 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 is a calendered product with high inherent dielectric strength (30 to 40 kV/mm) (760 to 1015 V/mil), but can also be readily impregnated with varnishes where this is desirable. NOMEX® Type 418 offers increased voltage endurance when compared to NOMEX® Type 410.

TYPE 419

is the uncalendered precursor 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 conformance 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 calendered paper has mechanical and electrical properties intermediate 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 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 which insures 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 to 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 densified version of NOMEX® Type 993, 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, 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.

CONTINUOUS DEVELOPMENT

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 calendered forms, moderate density (Styles 309A, 320A and 326A) and higher density (Styles 309B and 320B). These products are produced in thicknesses from .05 to .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 non-calendered form in a variety of weights and thicknesses for applications requiring more bulk and conformability. These products as well offer excellent saturability. Information about these products is available upon request.

New product development

DuPont is committed to continuously developing and commercializing new and modified products to satisfy new and increasing needs for the electrical industry. In many arenas, DuPont personnel are involved with customers to better understand their needs and help 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 identify or to develop the most suitable product to match your specific requirements.

Fabricated parts

NOMEX® products are also commercially available in a wide range of coated, laminated, formed, creped, punched and prefab-ricated 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: Laminates based on NOMEX® brand paper as described on page 15, which include MYLAR® or MELINEX® polyester films or KAPTON® polyimide film; 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.





NOMEX®: proven performance worldwide

INTERNATIONAL RECOGNITION

NOMEX® papers have been in use for more than 35 years in electrical equipment around the world. NOMEX® pressboards and non-woven products have also received worldwide acceptance. NOMEX® paper is officially recognised as a 220°C insulating material by:

- IEC 819-3-3
- Underwriters Laboratories, Inc. (UL) (file nr E34739)
- Bureau Veritas (France)
- Lloyds Register of Shipping (England)
- Japan Electric Manufacturers Association (file nr JEM-1264)
- NEMA (National Electrical Manufacturers Association – FI-3)

Rating organisations in Germany and Italy recognize NOMEX® papers in their highest temperature class for insulating materials.

PLASTICS-COMPONENT RECOGNITION

Other than polyimide films, NOMEX® papers and pressboards are the only sheet materials which are Component Recognised by UL as a 220°C material for electrical and mechanical uses.

Support services for users of NOMEX®

UNDERWRITERS LABORATORIES SYSTEMS

UL has recognised over 100 insulation systems based on NOMEX® paper in conjunction with other components (wire enamels, sleeveings, spacers, tapes, tie cords, varnishes, and encapsulating compounds) required for motor or transformer applications. NOMEX® pressboards have also been approved by UL as suitable substitutes for NOMEX® paper in these systems. The systems cover temperatures from 130 to 220°C and voltages up to 34.5 kV, and are freely available to users of NOMEX®. Use of such a system enables a manufacturer to obtain UL listing of his products without the lengthy and costly heat ageing 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.

A brochure listing the UL-recognized insulation systems involving NOMEX®, with information on how to use them, may be obtained upon request from DuPont or from your authorised distributor of NOMEX®.

TECHNICAL ASSISTANCE

Our staff of technical specialists is available to answer questions or assist in solving technical problems, which may be related to the use of NOMEX® papers or pressboards. We can be reached 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 the most effective course of action.

MEETING AND EXCEEDING STANDARDS

State-of-the-art quality control assures 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. Paper-forming conditions are computer controlled, utilizing feedback of process and quality measurements continuously monitored on the machine.
- Routine testing of statistically selected samples of all products in standardised, state-of-the art laboratories.
- Visual inspection, with both reflected and transmitted light, which supplements on-line automatic 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

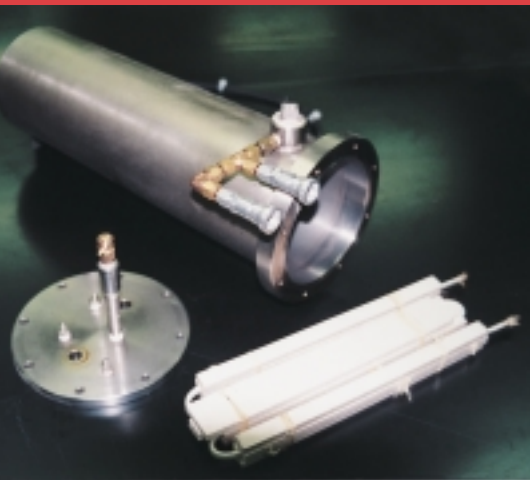
certified to ISO 9002 since 1991.

We have also recently upgraded our certification to the new ISO 9001:2000 standards in year 2002.

Additional information

Please do not hesitate to contact your local Authorised Distributor or us directly to obtain more detailed information about the behaviour 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.
- Computerised thermal simulations for fluid-filled transformer designs enhanced with NOMEX®.
- Safety data sheets (MSDS).
- Minimum guaranteed Product Purchasing Specifications.
- Case histories of applications using NOMEX® papers and pressboards.
- Moisture effects on NOMEX®.
- Info on non-electrical applications using NOMEX®.





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Product safety information is available upon request. This information corresponds to our current knowledge on the subject. It is offered solely to provide possible suggestions for your own experimentations. It is not intended, however, to substitute for any testing you may need to conduct to determine for yourself the suitability of our products for your particular purposes. This information may be subject to revision as new knowledge and experience becomes available. Since we cannot anticipate all variations in actual end-use conditions, DUPONT MAKES NO WARRANTIES AND ASSUMES NO LIABILITY WHATSOEVER IN CONNECTION WITH ANY USE OF THIS INFORMATION. Nothing in this publication is to be considered as a license to operate under or a recommendation to infringe any patent right.

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