

NOMEX® TYPE 993

Type 993 is a medium-density pressboard which offers a balance of rigidity and conformability along with outstanding saturability and excellent properties in air and oil. Typical applications include 3-dimensional parts such as V-rings, angle rings and spools, as well as barrier, gap spacers and core tubes. Type 993 is available in six thicknesses ranging from 1.0 to 4.0 mm, as is shown in Table I.

Table I – **TYPICAL THICKNESS**

| (mils) | (mm) |
|--------|------|
| 40 | 1.0 |
| 60 | 1.5 |
| 80 | 2.0 |
| 95 | 2.4 |
| 120 | 3.0 |
| 160 | 4.0 |

Electrical properties

The typical electrical property values for Type 993 pressboard in air and oil are shown in Tables II, III and IV. The data in these Tables are representative of data for all thicknesses of Type 993. The AC Rapid Rise dielectric strength data of Tables II and III represent voltage stress levels withstood for 10 to 20 second time periods at a frequency of 60 Hz. These values differ from long-term strength potential. DuPont recommends that continuous stresses in dry-type transformers not exceed 1.6 V/mm (40V/mil) to minimize the risk of partial discharges (corona).

The Full Wave Impulse dielectric strength data of Table III were generated on flat sheets,

such as in layer and barrier applications. The geometry of the system has an effect on the actual impulse strength values of the material. The dielectric strength data are typical values and not recommended for design purposes. Design values can be supplied upon request.

Table II – **DIELECTRIC STRENGTH IN AIR**

| Thickness (mm) | Dielectric Strength | |
|-------------------|--|---------|
| | AC Rapid Rise ¹⁾ (kV/mm) | (V/mil) |
| 1.0 | 21 | 540 |
| 1.5 | 22 | 550 |
| 2.0 | 20 | 520 |
| 2.4 | 20 | 520 |
| 3.0 | 20 | 520 |
| 4.0 | 19 | 490 |

¹⁾ASTM D-149, 50 mm electrodes, rapid rise; corresponds with IEC 243-1, subclause 9.1, except for electrode set-up of 50 mm

Table III – **TYPICAL ELECTRICAL PROPERTIES IN OIL**

| Nominal Thickness (mm) | 1.5 | 3.0 | 4.0 |
|--|------------------|------------------|------------------|
| Dielectric Strength | | | |
| AC rapid rise ¹⁾ (kV/mm) | 34 | 30 | 27 |
| Full wave impulse ²⁾ (kV/mm) | 73 | 62 | 60 |
| Dielectric Constant ³⁾ at 60 Hz | | | |
| 25°C | 3.2 | 3.5 | 3.6 |
| 90°C | 3.2 | 3.5 | 3.7 |
| 130°C | 3.3 | 3.7 | 3.8 |
| Dissipation Factor ³⁾ at 60 Hz (x10 ⁻³) | | | |
| 25°C | 5 | 6 | 7 |
| 90°C | 5 | 5 | 5 |
| 130°C | 7 | 7 | 6 |
| Volume Resistivity ⁴⁾ (ohm-cm) | | | |
| 90°C | 10 ¹⁶ | 10 ¹⁶ | 10 ¹⁶ |
| 130°C | 10 ¹⁵ | 10 ¹⁵ | 10 ¹⁵ |

¹⁾ASTM D-149, 50 mm electrodes, rapid rise; corresponds with IEC 243-1, subclause 9.1, except for electrode set-up of 50 mm

²⁾ASTM D-3426

³⁾ASTM D-150

⁴⁾ASTM D-257

TECHNICAL DATA SHEET

PLEASE NOTE:

The properties in this data sheet are typical, or average values and should not be used as specification limits. Unless otherwise noted, all properties were measured in air under "standard" conditions (in equilibrium at 23°C, 50% relative humidity). Note that, like other products of boardmaking technology, NOMEX® brand pressboards have somewhat different properties in the boardmaking machine direction (MD) compared to the cross direction (XD). In some applications it may be necessary to orient the board in the optimum direction to obtain its maximum potential performance.

The electrical properties are enhanced in oil due to the excellent impregnability of Type 993. This pressboard will pick up 30 to 60% oil by weight, with the oil absorption being inversely related to density. The effects of temperature on dielectric strength and dielectric constant are shown for Type 410 paper in Figure 1 of the Type 410 data sheet. Since Type 993 pressboard is chemically identical to Type 410 paper (differing only in structure), its electrical properties will react similarly to temperature changes up to and including 220°C. This is confirmed by the data on 3.0 mm (120 mil) Type 993 pressboard shown in Table IV.

Mechanical properties

The typical mechanical property values for Type 993 pressboard are shown in Table V. The effects of temperature on tensile strength and elongation are illustrated for Type 410 paper in Figure 5 of the Type 410 data sheet. The effects of short-term exposure to temperatures up to and including 220°C will be similar for Type 993 pressboard. In addition, however, the tensile strength of Type 993 NOMEX® brand pressboard can be significantly increased through heat-treatment under certain specific conditions. As with Type 410 papers, the tensile strength of Type 993 pressboard at minus 196°C (77K) exceeds its room temperature value while elongation to break is still greater than 3%. This makes Type 993 an excellent candidate for cryogenic applications.

Table IV – EFFECT OF TEMPERATURE ON ELECTRICAL PROPERTIES
3.0 mm (120 mil) Type 993

| Temperature (°C) | 23 | 50 | 100 | 150 | 220 |
|--|------------------|------------------|------------------|------------------|------------------|
| Dielectric Constant ¹⁾ at 60 Hz | 2.6 | 2.6 | 2.7 | 2.8 | 2.9 |
| Dissipation Factor ¹⁾ at 60 Hz (x10 ⁻³) | 15 | 12 | 5 | 6 | 12 |
| Volume Resistivity ²⁾ (ohm-cm) | 10 ¹⁷ | 10 ¹⁶ | 10 ¹⁶ | 10 ¹⁵ | 10 ¹³ |
| Surface Resistivity ²⁾ (ohm/square) | 10 ¹⁷ | 10 ¹⁷ | 10 ¹⁷ | 10 ¹⁶ | 10 ¹⁵ |

Values shown above were measured at 23°C after drying at 120°C until bone dry

1) ASTM D-150

2) ASTM D-257

Table V - TYPICAL MECHANICAL PROPERTIES

| Nominal Thickness (mm) | | 1.0 | 1.5 | 2.0 | 2.4 | 3.0 | 4.0 | |
|----------------------------------|-----------------------|------|------|------|------|------|------|------|
| Typical Thickness ¹⁾ | (mm) | 1.07 | 1.50 | 2.00 | 2.40 | 3.00 | 4.15 | |
| | (mils) | 42 | 59 | 79 | 94 | 118 | 163 | |
| Basis Weight ²⁾ | (g/m ²) | 720 | 1050 | 1530 | 1770 | 2270 | 3410 | |
| Density ³⁾ | (g/cm ³) | 0.70 | 0.73 | 0.76 | 0.77 | 0.82 | 0.87 | |
| Tensile Strength ⁴⁾ | (kN/cm ²) | MD | 3.53 | 4.00 | 4.75 | 4.40 | 4.60 | 4.91 |
| | | XD | 2.96 | 3.31 | 3.44 | 3.74 | 3.92 | 4.53 |
| Elongation ⁴⁾ | (%) | MD | 11.9 | 11.2 | 13.8 | 12.0 | 13.7 | 14.7 |
| | | XD | 12.7 | 12.9 | 14.1 | 12.1 | 14.2 | 15.3 |
| Shrinkage ²⁾ at 105°C | (%) | MD | 0.6 | 0.7 | 0.7 | 0.8 | 0.7 | 0.4 |
| | | XD | 0.9 | 1.0 | 1.1 | 1.1 | 1.0 | 0.6 |
| Shrinkage ²⁾ at 240°C | (%) | MD | 1.1 | 1.5 | 1.1 | 1.2 | 1.2 | 1.2 |
| | | XD | 1.6 | 1.6 | 2.0 | 1.8 | 1.8 | 1.5 |

¹⁾ASTM D-374, method D, using 17 N/cm²

²⁾ASTM D-3392

³⁾Calculated number using basis weight and thickness

⁴⁾ASTM D-828

Thermal properties

Arrhenius plots of thermal aging behavior for NOMEX® brand materials are exemplified by Figures 7, 8 and 9 of the Type 410 data sheet. Similar aging of Type 993 pressboard at elevated temperatures has resulted in its recognition as a 220°C insulating material.

The thermal conductivity of 4.0 mm (160 mil) Type 993 pressboard is shown in Figure 1 as a function of temperature. DuPont has also tested the thermal conductivity of this product impregnated with various types of transformer fluids. This data is available upon request. The graph is similar to those for cellulosic boards, and, as with most materials, is primarily affected by density. Thinner, less dense grades of Type 993 pressboard will have slightly lower conductivities, and thicker, denser grades will have higher conductivities.

Chemical stability

The compatibility of NOMEX® brand paper and pressboard with virtually all classes of electrical varnishes and adhesives (polyimides, silicones, epoxies, polyesters, acrylics, phenolics, synthetic rubbers, etc.), as well as other components of electrical equipment, is demonstrated by the many UL-recognized systems which include NOMEX® brand materials, as well as longstanding commercial experience. NOMEX® papers and pressboards are also compatible with transformer fluids, including mineral and silicone oils and other synthetics.

The Limiting Oxygen Index (LOI) of 3.0 mm (120 mil) Type 993 pressboard at room temperature is 32%, declining to 23% at 180°C. Materials with LOI above 20.8% (ambient air) will not support combustion. 3.0 mm (120 mil) Type 993 pressboard must be heated above 230°C before its LOI declines below the flammability threshold, as is shown in Figure 2.

Figure 1 - **THERMAL CONDUCTIVITY VS. TEMPERATURE** 4.0 mm (160 mil) Type 993

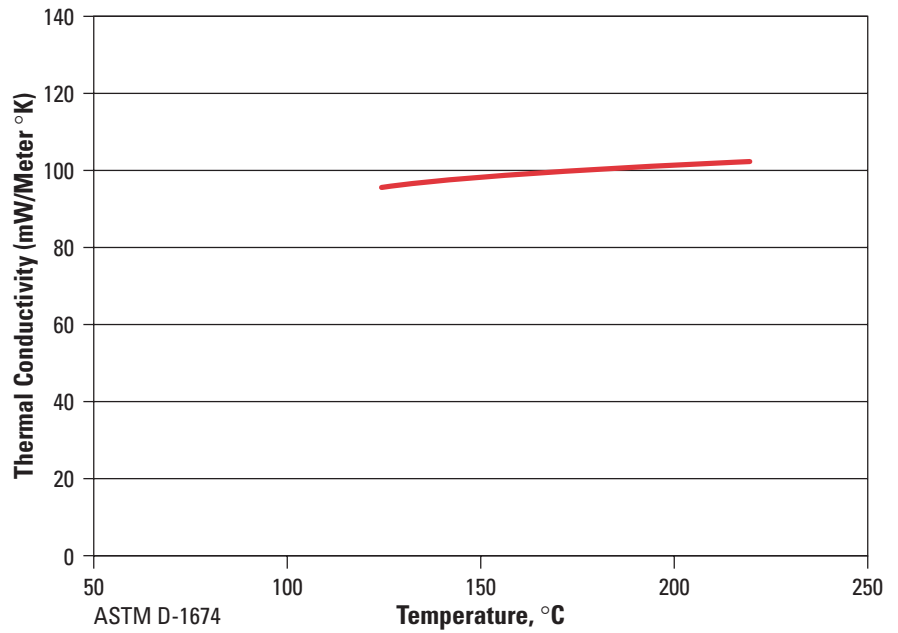
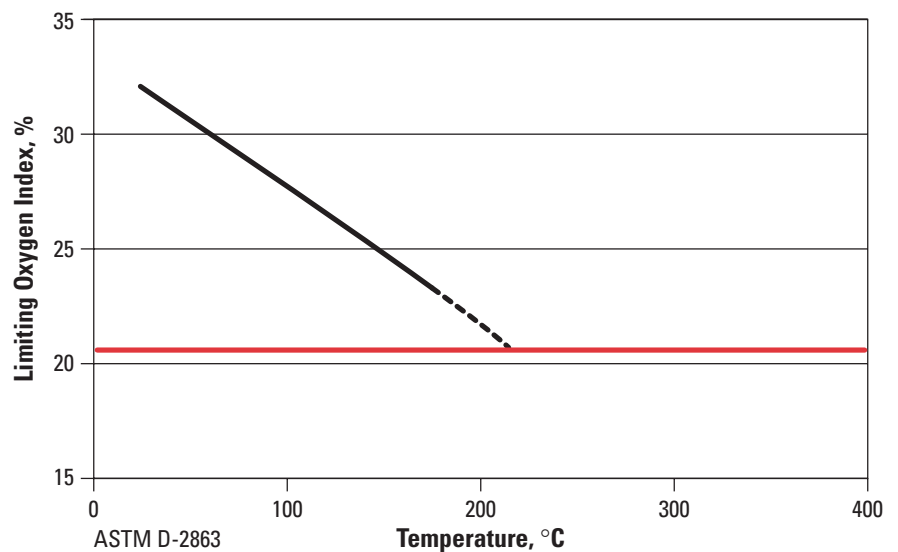


Figure 2 - **LIMITING OXYGEN INDEX (LOI)** 3.0 mm (120 mil) Type 993



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Product safety information is available upon request.

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