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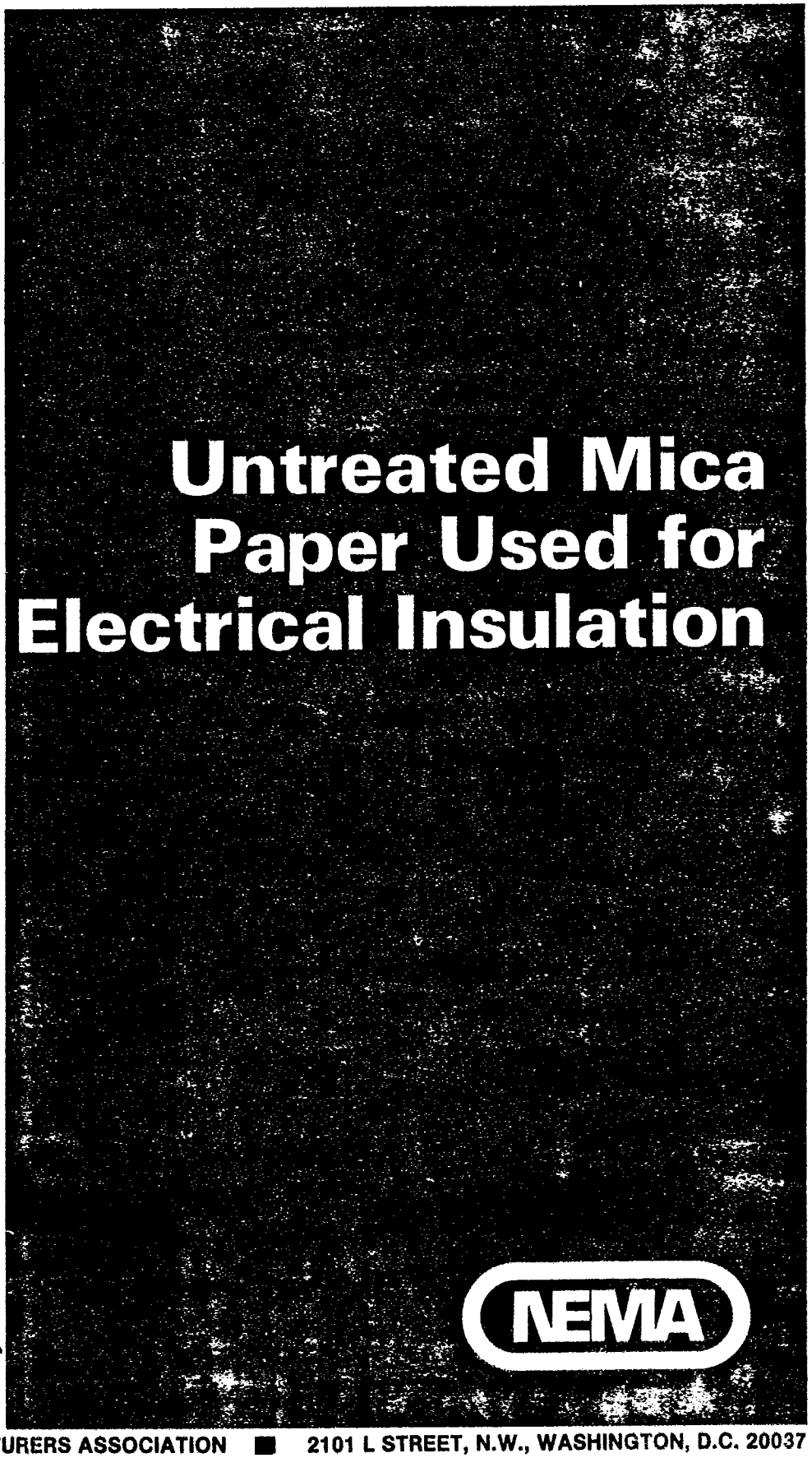
Untreated Mica Paper Used for Electrical Insulation



NATIONAL ELECTRICAL MANUFACTURERS ASSOCIATION ■ 2101 L STREET, N.W., WASHINGTON, D.C. 20037

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Foreword

These standards have been developed over a period of years in close coordination with user needs. The Flexible Insulation and Mica Section of NEMA reviews these standards periodically for any revisions necessary to keep them up to date. Proposed revisions or comments should be submitted to:

Manager, Engineering Department
National Electrical Manufacturers Association
2101 L Street, N.W.
Washington, D.C. 20037

Scope

This Standards Publication covers the procedures, conditions, and methods of sampling and testing properties of untreated mica paper used as electrical insulation or as a component in a composite used for electrical insulating purposes. The attached tables in Section 2 are typical of commercially available mica papers. Actual property values are to be established between buyer and seller.

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UNTREATED MICA PAPER USED FOR ELECTRICAL INSULATION

Section 1
DEFINITIONS AND REFERENCES

1.1 DEFINITIONS AND CHEMICAL COMPOSITION

Mica paper is defined as flexible, continuous, and uniform layers of mica reconstituted into a paper-like, electrical insulating material composed entirely of small, thin, overlapping flakes or platelets, and which has sufficient strength to be self-supporting and to be capable of being wound into roll form for commercial use. Mica paper as defined by this standard shall contain no binders, adhesives, foreign matter, or coloring agents, and shall be substantially free of any substance which will adversely affect its performance as electrical insulating material.

NEMA Standard 11-3-1983.

1.1.1 Chemical Composition of Type M—Muscovite (Granitic)

Type M—Muscovite (granitic) is sometimes called India, white, ruby, or potassium mica and is represented by typical, idealized chemical formulas $K_2Al_4Al_2Si_6O_{20}(OH)_4$ and $H_2KAl_3(SiO_4)_3$. However, some natural micas may contain other elements as isomorphous replacements in varying proportions.

1.1.2 Chemical Composition of Type P—Phlogopite (Pyroxenic)

Type P—Phlogopite (pyroxenic) is sometimes referred to as amber or magnesium mica and is represented by typical, idealized chemical formulas $K_2Mg_6Al_2Si_6O_{20}(OH)_4$ and $H_2KMg_3Al(SiO_4)_3$, but naturally occurring phlogopite mica may also contain other elements in varying proportions as isomorphic replacements.

Authorized Engineering Information 11-3-1983.

1.2 REFERENCES

In this publication, reference is made to the standards listed below:

ASTM D374-79	*Tests Methods for Thickness of Solid Electrical Insulation*
ASTM D726-58 (1971)	*Tests for Resistance of Paper to Passage of Air*
ASTM D1677-77 (1980)	*Sampling and Testing Untreated Mica Paper Used for Electrical Insulation*
ASTM D3636-80	*Sampling and Judging Quality of Solid Electrical Insulating Materials*

Copies of the above standards may be purchased from:

American Society for Testing and Materials
1916 Race Street
Philadelphia, PA 19103

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Section 2
CLASSIFICATIONS

2.1 MUSCOVITE MICA PAPER, UNCALCINED (UNFIRED) AND NOT CHEMICALLY TREATED, LARGE FLAKE SIZE (CLASSIFICATION 2.1)—TYPICAL PROPERTIES*

AVERAGE THICKNESS		RANGE OF AVERAGE THICKNESS		BASIC WEIGHT RANGE		TENSILE STRENGTH		PENE-TRATION TIME	ELECTRIC STRENGTH		MOISTURE CONTENT MAXIMUM
in	mm	in	mm	G/ft^2	G/m^2	lb/in	n/m	SECONDS	V/mil	(kV/mm)	PERCENT
0.0033	(0.0838)	0.0029-0.0038	(0.0737-0.0965)	12.10-14.10	(130.42-151.98)	5	(44)	10- 30	250	(9.84)	1
0.0053	(0.1346)	0.0044-0.0062	(0.1118-0.1575)	19.00-24.00	(204.79-258.68)	5	(44)	15- 40	250	(9.84)	1
0.0080	(0.2032)	0.0070-0.0090	(0.1778-0.2286)	30.50-34.00	(328.74-366.47)	9	(79)	35- 75	350	(13.78)	1
0.0100	(0.2540)	0.0088-0.0112	(0.2235-0.2845)	38.00-43.00	(409.58-463.48)	9	(79)	50-100	350	(13.78)	1

*These data are indicative of commercially available mica papers in general use. Actual product values are to be established between the vendor and the user.

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2.2 MUSCOVITE MICA PAPER, UNCALCINED (UNFIRED) AND NOT CHEMICALLY TREATED, MEDIUM FLAKE SIZE (CLASSIFICATION 2.2) — TYPICAL PROPERTIES*

AVERAGE THICKNESS		RANGE OF AVERAGE THICKNESS		BASIC WEIGHT RANGE		TENSILE STRENGTH		PENE-TRATION TIME	ELECTRIC STRENGTH		MOISTURE CONTENT MAXIMUM
in	mm	in	mm	G/ft^2	G/m^2	lb/in	n/m	SECONDS	V/mil	(kV/mm)	PERCENT
0.0035	(0.0900)	0.0029-0.0041	(0.075-0.105)	10.6-11.7	(114-126)	. . .	. . .	10- 20	. . .	. . .	1
0.0043	(0.1100)	0.0037-0.0049	(0.095-0.125)	14.1-15.6	(152-168)	4.5	(40)	15- 25	. . .	. . .	1
0.0063	(0.1600)	0.0051-0.0074	(0.130-0.190)	22.1-24.3	(238-262)	. . .	. . .	25- 50	. . .	. . .	1
0.0080	(0.2030)	. . .	. . .	28.0-34.4	(319-353)	4.4	(39)	97-153	435	(17.14)	1
0.0095	(0.2400)	0.0079-0.0115	(0.200-0.290)	32.7-35.6	(352-387)	4.5	(40)	60-100	. . .	. . .	1
0.0100	(0.0254)	. . .	. . .	35.0-43.0	(399-441)	5.4	(47.9)	131-209	400	(15.76)	1
0.0120	(0.3050)	. . .	. . .	42.1-51.5	(453-554)	6.25	(55.3)	154-246	375	(11.78)	1
0.0140	(0.3550)	. . .	. . .	49.0-60.2	(529-646)	7.2	(63.7)	174-276	350	(13.79)	1
0.0160	(0.4060)	. . .	. . .	56.2-68.6	(604-739)	8.1	(71.7)	185-295	335	(13.2)	1
0.0180	(0.4570)	. . .	. . .	63.0-77.2	(680-831)	9.0	(79.7)	201-319	325	(12.81)	1
0.0200	(0.5080)	. . .	. . .	72.2-85.8	(755-924)	10.0	(88.5)	212-338	315	(12.41)	1

*These data are indicative of commercially available mica papers in general use. Actual product values are to be established between the vendor and user.

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2.3 MUSCOVITE MICA PAPER, PARTIALLY CALCINED (FIRED) OR CHEMICALLY TREATED,* OR BOTH, FINE FLAKE SIZE (CLASSIFICATION 2.3)—TYPICAL PROPERTIES†

AVERAGE THICKNESS		RANGE OF AVERAGE THICKNESS		BASIC WEIGHT RANGE		TENSILE STRENGTH		PENE-TRATION TIME	ELECTRIC STRENGTH		MOISTURE CONTENT MAXIMUM
in	mm	in	mm	G/ft^2	G/m^2	lb/in	n/m	SECONDS	V/mil	(kV/mm)	PERCENT
0.0015	(0.038)	0.00135-0.00165	(0.034 -0.042)	5.1- 6.1	(54.9-65.7)	3.5	(30.9)	28	600	(23.6)	1
0.0018	(0.046)	0.00160-0.00200	(0.039 -0.051)	6.0- 7.4	(64 -80)	4	(35)	35	600	(23.6)	1
0.0020	(0.051)	0.00180-0.00220	(0.041 -0.056)	7.1- 8.3	(76 -89)	4.5	(39)	40	600	(23.6)	1
0.0026	(0.064)	0.0024 -0.0028	(0.056 -0.071)	9.1-11.1	(98 -119)	4.5	(39)	42	600	(23.6)	1
0.0030	(0.076)	0.0026 -0.0034	(0.066 -0.086)	9.4-11.4	(101 -123)	5	(44)	70‡	600	(23.6)	1
0.0040	(0.102)	0.0035 -0.0045	(0.089 -0.114)	12.6-15.2	(136 -164)	5	(44)	88‡	600	(23.6)	1
0.0050	(0.127	0.0043 -0.0056	(0.109 -0.142)	15.9-18.9	(171-203)	6	(53)	70	600	(23.6)	1
0.0060	(0.152)	0.0053 -0.0067	(0.134 -0.170)	18.8-11.3	(202 -241)	4	(53)	70	600	(23.6)	1

*The fine flakes used to make the paper may be chemically treated in the pulping operation.

†These data are indicative of commercially available mica papers in general use. Actual product values are to be established between the vendor and user.

‡These thicknesses are also available in softer varieties having penetration times of 43 and 53 seconds respectively.

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2.4 MUSCOVITE MICA PAPER, CAPACITOR GRADE, FINE FLAKE SIZE (CLASSIFICATION 2.4)—TYPICAL PROPERTIES*

AVERAGE THICKNESS		RANGE OF AVERAGE THICKNESS		BASIC WEIGHT RANGE		TENSILE STRENGTH		ELECTRIC STRENGTH		MOISTURE CONTENT MAXIMUM	MAXIMUM AQUEOUS EXTRACT CONDUCTIVITY
in	mm	in	mm	G/ft^2	G/m^2	lb/in	n/m	V/mil	(kV/mm)	PERCENT	
0.0007	(0.0177)	0.00060-0.0008	(0.0164-0.0202)	2.4-3.2	(25.8 -34.4)	2.0	(17.7)	650	(25.5)	1	5 MICROMHOS/CM
0.0009	(0.0228)	0.00075-0.00095	(0.0195-0.024)	3.1-3.9	(33.30-42.0)	3.0	(26.5)	800	(31.5)	1	
0.0013	(0.0330)	0.00115-0.00145	(0.0292-0.0368)	4.4-5.2	(47.3 -55.6)	3.0	(26.5)	1200	(47.0)	1	
0.0015	(0.0381)	0.00135-0.00175	(0.0331-0.0431)	5.0-6.4	(53.8 -68.9)	3.0	(26.5)	1400	(55.1)	1	
0.0020	(0.0508)	0.00175-0.00225	(0.0445-0.0571)	6.9-8.4	(74.2 -90.4)	4.0	(35.4)	1800	(70.8)	1	

*These data are indicative of commercially available mica papers in general use. Actual product values are to be established between the vendor and user.

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2.5 PHLOGOPITE MICA PAPER, UNCALCINED (UNFIRED) AND NOT CHEMICALLY TREATED, MEDIUM FLAKE SIZE (CLASSIFICATION 2.5)—TYPICAL PROPERTIES*

AVERAGE THICKNESS		RANGE OF AVERAGE THICKNESS		BASIC WEIGHT RANGE		TENSILE STRENGTH		PENE-TRATION TIME	ELECTRIC STRENGTH		MOISTURE CONTENT MAXIMUM
in	mm	in	mm	G/ft^2	G/m^2	lb/in	n/m	SECONDS	V/mil	(kV/mm)	PERCENT
0.0020	(0.0500)	1.6-2.4	(0.040-0.060)	5.3- 5.9	(57-63)	. . .	. . .	. . .	. . .	. . .	0.5
0.0026	(0.0650)	2.2-3.0	(0.055-0.075)	7.0- 7.8	(76-84)	4.5	(40)	7-15	. . .	. . .	0.5
0.0031	(0.0800)	2.5-3.7	(0.065-0.095)	10.6-11.7	(114-126)	6.8	(60)	15-35	. . .	. . .	0.5
0.0039	(0.1000)	3.1-4.7	(0.080-0.120)	14.1-15.6	(152-168)	7.9	(70)	25-70	. . .	. . .	0.5
0.0057	(0.1450)	4.5-6.9	(0.115-0.175)	22.1-24.3	(238-262)	9.0	(80)	40-100	. . .	. . .	0.5
0.0080	(0.2030)	. . .	. . .	28.0-34.4	(319-353)	4.4	(39)	97-153	435	(17.14)	0.5
0.0100	(0.254)	. . .	. . .	35.0-43.0	(399-441)	5.4	(47.9)	131-209	400	(15.76)	0.5
0.0120	(0.3050)	. . .	. . .	42.1-51.5	(453-554)	6.25	(55.3)	154-246	375	(11.78)	0.5
0.0140	(0.3550)	. . .	. . .	49.0-60.2	(529-646)	7.2	(63.7)	174-276	350	(13.79)	0.5
0.0160	(0.4060)	. . .	. . .	56.2-68.6	(604-739)	8.1	(71.7)	185-295	335	(13.20)	0.5
0.0180	(0.4570)	. . .	. . .	63.0-77.2	(680-831)	9.0	(79.7)	201-319	325	(12.81)	0.5
0.0200	(0.5080)	. . .	. . .	72.2-85.8	(755-924)	10.0	(88.5)	212.338	315	(12.41)	0.5

*These data are indicative of commercially available mica papers in general use. Actual product values are to be established between the vendor and user.

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Section 3
MANUFACTURING

3.1 ORDERING INFORMATION

Orders for mica paper materials should include the following information:

1. Mica paper classification.
2. Basis weight, total mass per unit area in grams/foot^2 (grams/meter^2).
3. Nominal thickness, inches (mm).
4. Roll width, inches (mm).
5. Core size, inside diameter, inches (mm).
6. Roll weight or length per roll, or both.

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3.2 PACKAGING

The mica paper should be secured firmly to the core in a manner that prevents slippage under tension. Mica paper rolls should be packaged in high strength containers which should resist crushing during shipment. There should be adequate clearance between the sides of the container and the roll of mica paper so that slight crushing of the container does not cause damage to the mica paper. Well designed headers should be used to support the ends of the roll to prevent shifting of the mica paper during shipping. The outside of the roll should be wrapped with a suitable moisture-barrier material.

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3.3 MARKING AND IDENTIFICATION

The shipping carton and core of each roll should be prominently and permanently marked with the following information:

1. Name of supplier.
2. Roll number or lot number, or both.
3. Mica paper class and basis weight in grams/foot^2 (grams/meter^2).
4. Weight or length of roll, or both.
5. Penetration time in seconds.

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Section 4
TEST METHODS

4.1 SPECIMENS AND CONDITIONING

Specimens shall be conditioned in accordance with ASTM D1677 insofar as it is practical to do so, or as mutually agreed upon by customer and supplier.

NEMA Standard 11-3-1983.

4.2 APPEARANCE—VISUAL INSPECTION

Upon visual inspection, the mica paper shall be examined for deleterious pieces of block mica, mineral, metallic inclusions, dirt, grit, wood, straw, paper, and so forth, and shall not contain any foreign substance which will cause staining of the mica paper when it is subsequently treated or impregnated with resinous solutions or solvents. Visible defects such as: excessive flaking of loose mica flakes and platelets, voids, cracks, folds or creases, interlaminar separation, thin edges or bands, and large variations in density or uniformity shall be noted.

NEMA Standard 11-3-1983.

4.3 THICKNESS AND THICKNESS VARIATION

4.3.1 Significance

The nominal thickness and thickness tolerance is generally specified when ordering mica paper and therefore, accurate determination of thickness by a standard procedure is important for identification of the material. Also, thickness must be determined in order to determine mass per unit area and the apparent density.

4.3.2 Thickness

Thickness is the measure of the average perpendicular distance between the two principal surfaces of the mica paper as determined in accordance with ASTM D1677.

The preferred method of test shall be Method D, Motor-Operated Dead-Weight Dial Gage, of ASTM D374, with a drop rate of 0.012 ± 0.004 in./s (0.3 ± 0.1 mm/s) and a dwell time of 3 ± 1s for thicknesses of 0.002 to 0.006 in. (0.05 to 0.15 mm) and 6 ± 2s for thicknesses greater than 0.006 in. (0.15 mm). However, Method C, Manually Operated Dead-Weight Dial-Type Thickness Gage, of ASTM D374 is an acceptable alternative. The diameter of the presser foot and the anvil shall be 0.250 ± 0.001 in. (6.35 ± 0.03 mm) and the pressure of the presser foot shall be 25 ± 2 psi (172 ± 14 kPa). Average, minimum, and maximum thicknesses shall be reported.

4.3.3 Thickness Variation

Thickness variation is a measure of the nonuniformity (or uniformity) of adjacent and nearby areas of a given sample of mica paper across its full width. Variation in thickness can adversely affect the quality of roll winding. Determination of thickness variation can be useful in judging the overall uniformity of a particular roll of mica paper and its performance, particularly with respect to dielectric breakdown voltage, impregnation time, and also in estimating the ultimate properties of the end product in which the mica paper is used.

Thickness variation shall be determined on specimens which include the full roll width and which have a length at least twice the roll width whenever it is practical to do so. Two straight lines shall be marked at right angles to the machine direction of the mica paper, the two lines being separated by a distance equal to or greater than the roll width. Each line shall be divided into five equal segments and marked off in squares 2 x 2 in. (50 x 50 mm) at the midpoints of each segment. Three thickness measurements shall be taken within each area and the average value of these three readings shall be recorded as the thickness of each of the areas. The results shall be tabulated as follows:

	Line 1	Line 2
Area a	ta	Ta
Area b	tb	Tb
Area c	tc	Tc
Area d	td	Td
Area e	te	Te
Total t	$= \Sigma t$	$= \Sigma T$
Avg. t	$= \frac{\Sigma t}{5}$ Avg. T	$= \frac{\Sigma T}{5}$

Thickness variation shall be calculated from the following: Take the difference between the minimum and maximum t in Column 1. Take the difference between the minimum and maximum T in Column 2. Take the difference between the average t and average T. The thickness variation shall be whichever value is the largest difference of these three determinations and it shall be reported as a percent using the ratio of thickness variation to the nominal thickness of the mica paper.

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4.4 BASIS WEIGHT AND WEIGHT VARIATION

Basis weight is the mass per unit area; weight variation is a measure of the difference in weight uniformity across the full width of the sheet. The degree of variation in basis weight from point to point on a sheet of mica paper can have an effect on the physical and electrical properties of the sheet itself, as well as on the coated or laminated products of which the sheet is a component.

In general, weight variation is greater across the width of the sheet than along its length. For this reason, specimens for the determination of basis weight and weight variation must be representative of the entire width of the material being sampled. Sampling and testing shall be in accordance with ASTM D1677. All specimens shall be carefully cut to specified dimensions—preferably by a sharp die—so as not to dislodge mica flakes on the edges. Sample size shall be at least 36 in.^{2} but not greater than 144 in.^{2}

Basis weight shall be reported as g/ft^2 (g/m^2) and weight variability as the percentage variation of the smallest and the largest individual basis weight values from the average.

NEMA Standard 11-3-1983.

4.5 APPARENT DENSITY

Apparent density is the mass of the mica paper per unit volume and is expressed as g/cm^3. Apparent density shall be determined from the thickness and basis weight measurements above in accordance with ASTM D1677 and shall be calculated as follows:

$$D = \frac{A}{B}$$ where: A = basis weight, g/m^2
B = thickness, cm
D = apparent density, g/cm^3

NEMA Standard 11-3-1983.

4.6 TENSILE STRENGTH

Tensile strength is the force required to rupture or break a test specimen of definite width and length, cut from each principle direction, that is, machine-direction and cross-machine direction, of the mica paper conditioned and tested as specified. The results of the test are suitable for acceptance and product control. They are also useful for determining the ability of the mica paper to withstand the tensile stresses encountered in unwinding from a roll and in application processes. Tensile strength shall be reported as the force per unit width, either pounds per inch (lbs./in.) or Newtons per meter width (N/m). Because of the fragile nature of mica paper, extreme care must be exercised in preparing tensile strength test specimens so as not to damage the edges. Cutting with a sharp die is preferred. Tensile breaking strength shall be determined in accordance with ASTM D1677, except that specimens shall be 1 to 3 in. (25 to 77 mm) wide, and the distance between jaws (grips) shall be 3 to 5 in. (77 to 127 mm). Rate of jaw separation for specimens 0.006 in. (0.15 mm) thick and below is normally 0.2 to 2 in. (5.1 to 50.8 mm) per minute. For specimens above 0.006 in. (0.15 mm) jaw separation can be up to 12 in. (305 mm) per minute.

NEMA Standard 11-3-1983.

4.7 PENETRATION (IMPREGNATION) TIME

Penetration time is the time in seconds required for a liquid of definite composition and specific gravity to penetrate completely, that is, at least 95 percent of the area, from one surface of the mica paper to the other under specified conditions. Penetration (impregnation) time influences the speed and quality of resin penetration of the mica paper and the ultimate resin content in the product. Specimens shall be placed on the penetrometer with the core side (screen side) in contact with the solution.

Penetration time shall be determined in accordance with ASTM D1677, using a test solution of approximately 60 parts cold pressed castor coil (USP No. 1 Grade) and 40 parts toluene, adjusted to a specific gravity of 0.917 ± 0.001 at 77°F (25°C). A Williams Penetrometer, or similar instrument, shall be used to make the measurements.

Because of the volatile nature of the impregnation solution, it shall be checked frequently and the specific gravity adjusted accordingly.

NEMA Standard 11-3-1983.

4.8 ELECTRIC STRENGTH

Electric breakdown voltage is the voltage at which electrical breakdown of a mica paper specimen between two electrodes occurs under prescribed conditions of test. Electric strength is the ratio of the dielectric breakdown voltage to the thickness of the mica paper tested. It is usually expressed in volts per mil (V/mil) or kilovolts/millimeter (kV/mm) and is obtained by dividing the average breakdown voltage by the average thickness of the mica paper specimen tested.

For mica paper to be used in the untreated state, this test gives some indication of its electrical strength. This test also has value for quality control purposes for mica paper that is subsequently treated.

Dielectric strength shall be determined in accordance with ASTM D1677 using 2-in. (50.8 mm) diameter electrodes in air and the short-time (500 V/s), continuous-rise method.

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September 1984

NEMA STANDARDIZATION

The purpose of NEMA Standards, their classification and status are set forth in certain clauses of the NEMA Bylaws, which are quoted below:

Purpose of Standards

National Electrical Manufacturers Association Standards are adopted in the public interest and are designed to eliminate misunderstandings between the manufacturer and the purchaser and to assist the purchaser in selecting and obtaining the proper product for its particular need. Existence of a National Electrical Manufacturers Association Standard does not in any respect preclude any member or nonmember from manufacturing or selling products not conforming to the standard.

(Bylaw—Art. V, Sec. 1)

Definition of a Standard

A standard of the National Electrical Manufacturers Association defines a product, process or procedure with reference to one or more of the following: nomenclature, composition, construction, dimensions, tolerances, safety, operating characteristics, performance, rating, testing, and the service for which they are designed.

(Bylaw—Art. V, Sec. 2, Subsection A)

Dimensions

Where dimensions are given for interchangeability purposes, alternate dimensions satisfying the other provisions of the standards publication may be capable of otherwise equivalent performance.

(NEMA Policy Memorandum 84-2, dated June 7, 1984)

Classes of Standards

National Electrical Manufacturers Association Standards are of two classes:

1. NEMA Standard, which relates to a product commercially standardized and subject to repetitive manufacture, which standard has been approved by at least 90 percent of the members of the Subdivision eligible to vote thereon;
2. Suggested Standard for Future Design, which may not have been regularly applied to a commercial product, but which suggests a sound engineering approach to future development, which standard has been approved by at least two-thirds of the members of the Subdivision eligible to vote thereon.

(Bylaw—Art. V, Sec. 2, Subsection B)

Authorized Engineering Information

Authorized Engineering Information consists of explanatory data and other engineering information of an informative character not falling within the classification of NEMA Standard or Suggested Standard for Future Design.

(Bylaw—Art. V, Sec. 6, 1st Sentence)

Official Standards Proposal

An Official Standards Proposal is an official draft of a proposed standard which is formally recommended to an outside organization(s) for consideration, comment and/or approval.

(Bylaw—Art. V, Sec. 4, Subsection A)

Identification of Status

Standards in NEMA Standards Publications are identified in the foreword or following each standard as "NEMA Standard" or "Suggested Standard for Future Design." These indicate the status of the standard. These words are followed by a date which indicates when the standard was adopted in its present form by the Association.

The material identified as "Authorized Engineering Information" and "Official Standards Proposal" is designated similarly.

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