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APPENDIX

The table in this appendix is intended as a general guide to the classification of a number of particular insulating materials. This classification must not be considered mandatory since only experience or adequate accepted tests should finally establish temperature limits. Moreover, no list of materials can be comprehensive, since new insulating materials are constantly being developed.

It is also recognized that:

(*i*) Many materials are available in a number of variants of differing thermal stability;

(*ii*) The thermal stability of some materials is affected by the way in which they are combined with other materials;

(*iii*) The suitability of some materials for use in a particular class depends upon the function which they will be called upon to fulfil.

In view of these factors, the manufacturer of apparatus should satisfy himself that his selection of materials for any particular application is appropriate to the conditions of service involved.

In the table, the materials in each class are divided into a principal list and a subsidiary list. The principal list comprises materials generally accepted in the class under consideration. The subsidiary list comprises materials of which some experience is available but whose introduction into the class under consideration is not universally accepted.

TABLE

Materials shown in Column 4 are those used by the manufacturer of the insulating products listed in Column 3. The materials listed in Column 5 are those used by the electrical manufacturer for the treatment of windings and equipment. For any particular class he should choose from the materials in Column 5 those which are appropriate for use with the selected products from Columns 3 and 4.

1	2	3	4	5
Class		Insulating Material	Bonding, impregnating or coating substances (*) used in the manufacture of the material in Column 3	Impregnating substances (*) which may be used in the treatment of the insulated assembly
Y	Principal	Cotton Natural silk Regenerated cellulose fibre Cellulose acetate fibre Polyamide fibre Paper and paper products Pressboard Vulcanized fibre Wood Aniline-formaldehyde resins Urea-formaldehyde resins	None	None required
	Subsidiary	Polyacrylates, Polyethylene, Polystyrene } May be limited to less than 90° C by softening temperature Polyvinyl chloride with or without plasticizer Vulcanized natural rubber	None	None required

* Bonding and impregnating substances may often be limited by factors other than thermal stability, such as mechanical properties at operating temperatures. For example, some epoxy and polyester resins under severe mechanical stress may be limited to Class A temperature.

1	2	3		4	
Class		Insulating Material		Bonding, impregnating or coating substances (*) used in the manufacture of the material in Column 3	Impregnating substances (*) which may be used in the treatment of the insulated assembly
A	Principal	Cotton Natural silk Regenerated cellulose fibre Cellulose acetate fibre Polyamide fibre Paper and paper products Pressboard Vulcanized fibre Wood	When impregnated or when immersed in a liquid dielectric	None	Drying oil-modified natural resins; shellac, copal and other natural resins; solutions or suspensions of cellulose esters and ethers Those listed in higher temperature classes Insulating oil and synthetic dielectric liquids
		Varnished textile based on cotton, natural silk, regenerated cellulose, cellulose acetate or polyamide fibre Varnished paper		Drying oil-modified natural or synthetic resin varnish	
		Laminated wood		Phenol-formaldehyde resin	
		Cellulose acetate film Cellulose acetate butyrate film Cross-linked polyester resins Wire enamel of oleo-resinous type Wire enamel based on polyamide resin		None	
	Subsidiary	Polychloroprene elastomers Butadiene acrylonitrile elastomers		None	Those listed above and in higher temperature classes

* Bonding and impregnating substances may often be limited by factors other than thermal stability, such as mechanical properties at operating temperatures. For example, some epoxy and polyester resins under severe mechanical stress may be limited to Class A temperature.

1	2	3	4	5
Class		Insulating Material	Bonding, impregnating or coating substances (*) used in the manufacture of the material in Column 3	Impregnating substances (*) which may be used in the treatment of the insulated assembly
E	Principal	—	—	—
	Subsidiary	Wire enamels based on polyvinylformal, polyurethane or epoxy resins	None	Oil-modified asphalt and synthetic resins; cross-linked polyester resins; epoxy resins Those listed in higher temperature classes
		Mouldings with cellulose fillers Cotton fabric laminates Paper laminates	Melamine-formaldehyde, phenol-formaldehyde and phenol-furfural resins	
		Cross-linked polyester resins Cellulose triacetate film Polyethylene terephthalate film Polyethylene terephthalate fibre	None	
		Varnished polyethylene terephthalate textile	Oil-modified alkyd resin varnish	

* Bonding and impregnating substances may often be limited by factors other than thermal stability, such as mechanical properties at operating temperatures. For example, some epoxy and polyester resins under severe mechanical stress may be limited to Class A temperature.

1	2	3	4	5
Class		Insulating Material	Bonding, impregnating or coating substances (*) used in the manufacture of the material in Column 3	Impregnating substances (*) which may be used in the treatment of the insulated assembly
B	Principal	Glass fibre Asbestos	None	Oil-modified asphalt and synthetic resins; cross-linked polyester resins; epoxy resins. (Under severe mechanical stress, materials above may prove to be inadequate, and unmodified phenolic resins may be needed) Those listed in higher temperature classes
		Varnished glass fibre textile Varnished asbestos	Oil-modified synthetic resin varnishes	
		Built-up mica (with or without supporting materials)	Shellac, asphalt or bituminous compounds Oil-modified synthetic resins Alkyd resins Cross-linked polyester resins Epoxy resins	
		Glass fibre laminates Asbestos laminates Mouldings with mineral fillers	Melamine-formaldehyde resins Phenol-formaldehyde resins	
	Subsidiary	Mouldings with mineral fillers	Cross-linked polyester resins	Those listed above, in this class, and those listed in higher temperature classes
		Polymonochlorotrifluoroethylene	None	

* Bonding and impregnating substances may often be limited by factors other than thermal stability, such as mechanical properties at operating temperatures. For example, some epoxy and polyester resins under severe mechanical stress may be limited to Class A temperature.

1	2	3	4	5
Class		Insulating Material	Bonding, impregnating or coating substances (*) used in the manufacture of the materia l in Column 3	Impregnating substances (*) which may be used in the treatment of the insulated assembly
F	Principal	—	—	—
	Subsidiary	Glass fibre Asbestos	None	Alkyd, epoxy, cross-linked polyester and polyurethane resins with superior thermal stability Silicone-alkyd and silicone-phenolic resins Those listed in higher temperature classes
		Varnished glass fibre textile Varnished asbestos Built-up mica (with or without supporting materials)	Alkyd, epoxy, cross-linked polyester and polyurethane resins with superior thermal stability Silicone-alkyd resins	

* Bonding and impregnating substances may often be limited by factors other than thermal stability, such as mechanical properties at operating temperatures. For example some epoxy and polyester resins under severe mechanical stress may be limited to Class A temperature.

1	2	3	4	5
Class		Insulating Material	Bonding, impregnating or coating substances (*) used in the manufacture of the material in Column 3	Impregnating substances (*) which may be used in the treatment of the insulated assembly
H	Principal	Glass fibre Asbestos	None	Appropriate silicone resins
		Varnished glass fibre textile Varnished asbestos	Appropriate silicone resins Silicone elastomer	
		Built-up mica (with or without supporting materials) Glass fibre laminates Asbestos laminates	Appropriate silicone resins	
		Silicone elastomer	None	
	Subsidiary	—	—	—

* Bonding and impregnating substances may often be limited by factors other than thermal stability, such as mechanical properties at operating temperatures. For example, some epoxy and polyester resins under severe mechanical stress may be limited to Class A temperature.

1	2	3	4	5
Class		Insulating Material	Bonding, impregnating or coating substances (*) used in the manufacture of the material in Column 3	Impregnating substances (*) which may be used in the treatment of the insulated assembly
C	Principal	Mica Porcelain and other ceramics Glass Quartz (N. B. — Maximum operating temperature may be limited by physical, chemical or electrical properties at operating temperature)	None	Inorganic binders such as glass or cement
	Subsidiary	Treated glass fibre textile Treated asbestos Built-up mica	Silicone resins possessing superior thermal stability (limited stability above 225° C)	Silicone resins possessing superior thermal stability (limited stability above 225° C)
		Polytetrafluoroethylene (limited stability above 250° C)	None	

* Bonding and impregnating substances may often be limited by factors other than thermal stability, such as mechanical properties at operating temperatures. For example, some epoxy and polyester resins under severe mechanical stress may be limited to Class A temperature.

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SIGNIFICANCE OF THE DIELECTRIC STRENGTH TEST

SIGNIFICANCE OF THE DIELECTRIC STRENGTH TEST

Introduction:

A1. A brief review of three postulated mechanisms of breakdown, namely, the discharge or corona mechanism, the thermal mechanism, and the intrinsic mechanism, and a discussion of the principal factors affecting tests on practical dielectrics are given here to aid in interpreting the data. The breakdown mechanisms usually operate in combination rather than singly. The following discussion applies only to solid, semi-solid, and liquid materials. Gaseous dielectrics are not included in the scope of ASTM Methods D 149.

Postulated Mechanisms of Dielectric Breakdown:

A2. (a) Breakdown Caused by Electric Discharges. — In most tests on commercial materials, breakdown is caused by electric discharges, which produce high local fields. With solid materials the discharges usually occur in the ambient medium and produce failure at or beyond the electrode edge. Discharges may occur in any internal voids or bubbles which are present or which may develop, and may cause local erosion or chemical decomposition. These processes may continue until a complete failure path is formed between the electrodes.

(b) Thermal Breakdown. Cumulative heating develops in local paths within many materials when they are subjected to high field intensities because dielectric and ionic conduction losses generate heat more rapidly than it can be dissipated. Breakdown may then occur because of thermal instability of the material.

(c) Intrinsic Breakdown. If failures by electric discharges or thermal instability are avoided, breakdown will occur at field intensities sufficient to accelerate electrons through the material. This critical field intensity is called the intrinsic dielectric strength. It cannot be determined by this test method, although the mechanism itself may be involved.

Nature of Electrical Insulating Materials:

A3. Solid commercial electrical insulating materials are generally nonhomogeneous and may contain dielectric defects of various kinds. Experience often has revealed dielectric breakdown in an area of the test specimen other than that where the calculated field intensity was greatest, and at times in an area remote from the material directly between the electrodes. Dielectric strength tests usually have the nature of weak spot test, and the probability of week spots within the volume under stress may control the test results.

Influence of Test and Specimen Conditions:

A4. (a) Electrodes.— In general, the breakdown voltage will tend to decrease with increasing electrode area, this area effect being more pronounced with thin test specimens. Test results are also affected by the electrode geometry. Results may be affected also by the material from which the electrodes are constructed, since the thermal and discharge mechanisms are influenced by the thermal conductivity and the work function, respectively, of the electrode material. Generally speaking, the effect of the electrode material is difficult to establish because of the scatter of experimental data.

(b) Specimen Thickness.— The delectric strength of solid commercial electrical insulating materials is greatly dependent upon the specimen thickness. Experience has shown that for solid and semi-solid materials the dielectric strength varies inversely as a fractional power of the specimen thickness, and there is a substantial amount of evidence that for relatively homogeneous solids the dielectric strength

Results in one medium cannot be compared with those in a different medium.

(h) Relative Humidity.— The relative humidity influences the dielectric strength to the extent that moisture absorbed by, or on the surface of, the material under test affects the dielectric loss and surface conductivity. Hence its importance will depend to a large extent upon the nature of the material being tested. However, even materials that absorb little or nomoisture may be affected because of greatly increased chemical effects of discharges in the presence of moisture. Except in cases where the effect of exposure on dielectric strength is being investigated, it is customary to control or limit the relative humidity effects by standard conditioning procedures

(i) General.— Because the dielectric strength depends critically on the above factors, they must be reported completely along with the test results.

Significance:

A5. (a) A fundamental requirement of the insulation in electrical apparatus is that it with-stand the voltage imposed on it in service. There-fore there is a great need for a test to evaluate the performance of particular materials at high voltage stress. The dielectric breakdown voltage test represents a convenient preliminary test to determine whether a material merits further consideration, but it falls short of a complete evaluation in two important respects. First, the condition of a material as installed in apparatus is much different from its condition in this test, particularly with regard to the configuration of the electric field and the area of material exposed to it, corona, mechanical stress, ambient medium, and association with other materials. Second, in service there are deteriorating influences, heat, mechanical stress, corona and its products, contaminants, etc., which may reduce the breakdown voltage far below its value as originally installed. Some of these effects can be incorporated in laboratory tests, and a better estimated of the material will result, but the final test muxt always be that of the performance of the material in actual service.

(b) The dielectric breakdown test may used as a material inspection or quality control test, as a means of inferring other properties such as variability, or to indicate deteriorating processes such as thermal aging. In these uses of the test it is the relative value of the breakdown voltage that is important rather than the absolute value.

varies approximately as the reciprocal of the square root of the thickness. In the case of liquids, or of solids that can be melted and poured to solidify between fixed electrodes, the effect of electrode separation is less clearly defined. Since the electrode separation can be fixed at will in such cases, it is customary to perform dielectric strength tests on liquids, and usually on fusible solids, with electrodes having a standardized fixed spacing. Since the dielectric strength is so dependent upon thickness, it is meaningless to report dielectric strength data for a material without stating the thickness of the test specimens used.

(c) Temperature.---The temperature of the test specimen and ambient medium influences the dielectric strength, although for most materials small variations of normal ambient temperature may have a practically negligible effect. In general, the dielectric strength will decrease with increasing temperature, but the extent to which this is true depends upon the material under test. When it is known that a material will be required to function at other than normal room temperatures, it is essential that the dielectric strength-temperature relationship for the material be determined over the range of expected operating temperatures.

(d) Time. — Test results will be influenced by the rate of voltage application. In general the breakdown voltage will tend to increase with increasing rate of voltage application. This is to be expected because the thermal breakdown mechanism is time-dependent and the discharge mechanism is usually time-dependent, although in some cases the latter mechanism may cause rapid failure by producing critically high local field strengths.

(e) Wave Form. — In general, the dielectric strength is influenced by the wave form of the applied voltage. Within the limits specified in this method the influence of wave form is not significant.

(f) Frequency. — The dielectric strength is not significantly influenced by frequency variations within the range of commercial power frequencies provided for in this method. However, inferences concerning dielectric strength behavior at other than commercial power frequencies (50 to 60 cps) must not be made from results obtained by this method.

(g) Ambient Medium. — The ambient medium can affect the heat transfer rate, external discharges, and field uniformity, thereby greatly influencing the test results.

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STANDARD SPECIFICATIONS FOR

INSULATION OF INSULATED CONDUCTORS

STANDARDS AND SAFETY SECTION

REGULATORY DIVISION

NATIONAL ENERGY AUTHORITY

17 June 1965

SPECIFICATION FOR INSULATION OF INSULATED CONDUCTORS

1. <u>SCOPE</u>

These specifications apply to insulating covering and sheaths at thermoplastic material and rubber for insulated cables and flexible cords for electric power and communication. These insulation is only recommended for use at conductor temperatures not in excess of 60°C.

2. <u>DEFINITION</u>

2.1 <u>Thermoplastic material</u> means polymerizates or polycondensates, with or without the addition of fillers, which become plastic on being heated but do not set.

2.2 <u>Rubber</u> means vulcanized soft rubber compounds with natural India rubber, synthetic rubber or a mixture of both as a base substance.

3. <u>GENERAL REQUIREMENT</u>

3.1 For the purpose of these specifications all properties of insulations shall be considered as occuring at the internationally standardized reference testing temperature of 20°C

3.2 All units in these specifications shall be used in metric system.

3.3 Insulating coverings and sheaths of thermoplastic material and rubber shall have the properties specified in Table 1

/ unless

unless otherwise in the relevant specifications for cables and flexible cords.

3.4. In general, the volume resistivity of thermoplastic material shall be at least 2 X 10^{13} ohm-cm at 20°C.

Note Resistivity of P.V.C. compound at 60°C is 1000 times of that at 20°C

3.5 Rubber compounds with a resistivity of not less than 10^{12} ohm-cm at 20°C are adequate for core insulation. Outer sheaths of rubber compound shall have a surface resistance of not less than 10^9 ohms at 20°C

3.6 The minimum insulation resistance R_m of single core in megohms based on 1 conductor kilometers at 20°C can be calculated from the minimum value of the resistivity given in 3.4 and 3.5 by means of the following formula:

$$R_m = K \ln \frac{d + 2a}{d} \quad M\Omega/km$$

where K for thermoplastic = 32

K for rubber = 372

d is the nominal diameter of the conductor

a is the thickness of insulation

TABLE I

Properties of Insulating Covering and Sheaths of Rubber and Thermoplastic Compounds

Mechanical Properties at 20 2°C		Thermal Properties		Compounds
Minimum Tensile Strength kg/cm^2	Minimum Elongation %	Hot Deformation Resistance Up to °C	Freedom from tackiness Up to °C	
100	120	70	70	Thermoplastics
50	250	-	-	Rubber for inner sheath or core insulation
100	300	-	-	Rubber for outer sheath

4. Performance Test

4.1 All properties of P.V.C, compounds shall be tested according to "Safety Standard for P.V.C-insulated Cables and Flexible Cords"

4.2 All properties of Rubber compounds shall be performed as in "Safety Standard for Rubber - insulated Cables and Flexible Cords"