UL 840

ISBN 1-55989-391-5

Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment

Underwriters Laboratories Inc. (UL)
333 Pfingsten Road
Northbrook, IL 60062-2096

UL Standard for Safety for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840

Second Edition, Dated May 20, 1993

Revisions: This Standard contains revisions through and including September 7, 2000.

UL is in the process of converting its Standards for Safety to the Standard Generalized Markup Language (SGML), and implementing an SGML compliant document management and publishing system. SGML - an international standard (ISO 8879-1986) - is a descriptive markup language that describes a document's structure and purpose, rather than its physical appearance on a page. Significant benefits that will result from UL's use of SGML and these new systems include increased productivity, reduced turnaround times, and data and information consistency, reusability, shareability, and portability. However, the fonts, pagination, and general formatting of UL's new electronic publishing system differ from that of UL's previous publishing system. Consequently, when revision pages are issued for a Standard with the new publishing system, these differences may result in the printing of pages on which no requirements have been changed - these additional pages result from relocation of text due to repagination and reformatting of the Standard with the new publishing system.

Text that has been changed in any manner is marked with a vertical line in the margin. Changes in requirements are marked with a vertical line in the margin and are followed by an effective date note indicating the date of publication or the date on which the changed requirement becomes effective.

The revisions dated September 7, 2000 include a reprinted title page (page1) for this Standard.

The revisions dated October 6, 1999 were issued for editorial corrections. These corrections include any combination of the following: Updated Foreword (item D); Updated Scope; title changes to UL 489 and/or UL 1950; Withdrawn standards, UL 519 and UL 547, being replaced by UL 2111; Removal of the "94" flammability classification. These revisions may also include other miscellaneous editorial corrections.

As indicated on the title page (page 1), this UL Standard for Safety is an American National Standard. Attention is directed to the note on the title page of this Standard outlining the procedures to be followed to retain the approved text of this ANSI/UL Standard.

The master for this Standard at UL's Northbrook Office is the official document insofar as it relates to a UL service and the compliance of a product with respect to the requirements for that product and service, or if there are questions regarding the accuracy of this Standard.

Revisions of UL Standards for Safety are issued from time to time. A UL Standard for Safety is current only if it incorporates the most recently adopted revisions.

UL provides this Standard ″as is″ without warranty of any kind, either expressed or implied, including but not limited to, the implied warranties of merchantability or fitness for any purpose.

In no event will UL be liable for any special, incidental, consequential, indirect or similar damages, including loss of profits, lost savings, loss of data, or any other damages arising out of the use of or the inability to use this Standard, even if UL or an authorized UL representative has been advised of the possibility of such damage. In no event shall UL's liability for any damage ever exceed the price paid for this Standard, regardless of the form of the claim.

UL will attempt to answer support requests concerning electronic versions of its Standards. However, this support service is offered on a reasonable efforts basis only, and UL may not be able to resolve every support request. UL supports the electronic versions of its Standards only if they are used under the conditions and operating systems for which it is intended. UL's support policies may change from time-to-time without notification.

UL reserves the right to change the format, presentation, file types and formats, delivery methods and formats, and the like of both its printed and electronic Standards without prior notice.

Purchasers of the electronic versions of UL's Standards for Safety agree to defend, indemnify, and hold UL harmless from and against any loss, expense, liability, damage, claim, or judgement (including reasonable attorney's fees) resulting from any error or deviation introduced while purchaser is storing an electronic Standard on the purchaser's computer system.

If a single-user version electronic Standard was purchased, one copy of this Standard may be stored on the hard disk of a single personal computer, or on a single LAN file-server or the permanent storage device of a multiple-user computer in such a manner that this Standard may only be accessed by one user at a time and for which there is no possibility of multiple concurrent access.

If a multiple-user version electronic Standard was purchased, one copy of the Standard may be stored on a single LAN file-server, or on the permanent storage device of a multiple-user computer, or on an Intranet server. The number of concurrent users shall not exceed the number of users authorized.

Electronic Standards are intended for on-line use, such as for viewing the requirements of a Standard, conducting a word search, and the like. Only one copy of the Standard may be printed from each single-user version of an electronic Standard. Only one copy of the Standard may be printed for each authorized user of a multiple-user version of an electronic Standard. Because of differences in the computer/software/printer setup used by UL and those of electronic Standards purchasers, the printed copy obtained by a purchaser may not look exactly like the on-line screen view or the printed Standard.

An employee of an organization purchasing a UL Standard can make a copy of the page or pages being viewed for their own fair and/or practical internal use.

The requirements in this Standard are now in effect, except for those paragraphs, sections, tables, figures, and/or other elements of the Standard having future effective dates as indicated in the note following the affected item. The prior text for requirements that have been revised and that have a future effective date are located after the Standard, and are preceded by a ″SUPERSEDED REQUIREMENTS″ notice.

New product submittals made prior to a specified future effective date will be judged under all of the requirements in this Standard including those requirements with a specified future effective date, unless the applicant specifically requests that the product be judged under the current requirements. However, if the applicant elects this option, it should be noted that compliance with all the requirements in this Standard will be required as a condition of continued Listing and Follow-Up Services after the effective date, and understanding of this should be signified in writing.

This Standard consists of pages dated as shown in the following checklist:

Page	Date
1-3	September 7, 2000
4	April 1, 1999
5	September 7, 2000
6-6B	October 6, 1999
7-8A	September 7, 2000
8B	October 6, 1999
9-15	May 20, 1993
16-22B	April 1, 1999
23	January 30, 1995
24	May 20, 1993
25	January 30, 1995
26-27	May 20, 1993
28-29	January 30, 1995
32	April 1, 1999

No Text on This Page

UL 840

Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment

First Edition – December, 1984

Second Edition

May 20, 1993

The most recent designation of UL 840 as an American National Standard occurred on May 12, 2000.

This ANSI/UL Standard for Safety, which consists of the Second edition with revisions through September 7, 2000, is under continuous maintenance, whereby each revision is ANSI approved upon publication. Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Written comments are to be sent to the UL-RTP Standards Department, 12 Laboratory Dr., Research Triangle Park, NC 27709.

An effective date included as a note immediately following certain requirements is one established by Underwriters Laboratories Inc.

Revisions of this Standard will be made by issuing revised or additional pages bearing their date of issue. A UL Standard is current only if it incorporates the most recently adopted revisions, all of which are itemized on the transmittal notice that accompanies the latest set of revised requirements.

ISBN 1-55989-391-5

No Text on This Page

CONTENTS

FOREWORD

A. This Standard contains basic requirements for products covered by Underwriters Laboratories Inc. (UL) under its Follow-Up Service for this category within the limitations given below and in the Scope section of this Standard. These requirements are based upon sound engineering principles, research, records of tests and field experience, and an appreciation of the problems of manufacture, installation, and use derived from consultation with and information obtained from manufacturers, users, inspection authorities, and others having specialized experience. They are subject to revision as further experience and investigation may show is necessary or desirable.

B. The observance of the requirements of this Standard by a manufacturer is one of the conditions of the continued coverage of the manufacturer's product.

C. A product which complies with the text of this Standard will not necessarily be judged to comply with the Standard if, when examined and tested, it is found to have other features which impair the level of safety contemplated by these requirements.

D. A product employing materials or having forms of construction which conflict with specific requirements of the Standard cannot be judged to comply with the Standard. A product employing materials or having forms of construction not addressed by this Standard may be examined and tested according to the intent of the requirements and, if found to meet the intent of this Standard, may be judged to comply with the Standard.

E. UL, in performing its functions in accordance with its objectives, does not assume or undertake to discharge any responsibility of the manufacturer or any other party. The opinions and findings of UL represent its professional judgment given with due consideration to the necessary limitations of practical operation and state of the art at the time the Standard is processed. UL shall not be responsible to anyone for the use of or reliance upon this Standard by anyone. UL shall not incur any obligation or liability for damages, including consequential damages, arising out of or in connection with the use, interpretation of, or reliance upon this Standard.

F. Many tests required by the Standards of UL are inherently hazardous and adequate safeguards for personnel and property shall be employed in conducting such tests.

INTRODUCTION

1 Scope

1.1 These requirements cover an alternate approach to specifying through air and over surface spacings for electrical equipment through the use of the principles of insulation coordination.

1.2 The complete principles of insulation coordination involve the consideration of the combination of clearances, creepage distances, and the properties of solid insulation used to constitute the insulation system. The empirical data gathered thus far has been used to develop the requirements for clearances and creepage distances as presented in this standard. The data needed to develop the evaluation procedure for solid insulation is still being gathered. When available, this evaluation procedure will be added to this standard and is not expected to affect the requirements for clearances and creepage distances.

1.3 These requirements may be used as an alternate to required spacing levels specified in end-product standards. The end product standard spacing requirements may be based on use and systems where overvoltages are not controlled, or if controlled, the level of control is unknown.

1.4 These alternate requirements are intended to be applied to a particular product category if the standard covering the product category specifically references UL 840 or any of the requirements therein.

1.5 Users of these requirements may need to specify the overvoltage levels and the methods of control which will be utilized, and establish the pollution degree to which the product insulation system will be expected to be subjected.

1.6 It is not intended that the test values in this standard be employed for production line testing. However, users of these requirements will need to establish a means to ensure that production controls applied to permit the spacing reduction remain in effect during the manufacture of the product. This could include sample testing or physical measurements or another equivalent means.

1.7 Users of these requirements will additionally need to ensure that influencing factors not addressed in this standard, such as mechanical movement, field placement of conductive material, and product damage, will not affect the system for insulation coordination. Examples are the deformation of the enclosure, movement of the fittings for conduit or armored cable, or the improper installation of field wiring. Clearances and creepage distances at those locations must be verified for compliance by physical measurement in accordance with Section 7, Measurement of Clearance and Creepage Distances.

1.8 A product that contains features, characteristics, components, materials, or systems new or different from those covered by the requirements in this standard, and that involves a risk of fire or of electric shock or injury to persons shall be evaluated using appropriate additional component and end-product requirements to maintain the level of safety as originally anticipated by the intent of this standard. A product whose features, characteristics, components, materials, or systems conflict with specific requirements or provisions of this standard does not comply with this standard. Revision of requirements shall be proposed and adopted in conformance with the methods employed for development, revision, and implementation of this standard.

1.8 revised September 7, 2000

2 General

2.1 Insulation coordination

2.1.1 This standard uses the principles of insulation coordination to provide requirements for clearances and creepage distances for electrical equipment. A design consideration is to prevent undesirable breakdowns in some areas due to their disruptive nature and potential for risk of fire and electric shock. Insulation coordination also requires the awareness of the insulating material properties so that design of the product can utilize the reduced spacing concept.

2.1.2 Insulation coordination, as evaluated and implemented through the use of this standard, can be achieved in a multiconcept process.

a) The first concept detailed in Section 4, Clearance A (Equivalency), of this standard is an alternative approach to measuring spacings currently defined in various product standards. This approach uses a dielectric voltage-withstand test impulse to evaluate equivalence of designed spacings to the predefined dimension. An actual reduction in spacings can be permitted through a refinement in manufacturing techniques while maintaining equivalent breakdown levels.

b) The second concept detailed in Section 5, Clearance B (Controlled Overvoltage), of this standard, a step in the insulation coordination process, is the selection of clearances based on the level of overvoltage protection and pollution degree.

c) The third concept detailed in Section 6, Creepage Distances, of this standard is the selection of an appropriate set of creepage distances based on operating voltage, pollution degree and material tracking characteristics.

d) The last concept, currently anticipated though not described in detail in this standard, is the choice of solid insulation to coordinate with the clearances and creepage distances chosen. The solid insulation must have suitable tracking properties for creepage considerations and it must have a breakdown level exceeding that of the controlled overvoltage level provided.

2.1.3 The database upon which these requirements are based is contained in the International Electrotechnical Commission (IEC) Publications for Insulation Coordination Within Low Voltage Systems Including Clearances and Creepage Distances for Equipment, 664, and the Supplement, IEC Publication 664A.

2.1.4 The data contained in these IEC documents relate the ability of clearances to withstand overvoltages based on the characteristics of the electrical field. For a specified overvoltage, an inhomogeneous field condition of two electrodes, which is represented by a point and a plane, requires the largest clearance. As the condition of the electric field is improved by control of electrode shape, the clearance required to withstand the overvoltage decreases. The limit for this decrease in clearance is that of the homogenous field which is represented by two parallel planes. Using this data it is possible to evaluate clearances by their ability to withstand overvoltages. It should be recognized that the use of this technique requires the regular rechecking of the ability of the clearance to withstand the prescribed overvoltage because of possible variations in the production process, the wearing of tools, or other factors that might influence the clearance or electrical field condition. The database may also be used to specify, for a given overvoltage, the inhomogeneous field clearance, and the continued provision of this clearance may be made by measurements of the clearance.

2.1.5 The data contained in these documents relating to the selection of creepage distances is based on an evaluation of empirical data coming from experience, and the results of extensive testing of certain combinations of materials in differing pollution degrees. The major variables for the selection of creepage distances are the arc tracking characteristics of the material used and the conditions of pollution. The four pollution degrees are based on the levels of moisture and contaminants at the creepage distance and therefore, the pollution degree which may exist.

2.1.6 The values for creepage distances presented in this standard are for equipment being subjected to long term stress. Many products, and circuits within those products, are only subjected to short term or intermittent stress. End-product standards can permit a reduction in minimum creepage distance based on this use factor. A single row reduction (in Table 6.1) while maintaining the same pollution degree and material group, would be typical.

No Text on This Page

2.1.7 These requirements are based on the electrical characteristics of the clearances and creepage distances, and the assumption that the spacings will be maintained over the life of the equipment. In those locations where the spacings may be influenced by other conditions, the end-product standard users will need to separately consider whether use of this standard is appropriate. Examples might be the spacings between terminals that may be reduced by protruding wires or strands, or the spacings to enclosures where possible indentations may reduce the spacings. Spacings at arcing parts may need to be additionally evaluated for conductive deposits or loss of material during arcing tests.

2.1.8 Within this standard, clearance and creepage distance requirements are separate and may be individually referenced. While creepage distances cannot be less than the associated clearances, each spacing parameter is influenced by different conditions. The clearances may be measured or tested, and can be further reduced by controlling overvoltages and pollution degree. Creepage distances may be measured, and may be reduced by controlling the materials and pollution degree present in the equipment.

2.1.9 Other considerations which must be employed when pursuing insulation coordination include the following:

a) Insulation systems consist of a set of series and parallel insulators (of air and solid and liquid insulation for example) and control over the system and internal spacings and voltages;

b) Air is considered a renewable insulation material;

c) Transient overvoltages may occur due to both internal (circuit generated) and external (lightning) events; and

d) Solid (nonrenewable material) insulating material should have a dielectric strength greater than the associated creepages and clearances.

2.2 Undated references

2.2.1 Any undated reference to a code or standard appearing in the requirements of this standard shall be interpreted as referring to the latest edition of that code or standard.

2.2.1 revised September 7, 2000

2.3 Units of measurement

2.3.1 Values stated without parentheses are the requirement. Values in parentheses are explanatory or approximate information.

2.3.1 revised September 7, 2000

2.4 Components

2.4.1 Except of indicated in 2.4.2, a component of a product covered by this standard shall comply with the requirements for that component.

2.4.1 added September 7, 2000

2.4.2 A component is not required to comply with a specific requirement that:

a) Involves a feature or characteristic not required in the application of the component in the product covered by this standard, or

b) Is superseded by a requirement in this standard.

2.4.2 added September 7, 2000

2.4.3 A component shall be used in accordance with its rating established for the intended conditions of use.

2.4.3 added September 7, 2000

2.4.4 Specific components are incomplete in construction features or restricted in performance capabilities. Such components are intended for use only under limited conditions, such as certain temperatures not exceeding specified limits, and shall be used only under those specific conditions.

2.4.4 added September 7, 2000

3 Glossary

3.1 For the purpose of this standard, the following definitions apply.

3.2 CLEARANCES – Through air spacing.

3.3 CREEPAGE DISTANCES (CREEPAGES) – Over surface spacings.

3.4 FUNCTIONAL OVERVOLTAGE – Deliberately imposed transient overvoltages necessary for the function of a device.

3.5 GENERAL ENVIRONMENT – The overall area or space in which the equipment is located. Commonly referred to as ambient conditions.

3.6 IMPULSE WITHSTAND VOLTAGE – The highest peak value of impulse voltages, of prescribed form and polarity, that does not cause breakdown under specified conditions of test.

3.7 INSULATION COORDINATION – The correlation of insulating characteristics of electrical equipment:

a) With expected overvoltages and characteristics of overvoltage protective devices (a key consideration for clearances); and

b) With the expected micro-environment and pollution protective means (key considerations for creepage distances).

3.8 LEAKAGE CURRENT – The current that can be measured as flowing between test points during a dielectric voltage-withstand test.

3.9 LIGHTNING OVERVOLTAGE – The transient overvoltage at a given location on a system due to a specific lightning discharge.

3.10 MICRO-ENVIRONMENT – The conditions that immediately surround the clearance or creepage distance under consideration. The micro-environment of the creepage distance or clearance and not the general environment of the equipment determines the effect on the insulation. The micro-environment might be less severe or more severe than the general environment that the equipment is in. It includes all factors influencing the insulation, such as climatic, electromagnetic, and generation of pollution.

3.11 OPERATING VOLTAGE – The voltage across two points occurring due to normal operation of the product when controls are set in any position.

3.12 OVERVOLTAGE CATEGORY – Grouping of products based on typical installed location with respect to overvoltage protection and available energy. See note c of Table 5.1.

3.13 POLLUTION – Any addition of contaminants, solid, liquid or gaseous (ionized gases), and moisture that may produce a reduction of dielectric strength or surface resistivity.

3.14 POLLUTION DEGREE – The level of pollution present at the location on or in a product where the clearance and creepage distance measurement is made, and can be controlled by design of the product. For example, enclosures can be used to achieve pollution degree 3, heaters within enclosures can help achieve pollution degree 2, and encapsulation can be used to achieve pollution degree 1. See 6.3.

3.15 RATED VOLTAGE – The voltage employed for test purposes by the end-product standard.

3.16 RECURRING PEAK VOLTAGE – Deliberately or naturally imposed transient overvoltage that exceeds the steady state voltage, and is caused by operating a control or adjustable component. The voltage level will be consistent for the same operation under the same conditions. Insulating materials can be degraded by ozone generated by partial discharges due to recurring peak voltages.

3.17 SWITCHING OVERVOLTAGE – The transient overvoltage at a given location on a system due to a specific switching operation or fault.

3.18 SYSTEM VOLTAGE – The rated supply or line voltage to which the product will be connected.

3.19 TRANSIENT OVERVOLTAGE – Nonperiodic voltages that may be caused by switching, lightning, or function of a device.

No Text on This Page

CONSTRUCTION

4 Clearance A (Equivalency)

4.1 Other than as noted in 1.6, the requirements of this section may be used to evaluate clearances less than those specified for the end product while maintaining the same overvoltage withstand capability for the equipment.

4.2 A clearance, less than the specified minimum through air spacing, in the product standard, may be suitable if acceptable results are obtained when tested in accordance with Section 10, Dielectric Voltage-Withstand Tests, using a voltage with a value in accordance with Table 4.1. For specified minimum clearances between the values in Table 4.1, interpolation may be used to determine the test voltage.

Table 4.1
Test voltages for verifying through air spacings (clearances)

End-product Standard specified minimum through air spacing,		Test voltages, kilovolts									
		AC impulse, AC peak, or DC					AC rms				
		Altitude[a], m or (air pressure, kPa)[b]					Altitude[a], m or (air pressure, kPa)[b]				
Inches	(mm)	0 (101.3)	200 (98.8)	500 (95.0)	1000 (90.0)	2000 (80.0)	0 (101.3)	200 (98.8)	500 (95.0)	1000 (90.0)	2000 (80.0)
1/64	(0.4)	1.7	1.7	1.7	1.6	1.5	1.2	1.2	1.2	1.2	1.1
1/32	(0.8)	2.2	2.1	2.1	2.0	1.9	1.5	1.5	1.5	1.4	1.3
3/64	(1.2)	2.75	2.7	2.65	2.5	2.3	1.95	1.9	1.9	1.75	1.6
1/16	(1.6)	3.3	3.3	3.2	3.0	2.7	2.4	2.3	2.3	2.1	1.9
3/32	(2.4)	4.4	4.3	4.1	3.9	3.5	3.1	3.0	2.9	2.8	2.5
1/8	(3.2)	5.3	5.2	5.0	4.8	4.3	3.7	3.7	3.6	3.4	3.0
3/16	(4.8)	6.9	6.8	6.6	6.2	5.6	4.9	4.8	4.7	4.4	4.0
1/4	(6.4)	8.3	8.2	7.9	7.5	6.8	5.9	5.9	5.6	5.3	4.8
3/8	(9.5)	10.9	10.7	10.3	9.8	8.8	7.7	7.7	7.3	7.0	6.3
1/2	(12.7)	14.0	13.7	13.2	12.5	11.2	9.9	9.7	9.3	8.9	7.9
1	(25.4)	25.5	24.6	24.0	22.7	20.2	18.2	17.6	17.1	16.2	14.4

[a] Next lower specified altitude to be used for intermediate altitudes.

[b] Values of air pressure in kilopascals are provided to permit testing at pressures simulating elevations different from the elevation of the test facility.

4.3 The withstand capability of a clearance is related to air pressure, therefore, the selection of test voltage is to be based on the altitude of the test location.

5 Clearance B (Controlled Overvoltage)

5.1 The requirements of this section may be used to evaluate clearances where the levels of overvoltage are controlled.

5.2 Control of overvoltages may be achieved by either:

a) Providing overvoltage devices or systems as an integral part of the product; or

b) Marking the product with the rating of overvoltage control to which the product is to be connected, and the energy handling capability of the overvoltage device, if appropriate.

5.3 With reference to the marking in 5.2, the users of this standard must determine the appropriate method to state that the overvoltage control device or system should comply with the requirements in 5.4. One of the alternatives to marking the product would be to provide the information in published documentation.

5.4 Devices or systems, including filters or air gaps, used to control overvoltages in accordance with this section shall be evaluated using the requirements in the Standard for Transient Voltage Surge Suppressors, UL 1449. If used in products having short circuit withstand ratings, the suppressors shall also withstand the available current when tested in accordance with UL 1449.

5.5 If a clearance is used to perform the function of controlling overvoltages, then consideration must be given to the ability of the clearance to handle the energy which may be available, to the overvoltage breakdown level of other clearances, and to the changes which may occur in and to an electric field when arc-over occurs.

5.6 The end product standards that reference this standard will need to specify if a mechanism to indicate the failure of a component of the system or device employed for overvoltage protection is required. For example, the mechanism could indicate that a transient voltage surge suppressor is no longer functional due to the absorption of an excessive amount of energy.

5.7 Line connected devices and circuits shall be assigned both a phase-to-ground rated system voltage and an overvoltage category as specified in Table 5.1. Circuits, line connected or secondary, employing the clearances of Table 5.1, shall be protected for the rated impulse withstand voltage peak identified in Table 5.1. The switching test detailed in Section 8, Switching Test, should be conducted unless circuit analysis reveals that the appropriate protection is provided wherever Table 5.1 clearances are used.

5.8 Except as noted in 1.7, clearances may be:

a) Evaluated by the dielectric voltage-withstand test in 10.2.1; or

b) Selected and measured in accordance with the dimensions in Table 5.1.

5.9 Clearances selected and measured in accordance with the dimensions in Table 5.1 do not require testing.

Table 5.1
Minimum clearances for equipment[a,e]

Phase-to-ground[b] rated system voltage (rms and dc)				Rated impulse withstand voltage peak, kV[d]	Clearance, mm			
Overvoltage category[c]					Pollution degree[f]			
I	II	III	IV		1	2	3	4
50	–	–	–	0.33	0.01	0.2	0.8	1.6
100	50	–	–	0.50	0.04	0.2	0.8	1.6
150	100	50	–	0.80	0.10	0.2	0.8	1.6
300	150	100	50	1.5	0.5	0.5	0.8	1.6
600	300	150	100	2.5	1.5	1.5	1.5	1.6
1000	600	300	150	4.0	3.0	3.0	3.0	3.0
1500	1000	600	300	6.0	5.5	5.5	5.5	5.5
–	1500	1000	600	8.0	8.0	8.0	8.0	8.0
–	–	1500	1000	12.0	14.0	14.0	14.0	14.0
–	–	–	1500	16.0	19.4	19.4	19.4	19.4

[a] The minimum values for pollution degrees 2, 3, and 4 are premised on the concept that pollution which may be present in these micro-environments may bridge small clearances.

[b] For ungrounded systems or systems with one phase grounded, the phase-to-ground voltage is considered to be the same as the phase-to-phase voltage for the purposes of using this table.

[c] Typical examples of categories for products are given below. Users of this standard will need to establish that rated impulse voltage values are appropriate for the expected applications of the products covered.

Category IV – Primary Supply Level. Overhead lines and cable systems including distribution and its associated overcurrent protective equipment (equipment installed at the service entrance).

Category III – Distribution Level. Fixed wiring and associated equipment (not electrical loads) connected to the primary supply level, Category IV.

Category II – Load Level. Appliances and portable equipment and the like connected to the distribution level, Category III.

Category I – Signal Level. Special equipment or parts of equipment such as low-voltage electronic logic systems, remote controls, signaling and power limited (per NEC Article 725) circuits connected to the load level, Category II.

[d] Value to use based on the rating of the overvoltage protection means.

[e] Linear interpolation of the values is permitted.

[f] See 6.3.

6 Creepage Distances

6.1 The requirements of this section may be used to evaluate creepage distances. Creepage distances shall be at least the value in Table 6.1 or 6.2, based on the operating voltage across the distance, the comparative tracking index (CTI) of the insulating material, and the level of pollution expected or controlled at the creepage distance. For printed wiring boards using Table 6.2, the existence of recurring voltages is to be evaluated in accordance with 6.6.

Table 6.1
Minimum acceptable creepage distances[w]

Operating voltage, volts ac rms or dc[z]	Creepage distances for equipment subject to long-term stress, mm										
	Pollution degree 1	Pollution degree 2			Pollution degree 3				Pollution degree 4		
	All material groups	Material group[x]			Material group[x]				Material group[x]		
		I	II	IIIa,b	I	II	IIIa	IIIb	I	II	IIIa
10	0.08	0.4	0.4	0.4	1.0	1.0	1.0	1.0	1.6	1.6	1.6
12.5	0.09	0.42	0.42	0.42	1.05	1.05	1.05	1.05	1.6	1.6	1.6
16	0.1	0.45	0.45	0.45	1.1	1.1	1.1	1.1	1.6	1.6	1.6
20	0.11	0.48	0.48	0.48	1.2	1.2	1.2	1.2	1.6	1.6	1.6
25	0.125	0.5	0.5	0.5	1.25	1.25	1.25	1.25	1.7	1.7	1.7
32	0.14	0.53	0.53	0.53	1.3	1.3	1.3	1.3	1.8	1.8	1.8
40	0.16	0.56	0.8	1.1	1.4	1.6	1.8	1.8	1.9	2.4	3.0
50	0.18	0.6	0.85	1.2	1.5	1.7	1.9	1.9	2.0	2.5	3.2
63	0.2	0.63	0.9	1.25	1.6	1.8	2.0	2.0	2.1	2.6	3.4
80	0.22	0.67	0.95	1.3	1.7	1.9	2.1	2.1	2.2	2.8	3.6
100	0.25	0.71	1.0	1.4	1.8	2.0	2.2	2.2	2.4	3.0	3.8
125	0.28	0.75	1.05	1.5	1.9	2.1	2.4	2.4	2.5	3.2	4.0
160	0.32	0.8	1.1	1.6	2.0	2.2	2.5	2.5	3.2	4.0	5.0
200	0.42	1.0	1.4	2.0	2.5	2.8	3.2	3.2	4.0	5.0	6.3
250	0.56	1.25	1.8	2.5	3.2	3.6	4.0	4.0	5.0	6.3	8.0
320	0.75	1.6	2.2	3.2	4.0	4.5	5.0	5.0	6.3	8.0	10.0
400	1.0	2.0	2.8	4.0	5.0	5.6	6.3	6.3	8.0	10.0	12.5
500	1.3	2.5	3.6	5.0	6.3	7.1	8.0	8.0	10.0	12.5	16.0
630	1.8	3.2	4.5	6.3	8.0	9.0	10.0	10.0	12.5	16.0	20.0
800	2.4	4.0	5.6	8.0	10.0	11.0	12.5	y	16.0	20.0	25.0
1000	3.2	5.0	7.1	10.0	12.5	14.0	16.0	y	20.0	25.0	32.0
1250	4.2	6.3	9.0	12.5	16.0	18.0	20.0	y	25.0	32.0	40.0
1600	5.6	8.0	11.0	16.0	20.0	22.0	25.0	y	32.0	40.0	50.0
2000	7.5	10.0	14.0	20.0	25.0	28.0	32.0	y	40.0	50.0	63.0

Table 6.1 Continued on Next Page

Table 6.1 Continued

Operating voltage, volts ac rms or dc[z]	Creepage distances for equipment subject to long-term stress, mm										
	Pollution degree 1	Pollution degree 2			Pollution degree 3				Pollution degree 4		
	All material groups	Material group[x]			Material group[x]				Material group[x]		
		I	II	IIIa,b	I	II	IIIa	IIIb	I	II	IIIa
2500	10.0	12.5	18.0	25.0	32.0	36.0	40.0	y	50.0	63.0	80.0
3200	12.5	16.0	22.0	32.0	40.0	45.0	30.0	y	63.0	80.0	100.0
4000	16.0	20.0	28.0	40.0	50.0	56.0	63.0	y	80.0	100.0	125.0
5000	20.0	25.0	36.0	50.0	63.0	71.0	80.0	y	100.0	125.0	160.0
6300	25.0	32.0	45.0	63.0	80.0	90.0	100.0	y	125.0	160.0	200.0
8000	32.0	40.0	56.0	80.0	100.0	110.0	125.0	y	160.0	200.0	250.0
10000	40.0	50.0	71.0	100.0	125.0	140.0	160.0	y	200.0	250.0	320.0

[w] Linear interpolation of the values is permitted.

[x] See 6.2.

[y] Material group IIIb shall not be used for application in pollution degree 3 above 630 volts.

[z] It is appreciated that tracking or erosion will not occur on insulation subjected to a working voltage of 32 volts and below. However, the possibility of electrolytic corrosion has to be considered, and for this reason, minimum creepages have been specified.

6.2 The material groups of Tables 6.1 and 6.2 are related to the CTI performance level category values of insulating materials that are specified in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A, to be included in the group, as follows:

Material Group:

I – CTI ≥ 600 (PLC = 0)

II – 400 ≤ CTI < 600 (PLC = 1)

IIIa – 175 ≤ CTI < 400 (PLC = 2 or 3)

IIIb – 100 ≤ CTI < 175 (PLC = 4)

Note: PLC stands for Performance Level Category, and CTI stands for Comparative Tracking Index.

6.3 Pollution degrees based on the presence of contaminants and possibility of condensation or moisture at the creepage distance are as follows:

a) Pollution Degree 1 – No pollution or only dry, nonconductive pollution. The pollution has no influence.

b) Pollution Degree 2 – Normally, only nonconductive pollution. However, a temporary conductivity caused by condensation may be expected.

c) Pollution Degree 3 – Conductive pollution, or dry, nonconductive pollution that becomes conductive due to condensation that is expected.

d) Pollution Degree 4 – Pollution that generates persistent conductivity through conductive dust or rain and snow.

Table 6.2
Minimum acceptable creepage distances on printed wiring boards[a,d]

Operating voltage, volts ac rms or dc	Minimum creepage, mm	
	Pollution degree	
	1[b]	2[c]
10 – 50	0.025	0.04
63	0.04	0.063
80	0.063	0.1
100	0.1	0.16
125	0.16	0.25
160	0.25	0.4
200	0.4	0.63
250	0.56	1.0
320	0.75	1.6
400	1.0	2.0
500	1.3	2.5
630	1.8	3.2
800	2.4	4.0
1000	3.2	5.0

[a] Use Table 6.1 for pollution degrees 3 and 4.
[b] Material Groups I, II, IIIa, IIIb.
[c] Material Groups I, II, IIIa. For Material Group IIIb use Table 6.1.
[d] Linear interpolation of the values is permitted.

6.4 CONTROL OF POLLUTION DEGREE – Steps can be taken to control the pollution degree at the creepage distance by design features or the consideration of the operating characteristics of the product. See following examples:

a) Pollution degree 1 can be achieved by the encapsulation or hermetic sealing of the product. For printed circuit boards, coatings may be used that comply with the performance criteria of Section 11.

b) Pollution degree 2 can be achieved by reducing possibilities of condensation or high humidity at the creepage distance, through the provision of ventilation or the continuous application of heat, through the use of heaters or continuous energizing of the equipment when it is in use. Continuous energizing is considered to exist when the equipment is operated without interruption every day and 24 hours per day or when the equipment is operated with interruptions of a duration which do not permit cooling to the point of condensation to occur.

c) Pollution degree 3 can be achieved by the use of appropriate enclosures which act to exclude or reduce environmental influences, particularly moisture in the form of water droplets.

6.5 It is also necessary to consider some conditions where equipment may make the pollution degree at creepage distances more severe than the general environment. Examples of this concern would be operation which generates contaminates such as carbon brush particles or the arcing of switch parts.

6.6 RECURRING PEAK VOLTAGES – The value of recurring peak voltages appearing across creepage distances based on Table 6.2 on printed wiring boards shall be limited to a value not greater than the maximum allowable recurring peak voltage given in Table 6.3. The measurement of recurring peak voltages is to be in accordance with Section 9, Recurring Peak Voltage Determination.

Exception No. 1: Measurement in accordance with Section 9 need not be done if circuit analysis can be employed to determine the maximum recurring peak voltage due to regular operating characteristics, and due to adjustment of device controls.

Exception No. 2: The value of the recurring peak voltage need not be limited to the value in Table 6.3 if no air or gases are in contact with the related creepage point. Coating or encapsulation does not necessarily ensure that no air or gases are present.

Table 6.3
Maximum recurring peak voltage related to creepage distance on printed wiring boards[a]

Creepage distance mm	Maximum allowable recurring peak voltage
0.025	330
0.04	336
0.063	345
0.1	360
0.16	384
0.2	400
0.25	450
0.4	600
0.5	640
0.56	678
0.63	723
0.75	800
1.0	913
1.3	1049
1.5	1140
1.6	1150
1.8	1250
2.0	1314
2.4	1443
2.5	1475
3.2	1700
4.0	1922
5.0	2200

[a] Voltage and creepage values may be interpolated linearly.

7 Measurement of Clearance and Creepage Distances

7.1 Clearance and creepage distances are to be measured as illustrated in the examples contained in Figure 7.1.

7.2 The ″X″ values are a function of pollution degree and shall be as specified in Table 7.1.

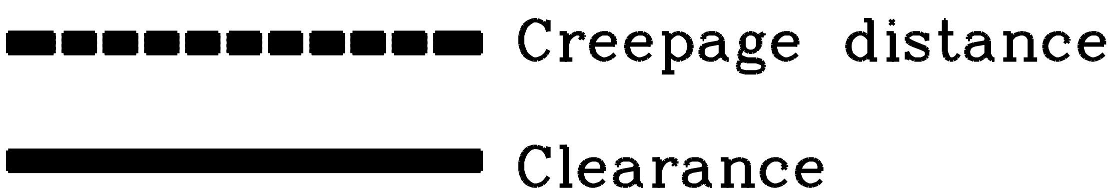
Exception: If the associated permitted clearance is less than 3 millimeters, the X value is one-third of the clearance.

Table 7.1
Width of grooves by pollution degree

Pollution degree	X value millimeters
1	0.25
2	1.0
3	1.5
4	2.5

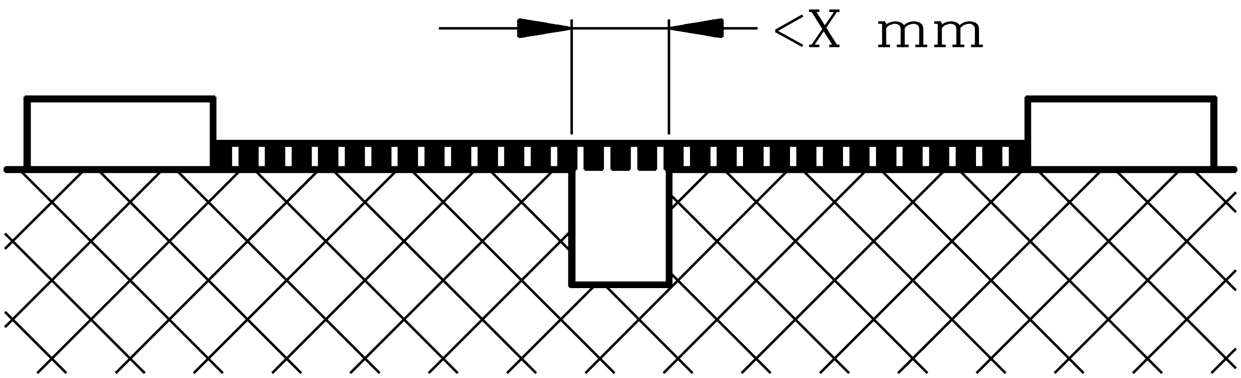
Figure 7.1
Examples of clearance and creepage distance measurement

Figure 7.1 revised April 1, 1999



S3433

EXAMPLE 1

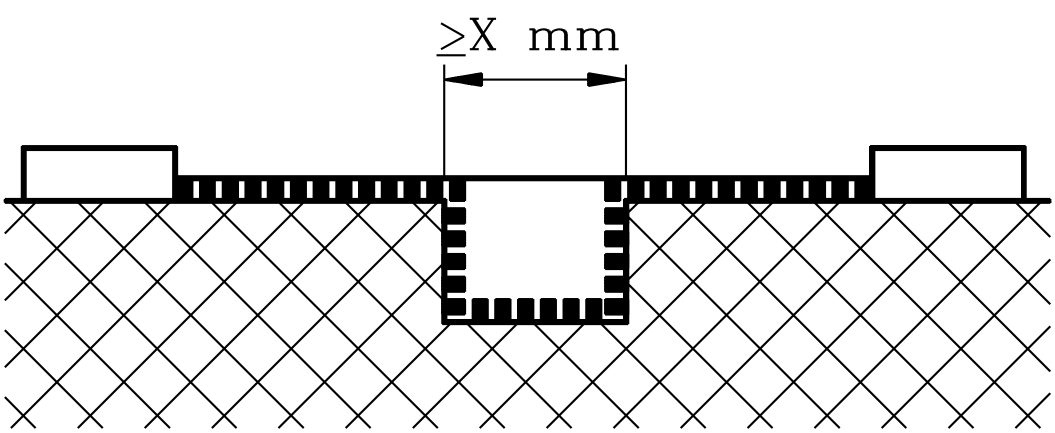


S3409A

Condition: Path under consideration includes a parallel, diverging or converging-sided groove of any depth with a width less than X mm.

Rule: Creepage distance and clearance are measured directly across the groove as shown.

EXAMPLE 2

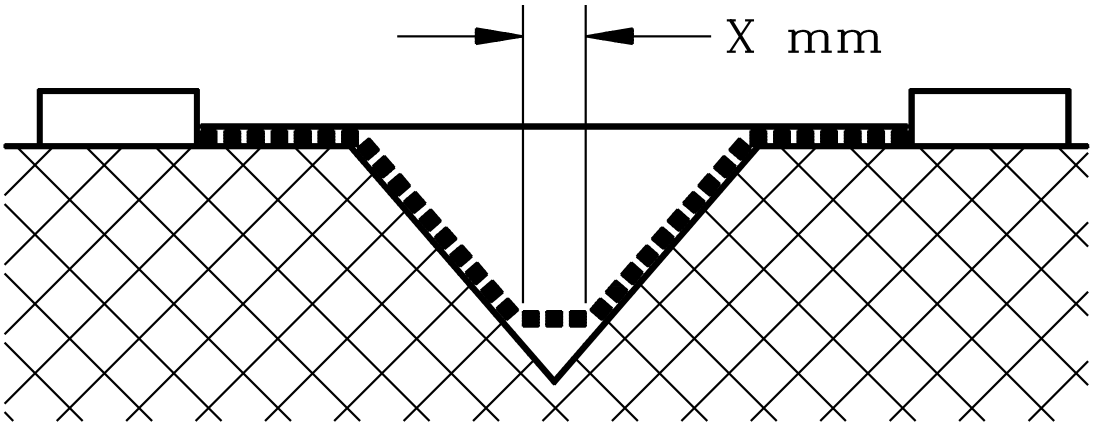


S3410A

Condition: Path under consideration includes a parallel or diverging-sided groove of any depth with a width equal to or more than X mm.

Rule: Clearance is the ″line of sight″ distance. Creepage path follows the contour of the groove.

EXAMPLE 3

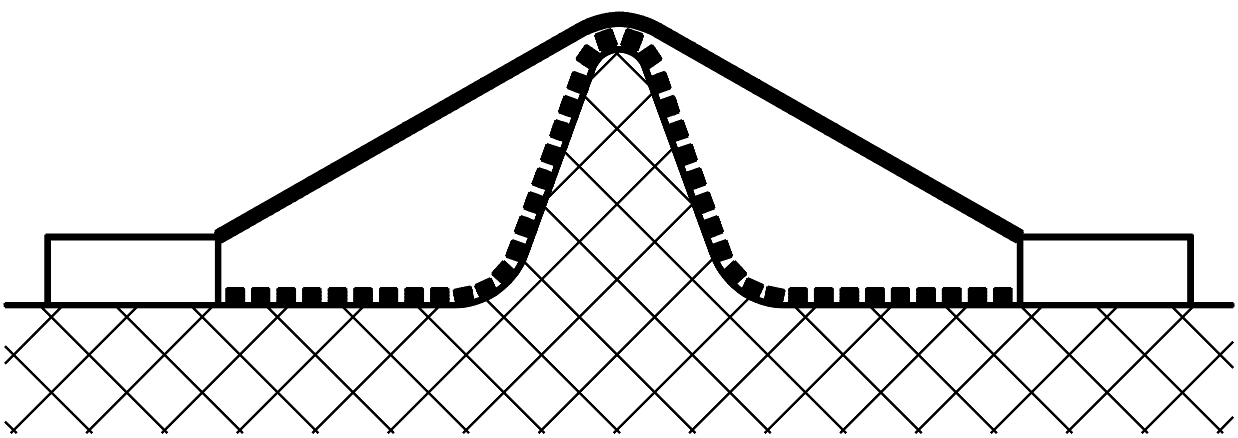


S3411A

Condition: Path under consideration includes a V-shaped groove with a width greater than X mm.

Rule: Clearance is the ″line of sight″ distance. Creepage path follows the contour of the groove but ″short-circuits″ the bottom of the groove by X mm link.

EXAMPLE 4

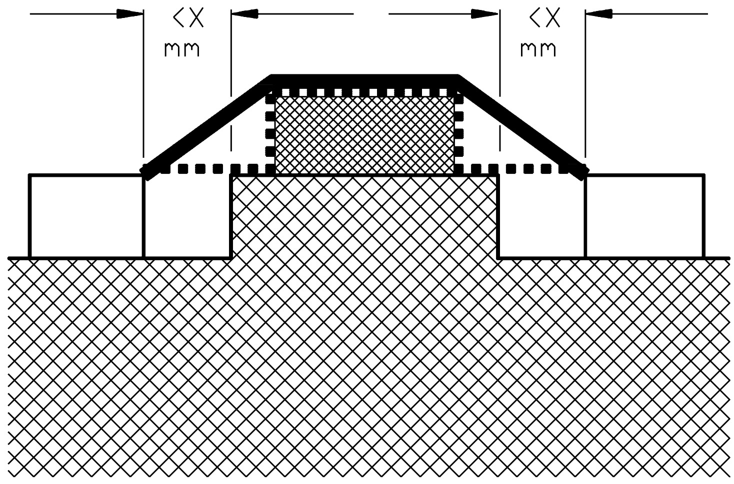


S3412

Condition: Path under consideration includes a rib.

Rule: Clearance is the shortest air path over the top of the rib. Creepage path follows the contour of the rib.

EXAMPLE 5

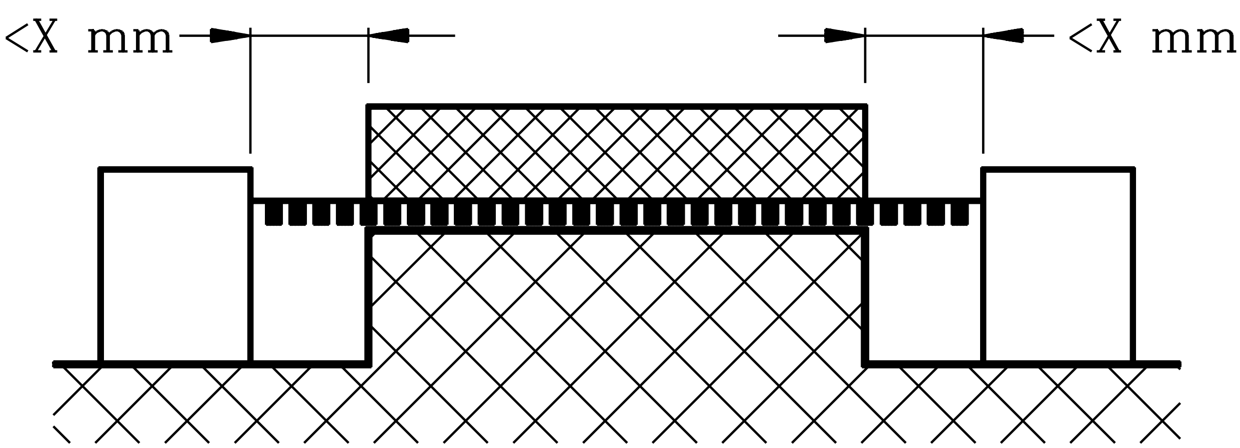


S3502

Condition: Path under consideration includes a cemented joint with grooves less than X mm wide on each side.

Rule: Clearance is the shortest air path over the top of the joint. Creepage distance is measured directly across the grooves and follows the contour of the joint.

EXAMPLE 6

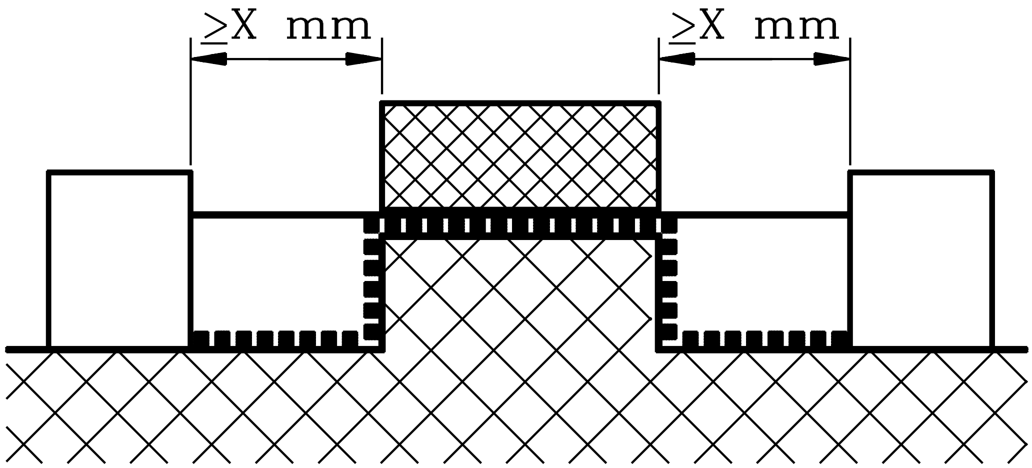


S3413A

Condition: Path under consideration includes an uncemented joint with grooves less than X mm wide on each side.

Rule: Creepage and clearance path is the ″line of sight″ distance shown.

EXAMPLE 7

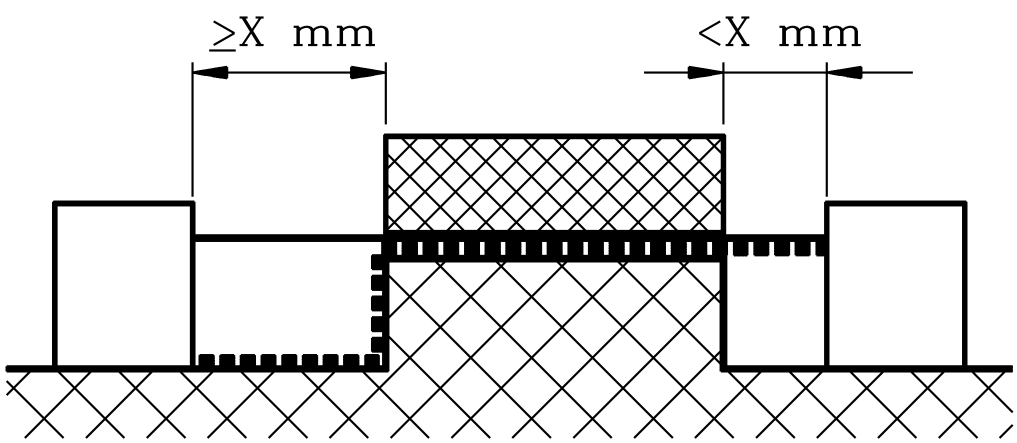


S3414A

Condition: Path under consideration includes an uncemented joint with grooves equal to or more than X mm wide on each side.

Rule: Clearance is the ″line of sight″ distance. Creepage path follows the contour of the grooves.

EXAMPLE 8

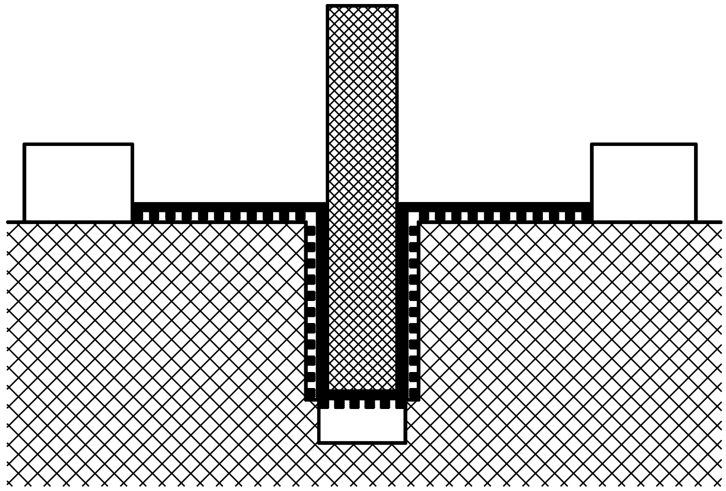


S3415A

Condition: Path under consideration includes an uncemented joint with a groove on one side less than X mm wide and the groove on the other side equal to or more than X mm wide.

Rule: Clearance and creepage paths are as shown.

EXAMPLE 9

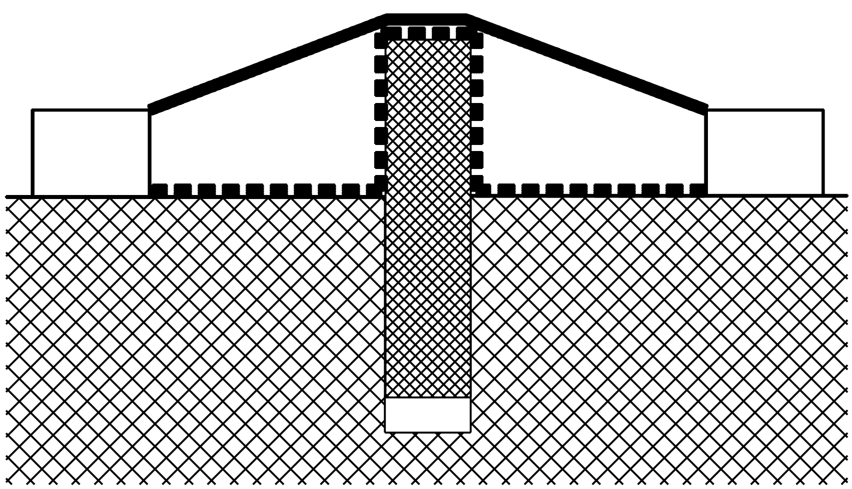


S3503

Condition: Path under consideration includes an uncemented barrier when path under the barrier is less than the path over the barrier.

Rule: Clearance and creepage paths follow the contour under the barrier.

EXAMPLE 10

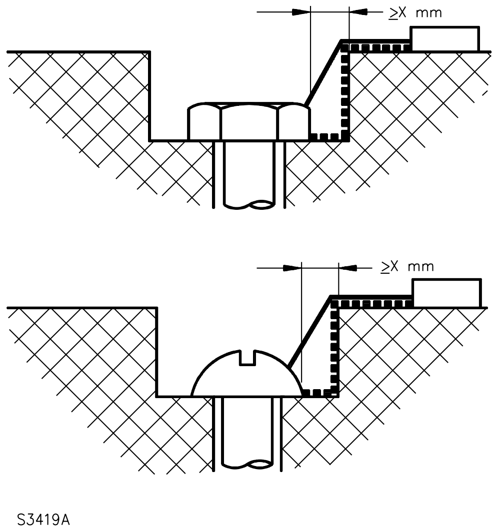


S3504

Conditions: Path under consideration includes an uncemented barrier when path over the barrier is less than the path under the barrier.

Rule: Clearance is the shortest air path over the top of the barrier. Creepage path follows the contour of the barrier.

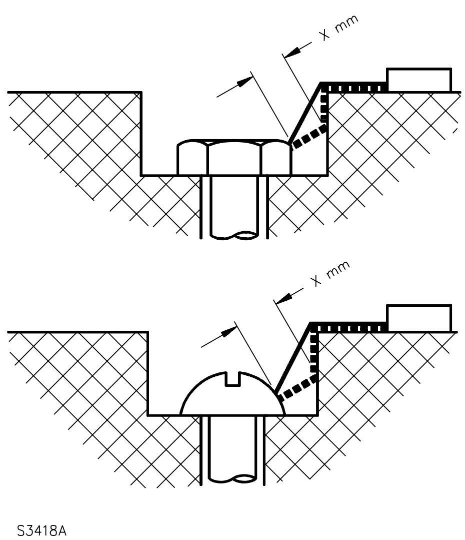
EXAMPLE 11



Condition: Path under consideration includes a gap between head of screw and wall of recess that is equal to or more than X mm wide.

Rule: Clearance is the shortest air path through the gap and over the top surface. Creepage path follows the contour of the surfaces.

EXAMPLE 12

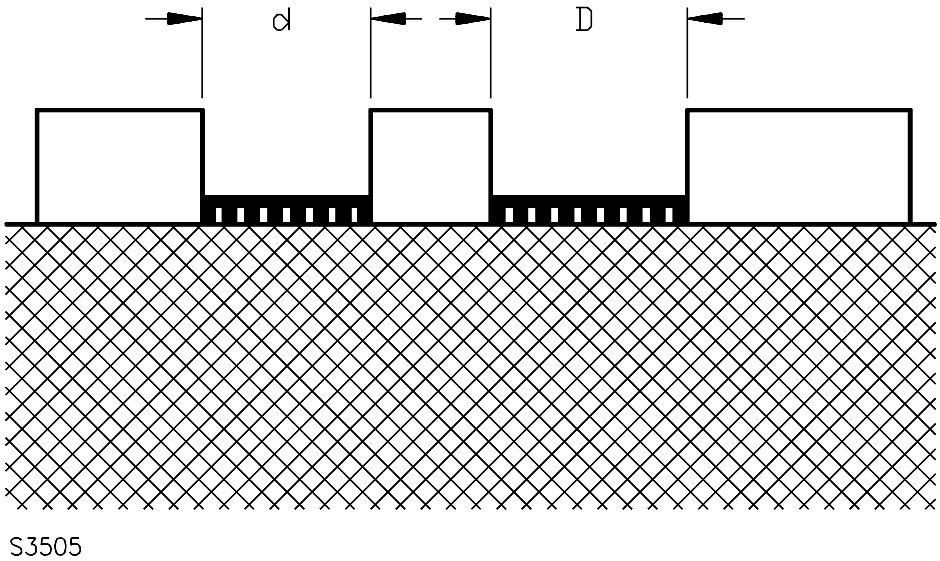


Condition: Path under consideration includes a gap between head of screw and wall of recess that is less than X mm wide.

Rule: Clearance is the shortest air path through the gap and over the top surface. Creepage path follows the contour of the surfaces but ″short-circuits″ the bottom of the recess by X mm link.

7A *Reserved*

EXAMPLE 13



Condition: Path under consideration includes an isolated part of conductive material.

Rule: Clearance and creepage paths are the sum of d plus D.

7B Use of Coatings to Achieve Insulation Coordination

7B.1 A coating intended to be used on a printed wiring board as an alternate to providing required creepage distances under the coating shall comply with Section 11, Printed Wiring Board Coating Performance Test.

7B.1 added January 30, 1995

7B.2 A coating intended to be used on a printed wiring board to provide a Pollution Degree 1 environment shall comply with 11.1 – 11.5.

7B.2 added January 30, 1995

PERFORMANCE

8 Switching Test

8.1 Where required by Section 5, Clearance B (Controlled Overvoltage), line and load terminals of a device are to be monitored for generated voltages during normal operation, including adjusting switches and controls, at rated operational voltage under load and no-load conditions. Generated voltages shall not be greater than the rated impulse withstand voltage peak specified in Table 5.1 for the device. This monitoring is to be done using an oscillographic study during a suitable test such as an overload test.

9 Recurring Peak Voltage Determination

9.1 To determine the maximum recurring peak voltage, as required in 6.6, a device having a coated or uncoated printed wiring board(s) is to be tested in accordance with 9.2.

9.2 Devices having a coated wiring board are tested in the uncoated condition. The device is to be operated under conditions for which it is intended. Controls and adjustments are to be manipulated for 100 cycles. The voltage at the point of reduced creepage distance shall be monitored by an oscilloscope having a frequency response of at least 1 megahertz.

Exception: Those controls and adjustments which have been shown to have no effect on the measured voltage for 5 cycles between maximum and minimum, need not be cycled 100 times.

10 Dielectric Voltage-Withstand Tests

10.1 Testing in lieu of measuring clearances

10.1.1 If one or more components would cause the indication of a breakdown because they complete the path between the points being tested, those components may have one termination disconnected, so long as the points in question are subjected to the same test voltage.

10.1.2 Clearance values may be verified by conducting the impulse withstand voltage test described in 10.1.4. The equipment shall withstand the voltage impulse without breakdown or disruptive discharge. Breakdown is considered to have occurred when the leakage current exceeds 4 milliamperes or when the test voltage is interrupted prior to completion. Operation of an overvoltage protective device is not considered a breakdown.

10.1.3 If a disruptive discharge occurs through an overvoltage protective device or system, that device or system is to be removed from the circuit and the test voltage is to be reduced to the impulse withstand voltage of that device or system. The test voltage is then to be applied across the load side at the point where the overvoltage protection was connected.

10.1.4 With reference to 4.2 and 5.7, a previously untested product is to be used. The voltage is to be full lightning 1.2/50 microsecond impulses in accordance with Techniques for High-Voltage Testing, ANSI/IEEE 4-1978. Three positive and three negative impulses are to be applied. The minimum interval between pulses is to be 1 second. Other equivalent methods, as shown in Table 4.1 or 5.1, as appropriate, may be used. The test voltage is to be applied at the supply input to the product under considerations.

10.1.4 revised January 30, 1995

Table 10.1
Test methods to be used to test spacings

Type of test	Impulse	AC rms	AC peak or DC	AC peak 1/2 sine wave	AC peak ramp
Rate of rise	1.2/50	–	–	–	6000 V/sec.
Hertz	–	50 – 60	50 – 60	50 – 60	50 – 60
Duration of test	3 Pos. & 3 Neg.[a] cycles	3 Pos. & 3 Neg.[a] cycles	3 Pos. & 3 Neg.[a] cycles DC, min. 10 ms	3 Pos. & 3 Neg.[a]	4 – 5 mA leakage current detection[b]

[a] The available current is to be limited to 4 – 5 milliamperes. The test equipment can be power limited or designed to shut off by the detection of 4 – 5 milliampere leakage current.

[b] The measured voltage must exceed the values in Table 4.1 or 5.1 as appropriate when the leakage current of 4 – 5 milliamperes is measured.

10.2 Testing for controlled overvoltage

10.2.1 With regard to 5.8, the dielectric voltage-withstand test for verifying clearances in equipment with overvoltage control is to be conducted in accordance with 10.2.2, and 10.1.1 – 10.1.4.

10.2.2 Three samples of the equipment that have not been previously tested are to be connected to a source of supply operating at rated voltage. Consideration must be given to connecting a filter at the equipment input to prevent the surge from reaching the supply source.

11 Printed Wiring Board Coating Performance Test

11.1 General

11.1.1 A coating intended to be used on a printed wiring board that has creepages in accordance with Table 6.2, pollution degree 1, shall comply with the requirements in 11.1 – 11.5.

11.1.1 revised January 30, 1995

11.1.1.1 A coating intended to be used on a printed wiring board as an alternate to providing required creepage distances shall comply with 11.1 – 11.11.

11.1.1.1 added January 30, 1995

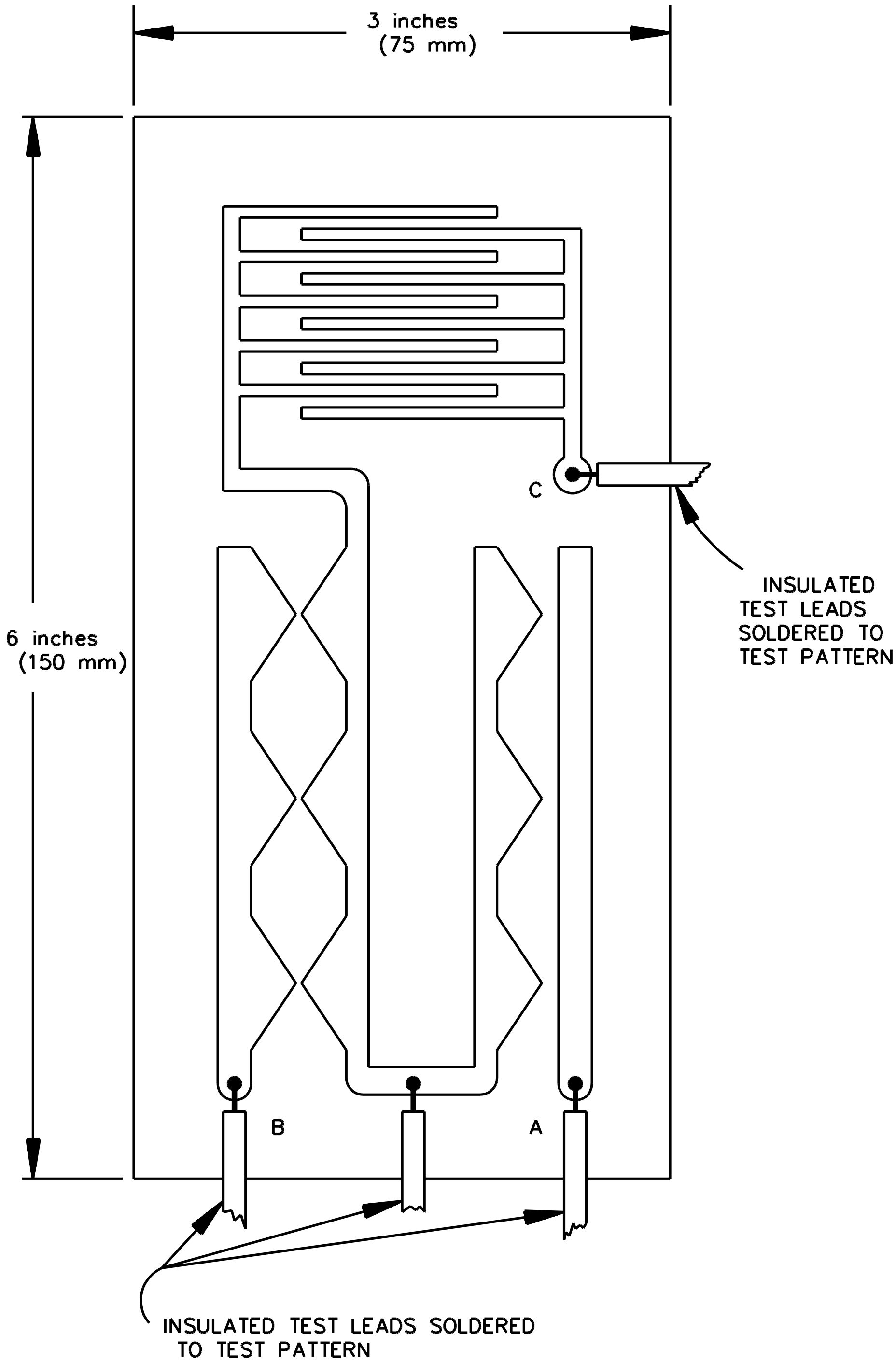
11.1.2 A printed-wiring board that is used with a coating is to be evaluated in accordance with the Standard for Printed-Wiring Boards, UL 796, and is to be acceptable for the temperature, solder conditions, conductor size, and adhesive to the base material under the conditions encountered in the end-use application. Tests are to be conducted on a fully processed printed-wiring board representative of production, containing such items as inks and solder resists, if applicable.

11.1.3 Test samples are to be provided with the minimum creepage, as applicable, and the minimum coating thickness using the pattern shown in Figure 11.1. The samples are to be prepared by normal production means employing the primer or cleaner employed by the end-product manufacturer. Lead wires that are considered acceptable for the voltage stress and temperatures involved are to be attached.

Exception: A representative printed wiring board with components removed may be used for this test.

11.1.3 revised January 30, 1995

Figure 11.1
Dielectric test pattern



S2005

Note: Distances between adjacent foil patterns should represent the minimum distances employed by the manufacturer.

11.1.4 Testing is to be conducted as described in 11.2.2 – 11.6.1 on each type of industrial laminate material that is to be considered. However, if several laminates are to be considered, and they are covered under the requirements of the Standard Specification for Laminated Thermosetting Materials, ASTM D709-92:

a) Testing of ANSI FR-4 is considered representative of ANSI FR-5, G-10, G-11, CEM-1, and CEM-3 materials.

b) Testing of ANSI XXXPC is considered representative of ANSI X, XP, XPC, XX, XXP, XXX, and XXXP materials.

c) Testing of ANSI GPO-2 is considered representative of ANSI GPO-3 material.

11.1.5 For the tests specified in 11.7 and 11.8, the test samples are to be conditioned first at a temperature of 40°C (104°F) and at 93 ±2 percent relative humidity for 48 hours. The tests are to be conducted at these conditions.

11.1.5 added January 30, 1995

11.2 Dielectric voltage-withstand test

11.2.1 A coating shall withstand a 1000-volt, ac potential difference for 1 minute without breakdown in accordance with 11.2.2 – 11.5.1. Conditioned samples (see 11.3.1 – 11.6.1) shall;

a) Withstand the dielectric stress for 1 minute without breakdown; and

b) Have a dielectric breakdown value at least 50 percent of the unconditioned level as determined in accordance with 11.2.4.

11.2.2 The coating is to be tested by means of a 500 volt-ampere or larger capacity transformer, the output voltage of which is essentially sinusoidal and can be varied. A direct-current source shall be used for a direct-current circuit. The applied potential is to be increased from zero to the required value at a substantially uniform rate, and as rapidly as is consistent with its value being correctly indicated by a voltmeter.

Exception: A 500 volt-ampere or larger capacity transformer need not be used if the transformer is provided with a voltmeter that directly measures the applied output potential.

11.2.3 Five samples of the coated board as described in 11.1.3 are to be provided with tight-fitting aluminum foil (representing an electrically conductive deposit along the surface of the coating) that covers the test pattern except for the insulated test lead wire and solder points.

11.2.4 After the preparation described in 11.2.3, the voltage stress is to be applied for 1 minute, between leads A, B, and C individually and the common lead as shown in Figure 11.1. After 1 minute, the voltage stress is to be gradually increased until breakdown occurs.

11.3 Environmental cycling test

11.3.1 Five samples of the coated board as described in 11.1.3 are to be subjected to three complete cycles of environmental conditioning as described in Table 11.1. Following the conditioning, each sample is to be subjected to the dielectric voltage-withstand test described in 11.2.1 – 11.2.4.

Table 11.1
Cycling conditions

For indoor end-use applications	For outdoor end-use applications
24 hours at T[a]; followed by at least 96 hours at 35.0 ±2.0°C (95.0 ±3.6°F) 90 ±5 percent relative humidity; followed by 8 hours at 0.0 ±2.0°C (32.0 ±3.6°F).	A minimum of 24 hours immersed at 25.0 ±2°C (77.0 ±3.6°F) water; followed immediately by at least 96 hours at 35.0 ±2.0°C (95.0 ±3.6°F) 90 ±5 percent relative humidity; followed by 8 hours at minus 35.0 ±2.0°C (minus 31.0 ±3.6°F).
[a] T is 60°C (140°F), unless device rated for higher temperature, in which case T is the rated temperature.	

11.4 Humidity conditioning test

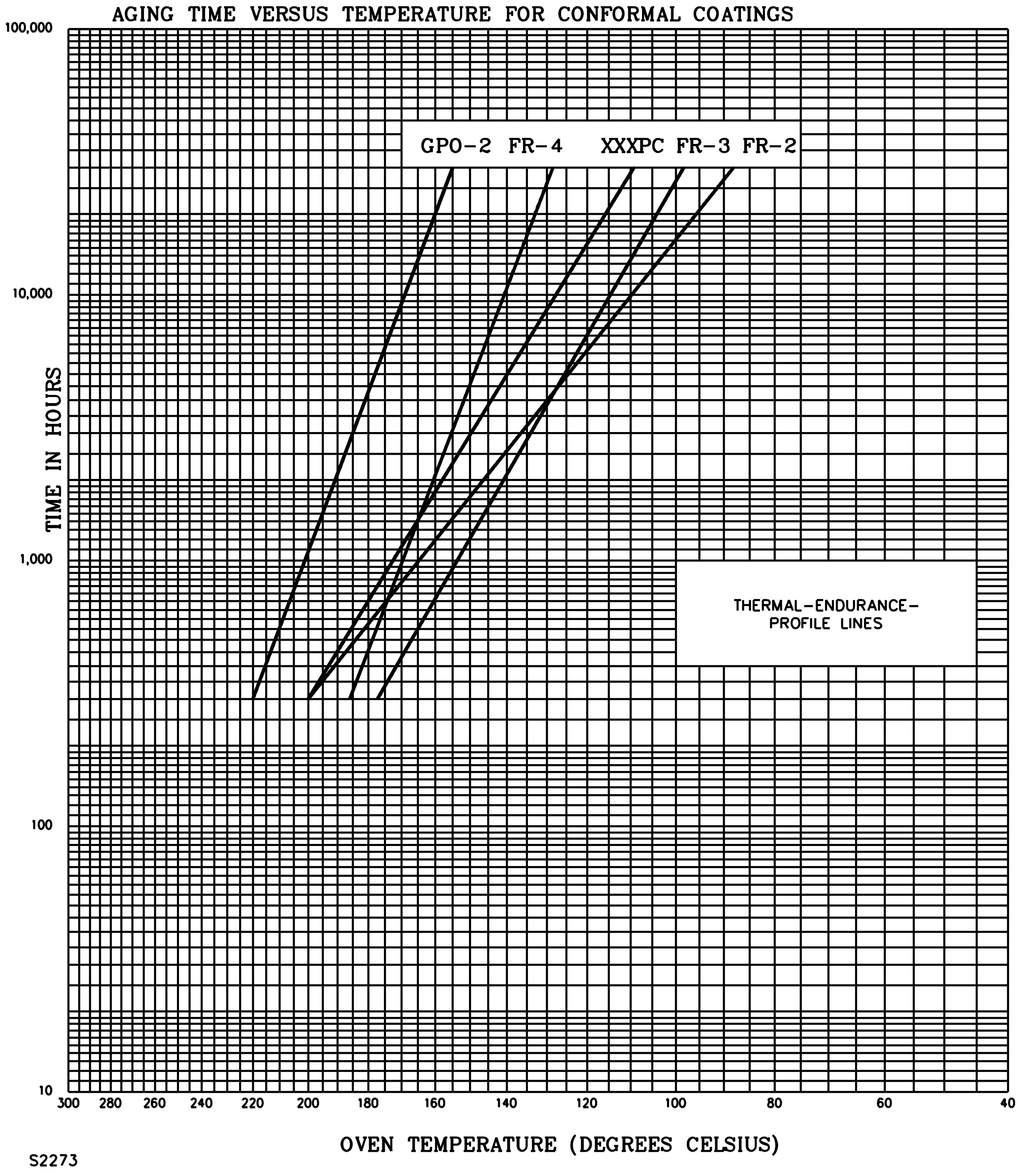
11.4.1 Five samples of the coated board as described in 11.1.3 are to be conditioned for 7 days in a test chamber at a temperature of 35 ±1°C (95 ±2°F) and 90 ±5 percent relative humidity. Within 2 minutes of removal from the test chamber, each sample is to be subjected to the dielectric voltage-withstand test described in 11.2.1 – 11.2.4.

11.5 Thermal conditioning test

11.5.1 Five samples of the coated board as described in 11.1.3 are to be conditioned for 1000 hours at the appropriate oven temperature in accordance with Figure 11.2. The temperature is based on the ANSI designation of the Industrial Laminate Material. The equivalent statements of 11.1.4 apply. After conditioning, each sample is to be cooled for 40 or more hours at a temperature of 23 ±2°C (73 ±4°F) and a relative humidity of 50 ±5 percent. Upon completion of the cooling, each sample shall comply with the dielectric voltage-withstand test requirements in 11.2.1 – 11.2.4.

Exception: On the same thermal endurance profile line in Figure 11.2, a shorter or longer time at a higher or lower temperature, respectively, may be employed if agreeable to those concerned, but the minimum test time is 300 hours.

Figure 11.2
Conditioning time versus oven temperature for normal operating temperature of coatings



11.6 Coating adhesion

11.6.1 A coating shall adhere to the printed wiring board after being tested in accordance with 11.6.2 and 11.6.3. Five samples of the printed wiring board are to be subjected to this test. For all five samples, there shall be no blistering, swelling, or cracking of the coating as a result of the test, and the coating shall not separate from the base material.

11.6.1 added January 30, 1995

11.6.2 The adhesive side of a non-transferable transparent adhesive tape having a minimum pull strength of 35 ±5 ounces per inch (0.39 ±0.056 N/mm) as determined by the Standard for Methods of Testing Pressure-Sensitive Adhesive Coated Tapes Used for Electrical Insulation, ASTM D1000-82(1988), is to be applied to the coating by finger pressure, care being taken to exclude all air bubbles. After an interval of 10 seconds, the tape is to be removed by applying a steady pulling force on the tape in a direction perpendicular to the surface of the coating under test. The coated area under test is to be at least 1 square cm (0.1550 square inches).

11.6.2 added January 30, 1995

11.6.3 The test in 11.6.2 is to be repeated following the cycles of environmental conditioning specified in 11.3 and Table 11.1.

11.6.3 added January 30, 1995

11.7 Insulation resistance between conductors

11.7.1 After being conditioned in accordance with 11.1.5, a sample shall be tested in accordance with 11.7.2, and shall have a minimum insulation resistance of 100 MΩ or greater.

11.7.1 added January 30, 1995

11.7.2 The test voltage is to be the closest voltage of the following to the working voltage of the end product:

a) 10 ±1 V;

b) 100 ±15 V; or

c) 500 ±50 V.

The test voltage is to be applied between conductors for 1 minute before measurement. If a stable reading is obtained earlier, the measurement may be made earlier.

11.7.2 added January 30, 1995

11.8 Impulse withstand voltage

11.8.1 After being conditioned in accordance with 11.1.5, a sample is to be tested in accordance with 10.1.4, and shall comply with 10.1.2.

11.8.1 added January 30, 1995

11.9 Resistance to soldering heat

11.9.1 A coated printed wiring board is to be tested in accordance with 11.9.2 and 11.9.3. As a result of the test, the coating shall continue to adhere to the surface, and shall show no evidence of blistering, swelling, or cracking.

11.9.1 added January 30, 1995

11.9.2 For this test, a solder bath kept at 260 (+5, -0)°C (500°F) throughout the test, is to be used. The temperature is to be measured at 25 mm (1 inch) below the surface. The oxide is to be removed from the surface of the solder prior to initiating this test.

11.9.2 added January 30, 1995

11.9.3 The sample is to be floated for 20 seconds on the solder in such a manner that only one side of the board is directly in contact with the solder. After removal from the solder bath, the sample is to be allowed to cool to between 15°C (59°F) and 35°C (95°F).

11.9.3 added January 30, 1995

11.10 Flammability

11.10.1 A coating shall not adversely affect the flammability of a printed wiring board as determined by 11.10.2.

11.10.1 added January 30, 1995

11.10.2 Two printed wiring boards, one coated and one without coating, are to be subjected to the Flammability Evaluation in UL 796 , the Standard for Printed-Wiring Boards. As a result of this test, the flammability rating for the coated and the uncoated printed wiring board shall be the same or better.

11.10.2 added January 30, 1995

11.11 Comparative tracking index (CTI)

11.11.1 A coating shall not adversely affect the Comparative Tracking Index (CTI) of a printed wiring board as determined by 11.11.2.

11.11.1 added January 30, 1995

11.11.2 The Comparative Tracking Index (CTI) of a coated and an uncoated printed wiring board is to be determined in accordance with the methods prescribed in UL 746C , the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations. The Performance Level Category (PLC) shall be the same or better for each test.

11.11.2 added January 30, 1995

No Text on This Page