UL 2557

STANDARD FOR SAFETY

Membrane Switches

UL Standard for Safety for Membrane Switches, UL 2557

First Edition, Dated December 4, 2020

Summary of Topics

This First Edition ANSI/UL 2557 dated December 4, 2020 covers membrane switches actuated by human activity, via a membrane or sensing substrate, to operate or control appliances and electrical equipment. The membrane switch electrical rating is not to exceed 30 Vrms and power not greater than 100 VA.

The requirements are substantially in accordance with Proposal(s) on this subject dated May 8, 2020 and July 31, 2020.

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Standard for Membrane Switches

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This ANSI/UL Standard for Safety consists of the First Edition.

The most recent designation of ANSI/UL 2557 as an American National Standard (ANSI) occurred on October 5, 2020. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

Comments or proposals for revisions on any part of the Standard may be submitted to UL at any time. Proposals should be submitted via a Proposal Request in UL's On-Line Collaborative Standards Development System (CSDS) at https://csds.ul.com.

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INTRODUCTION

1 Scope

1.1 These requirements apply to membrane switches actuated by human activity, via a membrane or sensing substrate, to operate or control appliances and electrical equipment. The membrane switch electrical rating not to exceed 30 Vrms and power not greater than 100 VA.

1.2 When this standard references "switches" it shall mean "membrane switches" unless specifically indicated.

1.3 Membrane switches which incorporate additional control functions governed by the switch function are within the scope of these requirements. Additional control functions shall be evaluated for their suitability using the applicable standards for the application.

1.4 These membrane switches are intended to be operated by a person, via a membrane or by actuating a sensing substrate.

1.5 These requirements cover the indirect actuation of the switch when the operation of the actuating member or sensing unit is provided by a remote control or a part of an appliance or equipment such as a door.

1.6 Embedded components are evaluated with regards to their safety and application to the membrane switch construction. The acceptability of an embedded component in the membrane switch shall be considered with regards to construction and performance requirements in the end product final application.

2 Components

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

2.2 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.

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

2.4 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.

3 Units of Measurement

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

4 References

4.1 Undated references

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

4.2 Normative references

4.2.1 The following normative documents contain provisions which, through reference in this text, constitute provisions of this part of the standard.

4.2.2 The following are ASTM test procedures referenced:

a) Standard Test Methods for DC Resistance or Conductance of Insulating Materials, ASTM D257

b) Standard Test Methods for Thickness of Solid Electrical Insulation, ASTM D374

c) Standard Test Method for Pressure-Sensitive Adhesive-Coated Tapes Used for Electrical and Electronic Applications, ASTM D1000

d) Standard Test Method for Contact Closure Cycling of a Membrane Switch, ASTM F1578

e) Standard Practice for Viewing Conditions for Visual Inspection of Membrane Switches, ASTM F1595

f) Standard Test Method for Exposure of a Membrane Switches or Printed Electronic Device to Temperature and Relative Humidity, ASTM F1596

g) Standard Test Method for Determining the Effects of Chemical/Solvent Exposure to a Membrane Switch/Graphic Overlay (Spot Test Method), ASTM F1598

h) Standard Test Method for Determining the Contact Bounce Time of a Membrane Switch, ASTM F1661

i) Standard Test Method for Verifying the Specified Dielectric Withstand Voltage and Determining the Dielectric Breakdown Voltage of a Membrane Switch or Printed Electronic Device, ASTM F1662

j) Standard Test Method for Determining the Capacitance of a Membrane Switch or Printed Electronic Device, ASTM F1663

k) Standard Test Method for Determining Circuit Resistance of a Membrane Switch, ASTM F1680

l) Standard Test Method for Determining the Insulation Resistance of a Membrane Switch, ASTM F1689

m) Standard Test Method for Determining the Effects of Atmospheric Pressure Variation on a Membrane Switch, ASTM F1762

n) Standard Test Method for Determining the Effect of an ESD Discharge on a Membrane Switch or Printed Electronic Device, ASTM F1812

o) Standard Test Method for Submersion of a Membrane Switch, ASTM F1895

p) Standard Test Method for Determining the Shear Strength of the Bond between a Surface Mount Device (SMD) and Substrate in a Membrane Switch, ASTM F1995

q) Standard Test Method for Silver Migration for Membrane Switch Circuitry, ASTM F1996

r) Standard Test Method for Hosedown of a Membrane Switch, ASTM F2072

s) Standard Test Method for Measuring the Force-Displacement of a Membrane Switch, ASTM F2592

4.2.3 These requirements are intended to be used in conjunction with the following requirements or standards.

a) Polymeric Materials – Short Term Property Evaluations, UL 746A

b) Polymeric Materials – Long Term Property Evaluations, UL 746B

c) Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C

d) Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used in Printed Wiring Boards, UL 746E

e) Polymeric Materials – Flexible Dielectric Film Materials For Use In Printed-Wiring Boards and Flexible Materials Interconnect Constructions, UL 746F

f) Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94

5 Glossary

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

5.2 ABNORMAL CONDITIONS – Conditions which may occur in the appliance or in the switch during normal operation.

5.3 ACCESS HOLE – Holes (such as through hole or via) on the same axis through successive layers of materials intended to provide access to the surface of the land on an inner conductor layer of a multi-layer category construction.

5.4 ACTUATING MEMBER – Part which is pulled, pushed, or otherwise moved to cause an operation.

5.5 ACTUATION – Movement of the actuating member of the switch by hand, by foot, or by any other human activity to provide electrical closure of the momentary switch.

5.6 ACTUATION FORCE – The maximum force measured prior to or including point at which contact closure is achieved on a membrane switch.

5.7 ADDITIVE PROCESS – A selective or non-selective process used to deposit a pattern of conductor material(s) on clad or unclad base material.

5.8 ADD-ON COMPONENT – Discrete, integrated, packaged, or chip components that are attached to a membrane switch to function as part of a complete circuit or assembly.

5.9 ADHESIVE – A gelatinous substance such as glue used to join, bond, or fasten materials or objects together.

5.10 AS-RECEIVED – Specimens or samples in an unconditioned state, prior to being subject to conditioning, or without a history of conditioning.

5.11 ASSEMBLY – Various parts, subassemblies, and combinations thereof, joined together.

5.12 BASIC INSULATION – Insulation applied to live parts to provide basic protection against electric shock.

5.13 BEND – To force from a straight form into different and especially a curved one.

5.14 BEND CYCLE – A fold of a specimen around a specified mandrel which is "rolled" in one direction, followed by rolling in the opposite direction, returning the specimen to its original position.

5.15 BLIND VIA – A via extending to only one surface of the membrane switch construction.

5.16 BONDING FILM – The layer of insulation used to bond discrete layers during lamination of membrane switch constructions. See spacer layer.

5.17 BONDING LAYER – An adhesive layer used to bond discrete layers of multilayer membrane switch constructions. See spacer layer.

5.18 BUILD-UP THICKNESS – Overall thickness of a combination of materials. Unless otherwise indicated, the build-up thickness will refer to the overall thickness in the area of a membrane switch construction where no internal or external conductor material resides.

5.19 BURIED VIA – A via that does not extend to the surface of a membrane switch construction.

5.20 CALCULATED THICKNESS – The calculated thickness is a thickness value determined by adding suggested material component thicknesses, or a thickness value determined by adding or subtracting one measured value to or from another measured value.

5.21 CIRCUIT – Electrical devices and elements interconnected to perform a desired electrical function.

5.22 CIRCUIT LAYER – Conductor layer or plane in or on a membrane switch construction.

5.23 CIRCUIT LAYER BASE MATERIAL – An organic or inorganic dielectric barrier material, used to support conductor material, with or without adhesive material.

5.24 CIRCUIT LAYER BASE MATERIAL THICKNESS – The thickness of the base dielectric material. If an adhesive is used for the base material, the adhesive thickness and number of sides is indicated separately.

5.25 CIRCUIT RESISTANCE – Electrical resistance as measured between two test points whose internal contacts, when held closed, complete a circuit.

5.26 CLASS 0 APPLIANCE – Appliance in which protection against electric shock relies upon basic insulation; this implies that there are no means for the connection of accessible conductive parts, if any, to the protective conductor in the fixed wiring of the installation, reliance in the event of a failure of the basic insulation being placed upon the environment.

5.27 CLASS I APPLIANCE – Appliance in which protection against electric shock does not rely on basic insulation only, but which includes an additional safety precaution in such a way that means are provided for the connection of conductive parts (which are not live parts) to the protective (earthing) conductor in the fixed wiring in such a way that these parts cannot become live in the event of a failure of the basic insulation.

5.28 CLASS II APPLIANCE – Appliance in which protection against electric shock does not rely on basic insulation only, but in which additional safety precautions such as double insulation or reinforced insulation are provided, there being no provision for protective earthing or reliance upon installation conditions. A Class II appliance may be provided with means for maintaining the continuity of protective circuits, provided that such means are within the appliance and are insulated from accessible surfaces according to the requirements of Class II.

5.29 CLASS III APPLIANCE – Appliance in which protection against electric shock relies on supply at SELV and in which voltages higher than those of SELV are not generated.

5.30 CLASS 2 CIRCUIT – A control circuit supplied from a source having limited voltage (30 Vrms or less) and current capacity, such as from the secondary of a Class 2 transformer, and rated for use with Class 2 remote-control or signaling circuits.

5.31 CLEARANCE – The shortest distance in air between two conductive parts.

5.32 COATING – A non-metallic substance applied by some process, such as dipping, curtain coating, film laminating, screening, spraying, or melt-flow.

5.33 COMPARATIVE TRACKING INDEX (CTI) – Expressed as that voltage which causes tracking after 50 drops of 0.1% ammonium chloride solution have fallen on the material.

5.34 COMPONENT – An individual or combination of parts intended to perform a desired function.

5.35 CONDITIONING – Exposure of test specimens to an environment for a period of time, prior to or after testing, and prior to evaluation.

5.36 CONDUCTIVE FOIL – A thin metal sheet intended for forming a conductor pattern on a base material.

5.37 CONDUCTIVE PASTE – An organic or inorganic paste substance capable of transmitting electricity, used for circuit conductors, including but not limited to carbon, copper, and silver.

5.38 CONDUCTOR – A trace or path for electricity to transmit in a conductor pattern.

5.39 CONDUCTOR ADHESIVE – Adhesive material used to attach conductor material to a base material or dielectric material.

5.40 CONDUCTOR LAYER – A single plane of a conductor material or pattern on base material.

5.41 CONDUCTOR MATERIAL – An organic or inorganic substance capable of transmitting electricity, used for circuit conductors, including but not limited to copper, tin, nickel, gold, copper paste, silver paste, carbon paste, ruthenium oxide paste, etc.

5.42 CONDUCTOR PATTERN – The path, design, or configuration of conductor material on the base material, including but not limited to conductors, lands, through-holes, and vias.

5.43 CONDUCTOR RESISTANCE – The measured electrical resistance through a circuit loop between two test points.

5.44 CONDUCTOR SPACING – The minimum distance between adjacent conductors.

5.45 CONDUCTOR THICKNESS – The thickness of the conductor and additional metallic platings or coatings, excluding non-conductive coatings.

5.46 CONDUCTOR WIDTH – The width of the conductor as viewed from a top view or at the plane of the surface of a base material, whichever is less.

5.47 CONFORMAL COATING – An insulating, environmentally protective coating capable of conforming to the objects coated.

5.48 CONNECTOR – A terminal device capable of connect/disconnect service for electrical components.

5.49 CONSTRUCTION – A variation in membrane switch material build-up, including but not limited to film, adhesive, base material, bond ply, cover layer, or other insulation materials. Variations include single layer, multi-layer, flexible, flex-to-install, rigid, and multi-layer flex/rigid composite constructions.

5.50 CONTACT BOUNCE – Intermittent contact opening and contact closure that may occur after switch operation.

5.51 CONTACT CLOSURE – The event at which a specified resistance is achieved on a membrane switch.

5.52 CONTACT FINGER – A conductive surface used to provide electrical connection by pressure contact, usually located at an edge of a membrane switch.

5.53 CONTACT FORCE – The force at contact closure.

5.54 CONTINUITY – An uninterrupted path of electrical current.

5.55 COPPERCLAD POLYIMIDE FLEXIBLE CONSTRUCTION – Switches that use a polyimide substrate with copper traces and either a metal dome, polydome or silicone rubber overlay to provide the electrical closure of the switch and tactile response.

5.56 COVERCOAT – A thin dielectric material deposited as a liquid used to cover the circuit pattern that subsequently becomes a permanent coating. See coverlay, 5.58.

5.57 COVERFILM ADHESIVE – Adhesive used with film to prepare cover film on a base material or dielectric material. The film may be a base dielectric material.

5.58 COVERLAY – A combination of film and adhesive, which may be made from different chemistries, used to cover the circuit pattern.

5.59 CREASE – A ridge or groove made by folding and pressing.

5.60 CREASE CYCLE – A 180° crease followed by a flattening of the crease.

5.61 CREEPAGE DISTANCE – The shortest distance along the surface of the insulation material between two conductive parts.

5.62 CRITICAL OPERATION – Production process or fabrication step considered potentially detrimental to the materials subject to the operation.

5.63 CURRENT – The movement or flow of electrons in a conductor due to a voltage potential difference at opposing ends of the conductor.

5.64 CURRENT CARRYING CAPACITY – The maximum level of electrical current that a circuit can conduct without sustaining damage.

5.65 DELAMINATION – A planar separation of materials (i.e., separation between conductor and base material, bonding layer and base material, coverfilm and conductor, etc.).

5.66 DIELECTRIC – A material capable of high resistance to the flow of electrical current and capable of being polarized by electric field.

5.67 DIELECTRIC WITHSTAND VOLTAGE – The maximum voltage a dielectric can withstand in a membrane switch without a visual change from a voltage discharge or specified change of insulation resistance, or both.

5.68 DISSCONNECTION – Interruption of an electrical circuit in a pole so as to provide insulation between the supply and those parts intended to be disconnected from the supply.

5.69 DOUBLE INSULATION – Insulation comprising both basic insulation and supplementary insulation.

5.70 DOUBLE SIDED – A single layer membrane switch construction or printed wiring board with conductor pattern on the two external sides of the circuit base material.

5.71 DUTY CYCLE – The ratio of switch closed time to total cycle time.

5.72 EDGE, CONDUCTOR – A conductor parallel with and spaced not more than 0.4 mm (1/64 in) from the edge of the base material.

5.73 ELASTOMERIC (RUBBER) CONSTRUCTION – Switches that use mold injected rubber, with an impregnated carbon pill or screen printed emboss as the means for electrical closure of the switch, the spring force is inherent to the upper layer substrate material and dependent upon design and webbing thickness.

5.74 ELECTROLESS PLATING – The depositing of conductor material from an autocatalytic plating solution without the application of electrical current.

5.75 ELECTRONIC DISCONNECTION – A high resistance open, that provides a non-cycling correct functional performance without a complete micro or full "air gap" disconnect.

5.76 ELECTROPLATING – The depositing of conductor material from a plating solution by the application of electrical current.

5.77 EMBEDDED COMPONENT – A discrete component integrated into the membrane switch during fabrication.

5.78 END PRODUCT – A device or appliance in which a membrane switch is installed as a component.

5.79 ETCHANT – A chemically reactive solution used to remove portions or all material from a base material.

5.80 ETCHING – The action of chemical, or chemical and electrolytic, removal of conductive or resistive material.

5.81 FILM – A thin coating or membrane material, usually 0.25 mm (0.010 in) or less in thickness.

5.82 FLAMMABILITY CLASSIFICATION ONLY – A membrane switch construction intended for use where the construction shall be evaluated for flammability classification only, and the thermal, mechanical, and electrical capacity of the construction materials is not of concern and only the flammability classification of the resulting membrane switch is of concern in the end product.

5.83 FLAT (PANEL) – Any number of membrane switch constructions assembled together in a sheet, usually with a frame around the side.

5.84 FLAT MEMBRANE CONSTRUCTION – Switches that use a spacer layer (air gap) or a matrix of dielectric dots to separate the conductive surfaces, the spring force is inherent to the substrate materials.

5.85 FLEXIBLE CONSTRUCTION – A sub-category membrane switch construction intended for use where some portion of the construction shall be subject to flexing in the end product application.

5.86 FLEX-TO-INSTALL CONSTRUCTION – A sub-category membrane switch construction intended for use where some portion of the construction may be subject to flex for installation or service in the end product.

5.87 FUNCTIONAL INSULATION – Insulation between live parts which is necessary only for the proper functioning of the switch.

5.88 GRADE – A designation arbitrarily assigned to a material by the material manufacturer.

5.89 GRAPHIC LAYER – Optional decorated layer of a membrane switch. See Figure Figure 7.1.

5.90 GROUND – A common reference point for conductor circuits.

5.91 GROUND PLANE – A conductor plane used as a common reference point for conductor circuits.

5.92 HAND SOLDERING – Hand-held, operator-controlled soldering, usually with a soldering iron.

5.93 HEATSINK – A device made of high thermal conductivity and low specific heat material capable of dissipating heat generated by a component or assembly.

5.94 HEATSINK PLANE – A continuous sheet of high thermal conductivity and low specific heat material intended to dissipate heat from heat generating components or assemblies.

5.95 IDENTICAL PROCESSING – Production or fabrication processes with the same manufacturing steps required to fabricate a membrane switch.

5.96 IMMERSION SILVER – Consists of a very thin coating typically less than 0.55 microns (0.0217 mils) of nearly pure silver created by galvanic displacement and may contain a slight amount of organic material deposited with the silver.

5.97 INCORPORATED SWITCH – A switch intended to be incorporated in or fixed to an appliance, which however can be tested separately.

5.98 INTEGRATED SWITCH – A switch, the function of which depends on its correct mounting and fixing in an appliance, and which can be tested only in combination with the relevant parts of that appliance.

5.99 INDUSTRIAL LAMINATE – Fibrous reinforcement material impregnated or coated with a thermosetting resin binder, and consolidated under high temperature and pressure into a dense solid product.

5.100 INFRARED REFLOW (IR) – Melting of solder alloys using infrared heat as the primary source of energy.

5.101 INNERLAYER CONNECTION – An electrical connection between two or more internal conductor layers of a membrane switch construction.

5.102 INSULATION DISTANCE – The shortest distance between conductive parts located on the circuit base material.

5.103 INSULATION RESISTANCE – The electrical resistance between two isolated test points on a membrane switch.

5.104 LAND – Part of the conductor pattern, usually where components are attached, mounted, or connected.

5.105 LAYER-TO-LAYER SPACING – The thickness of dielectric material between adjacent conductor planes (i.e. the physical distance between adjacent conductor planes).

5.106 LEAKAGE CURRENT – Current flow through the insulation between test points.

5.107 LIVE PART – A conductor or conductive part intended to be energized in normal use, including a neutral conductor, but, by convention, not a PEN conductor.

5.108 MACRO ENVIRONMENT – Environment of the room or other location in which the switch is installed or used.

5.109 MAXIMUM OPERATING AMBIENT TEMPERATURE (MOAT) – The maximum operating temperature is the maximum continuous use temperature that the membrane switch may be exposed to under normal operating conditions.

5.110 MEMBRANE LAYER – A flexible dynamic layer which carries one or both switch poles the deflection of which is used to short both poles together. The membrane layer is a required component of a membrane switch.

5.111 MEMBRANE SWITCH – A momentary switching device in which at least one contact is on, or made of, a flexible substrate.

5.112 MEMBRANE SWITCH FLEX TAIL – Flexible portion of a membrane switch used for input/output connection.

5.113 METAL-CLAD BASE MATERIAL – Base material with integral metal conductor material on one or both sides.

5.114 METAL DOME CONSTRUCTION – Switches that use a metallic metal dome as the lifting (spring force) to separate the actuating member and the conductive traces and provide the tactile response.

5.115 MICRO DISCONNECTION – Disconnection that provides correct functional performance by contact separation in the case of long-term temporary overvoltage.

5.116 MICRO ENVIRONMENT – Immediate environment of the insulation which particularly influences the dimensioning of creepage distances.

5.117 MIDBOARD CONDUCTOR – A conductor spaced more than 0.4 mm (0.016 in) from the edge of a membrane switch construction.

5.118 MULTILAYER – Membrane switch construction category that consists of alternate layers of conductor and dielectric materials laminated or bonded together, including at least three conductor layers separated by two dielectric layers, with at least one internal conductor layer.

5.119 NON-TACTILE SWITCH – A switch assembly that has a tactile ratio equal to zero.

5.120 NORMAL USE – Use of the switch for the purpose for which it was made and declared.

5.121 OPEN CIRCUIT RESISTANCE – The minimum allowable resistance as measured between two test points that, if lower than, will indicate an electrical short.

5.122 OPERATING AMBIENT AIR TEMPERATURE – The temperature or temperatures, determined under prescribed conditions, of the air surrounding the switch when mounted as declared by the manufacturer.

5.123 OPERATING CYCLE – Succession of operations from one position to another and back to the first position through all other positions, if any.

5.124 OPERATION – Transfer of the moving contact(s) from one position to an adjacent position.

5.125 PERMANENT RESIST – A solder resist or mask material intended to be a part of the membrane switch, for the life of the product.

5.126 PLATED-THROUGH HOLE – A connection between different planes of conductor patterns on double sided, or multi-layer membrane switches, by means of a plating process that deposits a conductor material on the side of a hole.

5.127 PLATING – A chemically or electrochemically deposited metallic coating.

5.128 POWER CAPACITY – Electrical power is defined as current × voltage = V × I (watts).

5.129 POLE OF A SWITCH – The part of the switch associated exclusively with one, electrically separated, conducting path of the switch. A switch is called "single-pole" if it has only one pole. If it has more than one pole, it may be called "multipole" (two-pole, three-pole, etc.) provided that the poles are coupled in such a manner as to operate together.

5.130 POLLUTION – Any addition of foreign matter, solid, liquid, or gaseous that can result in a reduction of dielectric strength or surface resistivity of the insulation.

5.131 POLLUTION DEGREE – Numeral characterizing the expected pollution of the micro-environment.

5.132 POLLUTION DEGREE 1 – No pollution or only dry, non-conductive pollution occurs. The pollution has no influence.

5.133 POLLUTION DEGREE 2 – Only non-conductive pollution occurs except that occasionally a temporary conductivity caused by condensation is to be expected.

5.134 POLLUTION DEGREE 3 – Conductive pollution occurs or dry non-conductive pollution occurs which becomes conductive due to condensation which is to be expected.

5.135 POLY DOME CONSTRUCTION – Switches that use a non-metallic dome (such as a polyester) as the lifting (spring force) to separate the actuating member and the conductive traces and provide the tactile response.

5.136 POLYMER THICK FILM – Referred to in this Standard as conductive paste.

5.137 PRE-PREG – Fibrous reinforcement material impregnated or coated with a thermosetting resin binder, and consolidated and cured to an intermediate stage semi-solid product (B-stage resin).

5.138 PRINTED (CIRCUIT) BOARD – A printed board produced from rigid industrial laminate material that provides point-to-point connections and printed components in a predetermined arrangement. See the Standard for Printed-Wiring Boards, UL 796.

5.139 PRINTED (CIRCUIT) BOARD ASSEMBLY – An assembly that uses a printed wiring board for component mounting and interconnecting purposes.

5.140 PRINTED CONDUCTOR – A conductor applied to a base material, or to an existing conductor on base material, by means of a printing process.

5.141 PRINTED WIRING – A pattern of conductive material formed on the surface of a base or dielectric material with point-to-point electrical connections or shielding.

5.142 PRINTED WIRING BOARD – A completely processed combination of a printed-wiring pattern, including printed components, and the base material.

5.143 PRODUCTION MEMBRANE SWITCH – A complete fabricated membrane switch intended for shipment.

5.144 PROTECTIVE IMPEDANCE – An impedance connected between live parts and accessible conductive parts, of such value that the current, in normal use and under likely fault conditions in the electronic switch, is limited to a safe value; it is so constructed that the reliability is maintained throughout the life of the electronic switch.

5.145 RATED LOAD – Type of load assigned to the switch by the manufacturer.

5.146 RATED VOLTAGE, CURRENT, FREQUENCY, WATTAGE, ETC. – Voltage, current, frequency, wattage etc. assigned to a switch by the manufacturer and to which operation and performance characteristics are referred.

5.147 REINFORCED INSULATION – Single insulation system applied to live parts which provides a degree of protection against electric shock equivalent to double insulation. The term "insulation system" does not imply that the insulation must be one homogeneous piece. It may comprise several layers which cannot be tested separately as supplementary or basic insulation.

5.148 RIGID – A sub-category construction intended for use where no portion of the membrane switch construction shall be subject to flexing, bending, or flex-to-install in the end product application.

5.149 RIGID LAYER – Provides mechanical support for the membrane switch. See Stiffener.

5.150 SELV – Voltage which does not exceed 50 V ac rms or 120 V dc between conductors or between any conductor and earth in a circuit which is insulated from the supply mains. SELV is an unearthed extra low voltage (see the Standard for Low-Voltage Electrical Installations – Part 4-41: Protection for Safety – Protection Against Electric Shock, IEC 60364-4-41).

5.151 SENSING UNIT – Unit that is activated by any physical phenomenon or combination of those.

5.152 SILVER MIGRATION – The ionic movement of silver due to migration inducing affects. (silver migration – a process by which silver, when in contact with insulating materials under electrical potential, is removed ionically from its original location, and is redeposited as a metal (silver dendrite) at some other location.)

5.153 SINGLE LAYER – Single layer membrane switch constructions are double-sided constructions with one layer of dielectric material(s) separating the conductor planes, and single-sided constructions with a single conductor plane on one side of a dielectric material(s).

5.154 SINGLE-SIDED – A single layer membrane switch or printed wiring board with conductor pattern on one side of the circuit base material.

5.155 SOLDER – A metal alloy with a melting temperature below 427°C (800°F).

5.156 SOLDER MASK – See Solder Resist.

5.157 SOLDER RESIST – A coating material intended to prevent deposition of solder upon selected areas during solder operations.

5.158 SPACER LAYER – A material (usually dielectric) sometimes used to maintain a separation between the membrane layer and static layer of a membrane switch.

5.159 SPECIFIED CIRCUIT RESISTANCE – Maximum allowable circuit resistance as measured between two terminations whose internal contacts, when held closed, complete a circuit.

5.160 STATIC LAYER – A mechanically supported layer which carries one or both poles of the switch or is used to short both poles together. The static layer is a required component of a membrane switch.

5.161 STIFFENER – An organic or inorganic material used to provide support or strength to interconnect constructions as part of the membrane switch.

5.162 SUPPLEMENTARY INSULATION – Independent insulation applied in addition to the basic insulation in order to provide protection against electric shock in the event of a failure of the basic insulation.

5.163 SURFACE MOUNT COMPONENT – A leaded or leadless component capable of being attached to a membrane switch construction by surface mounting.

5.164 SURFACE MOUNTING – Electrical connection of components on the surface of the conductor pattern.

5.165 TACTILE LAYER – Optional feature incorporated into a membrane switch to alter the tactile response.

5.166 TACTILE RESPONSE – A physical sensation caused by a sudden collapse and/or snapback of a membrane switch.

5.167 TACTILE SWITCH – A switch assembly that provides a tactile ratio greater than zero.

5.168 TEMPERATURE PROFILE – The temperatures a select point traverses as it passes through a process involving multiple temperatures and dwell times.

5.169 TERMINAL – Conductive part of a switch provided for reusable electrical connections without the use of a special purpose tool or a special process.

5.170 TERMINATION – Connection between two or more conductive parts which can only be made or replaced by either a special purpose tool or a special process.

5.171 TEST PATTERN – The conductor pattern intended for test and inspection purposes.

5.172 TEST POINTS – Two pre-selected conductive points in a circuit loop, possibly including a switch.

5.173 TEST SPECIMEN – A complete (or portion of a) production membrane switch or a coupon formed by the membrane switch production processes incorporating specific features.

5.174 TRAVEL – Measured distance of movement when a membrane switch is depressed.

5.175 TOUCH SCREEN CONSTRUCTION – Switches that use a matrix of dielectric dots to separate the conductive surfaces, the spring force is inherent to the substrate materials.

5.176 TYPE – A designation arbitrarily assigned to a membrane switch by the fabricator.

5.177 UNDERCOAT – A thin coating or membrane material between conductor planes intended for use as a dielectric material, used to cover a conductive pattern on a base material, or some portion thereof, and conductor material is applied to the exposed undercoat surface.

5.178 VIA – A conductor plated through-hole, in which there is no intent to insert a component lead or other reinforcement material, for interlayer connection of conductor planes. See also Blind Via, and Buried Via.

5.179 VOID – The absence of metallic or nonmetallic substance in a localized area, in or on an membrane switch construction.

5.180 WORKING VOLTAGE – Highest rms value of the ac or dc voltage across any particular insulation which can occur when the switch is supplied at rated voltage. Where the terms "voltage" and "current" are used, they imply the rms values unless otherwise specified.

5.181 X-AXIS – A reference axis, usually horizontal or left-to-right direction in a two dimension coordinate system.

5.182 Y-AXIS – A reference axis, usually vertical or bottom-to-top direction in a two dimension coordinate system. The x and y axes are usually perpendicular to one another in a two or three dimension coordinate system.

5.183 Z-AXIS – The axis perpendicular to the plane created by the x and y reference axes. This axis usually refers to the thickness of a membrane switch.

CLASSIFICATIONS

6 Classification of Switches

6.1 According to the switch design

6.1.1 – Tactile;

6.1.2 – Non-tactile;

6.2 According to the basic actuation construction of the switch

6.2.1 – Metal dome switch;

6.2.2 – Poly dome switch;

6.2.3 – Touch screen switch;

6.2.4 – Elastomeric (Silicone Rubber) switch;

6.2.5 – Copper-clad polyimide flexible switch;

6.2.6 – Flat membrane switch;

6.3 According to the nature of supply

6.3.1 – Switches for ac only;

6.3.2 – Switches for dc only;

6.3.3 – Switches for both ac and dc;

6.4 According to the type of load to be controlled by each circuit of the switch

6.4.1 – circuit for a substantially resistive load with a power factor of not less than 0.9;

6.4.2 – circuit for other than resistive (specifically declared);

6.5 According to the number of operating cycles

6.5.1 – 100,000 operating cycles;

6.5.2 – Cycles above 100,000 as declared by the manufacturer;

6.6 According to the operating surface temperature of mounting

6.6.1 – The operating surface temperature of mounting, is intended to be between a minimum value of 0°C (32°F) and a maximum value of 50°C (122°F).

6.6.2 – The operating surface temperature of the mounting , is intended to be between a minimum value below 0°C (32°F) or a maximum value above 50°C (122°F) (or both). The operating ambient temperature

shall be described in increments of 5° C (9° F). The maximum operating surface temperature of the mounting shall not exceed the Relative Temperature Indices (RTI) established for the insulation materials.

6.7 According to the ambient temperature of the environment

6.7.1 – The operating ambient temperature of environment (50 mm (1.97 in) above the switch), is intended to be between a minimum value of 0°C (32°F) and a maximum value of 40°C (104°F).

6.7.2 – The operating ambient temperature of environment (50 mm (1.97 in) above the switch), is intended to be between a minimum value below 0°C (32°F) or a maximum value above 40°C (104°F) (or both). The operating ambient temperature shall be described in increments of 5°C (9°F). The maximum operating ambient temperature of environment shall not exceed the Relative Temperature Indices (RTI) established for the insulation materials.

6.8 According to the flammability classification

6.8.1 – Decorative part (no flammability evaluation, for end product use as a decorative part only).

6.8.2 – HB;

6.8.3 – V-2;

6.8.4 – V-1;

6.8.5 – V-0.

6.9 According to degree of protection provided by the switch against the environment

6.9.1 – Degree of protection against solid foreign objects (Particles / Dust, Degrees of Protection Provided by Enclosures (IP Code), IEC 60529)

6.9.1.1 – non-protected against solid foreign objects (IP0X);

6.9.1.2 – protected against solid foreign objects of 50-mm (1.9-in) diameter and greater (IP1X);

6.9.1.3 – protected against solid foreign objects of 12.5-mm (0.5-in) diameter and greater (IP2X);

6.9.1.4 – protected against solid foreign objects of 2.5-mm (0.1-in) diameter and greater (IP3X);

6.9.1.5 – protected against solid foreign objects of 1.0-mm (0.04-in) diameter and greater (IP4X);

6.9.1.6 – dust-tight (IP6X).

6.9.2 Degree of protection against ingress of water (according to the Degrees of Protection Provided by Enclosures (IP Code), IEC 60529)

6.9.2.1 – non-protected against ingress of water (IPX0);

6.9.2.2 – protected against vertically falling water drops (IPX1);

6.9.2.3 – protected against vertically falling water drops when enclosure tilted up to 15° (IPX2);

6.9.2.4 – protected against spraying water (IPX3);

6.9.2.5 – protected against splashing water (IPX4);

6.9.2.6 – protected against water jets (IPX5);

6.9.2.7 – protected against powerful water jets (IPX6);

6.9.2.8 – protected against the effects of temporary immersion in water (IPX7).

6.9.3 Other protection against environment

6.9.3.1 – "hosedown" per the Standard Practice for Hosedown of a Membrane Switch, ASTM F 2072;

6.9.3.2 – "venting vapors";

6.9.3.3 – "submersion";

6.9.3.4 – "atmospheric pressure";

6.9.3.5 – "chemical solvent".

6.10 According to the basic circuit layer construction of the switch

6.10.1 Single-layer (single-sided or double-sided dielectrics);

6.10.2 Multilayer (dielectrics).

6.11 According to type of disconnection

6.11.1 – micro disconnection;

6.11.2 – electronic interruption.

6.12 According to the end product application of switch tail flexibility

6.12.1 – Flexible;

6.12.2 – Flex-to-install;

6.12.3 – Rigid.

CONSTRUCTION

7 General

7.1 Switches shall be designed and constructed so that in normal use they function safely so as to cause no danger to persons or surroundings even in the event of such careless use as may occur in normal use. Compliance with the basic construction elements in Sections 7 – 28 and demonstrated by carrying out the tests specified in Table 29.1 to Table 29.4.

7.2 All membrane switches shall be defined by classification category and subcategory constructions according to Classifications, Section 6.

7.3 The membrane switch test specimens shall be representative of all production including materials and material thickness ranges.

Exception: When production specimens are tested in lieu of the representative conductor test pattern specimens, the applicable parameter profile indices (i. e., material components, construction build-up thickness, conductor line widths, conductor weight, etc.) of the production specimens shall be determined to be equal to or more severe than the parameter profile indices established for the membrane switch.

7.4 Membrane switches shall consist of, but not be limited to, the following construction features. See Figure 7.1.

a) graphic

b) graphic ink

c) spacer

d) spacer adhesive

e) dome type (metal or polymer domes)

f) cavity area

g) venting

h) components (ie. diodes, LEDs, etc.)

i) circuit base material layer with copper and/or polymer thick film conductive paste

j) circuit crossover material

k) dielectric film or coating (coverlay or covercoat)

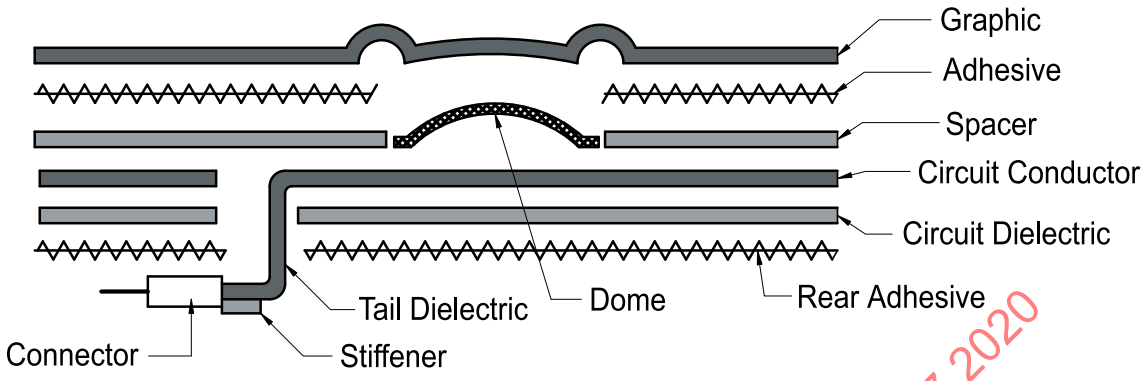
l) tail connector

m) tail stiffener

n) rear adhesive

Figure 7.1

Example of membrane switch construction



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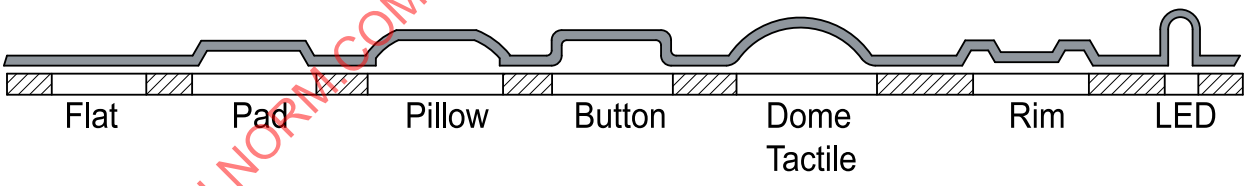
8 Graphic, Adhesive, Ink, and Embossing

8.1 Reference to graphic, graphic adhesive, and graphic ink in these requirements shall apply to materials used as the overlay in the switch.

8.2 Embossing shall refer to the raised portion of the graphic surface. The phrase "plateau embossing" is used to describe keys that are raised and flat on the top. The phrase "rim embossing" is used to describe only the border of a key being raised. Embossing shall be evaluated for mechanical stress of the switch material. See Figure 8.1.

Figure 8.1

Embossing example



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8.3 The graphic layer shall include film, adhesive, and ink (if applicable).

8.4 The graphic thickness describes the thickness of the film and adhesive. The film and adhesive thicknesses shall be specified separately.

8.5 The minimum and maximum thickness of base material shall be identified for each graphic layer.

8.6 The minimum and maximum thickness of adhesive shall be identified for each graphic layer.

8.7 Each graphic material in combination with each applicable combination of material components intended in the construction shall comply with the tests specified in Table 29.1 to Table 29.4.

9 Spacer and Adhesive

9.1 Reference to spacer and spacer adhesive in these requirements shall apply to materials used to provide space for the cavity and also used to laminate and adhere materials together.

9.2 The spacer layer shall include film and adhesive.

9.3 The spacer thickness describes the thickness of the film and adhesive on two sides. The film and adhesive thicknesses shall be specified separately.

9.4 The minimum and maximum thickness of base material shall be identified for each spacer grade.

9.5 The minimum and maximum thickness of adhesive shall be identified for each spacer grade.

9.6 Each spacer in combination with each applicable combination of material components intended in the construction shall comply with the tests specified in Table 29.1 to Table 29.4.

10 Dome, Cavity, and Venting

10.1 Reference to Dome, if applicable to the construction, shall apply to the material used to provide the return force.

10.2 Reference to cavity shall apply to the area provided, for example the area removed from a spacer layer, for the dome.

10.3 Reference to venting shall apply to the method for allowing air volume transfer from one cavity to another or the outside.

11 Circuit Crossover Material

11.1 Reference to crossover material in these requirements shall apply to materials used to partially or entirely cover a conductive pattern used as a dielectric barrier between two opposing conductors planes in the switch circuit layer.

11.2 Crossover material shall be a dielectric adhesive, coating, and other insulation materials as defined in the terms and shall have been previously determined to have acceptable mechanical and electrical relative temperature indices at or above the MOT of the switch.

11.3 Crossover thickness describes the thickness of base dielectric material (if applicable) and adhesive. The base dielectric material and adhesive thickness shall be specified separately.

11.4 The minimum and maximum thickness of crossover shall be identified.

11.5 Each crossover material in combination with each applicable combination of material components intended in the construction shall comply with the tests specified in Table 29.1 to Table 29.4.

12 Cover Materials (Dielectric Film or Coating)

12.1 Reference to cover material in these requirements shall apply to materials used to partially or entirely cover a conductive pattern on the outer surface(s) of the circuit layer in the switch.

12.2 Cover material shall be a coverlay or covercoat material, and shall include film, adhesive, coating, and other insulation materials as defined in the terms.

12.3 Marking ink is not considered a cover material or protective coating.

12.4 Coverlay thickness describes the thickness of base dielectric material and adhesive. The base dielectric material and adhesive minimum and maximum thickness shall be specified separately.

12.5 Covercoat minimum and maximum thickness shall describe the coating thickness.

12.6 Each cover material in combination with each applicable combination of material components intended in the construction shall comply with the tests specified in Table 29.1 to Table 29.4.

12.7 When conductor material is laminated or adhered directly to cover material, the resultant combination of cover material and conductor materials is considered base material. See Circuit Base Materials (Dielectric Layers), Section 24.

12.8 Cover material, when used as a dielectric barrier between opposing conductor planes, shall have been previously determined to have acceptable mechanical and electrical relative temperature indices at or above the MOT of the switch.

13 Tail Connector

13.1 References to a specific connector attached or intrigue to the tail allowing connection to the end product.

14 Tail Stiffener

14.1 Reference to stiffener materials in these requirements shall apply to materials used to provide additional stiffness, rigidity, or support to constructions, by attaching the stiffener material to the construction.

14.2 The stiffener material shall not include conductors or integral electrical connection to and from the switch construction. Stiffener materials shall not be in direct contact with conductor material.

14.3 EMI shielding is not considered a stiffener material.

14.4 Stiffener and stiffener adhesive materials shall be identified by manufacturer and grade designation.

14.5 The minimum and maximum thickness of the stiffener and stiffener adhesive shall be identified.

14.6 Stiffener materials shall possess a flammability classification considered equal to or greater than the flammability classification of the switch if a flammability classification is requested. The stiffener material shall not reduce the flammability classification of the switch. Rigid and flex printed wiring boards are not considered stiffener materials.

14.7 Stiffener materials shall be subject to identification by infrared analyses if organic and not previously evaluated. IR shall be performed in accordance with the Standard for Polymeric Materials – Short Term Property Evaluations, 746A.

14.8 Each manufacturer and grade of stiffener adhesive (external bonding) and stiffener shall be evaluated in accordance with the stiffener bond strength test, as applicable.

15 Rear Adhesive

15.1 Reference to rear adhesive (external bonding) materials in this standard shall apply to materials used to attach switches to end product constructions, and shall not be considered a dielectric material.

15.2 Adhesive material shall not be water soluble.

15.3 Adhesive material shall be identified by manufacturer and grade designation.

15.4 The minimum and maximum thickness of the rear adhesive shall be identified.

15.5 The rear adhesive can be evaluated for adhesion to a specific end product surface.

15.6 Each manufacturer and grade of adhesive (external bonding) shall be evaluated in accordance with Table 29.1 to Table 29.4, as applicable.

16 Other Construction Features

16.1 Other construction features shall be described and evaluated as applicable in the switch construction.

17 Provision for Earthing

17.1 Switches that rely on an earthing (grounding) termination for safety, shall be investigated for suitability of the connection in accordance with the earthing test method.

18 Terminals and Terminations

18.1 Switch terminations shall be suitable for their application.

18.2 A termination intended to be soldered in the end application, shall be evaluated for suitability of soldering surface and suitability of materials to withstand the temperature associated with soldering.

18.3 Compliance is checked in the end product application.

19 Current Carrying Parts

19.1 The suitability of current carrying parts shall be demonstrated by the test sequence of Table 29.1 to Table 29.4.

20 Clearance and Creepage Distances – Spacings

20.1 The distance through a glued joint (trace to trace or live part to live part, creepage) is the same as the required clearance distance.

20.2 The creepage spacing requirements are based upon the characterization test sequence and spacing requirements of the intended end product Standard.

20.3 Compliance is checked by inspection after tests and in the end application.

21 Resistance to Heat and Fire

21.1 RTI (Relative Thermal Index)

21.2 The dielectric materials shall have an established mechanical and electrical relative temperature indices (RTI) equal to or greater than the maximum temperature experienced in the application. The maximum temperature measured during the Heating Test in Section 42 and Operating Ambient Temperature or Surface Mount Temperature (which ever is higher).

21.3 The RTI is determined in accordance with the Standard for Polymeric Materials – Flexible Dielectric Film Materials For Use In Printed-Wiring Boards and Flexible Materials Interconnect Constructions, UL 746F. The RTI shall be established by a long term thermal aging investigation or based on the chemical structure of the material compared to a generic material class.

Exception: Long-term temperature stability is typically not required for a non-metallic material intended to be used at a temperature below 50°C (122°F).

21.4 Compliance is checked by the results of temperature tests and the established RTI value of the materials.

21.5 Each material shall be subject to identification by infrared analysis (IR) and thermogravimetric analysis (TGA) in accordance with Table 29.1 to Table 29.4.

Exception: IR and TGA testing for the dielectric material and/or adhesive shall be waived if the IR and TGA have been previously established.

22 Flammability Classification

22.1 The membrane switch shall comply with the flammability test per the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94 or the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, according to the desired flammability classification. These requirements do not apply to membrane switches declared to be decorative parts.

22.2 The flammability classification of the membrane switch construction shall not exceed the flammability classifications established for the each individual material in the construction.

22.3 The Assembly of a membrane switch shall comply with the flammability test per the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

22.4 Compliance is checked by the applicable tests of the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94 or the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

23 Endurance Classification

23.1 The membrane switch shall comply with the testing specified as characteristics testing, according to the desired number of endurance cycles.

23.2 The membrane switch shall be tested for the test sequence specified in Table 29.1.

23.3 Compliance is checked by the application of the complete characteristics test sequence per Table 29.1.

24 Circuit Base Materials (Dielectric Layers)

24.1 The base material shall have mechanical and electrical relative temperature indices (RTIs) and properties at the intended minimum thickness and at the intended maximum operating ambient temperature (MOAT) of the completed membrane switch. Examples of values for the temperature rating include 90°C (194°F), 105°C (221°F), 130°C (266°F), and 150°C (302°F). The MOAT rating shall not exceed the assigned RTI rating of the base material.

24.2 A membrane switch build-up and sheet material shall be evaluated with specimens provided in accordance with the thickness tolerances given in Table 24.1.

Table 24.1
Base material specimen build-up and sheet thickness tolerance

Base material nominal thickness		Thickness tolerance	
mm	(in)	mm	(in)
Less than 0.020	Less than (0.0008)	±0.003	(±0.0001)
0.020 – 0.024	(0.0008 – 0.0009)	±0.005	(±0.0002)
0.025 – 0.074	(0.001 – 0.003)	±0.008	(±0.0003)
0.075 – 0.099	(0.003 – 0.004)	±0.01	(±0.0004)
0.10 – 0.19	(0.004 – 0.007)	±0.02	(±0.0008)
0.20 – 0.37	(0.008 – 0.014)	±0.03	(±0.001)
0.38 – 0.62	(0.015 – 0.024)	±0.05	(±0.002)
0.63 – 1.59	(0.025 – 0.061)	±0.08	(±0.003)
1.60 – 2.54	(0.062 – 0.100)	±0.10	(±0.004)
Greater than 2.55	Greater than (0.100)	±0.13	(±0.005)

24.3 The membrane switch build-up and sheet material specimen thicknesses shall be measured in accordance with the Standard Test Methods for Thickness of Solid Electrical Insulation, ASTM D 374, Method A or C. The deviation from the specimen minimum base material thickness shall be within the allowable range or tolerance specified in Table 24.1.

24.4 The base material identified for the direct support of current carrying parts greater than 30 Vrms, but less than 120 Vrms or less and 15 A or less, shall have a base material that complies with the performance profile in Table 24.2.

Table 24.2
Performance level categories (PLC) of base materials that provide direct support of current carrying parts

Test[a]	Units or PLC	Minimum rating	Minimum thickness[b] mm (in)
Flammability classification	n/a	V-0, V-1, V-2, HB	Actual[c]
High current arc ignition (HAI)	Max PLC	3	Actual[c]
Hot wire ignition (HWI)	Max PLC	4	Actual[c]
Volume Resistivity (VR) – Dry	Min Ω-cm $\times 10^6$	50	1.6 (0.062)[d]
Volume Resistivity (VR) – Wet	Min Ω-cm $\times 10^6$	10	1.6 (0.062)[d]
Dielectric Strength (DS) – Dry and Wet	kV/mm	6.89	1.6 (0.062)[d]
Comparative Tracking Index (CTI)	Max PLC	4	2.5 (0.098)[d]
Heat deflection	°C	e	2.5 (0.098)[d]

[a] Testing in accordance with the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A.

[b] Test specimen thickness on which the index value is to be based.

[c] Actual thickness or minimum thickness of evaluated material.

[d] Test specimen thickness representative of all thicknesses.

[e] Not required for thermosets or films; for thermoplastics, at least 10°C (50°F) above rated ambient operating temperature with 90°C (194°F) minimum value.

25 Circuit Conductors

25.1 General

25.1.1 Membrane switch conductors shall be of etched, die-stamped, pre-cut, flush-press, or additive-type conductive material having similar corrosion resistant properties.

25.2 Conductive coating

25.2.1 Paste-type conductive coatings and/or conductors, such as carbon, copper, silver or other conductive coatings, shall be investigated for adhesion in accordance with the Conductive Paste Adhesion Test, 45.3. Based on the membrane switch production construction, paste type conductor adhesion shall be evaluated on each generic base laminate in combination with each membrane switch material surface, such as base material, metal and paste-type conductors, undercoats (solder resist), in through holes, and the like.

25.2.2 The conductive coating used on the membrane switch shall be smooth, ductile, and not interfere with electrical connections in the assembly.

25.3 Silver

25.3.1 Membrane switch constructions employing conductors consisting of silver paste, silver, silver plating, shall be investigated for silver migration in accordance with the Silver Migration Test (IPC), 45.8, or the Silver Migration Test ASTM F 1996, 45.9.

Exception No. 1: Membrane switches intended for use in flammability-only applications do not require silver migration testing. Flammability testing is required unless the construction has been previously evaluated. Flammability only switches require a unique Type designation.

Exception No. 2: Membrane switches employing conductors coated with immersion silver do not require silver migration testing.

Exception No. 3: Membrane switches employing silver material encased in copper (such as a plated thru hole containing silver material and capped by copper plating) do not require silver migration testing.

Exception No. 4: Membrane switches employing silver material on the internal layers of a multi-layer construction do not require silver migration testing.

Exception No. 5: Membrane switches employing conductors coated with tin-silver-copper (Sn-Ag-Cu (SAC)) alloys do not require silver migration testing.

25.4 External copper foil or metal cladding

25.4.1 Metal type conductors, such as copper or other metal conductors, shall be investigated for adhesion in accordance with the Bond Strength Test, 45.5 and the Delamination and Blistering Test, 45.7. Based on the membrane switch production construction, metal type conductor adhesion shall be evaluated on each membrane switch material surface, such as base materials.

25.4.2 Representative membrane switch specimen shall be included for each copper foil weight range or cladding process for the base material.

25.4.3 A retest is required when the weight of the copper foil or cladding process is to be increased or decreased, beyond the existing limits. Testing shall be in accordance with the Bond Strength Test, 45.5 and the Delamination and Blistering Test, 45.7.

25.4.4 For weights of external copper foil or cladding process less than 33 µm (1 oz/ft^2), the conductor shall be copper plated as close as possible to a total thickness of 33 µm (1 oz/ft^2) for test purposes, and is then representative of weights up to and including 102 µm (3 oz/ft^2). For weights of external copper foil and/or cladding process up to and including 102 µm (3 oz/ft^2), the minimum weight to be used in production is representative of this range.

25.4.5 For weights of external copper foil or cladding process heavier than 102 µm (3 oz/ft^2), the maximum weight to be used in production is representative of the copper weight range down to 102 µm (3 oz/ft^2).

25.5 Conductor width

25.5.1 The conductor width dimension shall be measured by microsection analysis and shall constitute the minimum required conductor widths. The deviation from the conductor width thickness shall be within ±10% tolerance of the request minimum conductor width. There shall be good register with the membrane switch circuit pattern of added plating and other add-on considerations.

25.5.2 A retest is necessary when a reduction in the minimum width of conductor is desired. Testing shall be in accordance with the Solder Thermal Shock Test, 45.2 and the Bond Strength Test, 45.5.

25.6 Midboard conductor

25.6.1 The specimen pattern shall employ a midboard conductor of the minimum width to be used in production (see Figure 28.1). A midboard conductor is not prohibited from terminating with its smallest dimension on the edge of the membrane switch. The pattern shall also employ a 1.6 mm (0.062 in) conductor width. Secondary conductor widths can be included in the specimen pattern in the event the minimum conductor width receives non-compliant results.

25.7 Edge conductor

25.7.1 The specimen pattern shall employ an edge conductor of the minimum width to be used in production (see Figure 28.1). The edge conductor shall be within 0.4 mm (0.015 in) of the switch edge, and not sheared at the edge. When an edge conductor is not provided with a width of less than three times the minimum width of a midboard conductor, then the membrane switch shall be assigned an edge conductor width at three times the minimum midboard conductor width.

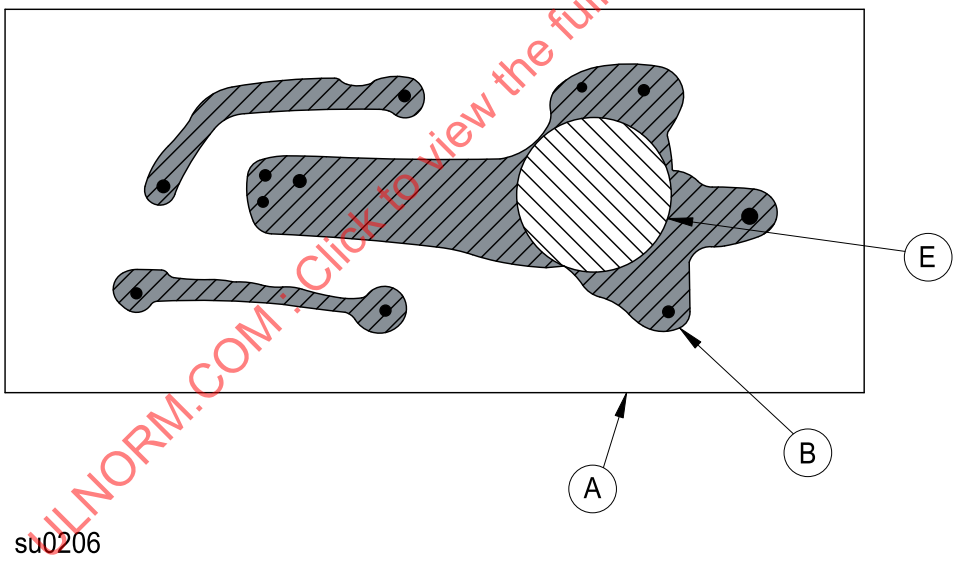
25.8 Maximum area diameter conductor

25.8.1 A solid, unpierced circle of conductive material represents the maximum unpierced conductor area capable of being used in any membrane switch production pattern.

25.8.2 The production maximum unpierced conductor area shall be determined by the largest circle that can be inscribed within the pattern (see Figure 28.1, not to exceed E in Figure 28.1). A second set of specimens with a pattern containing only the largest circle are to be tested (delamination test pattern) when the largest diameter circle will not fit on the overall specimen size dimensions shown in Figure 25.1. See the delamination test pattern in Figure 28.2.

Figure 25.1

Maximum unpierced conductor area measurement



A – Production membrane switch circuit layer.

B – Largest unpierced conductor section.

E – Largest circle that fits B (the area is not to exceed that of circle E in Figure 28.1)

25.9 Adhesives for conductor bonding

25.9.1 An adhesive used to bond the conductive material to the base material shall not be water soluble.

25.9.2 If the adhesive used to bond the conductive material has not been previously evaluated as an integral part of a (conductor-clad) base material in accordance with the applicable testing requirements in the Standard for Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used in Printed Wiring Boards, UL 746E, or the Standard for Polymeric Materials – Flexible Dielectric Film Materials for use in Printed-Wiring Boards and Flexible Materials Interconnect

Constructions, UL 746F, the adhesive shall be subject to Infrared Analyses, Bond Strength, Delamination and Blistering, and Flammability. The adhesive shall also be evaluated with the following tests for Direct Support requirements: Comparative Tracking Index (CTI), High Current Arc Ignition (HAI), and Hot Wire Ignition (HWI). Testing is to be performed in accordance with the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A.

25.9.3 Adhesive material used to bond the conductive material to the base material shall be identified with regard to:

a) The generic type of material; and

b) The specific manufacturer and grade designation.

25.10 Contact surface plating

25.10.1 Plating of a contact surface shall be uniform, smooth, and without nodules. Contact plating shall adhere well to the conductor surface and, to provide a full contact area, it shall extend to the conductor edges. Plating adhesion to the conductor surface shall be investigated in accordance with the Plating Adhesion Test, 45.4.

25.11 Through holes

25.11.1 Through holes shall be investigated in accordance with the Delamination and Blistering Test, 45.7 and the Plating Adhesion Test, 45.4.

25.11.2 The specimens shall employ through-holes filled with conductive material if used in production.

25.11.3 The specimen pattern shall employ plated-through holes if used in production (see Figure 28.1).

25.12 Additional conductive plating

25.12.1 When one or more additional platings are intended to be used on production membrane switch circuit layers, and when no additional etchant is used in the plating process, one plating may be selected as representative and shall be provided on the test specimens.

Exception: If silver is used as a conductive plating (excluding immersion silver), see Circuit Conductors, Section 25 for additional requirements.

26 Assembly Process Solder Limits

26.1 The solder limits are temperature (s) and time (s) reflecting the anticipated assembly production soldering operations. The solder limits are determined by analyses of physical property data obtained from evaluation of the metal clad base material specimen or membrane switch following short term thermal shock conditioning. If the evaluation test criteria are met, the solder limits are granted to the membrane switch.

26.2 Each membrane switch construction shall have solder limits reflecting the maximum temperature and dwell time limits of the anticipated assembly soldering process. When a soldering process involves a repeated soldering operation or reflow temperature profile, multiple solder limits representing the temperature profile shall be evaluated.

Exception: Membrane switches intended for hand soldering only do not require evaluation of solder limits.

26.3 The solder limits for the membrane switch shall be suggested by the fabricator, and the suggested solder limits will be used for thermal shock conditioning of specimens as indicated in the required tests.

26.4 The solder limits shall reflect the maximum limiting temperature and cumulative dwell time conditions to which the membrane switch is to be subjected to during the assembly soldering process.

26.5 A retest is required when the dwell time and/or temperature of the membrane switch solder limits are to be increased beyond the existing limits. Testing shall be in accordance with the Solder Thermal Shock Test, 45.2, the Bond Strength Test, 45.5, the Conductive Paste Adhesion Test, 45.3, the Delamination and Blistering Test, 45.7, and the Flammability Classification, Section 22. If the membrane switch construction includes dissimilar materials the investigation shall also include the Dissimilar Dielectric Materials Thermal Cycling Test, 45.18.

27 Manufacturing Processes

27.1 General

27.1.1 Specimens shall be provided for each production process used to manufacture each category and subcategory of switch.

27.1.2 The process description shall reflect the severity of the production process and shall be determined by review of the process flow.

27.1.3 The process description shall be a chronological description reflecting the production practices used to manufacture the switch.

27.1.4 The process description shall identify any laminating, printing, etching, plating, baking , curing, and addition of permanent materials to the switch during the manufacturing of the switch.

27.1.5 The process of forming the conductor shall result in smooth edges without excessive undercutting and with dimensions not less than represented by the membrane switch specimen.

27.1.6 Chromic/sulfuric etchant shall be considered representative of all etchants. Any other acidic or alkaline etchant shall be representative of all etchants except chromic/sulfuric.

27.1.7 The process description shall include the highest temperatures, longest dwell times, and highest pressures associated with any given step.

27.1.8 The specimens shall be subjected to each step of the most severe production practices, including the highest temperatures, longest dwell times, and highest pressures associated with any given step.

27.1.9 When temperature differences are not involved, a change or variation of imprinting method (such as silk screening to a photographic method, one silk-screening method to another, or one photo-emulsion material to another) shall not always necessitate testing of the membrane switch.

27.1.10 A retest is required for any one or more of the following or similar changes. Tests shall be conducted on representative specimens in accordance with the Solder Thermal Shock Test, 45.2, the Bond Strength Test, 45.5, the Conductive Paste Adhesion Test, 45.3, the Delamination and Blistering Test, 45.7, the Cover Material Adhesion Test, 45.12, the Stiffener Bond Strength Test, 45.16, and the Flammability Classification, Section 22, unless otherwise indicated:

a) A change in the process temperature exceeding 100° C (212° F) or the ambient maximum operating temperature of the membrane switch, whichever is greater.

b) An increase in the lamination pressure. Testing shall be in accordance with the Solder Thermal Shock Test, 45.2 and the Delamination and Blistering Test, 45.7. An increase in the lamination temperature shall require full testing.

c) Addition of silver, carbon, copper paste, or other polymer thick film type conductors not previously identified in the process description.

d) Addition of permanent materials (i. e. film, adhesive, stiffener, coatings, etc.) not previously identified in the process description.

e) A change in etchant. If the fabricator changes the etchant to chromic/sulfuric, a retest shall be conducted for the Solder Thermal Shock Test, 45.2 and the Bond Strength Test, 45.5. When the fabricator changes from any acidic to alkaline etchant (or vice versa) except chromic/sulfuric, testing is not required.

f) The addition of plated contact fingers to an existing process. Testing shall be in accordance with the Plating Adhesion Test, 45.4. The addition of any other metallic plating, including Immersion Silver, but excluding all other silver not in contact with the base material, does not require testing.

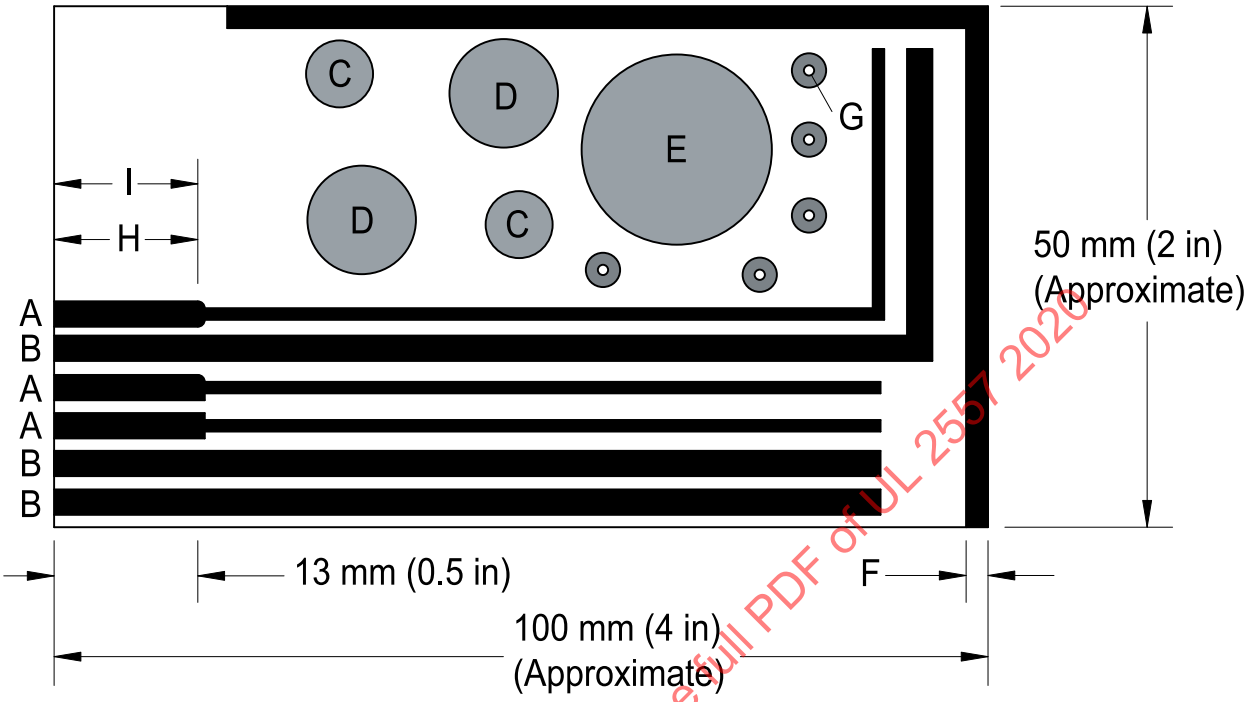
g) The addition of plugged, filled, or plated through holes to an existing process. Testing shall be in accordance with the Solder Thermal Shock Test, 45.2, the Delamination and Blistering Test, 45.7, and the Plating Adhesion Test, 45.4. The addition of any other metallic plating, except silver, not in contact with the base material, does not require testing.

28 Sample Circuit Conductor Pattern

28.1 The specimen conductor pattern shall include sizes, platings, and contacts in a configuration specified by the fabricator. See Figure 28.1 – Figure 28.4 for typical test patterns.

Figure 28.1

Sample circuit conductor test pattern



su0207

A – Minimum width conductor of configuration specified by the fabricator.

B – 1.6-mm (0.062 -in) wide conductor of configuration specified by the fabricator.

B1 – (Not Shown) one or more potential widths may be included between A and B.

C – 10-mm (0.375-in) diameter unpierced circular conductor.[1]

D – 13-mm (0.5-in) diameter unpierced circular conductor.[1]

E – Maximum diameter unpierced circular conductor specified by fabricator.

F – Edge conductor. Shall be within 0.4 mm (0.015 in) of the circuit base material edge, and not sheared at the edge.[1]

G – Plated-through holes.[1, 2]

H – Plated contacts, of minimum width.[1, 2, 3]

I – Three contacts, of maximum width.[1, 2, 3, 4]

[1] Optional, but must be on specimens if acceptance of this type of construction is desired.

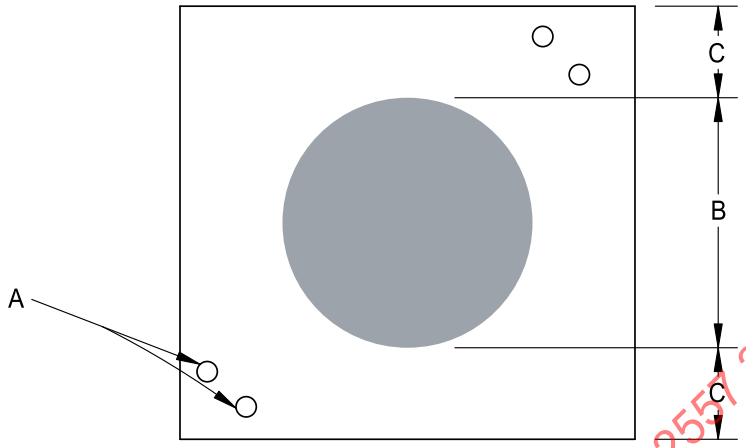
[2] Items E, G, H, and I may be provided on separate specimens.

[3] Plated contacts are required only if the plating is different from the conductor.

[4] Conductor patterns are required on the internal layers of multi-layer specimens. Internal conductor widths are to vary as needed for the metal weights and thickness employed but shall not be narrower than the external conductor width.

Figure 28.2

Delamination test pattern



su0208

A – Plated – through holes.[1]

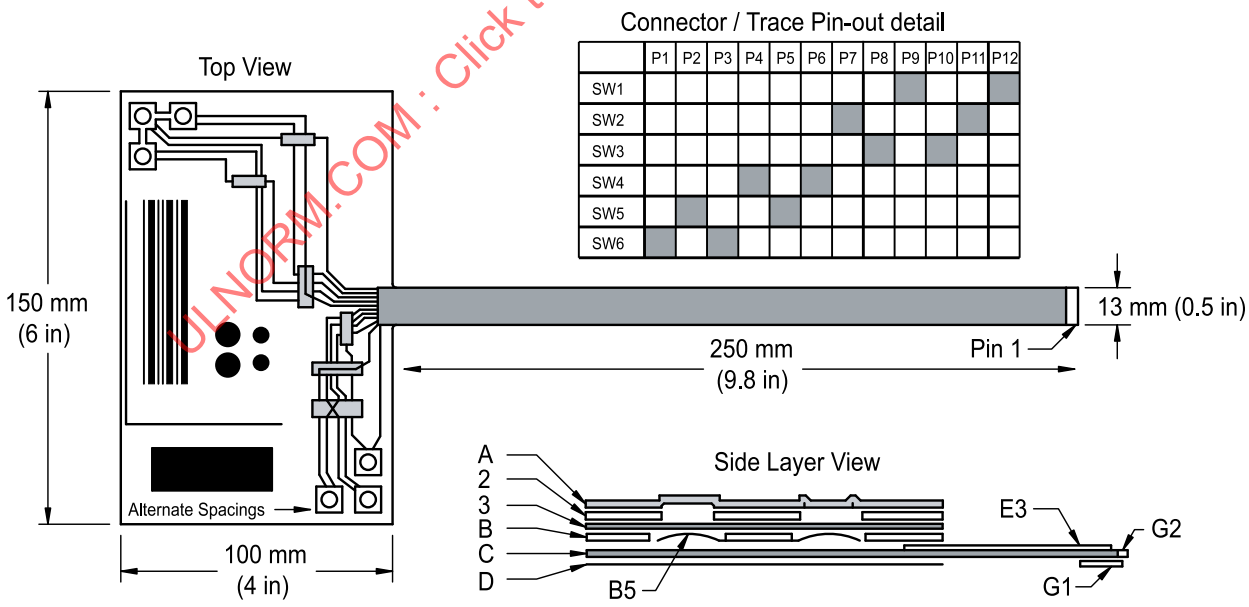
B – Maximum diameter unpierced circular conductor specified by fabricator.

C – Distance edge of circular conductor (B) to edge of specimen shall be sufficient to accommodate plated through holes (A).

[1] Optional, but MUST be on specimens if acceptance of this type of construction is desired.

Figure 28.3

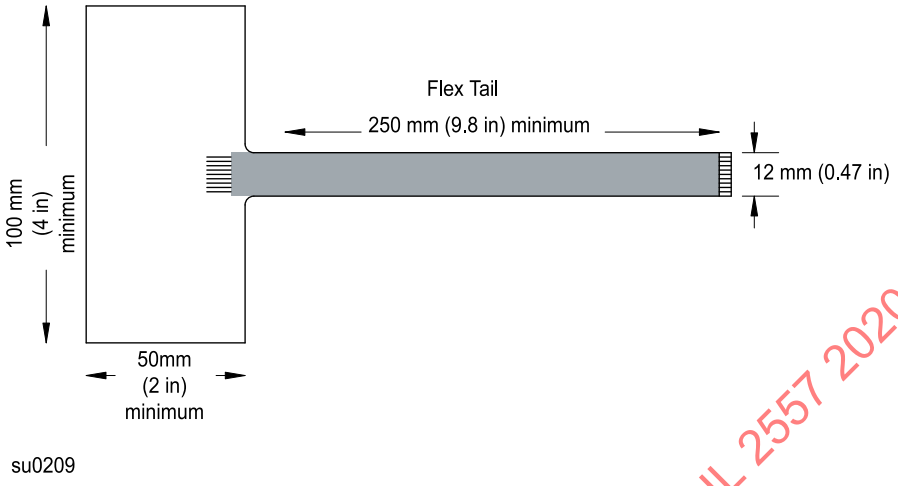
Example of structural and endurance test pattern



su0256

Figure 28.4

Flex tail test pattern



28.2 The conductor pattern surface shall be smooth, even, and free of wrinkles, holes, voids, blisters, corrosion, or other imperfections that impair the function of the switch.

PERFORMANCE

29 General

29.1 Switches are tested with the rated supply voltage. Switches rated both ac and dc are tested with dc to represent ac provided the voltage and amps are equal.

29.2 Switches with a rated frequency are tested at that frequency. Switches without a rated frequency are tested at 60 Hz. Switches with a rated frequency range are tested at the most unfavorable frequency within that range (for example testing at 50 Hz represents use at 50 to 60 Hz).

29.3 During the characterization/endurance testing, one (and only one) failure of the six specimens, shall result in retesting a second sampling of six specimens. All preceding tests that condition or effect the results shall be repeated on the second sampling. No failure shall occur during the repeated tests. Only one repeated test shall be permitted. An additional set of specimens may be submitted together with the first set of specimens, which may be needed in case one specimen fails. If the additional set of specimens is not submitted at the same time, a failure of one specimen will entail a rejection.

29.4 A failure of more than one specimen (of the first sampling) shall entail a rejection of the nonconforming constructions.

29.5 A failure of one specimen (of the second sampling) shall entail a rejection of the nonconforming constructions.

29.6 Test specimens shall be provided for each alternate material manufacturer and each different manufacturer's grade of material.

29.7 When a difference in the material catalog number or grade reflects a minor change, such as a change of color not affecting the base characteristics or a different manufacturing location for the same supplier, a separate investigation is not needed.

29.8 Membrane switch category constructions, depending on the construction materials, build-up, and conductor type, shall comply with one or more of the following tests listed in Table 29.1 – Table 29.4.

Table 29.1
Construction – characteristic and endurance test program

Set	Property	Sample	Spacer thickness	Cavity area	Actuation force	Minimum number of specimens[b]	Reference
A	Marking durability	Any	n/a	n/a	n/a	1	30
A	Earthing	Any	n/a	n/a	n/a	1	31
A	Visual inspection	Figure 28.3 or production specimen	Min + Max	Min + Max[a]	Min + Max[a]	6	32
A	Circuit resistance	Figure 28.3 or production specimen	Min + Max[a]	Min + Max[a]	Min + Max[a]	6	33
A	Switch capacitance	Figure 28.3 or production specimen	Min + Max[a]	Min + Max[a]	Min + Max[a]	6	34
A	Force displacement	Figure 28.3 or production specimen	Min + Max[a]	Min + Max[a]	Min + Max[a]	6	35
A	Contact bounce (optional)	Figure 28.3 or production specimen	Min + Max[a]	Min + Max[a]	Min + Max[a]	6	36
A	Sensitivity teasing (optional)	Figure 28.3 or production specimen	Min + Max[a]	Min + Max[a]	Min + Max[a]	6	37
A	Electrostatic discharge (ESD) shielding (optional)	Figure 28.3 or production specimen	Min + Max[a]	Min + Max[a]	Min + Max[a]	6	38
A	Insulation resistance	Figure 28.3 or production specimen	Min + Max[a]	Min + Max[a]	Min + Max[a]	6	39
A	Dielectric of insulation	Figure 28.3 or production specimen	Min + Max[a]	Min + Max[a]	Min + Max[a]	6	40/41
A	Heating	Figure 28.3 or production specimen	Min + Max[a]	Min + Max[a]	Min + Max[a]	6	42
A	Contact closure cycles/endurance	Figure 28.3 or production specimen	Min + Max[a]	Min + Max[a]	Min + Max[a]	6	43
A	Visual inspection	Figure 28.3 or production specimen	Min + Max[a]	Min + Max[a]	Min + Max[a]	6	43.5.1
A	Circuit resistance	Figure 28.3 or production specimen	Min + Max[a]	Min + Max[a]	Min + Max[a]	6	43.5.2

Table 29.1 Continued on Next Page

Table 29.1 Continued

Set	Property	Sample	Spacer thickness	Cavity area	Actuation force	Minimum number of specimens[b]	Reference
A	Switch capacitance	Figure 28.3 or production specimen	Min + Max[a]	Min + Max[a]	Min + Max[a]	6	43.5.3
A	Force displacement	Figure 28.3 or production specimen	Min + Max[a]	Min + Max[a]	Min + Max[a]	6	43.5.4
A	Insulation resistance	Figure 28.3 or production specimen	Min + Max[a]	Min + Max[a]	Min + Max[a]	6	43.5.5
A	Dielectrics of insulation	Figure 28.3 or production specimen	Min + Max[a]	Min + Max[a]	Min + Max[a]	6	43.5.6

[a] Minimum + maximum of range when the range is conservative and represented by the minimum and maximum.

[b] Specimens requested represent the general number required to efficiently complete testing and not necessarily the number required by the test.

Table 29.2
Tail – adhesion and operating temperature test program

Set	Property	Sample dimensions (length by width) mm (in)	Circuit layer thickness	Conductor thickness	Cover material thickness	Minimum number of specimens	Method and sample build-up refer to:
All	Conditioning – solder thermal shock	–	–	–	–	Preconditioning for test below see test description	45.2
	Conductive paste adhesion – paste conductors without coverlay	Figure 28.1, Figure 28.2, or Figure 28.3 or production specimen	Min	Min	Min	3	45.3
X1	Plating adhesion – electroplated flex tail leads without coverlay	Figure 28.1, Figure 28.2, or Figure 28.3 or production specimen	Min	Min	Min	1	45.4
	Bond strength – copper conductors without coverlay	Figure 28.1, Figure 28.2, or Figure 28.3 or production specimen	Min	Min	Min	4	45.5
	Delamination and blistering (layer to layer)	Figure 28.3 or production specimen	Min	Min	Min	4	45.7
	Silver migration	Figure 45.1	Min	Min	Min	5	45.8 or 45.9
	Flex tail crease and bending with coverlay	Figure 28.3, or Figure 28.4	Min	Min	Min	8	45.10
			Max	Max	Max	8	

Table 29.2 Continued on Next Page

Table 29.2 Continued

Set	Property	Sample dimensions (length by width) mm (in)	Circuit layer thickness	Conductor thickness	Cover material thickness	Minimum number of specimens	Method and sample build-up refer to:
		production specimen					
	Flex tail pull with coverlay	Figure 28.3, or Figure 28.4 production specimen	Min	Min	Min	8	45.11
	Cove material adhesion minimum construction	Figure 28.1, Figure 28.2, or Figure 28.3 or production specimen	Min	Min	Min	10	45.12
	Cover material adhesion maximum construction	Figure 28.1, Figure 28.2, or Figure 28.3 or production specimen	Max	Max	Max	10	45.12
	Ambient bend minimum construction with and without coverlay	Figure 45.4	Min	Min	Min	10	45.13
	Ambient bend maximum construction with and without coverlay	Figure 45.4	Max	Max	Max	10	45.13
	Cold bend minimum construction with and without coverlay	Figure 45.4	Min	Min	Min	5	45.13
	Cold bend maximum construction with and without coverlay	Figure 45.4	Max	Max	Max	5	45.14
	Repeat flex minimum construction with and without coverlay	Figure 45.4	Min	Min	Min	2	45.15
	Repeat flex maximum construction with and without coverlay	Figure 45.4	Max	Max	Max	2	45.15

Table 29.2 Continued on Next Page

Table 29.2 Continued

Set	Property	Sample dimensions (length by width) mm (in)	Circuit layer thickness	Conductor thickness	Cover material thickness	Minimum number of specimens	Method and sample build-up refer to:
	Stiffener bond strength	Figure 45.6	Min	Min	Min	9	45.16
	Connector pull (optional)	Figure 28.3 or Figure 28.4	n/a	n/a	n/a	4	45.17
	Dissimilar material thermal cycling	Figure 28.3	Min	Min	Min	3	45.18
	Rear adhesion to mounting surface test (optional)	Figure 28.3 or production specimen	n/a	n/a	n/a	2	45.19
Specimens requested represent the general number required to efficiently complete testing and not necessarily the number required by the test.							

Table 29.3
Construction build-up test program

Set	Property	Sample dimensions	Circuit layer thickness	Conductor thickness	Cover material thickness	Minimum number of specimens	Method and sample build-up refer to
	Flammability	Figure 28.3 or production specimen	Min	Min	Min	10	22
	Flammability	Figure 28.3 or production specimen	Min	Max	Min	10	22
	Flammability	Figure 28.3 or production specimen	Min	Max	Max	10	22
	Flammability	Figure 28.3 or production specimen	Max	Max	Max	10	22
Specimens requested represent the general number required to efficiently complete testing and not necessarily the number required by the test.							

Table 29.4
Protection against environmental and abuse- construction build-up test program

Set	Property	Sample dimensions	Circuit layer thickness	Conductor thickness	Cover material thickness	Minimum number of specimens	Method and sample build-up reference
	IP solid objects (dust)	Figure 28.3 or production specimen	Min	n/a	Min	3	44.2
	IP ingress of water	Figure 28.3 or production specimen	Min	n/a	Min	3	44.3

Table 29.4 Continued on Next Page

Table 29.4 Continued

Set	Property	Sample dimensions	Circuit layer thickness	Conductor thickness	Cover material thickness	Minimum number of specimens	Method and sample build-up reference
	Chemical / solvent	Figure 28.3 or production specimen	Min	n/a	Min	3	44.5
	Hosedown	Figure 28.3 or production specimen	Max	n/a	Min	3	44.6
	Humid conditions	Figure 28.3 or production specimen	Max	n/a	Min	3	44.7
Specimens requested represent the general number required to efficiently complete testing and not necessarily the number required by the test.							

30 Marking Rub Durability Test

30.1 Rubbing the marking by hand using a soaked piece of cloth pressed on the marking with a pressure of about 2 N/cm^2 (2.9 lbf/in^2) for 15 back-and-forth movements in about 15 s. The cloth shall be soaked in distilled water.

30.2 Rubbing the marking by hand using a soaked piece of cloth pressed on the marking with a pressure of about 2 N/cm^2 (2.9 lbf/in^2) for 15 back-and-forth movements in about 15 s. The cloth shall be soaked in petroleum spirit.

30.3 Compliance is checked by inspection after the following test, the marking shall be legible.

31 Earthing Test

31.1 The connection between an earthing terminal, earthing termination or other earthing means and parts required to be connected thereto shall be of low resistance. The test is completed as follows.

31.2 A current of 1.5 times the rated current but not less than 25 A, derived from an ac source, with a no-load voltage not exceeding 12 V, is passed between the earthing terminal, earthing termination, or other earthing means, and each of the parts in turn.

31.3 The voltage drop between the earthing terminal, earthing termination, or other earthing means, and each part connected thereto is measured when steady-state conditions have been achieved, and the resistance is calculated on the basis of the current and this voltage drop.

31.4 Compliance is checked by test, the resistance shall not exceed 0.050 Ω.

32 Visual Inspection – Characterization Test

32.1 The visual examination shall be completed in accordance with the Standard Practice for Viewing Conditions for Visual Inspection of Membrane Switches, ASTM F 1595.

32.2 Compliance is checked by inspection, no defects or flaws that would impact the performance of the switch shall be detected.

33 Circuit Resistance – Characterization Test

33.1 The circuit resistance (open and closed) shall be completed in accordance with the Standard Test Method for Determining Circuit Resistance of a Membrane Switch, ASTM F 1680.

33.2 Compliance is checked by measurement, for comparison during later testing.

34 Capacitance – Characterization Test

34.1 The capacitance of the membrane switch shall be completed in accordance with the Standard Test Method for Determining the Capacitance of a Membrane Switch, ASTM F 1663.

34.2 Compliance is checked by measurement, the capacity of the switch shall be recorded for comparison during later testing.

35 Force Displacement Test

35.1 The force displacement test shall be completed in accordance with the Standard Test Method for Measuring the Force-Displacement of a Membrane Switch, ASTM F 2592.

35.2 Compliance is checked by measurement, the slope, force maximum and force minimum shall be recorded for comparison during later testing.

36 Contact Bounce Time Test (optional)

36.1 The contact bounce time shall be completed in accordance with the Standard Test Method for Determining the Contact Bounce Time of a Membrane Switch, ASTM F 1661. The purpose of this test is to determine the time required for the opening or closing of a switch to remain steady state within the desired transition voltage.

36.2 Compliance is checked by measurement, the performance parameters of the test are recorded.

37 Sensitivity / Teasing Test (optional)

37.1 The sensitivity or teasing test shall be completed in accordance with the Standard Test Method for Determining the Contact Bounce Time of a Membrane Switch, ASTM F 1661. The purpose of this test is to determine the tendency of a switch to make or break electrical contact at unexpected moments during closure or release force.

37.2 Compliance is checked by measurement, the performance parameters of the test are recorded.

38 Electrostatic Discharge (ESD) Shielding Test (optional)

38.1 The electrostatic discharge (ESD) shielding test shall be completed in accordance with the Standard Test Method for Determining the Effectiveness of Membrane Switch ESD Shielding, ASTM F 1812. The purpose of this test is to determine the electrostatic discharge (ESD) shielding effectiveness of a membrane switch assembly.

38.2 Compliance is checked by measurement, the performance parameters of the test are recorded.

39 Insulation Resistance Test

39.1 The insulation resistance test shall be completed in accordance with the Standard Test Method for Determining the Insulation Resistance of a Membrane Switch, ASTM F 1689.

39.2 Compliance is checked by measurement, the insulation resistance value is recorded for comparison in later tests.

40 Dielectric Strength Test (Working Voltages Less Than and Equal to 30 Vrms)

40.1 The dielectric strength test shall be completed in accordance with the Standard Test Method for Verifying the Specified Dielectric Withstand Voltage and Determining the Dielectric Breakdown Voltage of a Membrane Switch, ASTM F 1662. The purpose of this test is to determine the ability of the material to insulate the user.

40.2 The specific areas of testing shall additionally include:

a) Conductors tested to user accessible layers (covered tightly by metallic foil);

b) Conductors tested to the bottom layer (adhered to metallic foil).

40.3 The operation of the dielectric tester (fault indicator; visual, audible or meter) shall be verified before and after testing.

40.4 The capacity of the transformer shall be 500 VA or larger, the output voltage. A 500 VA or larger capacity transformer need not be used if the transformer is provided with a calibrated voltmeter that directly measures the applied output potential.

40.5 Compliance is checked by measurement, no breakdown between test points shall be indicated.

41 Dielectric Strength Test (Working Voltages Greater Than 30 Vrms)

41.1 The dielectric test voltage from Table 41.1 is used when working voltages exceeds 30 Vrms.

Table 41.1
Dielectric Voltage test values for working voltages exceeding 30 Vrms

Test location high voltage live parts to: low voltage circuits, user interface, mounting surface.	Test voltage rms			
	Rated voltage up to / including 50 V	Rated voltage above 50 V up to / including 130 V	Rated voltage above 130 V up to / including 440 V	Rated voltage above 440 V
Reinforced	500	2600	3000	5000

41.2 The insulation is subjected to a voltage of substantially sine-wave form, having a frequency of 50 Hz or 60 Hz. The test voltage shall be raised uniformly from 0 V to the value specified within not more than 5 s and held at that value for 60 s.

41.3 Compliance is checked by testing, no flashover or breakdown shall occur.

42 Heating Test

42.1 Switches shall be constructed so that they do not attain excessive temperatures in normal use. The materials used shall be such that the performance of the switches is not adversely affected by operation in normal use at the maximum rated current or declared thermal current and rated temperature of the switch.

42.2 Place the switch in an oven and/or on a heated surface (according to the manufacturers declaration). The test temperatures shall be with in 5% of the declared rated temperature.

42.3 A switch operating surface temperature rated greater than 50° C (122° F), shall be tested on a mounting surface at maximum rated temperature.

42.4 A switch operating ambient temperature of environment rated greater than 40°C (104°F), shall be tested in an oven ambient at maximum rated temperature.

42.5 A switch with rated temperatures, 0 – 50° C (32 – 122° F) surface and ambient 0 – 40° C (32 – 104°F), is tested at 25 ±10°C (77 ±18°F). The greater difference between the test temperature and rated temperature (surface or ambient) shall be added to the measured to determine the maximum material temperature.

42.6 The maximum current is maintained at least for 1 h or until a constant temperature at the terminals is attained. A temperature is considered to be constant when three successive readings taken at intervals of 5 min indicate no change greater than ±2°C (±3.6°F).

42.7 The material temperature is measured by thermal couples at suitable locations such as:

a) On the external surface as close to the contact as possible.

b) On the external surface over the trace carrying the test current approximately 15 mm (0.59 in) from the contact.

c) On the mounting surface.

d) Ambient test temperature measured approximately 50 mm (1.97 in) above the membrane switch surface.

42.8 Compliance is demonstrated by test, no recorded temperature (with applicable calculations) of a material shall be greater than the rated RTI value (the lower rated value for mechanical without impact or electrical). No user-accessible surface of the membrane switch shall be greater than 65°C (149°F) when tested in the (or calculated to the) maximum ambient temperature.

43 Endurance Contact Closure Cycling Test

43.1 General

43.1.1 Switches shall withstand without excessive wear or other harmful effect the electrical, thermal and mechanical stresses that occur in normal use.

43.1.2 After all the tests specified, the specimens shall meet the requirements of the Effects of Endurance Cycling tests in 43.5.

43.2 Electrical conditions

43.2.1 The switch shall be tested for the declared electrical values (voltage, amperage and power factor). When the testing itself causes one of the values to varies, the rated electrical supply and load shall be set at the beginning of the test and unless otherwise indicated the voltage shall be held constant.

43.3 Temperature / environmental conditions

43.3.1 All switches shall be subjected to the humid conditions per level 2 of the Standard Practice for Exposure of Membrane Switches to Temperature and Relative Humidity, ASTM F 1596. After the humidity conditioning the sample shall be removed from the chamber and mounted. The test mounting surface and environment ambient shall be as described in Table 43.1 according to the manufacturer's declaration.

Table 43.1
Test thermal conditions according to switch temperature ratings

Operating surface temperature of mounting	Operating ambient temperature of environment	Test surface temperature		Test ambient temperature	
0 – 50°C (32 – 122°F)	0 – 40°C (32 – 104°F)	25 ±10°C (77 ±18°F)		25 ±10°C (77 ±18°F)	
0°C – greater than 50°C (32°F – greater than 122°F)	0 – 40°C (32 – 104°F)	1/2 cycles minimum rated temperature T +0/-5°C	+1/2 cycles at 25 ±10°C (77 ±18°F)	25 ±10°C (77 ±18°F)	
less than 0°C – 55°C (32°F – 131°F)	0 – 40°C (32 – 104°F)	1/2 cycles minimum rated temperature T +0/-5°C	+1/2 cycles at 25 ±10°C (77 ±18°F)	25 ±10°C (77 ±18°F)	
0 – 50°C (32 – 122°F)	greater than 40°C (104°F)	1/2 cycles minimum rated temperature T +0/-5°C	+1/2 cycles at 25 ±10°C (77 ±18°F)	1/2 cycles maximum rated temperature T +5/-0°C	+1/2 cycles at 25 ±10°C (77 ±18°F)
0 – 50°C (32 – 122°F)	less than 0°C (32°F)	1/2 cycles minimum rated temperature T +0/-5°C	+1/2 cycles at 25 ±10°C (77 ±18°F)	1/2 cycles at 25 ±10°C (77 ±18°F)	+1/2 cycles minimum rated temperature T +0/-5°C

43.3.2 A switch operating surface temperature of mounting, rated both less than 0°C (32°F) and greater than 50°C (122°F), shall be tested for the first half cycle at maximum and second half cycle at minimum rated temperature.

43.3.3 A switch operating ambient temperature of environment, rated both less than 0°C (32°F) and greater than 40°C (104°F), shall be tested for the first half cycle at maximum and second half cycle at minimum rated temperature.

43.3.4 A switch with rated temperatures, 0 – 50°C (32 – 122°F) surface and ambient 0 – 40°C (32 – 104°F), is tested at 25 ±10°C (77 ±18°F).

43.4 Actuation Test

43.4.1 The endurance test shall be completed in accordance with the Standard Test Method for Contact Closure Cycling of a Membrane Switch, ASTM F 1578. The purpose of this test is to cycle the membrane switch for the anticipated number of cycles under the declared thermal and electrical conditions. The effect of repeated closing of the switch contacts and flexing of the materials is investigated.

43.4.2 The opening and closing continuity of the circuit shall be monitored for each cycle of the test.

43.4.3 The circuit resistance (open and closed) is measured and recorded during the cycling test at intervals of at least 10,000 cycles.

43.4.4 The cycling rate shall not be greater than 3 cycles per second.

43.4.5 The speed of actuation shall not be greater than 80 mm/s.

43.4.6 The probe force shall not be less then the as received force displacement value.

43.4.7 The on time shall not be less than 25% of the total duration of the cycle.

43.5 Effects of endurance cycling

43.5.1 Visual inspection of the membrane switch

43.5.1.1 The visual examination shall be completed in accordance with the Standard Practice for Viewing Conditions for Visual Inspection of Membrane Switches, ASTM F 1595.

43.5.1.2 Compliance is checked by completion of the specimen to open and close for the total number of inspection, no opening of the top layer that would permit the ingress of dust or water or expose live parts.

43.5.2 Circuit resistance of the membrane switch

43.5.2.1 The circuit resistance (open and closed) shall be measured at intervals of at least every 10,000 cycles (±100 cycles), and averaged based on 5 consecutive cycles. The average opening and average closing resistances shall be recorded. The test shall be completed in accordance with the Standard Test Method for Determining Circuit Resistance of a Membrane Switch, ASTM F 1680.

43.5.2.2 Compliance is checked by the following:

a) The switch closing (defined by a resistance less than 100 Ω or not greater than 25% of the as received measurement).

b) The switch opening (resistance not less than 15% of the as received measurement) is measured and recorded.

43.5.3 Capacitance of the membrane switch

43.5.3.1 The capacitance of the membrane switch shall be completed in accordance with the Standard Test Method for Determining the Capacitance of a Membrane Switch, ASTM F 1663.

43.5.3.2 Compliance is checked by measurement, the capacity of the switch after the endurance cycles shall not differ from the as received measurement by greater than 25%.

43.5.4 Force displacement test

43.5.4.1 The force displacement test shall be completed in accordance with the Standard Test Method for Measuring the Force-Displacement of a Membrane Switch, ASTM F 2592.

43.5.4.2 Compliance is checked by measurement, the force maximum and force minimum shall not differ from the as received measured force maximum and force minimum by greater than 30%.

43.5.5 Insulation resistance test

43.5.5.1 The insulation resistance test shall be completed in accordance with the Standard Test Method for Determining the Insulation Resistance of a Membrane Switch, ASTM F 1689.

43.5.5.2 Compliance is checked by measurement, the insulation resistance shall not differ from the as received insulation resistance measurement by greater than 30%.

43.5.6 Dielectric strength test

43.5.6.1 The dielectric strength test shall be completed per Sections 40 or 41.

44 Protection Against Environmental and Abuse

44.1 Protection against solid foreign objects

44.1.1 Switches shall provide the declared degree of protection, against solid foreign objects when mounted and used as declared. Switches are mounted in or on a surface to simulate the appliance. And shall comply with the IP exposure codes in Table 44.1. Compliance is checked per the appropriate test specified in the Degrees of Protection Provided by Enclosures (IP Code), IEC 60529.

Table 44.1
IP exposure

First number	Particle / Dust Characteristics	Second number	Water / Liquid Characteristic
0	No test required	0	No test required
1	Rigid sphere without handle of guard 50-mm (2-in) diameter	1	In accordance with the Test for Second Characteristic Numeral 1 with the Drip Box, 14.2.1, in the Degrees of Protection Provided by Enclosures (IP Code), IEC 60529 (water drops)
2	Rigid sphere without handle of guard 12.5-mm (0.5-in) diameter	2	In accordance with the Test for Second Characteristic Numeral 2 with the Drip Box, 14.2.2, in the Degrees of Protection Provided by Enclosures (IP Code), IEC 60529 (water drops, with tilt)
3	Rigid steel rod 2.5-mm (0.1-in) diameter with edge free from burrs	3	In accordance with the Test for Second Characteristic Numeral 3 with Oscillating Tube or Spray Nozzle, 14.2.3, in the Degrees of Protection Provided by Enclosures (IP Code), IEC 60529 (spray nozzle)
4	Rigid steel rod 2.5-mm (0.1-in) diameter with edge free from burrs	4	In accordance with the Test for Second Characteristic Numeral 4 with Oscillating Tube or Spray Nozzle, 14.2.4, in the Degrees of Protection Provided by Enclosures (IP Code), IEC 60529 (spray nozzle with tilt)
5	Dust chamber with or without low-pressure	5	In accordance with the Test for Second Characteristic Numeral 5 with the 6,3 mm Nozzle, 14.2.5, in the Degrees of Protection Provided by Enclosures (IP Code), IEC 60529 (spray nozzle – 6.3 mm)
6	Dust chamber with low-pressure	6	In accordance with the Test for Second Characteristic Numeral 6 with the 12,5 mm Nozzle, 14.2.6, in the Degrees of Protection Provided by Enclosures (IP Code), IEC 60529 (spray nozzle – 12.5 mm)
–	–	7	In accordance with the Test for Second Characteristic Numeral 7: Temporary Immersion Between 0,15 m and 1 m, 14.2.7, in the Degrees of Protection Provided by Enclosures (IP Code), IEC 60529 (temporary immersion)

44.2 Protection against ingress of dust

44.2.1 Switches shall provide the declared degree of protection against ingress of dust when mounted and used as declared.

44.2.2 The protection against ingress of dust tests shall be completed in accordance with the Degrees of Protection Provided by Enclosures (IP Code), IEC 60529. The purpose of this test is to determine the resistance to ingress of dust according to the declared environmental severity. IP1X to IP6X per category 2.

44.2.3 The switches are placed in a position of normal use inside the test chamber, mounted on the surface to simulate the appliance.

44.2.4 The test shall be continued for a period of 8 h. During the 8 h period, the switch under test shall be alternatively loaded for 1 h with the maximum rated current and 1 h without current.

44.2.5 Compliance to the IP exposure code in Table 44.1 is checked by inspection, all functions shall operate as declared, no break down of dielectric shall be indicted during the dielectric testing and no penetration of dust shall be observed.

44.3 Protection against ingress of water

44.3.1 Switches shall provide the declared degree of protection against ingress of water when mounted and used as declared.

44.3.2 The protection against ingress of water tests shall be completed in accordance with the Degrees of Protection Provided by Enclosures (IP Code), IEC 60529. The purpose of this test is to determine the resistance to ingress of liquids according to the declared environmental severity.

44.3.3 With the switch placed in any position of normal use. Switches are allowed to stand at 25 ±10°C (77 ±18°F) for 24 h before being subjected to the following test.

44.3.4 The switch shall not be electrically loaded during these tests. The water temperature shall not differ from that of the switch by more than 5 K.

44.3.5 Ageing – switches without T-rating are kept in the cabinet at a temperature of 70°C (158°F), and switches with T-rating are kept in the cabinet at a temperature of T + 30°C for 240 h. (Cabinet tolerance ±2°C (±3.6°F)

44.3.6 Immediately after ageing, the parts are taken out of the cabinet and left at 25 ±10°C (77 ±18°F), avoiding direct daylight, for at least 16 h.

44.3.7 The switches are placed in a position of normal use inside the test chamber, mounted on the surface to simulate the appliance.

44.3.8 For the tests of second characteristic numerals 3 and 4, preferably the hand-held spray nozzle specified in the Degrees of Protection Provided by Enclosures (IP Code), IEC 60529 shall be used.

44.3.9 Immediately after the appropriate test, the switch shall withstand the appropriate dielectric strength test specified in Sections 40 or 41, and inspection shall show that there is no penetration of water.

44.3.10 Compliance is checked by inspection, no break down of dielectric shall be indicted during the dielectric testing and no penetration of water shall be observed.

44.4 Submersion test (optional)

44.4.1 The submersion environmental test shall be completed in accordance with the Practice for Submersion of a Membrane Switch, ASTM F 1895. The purpose of this test is to determine the resistance to ingress of liquids from submersion.

44.4.2 Compliance is checked by inspection, no breakdown of the seal or evidence of liquid penetration shall be indicated.

44.5 Chemical/solvent exposure test (optional)

44.5.1 The chemical exposure test shall be completed in accordance with the Standard Test Method for Determining the Effects of Chemical/Solvent Exposure to a Membrane Switch/Graphic Overlay (Spot Test Method), ASTM F 1598. The purpose of this test is to determine the effects of chemicals on the membrane switch overlay.

44.5.2 Compliance is checked by inspection, no discoloration, crazing, swelling, blistering, pitting, hazing or changes permitting the ingress of water shall be indicted.

44.6 Hosedown test (optional)

44.6.1 The hosedown test shall be completed in accordance with the Standard Practice for Hosedown of a Membrane Switch, ASTM F 2072. The purpose of this test is to determine the resistance to ingress of water from a high volume water spray.

44.6.2 Compliance is checked by inspection, no liquid shall have penetrate the assembly, the specimen shall function as intended.

44.7 Protection against humid conditions

44.7.1 All switches shall be constructed to withstand humid conditions which may occur in normal use.

44.7.2 The humidity conditioning shall be completed per level 2 of the Standard Practice for Exposure of Membrane Switches to Temperature and Relative Humidity, ASTM F 1596. The purpose of this test is to condition the specimens to humidly conditions before subsequent testing.

44.7.3 Compliance is checked by inspection, the specimen shall function as intended.

45 Circuit Test Methods

45.1 General

45.1.1 Switches shall have adequate mechanical strength and be constructed so as to withstand such rough handling as may be expected in normal use.

45.2 Solder thermal shock test

45.2.1 The purpose of this test method is to assess the physical fatigue of the membrane switch exposed to the anticipated assembly soldering and process temperatures. The thermal shock test is a prerequisite to various other tests (Bond Strength Test, 45.5, Delamination and Blistering Test 45.7, Conductive Paste Adhesion, Test 45.3, Ambient Bend Test, 45.13, Stiffener Bond Strength Test, 45.16, Dissimilar Dielectric Materials Thermal Cycling Test, 45.18, and Flammability Classification, Section 22).

45.2.2 All specimens are to be preconditioned to remove moisture at 121 ±2°C (250 ±3.6°F) for 1-1/2 h prior to being subjected to thermal shock. Thermal shock shall be performed immediately after the preconditioning or the specimens shall be stored in a desiccator (apparatus for absorbing moisture).

45.2.3 Subject the specimens to thermal shock reflecting the maximum temperature and dwell time using one of the following apparatus:

a) Convection oven – attention shall be directed to maintaining the test temperature, when introducing and removing the specimens into and from the oven chamber.

b) Sand Bath – attention shall be directed to the uniformity of temperature throughout the fluidized bed, and avoid mechanical damage imposed by an inadequately fluidized sand bath.

c) Solder pot – attention shall be directed to the specimens when removing them from the solder pot so the solder does not join with the conductor traces. Specimens shall be prepared without solder or solder resist on conductor traces.

d) IR reflow oven – attention shall be directed to the uniformity of temperature across the specimen, due to the susceptibility of the materials used to fabricate test specimens to infrared absorption.

45.2.4 When a solder process involves a repeated soldering operation with a range of intervening cooling periods, the minimum cooling period is to be used. When required, a removable solder resist is to be applied at the time of the testing so that solder does not adhere. The solder resist is to be removed from the specimen before further testing.

45.2.5 Compliance is checked by inspection. There shall be no presence of any wrinkling, cracking, blistering, or loosening of any conductor, or any delamination, wrinkling, cracking, blistering, or loosening of any film, adhesive, base material, cover material, or other insulation and conductor material as a result of the pre-conditioning and thermal shock testing.

45.3 Conductive paste adhesion test

45.3.1 The purpose of this test method is to assess the physical fatigue and adhesion of conductive paste and polymer thick film type conductors applied on base material, film, adhesive, conductors, cover material, laminate, and other insulation or conductor material in the membrane switch following exposure to cycled environmental conditioning, including thermal conditioning, water immersion, cold, and high humidity environments.

45.3.2 Three specimens shall include all material components representing the minimum build-up construction in accordance with the construction materials for the desired membrane switch construction.

45.3.3 Specimens shall include a conductor pattern as shown in Figure 28.1. Conductive paste is to be applied on each surface that is used in production (such as laminate, copper, cover material, or dielectric material). The conductive paste adhesion is to be tested on each dissimilar material.

45.3.4 Each cover material or solder resist material applied over the conductive paste shall be tested.

Exception: Specimens without cover material or solder resist material applied over the conductive paste may be tested to represent specimens with overcoat materials.

45.3.5 Subject the specimens to the thermal shock test at the manufacturer's specified solder limit temperature and dwell time, for circuits that are soldered.

45.3.6 Subject the specimens to the following environmental conditioning using the schedule described in Table 45.1:

a) 48 h at 10 ±2°C (18 ±3.6°F) above the maximum operating ambient temperature specified by the manufacturer;

b) 64 h at 35 ±2°C (95 ±3.6°F) at 90 ±5% relative humidity;

c) 8 h at 0°C minus 2°C (32°F minus 3.6°F); and

d) 64 h at 35 ±2°C (95 ±3.6°F) at 90 ±5% relative humidity.

Table 45.1
Thermal cycling schedule

Day	Time	Conditioning
Day 1 (Wednesday)	15:00	in oven @ TI°C (T +10°C)
Day 2 (Thursday)	–	(in oven)
Day 3 (Friday)	15:00	(out of oven – into H.C. @90% R.H.)
Day 4 (Saturday)	–	(in H.C.)
Day 5 (Sunday)	–	(in H.C.)
Day 6 (Monday)	7:00	out of H.C. – into freezer @ 0°C (32°F)
Day 6 (Monday)	15:00	out of freezer into H.C. @ 90% R.H.
Day 7 (Tuesday)	–	(in H.C.)
Day 8 (Wednesday)		(in H.C.)
Day 9 (Thursday)	7:00	out of H.C. – end of cycle
Day 1 through 9 represents one cycle. All times may be adjusted to equal increments to reflect a later start date. Specimens shall be stored at 23 ±2°C (73.4 ±3.6°F) and 50% R.H. between cycles. T = Maximum Operating Ambient Temperature (MOAT) of the material that makes up the switch TI = Thermal Conditioning Temperature H.C. = Humidity Chamber R.H. = Relative Humidity		

45.3.7 After the environmental conditioning examine the specimens and record non-compliance.

45.3.8 Repeat the environmental conditioning in 45.3.6 and examination in 45.3.7 for a total of three exposures.

45.3.9 Attach a rigid reinforcement material to the back-side of the specimen, the side of the specimen not being subjected to the conductive paste adhesion test, using double-faced adhesive tape or an adhesive system. The specimens shall be subjected to the thermal cycling and examination without any supplemental reinforcement attached; a supplemental reinforcement material shall be applied to the specimens only after the thermal cycling.

45.3.10 The conditioned specimens shall be tested as described in the plating adhesion test.

45.3.11 Compliance is checked by inspection. There shall be no evidence of the conductor pattern being removed as shown by the pattern particles adhering to the tape. If small particles of conductor material

from the edge of the conductor trace adhere to the tape, it may be evidence of overhang and not of unacceptable adhesion.

45.3.12 There shall be no presence of any wrinkling, cracking, blistering, or loosening of any conductor, or any delamination, wrinkling, cracking, blistering, or loosening of any film, adhesive, base material, cover material, or other insulation and conductor material as a result of the pre-conditioning, thermal shock, oven conditioning, or cooling.

45.4 Plating adhesion test (for flex tail leads that are electro plated)

45.4.1 The purpose of this test method is to assess the adhesion of plated metallic conductors of membrane switches without exposure to solder limits or thermal conditioning. Plating such as gold, nickel and other metallic surface finishes, this does not include conductive paste and polymer thick films.

45.4.2 One specimen (minimum and maximum construction) shall include all material components representing the minimum build-up membrane switch construction as described in the requirement for platings in 25.10 and Table 29.2 shall be tested.

45.4.3 Specimens shall include a conductor pattern as shown in Figure 28.1 or Figure 28.3.

45.4.4 A steel roller 80 mm ±2.5 mm (3.25 in) in diameter, 45 mm ±1-mm (1.75-in) wide, and weighing 2000 g ±50 g (4.4 ±0.1 lbs) covered with rubber approximately 6 mm (0.25 in) in thickness shall be used for this test.

45.4.5 Pressure sensitive cellophane tape, 13-mm (0.5-in) wide, with an adhesion of 0.38 ±0.055 N/mm (35 ±5 oz/in) as determined by the Standard Test Method for Pressure-Sensitive Adhesive-Coated Tapes Used for Electrical and Electronic Applications, ASTM D 1000, shall be used for this test.

45.4.6 A strip of pressure-sensitive cellophane tape is to be pressed onto the surface of the conductor pattern using the steel roller. The roller shall remove all air bubbles so a minimum of 50-mm (2-in) length of tape is securely attached to the test pattern.

45.4.7 Mechanically remove the pressure-sensitive cellophane tape by gripping one end of the tape, and removing it at a rate of approximately 25.4 mm (1 in) in 5 s at an angle of approximately 90° to the base material. The pressure sensitive tape shall be compatible with the membrane switch materials and not adversely affect the materials.

45.4.8 The tape is to be applied and removed at three different locations on the specimen with fresh tape being used for each application. The locations on the specimen should incorporate the different conductor constructions.

45.4.9 Compliance is checked by inspection. There shall be no evidence of the protective plating or the conductor pattern being removed as shown by the pattern particles adhering to the tape. If small particles of metal from the edge of the conductor trace adhere to the tape, it may be evidence of overhang and not of unacceptable adhesion.

45.5 Bond strength test

45.5.1 The purpose of this test method is to assess the physical fatigue and adhesion of metallic conductors on base materials of membrane switches, following exposure to solder limits and thermal conditioning based on the maximum operating ambient temperature.

45.5.2 Specimens

45.5.2.1 Four specimens shall include all material components representing a minimum build-up construction in accordance with the construction materials for the desired membrane switch construction.

45.5.2.2 Specimens shall include a conductor pattern representative of the request parameters. A representative conductor pattern is shown in Figure 28.1 or Figure 28.3.

Exception: When production specimens are tested in lieu of the representative conductor test pattern specimens, the applicable parameter profile indices (i. e., material components, construction build-up thickness, conductor line widths, conductor weight, etc.) of the production specimens shall be determined to be equal to or more severe than the parameter profile indices established for the membrane switch.

45.5.2.3 External conductors of the minimum weight shall be provided for the bond strength test. For conductor weights less than 34 mic (1 oz/ft^2), the conductors shall be plated to a 34 mic (1 oz/ft^2) thickness to aid the bond strength pull.

Exception: The conductor weight and narrow width conductors may prohibit plating to a thickness corresponding to 34 mic (1 oz/ft^2), so narrow width conductors shall be plated to the maximum conductor weight intended for production of the corresponding conductor width.

45.5.2.4 Conductors on the specimens for bond strength test shall be continuous.

45.5.2.5 Cover material and solder resist materials shall not be present on the external surfaces of the membrane switch. The bond strength test shall be conducted by peeling the conductor from the base material without obstruction of other surface materials.

45.5.3 Apparatus

45.5.3.1 Double-faced adhesive tape or an adhesive system with an adhesive strength capable of attaching a rigid supplemental reinforcement material to the test specimen for bond strength testing shall be used for this test.

45.5.3.2 A rigid supplemental reinforcement material to be bonded to the test specimens shall be used for this test. The rigid supplemental reinforcement material is intended to eliminate tenting and flexing of the specimen during the bond strength test. The adhesive tape and reinforcement material should be compatible with the materials used in the construction, and should not be detrimental to or adversely affect the materials in the construction.

45.5.3.3 A pry tool, such as a knife or scalpel, capable of separating the conductor from the substrate adhesive or film material to initiate the conductor bond strength pull shall be used for this test.

45.5.3.4 A conditioning (convection) oven capable of maintaining the specified conditioning temperatures shall be used for this test.

45.5.3.5 A bond strength tester capable of providing and measuring the force required to separate the conductor material from the substrate material with an accuracy within 10% of the measured force value shall be used for this test.

45.5.4 Procedure

45.5.4.1 Measure the overall specimen build-up thickness in three separate areas, where no conductor material resides on the internal or external surfaces of the membrane switch specimens.

45.5.4.2 Measure and verify the conductor average widths of the following conductors.

a) A minimum midboard conductor;

b) A 1.6-mm (0.063-in) wide conductor;

c) An edge conductor, except as described in conductor width; and

d) A midboard/non-edge conductor of another width (optional), to be specified by the fabricator.

45.5.4.3 Subject the specimens to the thermal shock.

45.5.4.4 The specimens shall be subjected to the thermal shock test without any reinforcement attached; a supplemental reinforcement material shall be applied to these specimens only after the thermal shock test.

45.5.4.5 Attach a rigid reinforcement material to the back-side of the as-received specimen, the side of the specimen not being subjected to the bond strength test, of four of the minimum build-up interconnect construction specimens using double-faced adhesive tape or adhesive system.

45.5.4.6 Separate or pry the end of the conductor from the base material, so that the conductor can be grasped for the bond strength pull.

Exception: After attempting to pry up an end of a conductor, if the conductor material and base material interface remain intact, the base material rips or tears when the bond strength pull is conducted, and the forces imparted to the conductor material exceeds 0.350 N/mm (2 lbf/in), the bond strength of that conductor shall be considered greater than 0.350 N/mm (2 lbf/in).

45.5.4.7 Peel a uniform width of the conductor from the base material for a distance of 7 to 14 mm (0.275 to 0.551 in) at a uniform rate of approximately 300 mm/min (12 in/min) [or, approximately 12.7 mm in 2.5 s (0.50 inch in 2.5 s)]. The angle between the conductor and the base material shall be maintained at not less than 85° during the test. Three determinations [i.e., three pulls for a distance of 7 to 14 mm (0.275 to 0.551 in)] shall be made, on each of:

a) A minimum average conductor width;

b) A 1.6-mm (0.063-in) wide conductor;

c) An edge conductor; and

d) A conductor of another width, specified by the fabricator (optional).

Exception: When the characteristics of the conductor material inhibit measurement of the bond strength with test equipment, the bond strength shall be evaluated manually. A reference material previously evaluated with test equipment and found to have bond strength greater than 0.350 N/mm (2 lbf/in) for each individual conductor of similar width shall be used to compare with the bond strength of each individual conductor width, respectively, on unconditioned and oven conditioned specimens. A tool can be used to pry the conductor from the base material surface and the bond strength shall be evaluated manually. The same conductor traces on unconditioned and oven conditioned specimens shall be evaluated in the same manner. The conductor adhesion to the base material shall compare favorably to the reference material.

45.5.4.8 Compliance is checked by inspection. The average bond strength between the conductor and base material shall not be less than 0.350 N/mm (2 lbf/in) for each individual conductor for the average bond strength determined after being subject to thermal shock.

45.5.4.9 There shall be no presence of any wrinkling, cracking, blistering, or loosening of any conductor, or any delamination, wrinkling, cracking, blistering, or loosening of any film, adhesive, base material, cover material, or other dielectric and conductor material as a result of the pre-conditioning, thermal shock, oven conditioning, or cooling.

45.5.4.10 Place two specimens in a full-draft circulating-air oven for 240 consecutive hours, maintained at a temperature determined by the following formula. See Table 45.2 for the 240-h oven conditioning temperatures corresponding to the desired or established MOAT (Maximum Operating Ambient Temperature).

$$t_2 = 1.076(t_1 + 288) - 273$$

in which:

t_2 is the oven conditioning temperature in °C for 240-h oven conditioning.

t_1 is the MOAT in °C of the membrane switch.

Table 45.2
Oven conditioning temperatures for the desired (or established) MOAT

"t_1" Desired MOAT °C (°F)	"t_2" Oven temperature for 240-h (10 day) oven conditioning °C (°F)	"t_3" Oven temperature for 1344-h (56 day) oven conditioning °C (°F)
75 (167)	118 (244.4)	98 (208.4)
80 (176)	123 (253.4)	103 (217.4)
85 (185)	129 (264.2)	108 (226.4)
90 (194)	134 (273.2)	113 (235.4)
105 (221)	150 (302)	128 (262.4)
120 (248)	167 (332.6)	144 (291.2)
125 (257)	172 (341.6)	149 (300.2)
130 (266)	177 (350.6)	154 (309.2)
150 (302)	199 (390.2)	174 (345.2)
155 (311)	204 (399.2)	179 (354.2)
160 (320)	210 (410)	184 (363.2)
170 (338)	220 (428)	195 (383)
175 (347)	226 (438.8)	200 (392)
180 (356)	231 (447.8)	205 (401)

45.5.4.11 When the fabricator so requests, an alternate longer oven conditioning time at a lower temperature can be used. Place two specimens in a full-draft circulating-air oven for 1344 consecutive hours, maintained at a temperature determined by the following formula. See Table Table 45.2 for the 1344-h oven conditioning temperatures corresponding to the desired or established MOAT.

$$t_3 = 1.02(t_1 + 288) - 273$$

in which:

t_3 is the oven conditioning temperature in °C for 1344-h oven conditioning.

t_1 is the MOAT in °C of the FMIC type (Flexible Materials Interconnect Construction).

45.5.4.12 Cool the test specimens to room temperature at standard ambient laboratory conditions after being oven conditioned (240-h oven conditioning) or (1344-h oven conditioning). The specimens shall be placed on a ceramic plate or tile, hung, or racked such that the specimens are not adversely affected by the mechanism used to hold or retain the specimens during cooling.

45.5.4.13 Examine the specimens and record any presence of any wrinkles, cracks, blisters, or loose conductors, or any delamination, wrinkles, cracks, blisters, or loose film, adhesive, base material, or other dielectric materials.

45.5.4.14 Attach a rigid reinforcement material to the back-side of the oven-conditioned specimens using double-faced adhesive tape or an adhesive system so the specimens do not flex or tent during the bond strength test. The test specimens shall be oven conditioned without any supplemental reinforcement attached. A supplemental reinforcement material shall be applied to the test specimens only after the stabilization period following oven conditioning and cooling.

45.5.4.15 The force required to separate the conductor from the base material shall be measured on each specimen (240-h oven conditioning at temperature "t_2").

45.5.4.16 Compliance is checked by inspection. Compliance criteria for thermal conditioned specimens is an average bond strength between the conductor and base material shall not be less than 0.350 N/mm (2 lbf/in) for each individual conductor after being subject to thermal shock and 240-h oven conditioning.

45.5.4.17 There shall be no presence of any wrinkling, cracking, blistering, or loosening of any conductor, or any delamination, wrinkling, cracking, blistering, or loosening of any film, adhesive, base material, cover material, or other dielectric and conductor material as a result of the pre-conditioning, thermal shock, oven conditioning, or cooling.

45.5.4.18 If the fabricator requests a lower oven conditioning temperature lower, the force required to separate the conductor from the base material shall be measured on each specimen (1344-h oven conditioning at temperature "t_3").

45.5.4.19 Compliance is checked by inspection. Compliance criteria for thermal conditioned specimens is an average bond strength between the conductor and base material shall not be less than 0.175 N/mm (1 lbf/in) for each individual conductor after being subject to thermal shock and 1344-h oven conditioning.

45.5.4.20 There shall be no presence of any wrinkling, cracking, blistering, or loosening of any conductor, or any delamination, wrinkling, cracking, blistering, or loosening of any film, adhesive, base material, cover material, or other dielectric and conductor material as a result of the pre-conditioning, thermal shock, oven conditioning, or cooling.

45.6 Delamination layer to layer resistance test

45.6.1 Reserved for future use.

45.7 Delamination and blistering test (layer to layer)

45.7.1 General

45.7.1.1 The purpose of this test method is to assess the physical fatigue of membrane switches following exposure to solder limits and thermal conditioning based on the maximum operating ambient temperature.

45.7.2 Specimens

45.7.2.1 Four specimens shall include all material components representing a minimum build-up construction in accordance with the construction materials for the desired membrane switch construction.

45.7.2.2 Specimens shall include a conductor pattern representative of the request parameters. A representative conductor pattern is shown in Figure 28.1 or Figure 28.3.

Exception: When production specimens are tested in lieu of the representative conductor test pattern specimens, the applicable parameter profile indices (i. e., material components, construction build-up thickness, conductor line widths, conductor weight, etc.) of the production specimens shall be determined to be equal to or more severe than the parameter profile indices established for the membrane switch.

45.7.2.3 Specimens shall include external conductors of the minimum weight.

45.7.3 Procedure

45.7.3.1 The specimens shall be conditioned and examined as described in the Bond Strength Test, 45.5.

45.7.3.2 Compliance is checked by inspection. There shall be no presence of any wrinkling, cracking, blistering, or loosening of any conductor, or any delamination, wrinkling, cracking, blistering, or loosening of any film, adhesive, base material, cover material, or other dielectric and conductor material as a result of the pre-conditioning, thermal shock, oven conditioning, or cooling.

45.8 Silver migration test (IPC)

45.8.1 General

45.8.1.1 The purpose of this test method is to assess the propensity for silver surface electrochemical migration.

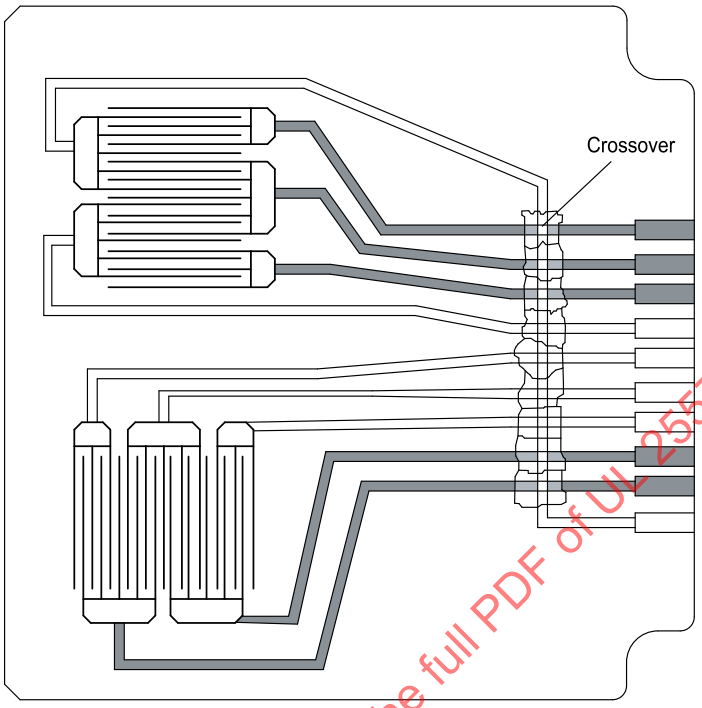
45.8.2 Test specimens

45.8.2.1 Five specimens shall include all material components representing the minimum build-up construction in accordance with the construction materials for the desired membrane switch construction. The silver material is to be tested on each dissimilar base material.

45.8.2.2 Specimens shall include a conductor pattern as shown in Figure 45.1. Silver material is to be applied on each surface that is used in production (such as laminate, copper, solder resist, or dielectric material). The conductor minimum widths and minimum spacings shall be defined by the manufacturer. A standard conductor width of 0.3 mm (0.012 in) shall also be included in the conductor pattern.

Figure 45.1

Silver migration test pattern



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45.8.3 Equipment/Apparatus

45.8.3.1 A temperature/humidity chamber capable of producing an environment of 40° C ±2° C (104 ±3.6° F), 93% ±2% RH, and allowing test switches to be electrically biased and measured without being opened under these temperature and humidity conditions is used.

45.8.3.2 Measuring equipment: High resistance measuring equipment, equivalent to that described in the Standard Test Methods for DC Resistance or Conductance of Insulating Materials, ASTM D 257, with a range up to 1012 W and capable of yielding an accuracy of ±5% at 1010 W with an applied potential of 100 Vdc (10% tolerance); standard resistors should be used for routine calibration.

45.8.3.3 Power supply: Equipment capable of providing 10 Vdc at 100 µA, with a 10% tolerance, shall be used.

45.8.3.4 Current-limiting resistors: Use one 106 W resistor in each current path. This equates to three current-limiting resistors for each 5-point comb pattern.

45.8.3.5 Connecting wire: Use PTFE-insulated, solid conductor, copper wire, or equivalent.

45.8.3.6 Other dedicated fixtures: Hardwiring is the default connection method. Other dedicated fixtures may be used, provided that the fixture does not change the resistance for more than 0.1 decade compared to a comparable hardwired system, when measured at the test conditions.

45.8.4 Procedure

45.8.4.1 A minimum of three test specimens shall be placed in a suitable rack that maintains the specimens at least 2.5 cm (1 in) apart and such that the air flow is parallel to the direction of the test specimens in the chamber. For hardwiring, wires should be dressed from the bottom to prevent flux residues from the wire attachment from flowing onto the test patterns. With mechanical fixtures, fixtures should be to the side. Insert the limiting resistors in terminating leads 1, 3, and 5 of each pattern.

45.8.4.2 Place the rack approximately in the center of the test chamber. Route the wires to the outside of the chamber; dress the wiring away from the test patterns. Ensure that drops of condensation cannot fall on the specimens.

45.8.4.3 Close the chamber and allow all specimens to stabilize for 96 h at the specific temperature and humidity. After the 96-h stabilization period, the initial dielectric resistance measurements shall be made using voltage in the range of 45 Vdc to 100 Vdc. Due to polarity, measurements should be made between terminals 1 and 2, 3 and 2, 3 and 4, and 5 and 4, at the specific temperature and humidity with the current limiting resistors placed in series with the test circuit. Terminals 2 and 4 shall be at one potential, and terminals 1, 3, and 5 at the opposite potential.

45.8.4.4 Connect the specimens to the power supply with the current limiting resistors placed in series with the test circuit, and apply 10 Vdc for the duration of the test. The test polarity shall be the same as the measurement polarity used for the previous "dielectric resistance measurement."

45.8.4.5 After 500 h of applied bias (596 h total), disconnect the power supply and repeat the measurements per the previous "dielectric resistance measurement," with the specimens under test conditions.

45.8.4.6 The average (geometric mean) insulation resistance (IR_{avg}) is calculated from:

$$IR_{avg} = 10^{\left(1/N \sum_{1}^{N} \log IR_i\right)}$$

where:

IR_{avg} = Insulation resistance (average, geometric mean)

N = Number of test points (10 minimum)

IR_i = Individual insulation resistance measurements

A minimum of 10 test measurements is required for the test to be valid.

Exception: Where an assignable cause of low insulation resistance, which is properly attributable to the materials of construction or to the process used to produce the specimens, can be found, then such a value can be excluded from calculating the average. Such assignable causes include:

a) Contamination on the specimen surface from solder splints or water droplets from the conditioning chamber.

b) Scratched, cracked, or obviously damaged insulation between conductors.

45.8.4.7 Visually examine the sample after completion of the test, the test specimens shall be removed from the test chamber and examined, with back-lighting, at 10× magnification for evidence of

electrochemical migration (filament growth), discoloration, and corrosion. Localized electrochemical migration on one comb may be caused by a testing anomaly.

45.8.4.8 Compliance is checked by inspection. There shall be no presence at 10× magnification for evidence of electrochemical migration (filament growth), discoloration, and corrosion. There shall be no change in resistance greater than 20%. Localized electrochemical migration on one comb may be caused by a testing anomaly.

45.8.4.9 Reference documents: Generic Requirements for the Physical Design and Manufacture of Telecommunications Products and Equipment, GR-78-CORE.

45.9 Silver migration test (ASTM F 1996) (alternate to IPC silver migration test method)

45.9.1 The silver migration test shall be completed in accordance with the Standard Test Method for Silver Migration for Membrane Switch Circuitry, ASTM F 1996. The purpose of this test method is to determine the susceptibility of a membrane switch to the migration of the silver material between conductors under dc voltage potential. See Figure 45.1.

45.9.2 Five specimens shall include all material components representing the minimum build-up construction in accordance with the construction materials for the desired membrane switch construction. The silver material is to be tested on each dissimilar base material.

45.9.3 Compliance is checked by inspection after the test, no evidence of electrochemical migration (filament growth), discoloration, and corrosion shall be present when viewed at 10× magnification. The resistance measured after the test shall not differ by more than 20% from the as received measurement.

45.10 Flex tail assembly creasing and bending test

45.10.1 The flex tail creasing or bending test shall be completed in accordance with the Standard Practice for Creasing or Bending a Membrane Switch, Membrane Switch Tail Assembly or Membrane Switch Component, ASTM F 1683 (withdrawn). See Annex A for a copy of this ASTM Standard. The purpose of this test is to simulate the conditions on a flexible part of a membrane switch or assembly during manufacturing, installation or use.

45.10.2 Sixteen specimens shall include all material components in accordance with construction materials for the desired membrane construction of the membrane switch:

a) Eight specimens shall represent a minimum build-up construction; and

b) Eight specimens shall represent a maximum build-up construction.

45.10.3 Sixteen specimens shall be measured and recorded for the as received termination resistance.

45.10.4 Subject four minimum build-up specimens and four maximum build-up specimens to the creasing test (two specimens from each set shall be tested with an identified surface in compression and two specimens from each set with the identified surface in expansion).

45.10.5 The cylindrical weight shall be recorded.

45.10.6 Subject four minimum build-up specimens and four maximum build-up specimens to the bending test, the number of cycles shall be five clockwise and five counter clockwise.

45.10.7 The mandrel shall have a maximum diameter of 6.4 mm (0.04 in).

45.10.8 Compliance is checked by inspection, there shall be no evidence of cracking, flaking, delaminating of the flex tail. The circuit resistance after conditioning shall not change by more than 10% from the as received measurement.

45.11 Flex tail pull test

45.11.1 The purpose of this test method is to simulate handling of the assembly.

45.11.2 Compliance is checked by the following test, no openings of the trace during testing shall be detected.

45.11.3 Subject four specimens of the minimum build-up construction to an as received trace continuity test. All traces shall demonstrate continuity between test points on opposite sides of the test specimens.

45.11.4 Vertical mounting, two flex tail specimen shall hang at an angle of 180°, from the membrane actuation surface.

45.11.5 Horizontal mounting, two flex tail specimen shall hang at an angle of 90°, from the membrane actuation surface.

45.11.6 Secure one end of the specimen to a test fixture, to the opposite end attach a weight of 4.5 kg (10 lbs). The weight shall be applied in a slow continues motion, and allowed to hang freely for 4 h.

45.11.7 The test trace shall be monitored for continuity during the test. A continuity tester shall record any openings in the trace, or provide an auditable alarm.

45.11.8 The presence of any open circuit condition during the test, as indicated by the continuity detecting circuit, shall be recorded.

45.12 Cover material adhesion test

45.12.1 General

45.12.1.1 The purpose of this test method is to determine the adhesion of the cover material to the base material of the membrane switch following exposure to thermal cycling, including thermal conditioning, water immersion, cold, and high humidity environments.

45.12.2 Test specimens

45.12.2.1 Ten specimens shall include all material components in accordance with construction materials for the desired membrane construction with cover material on the external service of the membrane switch:

a) Five specimens shall represent a minimum build-up construction; and

b) Five specimens shall represent a maximum build-up construction.

45.12.2.2 Specimens shall include a conductor pattern representative of the request parameters. A representative conductor pattern is shown in Figure 28.1, Figure 28.2, or Figure 28.3.

45.12.2.3 Conductors on the cover material test specimens shall reflect the conductors submitted for the bond strength test.

Exception: Due to the materials thickness and copper weights used to produce the maximum build-up construction specimens, the conductor trace average widths on the maximum build-up specimens can be wider than on the minimum build-up construction specimens submitted for test.

45.12.3 Apparatus

45.12.3.1 A conditioning (convection) oven capable of maintaining the specified conditioning temperature shall be used for this test.

45.12.3.2 A cold conditioning chamber capable of maintaining conditioning temperature shall be used for this test.

45.12.3.3 A humidity conditioning chamber capable of maintaining the specified conditioning temperature and relative humidity shall be used for this test.

45.12.3.4 A vessel capable of holding liquid water with the test specimens completely immersed can be used for this test.

45.12.3.5 A ceramic plate or tile, rack, or hanging device capable of being maintained at standard ambient laboratory conditions to hold or retain oven conditioned specimens for cooling shall be used for this test.

45.12.4 Procedure

45.12.4.1 Measure the overall construction build-up thickness of each of the specimens, in three separate areas, where no conductor material resides on the internal or external surfaces.

45.12.4.2 Measure and verify the conductor widths of the following conductors:

a) A minimum midboard conductor;

b) A 1.6-mm (0.063-in) wide conductor;

c) An edge conductor, except as described in conductor width; and

d) A midboard/non-edge conductor of another width (optional), to be specified by the fabricator.

45.12.4.3 Subject the specimens to the following environmental conditioning. Each step should immediately follow the previous:

a) Place the specimens in a full-draft circulating-air oven maintained at 71.0 ±2°C (159.8 ±3.6°F) for 48 consecutive hours;

b) Immerse the specimens in water at 25.0 ±2.0°C (77.0 ±3.6°F) for 48 consecutive hours;

c) Place the specimens in a cold chamber at minus 35.0 ±2.0°C (minus 31.0 ±3.6°F) for eight consecutive hours; and

d) Place the specimens in a humidity chamber at 40.0 ±2.0°C (104.0 ±3.6°F) at 95 – 100% RH for 64 consecutive hours.

45.12.4.4 Cool the test specimens to room temperature at standard ambient laboratory conditions. The specimens shall be placed on a ceramic plate or tile, hung, or racked such that the specimens are not adversely affected by the mechanism used to hold or retain the specimens during cooling.

45.12.4.5 Compliance is checked by inspection after the test. There shall be no presence of any wrinkling, cracking, blistering, or loosening of any conductor, or any delamination, wrinkling, cracking, blistering, or loosening of any cover material, film, adhesive, base material, dielectric material, or other dielectric material as a result of the thermal cycling or cooling.

45.13 Ambient bend test

45.13.1 General

45.13.1.1 The purpose of this test method is to assess the bend-ability and physical fatigue of the membrane switch intended for flexible and flex-to-install applications following exposure to solder limits and thermal conditioning based on the maximum operating ambient temperature.

45.13.2 Test specimens

45.13.2.1 Twenty specimens shall include all material components in accordance with Construction Materials for the desired membrane switch construction:

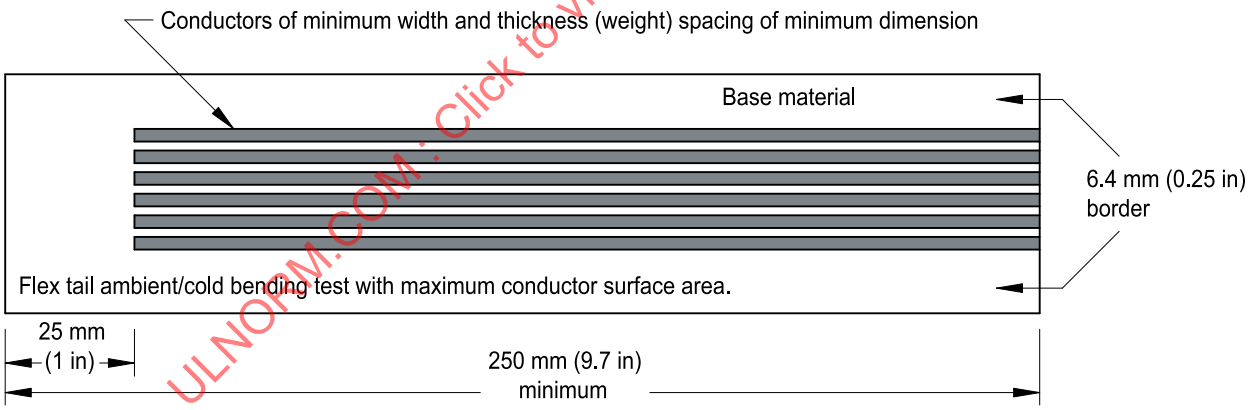
a) Ten specimens shall represent a minimum build-up construction; and

b) Ten specimens shall represent a maximum build-up construction.

45.13.2.2 The test specimen conductor pattern is shown in Figure 45.2.

Figure 45.2

Ambient bend test



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45.13.3 Apparatus

45.13.3.1 A conditioning (convection) oven capable of maintaining the specified conditioning temperatures shall be used for this test.

45.13.3.2 A 6.35-mm (0.25-in) diameter rigid mandrel shall be used for this test.

45.13.4 Procedure

45.13.4.1 Measure the overall construction build-up thickness of each specimen in three separate areas, where no conductor material resides on the internal or external surfaces.

45.13.4.2 Measure and verify the 12.7 mm (0.5 in) conductor width on the specimens.

45.13.4.3 Subject the specimens to thermal shock.

45.13.4.4 Place five of the minimum build-up construction specimens and five of the maximum build-up construction specimens in a full-draft circulating-air oven for 240 consecutive hours, maintained at a temperature determined by the following formula. See Table 45.2 for the 240-h oven conditioning temperatures corresponding to the desired or established MOAT.

$$t_2 = 1.076(t_1 + 288) - 273$$

in which:

t_2 is the oven conditioning temperature in °C for 240-h oven conditioning.

t_1 is the MOAT in °C of the membrane switch type.

45.13.4.5 Place the remaining five minimum build-up construction specimens and five maximum build-up construction specimens in a full-draft circulating-air oven for 1344 consecutive hours, maintained at a temperature determined by the following formula. See Table 45.2 for the 1344-h oven conditioning temperatures corresponding to the desired or established MOAT.

$$t_3 = 1.02(t_1 + 288) - 273$$

in which:

t_3 is the oven conditioning temperature in °C for 1344-h oven conditioning.

t_1 is the MOAT in °C of the membrane switch type.

45.13.4.6 Cool the test specimens to room temperature. Place the specimens on a ceramic plate or tile, or hang or rack them such that the specimens are not adversely affected by the mechanism used to hold or retain the specimens during cooling.

45.13.4.7 Bend a specimen around a 6.35-mm (0.25-in) diameter rigid mandrel for five completely closed turns, noting where the first turn is completed. The first bend shall be initiated at least 25.4 mm (1 in) away from the end of the specimen. Bending of the specimen around the mandrel shall be initiated at an angle to the mandrel, such that overlap of the specimen is maximized, the specimen is intimately wrapped onto the mandrel and previous wrap of specimen, and the number of completely closed turns can be easily counted.

Exception: Due to specimen thickness or material rigidity, six turns may be required to establish five completely closed turns; in this case, note where the first turn is initiated and completed.

45.13.4.8 Release the completely closed turns of the specimen, without altering the resulting configuration or condition of the specimen due to the bending around the rigid mandrel.

45.13.4.9 Examine the specimen using normal or corrected 20/20 vision, and record any presence of any wrinkles, cracks, blisters, or loose conductors, or any delamination, wrinkles, cracks, blisters, or loose film, adhesive, base material, bond ply, cover material, or other dielectric material.

45.13.4.10 Slowly and carefully flatten the specimen by hand, being careful not to crease or fold the specimen, and allow the specimen to relax.

45.13.4.11 Examine the specimen using normal or corrected 20/20 vision, and record any presence of any wrinkles, cracks, blisters, or loose conductors, or any delamination, wrinkles, cracks, blisters, or loose base material, film, adhesive, bond ply, cover material, or other dielectric material.

45.13.4.12 Compliance is checked by inspection. There shall be no presence of any wrinkling, cracking, blistering, or loosening of any conductor, or any delamination, wrinkling, cracking, blistering, or loosening of any cover material, film, adhesive, base material, dielectric material, or other dielectric material as a result of the pre-conditioning, thermal shock, oven conditioning, or cooling.

45.14 Cold-bend test

45.14.1 General

45.14.1.1 The purpose of this test method is to assess the bend-ability and physical fatigue of the membrane switch intended for flexible and flex-to-install applications following exposure to low temperature conditioning.

45.14.2 Test specimens

45.14.2.1 Ten specimens shall include all material components in accordance with construction materials for the desired membrane switch construction:

a) Five specimens shall represent a minimum build-up construction and

b) Five specimens shall represent a maximum build-up construction.

45.14.2.2 The test specimen conductor pattern is shown in Figure 45.2. Same as ambient bend.

45.14.3 Apparatus

45.14.3.1 A cold conditioning chamber capable of maintaining the specified conditioning temperature of minus 20 ±2.0°C (minus 4.0 ±3.6°F) for a minimum of one hour shall be used for this test.

45.14.3.2 A 6.35-mm (0.25-in) diameter rigid mandrel hour shall be used for this test.

45.14.4 Procedure

45.14.4.1 Measure the overall construction build-up thickness of each specimen in three separate areas, where no conductor material resides on the internal or external surfaces.

45.14.4.2 Measure and verify the 12.7-mm (0.5-in) conductor width on the specimens.

45.14.4.3 Subject the specimens to minus 20 ±2.0°C (minus 4.0 ±3.6°F) for a minimum of 1 h.

45.14.4.4 Bend a specimen around a 6.35-mm (0.25-in) diameter rigid mandrel for five completely closed turns, noting where the first turn is completed. The first bend shall be initiated at least 25.4 mm (1 in) away from the end of the specimen. Bending of the specimen around the mandrel shall be initiated at an angle to the mandrel, such that overlap of the specimen is maximized, the specimen is intimately wrapped onto the mandrel and previous wrap of specimen, and the number of completely closed turns can be easily counted.

Exception: Due to specimen thickness or material rigidity, six turns may be required to establish five completely closed turns; in this case, note where the first turn is initiated and completed.

45.14.4.5 Release the completely closed turns of the specimen, without altering the resulting configuration or condition of the specimen due to the bending around the rigid mandrel.

45.14.4.6 Examine the specimen using normal or corrected 20/20 vision, and record any presence of any wrinkles, cracks, blisters, or loose conductors, or any delamination, wrinkles, cracks, blisters, or loose film, adhesive, base material, bond ply, cover material, or other dielectric material.

45.14.4.7 Slowly and carefully flatten the specimen by hand, being careful not to crease or fold the specimen, and allow the specimen to relax.

45.14.4.8 Examine the specimen using normal or corrected 20/20 vision, and record any presence of any wrinkles, cracks, blisters, or loose conductors, or any delamination, wrinkles, cracks, blisters, or loose base material, film, adhesive, bond ply, cover material, or other dielectric material.

45.14.4.9 Compliance is checked by inspection. There shall be no presence of any wrinkling, cracking, blistering, or loosening of any conductor, or any delamination, wrinkling, cracking, blistering, or loosening of any cover material, film, adhesive, base material, dielectric material, or other dielectric material as a result of the cold conditioning.

45.14.4.10 Repeat the steps for the remaining specimens.

45.15 Repeated flexing test

45.15.1 General

45.15.1.1 The purpose of this test method is to assess the physical fatigue and conductor continuity of the membrane switch intended for flexible applications after exposure to limited flexing.

45.15.2 Test specimens

45.15.2.1 Ten specimens shall include all material components in accordance with construction materials for the desired membrane switch construction:

a) Two specimens shall represent a minimum build-up construction; and

b) Two specimens shall represent a maximum build-up construction.

45.15.2.2 The test specimen conductor pattern is shown in Figure 45.3 and Figure 45.4.