UL 1951

STANDARD FOR SAFETY

Electric Plumbing Accessories

UL Standard for Safety for Electric Plumbing Accessories, UL 1951

Second Edition, Dated July 22, 2011

SUMMARY OF TOPICS

This revision to ANSI/UL 1951 dated June 27, 2020 include the following changes:

Addition of reference to UL 61800-5-1 as a replacement to UL 508C; 5.5.4.1, 5.5.4.2

Addition of reference to UL 62368-1 as an alternative to UL 60950-1; 5.3.4, 5.3.5, 5.12.1, 5.12.2

Text that has been changed in any manner or impacted by UL's electronic publishing system is marked with a vertical line in the margin.

The revised requirements are substantially in accordance with Proposal(s) on this subject dated April 10, 2020.

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UL 1951

Standard for Electric Plumbing Accessories

First Edition – April, 1994

Second Edition

July 22, 2011

This ANSI/UL Standard for Safety consists of the Second Edition including revisions through June 27, 2020.

The most recent designation of ANSI/UL 1951 as an American National Standard (ANSI) occurred on June 11, 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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PART 1 – ALL EQUIPMENT

INTRODUCTION

1 Scope

1.1 These requirements cover equipment connected to or used with plumbing in commercial or household locations. Examples of equipment covered by these requirements are irrigation equipment, sprinkler controls, pedicure spas, water controls located in kitchens and bathrooms, electric faucets, toilets and toilet flushing systems. All equipment is intended for installation and use in accordance with the National Electrical Code, NFPA 70, and is rated 600 volts or less.

1.2 These requirements do not cover pumps, dishwashers, washing machines, or other equipment connected to plumbing that is covered by individual requirements.

1.3 These requirements do not cover refrigeration systems or controls that regulate water temperature, or equipment for use in hazardous locations as defined in the National Electrical Code, NFPA 70.

2 Units of Measurement

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

2.2 Unless indicated otherwise, all voltage and current values are rms and wattage values are average power.

3 Undated References

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

4 Glossary

4.1 For the purpose of this standard the following definitions apply.

4.2 FIELD-WIRING TERMINAL – A terminal to which power supply (including equipment grounding) or control connection will be made in the field when the product is installed as intended. If the wire, to be connected to the terminal, is provided as part of the unit and a pressure terminal, connector, soldering lug, soldered loop, crimped eyelet, or other means for making the connection is factory-assembled to the wire, it is not a field wiring terminal.

4.2.1 CAPACITOR, CLASS X – Capacitor or RC unit of a type suitable for use in situations where failure of the capacitor or RC unit would not lead to danger of electrical shock but could result in a risk of fire. Examples would be units connected phase to phase or phase to neutral.

4.2.2 CAPACITOR, CLASS Y – Capacitor or RC unit of a type suitable for use in situations where failure of the capacitor could lead to danger of electric shock. Examples would be capacitors connected across the primary and secondary circuits where electrical isolation is required to prevent an electric shock or between hazardous live parts and accessible parts.

4.3 CONTROLS, AUTOMATIC ACTION – A device in which the transmission and operation of at least one function are produced by initiation which is not the result of manual actuation.

4.4 CONTROL, AUXILIARY – A device that provides a functional utility but is not relied on as an operational or protective control. The failure of an auxiliary control generally does not cause the operation of a protective control. An example of an auxiliary control is a safety related control where other controls are being relied upon during testing for the safety function. The auxiliary control might more likely function in actual use but for test purposes, it is bypassed.

4.5 CONTROL, MANUAL – A device that requires direct human interaction to activate or test the control.

4.6 CONTROL, OPERATING – A device that starts or regulates the operation of an appliance during normal operation. The failure of an operational control generally causes the operation of a protective control. An example of an operating control is a temperature regulating control – a control that maintains the temperature of water to a user-determined level.

4.7 CONTROL, PROTECTIVE – A device or assembly of devices, the operation of which is intended to reduce the risk of fire, electric shock, or injury to persons during normal and reasonably anticipated abnormal operation of the appliance whereby during the evaluation of the protective control/circuit, the protective functions are verified under normal and single-fault conditions of the control. For example, a thermal cutout/limiter, or any other control/circuit relied upon for normal and abnormal conditions, is considered a protective control.

4.8 CONTROL, TYPE 2 ACTION – The actuation of an automatic control of 2.1.1 for which the manufacturing deviation and the drift of its operating value, operating time, or operating sequence have been declared and tested under this end product standard.

4.9 CONTROL, TYPE (2) D.H ACTION – This action is applicable to manual controls (described in 2.1.4 above). A Type D.H action shall be so designed that the contacts cannot be prevented from opening and which may automatically reset to the closed position if the reset means is held in the reset position. The control shall not reset automatically at any temperature above -35 °C with the reset mechanism in the normal position.

4.10 CONTROL, TYPE (2) D.J ACTION – This action is applicable to manual controls (described in 4.6 above). A Type D.J action shall be so designed that the contacts cannot be prevented from opening, and the control is not permitted to function as an automatic reset device if the reset means is held in the reset position. The control shall not reset automatically at any temperature above -35 °C.

4.10.1 DANGEROUS MALFUNCTION – Unintended operation of the appliance that may impair safety. Operating Control functions whose failure would result in a Dangerous Malfunction would be considered Safety Critical Functions.

Note – Control functions whose failure might result in a Dangerous Malfunction would include:

a) Unexpected operation of the appliance where the operation would result in risk of electric shock, fire or mechanical hazard.

b) Unattended energization of a heating appliance where the user has placed flammable materials near the appliance based on the assumption the appliance would remain off.

4.11 LINE-VOLTAGE CIRCUIT – A circuit involving a potential of not more than 600 volts and having circuit characteristics in excess of those of a low-voltage circuit.

4.12 LOW-VOLTAGE CIRCUIT – A circuit involving a peak open-circuit potential of not more than 42.4 volts supplied by a battery, by a Class 2 transformer, or by a combination of a transformer and a fixed impedance that as a unit, complies with all performance requirements for a Class 2 transformer. A circuit derived from a line-voltage circuit by connecting a resistance in series with the supply circuit as a means of limiting the voltage and current is not a low-voltage circuit.

4.13 OPPOSITE POLARITY – A difference of potential between two points, where shorting of these two points would result in a condition involving overload, rupturing of printed wiring-board tracks, components or fuses, and the like.

4.13.1 PEDICURE SPA – An appliance intended for water immersion of feet, usually (but not necessarily) associated with professional pedicure services. A pedicure spa usually has a water circulation/foot massage function and a water heater, and may additionally have heat and massage functions in an integral chair. A pedicure spa may be portable, stationary or be intended to be permanently fixed in place.

4.14 PRIMARY CIRCUITS – The wiring and components that are conductively connected to the supply circuit.

4.14.1 RISK OF ELECTRIC SHOCK – A risk of electric shock is considered to exist within a circuit unless the circuit meets one of the following criteria. The circuit shall be supplied by an isolating source such that:

a) The voltage does not exceed 30 V rms;

b) The voltage does not exceed 42.4 V peak;

c) The voltage does not exceed 60 V dc continuous; or

d) The voltage does not exceed 24.8 V peak for DC interrupted at a rate of 200 Hz or less with approximately 50 percent duty cycle.

e) When protective impedance is used, the current available through a 1500 ohm resistor between the part or parts and either pole of the supply source does not exceed 0.7 mA peak or 2 mA DC;

1) For frequencies exceeding 1 kHz, the limit of 0.7 mA (peak value) is multiplied by the value of the frequency in kHz but shall not exceed 70 mA peak;

2) For voltages over 42.4 V peak and up to and including 450 V (peak value) the capacitance shall not exceed 0.1 µF.

4.15 SAFETY CIRCUIT – A primary or secondary circuit that contains a control relied upon to reduce a risk of fire, electric shock, or injury to persons.

4.15.1 SAFETY CRITICAL FUNCTION (SCF) – Control, protection and monitoring functions which are being relied upon to reduce the risk of fire, electric shock or casualty hazards.

4.16 SECONDARY CIRCUIT – A circuit supplied from a secondary winding of an isolation transformer.

4.17 USER SERVICING – Any form of servicing that can be performed by personnel other than those who are trained to maintain the particular equipment is considered user servicing. Some examples of user servicing are:

a) Attaching accessories by means of attachment plugs and receptacles or by means of other separable connectors.

b) Replacing lamps and fuses and resetting circuit breakers located in an operator-access area unless the lamps, fuses, or circuit breakers are marked to indicate replacement or resetting only by qualified service personnel.

c) Making routine operating adjustments necessary to adapt the unit for its different intended functions.

d) Any operation described or implied in the operator's manual, whether or not tools are required.

4.18 VOLTAGE FOLDBACK – A circuit design feature intended to protect the power supply output transistors. When overcurrent is drawn by the load, the supply reduces the output voltage and current to within the safe power dissipation limit of the output transistors.

4.19 WORKING VOLTAGE – The highest voltage to which the insulation or the component under consideration is, or can be, subjected when the equipment is operating under conditions of normal use. Overvoltages that originate outside the equipment are not taken into account.

CONSTRUCTION

5 Components

5.1 General

5.1.1 A component of a product covered by this standard shall:

a) Comply with the requirements for that component as indicated in 5.2 – 5.21;

b) Be used in accordance with its rating(s) established for the intended conditions of use;

c) Be used within its established use limitations or conditions of acceptability; and

d) Additionally comply with the applicable requirements of this end product standard.

Exception No. 1: A component of a product covered by this end product standard is not required to comply with a specific component requirement that:

a) Involves a feature or characteristic not required in the application of the component in the product;

b) Is superseded by a requirement in this end product standard; or

c) Is separately investigated when forming part of another component, provided the component is used within its established ratings and limitations.

Exception No. 2: A component complying with a UL component standard other than those cited in 5.2 – 5.21 is acceptable if:

a) The component also complies with the applicable component standard of 5.2 – 5.21; or

b) The component standard:

1) Is compatible with the ampacity and overcurrent protection requirements National Electrical Code, ANSI/NFPA 70, where appropriate;

2) Considers long-term thermal properties of polymeric insulating materials in accordance with the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B; and

3) Any use limitations of the other component UL standard is identified and appropriately accommodated in the end use application. For example, a component used in a household application, but intended for industrial use and complying with the relevant component standard may assume user expertise not common in household applications.

5.1.2 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.

5.1.3 A component that is also intended to perform other functions, such as overcurrent protection, ground-fault circuit-interruption, surge suppression, any other similar functions, or any combination thereof, shall comply additionally with the requirements of the applicable UL standard(s) that cover devices that provide those functions.

Exception: Where these other functions are not required for the application and not identified as part of markings, instructions, or packaging for the appliance, the additional component UL standard(s) need not be applied.

5.1.4 A component not anticipated by the requirements of this end product standard, not specifically covered by the component standards of 5.2 – 5.21, and that involves a potential risk of electric shock, fire, or personal injury, shall be additionally investigated in accordance with the applicable UL standard, and shall comply with 5.1.1 (b) – (d).

5.1.5 With regard to a component being additionally investigated, reference to construction and performance requirements in another UL end product standard is appropriate where that standard anticipates normal and abnormal use conditions consistent with the application of this end product standard.

5.2 Attachment plugs and receptacles

5.2.1 Attachment plugs and receptacles shall comply with the Standard for Attachment Plugs and Receptacles, UL 498.

Exception No. 1: Attachment plugs integral to cord sets or power supply cords are covered under the requirements of the Standard for Cord Sets and Power-Supply Cords, UL 817 and are not required to comply with UL 498.

Exception No. 2: A fabricated pin terminal assembly (ies) is not required to comply with UL 498 if it complies with requirements in Current-Carrying Parts, Section 13, Insulating Material, Section 14, and Spacings, Section 25 of this end product standard.

5.2.2 Single and multipole connectors for use in data, signal, control and power applications within and between electrical equipment, and that are intended for factory assembly to copper or copper alloy conductors, or for factory assembly to printed wiring boards, shall comply with the Standard for Component Connectors for Data, Signal, Control and Power Applications, UL 1977.

5.2.3 Female devices (such as receptacles and connectors) that are intended, or that may be used, to interrupt current in the end product, shall be suitably rated for current interruption of the specific type of load, when evaluated with its mating plug or connector.

5.3 Batteries and battery chargers

5.3.1 A lithium ion (Li-On) single cell battery shall comply with the requirements for secondary lithium cells in the Standard for Lithium Batteries, UL 1642. A lithium ion muiltiple cell battery, and a lithium ion battery pack, shall comply with the applicable requirements for secondary lithium cells or battery packs in the Standard for Household and Commercial Batteries, UL 2054. The unit shall also be marked in accordance with 58.6.

5.3.2 Rechargeable nickel metal-hydride (Ni-MH) battery cells and packs shall comply with construction and performance requirements of this end product standard, or the applicable requirements for secondary cells or battery packs in the Standard for Household and Commercial Batteries, UL 2054.

5.3.3 Primary batteries (non-rechargeable) that comply with the relevant UL standard and 5.1 are considered to comply with the requirements of this end product standard.

5.3.4 A Class 2 battery charger shall comply with one of the following:

a) The Standard for Class 2 Power Units, UL 1310;

b) The Standard for Information Technology Equipment, Part 1: General Requirements, UL 60950-1, with an output marked "Class 2", or that complies with the limited power source (LPS) requirements and is marked "LPS"; or

c) The Standard for Audio/Video, Information and Communication Technology Equipment – Part 1: Safety Requirements, UL 62368-1, marked “Class 2” that complies with the limited power source (LPS) requirements and is marked "LPS".

5.3.5 A non-Class 2 battery charger shall comply with one of the following:

a) The Standard for Power Units Other Than Class 2, UL 1012;

b) The Standard for Information Technology Equipment, Part 1: General Requirements, UL 60950-1; or

c) The Standard for Audio/Video, Information and Communication Technology Equipment – Part 1: Safety Requirements, UL 62368-1.

5.3A Button or coin cell batteries of lithium technologies

Section 5.3A deleted

5.4 Capacitors and filters

5.4.1 The component requirements for a capacitor are not specified. A capacitor complying with the Standard for Capacitors, UL 810, is considered to comply with the requirements of 21.1.

5.4.2 Electromagnetic interference filters with integral enclosures that comply with the Standard for Electromagnetic Interference Filters, UL 1283, are considered to comply with the requirements of 21.1.

5.4.3 A capacitor connected across the line or between line and ground (such as a capacitor for radio-interference elimination) shall be suitable for the voltage involved and comply with the Standard for Fixed Capacitors for Use in Electronic Equipment – Part 14: Sectional Specification: Fixed Capacitors for Electromagnetic Interference Suppression and Connection to the Supply Mains, UL 60384-14. They shall be rated for the intended application, including operating voltage, subclass, Upper and Lower Temperature rating. The duration of the damp-heat test shall be 21 days for indoor use appliances and 56 days for appliances permanently installed outdoors.

5.4.3.1 X1 capacitors are generally used in circuits of permanently connected appliances. However, if the appliance is provided with a separate surge protective device that limits the impulse voltage to ≤ 2.5KV, an X2 capacitor is permitted.

5.4.3.2 Y1 capacitors are used in circuits where the prevention of electric shock is afforded solely by the isolation provided by the capacitor. Two Y2 capacitors connected in series is considered to provide the same level of protection as one Y1 capacitor.

5.4.3.3 Y2 capacitors are used where the prevention of electric shock is provided by the combination of the capacitor and earth ground for circuits operating at voltages ≥ 150V and ≤ 300V.

5.4.3.4 Y4 capacitors are used where the prevention of electric shock is provided by the combination of the capacitor and earth ground for circuits operating at voltages ≤ 150V.

5.5 Controls

5.5.1 General

5.5.1.1 Auxiliary controls shall be evaluated using the applicable requirements of this end product standard and the parameters in Controls – End Product Test Parameters, Section 23.

5.5.1.2 Operating (regulating) controls shall be evaluated using the applicable component standard requirements specified in 5.5.2 – 5.5.7, and if applicable, the test parameters in Controls – End Product Test Parameters, Section 23, unless otherwise specified in this end product standard.

5.5.1.3 Protective (limiting) controls shall be evaluated using the applicable component standard requirements specified in 5.5.2 – 5.5.7, and if applicable, the test parameters in Controls – End Product Test Parameters, Section 23, unless otherwise specified in this end product standard.

5.5.1.4 Solid-state protective controls shall comply with one of the following:

a) The Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991;

b) The Standard for Automatic Electrical Controls for Household and Similar Use, Part 1: General Requirements UL 60730-1, except Clause H 11.12 (Controls using software).

5.5.1.5 An electronic, non-protective control that is simple in design need only be subjected to the applicable requirements of this end-product standard. A control that does not include an integrated circuit or microprocessor, but does consist of a discrete switching device, capacitors, transistors, and resistors, is considered simple in design. Such controls shall comply with the Abnormal Operation Test, Section 53.

5.5.2 Controls, electromechanical and electronic

5.5.2.1 A control, other than as specified in 5.5.3 – 5.5.7, shall comply with one of the following:

a) The Standard for Solid-State Controls for Appliances, UL 244A;

b) The Standard for Temperature-Indicating and -Regulating Equipment, UL 873;

c) The Standard for Automatic Electrical Controls for Household and Similar Use; Part 1: General Requirements, UL 60730-1.

5.5.3 Controls, liquid level

5.5.3.1 A liquid level control shall comply with one of the following:

a) The Standard for Solid-State Controls for Appliances, UL 244A;

b) The Standard for Temperature-Indicating and -Regulating Equipment, UL 873;

c) The Standard for Industrial Control Equipment, UL 508;

d) The Standard for Automatic Electrical Controls for Household and Similar Use; Part 1: General Requirements, UL 60730-1; and one of the following:

1) The Standard for Automatic Electrical Controls for Household and Similar Use; Part 2: Particular Requirements for Automatic Electrical Water Level Controls of the Float Type for Household and Similar Applications, UL 60730-2-16A;

2) The Standard for Automatic Electrical Controls for Household and Similar Use; Part 2: Particular Requirements for Automatic Electrical Water and Air Flow Sensing Controls, Including Mechanical Requirements, UL 60730-2-18.

5.5.4 Controls, motor and speed

5.5.4.1 A control used to start, stop, regulate or control the speed of a motor shall comply with one of the following:

a) The Standard for Solid-State Controls for Appliances, UL 244A;

b) The Standard for Temperature-Indicating and -Regulating Equipment, UL 873;

c) The Standard for Industrial Control Equipment, UL 508;

d) The Standard for Adjustable Speed Electrical Power Drive Systems – Part 5-1: Safety Requirements – Electrical, Thermal, and Energy, UL 61800-5-1;

e) The Standard for Automatic Electrical Controls for Household and Similar Use; Part 1: General Requirements, UL 60730-1.

5.5.4.2 A motor speed control evaluated to the Standard for Adjustable Speed Electrical Power Drive Systems – Part 5-1: Safety Requirements – Electrical, Thermal, and Energy, UL 61800-5-1 shall not be utilized to provide motor overload protection specified in 19.2 – 19.3 unless the electronic protection features have additionally been determined to comply with Standard for Electronically Protected Motors, UL 1004-7.

5.5.5 Controls, pressure

5.5.5.1 A pressure control shall comply with one of the following:

a) The Standard for Temperature-Indicating and -Regulating Equipment, UL 873;

b) The Standard for Industrial Control Equipment, UL 508, if an operating control;

c) The Standard for Limit Controls, UL 353, if a protective control;

d) The Standard for Automatic Electrical Controls for Household and Similar Use; Part 1: General Requirements, UL 60730-1; and the Standard for Automatic Electrical Controls for Household and Similar Use; Part 2: Particular Requirements for Automatic Electrical Pressure Sensing Controls Including Mechanical Requirements, UL 60730-2-6.

5.5.6 Controls, temperature

5.5.6.1 A temperature control shall comply with one of the following:

a) The Standard for Solid-State Controls for Appliances, UL 244A;

b) The Standard for Temperature-Indicating and -Regulating Equipment, UL 873;

c) The Standard for Industrial Control Equipment, UL 508;

d) The Standard for Automatic Electrical Controls for Household and Similar Use; Part 1: General Requirements, UL 60730-1; and the Standard for Automatic Electrical Controls for Household and Similar Use; Part 2: Particular Requirements for Temperature Sensing Controls, UL 60730-2-9.

5.5.6.2 A temperature sensing positive temperature coefficient (PTC) or negative temperature coefficient (NTC) thermistor, that performs the same function as an operating or protective control shall comply with the Standard for Thermistor-Type Devices, UL 1434.

5.5.6.3 A thermal cutoff shall comply with the Standard for Thermal-Links – Requirements and Application Guide, UL 60691.

5.5.7 Controls, timer

5.5.7.1 A timer control shall comply with one of the following:

a) The Standard for Solid-State Controls for Appliances, UL 244A;

b) The Standard for Automatic Electrical Controls for Household and Similar Use; Part 1: General Requirements, UL 60730-1; and the Standard for Automatic Electrical Controls for Household and Similar Use; Part 2: Particular Requirements for Timers and Time Switches, UL 60730-2-7.

5.6 Cords, cables, and internal wiring

5.6.1 A cord set or power supply cord shall comply with the Standard for Cord Sets and Power Supply Cords, UL 817.

5.6.2 Flexible cords and cables shall comply with the Standard for Flexible Cords and Cables, UL 62. Flexible cord and cables are considered to comply with this requirement when pre-assembled in a cord set or power supply cord that complies with the Standard for Cord Sets and Power Supply Cords, UL 817.

5.6.3 Internal wiring composed of insulated conductors shall comply with the Standard for Appliance Wiring Material, UL 758.

Exception No. 1: Insulated conductors are not required to comply with UL 758 if they comply with one of the following:

a) The Standard for Thermoset-Insulated Wires and Cables, UL 44;

b) The Standard for Thermoplastic-Insulated Wires and Cables, UL 83;

c) The Standard for Fixture Wire, UL 66;

d) The appropriate UL standard(s) for other insulated conductor types specified in Wiring Methods and Materials, Chapter 3 of the National Electrical Code, ANSI/NFPA 70.

Exception No. 2: Insulated conductors for specialty applications (e.g. data processing or communications) and located in a low-voltage circuit not involving the risk of fire or personal injury is not required to comply with UL 758.

5.7 Ground-fault, arc-fault, and leakage current detectors/interrupters

5.7.1 Ground-fault circuit-interrupters (GFCI) for protection against electrical shock shall comply with the Standard for Ground-Fault Circuit-Interrupters, UL 943. The following statement, or equivalent, shall be included as a marking near the GFCI, or as an instruction in the manual: "Press the TEST button (then RESET button) every month to assure proper operation."

5.7.2 Appliance-leakage-current interrupters (ALCI) for protection against electrical shock shall comply with the Standard for Appliance-Leakage-Current Interrupters, UL 943B.

5.7.3 Arc-fault circuit-interrupters (AFCI) shall comply with the Standard for Arc-Fault Circuit-Interrupters, UL 1699.

5.8 Heaters, heating elements and pads

5.8.1 Electric resistance heating elements shall comply with the construction requirements in one of the following:

a) The Standard for Electric Heating Appliances, UL 499;

b) The Standard for Sheathed Heating Elements, UL 1030.

Exception: Heating wire (e.g. rope heater) that complies with the Standard for Appliance Wiring Material, UL 758, and the requirements of this end product standard comply with this requirement.

5.8.2 Thermistor-type heaters (e. g. PTC and NTC heaters) shall comply with the Standard for Thermistor-Type Devices, UL 1434.

5.9 Insulation systems

5.9.1 Materials used in a Class 105 (A) insulation system shall comply with Insulating Material, Section 14.

5.9.2 Materials used in an insulation system that operates above Class 105 (A) temperatures shall comply with the Standard for Systems of Insulating Materials – General, UL 1446.

5.10 Light sources and associated components

5.10.1 Lampholders and indicating lamps shall comply with the Standard for Lampholders, UL 496.

Exception: Lampholders forming part of a luminaire that complies with an appropriate UL luminaire standard are considered to fulfill this requirement.

5.10.2 Lighting ballasts shall comply with one of the following:

a) The Standard for Fluorescent-Lamp Ballasts, UL 935;

b) The Standard for High-Intensity Discharge Lamp Ballasts, UL 1029.

Exception No. 1: Ballasts forming part of a luminaire that complies with an appropriate UL luminaire standard are considered to fulfill this requirement.

Exception No. 2: Ballasts for other light sources shall comply with the appropriate UL standard(s).

5.10.3 Light emitting diode (LED) light sources shall comply with the Standard for Light Emitting Diode (LED) Light Sources For Use In Lighting Products, UL 8750.

Exception No. 1: LED light sources forming part of a luminaire that complies with an appropriate UL luminaire standard are considered to fulfill this requirement.

Exception No. 2: Individual LED light sources mounted on printed wiring boards and intended for indicating purposes need not comply with UL 8750, but shall comply with the applicable requirements of this end product standard.

5.11 Overcurrent protection

5.11.1 Fuses shall comply with the Standard for Low-Voltage Fuses – Part 1: General Requirements, UL 248-1; and the applicable UL 248 Part 2 (e. g. the Standard for Low-Voltage Fuses – Part 5: Class G Fuses, UL 248-5). Defined use fuses that comply with UL 248-1 and another appropriate UL standard for the fuse are considered to fulfill this requirement.

5.11.2 Fuseholders shall comply with The Standard for Fuseholders – Part 1: General Requirements, UL 4248-1, and the applicable Part 2 (e.g. the Standard for Fuseholders – Part 9: Class K, UL 4248-9).

5.11.3 Circuit breakers shall comply with the Standard for Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures, UL 489.

Exception: Circuit breakers used in telecommunications circuitry that comply with the Standard for Circuit Breakers For Use in Communications Equipment, UL 489A, is not required to comply with UL 489.

5.11.4 Circuit breakers having integral ground fault circuit interrupter capability for protection against electrical shock shall additionally comply with the Standard for Ground-Fault Circuit-Interrupters, UL 943.

5.11.5 Supplementary protectors shall comply with the Standard for Supplementary Protectors for Use in Electrical Equipment, UL 1077.

5.12 Power supplies

5.12.1 A Class 2 power supply shall comply with one of the following:

a) The Standard for Class 2 Power Units, UL 1310;

b) The Standard for Information Technology Equipment, Part 1: General Requirements, UL 60950-1, with an output marked "Class 2", or that complies with the limited power source (LPS) requirements and is marked "LPS"; or

c) The Standard for Audio/Video, Information and Communication Technology Equipment – Part 1: Safety Requirements, UL 62368-1, marked “Class 2” that complies with the limited power source (LPS) requirements and is marked "LPS".

5.12.2 A non-Class 2 power supply shall comply with one of the following:

a) The Standard for Power Units Other Than Class 2, UL 1012;

b) The Standard for Information Technology Equipment, Part 1: General Requirements, UL 60950-1; or

c) The Standard for Audio/Video, Information and Communication Technology Equipment – Part 1: Safety Requirements, UL 62368-1.

5.13 Printed wiring boards

5.13.1 Printed wiring boards shall comply with the Standard for Printed-Wiring Boards, UL 796. A printed wiring board shall have a temperature rating corresponding to the maximum temperature on the board during the Temperature Test. Unless wholly in a Class 2 circuit, it shall comply with the direct support of live parts requirements in UL 796.

5.14 Quick-connect wire connectors

5.14.1 Quick-connect type wire connectors shall be suitable for the wire size, type (solid or stranded), conductor material (copper or aluminum) and the number of conductors terminated. If insulated, they shall be rated for the voltage and temperature of the intended use. They shall be applied per the installation instructions of the wire connector manufacturer.

5.14.2 Quick-connect type wire connectors shall comply with the Standard for Electrical Quick-Connect Terminals, UL 310.

5.15 Semiconductors and small electronic components

5.15.1 A power switching semiconductor device that is relied upon to provide isolation to ground shall comply with the Standard of Safety for Electrically Isolated Semiconductor Devices, UL 1557. It shall have been evaluated for a minimum 1500 volts isolation.

5.15.2 An optical isolator that is relied upon to provide isolation between primary and secondary circuits or between other circuits as required by this end product standard shall comply with the Standard for Safety for Optical Isolators, UL 1577. It shall have been evaluated for a minimum 1500 volts isolation.

5.15.3 Except as specified in 5.15.4, component requirements are not specified for small electronic components on printed wiring boards, including diodes, transistors, resistors, inductors, integrated circuits, and capacitors not directly connected to the supply source.

5.15.4 Where an electronic component is determined to be a critical component during the Abnormal Operation Test, Section 51, one of the following standards shall be applied. See 23.4 of this end product standard for the test parameters to be used.

a) The Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991, including its Follow-Up Program; and as applicable, the Standard for Software in Programmable Components, UL 1998 for controls that rely upon software as a protective component; or

b) The Standard for Automatic Electrical Controls for Household and Similar Use; Part 1: General Requirements, UL 60730-1.

5.15.5 A critical component is a component that performs one or more safety-related functions whose failure results in a condition, such as the risk of fire, electric shock, or injury to persons, in the end product application.

5.15.6 A critical component may also be identified using a failure-mode and effect analysis (FMEA) in accordance with Failure-Mode and Effect Analysis (FMEA) requirements in the Standard for Tests for Safety Related Controls Employing Solid-State Devices, UL 991.

5.16 Supplemental insulation, insulating bushings, and assembly aids

5.16.1 The requirements for supplemental insulation (e.g. tape, sleeving, or tubing) are not specified unless the insulation or device is required to comply with the requirements in Insulating Material, Section 14, or a performance requirement of this end product standard. In such cases:

a) Insulating tape shall comply with the Standard for Polyvinyl Chloride, Polyethylene, and Rubber Insulating Tape, UL 510;

b) Sleeving shall comply with the Standard for Coated Electrical Sleeving, UL 1441;

c) Tubing shall comply with the Standard for Extruded Insulating Tubing, UL 224.

5.16.2 Wire positioning devices shall comply with the requirements in Insulating Materials, Sections 14 and Separation of Circuits, Section 16. A device that complies with the Standard for Positioning Devices, UL 1565, is considered to fulfill this requirement.

5.16.3 Insulating bushings that comply with the requirements in General, Section 5.1 of this end product standard, and the Standard for Insulating Bushings, UL 635, are considered to fulfill the requirements of this end product standard. Tests specified in this end product standard (e.g. Strain Relief Test) may still need to be performed to confirm the combination of the insulating bushing and the supporting part are suitable.

5.17 Switches

5.17.1 Switches shall comply with one of the following, as applicable:

a) *Deleted*;

b) The Standard for Switches for Appliances – Part 1: General Requirements, UL 61058-1;

c) The Standard for General-Use Snap Switches, UL 20;

d) The Standard for Nonindustrial Photoelectric Switches for Lighting Control, UL 773A.

Exception: Switching devices that comply with the appropriate UL standard for specialty applications (e.g. transfer switch equipment), industrial use (e.g. contactors, relays, auxiliary devices), or are integral to another component (e.g. switched lampholder) is not required to comply with this requirement.

5.17.2 A clock-operated switch, in which the switching contacts are actuated by a clock-work, by a gear-train, by electrically-wound spring motors, by electric clock-type motors, or by equivalent arrangements shall comply with one of the following:

a) The Standard for Clock-Operated Switches, UL 917;

b) The Standard for Automatic Electrical Controls for Household and Similar Use; Part 1: General Requirements, UL 60730-1; and the Standard for Automatic Electrical Controls for Household and Similar Use; Part 2: Particular Requirements for Timers and Time Switches, UL 60730-2-7.

5.17.3 A timer or time switch, incorporating electronic timing circuits or switching circuits, with or without separable contacts, shall comply with the requirements for an operating control 6000 cycles of operation, or as a manual control for 1000 cycles of operation, in accordance with one of the following:

a) The Standard for Solid-State Controls for Appliances, UL 244A;

b) The Standard for Automatic Electrical Controls for Household and Similar Use; Part 1: General Requirements, UL 60730-1; and the Standard for Automatic Electrical Controls for Household and Similar Use; Part 2: Particular Requirements for Timers and Time Switches, UL 60730-2-7.

5.17.4 A timer or time switch, incorporating electronic timing circuits or switching circuits, with or without separable contacts, that functions as a protective control, shall comply with the requirements for a protective control; see 5.5.7.

5.17.5 Switches that comply with Standard for Switches for Appliances – Part 1: General Requirements, UL 61058-1, shall be rated as specified in 5.17.6 – 5.17.8.

5.17.6 Power switches shall be rated as follows:

a) For a voltage not less than the standard rated voltage of the circuit or power supply to which they are connected;

b) For a current not less than the rated current of the appliance;

c) For Continuous Duty;

d) With respect to load:

1) Switches for motor-operated appliances: for resistance and motor load if the switch would encounter this load in normal use; or

2) Switches may be regarded as switches for a declared specific load and may be classified based upon the load conditions encountered in the appliance under normal load.

e) For ac if the appliance is rated for ac;

f) For dc if the appliance is rated for dc.

5.17.7 Ratings and load classifications for switches other than power switches shall be based on the conditions encountered in the appliance under normal load.

5.17.8 Switches shall also be rated with respect to endurance as follows:

a) Power switches: 6000 cycles;

b) Power switches provided with series electronics shall be subject to an additional 1000 cycles of operation with the electronics bypassed;

c) Switches other than power switches, such as speed selector switches, that may be switched under electrical load: 1000 cycles;

d) The following non-power switches are not required to be rated for endurance:

1) Switches not intended for operation without electrical load, and which can be operated only with the aid of a tool or are interlocked so that they cannot be operated under electrical load; or

2) Switches for 20 mA load as classified in the Standard for Switches for Appliances – Part 1: General Requirements, UL 61058-1.

5.18 Terminal blocks

5.18.1 Terminal blocks shall comply with one of the following:

a) The Standard for Terminal Blocks, UL 1059;

b) The Standard for Low-Voltage Switchgear And Controlgear – Part 7-1: Ancillary Equipment – Terminal Blocks for Copper Conductors, UL 60947-7-1;

c) The Standard for Low-Voltage Switchgear And Controlgear – Part 7-2: Ancillary Equipment – Protective Conductor Terminal Blocks for Copper Conductors, UL 60947-7-2;

d) The Standard for Low-Voltage Switchgear And Controlgear – Part 7-3: Ancillary Equipment – Safety Requirements for Fuse Terminal Blocks, UL 60947-7-3.

5.18.2 The UL 60947-7 series of standards specified in 5.18.1 (b) – (d) are used in conjunction with the Standard for Low-Voltage Switchgear and Controlgear – Part 1: General Rules, UL 60947-1.

5.18.3 Terminal blocks shall be suitable for the number of conductors per termination, wire size, type (solid or stranded), conductor material (copper or aluminum), voltage and current of the intended use.

5.19 Transformers

5.19.1 General-purpose transformers shall comply with the Standard for Low Voltage Transformers: General Requirements, UL 5085-1; and the Standard for Low Voltage Transformers: General Purpose Transformers, UL 5085-2.

Exception: A transformer that complies with the Standard for Transformers and Motor Transformers for Use in Audio-, Radio-, and Television-Type Appliances, UL 1411, and that is used in a circuit involving an audio or video component, complies with the intent of this requirement.

5.19.2 Class 2 and Class 3 transformers shall comply with the Standard for Low Voltage Transformers: General Requirements, UL 5085-1; and the Standard for Low Voltage Transformers: Class 2 and Class 3 Transformers, UL 5085-3.

5.20 Valves (electrically operated) and solenoids

5.20.1 Electrically operated valves shall comply with one of the following:

a) The Standard for Electrically Operated Valves, UL 429;

b) The Standard for Automatic Electrical Controls for Household and Similar Use; Part 1: General Requirements, UL 60730-1; and the Standard for Automatic Electrical Controls for Household and Similar Use; Part 2: Particular Requirements for Electrically Operated Water Valves, Including Mechanical Requirements, UL 60730-2-8.

5.21 Wire connectors

5.21.1 Wire connectors shall be suitable for the wire size, type (solid or stranded), conductor material (copper or aluminum) and the number of conductors terminated. If insulated they shall be suitable for the voltage and current of the intended use. They shall be applied per the installation instructions of the wire connector manufacturer.

5.21.2 Wire connectors shall comply with the Standard for Wire Connectors, UL 486A-486B, or the Standard for Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors, UL 486E.

5.21.3 Splicing wire connectors shall comply with the Standard for Splicing Wire Connectors, UL 486C.

5.22 Thermistors

5.22.1 Thermistors shall comply with the Standard for Thermistor-Type Devices, UL 1434. The thermistors shall be suitable for the application at the specified electrical and thermal ratings.

5.22.2 A temperature sensing positive temperature coefficient (PTC) or a negative temperature coefficient (NTC) thermistor, that is part of a circuit that manages a Safety Critical Function shall comply with:

a) The Standard for Automatic Electrical Controls – Part 1: General Requirements, UL 60730-1; and the Standard for Automatic Electrical Controls for Household and Similar Use – Part 2-9: Particular Requirements for Temperature Sensing Controls, UL 60730-2-9, with Annex J; or

b) The Standard for Thermistor-Type Devices, UL 1434.

5A Safety Critical Functions

5A.1 Any function involved in the control, protection, and monitoring of safety-related attributes of a unit whereby a loss/malfunction of its functionality would represent an unacceptable risk of fire, electric shock, or casualty hazards would be considered a Safety Critical Function.

5A.2 Electronic circuits that manage a Safety Critical Function (SCF) shall be:

a) Reliable as defined as being able to maintain the SCF in the event of single defined component faults and

b) Not susceptible to electromagnetic environmental stresses encountered in the anticipated environments of the appliance.

5A.3 Functions specified in the table represent the common safety critical circuit functions of typical appliances under the scope of this standard. It is not intended to represent all possible Safety Critical Functions. Any function involved in the control, protection, and monitoring of safety-related attributes of a unit whereby a loss/malfunction of its functionality would represent an unacceptable risk of fire, electric shock, or casualty hazards would be considered a Safety Critical Function.

Table 5A.1
Safety Critical Functions

Function	Hazard	Location of parameters and tests
Motor running overload protection	Risk of fire or electric shock	19.2
Motor locked rotor protection	Risk of fire or electric shock	19.2
Motor short circuit protection	Risk of fire or electric shock	19.2

6 Frame and Enclosure

6.1 General

6.1.1 Equipment shall be formed and assembled so that it will have the strength and rigidity necessary to resist the abuses to which it may be subjected, without increasing the risk of fire, electric shock, or injury to persons due to total or partial collapse resulting in a reduction of spacings, loosening or displacement of parts, or other defects.

6.1.2 Equipment that complies with the requirements in 6.1.3 – 6.7.1 is considered to comply with 6.1.1.

6.1.3 The enclosure shall prevent molten metal, burning insulation, flaming particles, or the like from falling on combustible materials, including the surface upon which the equipment is supported.

6.2 Barriers

6.2.1 The requirement in 6.1.3 will necessitate that a switch, a relay, a transformer, a solenoid, or the like be individually and completely enclosed, except for terminals, unless it can be shown that malfunction of the component would not result in a risk of fire, or there are no openings in the bottom of the appliance enclosure.

6.2.2 A barrier of noncombustible material shall be provided:

a) Under a motor unless:

1) The structural parts of the motor or of the equipment provide the equivalent of such a barrier; or

2) The protection provided with the motor is such that no burning insulation or molten material falls to the surface that supports the equipment when the motor is energized under each of the following fault conditions:

i) Open main winding;

ii) Open starting winding;

iii) Starting switch short-circuited; and

iv) Capacitor of permanent-split capacitor motor short-circuited – the short circuit is to be applied before the motor is energized, and the motor is to be locked; or

3) The motor is provided with a thermal motor protector – a protective device that is sensitive to temperature and current – that will prevent the temperature of the motor windings from exceeding 125°C (257°F) under the maximum load under which the motor will run without causing the protector to cycle and from exceeding 150°C (302°F) with the rotor of the motor locked; or

4) The motor complies with the requirements in the Standard for Overheating Protection for Motors, UL 2111, the Standard for Impedance Protected Motors, UL 1004-2, the Standard for Thermally Protected Motors, UL 1004-3, or the Standard for Electrictronically Protected Motors, UL 1004-7 and the temperature of the motor winding will not exceed 150°C during the first 72 hours of operation with the rotor of the motor locked.

b) Under wiring, unless it is neoprene, cross-linked polyethylene, or thermoplastic insulated.

6.2.3 The barrier mentioned in 6.2.2 shall be horizontal, shall be located as illustrated in Figure 6.1, and shall not have an area less than that described in that illustration. Openings for drainage, ventilation, and the like may be employed in the barrier, provided such openings would not permit molten metal, burning insulation, or the like to fall on combustible material.

6.3 Doors and covers

6.3.1 An enclosure and a part of an enclosure such as a door or cover shall be provided with means for firmly securing it in place.

6.3.2 An enclosure cover shall be hinged if:

a) It gives access to a fuse or other overcurrent device, the functioning of which requires renewal; or

b) It is necessary to open the cover in order to reset a device in connection with normal operation of the product.

6.3.3 If a cover is required by 6.3.2 to be hinged, then the cover shall not depend solely upon screws or other similar means requiring the use of a tool to hold it closed, but shall be provided with a spring latch or catch, or a hand-operable captive fastener.

6.4 Cast metal

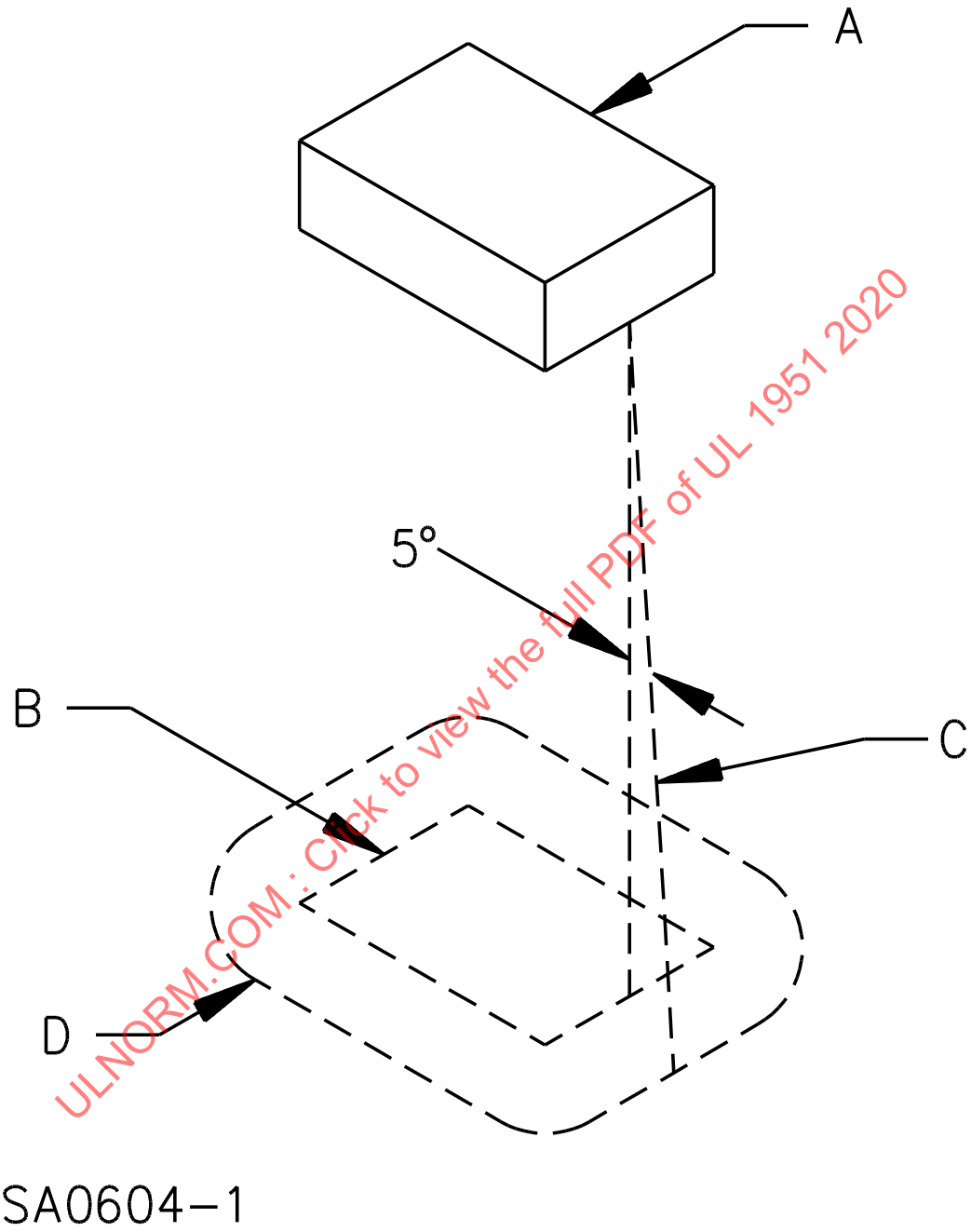
6.4.1 For unreinforced flat surfaces, in general, cast metal shall not be less than 1/8 inch (3.2 mm) thick, except that malleable iron may be not less than 3/32 inch (2.4 mm) and die-cast metal may be not less than 5/64 inch (2.0 mm) thick. Corresponding thicknesses of not less than 3/32 inch (2.4 mm), 1/16 inch (1.6 mm), and 3/64 inch (1.2 mm), respectively, may be acceptable if the surface under consideration is curved, ribbed, or otherwise reinforced, or if the shape or size, or both, of the surface is such that the necessary mechanical strength is provided.

6.5 Sheet metal

6.5.1 Other than at points where a wiring system is to be connected, the thickness of a sheet-metal enclosure shall not be less than that specified in Table 6.1 and Table 6.2.

Figure 6.1

Location and extent of barrier



A – Region to be shielded by barrier. This will consist of the entire component if it is not otherwise shielded, and will consist of the unshielded portion of a component that is partially shielded by the component enclosure or equivalent.

B – Projection of outline of component of horizontal plane.

C – Inclined line that traces out minimum area of barrier. When moving, the line is always tangent to the component, 5 degrees from the vertical, and so oriented that the area traced out on a horizontal plane is maximum.

D – Location (horizontal) and minimum area for barrier. The area is that included inside the line of intersection traced out by the inclined line C and the horizontal plane of the barrier.

Table 6.1
Minimum thickness of sheet metal for enclosures – carbon steel or stainless steel

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]				Minimum thickness			
Maximum width[b]		Maximum length[c]		Maximum width[b]		Maximum length,		Uncoated metal		Coated metal	
Inches	(cm)	Inches	(cm)	Inches	(cm)	Inches	(cm)	Inches	(cm)	Inches	(cm)
4.0	(10.2)	Not limited		6.25	(15.9)	Not limited		0.020[d]	(0.51)	0.023[d]	(0.58)
4.75	(12.1)	5.75	(14.6)	6.75	(17.1)	8.25	(21.0)				
6.0	(15.2)	Not limited		9.5	(24.1)	Not limited		0.026[d]	(0.66)	0.029[d]	(0.74)
7.0	(17.8)	8.75	(22.2)	10.0	(25.4)	12.5	(31.8)				
8.0	(20.3)	Not limited		12.0	(30.5)	Not limited		0.032	(0.81)	0.034	(0.86)
9.0	(22.9)	11.5	(29.2)	13.0	(33.0)	16.0	(40.6)				
12.5	(31.8)	Not limited		19.5	(49.5)	Not limited		0.042	(1.07)	0.045	(1.14)
14.0	(35.6)	18.0	(45.7)	21.0	(53.3)	25.0	(63.5)				
18.0	(45.7)	Not limited		27.0	(68.6)	Not limited		0.053	(1.35)	0.056	(1.42)
20.0	(50.8)	25.0	(63.5)	29.0	(73.7)	36.0	(91.4)				
22.0	(55.9)	Not limited		33.0	(83.8)	Not limited		0.060	(1.52)	0.063	(1.60)
25.0	(63.5)	31.0	(78.7)	35.0	(88.9)	43.0	(109.2)				
25.0	(63.5)	Not limited		39.0	(99.1)	Not limited		0.067	(1.70)	0.070	(1.78)
29.0	(73.7)	36.0	(91.4)	41.0	(104.1)	51.0	(129.5)				
33.0	(83.8)	Not limited		51.0	(129.5)	Not limited		0.080	(2.03)	0.084	(2.13)
38.0	(96.5)	47.0	(119.4)	54.0	(137.2)	66.0	(167.6)				
42.0	(106.7)	Not limited		64.0	(162.6)	Not limited		0.093	(2.36)	0.097	(2.46)
47.0	(119.4)	59.0	(149.9)	68.0	(172.7)	84.0	(213.4)				
52.0	(132.1)	Not limited		80.0	(203.2)	Not limited		0.108	(2.74)	0.111	(2.82)
60.0	(152.4)	74.0	(188.0)	84.0	(213.4)	103.0	(261.6)				
63.0	(160.0)	Not limited		97.0	(246.4)	Not limited		0.123	(3.12)	0.126	(3.20)
73.0	(185.4)	90.0	(228.6)	103.0	(261.6)	127.0	(322.6)				

[a] See 6.5.4.

[b] The width is the smaller dimension of a rectangular piece of sheet metal that is part of an enclosure. Adjacent surfaces of an enclosure may have common supports and be made of a single sheet.

[c] "Not limited" applies only if the edge of the surface is flanged at least 1/2 inch (12.7 mm) or fastened to adjacent surfaces not normally removed in use.

[d] Sheet steel for an enclosure intended for outdoor use shall not be less than 0.034 inch (0.86 mm) thick if zinc coated and not less than 0.032 inch (0.81 mm) thick if uncoated.

Table 6.2
Minimum acceptable thickness of sheet metal for enclosures – aluminum, copper, or brass

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]					
Maximum width[b]		Maximum length[c]		Maximum width[b]		Maximum length		Minimum thickness	
Inches	(cm)	Inches	(cm)	Inches	(cm)	Inches	(cm)	Inch	(mm)
3.0	(7.6)	Not limited		7.0	(17.8)	Not limited		0.023[d]	(0.58)
3.5	(8.9)	4.0	(10.2)	8.5	(21.6)	9.5	(24.1)		
4.0	(10.2)	Not limited		10.0	(25.4)	Not limited		0.029	(0.74)
5.0	(12.7)	6.0	(15.2)	10.5	(26.7)	13.5	(34.3)		
6.0	(15.2)	Not limited		14.0	(35.6)	Not limited		0.036	(0.91)
6.5	(16.5)	8.0	(20.3)	15.0	(38.1)	18.0	(45.7)		
8.0	(20.3)	Not limited		19.0	(48.3)	Not limited		0.045	(1.14)
9.5	(24.1)	11.5	(29.2)	21.0	(53.3)	25.0	(63.5)		
12.0	(30.5)	Not limited		28.0	(71.1)	Not limited		0.058	(1.47)
14.0	(35.6)	16.0	(40.6)	30.0	(76.2)	37.0	(94.0)		
18.0	(45.7)	Not limited		42.0	(106.7)	Not limited		0.075	(1.91)
20.0	(50.8)	25.0	(63.5)	45.0	(114.3)	55.0	(139.7)		
25.0	(63.5)	Not limited		60.0	(152.4)	Not limited		0.095	(2.41)
29.0	(73.7)	36.0	(91.4)	64.0	(162.6)	78.0	(198.1)		
37.0	(94.0)	Not limited		87.0	(221.0)	Not limited		0.122	(3.10)
42.0	(106.7)	53.0	(134.6)	93.0	(236.2)	114.0	(289.6)		
52.0	(132.1)	Not limited		123.0	(312.4)	Not limited		0.153	(3.89)
60.0	(152.4)	74.0	(188.0)	130.0	(330.2)	160.0	(406.4)		

[a] See 6.5.4.

[b] The width is the smaller dimension of a rectangular piece of sheet metal that is part of an enclosure. Adjacent surfaces of an enclosure may have common supports and be made of a single sheet.

[c] "Not limited" applies only if the edge of the surface is flanged at least 1/2 inch (12.7 mm) or fastened to adjacent surfaces not normally removed in use.

[d] Sheet copper, brass, or aluminum for an enclosure intended for outdoor use shall not be less than 0.029 inch (0.75 mm) thick.

6.5.2 At points at which a wiring system is to be connected, uncoated steel shall be at least 0.032 inch (0.81 mm) thick, zinc-coated steel shall be at least 0.034 inch (0.86 mm) thick, and nonferrous metal shall be at least 0.045 inch (1.14 mm) thick.

6.5.3 Table 6.1 and Table 6.2 are based on a uniform deflection of the enclosure surface for any given load concentrated at the center of the surface regardless of metal thickness.

6.5.4 With reference to Table 6.1 and Table 6.2, a supporting frame is a structure of angle or channel or a folded rigid section of sheet metal that is rigidly attached and has essentially the same outside dimensions as the enclosure surface and that has sufficient torsional rigidity to resist the bending moments that may be applied by the enclosure surface when it is deflected. A structure that is as rigid as one built with a frame of angles or channels is considered to have equivalent reinforcing. Constructions considered to be without supporting frame include:

a) Single sheet with single formed flanges – formed edges;

b) A single sheet that is corrugated or ribbed;

c) An enclosure surface loosely attached to a frame, for example, with spring clips; and

d) An enclosure surface having an unsupported edge.

6.6 Nonmetallic enclosures

6.6.1 General

6.6.1.1 Tests on nonmetallic enclosures shall be conducted in accordance with requirements for fixed or stationary equipment, as applicable in the Standard for Polymeric Materials– Use in Electrical Equipment Evaluations, UL 746C, and also with the additional requirement specified in this standard.

6.7 Outdoor-use enclosures

6.7.1 Equipment intended for outdoor use that is not intended to be submersible shall employ a construction that provides drainage.

6.8 Button or coin cell batteries of lithium technologies

6.8.1 The battery compartment of an appliance or any accessory, such as a wireless control, incorporating one or more coin cell batteries of lithium technologies shall comply with the Standard for Products Incorporating Button or Coin Cell Batteries of Lithium Technologies, UL 4200A, if the appliance or any accessory:

a) Is intended for use with one or more single cell batteries having a diameter of 32 mm (1.25 in) maximum with a diameter greater than its height; and

b) The appliance is intended for household use.

7 Mounting

7.1 Permanently connected units

7.1.1 Provision shall be made for securely mounting permanently connected equipment in position. Bolts, screws, or other parts used for assembling the equipment shall be independent of those used for securing component parts to the frame, base, or panel.

7.2 Cord-connected units

7.2.1 Cord-connected equipment shall not include means for permanent mounting. One or two keyhole slots for wall hanging may be provided if the hanging screws, nails, and the like, are not accessible for tightening, and if long nails, hooks, or screws for hanging will not be likely to touch internal wiring, components, or live parts, and will not result in spacing less than those required in Table 26.1.

8 Protection Against Corrosion

8.1 An iron or steel part shall be protected against corrosion by enameling, painting, galvanizing, plating, or an equivalent means, if corrosion of such a part would result in a risk of fire, electric shock, or injury to persons.

Exception No. 1: This requirement does not apply in certain instances where oxidation of iron or steel due to the exposure of the metal to air and moisture is not likely to be appreciable, thickness of metal and temperature also being factors.

Exception No. 2: This requirement does not apply to bearings, laminations, or other minor parts of iron or steel, such as a washer, a screw, and the like, or to spot welds in coated materials used indoors.

Exception No. 3: Stainless steel may be employed without additional corrosion resistance.

8.2 Cabinets and cutout boxes shall comply with the Standard for Enclosures for Electrical Equipment, UL 50.

9 Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts

9.1 To reduce the likelihood of unintentional contact that may involve a risk of electric shock from an uninsulated live part or film-coated wire or injury to persons from a moving part, an opening in an enclosure shall comply with either (a) or (b).

a) For an opening that has a minor dimension as described in 9.5 of less than 1 inch (25.4 mm), an uninsulated live part, a moving part, or film-coated wire shall not be contacted by the probe illustrated in Figure 9.1; or

b) For an opening that has a minor dimension as described in 9.5 of 1 inch or more, an uninsulated part, a moving part, or film-coated wire shall be spaced from the opening as specified in Table 9.1.

Exception: An opening in a motor need not comply with these requirements if it complies with the requirements in 9.2.

Figure 9.1

Accessibility probe

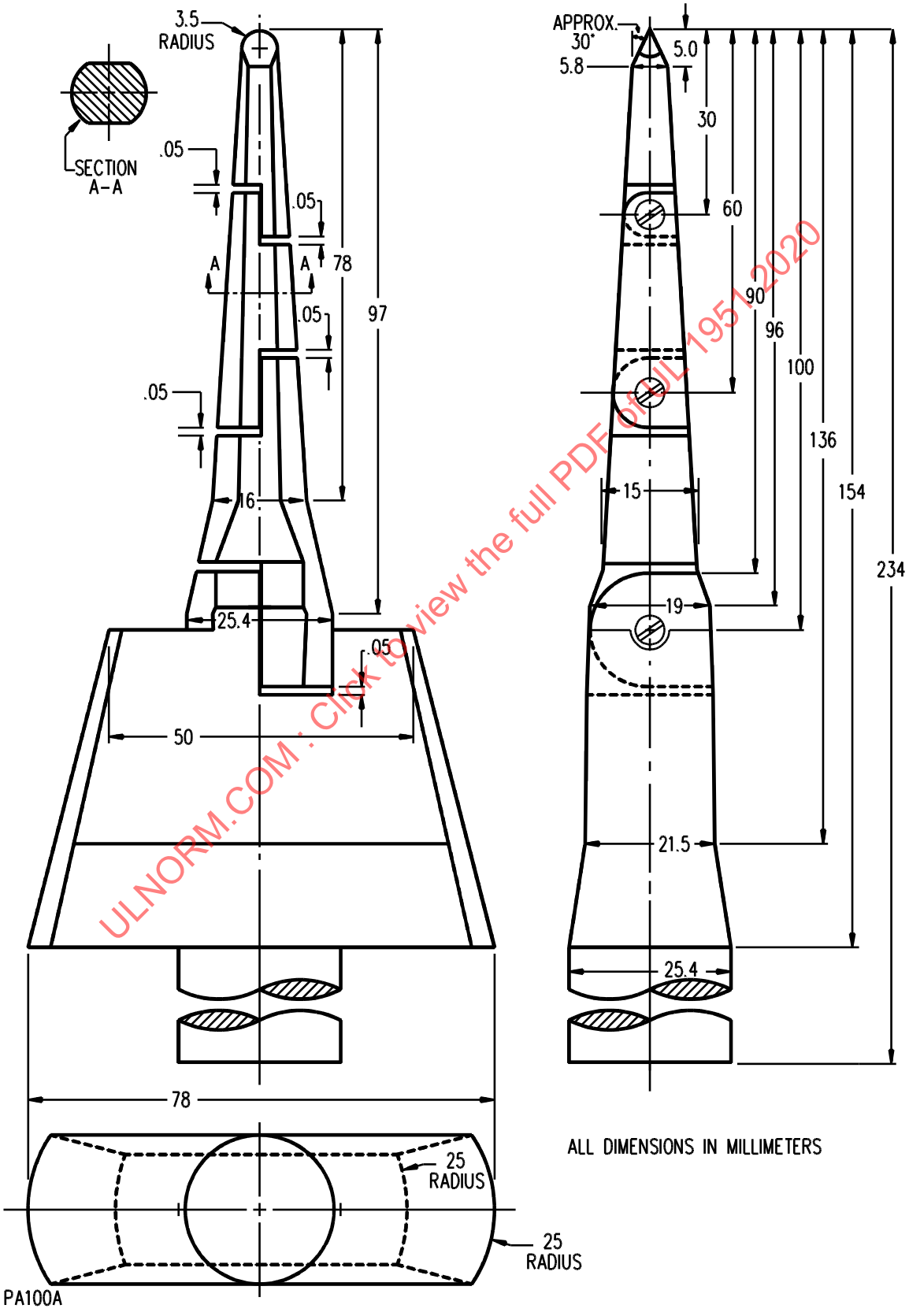


Table 9.1
Minimum distance from an opening to a part that may involve a risk of electric shock or injury to persons

Minor dimension[a] or opening		Minimum distance from opening to part,	
Inches[b]	(mm)[b]	Inches[b]	(mm)[b]
3/4[c]	(19.1)	4-1/2	(114.0)
1[c]	(25.4)	6-1/2	(165.0)
1-1/4	(31.8)	7-1/2	(191.0)
1-1/2	(38.1)	12-1/2	(318.0)
1-7/8	(47.6)	15-1/2	(394.0)
2-1/8	(54.0)	17-1/2	(445.0)
d		30	(762.0)

[a] See 9.5 for a description of the minor dimension of an opening.

[b] Between 3/4 inch and 2-1/8 inches, interpolation is to be used to determine a value between values specified in the table.

[c] Any dimension less than 1 inch applies to a motor only.

[d] More than 2-1/8 inches, but no more than 6 inches (152 mm).

9.2 With respect to a moving part or film-coated wire within the enclosure of a motor as specified in the Exception to 9.1:

a) An opening that has a minor dimension, as described in 9.5, of less than 3/4 inch (19.1 mm) is acceptable if:

1) In an indirectly accessible motor, an uninsulated live part or a moving part cannot be contacted by the probe illustrated in Figure 9.2;

2) Film-coated wire cannot be contacted by the probe illustrated in Figure 9.3; and

3) In a directly accessible motor, an uninsulated live part or a moving part cannot be contacted by the probe illustrated in Figure 9.4.

b) An opening that has a minor dimension of 3/4 inch or more is acceptable if an uninsulated live part, a moving part, or film-coated wire is spaced from the opening as specified in Table 9.1.

Figure 9.2

Probe for moving parts and uninsulated live parts

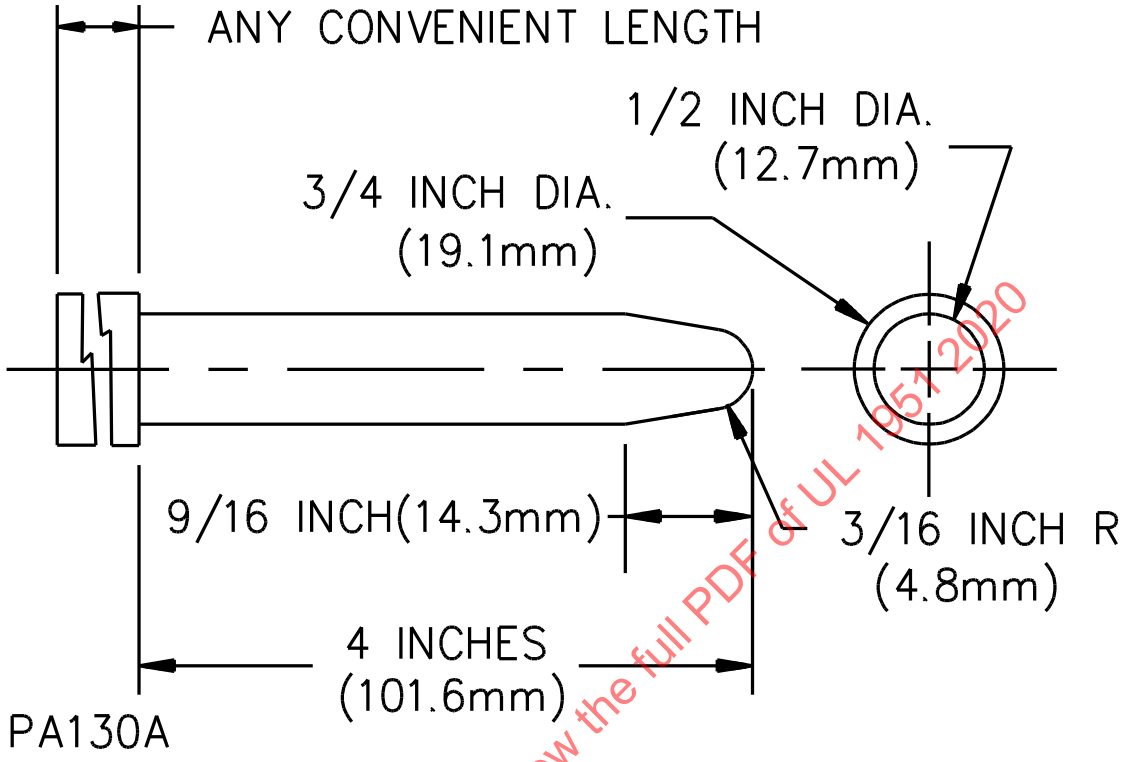


Figure 9.3

Probe for film-coated wire

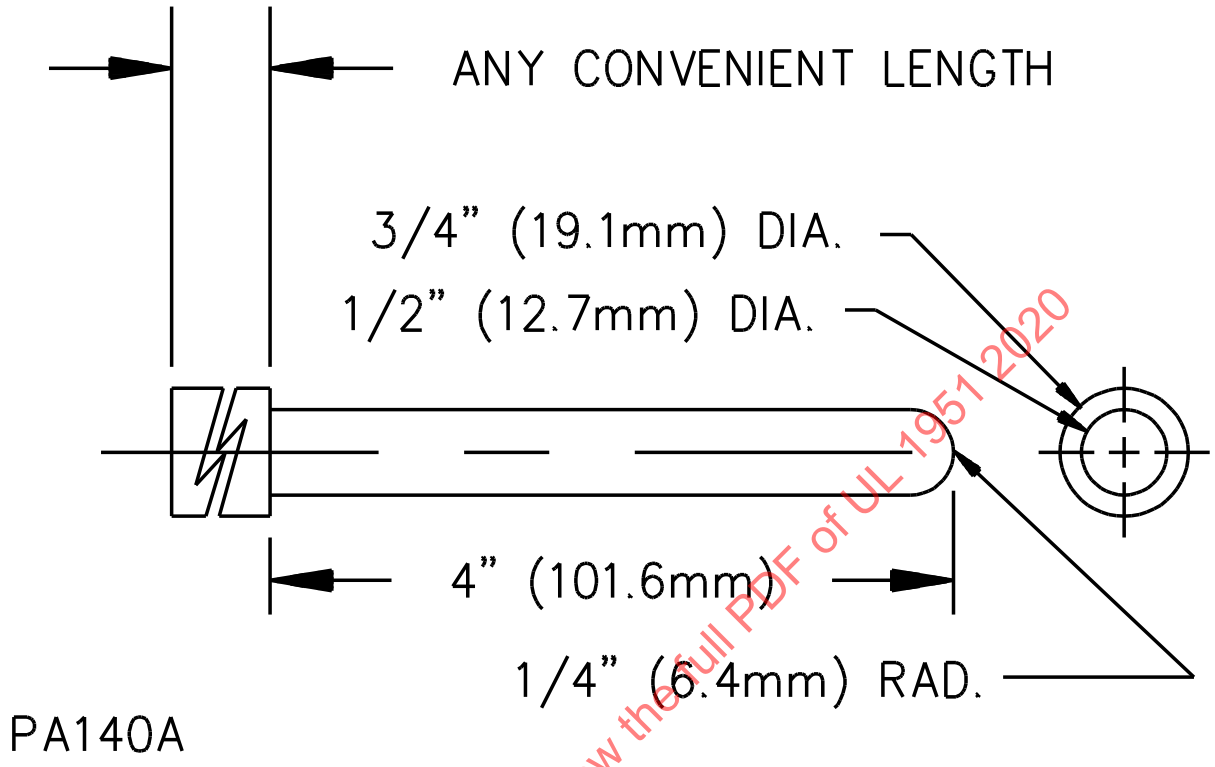
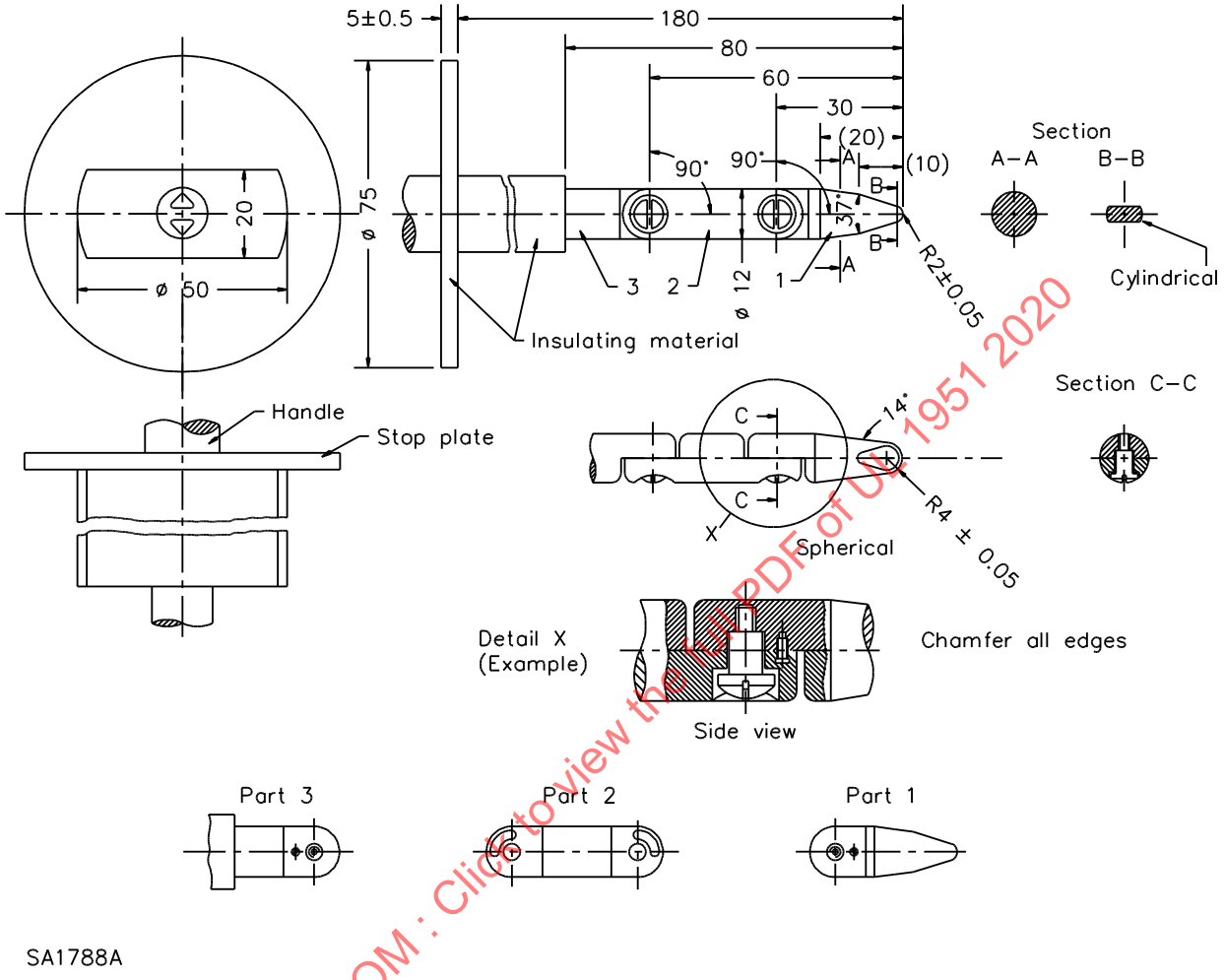


Figure 9.4

Articulated probe



9.3 The probes specified in 9.1 and 9.2 and illustrated in Figure 9.1 – Figure 9.4 shall be applied to any depth that the opening will permit, and shall be rotated or angled before, during, and after insertion through the opening to any position that is necessary to examine the enclosure. The probes illustrated in Figure 9.1 and Figure 9.4 shall be applied in any possible configuration; and, if necessary, the configuration shall be changed after insertion through the opening.

9.4 The probes illustrated in Figure 9.1 – Figure 9.4 shall be used as measuring instruments to judge the accessibility provided by an opening, and not as instruments to judge the strength of a material; they shall be applied with the minimum force necessary to determine accessibility.

9.5 With reference to the requirements in 9.1 and 9.2, the minor dimension of an opening is the diameter of the largest cylindrical probe having a hemispherical tip that can be inserted through the opening.

9.6 During the examination of a unit to determine whether it complies with the requirements in 9.1 or 9.2, a part of the enclosure that may be opened or removed by the user without using a tool (to attach an accessory, to make an operating adjustment, or for other reasons) is to be opened or removed.

9.7 A directly accessible motor is a motor that may be contacted without opening or removing any part and that is located so as to be accessible to contact. An indirectly accessible motor is a motor that is accessible only by opening or removing a part of the outer enclosure, such as a panel or service door, which can be removed without the use of tools or a motor that is located in such a position or is otherwise guarded or enclosed so that it is unlikely to be contacted.

10 Field Connections

10.1 General

10.1.1 Other than as noted in 10.1.2, equipment shall have provision for permanent connection of a wiring system in accordance with the National Electrical Code, ANSI/NFPA 70.

Exception No. 1: An enclosure need not have provision for the connection of a wiring system, such as a conduit hub, a knockout or a fitting, if it is intended to be drilled or punched in the field to accommodate a wiring system and is provided with appropriate installation instructions.

Exception No. 2: An enclosure provided with an integral conduit nipple that is part of an internal Class 2 transformer. Installation instructions shall be provided detailing the proper use of a conduit fitting to provide a compartment for field wiring and a termination for a permanent wiring system in the field.

Exception No. 3: A terminal compartment provided as an integral part of a motor that complies with the requirements for field wiring in the Standard for Rotating Electrical Machines – General Requirements, UL 1004-1, and is marked "Acceptable for Field Wiring" or the equivalent, is considered to comply with the requirements for a terminal compartment specified in 10.2.1 – 10.2.6.

10.1.2 The following shall be considered in determining the acceptability of a power supply cord for equipment:

a) The cord connection of the equipment facilitates frequent replacement;

b) Reduction of the transmission of noise or vibration is accomplished; and

c) The fastening means or mechanical connections are intended to permit removal for maintenance and repair.

10.2 Equipment permanently connected electrically

10.2.1 If a terminal compartment is provided, it shall be complete and shall enclose all field wiring terminals. No ventilation opening shall be located in the field wiring compartment.

10.2.2 A terminal compartment shall be located so that when conduit connections are made, internal wiring and electrical components shall not be exposed to mechanical abuse and strain. After the unit has been installed as intended, supply connections shall be accessible for inspection without exposing internal wiring and electrical components to mechanical abuse or strain.

10.2.3 Electrical components shall not be mounted on the terminal compartment cover unless the internal wiring is provided with a method of quick disconnection.

10.2.4 Except as noted in 10.1.1, Exception No. 2, a terminal compartment shall be attached to the unit at more than one point to reduce the likelihood of the terminal compartment turning.

10.2.5 Compartments, raceways, and the like, for routing and stowage of conductors connected in the field shall not contain rough, sharp, or moving parts that may damage conductor insulation.

10.2.6 A terminal box shall be provided with wiring terminals or leads for the connection of power supply conductors. It is assumed that the supply conductors will be of the smallest size having an ampacity of at least 125 percent of the test current for motor loads, continuous duty loads, and combination loads, and at least 100 percent for other loads. Wire size is to be determined in accordance with Table 310-16 of the National Electrical Code, ANSI/NFPA 70.

10.2.7 The free length of a lead inside the terminal compartment shall be at least 6 inches (152 mm) if the lead is intended for field connection to an external circuit. The leads provided for connection to the branch-circuit supply shall have an ampacity rating no less than that of a conductor of the next smaller size than that acceptable for the rating of the product.

Exception: For equipment intended to be connected to a branch circuit protected by a 15 ampere rated overcurrent protective device, the lead shall not be smaller in size then 18 AWG (0.8 mm^2).

10.2.8 A 14 AWG (2.1 mm^2) wire is the smallest conductor that may be used for branch circuit wiring, and thus is the smallest conductor that may be anticipated for connection of a power supply conductor.

10.2.9 A wiring terminal shall be provided with a pressure wire connector, firmly bolted or held by a screw.

Exception: A wire binding screw may be used at a terminal intended to accommodate a 10 AWG (5.3 mm^2) or smaller conductor if upturned lugs or the equivalent are provided to hold the wire in position.

10.2.10 Pressure terminal connectors shall comply with the Standard for Wire Connectors, UL 486A-486B.

10.2.11 A wire binding screw shall thread into metal and shall be no smaller than 10 AWG (4.8 mm diameter).

Exception: A 8 AWG (4.22 mm diameter) screw may be used at a terminal intended only for the connection of a 14 AWG (2.1 mm^2) conductor.

10.2.12 A terminal plate tapped for a wire binding screw shall be of metal no less than 0.030 inch (0.76 mm) thick. There shall be no fewer than two full threads in the metal, which may be extruded if necessary to provide the threads.

10.2.13 A terminal for connection of a grounded power supply conductor shall be of, or plated with, metal that is substantially white in color and shall be readily distinguishable from the other terminals; or proper identification of the terminal for the connection of the grounded conductor shall be clearly shown in some other manner, such as on an attached wiring diagram.

10.2.14 A lead for connection of a grounded power supply conductor shall be finished to show a white, silver, or gray color and shall be readily distinguishable from the other leads.

10.2.15 The threads of a conduit entry shall comply with the Standard for Pipe Threads, General Purpose (Inch), ASME B1.20.1; the Standard for Threaded Conduit Entries, , CSA C22.2 NO. 0.5, or the Standard for Unified Screw Threads – Specifications, ANCE NMX-H-146-SCFI.

10.3 Equipment cord connected

10.3.1 A cord-connected unit shall be provided with a flexible cord having a length of at least 18 inches (0.46 m) but no longer than 10 feet (3.05 m), and an attachment plug for connection to the branch-circuit supply. The cord shall:

a) Be Type S, SE, SJ, SJE, SJO, SJOO, SJT, SJTO, SJTOO, SO, SOO, ST, STO, or STOO; and

b) Include an equipment grounding conductor.

10.3.1.1 The flexible cord specified in 10.3.1 shall comply with the Standard for Cord Sets and Power-Supply Cords, UL 817, and the Standard for Flexible Cords and Cables, UL 62. Attachment plugs shall comply with the Standard for Attachment Plugs and Receptacles, UL 498.

10.3.2 The cord on outdoor equipment shall be marked "W," "W-A," or "outdoor" in connection with the type designation.

10.3.3 The cord shall have an ampacity no less than the ampere rating of the equipment.

10.3.4 An attachment plug shall be of a grounding type acceptable for use with a current not less than 125 percent of the rated current of the equipment, and at a voltage equal to the rated voltage of the equipment.

10.3.5 A 3-to-2 wire, grounding-type adapter shall not be provided.

10.4 Strain relief

10.4.1 A flexible cord shall be provided with means to reduce transmittal of tensional or rotational force from the cord to terminals, splices, or wiring within the unit.

10.4.2 Means such as a metal strain relief clamp or bushing shall be provided to reduce the likelihood of a flexible cord being pushed into an enclosure through the cord-entry hole, if such displacement can result in mechanical damage to the cord, exposure of the cord to a temperature higher than its rated temperature, or can reduce spacings below the minimum acceptable values.

10.4.3 The strain relief means shall be tested as described in Strain Relief Test, Section 48.

10.4.4 A knot in the flexible cord shall not be used to provide strain relief.

10.5 Bushing

10.5.1 At a point where a flexible cord passes through an opening in a wall, a barrier, or an enclosure, there shall be an acceptable bushing, or the equivalent, that shall be secured in place and have a smooth, rounded surface against which the cord can bear.

11 Adhesives Used to Secure Parts

11.1 An adhesive that is relied upon to reduce a risk of fire, electric shock, or injury to persons shall comply with the requirements for adhesives in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

11.2 The requirement in 11.1 applies to an adhesive used to secure a conductive part, including a nameplate, that may, if loosened or dislodged:

a) Energize an accessible dead metal part;

b) Make a live part accessible;

c) Reduce spacings below the minimum acceptable values; or

d) Short-circuit live parts.

11.3 Whether the conditions mentioned in 11.2 (a) – (d) can occur is to be considered with respect to both a part inside the device, and a part on the outside of the device that may affect equipment in which the device is to be installed.

12 Mechanical Assembly

12.1 Equipment shall be assembled so that it will not be adversely affected by the vibration of normal operation. Brush caps shall be tightly threaded or otherwise constructed to prevent loosening.

12.2 A switch, a lampholder, an attachment-plug receptacle, a motor-attachment plug, or similar component shall be securely mounted and shall be prevented from turning. See 12.4.

Exception No. 1: A switch need not be prevented from turning provided:

a) The switch is of a plunger or other type that does not tend to rotate when operated. A toggle switch is considered to be subject to forces that tend to turn the switch during normal operation of the switch;

b) The means for mounting the switch makes it unlikely that operation of the switch will loosen it;

c) The spacings are not reduced below the minimum required values if the switch rotates; and

d) The normal operation of the switch is by mechanical means rather than by direct contact by persons.

Exception No. 2: A lampholder of the type in which the lamp cannot be replaced, such as a neon pilot or indicator light in which the lamp is sealed in a nonremovable jewel, need not be prevented from turning if rotation cannot reduce spacings below the minimum required values.

12.3 Uninsulated live parts shall be secured to the base or mounting surface so that they will be prevented from turning or shifting in position, if such motion may result in a reduction of spacings below the minimum acceptable values.

12.4 The means for preventing the turning or shifting mentioned in 12.2 and 12.3 is to consist of more than friction between surfaces – for example, a properly applied lock washer is acceptable as the means for preventing a small stem-mounted switch or other device having a single-hole mounting means from turning.

13 Current-Carrying Parts

13.1 A current-carrying part shall be of silver, copper, a copper alloy, stainless steel, or other similar metal.

13.2 Ordinary iron or steel shall not be used as a current-carrying part.

Exception: Ordinary iron or steel provided with a corrosion-resistant coating may be used for a current-carrying part if:

a) Acceptable in accordance with General, Section5.1; or

b) Within a motor or associated governor.

14 Insulating Material

14.1 Material for mounting an uninsulated live part shall be porcelain, phenolic composition, or other equivalent material.

14.2 Ordinary vulcanized fiber may be used for insulating bushings, washers, separators, and barriers, but not as the sole support for uninsulated live parts where shrinkage, current leakage, or warpage may introduce a risk of fire or electric shock.

14.3 A thermoplastic or thermoset insulating material shall comply with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

14.4 A small molded part, such as a brush cap, shall be constructed to have the necessary mechanical strength and rigidity to withstand the stresses of actual service. A brush cap shall be secured or located so that it is protected from mechanical damage that may result during intended use.

15 Internal Wiring

15.1 Mechanical protection

15.1.1 Wiring and connections between parts of the equipment shall be protected or enclosed.

Exception: A length of flexible cord may be employed for external connections if flexibility is essential. Flexible cord shall be of the types included in 10.3.1.

15.1.2 A flexible cord used for external interconnection as mentioned in 15.1.1 shall be provided with strain relief and bushings in accordance with the requirements in 10.4.1 – 10.5.1, unless the construction is such that the cord will be protected from stress and motion.

15.1.3 Wires within an enclosure, a compartment, a raceway, or the like shall be routed or otherwise protected so that damage to conductor insulation cannot result from contact with any rough, sharp, or moving parts.

15.1.4 A hole through which insulated wires pass in a sheet-metal wall within the overall enclosure of an appliance shall be provided with a smooth, rounded bushing or shall have smooth, rounded surfaces upon which the wires may bear.

15.1.5 Insulated wires may be bunched and passed through a single opening in a metal wall within the enclosure of equipment.

15.1.6 Internal wiring shall consist of wires of a type or types that are acceptable for the application, when considered with respect to the temperature and voltage to which the wiring is likely to be subjected and with respect to its exposure to oil, grease, or other conditions of service to which it is likely to be subjected.

15.1.7 With reference to exposure of insulated wiring through an opening in the enclosure, the protection of such wiring required by 15.1.1 is considered to exist if, when judged as though it were film-coated wire, the wiring would be acceptable according to 9.1 and 9.2. Internal wiring not so protected may be accepted if it is secured within the enclosure so that it is unlikely to be subjected to stress or mechanical damage.

15.1.8 Wiring that may be located in proximity to combustible material or may be subjected to mechanical damage shall be in armored cable, rigid metal conduit, electrical metallic tubing, metal raceway, or be otherwise equivalently protected.

15.2 Splices and connections

15.2.1 Each splice and connection shall be mechanically secure and shall provide reliable electrical contact. A soldered connection shall be mechanically secured before being soldered.

15.2.2 A splice shall be provided with insulation equivalent to that of the wires involved if permanence of spacing between the splice and other metal parts may not be maintained.

15.2.3 Aluminum conductors, insulated or uninsulated, used as internal wiring, such as for internal connection, between current-carrying parts or as motor windings, shall be terminated by a method acceptable for the combination of metals involved at the point of connection.

15.2.4 With reference to the requirements in 15.2.3, if a pressure wire connector is used as a terminating device for aluminum, refer to 10.2.9.

15.2.5 Insulation consisting of two layers of friction tape, two layers of thermoplastic tape, or of one layer of friction tape on top of one layer of rubber tape, is acceptable on a splice if the voltage involved is less than 250 volts. In determining if splice insulation consisting of coated-fabric, thermoplastic or other type of tubing is acceptable, consideration is to be given to such factors as its dielectric properties, heat-resistant and moisture-resistant characteristics, and the like. Thermoplastic tape wrapped over a sharp edge is not acceptable.

15.2.6 If stranded internal wiring is connected to a wire-binding screw, loose strands of wire shall be prevented from contacting other uninsulated live parts that are not always of the same polarity as the wire and from contacting dead metal parts. This may be accomplished by use of pressure terminal connectors, soldering lugs, crimped eyelets, soldering all strands of the wire together, or other reliable means.

16 Separation of Circuits

16.1 General

16.1.1 Insulated conductors shall be segregated or separated by barriers from:

a) Each other if used in different internal wiring circuits; and

b) Uninsulated live parts connected to different circuits.

Exception: Conductors provided with insulation acceptable for the highest voltage involved need not be separated or segregated.

16.1.2 Segregation of insulated conductors may be accomplished by clamping, routing, or an equivalent means that provides permanent separation from insulated or uninsulated live parts of a different circuit.

16.1.3 In a compartment that is intended for the field installation of conductors, and that contains provision for connection of Class 2 or Class 3 circuit conductors, and Class 1, power, or lighting circuit conductors, a barrier shall be provided to separate the conductors of the different circuits, or the arrangement of the compartment shall be such that a minimum spacing of 1/4 inch (6.4 mm) can be maintained between the conductors of the different circuits including the conductors to be field installed.

17 Grounding and Bonding

17.1 General

17.1.1 All exposed dead metal parts and all dead metal parts within the enclosure that are exposed to contact during any user servicing operation and are likely to become energized shall be reliably connected to the means for grounding.

17.1.2 To determine whether a part is likely to become energized, such factors as construction and the proximity of wiring are to be evaluated.

17.2 Grounding means

17.2.1 An equipment-grounding terminal or lead-grounding point shall be connected to the frame or enclosure by a positive means, such as by a bolted or screwed connection.

17.2.2 A grounding connection shall reliably penetrate a nonconductive coating, such as paint or vitreous enamel.

17.2.3 A grounding point shall be located so that it is unlikely that the grounding means will be removed during normal servicing.

17.3 Terminals and leads

17.3.1 A terminal or lead intended for connection of an equipment-grounding conductor shall be constructed as specified in 10.2.7 – 10.2.12 to accommodate a conductor sized in accordance with the National Electrical Code, ANSI/NFPA 70.

17.3.2 The free length of a lead intended for connection to an equipment-grounding conductor shall be insulated – for example, shall have the end folded back and taped to the lead – unless the conductor is located so that it cannot contact live parts in the event that the conductor is not used in the field.

17.3.3 A multiple-conductor cord with a grounding conductor connected to the frame or enclosure is an acceptable grounding means for all cord-connected equipment.

17.3.4 The grounding conductor of a power-supply cord shall be attached to the grounding blade of an attachment plug and shall be connected within the frame or enclosure by means of a screw not likely to be removed during ordinary servicing not involving the power-supply cord.

17.3.5 The grounded-circuit conductor shall not be grounded at or in conjunction with the equipment.

17.4 Grounding identification

17.4.1 The surface of the insulation of a grounding conductor of a flexible cord or a lead intended solely for the connection of an equipment-grounding conductor shall be green with or without one or more yellow stripes, and no other lead shall be so identified.

17.4.2 A wire-binding screw intended for the connection of an equipment-grounding conductor shall have a green-colored head that is hexagonal or slotted, or both.

17.4.3 A pressure wire connector intended for connection of an equipment-grounding conductor shall be identified by:

a) Being marked "G," "GR," "GND," "Ground," "Grounding," or the like;

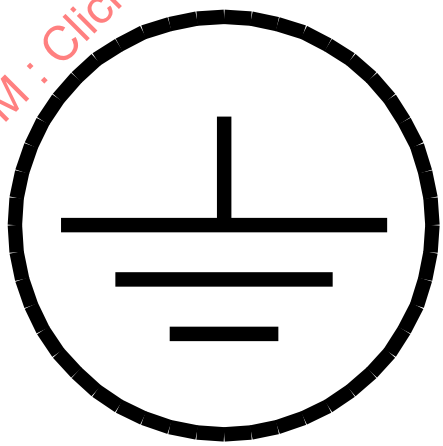
b) A marking on a wiring diagram provided on the product; or

c) The symbol shown in Figure 17.1 (IEC Publication 417, Symbol No. 5019) on or adjacent to the connector or on a wiring diagram provided on the product. See 17.4.4.

Figure 17.1

Grounding symbol

(IEC Publication 417, Symbol No. 5019)



17.4.4 If the symbol shown in Figure 17.1 is used in accordance with 17.4.3 (c), the installation instructions provided with the product shall define the symbol.

Exception: If the symbol in Figure 17.1 is used with one of the other means of identification specified in 17.4.3 (a) and (b), the definition need not be provided.

17.5 Bonding

17.5.1 A noncurrent-carrying metal part shall be bonded to the point of connection of the grounding conductor.

17.5.2 Means for accomplishing bonding shall penetrate all nonconductive coatings such as paint.

17.5.3 A bolted or screwed connection that incorporates a star washer under a screw head, a serrated screw head, or the equivalent is acceptable for penetrating nonconductive coatings as required by 17.5.2.

17.5.4 If the bonding means depends upon screw threads, there shall be two or more screws, or two full threads of a single screw, engaging metal.

18 Lampholders

18.1 The screw shell of an Edison-base lampholder in permanently connected equipment or equipment equipped with a polarized attachment plug shall be connected to the terminal or lead that is intended to be connected to the grounded conductor of the power-supply circuit.

18.2 A lampholder shall be constructed or installed so that uninsulated live parts other than a screw shell will not be exposed to contact by persons removing or replacing lamps in intended service.

Exception: This requirement does not apply if it is necessary to dismantle the equipment or remove a cover plate or other part by means of a tool in order to remove or replace a lamp.

19 Motors

19.1 An electric motor shall comply with the Standard for Rotating Electrical Machines – General Requirements, UL 1004-1, except as noted below:

a) The current and horsepower relation, cord-connected motors, factory wiring terminals and leads and non-metallic functional parts requirements in UL 1004-1 are not applicable.

b) A solid-state control that complies with the Standard for Solid-State Controls for Appliances, UL 244A, is considered to comply with the motors provided with controls requirements of UL 1004-1. Compliance with the Standard for Automatic Electrical Controls for Household and Similar Use, Part 1: General Requirements, UL 60730-1, and/or the applicable Part 2 standard from the UL 60730 series complies with the requirements in UL 244A.

c) See 6.6 of this end product standard for the applicability of the frame and enclosure (nonmetallic) requirements of UL 1004-1.

d) Metal enclosure requirements of UL 1004-1 are superseded by the requirements in Frame and Enclosure, Section 6 of this end product standard.

e) Grounding requirements of UL 1004-1 are superseded by the requirements in Grounding and Bonding, Section 17 of this end product standard.

f) The Ventilation Opening requirements of UL 1004-1 are only applicable where the openings are on surfaces considered to be the appliance enclosure (see 6.1.1 of this end product standard).

g) The accessibility of uninsulated live parts, film-coated wire, and moving parts requirements in UL 1004-1 is superseded by the requirements in Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts, Section 9 of this end-product standard.

h) The protection against corrosion requirements in UL 1004-1 are superseded by the requirements in Protection Against Corrosion, Section 8 of this end product standard.

i) The available fault current ratings for motor start and running capacitors specified in UL 1004-1 are not applicable to cord and plug connected pumps.

j) The switches section of UL 1004-1 is not applicable to centrifugal starting switches.

k) With the exception of the Resilient Mounting and Electrolytic Capacitor Tests, the performance tests of UL 1004-1 are not applicable.

l) The marking requirements of UL 1004-1 are not applicable except for the manufacturer's name or identification; rated voltage; rated frequency. If greater than 1, number of phases; and a multi-speed motor, other than a shaded-pole or a permanent-split-capacitor motor, shall be marked with the amperes and horsepower at each speed.

19.2 A motor shall incorporate overload protection against running-overload and locked-rotor conditions.

Exception No. 1: A motor intended to move air only by means of an air-moving fan that is integrally attached, keyed, or otherwise fixed to the motor shaft is not required to have running-overload protection.

Exception No. 2: A shaded-pole motor with a 2:1 or smaller ratio between locked-rotor and no-load currents and a 1-ampere or smaller difference between no-load and locked-rotor currents is determined to have acceptable overcurrent resistance when it is made resistant to locked-rotor conditions only.

19.3 The protection required by 19.2 shall consist of one of the following:

a) Thermal protection that complies with the applicable requirements in the Standard for Overheating Protection for Motors, UL 2111 or the Standard for Thermally Protected Motors, UL 1004-3.

b) Impedance protection complying with the Standard for Overheating Protection for Motors, UL 2111 or the Standard for Impedance Protected Motors, UL 1004-2, when the motor is tested as used in the equipment.

c) Electronic protection complying with the requirements in the Standard for Electronically Protected Motors, UL 1004-7.

20 Overcurrent- or Overload-Protective Devices

20.1 General

20.1.1 A fuseholder or circuit breaker shall be acceptable for the application. A plug fuseholder shall be Type S or Edison-base with a factory-installed nonremovable Type S adapter.

20.1.2 The screw shell of a plug-type fuseholder shall be connected toward the load.

20.1.3 A protective device, such as a fuse, the normal functioning of which requires renewal or replacement shall be in a readily accessible location.

20.1.4 A fuseholder shall be designed and installed so that no uninsulated live part other than the screw shell, terminals, clips, or center contact of a plug fuseholder will be exposed to contact by a person removing or replacing a fuse.

20.1.5 The operating handle of a circuit breaker, and the like shall be accessible for servicing without the necessity for exposing normally protected or enclosed live parts.

21 Capacitors

21.1 A capacitor provided to operate a motor and a capacitor connected across the line (such as a capacitor for radio-interference elimination or power factor correction) shall be housed within an enclosure or container so as not to be subjected to mechanical damage and to reduce the risk of emission of flame or molten material resulting from capacitor malfunction. The container shall be of metal providing strength equivalent to that of uncoated steel having an average thickness of 0.020 inch (0.51 mm).

Exception No. 1: The container of a capacitor may be of thinner sheet metal or may be of material other than metal provided that:

a) The capacitor is mounted in an enclosure that houses other parts of the unit; and

b) The enclosure complies with the requirements for enclosures of current-carrying parts.

Exception No. 2: The container of an electrolytic capacitor with means for venting is required to reduce the risk of mechanical damage only, and the requirement for minimum enclosure thickness does not apply. The container of an electrolytic capacitor that is not provided with means for venting need not comply with the requirement for enclosure thickness if the enclosure complies with the test in 21.4.

21.2 If a capacitor that is not a part of a capacitor motor or a capacitor-start motor is connected so that malfunction of the capacitor may result in a risk of fire or electric shock, thermal or overcurrent protection shall be provided in the unit to reduce such a risk.

21.3 Under both normal and abnormal conditions of use, a capacitor shall not result in a risk of fire or electric shock when tested in accordance with the applicable performance tests in this standard.

21.4 Three samples of the capacitor described in Exception No. 2 of 21.1, mounted in the intended manner and with cotton placed around openings in the enclosure, are each to be subjected to an overvoltage to cause the capacitor to cease to function. The results are acceptable if the cotton does not ignite during the test.

22 Switches and Controls

22.1 A switch or other control device shall have current and voltage ratings no less than those of the circuit (load) that it controls.

22.2 A solid-state circuit relied upon to comply with one or more requirements in this standard shall acceptably complete a reliability evaluation of electronic components.

22.3 If unintentional operation of a switch can result in a risk of injury to persons, the actuator of the switch shall be located or guarded so that such operation is unlikely.

22.4 A switch with a marked "off" position shall open all ungrounded conductors. If the product is cord connected and not provided with a polarized attachment plug cap, all supply conductors shall be considered to be ungrounded regardless of the voltage rating of the product.

22.5 The current rating of a switch or other control device that controls a solenoid, a magnet, a transformer, an electric-discharge-lamp ballast, or another inductive load shall be at least twice the rated full-load current of the component that it controls unless the switch is rated for the particular application.

22.6 A switch that controls a lampholder for an incandescent lamp other than a 15-watt or smaller pilot or indicating lamp shall be of a type that is acceptable for use with tungsten-filament lamps.

22.7 A switch or other device controlling a motor shall be rated in horsepower. A switch or other device controlling a coil shall be rated for pilot duty.

22.8 A switch or other device not having a rating as specified in 22.7 shall be subjected to the overload test described in Overload Test on Switches and Controls, Section 50.

23 Controls – End Product Test Parameters

23.1 General

23.1.1 Where reference is made to declared deviation and drift, this indicates the manufacturer's declaration of the control's tolerance before and after certain conditioning tests.

23.2 Auxiliary controls

23.2.1 Auxiliary controls shall not introduce a risk of electric shock, fire, or personal injury hazard.

23.2.2 Auxiliary controls shall comply with the requirements of this end product standard.

Exception: An auxiliary control that complies with a component standard(s) specified in Controls, Section 5.5 complies with this requirement.

23.3 Operating controls (regulating controls)

23.3.1 The following test parameters shall be among the items considered when judging the acceptability of an operating control investigated in accordance with the Standard for Automatic Electrical Controls – Part 1: General Requirements, UL 60730-1:

a) Control action Type 2.

b) Unless otherwise specified in this end product standard, manual and automatic controls shall be tested for 6,000 cycles with under maximum normal load conditions, and 50 cycles under overload conditions. See Overload Test on Switches and Controls, Section 50.

c) Installation class 2 in accordance with the Standard for Electromagnetic Compatibility (EMC) – Part 4-5: Testing and Measurement Techniques – Surge Immunity Test, IEC 61000-4-5.

d) For the applicable Overvoltage Category, see Table 26A.1.

e) For the applicable Material Group, see Table 26A.2.

f) For the applicable Pollution Degree, see Table 26A.3.

Table 23.1
Overvoltage categories

Table 23.1 relocated to Table 26A.1.

Table 23.2
Material group

Table 23.2 relocated to Table 26A.2.

Table 23.3
Pollution degrees

Table 23.3 relocated to Table 26A.3.

23.4 Protective controls (limiting controls)

23.4.1 An electronic control that performs a protective function shall comply with the requirements in Controls, Section 5.5 while tested using the parameters in this section. Examples of protective controls are: a control used to sense abnormal temperatures of components within the appliance; an interlock function to de-energize a motor; temperature protection of the motor due to locked rotor, running overload, loss of phase; or other function intended to reduce the risk of electric shock, fire, or injury to persons.

23.4.2 The following test parameters shall be among the items considered when judging the acceptability of an electronic protective control investigated in accordance with the Standard for Automatic Electrical Controls for Household and Similar Use, Part 1: General Requirements, UL 60730-1:

a) Failure-Mode and Effect Analysis (FMEA) or equivalent risk analysis method.

b) Power supply voltage dips, variation and interruptions within a temperature range of 10°C and the maximum ambient temperature determined by conducting the Temperature Test, Section 43.

c) Surge immunity test – installation class 3 shall be used.

d) Electrical fast transient/burst test, a test level 3 shall be used.

e) Electrostatic Discharge Test.

f) Radio-frequency electromagnetic field immunity:

1) Immunity to conducted disturbances, when applicable, test level 3 shall be used; and

2) Immunity to radiated electromagnetic fields; field strength of 3 V/m shall be used.

g) Thermal Cycling Test in UL 60730-1 shall be conducted at ambient temperatures of 10.0 +2°C and the maximum ambient temperature determined by conducting the Temperature Test, Section 45. The test shall be conducted for 14 days.

h) Overload shall be conducted based on the maximum declared ambient temperature (Tmax) or as determined by conducting the Temperature Test, Section 45.

23.4.3 The test parameters and conditions used in the investigation of the circuit specified in 23.4.1 shall be as specified in the Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991, in accordance with the following test parameters:

a) With regard to electrical supervision of critical components, for attended appliances, a motor operated system becoming permanently inoperative with respect to movement of an exposed portion of the appliance complies with the requirements for trouble indication. For unattended appliances, electrical supervision of critical components may not rely on trouble indication.

b) A field strength of 3 V per meter is to be used for the Radiated EMI Test.

c) The Composite Operational and Cycling Test is to be conducted for 14 days at temperature extremes of 0°C (32°F) and 70°C (158°F).

d) The Humidity Class is to be based on the appliance's intended end use and is to be used for the Humidity Test.

e) A vibration level of 5 g is to be used for the Vibration Test.

f) When a computational investigation is conducted, λ_p shall not be greater than X failures/10^6 hours for the entire system as specified in Table 23.4. For controls not specified in Table 23.4, the composite system failure shall be determined based on evaluation of the risks involved due to control failure. The Operational Test is to be conducted for 14 days.

g) When the Demonstrated Method Test is conducted, the multiplier for the test acceleration factor is to be 576.30 for intermittent use appliances, or 5763.00 for continuous use appliances. The test acceleration factor equation is to be based on a 25°C use ambient.

h) The Endurance Test is to be conducted concurrently with the Operational Test. The control shall perform its intended function while being conditioned for 14 days in an ambient air temperature of 60°C (140°F), or 10°C (18°F) greater than the operating temperature of the control, whichever is higher. During the test, the control is to be operated in a manner representing normal use.

i) For the Electrical Fast Transient Burst Test, test level 1 is to be used.

j) Conduct a failure-mode and effect analysis (FMEA).

Table 23.4
Composite system failure rate λ_p for solid-state protective controls

Control Function	λ_p
Scalding Protection Water Temperature Limiting Control	16

23.4.4 Unless otherwise specified in this end product standard, protective controls shall be evaluated for 100,000 cycles for automatic action devices, and 6,000 cycles for manual action devices, with rated current.

23.5 Controls using a temperature sensing device

23.5.1 A temperature sensing positive temperature coefficient (PTC) or negative temperature coefficient (NTC) thermistor, that performs the same function as an operating or protective control, shall be tested using the following number of cycles when testing a sensing device in accordance with the endurance test:

a) For a device employed as a operating device – 6000 cycles;

b) For a device employed as a protective device – 100,000 cycles, and

c) For a device employed as a combination operating and protective device – 100,000 cycles.

24 Electronic Circuits

24.1 General

24.1.1 Circuits on the line side of isolation components shall comply with the requirements in 24.2 for Electronic Circuits Evaluated to the UL 60335-1 Based Requirements.

24.1.2 All secondary circuits shall be judged under the requirements for primary circuits unless they comply with 24.1.3 – 24.1.5 or the requirements in 24.2 for Electronic Circuits Evaluated to the UL 60335-1 Based Requirements.

24.1.3 External wires and cables that are part of the secondary circuits covered in 24.1.2 shall be provided with strain relief in accordance with 10.4.2 – 10.5.1 if stresses on wire or cable could cause the internal wiring of the circuits to contact uninsulated live parts of other circuits.

24.1.4 In a circuit that is supplied from an isolating transformer that does not meet the requirements for a Class 2 transformer but does have an open-circuit sinusoidal potential of 30 volts rms (42.4 volts peak) or less, and that includes reliable fixed impedance, a fuse, or a nonadjustable manually reset circuit protector that limits the power available to the levels for Class 2 transformers, the portion of the circuit on the load side of the impedance, fuse, or protector is to be treated as if it were supplied from a Class 2 transformer. In such a case, the secondary winding of the transformer, either the impedance, the fuse, or the protector, and the wiring between the two are to be judged as if they were part of a line-voltage circuit.

24.1.5 A fuse or circuit protector used to limit the power as specified in 24.1.4 is to be rated or set at not more than 3.2 amperes for a circuit operating between 20 and 30 volts rms sinusoidal and not more than 5.0 amperes for a 0 – 20 volt rms sinusoidal circuit. If an impedance is used to limit the current, its value is to limit the current under short-circuit conditions to not more than 8.0 amperes measured after 1 minute.

24.2 Electronic circuits evaluated to UL 60335-1 based requirements

24.2.1 Identification of Safety Critical Circuit Functions

24.2.1.1 General

24.2.1.1.1 Electronic circuits or parts of circuits shall be analyzed to determine if the function of the control is necessary for compliance with this standard. A function is considered a Safety Critical Function (SCF) if failure (loss or malfunction) of its functionality would result in the risk of fire, electric shock or injury to persons using the appliance.

24.2.1.1.2 Safety Critical Functions shall be identified as either Protective Electronic Circuits as detailed in 24.2.2 or as those of operating circuits that mitigate Dangerous Malfunctions as detailed in 24.2.3.

24.2.1.1.3 In the evaluation of electronic circuits, all the contacts of relays or contactors that cycle during the Normal Temperature Test shall be simultaneously short-circuited.

24.2.1.1.4 See 5A.3 and Table 5A.1 for common Safety Critical Functions.

24.2.2 Protective electronic circuits

24.2.2.1 An electrical component shall not be connected across the contacts of a Protective Electronic Circuit.

Exception: Electrical components may be connected across the contacts provided that any single component fault does not result in a loss of protective function.

24.2.3 Operating circuits that mitigate a dangerous malfunction of the appliance

24.2.3.1 The suitability of stand-by or electronic disconnect circuits shall be as specified in this standard.

24.2.3.2 An electronic disconnection circuit whose failure could result in a Dangerous Malfunction shall have at least two components whose combined operation provides the load disconnection.

24.2.4 Evaluation of the different types of electronic circuits

24.2.4.1 All types of circuits

24.2.4.1.1 All circuit functions mandated by this standard shall be validated. This includes operating functions not designated as Safety Critical Functions.

24.2.4.1.2 All circuits shall be evaluated to determine the effects of electronic circuit faults.

24.2.4.1.3 When the applicable component/hardware faults specified in 53.4.5.10 are imposed one at a time they shall not result in:

a) The appliance presenting a risk of fire, electric shock or mechanical hazard, or

b) The loss of any Safety Critical Function either in that circuit or others.

24.2.4.1.4 The risk of electrically generated fire from the faults of 53.4.5.10 is considered to be mitigated in Low-Power Circuits.

24.2.5 Circuits that provide Safety Critical Functions

24.2.5.1 In addition to the requirements of 24.2.4, circuits that provide Safety Critical Functions shall incorporate measures to control the fault/error conditions that would impair the safety functions.

24.2.5.2 The evaluation of the programmable component shall be in accordance with Annex R of the Standard for Safety of Household and Similar Electrical Appliances, Part 1: General Requirements, UL 60335-1, Edition 5.

24.2.5.3 Circuits that provide Safety Critical Functions that rely upon a programmable component for one or more of its safety functions shall be subjected to the test of the Programmable component reduced supply voltage test, 53.4.6, unless restarting at any point in the operating cycle after interruption of operation due to a supply voltage dip will not result in a hazard. The test is carried out after removal of all batteries and other components intended to maintain the programmable component supply voltage during mains supply voltage dips, interruptions and variations.

24.2.5.4 Circuits that provide Safety Critical Functions shall maintain their required functions when subjected to the EMC related stresses specified in the Electromagnetic Compatibility (EMC) requirements – Immunity, 53.4.7.

24.2.5.5 The tests of 53.4.7 are carried out with surge protective devices disconnected, unless they incorporate spark gaps.

25 Diaphragms, Gaskets, and Seals

25.1 If the deterioration or breakage of a diaphragm, gasket, or seal could increase the risk of electric shock, the diaphragm, gasket, or seal shall be tested as specified in Accelerated Aging Test, Section 49.

26 Spacings

26.1 Other than at wiring terminals, the spacings between uninsulated live parts of opposite polarity and between an uninsulated live part and a dead metal part that is exposed to contact by persons or that may be grounded shall not be less than the value specified in Table 26.1.

Exception No. 1: The inherent spacings of a component of the equipment, such as a snap switch or motor, are judged on the basis of the requirements for the component in question.

Exception No. 2: This requirement does not apply if a spacing complies with the requirements in 26.3.

Table 26.1
Spacings at other than field-wiring terminals

Potential involved, Volts	Over surface		Through air	
	Inch	(mm)	Inch	(mm)
0 – 125	1/16	(1.6)	1/16	(1.6)
126 – 250	3/32	(2.4)	3/32	(2.4)
251 – 600	1/2	(12.7)	3/8	(9.5)

26.2 If an uninsulated live part is not rigidly fixed in position by means other than friction between surfaces, or if a movable dead metal part is in proximity to an uninsulated live part, the construction shall be such that the required minimum spacing will be maintained.

26.3 If an isolated dead metal part is interposed between or is in close proximity to:

a) Live parts of opposite polarity;

b) A live part and an exposed dead metal part; or

c) A live part and a dead metal part that may be grounded;

the spacing may be not less than 3/64 inch (1.2 mm) between the isolated dead metal part and any one of the other parts previously mentioned, provided the total spacing between the isolated dead metal part and the two other parts is not less than the value specified in Table 26.1.

26.4 An insulating lining or barrier employed where spacing would otherwise be insufficient shall comply with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

26.5 All uninsulated live parts connected to different circuits – line- or low-voltage – shall be spaced from one another as though they were parts of opposite polarity, in accordance with the requirements in 26.1 and 26.6 and shall be judged on the basis of the highest voltage involved.

26.6 The spacing between wiring terminals of opposite polarity, and between a wiring terminal and any other uninsulated metal part – dead or live – not of the same polarity, shall not be less than that specified in Table 26.2.

Table 26.2
Spacings at wiring terminals

Potential involved, volts	Minimum spacings, inch (mm)					
	Between wiring terminals, through air or over surface		Between terminals and other uninsulated metal parts not always of the same polarity[a]			
			Over surface		Through air	
	inch	(mm)	inch	(mm)	inch	(mm)
250 or less	1/4	(6.4)	1/4	(6.4)	1/4	(6.4)
More than 250	1/2	(12.7)[b]	1/2	(12.7)[b]	3/8	(9.5)

[a] Applies to the sum of the spacings involved where an isolated dead metal part is interposed.

[b] A spacing of not less than 3/8 inch, through air and over surface, is acceptable at wiring terminals in a wiring compartment or terminal box if the compartment or box is integral with a motor.

26A Clearance and creepage distances

26A.1 As an alternative approach to the spacing requirements specified in Spacings, Section 26, and other than as noted in 26.7.2 and 26.7.3, clearances and creepage distances may be evaluated in accordance with the requirements in the Standard for Insulation Coordination Including Clearance and Creepage Distances for Electrical Equipment, UL 840, as described in 26.7.4.

26A.2 Clearances between an uninsulated live part and the walls of a metal enclosure, including fittings for conduit or armored cable, shall be as noted in Table 26.1. The clearances shall be determined by physical measurement.

26A.3 The clearance and creepage distance at field wiring terminals shall be in accordance with the requirements in Table 26.2.

26A.4 In conducting evaluations in accordance with the requirements in the Standard for Insulation Coordination Including Clearance and Creepage Distances for Electrical Equipment, UL 840, the following guidelines shall be used:

a) For evaluating clearances:

1) Appliances intended to be permanently wired to their supply shall be evaluated for Overvoltage Category II;

2) The Phase-to-Ground Rated System Voltage used in the determination of clearances shall be the equipment rated supply voltage rounded to the next higher value.

3) To determine equivalence with current through air spacings requirements an impulse test potential having a value as determined in UL 840 is to be applied.

b) For evaluation of creepages:

1) Any printed wiring board which complies with the requirements for Direct Support in the Standard for Printed-Wiring Boards, UL 796, provides a Comparative Tracking Index (CTI) of 100;

2) Printed wiring boards are evaluated as Pollution Degree 2 when adjacent conductive material is covered by any coating, such as a solder mask, which provides an uninterrupted covering over at least one side and the complete distance up to the other side of conductive material;

3) Printed-wiring boards shall be evaluated as Pollution Degree 1 under one of the following conditions:

i) A coating which complies with the requirements for Conformal Coatings in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, or

ii) At a specific printed wiring board location by application of at least a 1/32 inch (0.79 mm) thick layer of silicone rubber or through potting, without air bubbles, in epoxy or potting material.

Table 26A.1
Overvoltage categories

Appliance	Overvoltage category
Control located in low-voltage circuit	I
Load Level. Appliances and portable equipment connected to the distribution level, Category III.	II
Distribution Level. Fixed wiring and associated equipment (not electrical loads) connected to the primary supply level.	III
NOTE – Applicable to low-voltage circuits if a short circuit between the parts involved may result in operation of the controlled equipment that would increase the risk of fire or electric shock.	

Table 26A.2
Material group

CTI PLC value of insulating materials	Material group
CTI ≥ 600 (PLC = 0)	I
400 ≤ CTI < 600 (PLC = 1)	II
175 ≤ CTI < 400 (PLC = 2 or 3)	IIIa
100 ≤ CTI < 175 (PLC = 4)	IIIb
NOTE – PLC stands for Performance Level Category, and CTI stands for Comparative Tracking Index as specified in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A.	

Table 26A.3
Pollution degrees

Appliance control microenvironment	Pollution degree
No pollution or only dry, nonconductive pollution. The pollution has no influence. Typically hermetically sealed or encapsulated control without contaminating influences, or printed wiring boards with a protective coating can achieve this degree.	1
Normally, only nonconductive pollution. However, a temporary conductivity caused by condensation may be expected. Typically indoor appliances for use in household or commercial clean environments achieve this degree.	2
Conductive pollution, or dry, nonconductive pollution that becomes conductive due to condensation that is expected. Typically controls located near and may be adversely affected by motors with graphite or graphite composite brushes, or outdoor use appliances achieve this degree.	3

26B Switch Mode Power Supplies

26B.1 Bridging components – switch mode power supplies

26B.1.1 Components connected between the primary and secondary circuits of an isolating device such as a switching transformer or between primary and secondary earth reference points shall be evaluated to provide the specified level of isolation for the application under normal and abnormal (single component fault) conditions.

26B.1.2 An optical isolator that is relied upon to provide feedback between primary and secondary circuits of a switch mode power supply shall comply with the Standard for Optical Isolators, UL 1577. It shall have a minimum isolation voltage of 1500V.

26B.1.3 A capacitor connected between primary and accessible secondary circuits shall comply with Capacitors, Section 21. This shall consist of a single Class Y1 capacitor or two Class Y2 capacitors connected in series.

26B.2 Transformer insulation system

26B.2.1 Insulation used within a transformer of switch mode power supply shall comply with the Standard for Systems of Insulating Materials, UL 1446, for the specified temperature class of the insulation system or the Standard for Single- and Multi-Layer Insulated Winding Wire, UL 2353.

PROTECTION AGAINST INJURY TO PERSONS

27 General

27.1 If the operation and maintenance of an appliance by the user involves the risk of injury to persons, protection shall be provided to reduce the risk.

27.2 With respect to the requirement in 27.1, consideration shall be given to reasonably foreseeable misuse of the appliance.

27.3 A functional attachment that is made available or recommended by the manufacturer for use with the basic appliance shall be included in the investigation of the appliance. Unless the manufacturer recommends the use of two or more attachments at the same time, only one attachment at a time is to be investigated with the appliance.

27.4 Whether a guard, a release, an interlock, or the like is required and whether such a device is adequate shall be determined from an investigation of the complete appliance, its operating characteristics, and the likelihood of a risk of injury to persons resulting from a cause other than gross negligence. The investigation shall include consideration of the results of breakdown or malfunction of any one component, but not more than one component at a time, unless one event contributes to another. If the investigation shows that breakdown or malfunction of a particular component can result in a risk of injury to persons, that component shall be investigated for reliability.

28 Sharp Edges

28.1 An enclosure, a frame, a guard, a handle, or the like shall not be sufficiently sharp to constitute a risk of injury to persons in normal maintenance and use.

Exception: This requirement does not apply to a part or portion of a part needed to perform a working function.

29 Enclosures and Guards

29.1 The rotor of a motor, a pulley, a belt, a gear, a fan, or other moving part that could cause injury to persons shall be enclosed or provided with means to reduce the likelihood of unintentional contact therewith, and such a part shall not be contacted by the probe illustrated in Figure 9.1.

Exception No. 1: An opening in the integral enclosure of a motor that is not used in either a hand-held appliance or a hand-supported portion of an appliance is acceptable if a moving part cannot be contacted by the probe illustrated in Figure 9.2.

Exception No. 2: A part or portion of a part that is necessarily exposed to perform the work function need not be enclosed but, when necessary, guarding shall be provided. See 29.4.

29.2 During the examination of an appliance to determine whether it complies with the requirements in 29.1, a part of the enclosure that may be removed without the use of a tool (to attach an accessory, to make an operating adjustment, or for other reasons) is to be opened or removed.

Exception: A part need not be opened or removed provided the appliance is marked in accordance with 36.8.

29.3 Among the factors to be considered in judging the acceptability of an exposed moving part are:

a) The degree of exposure necessary to perform the intended function;

b) The sharpness of the moving part;

c) The likelihood of unintentional contact therewith;

d) The speed of the moving part; and

e) The likelihood that a part of the body would be endangered or that clothing would be entangled by the moving part, resulting in a risk of injury to persons.

These factors are to be considered with respect to both intended operation of the appliance and any reasonably foreseeable misuse.

29.4 Some guards are required to be self-restoring. Other features of guards that are to be considered include:

a) Removability without the use of a tool;

b) Removability for servicing;

c) Strength and rigidity;

d) Completeness;

e) Creation of a risk of injury to persons such as a pinch point, and the necessity for additional handling because of the increased need for servicing, such as for cleaning, unjamming, and the like; and

f) Usage – household or commercial.

29.5 An enclosure or guard over a rotating part shall retain a part that, because of breakage or other reasons, may become loose or may separate from a rotating part, and retain a foreign object that may be struck and propelled by the rotating part.

29.6 If complete guarding of a moving part that could obviously cause injury to persons would defeat the utility of an appliance,

a) A control, such as a momentary contact switch, shall be provided; and

b) An appropriate marking shall be provided in the instruction manual warning the user of the potential risk.

30 Materials

30.1 The material of a part – such as an enclosure, a frame, a guard, or the like – the breakage or deterioration of which may result in a risk of injury to persons shall have such properties as to meet the demand of expected loading conditions.

30.2 The requirement in 30.1 applies to those portions of a part adjacent to a moving part considered to involve a risk of injury to persons.

31 Rotating or Moving Members

31.1 A rotating or moving part that, if it should become disengaged, may create a risk of injury to persons shall be provided with a means to retain the part in place under conditions of use.

31.2 A rotating member, the breakage of which may create a risk of injury to persons, shall be constructed to reduce the likelihood of its breakage, or the release or loosening of a part that could become a risk of injury to persons.

31.3 To determine whether an appliance employing a series motor complies with the requirement in 31.2, it shall be tested as described in 31.4. A part that can become a risk of injury to persons shall not work loose.

31.4 For the test required by 31.3, an appliance employing a series motor is to be operated for 1 minute at the no-load speed resulting from application of 1.3 times rated voltage. An appliance in which the rotating load may be varied is to be tested for each condition of loading that can occur.

32 Parts Subject to Pressure

32.1 A pressure vessel having an inside diameter more than 6 inches (152 mm), subjected to a pressure more than 15 psig (102 kPa), and eligible to be covered by the National Board of Boiler and Pressure Vessel Inspectors shall be marked in accordance with the appropriate boiler and pressure vessel code symbol of the American Society of Mechanical Engineers (ASME) for a working pressure not less than the pressure determined in accordance with 32.3.

32.2 A pressure vessel, because of its application, not covered by the scope of the inspection procedure of the ASME code shall be constructed so that it will comply with the requirements in 32.3.

32.3 A part or an assembly that is subject to air or vapor pressure, including the vapor pressure in a vessel containing only a superheated fluid, during normal or abnormal operation shall withstand a pressure equal to the highest of the following that is applicable.

a) Five times the pressure corresponding to the maximum setting of a pressure-reducing valve provided as part of the assembly, but not more than five times the marked maximum supply pressure from an external source and not more than five times the pressure setting of a pressure-relief device provided as a part of the assembly.

b) Five times the marked maximum supply pressure from an external source, unless the pressure is limited by a pressure-relief device in accordance with 32.3(a).

c) Five times the pressure setting of a required pressure-relief device.

d) Five times the maximum pressure that can be developed by an air compressor that is part of the assembly unless the pressure is limited by a pressure-relief device in accordance with 32.3(a).

e) Five times the working pressure marked on the part.

Exception No. 1: This requirement does not apply to a section of a pressure system constructed of continuous tubing or of lengths of tubing connected by hard-soldered, brazed, or welded joints, provided the wall thickness of tubing is not less than the value specified in Table 32.1.

Exception No. 2: This requirement does not apply to a pressure vessel bearing the ASME code inspection symbol – other than the UM symbol – provided the vessel is marked with a value of working pressure not less than that to which it is subjected during normal or abnormal operation.

32.4 If a test is necessary to determine whether a part complies with the requirements in 32.3, two samples of the part are to be subjected to a hydrostatic pressure test. Each sample is to be filled with water so as to exclude air, and is to be connected to a hydraulic pump. The pressure is to be raised gradually to the specified test value, and is to be held at that value for 1 minute. The results are not acceptable if either sample bursts or leaks.

Exception: Leakage or rupture of a nonmetallic fluid transfer line and its connections, or at a gasket is acceptable if repeated tests conducted with the media they are intended to contain show no evidence of presenting a risk of injury to persons or an electric shock.

32.5 A part supported or actuated hydraulically that could result in a risk of injury to persons due to pressure loss shall comply with the requirement in 32.4 when tested at a pressure equal to five times the maximum pressure capable of being developed in the system.

Table 32.1
Wall thickness for copper and steel tubing

Outside diameter,		Minimum wall thickness,		Maximum pressure to which tubing is subjected, PSIG (MPa)					
				Seamless copper		Butt-welded steel		Seamless steel	
Inch	(mm)	Inch	(mm)	Inch	(mm)	Inch	(mm)	Inch	(mm)
3/8 or smaller	(9.5)	0.016	(0.41)	500	(3.45)	600	(4.14)	1000	(6.90)
1/2	(12.7)	0.016	(0.41)	400	(2.76)	480	(3.31)	800	(5.52)
5/8	(15.9)	0.016	(0.41)	320	(2.21)	384	(2.65)	640	(4.42)
5/8	(15.9)	0.021	(0.53)	420	(2.90)	504	(3.48)	840	(5.80)
3/4	(19.0)	0.021	(0.53)	360	(2.48)	432	(2.98)	720	(4.97)
3/4	(19.0)	0.025	(0.64)	420	(2.90)	504	(3.48)	840	(5.80)
1	(25.4)	0.021	(0.53)	260	(1.79)	312	(2.15)	520	(3.59)
1	(25.4)	0.025	(0.64)	320	(2.21)	384	(2.65)	640	(4.42)

33 Pressure-Relief Devices

33.1 A means for relieving pressure shall be provided for a part in which pressure might be generated by an external source of heat.

33.2 A pressure-relief device, a fusible plug, a soldered joint, nonmetallic tubing, or other equivalent pressure-relief means may be employed to comply with the requirement in 33.1.

33.3 A pressure-relief device is considered to be a pressure-actuated valve or rupture member intended to relieve excessive pressures automatically.

33.4 There shall be no shut-off valve between the pressure-relief means and the parts that it is intended to protect.

33.5 A vessel having an inside diameter of more than 3 inches (76 mm) and subject to air or steam pressure generated or stored within the appliance shall be provided with a pressure-relief device.

33.6 The start-to-discharge pressure setting of a pressure-relief device shall not be higher than the working pressure marked on the vessel. The discharge rate of the device shall be adequate to relieve the pressure.

33.7 A pressure-relief device shall:

a) Be connected as close as possible to the pressure vessel or part of the system that it is intended to protect;

b) Be installed so that it is readily accessible for inspection and repair, and cannot be readily rendered inoperative so that it will not perform its intended function; and

c) Have its discharge opening located and directed so that:

1) Operation of the device will not deposit moisture on bare live parts or on insulation or components detrimentally affected by moisture; and

2) There is little likelihood of scalding persons.

33.8 A pressure-relief device having an adjustable setting is judged on the basis of the maximum setting unless the adjusting means is reliably sealed at a lower setting.

33.9 The control that limits the pressure in a vessel required to have a pressure-relief device shall perform under rated load for 100,000 cycles of operation, and shall operate so that the pressure does not exceed 90 percent of the relief-device setting under any condition of normal operation.

33.10 A pressure-relief device shall comply with the requirements specified as follows:

a) The Standard for Relief Valves for Hot Water Supply Systems, ANSI Z21.22 or the ASME Boiler and Pressure Vessel Code – Rules for Construction of Power Boilers, BPVC-1 or ASME Boiler and Pressure Vessel Code – Rules for Construction of Heating Boilers, BPVC-IV. Its marked output capacity rating shall be at least 3.5 lbs. of steam per hour per kilowatt of heating element rating.

b) Requirements for pressure-limit controls in the Standard for Limit Controls, UL 353.

c) Requirements for refrigeration pressure-limiting controls in the Standard for Temperature-Indicating and -Regulating Equipment, UL 873, or the Standard for Automatic Electrical Controls for Household and Similar Use, Part 1: General Requirements, UL 60730-1 and the Standard for Automatic Electrical Controls for Household and Similar Use; Part 2: Particular Requirements for Automatic Electrical Pressure Sensing Controls Including Mechanical Requirements, UL 60730-2-6, with the parameters specified in Table 33.1.

d) Construction that provides equivalent protection as that specified in Items (a), (b), or (c).

Table 33.1
Pressure-relief device parameters

UL 60730-2-6, Table 7.2DV item number	Information	Control requirement
6	Purpose of control	Protective control
7	Type of load controlled	Pilot duty (electric valve)
27	Number of automatic cycles (A)	100,000
29	Type of disconnection or interruption	Full-disconnection
36	Limits of activating quantity	Factory pressure setting
39	Type 1 or Type 2 action	Type 2
40	Additional features	Manual reset, Type (2) D, J action
41	Manufacturing Deviation, maximum	The operating pressure of a pressure control shall be within plus or minus 5 percent of its set point pressure
42	Drift	The operating pressure shall not vary from the operating pressure initially determined by more than 5 percent of the maximum set point pressure.
49	Pollution degree	Table 23.3
52	The minimum parameters of any heat dissipater (heat sink) not provided with an electronic control but essential to its correct operation	Must be specified
53	Output waveform if other than sinusoidal	Must be specified
58a	Required protection/immunity from mains borne perturbations, magnetic and electromagnetic disturbances	Required[a]
60	Surge immunity	The Standard for Electromagnetic compatibility (EMC) – Part 4-5: Testing and Measurement Techniques – Surge Immunity Test, IEC 61000-4-5 installation Class 3, Overvoltage category III
69	Software class	B
74	External load and emission control measures to be used for test purposes	Intended electric valve

[a] For the purpose of the tests specified in Annex H, in the Standard for Automatic Electrical Controls for Household and Similar Use, Part 1: General Requirements, UL 60730-1, the products covered by this end product standard should be considered as:

a) Installation Class 3 (See the Annex for Explanatory Notes for Surge Immunity Test in UL 60730-1);

b) Overvoltage Category II; and

c) Test Level 3.

34 Switches, Controls, and Interlocks

34.1 An appliance shall be constructed so as to reduce the likelihood of unexpected operation of any part capable of causing injury to persons.

34.2 Each function of a multiple-function appliance is to be taken into consideration in determining whether the appliance complies with the requirements in 34.1.

34.3 If, when energized, an appliance has a moving part that may cause injury to persons, a motor control switch, other than a momentary-contact switch, shall be provided on the appliance. See 36.5.

34.4 If unintentional operation of a switch can result in a risk of injury to persons, the actuator of the switch shall be located or guarded so that such operation is unlikely.

34.5 The actuator of a switch may be guarded by recessing, ribs, barriers, or the like.

34.6 The actuator of an interlock switch shall be located so that unintentional operation is unlikely.

34.7 Operation of an interlock in normal use shall not inconvenience the operator so as to encourage deliberate defeat of the interlock.

34.8 An interlock shall not be capable of being defeated by materials such as wood or metal chips that could accumulate in normal use.

34.9 An interlock shall be such that it cannot be defeated readily:

a) Without damaging the appliance,

b) Without making wiring connections or alterations;

c) By using materials that are readily available.

34.10 If an interlock is actuated by movement of a guard, the arrangement shall be such that the guard is in place when the interlock is in the position that permits operation of the parts being guarded. With the guard removed, the interlock shall comply with the requirements in 34.6.

34.11 A device that automatically starts an appliance, such as a timer, an automatically reset overload-protective device, or the like, shall not be employed unless it can be demonstrated that automatic starting will not result in a risk of injury to persons.

35 Printed-Wiring Boards

35.1 A printed-wiring board shall comply with the Standard for Printed-Wiring Boards, UL 796. The printed-wiring board shall have a minimum V-2 flammability rating as specified in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, and have a temperature rating not less than the temperatures attained in accordance with Temperature Test, Section 45.

Exception: A printed-wiring board in a Class 2 circuit having a minimum HB flammability rating in accordance with UL 94 meets the intent of this requirement.

36 Marking

36.1 An appliance having a hidden or unexpected risk of injury to persons shall be marked to inform the user of the risk.

36.2 A cautionary marking shall be permanent and legible and shall be located on a permanent part of the appliance. See Permanence of Marking, Section 37.

36.3 A cautionary marking intended to instruct the operator shall be legible and visible from the position normally assumed by the operator when starting the appliance or from the position normally assumed for the specific operation involved. Other such markings for servicing or making settings and adjustments shall be legible and visible to the individual when such work is being accomplished.

36.4 A marking intended to inform the user of a risk of injury to persons shall be prefixed by a signal word "CAUTION," "WARNING," or "DANGER." The marking shall be in letters not less than 3/32 inches (2.4 mm) high. The signal word shall be more prominent than any other required marking on the appliance.

36.5 If, when energized, an appliance has a moving part that may cause injury to persons, a switch that controls the motor that drives the part shall have a plainly marked "off" position.

Exception: A momentary-contact switch need not comply with this requirement.

36.6 The literature accompanying a package containing a basic appliance and attachments intended to be marketed as a complete unit shall indicate what attachments are intended for use with the basic appliance if use of such attachments may expose the user to a risk of injury.

36.7 An attachment that is packaged and marketed separately from the basic appliance and recommended by the manufacturer for use on the basic appliance shall be marked to identify the basic appliance with which it is intended to be used. The identification shall appear in at least one of the following locations:

a) On the attachment;

b) On the package housing the attachment;

c) In the instruction book for the basic appliance; or

d) In information furnished with the attachment.

36.8 An appliance having a part of an enclosure as described in the Exception to 29.2 shall be marked to indicate that such servicing is to be done with the appliance disconnected from the supply circuit.

37 Permanence of Marking

37.1 A marking required to be permanent shall be molded, die-stamped, paint-stenciled, stamped, or etched on metal, or indelibly stamped on a pressure-sensitive label secured by adhesive that, upon investigation, is found to be acceptable. Ordinary usage, handling, storage, and the like, of equipment shall be considered in determination of the permanence of a marking.

37.2 Unless it has been investigated and found to be acceptable for the application, a pressure-sensitive label or a label secured by cement or adhesive that is required to be permanent shall comply with the requirements in the Standard for Marking and Labeling Systems, UL 969.

37.3 The cautionary markings specified in 58.4 and 63.1.1 may be provided in the form of a flag-type tag with an adhesive back. The tag is to be wrapped around and adhered to the cord, and the ends of the tag are to adhere to each other and project as a flag. The tag shall be tear-resistant and permanently affixed to the cord set. The leading edge of the tag shall be located within 18 inches (46 cm) of the point where the cord enters the body of the attachment plug. The marking itself shall be indelible.

37.4 To determine compliance with 37.3 representative tags that have been subjected to the tests described in 37.5 – 37.13 shall meet the following requirements:

a) The tag shall resist tearing for longer than 1/16 inch (1.6 mm) at any point;

b) The tag shall not separate from the cord;

c) The tag shall not slip or move along the length of the cord set more than 1/2 inch (13 mm) and there shall not be any visible damage to the cord;

d) There shall not be any permanent shrinkage, deformation, cracking, or any other condition that will render the marking on the tag illegible; and

e) Overlamination, if provided, shall remain in place and shall not be torn or otherwise damaged. The printing shall remain legible.

37.5 For each type of conditioning mentioned in 37.6 – 37.9, three tags applied to the cord sets in the intended manner are to be used. Tests are to be conducted no sooner than 24 hours after application of the tag.

37.6 Each of three tags is to be tested as received.

37.7 Each of three tags is to be tested after 30 minutes of conditioning at 23.0 ±2.0°C (73.4 ±3.6°F) and 50 ±5 percent relative humidity, following 240 hours of conditioning in an air-circulating oven at 60 ±1°C (140 ±1.8°F).

37.8 Each of three tags is to be tested within 1 minute after being exposed for 72 hours to a relative humidity of 85 ±5 percent at a temperature of 32.0 ±2.0°C (89.6 ±3.6°F).

37.9 If the tag is intended to be applied to an outdoor cord (W), it is to be conditioned as follows and in 37.10 – 37.12. Each of three tags is to be tested after 24 hours of exposure conditioning at 23 ±2°C (73.4 ±3.6°F) and 50 ±5 percent relative humidity, followed by 48 hours of immersion to a depth of not less than 1/8 inch (3.2 mm) in demineralized water at a temperature of 23°C (73.4°F).

37.10 Each of three tags is to be tested after 24 hours of exposure conditioning at 23.0 ±2.0°C (73.4 ±3.6°F) and 50 ±5 percent relative humidity, followed by 10 days of exposure in an air-circulating oven at a temperature of 60°C (140°F).

37.11 Each of three tags is to be tested after 24 hours of exposure conditioning at 23.0 ±2.0°C (73.4 ±3.6°F) and 50 ±5 percent relative humidity, followed by 7 hours of exposure in a cold box at a temperature of -10 ±2°C (14.0 ±3.6°F).

37.12 Each of three tags is to be tested after 24 hours of exposure conditioning at 23.0 ±2.0°C (73.4 ±3.6°F) and 50 ±5 percent relative humidity, followed by exposure to ultraviolet light and water spray with ultraviolet light by using either of the following apparatus:

a) A Twin-Enclosed Carbon-Arc Weatherometer, (Type D or DH), as described in the Standard Practice for Operating Open Flame Carbon Arc Light Apparatus for Exposure of Nonmetallic Materials, ASTM G 152 and ASTM G 153. Each of the tags is to be exposed to 720 hours of ultraviolet light and water spray with ultraviolet light. The operating cycle is to be 20 minutes; 17 minutes of ultraviolet light only and 3 minutes of water spray and ultraviolet light; or

b) A Xenon-Arc Weatherometer, (Type B or similar apparatus), as described in the Standard Practice for Operating Xenon Arc Light Apparatus for Exposure of Non-Metallic Materials, ASTM G 155. Each of the tags is to be exposed to 1000 hours of ultraviolet light and water spray with ultraviolet light. The exposure shall be in accordance with Method A, with continuous exposure to ultraviolet light and intermittent water spray with ultraviolet light, using a programmed cycle of 120 minutes (102 minute ultraviolet light exposures and an 18 minute exposure to water spray with ultraviolet light). The apparatus shall include a 6500 W, water-cooled xenon-arc lamp, borosilicate glass inner and outer optical filters, a spectral irradiance of 0.35 W/m^2 at 340 nm and a black-panel temperature of 63.0 ±3.0°C (145.0 ±5.4°F).

37.13 Each test is to be performed on a length of cord to which the tag has been applied. The cord set, with the attachment plug pointing up, is to be held taught in a vertical plane. A force of 5 pounds force (22.2 N), which includes the weight of the clamp, is to be applied for 1 minute to the uppermost corner of

the tag farthest from the cord set, within 1/4 inch (6.4 mm) of the vertical edge of the tag. The force is to be applied by affixing a C-clamp with a pad diameter of 3/8 inch (9.5 mm) to the tag and securing the weight to the C-clamp. The force is to be applied vertically downward in a direction parallel to the major axis of the cord. To determine compliance with 37.4(d), manipulation is permissible, such as straightening of the tag by hand. To determine compliance with 37.4(e), each tag is to be scraped 10 times vertically across printed areas and edges, with a force of approximately 2 pounds force (9 N), using the edge of a 5/64 inch (2.0 mm) thick steel blade held at a right angle to the test surface. The edges of the steel blade are to be just rounded so as not to be sharp.

PERFORMANCE

38 General

38.1 Other than as noted in 38.2, equipment shall comply with the tests described in Sections 39 – 52. The tests shall be conducted at rated frequency and at the test potential specified in Table 38.1.

Table 38.1
Test voltages

Voltage rating of test product, volts[a]	Test potential, volts
110 – 120	120
200 – 208	208
220 – 240	240
254 – 277	277
440 – 480	480
550 – 600	600

[a] If a single voltage rating of a product does not fall within any of the indicated voltage ranges, the product is to be tested at its rated voltage. If a range of voltages is specified and one or more of the values fall within one of the indicated voltage ranges, the product is to be tested at the test potential specified for the indicated range or the highest value of the rating, whichever is greater. If a range of voltages is specified and none of the values fall within any of the indicated voltage ranges, the product shall be tested at the highest value in the specified range. For a product with a dual rating, the product is to be tested based on both ratings unless it can be shown that testing based on one rating would represent testing based on the other rating.

38.2 A secondary circuit powered by a Class 2 transformer that complies with the Standard for Low Voltage Transformers – Part 1: General Requirements – UL 5085-1 and the Standard for Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers – UL 5085-3, a low-voltage circuit, or equipment powered by a battery in accordance with 4.12 is not required to be subjected to the tests described in Sections 39 – 52.

39 Power Input Test

39.1 The power input to the equipment shall not exceed the marked rating by more than 10 percent when it is operated under the conditions of normal use while connected to a supply circuit as specified in Table 38.1.

40 Leakage Current Test

40.1 The leakage current of cord-and-plug-connected equipment rated for a nominal 120-, 208-, or 240-volt supply when tested in accordance with 40.3 – 40.8 shall not be more than:

a) 0.5 mA for an ungrounded 2-wire appliance;

b) 0.5 mA for a grounded 3-wire portable appliance; and

c) 0.75 mA for a grounded 3-wire stationary or fixed-in-place appliance;

1) Employing a standard attachment plug rated 20 A or less; and

2) Intended to be fastened in place or located in a dedicated space.

40.2 Leakage current refers to all currents, including capacitively coupled currents, that may be conveyed between exposed conductive surfaces of the equipment and ground or other exposed surfaces of the equipment.

40.3 All exposed conductive surfaces are to be tested for leakage currents. Leakage currents from these surfaces are to be measured to the grounded supply conductor individually as well as collectively if simultaneously accessible, and from one surface to another if simultaneously accessible. A part is considered to be exposed unless it is guarded by an enclosure that is acceptable for protection against the risk of electric shock. Surfaces are considered to be simultaneously accessible if they can be readily contacted by one or both hands of a person at the same time. These measurements do not apply to terminals operating at voltages that are not considered to involve a risk of electric shock. If all accessible surfaces are bonded together and connected to the grounding conductor of the power-supply cord, the leakage current can be measured between the grounding conductor and the grounded supply conductor.

40.4 If a conductive surface other than metal is used for the enclosure, or part of the enclosure, the leakage current is to be measured using a metal foil with an area of 10 by 20 centimeters (3.9 by 7.8 inches) in contact with the surface. If the surface is less than 10 by 20 centimeters, the metal foil is to be the same size as the surface. The metal foil is not to remain in place long enough to affect the temperature of the equipment.

40.5 The measurement circuit for leakage current is to be as illustrated in Figure 40.1. The measurement instrument is defined in 40.5 (a) – (c). The meter that is actually used for a measurement need only indicate the same numerical value for a particular measurement as would the defined instrument; it need not have all the attributes of the defined instrument.

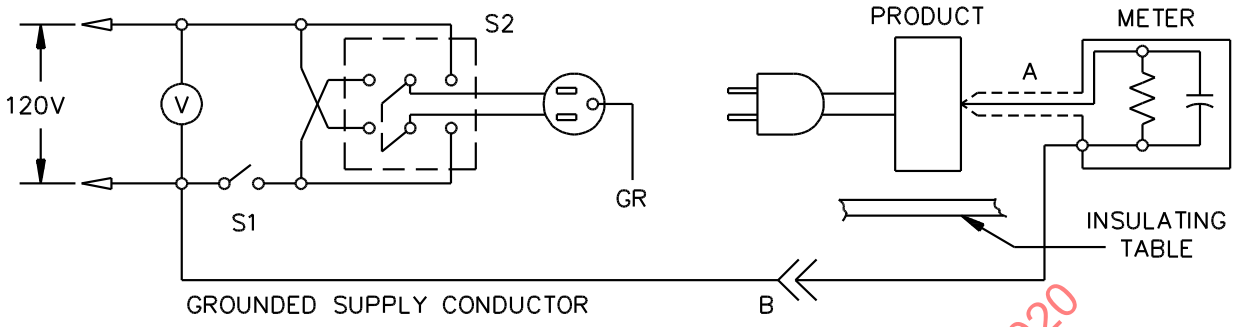
a) The meter is to have an input impedance of 1500 ohms resistive shunted by a capacitance of 0.15 microfarad.

b) The meter is to indicate 1.11 times the average of the full-wave rectified composite waveform of voltage across the resistor or current through the resistor.

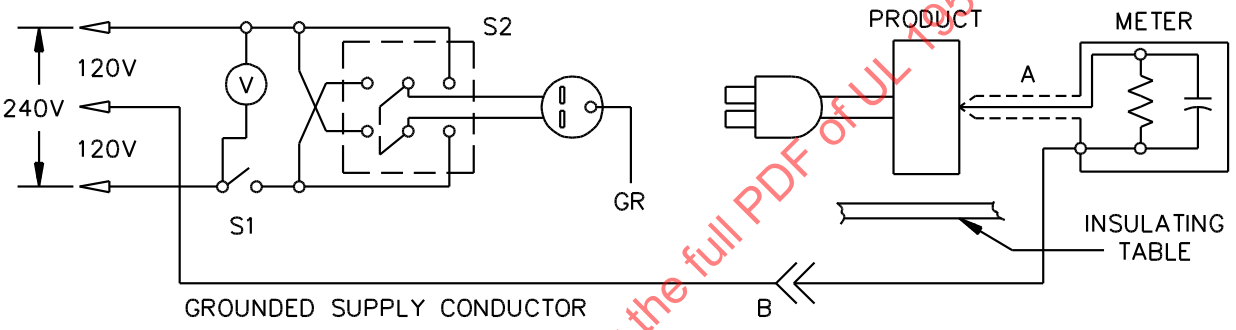
c) Over a frequency range of 0 – 100 kilohertz, the measurement circuitry is to have a frequency response – ratio of indicated to actual value of current – that is equal to the ratio of the impedance of a 1500-ohm resistor shunted by a 0.15-microfarad capacitor to 1500 ohms. At an indication of 0.75 milliampere, the measurement is to have an error of not more than 5 percent of 60 hertz.

Figure 40.1

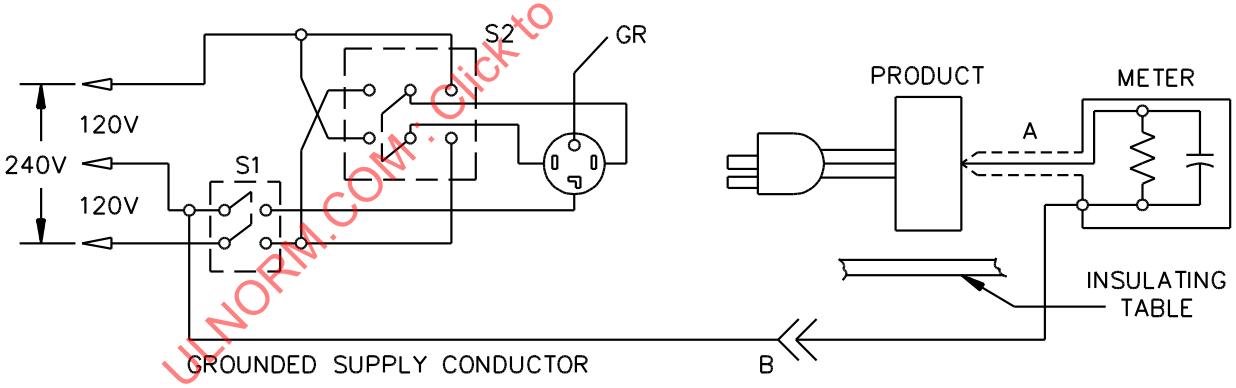
Leakage current measurement circuit



Product intended for connection to a 120–volt power supply, as illustrated above.



Product intended for connection to a 3–wire, grounded neutral power supply, as illustrated above.



Product intended for connection to a 3–wire, grounded neutral power supply, as illustrated above.

LC300J

NOTES –

A – Probe with shielded lead.

B – Separated and used as clip when measuring currents from one part of product to another.

40.6 Unless the meter is being used to measure leakage from one part of the equipment to another, the meter is to be connected between the accessible parts and the grounded supply conductor.

40.7 A sample of the equipment is to be tested for leakage current starting with the as-received condition – the as-received condition being without prior energization except as may occur as part of the production-line testing. The grounding conductor is to be open at the attachment plug. The supply voltage is to be in accordance with Table 38.1. The test sequence, with reference to the measuring circuit, Figure 40.1, is to be as follows:

a) With switch S1 open, the equipment is to be connected to the measuring circuit. Leakage current is to be measured using both positions of switch S2, and with the equipment switching devices in all their normal operating positions.

b) Switch S1 is then to be closed energizing the appliance and within 5 seconds the leakage current is to be measured using both positions of switch S2, and with the equipment switching devices in all their normal operating positions.

c) The leakage current is to be monitored until thermal stabilization. Both positions of switch S2 are to be used in determining this measurement. Thermal stabilization is to be obtained by operation as in the normal temperature test. The appliance shall be operated as described in Section 45, Temperature Test.

40.8 Normally the complete leakage-current-test program as described in 40.7 is to be conducted without interruption for other tests. However, with the concurrence of those concerned, the leakage current test may be interrupted to conduct other nondestructive tests.

40.9 The test sample is to be installed in a manner so that all parallel ground paths, such as through plumbing lines, will be eliminated.

41 Leakage Current Following Humidity Conditioning Test

41.1 Cord-and-plug-connected equipment rated for a nominal 120-, 208-, or 240-volt supply shall comply with the requirements for Leakage Current Test, Section 40, following exposure for 48 hours to air having a relative humidity of 88±2 percent at a room temperature of 32.0±2.0°C (89.6±3.6°F).

41.2 To determine whether equipment complies with the requirement in 41.1, a sample of the equipment is to be heated to a temperature just above 34° C (93° F) to reduce the likelihood of condensation of moisture during conditioning. The heated sample is to be placed in the humidity chamber and is to remain for 48 hours under the conditions specified in 41.1.

41.3 Following the conditioning, the sample is to be tested unenergized as described in 40.7 (a). The sample is then to be energized and tested as described in 40.7 (b) and (c). The test is to be discontinued when the leakage current stabilizes or decreases.

42 Insulation Resistance Following Humidity Conditioning Test

42.1 Equipment intended to be permanently connected electrically shall have an insulation resistance of at least 50,000 ohms between current-carrying parts and noncurrent-carrying parts after humidity conditioning as specified in 41.1 and 41.2.

42.2 Insulation resistance to be measured by applying a direct-current potential of 250 volts between live parts and the enclosure and other exposed dead metal parts, using two voltmeters – one voltmeter being connected across the supply line and the other connected in series with one of the leads to the equipment being tested. Designating the reading of the line voltage as V_1, the reading of the other voltmeter as V_2, and the resistance of the latter as R, the insulation resistance is to be calculated by the formula:

$$Insulation\ \ Resistance = \frac{(V_1 - V_2)R}{V_2}$$

Exception: Means providing equivalent results, such as a megohmmeter, can be used for conducting the insulation-resistance test.

43 Continuity of Grounding Circuit Test

43.1 The resistance shall be not more than 0.1 ohm between any point required to be grounded and:

a) For equipment intended for permanent electrical connection, the point on the enclosure at which the power-supply system will be connected.

b) For cord-connected equipment, the point to which the grounding conductor of the power-supply cord is connected.

43.2 Whether equipment complies with the requirements in 43.1 may be determined by any acceptable instrument. If the results are unacceptable, an alternating current of at least 20 amperes from a power supply of not more than 12 volts is to be passed from the point of connection of the equipment grounding means to the metal part in the grounding circuit, and the resulting drop in potential is to be measured between the two points. The resistance in ohms is to be determined by dividing the drop in potential in volts by the current in amperes passing between the two points. The grounding conductor of a power-supply cord is not to be included in this measurement.

44 Starting-Current Test

44.1 Equipment shall be capable of starting and operating as intended according to the requirements in 44.2 on a branch circuit protected by a fuse which is other than a time-delay type that has a current rating corresponding to that of the branch circuit to which the equipment is intended to be connected.

Exception: This requirement does not apply if each of the following conditions is satisfied:

a) The construction of the equipment or the nature of its use is such that the equipment is likely to be used on the same branch circuit after installation;

b) The equipment will start and operate normally on a circuit protected by a time-delay fuse; and

c) The equipment is marked in accordance with 57.5.

44.2 In a test to determine whether equipment complies with the requirement in 44.1, the equipment is to be started three times from standstill without opening the fuse. The equipment is to be at room temperature at the beginning of the test. The test is to be conducted at the voltage specified in Table 38.1 and at rated frequency. Each start is to be made under conditions representing the beginning of the intended operation (the beginning of the intended operating cycle in the case of automatic equipment), and any motor is to be allowed to come to rest between successive starts. Tripping of an overload protector provided as part of the equipment or opening of the fuse constitutes an unacceptable condition.

45 Temperature Test

45.1 Equipment, when operated under conditions of intended load and while connected to a supply circuit as described in 39.1, and while the unit is handling water at its maximum rated temperature and pressure shall not attain a temperature at any point higher than the temperatures specified in Table 45.1.

Table 45.1
Maximum temperatures

Materials and components	°C	°F
A. MOTORS AND TRANSFORMERS		
1. Class 105 insulation systems on coil windings of an a-c motor having a diameter of 7 inches (178 mm) or less, not including a universal motor, and of a vibrator coil[a]		
a. In an open motor:		
Thermocouple or resistance method	100	212
b. In a totally enclosed motor:		
Thermocouple or resistance method	105	221
2. Class 105 insulation systems on coil windings of an a-c motor having a diameter of more than 7 inches, of a d-c motor, and of a universal motor[a]		
a. In an open motor:		
Thermocouple method	90	194
Resistance method	100	212
b. In a totally enclosed motor:		
Thermocouple method	95	203
Resistance method	105	221
3. Class 130 insulation systems on coil windings of an a-c motor having a diameter of 7 inches or less, not including a universal motor[a]		
a. In an open motor:		
Thermocouple or resistance method	120	248
b. In a totally enclosed motor:		
Thermocouple or resistance method	125	257
4. Class 130 insulation systems on coil windings of an a-c motor having a diameter of more than 7 inches, of a d-c motor, and of a universal motor[a]		
a. In an open motor:		
Thermocouple method	110	230
Resistance method	120	248
b. In a totally enclosed motor:		
Thermocouple method	115	239
Resistance method	125	257
5. Coil windings of transformers		
a. Class 105 insulation systems:		
Thermocouple method	90	194
Resistance method	100	212
b. Class 130 insulation systems:		
Thermocouple method	110	230
Resistance method	120	248
B. COMPONENTS		
1. Capacitors		

Table 45.1 Continued on Next Page

Table 45.1 Continued

Materials and components	°C	°F
a. Electrolytic[b]	65	149
b. Other types[c]	90	194
2. Fuses		
Classes G, J, L, T, and CC:		
Tube	125	257
Ferrule or blade	110	230
Others	90	194
3. Relay, solenoid, and coils (except motors and transformers) with		
a. Class 105 insulation systems:		
Thermocouple method	90	194
Resistance method	110	230
b. Class 130 insulation systems:		
Thermocouple method	110	230
Resistance method	130	266
4. Printed-wiring boards	d	d
C. CONDUCTORS		
1. Rubber- or thermoplastic-insulated wires and cords[c]	60	140
2. Copper conductors		
a. A diameter less than 0.015 inch (0.38 mm)	150	302
b. A diameter of 0.015 inch or more	300	392
c. Plated with nickel, gold, silver, or a combination of these	250	482
D. ELECTRICAL INSULATION – GENERAL		
1. Fiber used as electrical insulation	90	194
2. Phenolic composition used as electrical insulation		
a. Laminated	125	257
b. Molded	150	302
3. Varnished-cloth insulation	85	185
E. SURFACES		
1. A surface upon which a unit is placed or mounted in service, and surfaces that are adjacent to the unit when it is so placed, or mounted	90	194
2. Any point within a terminal box or wiring compartment of a permanently connected appliance in which power supply conductors are to be connected, including such conductors themselves, unless the appliance is marked in accordance with 57.6	60	140
3. Wood or other combustible material, including the inside surface of the test enclosure and the surface supporting the appliance	65	117

[a] At a point on the surface of a coil where the temperature is affected by an external source of heat, the temperature measured by means of a thermocouple that is more than the temperature specified by:

1. 5°C (9°F) for Part 1a of item A,
2. 15°C (27°F) for Part 2a of item A,
3. 10°C (18°F) for Part 3a of item A, and
4. 20°C (36°F) for Part 4a of item A.

complies with the requirement where the temperature measured by the resistance method is not more than that specified in the table.

[b] For an electrolytic capacitor that is physically integral with or attached to a motor, the maximum temperature on insulating material integral with the capacitor enclosure shall not be more than 90°C (194°F).

Table 45.1 Continued on Next Page

Table 45.1 Continued

Materials and components	°C	°F
[c] A component that has a higher temperature rating, and is found to function without a risk of fire or electric shock at a higher temperature meets the intent of the requirement.		
[d] The temperature of a printed-wiring board shall not exceed the maximum operating temperature rating of the board.		

45.2 The temperatures specified in Table 45.1 are based on an assumed ambient temperature of 25°C (77°F). However, the test may be conducted within the range of 20 – 30°C (68 – 86°F) if the temperature is corrected to 25°C.

45.3 An observed temperature is to be corrected by addition [if the ambient temperature is lower than 25° C (77° F)] or subtraction (if the ambient temperature is higher than 25° C) of the difference between 25°C and the ambient temperature.

45.4 If a corrected temperature exceeds the values specified in Table 45.1, at the request of the manufacturer, the test may be repeated at an ambient temperature closer to 25°C (77°F).

45.5 A protective device shall not open or cycle during the temperature test.

45.6 Permanently connected equipment is to be tested with 4 feet (1.22 m) of wire attached to each field-wiring terminal. The wire is to be sized in accordance with 10.2.6.

45.7 Doors and covers that may be closed during operation of the equipment are to be closed during the test.

45.8 In a test to determine if an appliance complies with the temperature requirements, it is to be mounted or supported as in actual service and under conditions approximating those of normal operation. Temperatures are to be measured on nearby surfaces on the supporting surface, at points of support, and at other points as may be necessary.

45.9 Wall mounted equipment is to be placed in a wall angle of 90 degrees formed by two black-painted, vertical surfaces of 3/8 inch (9.5 mm) thick plywood having such width and height that they extend not less than 2 feet (0.6 m) beyond the physical limits of the equipment. The equipment is to be located as closely to the sides of the wall angle as its construction will permit and it is to be so placed relative to the walls that maximum heating will occur on the alcove walls and internal components of the equipment.

45.10 Equipment, other than as specified in 45.9, shall be located as close to a vertical wall of black-painted, 3/8 inch (9.5 mm) thick plywood as the construction will permit.

45.11 The temperature test is to be continued until thermal equilibrium is attained. Thermal equilibrium is considered to exist when three successive readings taken at intervals of 10 percent of the previously elapsed duration of the test, but not less than 5 minute intervals, indicate no change.

Exception: If the equipment is obviously not intended for continuous operation, the temperature test may be conducted so that probable intermittent or short-time operation is considered.

45.12 Coil winding temperatures are to be measured by thermocouples or by using the change-of-resistance method. For a coil of an alternating-current motor, other than a universal motor, the thermocouple is to be mounted on the integrally applied insulation on the conductor. For any other motor, the thermocouple may be applied on the outer surface of a wrap that is no more than 1/32 inch (0.8 mm) thick and consists of cotton, paper, or rayon.

45.13 Temperatures, other than as noted in 45.12, are to be measured by thermocouples consisting of wires no larger than 24 AWG (0.21 mm^2) and no smaller than 30 AWG (0.05 mm^2). When thermocouples are used in determining temperatures in electrical equipment, it is standard practice to use thermocouples consisting of 30 AWG iron and constantan wire and a potentiometer type instrument. This equipment shall be used whenever referee temperature measurements by thermocouples are necessary. The thermocouples and related instruments are to be accurate and calibrated. The thermocouple wire is to conform with the requirements given in Initial Calibration Tolerances for Thermocouples table in Temperature Measurement Thermocouples, ANSI/ISA MC96.1. The thermocouples are to be waterproof if immersed in water during testing.

45.14 When using the resistance method, the windings are to be at room temperature at the start of the test, and the temperature of a winding is to be calculated using the formula:

$$T = \frac{R}{r} - (k + t_1) - k$$

in which:

k is 234.5 for copper and 225.0 for electrical conductor grade (EC) aluminum; values of the constant for other conductors are to be determined;

R is the resistance of the coil in ohms at the end of the test;

r is the resistance of the coil in ohms at the beginning of the test;

T is the final temperature in °C;

t_1 is the temperature of the coil in °C at the time resistance r is being measured.

46 Dielectric Voltage-Withstand Test

46.1 When tested as described in 46.2 and 46.3, equipment shall withstand without breakdown a test potential of:

a) 1000 volts for equipment rated 250 volts or less; and

b) 1000 volts plus twice the rated voltage for equipment rated more than 250 volts.

46.2 The test is to be conducted when the equipment is at the temperature attained during normal operating conditions as described in Temperature Test, Section 45. The voltage is to be a 60-hertz essentially sinusoidal potential applied between live parts and exposed dead metal parts.

46.3 The equipment is to be tested by means of a 500-volt-ampere or larger capacity transformer the output voltage of which is essentially sinusoidal and can be varied. The applied potential is to be increased from zero until the required test level is reached, and is to be held at that level for 1 minute. The increase in the applied potential is to be at a substantially uniform rate as rapid as is consistent with correct indication of its value by a voltmeter.

47 Rain Test

47.1 Equipment intended for outdoor use shall be tested as described in 47.2 – 47.5.

47.2 The equipment is to be mounted as in actual service. Unspecified lengths of conduit are to be attached with normal torque and without a pipe thread compound. At each unthreaded wiring opening, a locknut and bushing are to be used. The unattached end of each conduit is to be covered to prevent entry