UL 22

STANDARD FOR SAFETY

Amusement and Gaming Machines

UL Standard for Safety for Amusement and Gaming Machines, UL 22

Sixth Edition, Dated May 30, 2008

Summary of Topics

This revision to ANSI/UL 22 dated February 6, 2019, is being issued to reflect the reaffirmation of the ANSI approval of the Standard. No technical changes have been made to the document.

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 requirements are substantially in accordance with Proposal(s) on this subject dated November 23, 2018.

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UL 22

Standard for Amusement and Gaming Machines

The first and second editions were titled Standard for Amusement Machines.

First Edition – June, 1977
Second Edition – August, 1979
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Fifth Edition – March, 1999

Sixth Edition

May 30, 2008

This ANSI/UL Standard for Safety consists of the Sixth Edition including revisions through February 6, 2019.

The most recent designation of ANSI/UL 22 as a Reaffirmed American National Standard (ANS) occurred on February 6, 2019. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

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

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INTRODUCTION

1 Scope

1.1 These requirements cover electrical, electronic, and electromechanical commercial amusement and gaming machines and accessories that are intended to be used in accordance with the National Electrical Code, NFPA 70.

1.2 Amusement and gaming machines as covered by this standard are intended for indoor use only, except that they will be investigated for outdoor use or use in a protected location if so designated by the manufacturer.

1.3 These requirements do not cover coin-operated sound-recording and -reproducing machines or carnival rides.

2 Components

2.1 Except as indicated in 2.2, a component of a product covered by this standard shall comply with the requirements for that component. See Appendix A for a list of standards covering components generally used in the products covered by this standard.

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

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

b) Is superseded by a requirement in this standard.

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

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

3 Units of Measurement

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

3.2 Unless indicated otherwise, all voltage and current values mentioned in this standard are root-mean-square (rms).

4 Undated References

4.1 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.

5 Terminology

5.1 A requirement in this Standard that applies only to a specific type of amusement or gaming machine is so identified by a specific reference in that requirement to the type involved. Absence of such specific reference or use of the term ″appliance″ indicates that the requirement applies to all amusement and gaming machines covered by this standard.

6 Glossary

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

6.2 BARRIER – A part inside an enclosure that reduces the accessibility to a part that involves a risk of electric shock or injury to persons.

6.3 CABINET – A part outside the enclosure that houses or covers only portions of the appliance that do not involve a risk of fire, electric shock, or injury to persons.

6.4 CONTINUOUS DUTY MOTOR – A motor that is intended to operate unattended for a period of 3 hours or more while under load.

6.5 ENCLOSURE – A housing of an appliance that reduces the accessibility to a part that may involve a risk of fire or electric shock. An enclosure can also prevent access to a part that involves a risk of injury to persons when evaluated in accordance with Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts, Section 10.

6.6 FIELD-WIRING TERMINAL – A terminal to which a supply or other wire may be connected by service personnel in the field, unless the wire is provided as part of the appliance and a pressure terminal, connector, soldering lug, soldered loop, crimped eyelet, or other means for making the connection is factory-assembled to the wire.

6.7 GUARD – A part outside of the enclosure that reduces the accessibility to a component that involves a risk of injury to persons when evaluated in accordance with Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts, Section 10.

6.8 INDOOR LOCATION – Inside a building where not normally subjected to the effects of weathering.

6.9 MAINTENANCE AREA – An area where access can only be gained by the use of a maintenance key.

6.10 MAINTENANCE KEY – Key or other means which provides access to the maintenance area but does not permit access to the service area.

6.11 MAINTENANCE PERSON – The person who performs routine maintenance such as the setting of controls and other minor adjustments. Some examples of maintenance are:

a) Replacement of lamps and fuses and resetting of circuit breakers located in a user-access area unless the lamps, fuses, or circuit breakers are marked to indicate replacement or resetting only by service personnel.

b) The making of routine operating adjustments including, but not limited to, cleaning the machine, clearing the coin mechanism of jams, removing coins or price changing.

6.12 NEON TUBE – A small diameter glass cylinder, evacuated of air and filled with an inert gas such as neon, which emits light when excited by a high voltage neon transformer or power supply.

6.13 OUTDOOR LOCATION – An area that is open and subjected to the full effects of weathering.

6.14 PRIMARY CIRCUIT – Wiring and components that are conductively connected to a branch circuit.

6.15 PROTECTED LOCATION – An area that is partially protected from the effects of weathering through the use of a roof, canopy, marquee, or the like.

6.16 SAFETY CIRCUIT – Any primary or secondary circuit that is relied upon to reduce the risk of fire, electric shock, high current levels of electrical energy, or injury to persons. For example, in some applications, an interlock circuit is considered to be a safety circuit.

6.17 SECONDARY CIRCUIT – A circuit supplied from a secondary winding of an isolating transformer.

6.18 SERVICE AREA – An area where access cannot be gained by the use of a maintenance key alone.

6.19 SERVICE PERSON – An authorized person who may periodically open an appliance to repair or maintain electrical or mechanical components. Some examples of servicing are:

a) The installation of accessories or conversion kits by means of attachment plugs and receptacles or by means of other separable connectors, and

b) The replacement of tapes, discs, or program boards.

6.20 TOOL – A screwdriver, coin, dedicated key, or any other object that may be used to operate a screw, latch, or similar fastening means.

6.21 USER – The player or participant of the amusement or gaming machine.

6.22 USER AREA – All external surface areas, all internal areas that can be entered without the use of a maintenance key or tools, and all areas that the user is instructed to enter regardless of whether or not tools are needed to gain access.

CONSTRUCTION

7 General

7.1 Only materials that are intended for the particular use shall be used in amusement and gaming machines.

7.2 When the deterioration or breakage of any part that contains, conducts, or otherwise contacts a liquid could result in a risk of fire, electric shock, or injury to persons, the part shall be of a material resistant to corrosion by the liquid to be used therein and shall have the strength to withstand the pressures involved.

8 Frame and Enclosure

8.1 General

8.1.1 An enclosure, guard, or barrier shall have the strength and rigidity to resist the abuses likely to be encountered during intended use of the appliance without increasing the risk of fire, electric shock, or injury to persons due to total or partial collapse with resulting reduction of spacings to less than required, or the loosening, displacement, or exposure of parts, or other serious defects.

8.1.2 An enclosure, guard, or barrier of an appliance shall be complete, or completion of the enclosure, guard, or barrier shall be attained when an appliance is installed for operation.

8.1.3 A required enclosure, guard, or barrier shall be capable of being removed and replaced with a minimum of effort when removal is necessary to service the protected parts.

8.1.4 The strength and rigidity is to be evaluated by the tests in:

a) 45.2.1– 45.2.3 and 45.4.1 for a nonmetallic enclosure or guard;

b) 45.3.1– 45.4.1 for a metal enclosure or guard; and

c) 45.4.1 for a barrier that is accessible to a maintenance person.

The enclosures, guards, and barriers of an appliance intended for outdoor use shall be tested for resistance to the atmospheric effects of rain and sunlight.

8.1.5 A handle or handles intended for lifting or carrying an appliance shall comply with the Handle Test, Section 40.

8.1.6 An enclosure may be provided with a door for maintenance access when:

a) The door is hinged or otherwise secured such that it is unlikely to be detached when opened for maintenance;

b) The door is intended to be closed and latched during normal operation; and

c) The appliance complies with the accessibility requirements in Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts, Section 10, when the door is open.

8.2 External materials

8.2.1 Materials such as steel, aluminum, wood, particle board, composite materials, glass, and other similar materials shall be used for the enclosure, guard, or cabinet of an appliance. Glass shall be heat-resistant, tempered, wired, or laminated. See 8.2.2 for small parts requirements.

Exception No. 1: Other materials may be used for part or all of an enclosure when they comply with the requirements in 8.1.4, 8.2.3, and the Standard for Polymeric Materials– Use in Electrical Equipment Evaluations, UL 746C.

Exception No. 2: Materials with a flammability rating of HB, V-2, V-1, V-0, or 5V in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, or material determined to be equivalent may be used for part or all of a cabinet. See also 8.2.3.

Exception No. 3: Materials that are classed HB, V-2, V-1, V-0, or 5V in accordance with UL 94, or an equivalent material may be used as guards when they comply with 8.1.4, 8.2.3, and 45.1 – 45.3.

Exception No. 4: Ordinary glass may be used when the optical or flatness requirement precludes the use of heat-resistant, tempered, wired, or laminated glass.

8.2.2 The flammability requirements in Exception No. 1 to 8.2.1 does not apply to small parts. For the purpose of these requirements, a small part is defined as one that complies with both of the following items:

a) A small part shall not be part of the appliance enclosure, or enclose live parts or be used to reduce the likelihood of electric shock.

b) The location of a small part is such that it cannot propagate flame from one area to another or act as a bridge between a possible source of ignition and other ignitable parts.

8.2.3 An external surface of combustible material having an exposed area greater than 10 square feet (0.93 m^2) or a single dimension larger than 6 feet (1.83 m) shall have a flame spread index of 200 or less when tested in accordance with:

a) The Standard for Test for Surface Burning Characteristics of Building Materials, UL 723, or

b) The radiant-panel furnace method in the Standard Test Method for Surface Flammability of Materials Using a Radiant-Heat Energy Source, ASTM E162.

Exception: The materials described in (a) – (b) below are not required to be tested:

a) 1/2-inch (12.7-mm) or 3/4-inch (19.0-mm) thick plywood with no coating;

b) 1/2-inch (12.7-mm) or 3/4-inch (19.0-mm) thick plywood with a latex paint coating; and

c) 3/4-inch (19.0-mm) thick plywood, particle board or medium density fiberboard (MDF) covered with a melamine laminate using a melamine resin adhesive.

8.2.4 The flame-spread index in 8.2.3(b) is the average value based on tests on six specimens representative of the wall thickness used, with no single specimen value greater than 300.

8.2.5 A material with a flame-spread index higher than specified in 8.2.3 may be used as the exterior finish or covering on any portion of the enclosure, guard, or cabinet if the flame-spread index of the combination of the base material and finish or covering complies with 8.2.3.

8.2.6 The size limitations mentioned in 8.2.3 refer to the exposed surface area of a single unbroken section. If two sides of a single piece are exposed, only the larger side is to be considered in computing the area.

8.2.7 A conductive coating applied to a surface (such as the inside surface of a cover or an enclosure) shall comply with the appropriate requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

Exception: When flaking or peeling of the coating will not result in the reduction of spacings or the bridging of live parts that may present a risk of fire or electric shock, then the coating need not comply with UL 746C.

8.3 Enclosure bottom openings

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

8.3.2 The requirement in 8.3.1 necessitates the use of a barrier or pan of noncombustible material:

a) Under a motor unless:

1) The structural parts of the motor or of the appliance provide a barrier that has been determined to be equivalent;

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

i) Open main winding,

ii) Open auxiliary winding, and

iii) Starting switch short-circuited; 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:

i) 125°C (257°F) when the motor is running at the maximum load at which it can operate without causing the protector to cycle and

ii) 150°C (302°F) with the rotor of the motor locked.

b) Under wire, unless it is flame-retardant such as thermoplastic- or neoprene-insulated wires.

c) Under a switch, a relay, a solenoid, a transformer, or the like unless it can be shown that malfunction of the component would not result in a risk of fire.

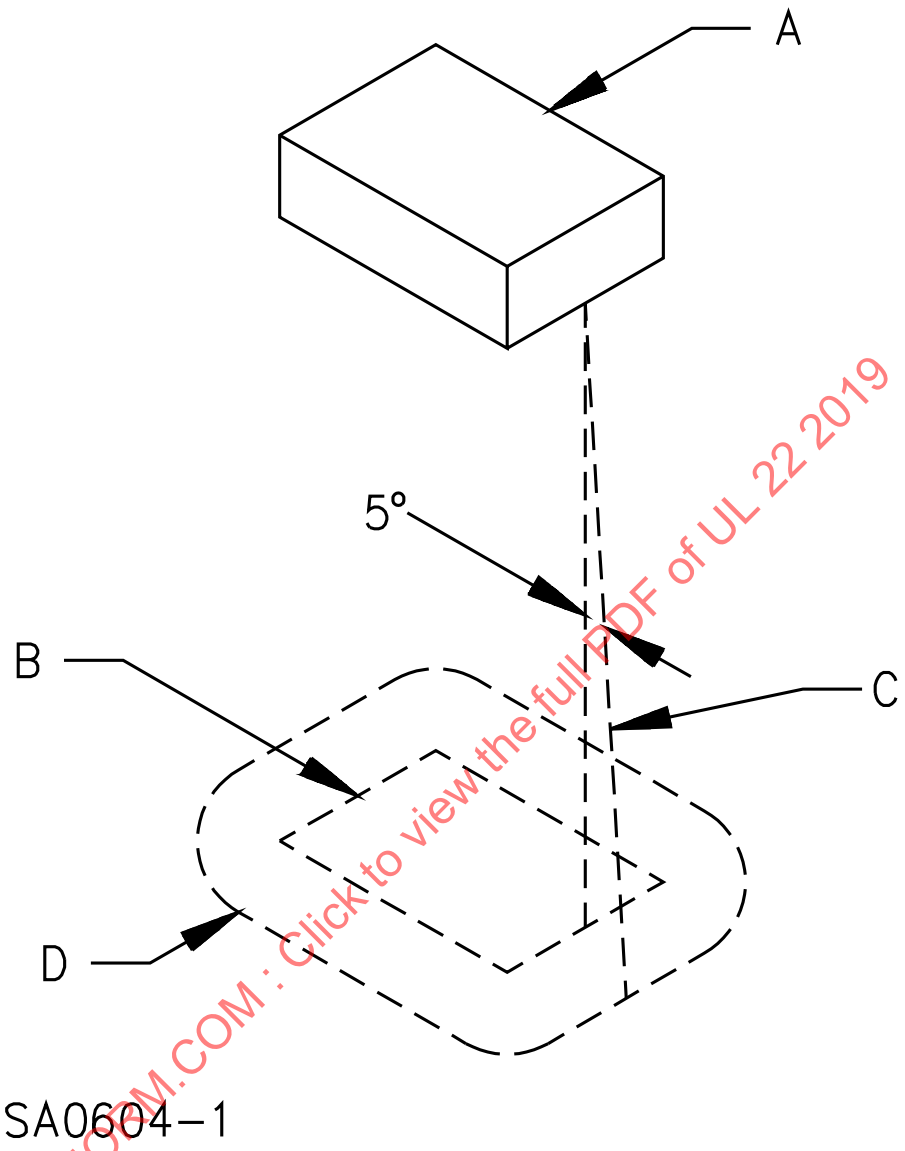
8.3.3 The barrier mentioned in 8.3.2 shall be:

a) Horizontal,

b) Located as illustrated in Figure 8.1, and

c) Have an area in accordance with that figure.

Figure 8.1
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 by a barrier that has been determined to be equivalent.

B – Projection of outline of component on horizontal plane.

C – Inclined line that traces out minimum area of barrier. The line is always tangent to the component, 5 degrees from the vertical, and oriented so 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.

8.3.4 Materials used for barriers have a flammability rating of V-2 or less in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94. Additionally, barriers that are accessible to a maintenance person shall comply with the requirements in 8.1.4 and 45.1– 45.3.

Exception: Barrier materials need not have a flammability rating of V-2 or less when they are one of the materials mentioned in 8.2.1 or comply with Exception Nos. 1 – 4 to 8.2.1.

8.4 Medium- and high-pressure lamps

8.4.1 A medium-pressure lamp shall be enclosed or guarded to protect against breakage due to external forces or impacts.

8.4.2 A high-pressure lamp shall be enclosed so that an explosion of the lamp will be contained. See 54.19 for high-pressure lamp caution marking.

8.4.3 High-pressure lamps may be exploded within the enclosure of the appliance to determine compliance with 8.4.2.

8.4.4 With reference to the requirements in 8.4.1 – 8.4.3, a medium-pressure lamp is considered to be one in which the contained atmospheric energy (CAE) is less than 5 joules and greater than 0.5 joules and a high-pressure lamp is considered to be one in which the CAE equals or exceeds 5 joules when defined as follows:

$$CAE = 0.15 (PC - PE) V$$

in which:

PC is the contained pressure in atmospheres, measured at 50°C or less;

PE is the external pressure in atmospheres, measured at 50°C or less; and

V is the volume in cubic centimeters.

8.5 Air filters

8.5.1 An air filter for use in a cooling system shall comply with the Standard for Air Filter Units, UL 900, or shall be constructed of materials with a flammability rating of V-2 or less in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

Exception No. 1: Air filters used in a closed system need not comply with this requirement. A closed system is defined as that which, although not necessarily air-tight, is not intended to be vented outside the enclosure.

Exception No. 2: Air filters located external to the enclosure and constructed of materials classed HB or less flammable need not comply with this requirement.

9 Mechanical Assembly

9.1 Loosening of parts in an appliance resulting from the vibration of handling and operation shall not result in a risk of fire, electric shock, or injury to persons.

9.2 Screws with properly applied lock washers, screws tightened by means of a power tool, and screws that are staked and upset are not considered subject to loosening.

9.3 A rotating part that when loosened, results in a risk of fire, electric shock, or injury to persons shall be assembled so that the direction of rotation tends to tighten the means that hold the rotating part in place.

Exception: A keyed part, a part locked in place with a pin, or a part that has been determined to be the equivalent may be used as a means of holding a rotating part in place.

9.4 A switch, a fuseholder, a lampholder, an attachment-plug receptacle, a motor-attachment plug, or similar component that is handled by persons shall be mounted securely, shall not turn or shift, and shall comply with the requirements specified in 9.5, 9.6, and 14.2.3.6.

Exception: The requirement that a switch shall not turn or shift may be waived if the following conditions are met:

a) The switch is of a plunger, slide, 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 of mounting the switch make it unlikely that operation of the switch will loosen it;

c) Spacings are not reduced below the minimum intended values if the switch rotates; and

d) Operation of the switch is by mechanical means rather than by direct contact by persons.

9.5 The means for securing a component mentioned in 9.4 is to consist of more than friction between surfaces – for example, a properly applied lock washer or a keyed part that has been determined to be an acceptable means for securing a small stem-mounted switch or other device having a single-hole mounting means.

9.6 An uninsulated live part or a component that has uninsulated live parts shall be secured to the base or mounting surface so that it will be prevented from turning or shifting in position if such displacement may result in a reduction of spacings below the minimum intended values. See 9.4.

9.7 A lampholder, a fuseholder, and a circuit breaker shall be constructed and installed so that persons servicing the lamp, the fuse, or the circuit breaker may not unintentionally touch an uninsulated live part other than the screw shell of a lampholder or fuseholder, or the clip of a fuseholder.

Exception: An appliance that is marked in accordance with 54.22 need not comply.

9.8 An appliance may be shipped from the factory unassembled, or disassembled to the degree necessary to facilitate shipment, when the conditions described in (a) – (d) are met:

a) All of the parts are furnished;

b) The appliance is constructed so that field assembly can be accomplished without drilling, cutting, threading, or any other alteration other than the attachment of field-installed electrical conduit or raceway;

c) The relationship between separate parts is established at the time of manufacture and is not dependent upon installation personnel; and

d) The assembly of the appliance is restricted to an arrangement whereby electrical connections are accomplished by means of properly identified receptacles and plug-in connectors.

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

10.1 To reduce the risk 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 (see 10.5) less than 1 inch (25.4 mm), such a part or wire shall not be contacted by the probe illustrated in Figure 10.1.

b) For an opening that has a minor dimension of 1 inch or more, such a part or wire shall be spaced from the opening as specified in Table 10.1.

Exception: A motor other than one used in either a hand-held product or a hand-supported portion of a product need not comply with these requirements when it complies with the requirements in 10.2.

Figure 10.1
Articulate probe with web stop

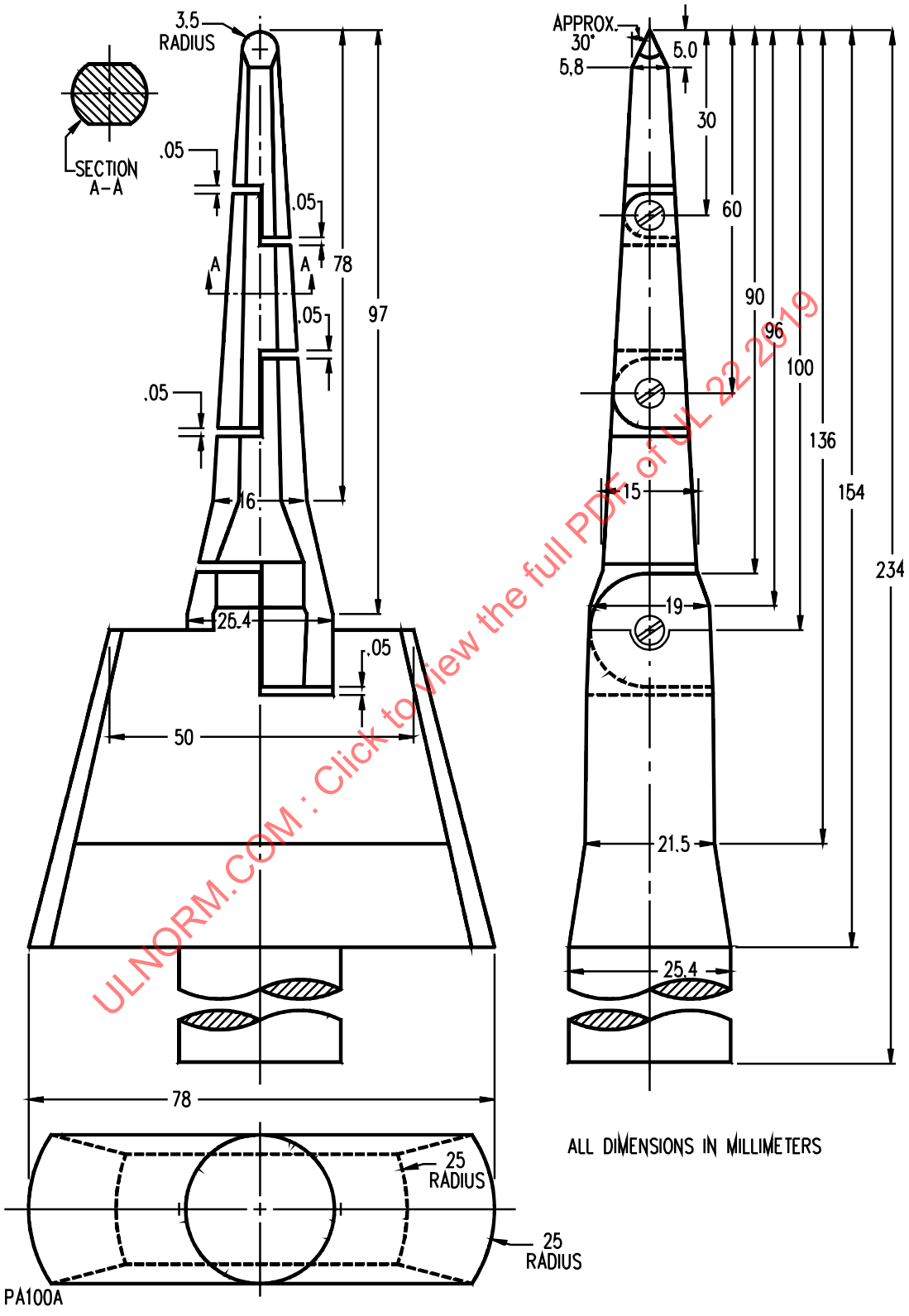


Table 10.1
Minimum distance from an opening to a part that may involve a risk of electric shock or injury to persons

Minor dimension of opening,[a] inches[b]	(mm)[b]	Minimum distance from opening to part, 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	190.0
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	444.0
d	d	30	762.0

[a] See 10.5.
[b] Between 3/4 and 2-1/8 inches (19.1 and 54 mm), interpolation is to be used to determine a value between the values specified in the table.
[c] Any dimension less than 1 inch (25.4 mm) applies to a motor only.
[d] More than 2-1/8 inches, but not more than 6 inches (152.0 mm).

10.2 With respect to a part or wire as mentioned in 10.1, in an integral enclosure of a motor as specified in the Exception to 10.1:

a) An opening that has a minor dimension (see 10.5) less than 3/4 inch (19.1 mm) may be used when:

1) A moving part cannot be contacted by the probe illustrated in Figure 10.2;

2) Film-coated wire cannot be contacted by the probe illustrated in Figure 10.3;

3) In a directly accessible motor (see 10.6), an uninsulated live part cannot be contacted by the probe illustrated in Figure 10.4; or

4) In an indirectly accessible motor (see 10.6), an uninsulated live part cannot be contacted by the probe illustrated in Figure 10.2.

b) An opening that has a minor dimension of 3/4 inch or more may be used if a part or wire is spaced from the opening as specified in Table 10.1.

Figure 10.2
Probe for moving parts and uninsulated live parts

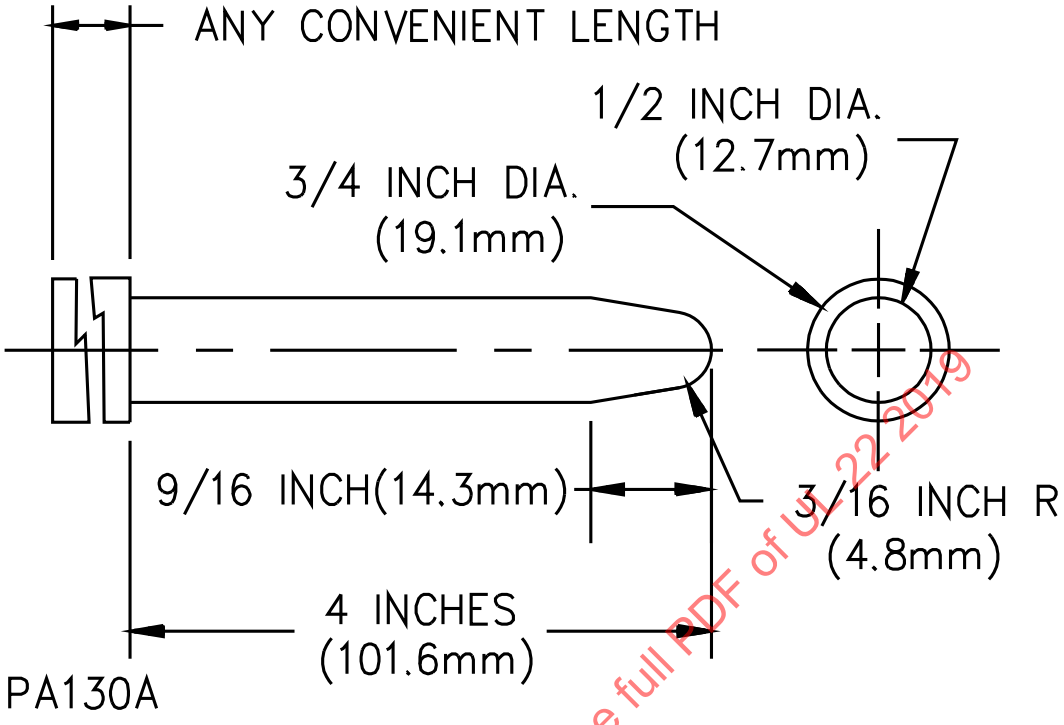


Figure 10.3
Probe for film-coated wire

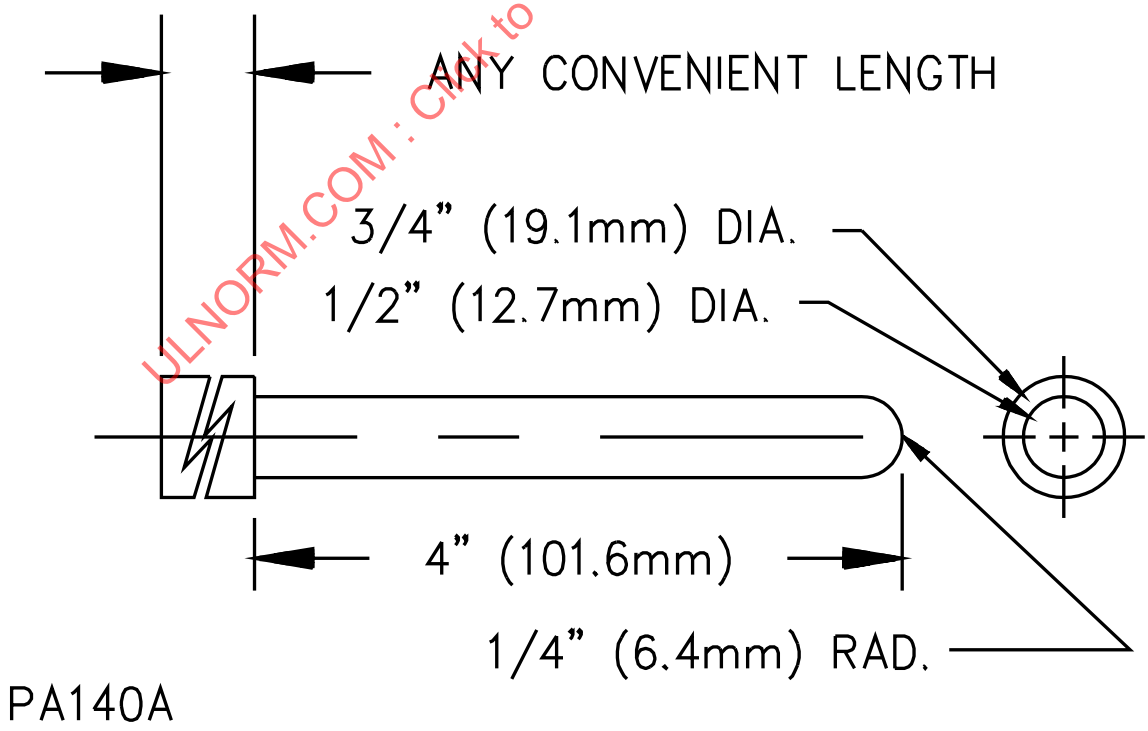
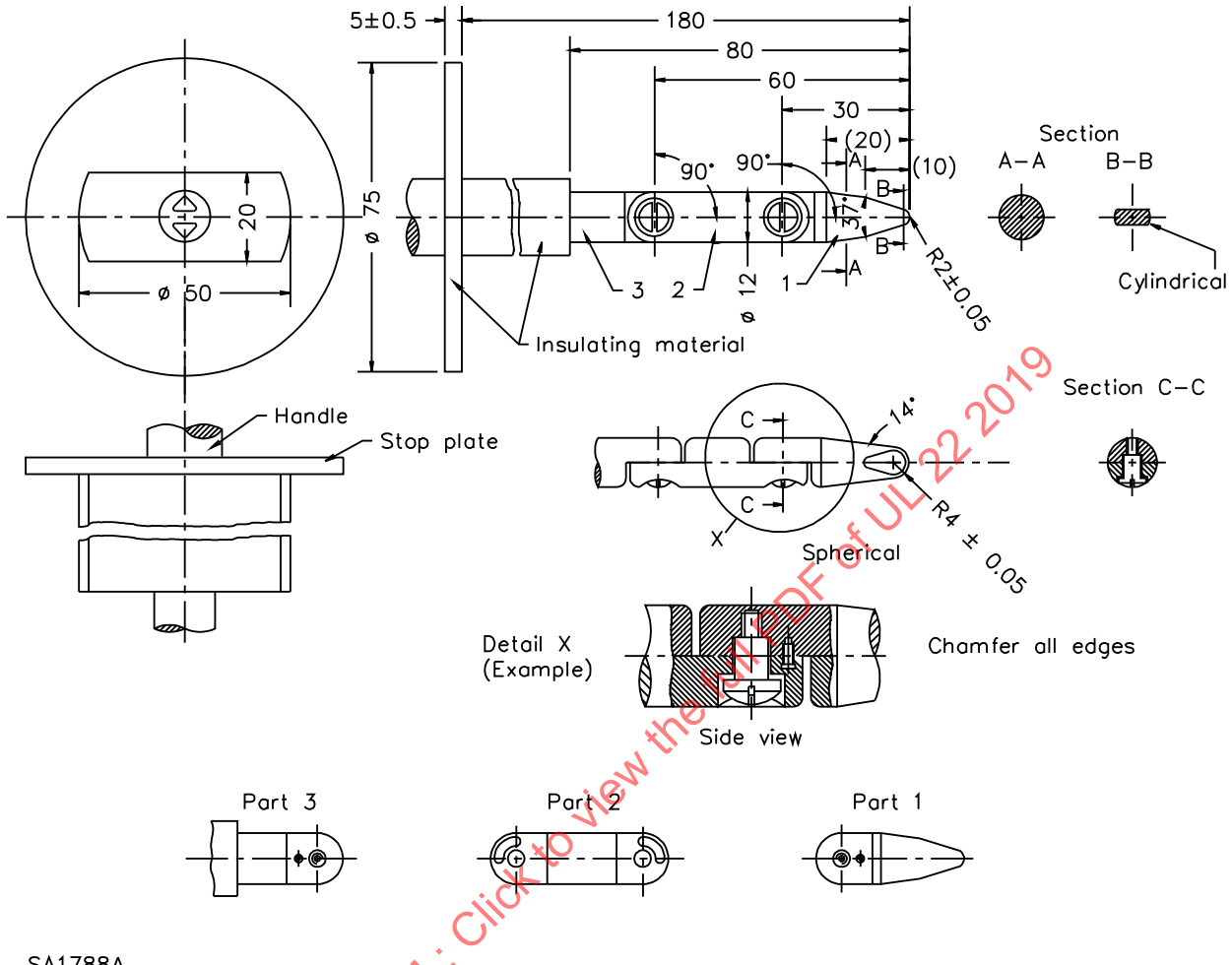


Figure 10.4
Articulate probe



10.3 The probes mentioned in 10.1 and 10.2 and illustrated in Figures 10.1 – 10.4 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 Figures 10.1 and 10.4 shall be applied in any possible configuration; and, if necessary, the configuration shall be changed after insertion through the opening.

10.4 The probes mentioned in 10.3 and 10.5 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.

10.5 With reference to the requirements in 10.1 and 10.2, 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.

10.6 With reference to the requirements in 10.2, an indirectly accessible motor is:

a) Accessible only by opening or removing a part of the outer enclosure, such as a guard or panel, that can be opened or removed without using a tool or

b) Located at such a height or is otherwise guarded or enclosed so that it is unlikely to be contacted.

A directly accessible motor is that which can be contacted without opening or removing any part, or is that which is located so as to be accessible to contact.

10.7 During the examination of a product to determine whether it complies with the requirements in 10.1 or 10.2, 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) or a part that is opened to collect coins is to be opened or removed.

10.8 With reference to the requirements in 10.1 and 10.2, insulated brush caps are not required to be additionally enclosed.

11 Protection Against Corrosion

11.1 Iron and steel parts shall be protected against corrosion by enameling, zinc coating, galvanizing, plating, or equivalent means if the corrosion of such unprotected parts is likely to result in a risk of fire, electric shock, or injury to persons.

Exception No. 1: Bearings, laminations, or minor parts made of iron or steel, such as washers, screws, and the like need not be so protected.

Exception No. 2: In certain instances where the 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 – surfaces of sheet steel and cast-iron parts within the enclosure may not be required to be protected against corrosion.

11.2 An electrical enclosure of sheet steel that may be exposed to the effects of weathering shall be protected against corrosion as specified in 11.3 – 11.9 or by other metallic or nonmetallic coatings that have been determined to provide equivalent protection.

Exception: A motor enclosure that is contained within the enclosure of the appliance need not comply.

11.3 An enclosure that is 0.053 inch (1.35 mm) thick or thicker and is contained within another enclosure shall be protected by one of the following coatings:

a) Hot-dipped, mill-galvanized sheet steel conforming with the coating Designation G60 or A60 in Table I of the Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process, ASTM A653/A653M. See 11.9.

b) A zinc coating, other than that provided on hot-dipped, mill-galvanized sheet steel, uniformly applied to an average thickness not less than 0.00041 inch (0.0104 mm) on each surface with a minimum thickness of 0.00034 inch (0.0086 mm). See 11.8.

c) Two coats of an organic finish of the epoxy or alkyd-resin type or other outdoor paint on each surface. The acceptability of the paint is to be determined by consideration of its composition or by corrosion tests if such tests are considered necessary.

11.4 An enclosure that is less than 0.053 inch (1.35 mm) thick, or that is intended to provide the sole enclosure of current-carrying parts shall be protected by one of the following coatings:

a) Hot-dipped, galvanized sheet steel conforming with the coating Designation G90 in Table I of the Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process, ASTM A653/A653M. See 11.9.

b) A zinc coating, other than that provided on hot-dipped, mill-galvanized sheet steel, uniformly applied to an average thickness not less than 0.00061 inch (0.0155 mm) on each surface with a minimum thickness of 0.00054 inch (0.0137 mm). An annealed coating shall also comply with the requirements in 11.5. See 11.8.

c) A cadmium coating not less than 0.001 inch (0.03 mm) thick on both surfaces. See 11.8.

d) A zinc coating conforming with 11.3 (a) or (b) with one coat of outdoor paint – applied after forming – as specified in 11.3(c).

e) A cadmium coating not less than 0.00075 inch (0.0191 mm) thick on both surfaces with one coat of outdoor paint on both surfaces, or not less than 0.0005 inch (0.013 mm) thick on both surfaces with two coats of outdoor paint on both surfaces. The paint shall be as specified in 11.3(c). See 11.8.

11.5 An annealed zinc coating that is bent or similarly formed after annealing shall additionally be painted in the bent or formed area if the bending or forming process damages the zinc coating.

11.6 When flaking or cracking of the zinc coating at the outside radius of the bent or formed section is visible at 25 times power magnification, the zinc coating is considered damaged. Simple sheared or cut edges and punched holes are not considered to be formed, but extruded and rolled edges and holes are to comply with 11.5.

11.7 With reference to the requirement in 11.2, other finishes, including paints, metallic finishes, and combinations of the two may be used if comparative tests with galvanized sheet steel, without annealing, wiping, or other surface treatment, complying with 11.3(a) or 11.4, as applicable, indicate they provide equivalent protection. Among the factors that are taken into consideration when judging the acceptability of such coating systems are exposure to salt spray, moist carbon dioxide-sulfur dioxide-air mixtures, moist hydrogen sulfide-air mixtures, ultraviolet light, and water.

11.8 The thickness of the metallic coating specified in 11.3(b), and 11.4 (b), (c), and (e) shall be established by the Metallic Coating Thickness Test, Section 48.

11.9 With reference to the coating specified in 11.3(a) and 11.4, not less than 40 percent of the zinc coating shall be on any side, based on the minimum single spot test requirement in the Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process, ASTM A653/A653M. The weight of zinc coating may be determined by an acceptable method; however, in case of question, the weight of coating shall be established in accordance with the Standard Test Method for Weight (Mass) of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings, ASTM A90/A90M REV A.

12 Insulating Material

12.1 Uninsulated live parts shall be mounted on material that has been determined to be acceptable for the particular application. A polymeric material shall comply with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

12.2 Vulcanized fiber may be used for an insulating bushing, a washer, a separator, and a barrier, but not as the sole support for uninsulated live parts where shrinkage, leakage current, or warpage may result in a risk of fire or electric shock.

12.3 A small molded part, such as a brush cap, shall have the necessary mechanical strength and rigidity to withstand the stresses of actual service.

13 Current-Carrying Parts

13.1 A current-carrying part shall be of silver, copper, copper alloy, stainless steel, aluminum, or other material that has been determined to be acceptable for the particular application.

Exception: Plated steel may be used for secondary-circuit parts and for some primary-circuit parts (such as for capacitor terminals where a glass-to-metal seal is necessary and for leads of threaded studs of semiconductor devices). Blued steel, or steel with corrosion resistance that has been determined to be equivalent, may be used for the current-carrying arms of mechanically or magnetically operated leaf switches and within a motor and its governor, motor terminals included, or where the temperatures are in excess of 100°C (212°F), but not elsewhere.

14 Supply Connections

14.1 Cord-connected appliances

14.1.1 Cords and plugs

14.1.1.1 The supply cord shall be attached permanently to the appliance or shall be in the form of a detachable power-supply cord with an acceptable means for connection to male contacts affixed to the appliance. An attachment plug shall be provided for connection to the power supply circuit.

14.1.1.2 The maximum cord length of a cord-connected appliance shall be 15 feet (4.6 m). Cord length is measured from the face of the attachment plug to the point where the flexible cord emerges from the product.

14.1.1.3 The attachment plug shall be a grounding-type plug that conforms to the appropriate American National Standards Institute designation given in Table 14.1.

Exception: See 14.1.1.4.

Table 14.1
ANSI designation for attachment plug

Amperes, volts	ANSI designation[a]
15, 125	C73.11
20, 125	C73.12
30, 125	C73.45
15, 250	C73.20
20, 250	C73.51
30, 250	C73.52

[a] As part of the Wiring Devices – Dimensional Requirements Revision and Redesignation of ANSI C73-73, NEMA, WD-6.

14.1.1.4 The attachment plug for a double-insulated appliance shall be of a two-blade type. If single-pole devices are incorporated in the appliance, then the plug shall be of the polarized type.

14.1.1.5 The attachment plug shall:

a) Be of a type intended for its application,

b) Have a current rating not less than 125 percent of the rated current of the appliance, and

c) Have a voltage rating equal to the rated voltage of the appliance.

If the appliance can be adapted for use on two or more different voltages by field alteration of internal connections, the attachment plug provided with the appliance shall be of a type, acceptable for the voltage and current for which the appliance is connected when shipped from the factory, and shall comply with the requirements in 54.10.

Exception: An appliance that is equipped with an adjustable voltage selector located in a maintenance area and a detachable power-supply cord may be connected for a voltage other than that matching the detachable power-supply cord, if a marking instructing the maintenance person to select the intended voltage is present and if connection to a different voltage does not result in a risk of fire, electric shock, or injury to persons.

14.1.1.6 The flexible cord shall be rated for use at a voltage not less than the rated voltage of the appliance, and shall have an ampacity not less than the current rating of the appliance.

14.1.1.7 The flexible cord on a cord-connected appliance shall be Type SJ, SJE, SJO, SJOO, SJT, SJTO, SJTOO, S, SE, SO, SOO, ST, STO, STOO, or of a type at least as serviceable for the particular application. An appliance intended for use in a protected location or an outdoor location shall use a cord intended for such use.

14.1.1.8 For an appliance provided with a polarized attachment plug, one of the circuit conductors in the flexible cord shall be identified for connection of the grounded (neutral) supply conductor if the appliance is rated at 125 volts or less, three wire, and contains either a screw-shell type of lampholder, a fuseholder, or a single-pole switch or overcurrent protective device other than an automatic control without a marked off position. The circuit conductor that shall be identified is the one that is connected directly to the screw shell of a lampholder but is not connected to a switch or overcurrent (overload) protective device of the single-pole type (other than an automatic control without a marked off position).

14.1.1.9 If an appliance incorporates a detachable power-supply cord, the arrangement shall be such that live parts will not be exposed under any condition of intended use.

14.1.2 Strain relief

14.1.2.1 Strain relief shall be provided to reduce the risk of mechanical stress on a flexible cord from being transmitted to terminals, splices, or internal wiring. See 43.1.

14.1.2.2 Means shall be provided to reduce the risk of the flexible cord from being pushed into the appliance through the cord-entry hole if such displacement results in:

a) Mechanical damage to the cord;

b) Exposure of the cord to a temperature higher than that for which it is rated; or

c) Reduced spacings, such as to a metal strain relief clamp, below the minimum intended values.

14.1.3 Bushings

14.1.3.1 At the point at which a supply cord passes through an opening in a wall, barrier, or the overall enclosure, there shall be a bushing or the equivalent that is secured in place, and that has a smooth, well-rounded surface against which the cord can bear. A cord hole through wood, porcelain, phenolic composition, or other nonconductive material, that has a smooth, well-rounded surface is considered to be the equivalent of a bushing. A smooth, well-rounded surface in a metal enclosure may also be used.

14.1.3.2 Ceramic materials and some molded compositions may be used for insulating bushings.

14.1.3.3 A bushing made of the same material as, and molded integrally with, the supply cord shall not be less than 1/16 inch (1.6 mm) thick at the point at which the cord passes through the enclosure.

14.2 Permanently-connected appliances

14.2.1 General

14.2.1.1 An appliance intended for permanent connection to the power-supply circuit shall have provision for connection of one of the wiring methods that, in accordance with the National Electrical Code, ANSI/NFPA 70, is intended for the purpose.

14.2.2 Field-wiring compartments

14.2.2.1 A field-wiring compartment in which power-supply connections are to be made shall be located so that these connections can be made and inspected without disturbing the wiring or the appliance after the appliance has been installed as intended.

14.2.2.2 A sheet-metal member to which a wiring system is to be connected in the field shall have a thickness not less than:

a) 0.032 inch (0.81 mm) if of uncoated sheet steel;

b) 0.034 inch (0.86 mm) if of galvanized sheet steel;

c) 0.0438 inch (1.113 mm) if of sheet aluminum; and

d) 0.0428 inch (1.087 mm) if of sheet copper or sheet brass.

14.2.2.3 A field-wiring compartment intended for connection of a supply raceway shall be attached to the appliance so as to be prevented from turning with respect thereto.

14.2.3 Field-wiring terminals and leads

14.2.3.1 A permanently-connected appliance shall be provided with field-wiring terminals for the connection of primary-circuit conductors having an ampacity not less than 125 percent of the current rating of the appliance, or the appliance shall be provided with leads for such connection.

14.2.3.2 The free length of a lead inside an outlet box or field-wiring compartment shall be 6 inches (152 mm) or more if the lead is intended for field connection to an external circuit.

Exception: Leads may be less than 6 inches long if the field-wiring supply connections are enclosed in a motor terminal box or motor wiring compartment or if longer leads may result in a risk of fire, electric shock, or injury to persons.

14.2.3.3 A field-wiring terminal shall be provided with a soldering lug or pressure terminal connector securely fastened in place– for example, firmly bolted or held by a screw.

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

14.2.3.4 A pressure terminal connector shall comply with the requirements in 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.

14.2.3.5 An upturned lug, cupped washer, or the equivalent shall be capable of retaining a supply conductor of the size indicated in 14.2.3.3 under the head of the wire-binding screw or washer.

14.2.3.6 A field-wiring terminal shall be prevented from turning by means other than friction between surfaces. A lock washer may be used in maintaining the position of live parts.

14.2.3.7 A field-wiring terminal marked to indicate that it may be used with a copper, a copper-clad aluminum, or an aluminum supply conductor shall comply with the requirements in 14.2.3.1 for a conductor of each metal for which it is marked. See 54.25 for markings.

14.2.3.8 A wire-binding screw shall not be smaller than No. 10 (4.8 mm diameter).

Exception: A No. 8 (4.2 mm diameter) screw may be used at a terminal intended for the connection of a 14 AWG (2.1 mm^2) conductor.

14.2.3.9 A wire-binding screw shall thread into metal.

14.2.3.10 A terminal plate tapped for a field-wiring wire-binding screw shall be of metal not less than 0.050 inch (1.27 mm) thick. There shall be at least two or more full threads in the metal of the plate that may be extruded at the tapped hole if necessary to provide the threads.

Exception: A terminal plate not less than 0.030 inch (0.76 mm) thick may be used if the tapped threads have equivalent mechanical strength.

14.2.3.11 A field-wiring terminal intended solely for connection of an equipment-grounding conductor shall be capable of securing a conductor of the size intended for the application, in accordance with the National Electrical Code, ANSI/NFPA 70. See 14.3.5.

14.2.3.12 An equipment-grounding terminal or lead shall be provided on the appliance.

14.3 Identification

14.3.1 A permanently-connected appliance rated 125 volts or 125/250 volts (3-wire) or less, and using a lampholder of the screw-shell type, or a single-pole switch or overcurrent protective device other than an automatic control without a marked off position, shall have one terminal or lead identified for the connection of the grounded (neutral) conductor of the supply circuit. The grounded (neutral) circuit terminal or lead shall be the one that is electrically-connected to screw shells of lampholders and to which are connected no switches or overcurrent protective devices of the single pole type, other than an automatic control without a marked off position.

14.3.2 A field-wiring terminal intended for connection of a grounded (neutral) circuit conductor shall be identified by means of a metallic coating that is substantially white in color and shall be readily distinguishable from the other terminals, or proper identification of that terminal shall be clearly shown in some other manner, such as on an attached wiring diagram, the word ″white,″ or the letter ″N″ located adjacent to the grounded circuit conductor terminal. If wire leads are provided instead of terminals, the grounded circuit lead shall have a white or gray color and shall be readily distinguishable from the other leads.

14.3.3 The surface of the insulation on a lead intended solely for 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.

14.3.4 The color coding requirements described in 14.3.2 and 14.3.3 relating to identification do not apply to internal wiring that is not visible in a wiring compartment in which field connections are to be made.

14.3.5 A wire-binding screw or pressure wire connector intended for the connection of an equipment-grounding conductor shall be located so that it is unlikely to be removed during normal servicing of the appliance and shall have upturned lugs or the equivalent to retain the conductor. The wire-binding screw shall have a green-colored head that is hexagonal, slotted, or both. A pressure wire connector intended for connection of such a conductor shall be plainly identified, such as by being marked ″G,″ ″GR,″ ″GND,″ ″Ground,″ ″Grounding,″ or the like, or by a marking on a wiring diagram provided on the appliance.

15 Grounding and Bonding

15.1 General

15.1.1 An appliance shall have provision for the grounding of all exposed dead metal parts that may become energized by a single electrical fault.

Exception No. 1: The metal parts as described in (a) – (d) need not be grounded:

a) An adhesive-attached, metal foil marking; a screw; a handle; or the like, located on the outside of an enclosure or cabinet and isolated from electrical components or wiring by grounded metal parts so that it is not likely to become energized;

b) An isolated metal part, such as a magnet frame and armature; a small assembly screw; or the like, that is positively separated from wiring and uninsulated live parts;

c) A panel or a cover that does not enclose uninsulated live parts when the wiring is positively separated from the panel or cover so that it is not likely to become energized; and

d) A panel or a cover that is insulated from electrical components, including wiring, by an insulating barrier of vulcanized fiber, varnished cloth, phenolic composition, or similar material not less than 1/32 inch (0.8 mm) thick and secured in place.

Exception No. 2: An appliance that is double insulated in accordance with the Standard for Double Insulation Systems for Use in Electrical Equipment, UL 1097.

15.1.2 When a grounding means is provided, all dead metal parts that are accessible during intended use or maintenance and that may become energized by a single electrical fault shall be reliably connected to the grounding means. The grounding means shall comply with the Grounding Impedance Test, Section 44.

Exception No. 1: The metal parts as described in (a) – (d) need not be grounded:

a) An adhesive-attached, metal foil marking; a screw; a handle; or the like, located on the outside of an enclosure or cabinet and isolated from electrical components or wiring by grounded metal parts so that it is not likely to become energized;

b) An isolated metal part, such as a magnet frame and armature; a small assembly screw; or the like, that is positively separated from wiring and uninsulated live parts;

c) A panel or a cover that does not enclose uninsulated live parts when the wiring is positively separated from the panel or cover so that it is not likely to become energized; and

d) A panel or a cover that is insulated from electrical components, including wiring, by an insulating barrier of vulcanized fiber, varnished cloth, phenolic composition, or similar material not less than 1/32 inch (0.8 mm) thick and secured in place.

Exception No. 2: An appliance that is double insulated in accordance with the Standard for Double Insulation Systems for Use in Electrical Equipment, UL 1097.

15.1.3 All conductive dead-metal parts that are accessible to service personnel and that are usually expected to be at ground potential (rubber cushion-mounted motor frames, electronic chassis, and the like) but may become energized by a single fault condition from a circuit involving risk of electric shock at an AC potential greater than 30 volts rms (42.4 volts peak) or a DC potential greater than 60 volts with reference to ground, shall be connected to the grounding means, or a marking in accordance with 54.16 shall be provided.

15.1.4 An appliance intended for permanent electrical connection shall have a field-wiring terminal intended solely for connection of an equipment-grounding conductor. The terminal shall comply with the requirements in 14.2.3.1, 14.2.3.2, 14.2.3.11, and 14.3.5.

15.1.5 In a cord-connected appliance, the provision of a multiple-conductor supply cord having a grounding conductor connected to the enclosure or frame of the appliance may be used as means for earth grounding.

15.1.6 The surface of any insulation on a grounding conductor of a flexible cord shall be green with or without one or more yellow stripes.

15.1.7 The grounding conductor of a flexible cord shall be secured to the frame or enclosure of the appliance by means of a screw that is not likely to be removed during ordinary servicing not involving the flexible cord, or by other reliable means. Solder alone shall not be used for securing the grounding conductor. The grounding conductor shall be connected to the grounding blade or equivalent fixed contacting member of an intended attachment plug.

Exception: The grounding conductor of a supply cord may be connected to the appliance ground with a female attachment plug that incorporates the line voltage connections.

15.2 Bonding

15.2.1 Uninsulated metal parts of a cabinet, an electrical enclosure, a motor frame and mounting brackets, a controller mounting bracket, a capacitor, and other electrical components, interconnecting tubing and piping, a valve, a plumbing accessory, and the like that involve a risk of electric shock shall be bonded for grounding if they may be contacted during intended use or servicing.

Exception No. 1: The metal parts as described in (a) – (d) need not be grounded:

a) An adhesive-attached, metal foil marking; a screw; a handle; or the like, located on the outside of an enclosure or cabinet and isolated from electrical components or wiring by grounded metal parts so that it is not likely to become energized;

b) An isolated metal part, such as a magnet frame and armature; a small assembly screw; or the like, that is positively separated from wiring and uninsulated live parts;

c) A panel or a cover that does not enclose uninsulated live parts when the wiring is positively separated from the panel or cover so that it is not likely to become energized; and

d) A panel or a cover that is insulated from electrical components, including wiring, by an insulating barrier of vulcanized fiber, varnished cloth, phenolic composition, or similar material not less than 1/32 inch (0.8 mm) thick and secured in place.

Exception No. 2: An appliance that is double insulated in accordance with the Standard for Double Insulation Systems for Use in Electrical Equipment, UL 1097.

15.2.2 Ferrous-metal parts in the grounding path shall be protected against corrosion by enameling, zinc coating, galvanizing, plating, or other equivalent means.

15.2.3 A separate component bonding conductor shall be of adequate size and shall be made of copper, copper alloy, or other material intended for use as an electrical conductor. See the Grounding Impedance Test, Section 44.

15.2.4 A separate bonding conductor or strap shall:

a) Be protected from mechanical damage or located within the outer enclosure or frame and

b) Not be secured by a removable fastener used for a purpose in addition to bonding unless the bonding conductor is unlikely to be omitted after removal and replacement of the fastener.

15.2.5 Bonding shall be by a positive means, such as by a clamp, rivet, bolt, screw, welded joint, or a soldered or brazed joint using materials having a softening or melting point higher than 454°C (850°F). The bonding connection shall penetrate nonconductive coatings such as paint or vitreous enamel. Bonding around a resilient mount shall not depend on the clamping action of rubber or similar material.

Exception: A connection that depends on the clamping action exerted by rubber or a similar material may be used if it complies with the Grounding Impedance Test, Section 44, under any degree of compression permitted by a variable clamping device and if the results are still acceptable after exposure to the effects of oil, grease, moisture, and thermal degradation likely to occur in service.

15.2.6 The effect of assembling and disassembling of a clamping device for maintenance purposes is to be considered with particular emphasis on the likelihood of the device being reassembled in its intended position.

15.2.7 In a cord-connected appliance, a bonding conductor or strap shall have a cross-sectional area not less than that of the grounding conductor of the supply cord.

Exception No. 1: A smaller conductor may be used if it complies with the requirement in Section 44.

Exception No. 2: A bonding conductor for a component or electrical enclosure need not be larger than the conductors supplying power to the component or components within the enclosure.

15.2.8 In a permanently-connected appliance, the size of a conductor or strap used to bond an electrical enclosure or a motor frame shall be based on the rating of the branch circuit overcurrent device to which the appliance will be connected in accordance with Table 15.1.

Exception No. 1: A smaller conductor may be used if it complies with the requirement in Section 44.

Exception No. 2: A bonding conductor for a component or electrical enclosure need not be larger than the conductors supplying power to the component or components within the enclosure.

Table 15.1
Size of bonding conductor

Rating of overcurrent device, amperes	Minimum size of bonding conductor[a]			
	Copper wire,		Aluminum wire,	
	AWG	(mm^2)	AWG	(mm^2)
15	14	2.1	12	3.3
20	12	3.3	10	5.3
30	10	5.3	8	8.4
40	10	5.3	8	8.4
60	10	5.3	8	8.4
100	8	8.4	6	13.3

[a] Or equivalent cross-sectional area.

15.2.9 If more than one rating of branch circuit overcurrent-protective device is involved, the size of the bonding conductor is to be based on the rating of the overcurrent-protective device intended to provide ground-fault protection of the component bonded by the conductor. For example, the size of the bonding conductor for a motor that is individually protected by a branch circuit overcurrent-protective device of lesser rating than other overcurrent-protective devices used with the appliance is to be based on the rating of the device intended for ground-fault protection of the motor.

16 Internal Wiring

16.1 General

16.1.1 Internal wiring shall be routed and secured so that neither it nor related electrical connections are likely to be subjected to stress and mechanical damage.

16.1.2 If servicing involves moving assemblies (such as reading heads, optical systems, and the like that have wiring connections to other parts of the appliance), or any wiring (other than an acceptable supply cord) that may involve a risk of electric shock and may be handled during such servicing shall comply with one of the following:

a) The wiring shall have supplementary insulation consisting of two layers of tape rated for the application.

b) The wiring shall have a length of tubing that has been determined to be acceptable for the application.

c) The appliance construction shall be such that the circuits are not energized during the servicing operation.

16.2 Wires

16.2.1 The internal wiring of an appliance is acceptable for the particular application when considered with regard to:

a) The temperature and voltage to which the wiring may be subjected;

b) Exposure to oil or grease; and

c) Other conditions of service to which the wiring may be subjected.

16.2.2 Internal wiring accessible during maintenance shall consist of wires that have insulation having a wall thickness of not less than 0.028 inch (0.71 mm).

Exception No. 1: A secondary circuit that is not required to be investigated in accordance with Exception Nos. 2 and 3 to 26.3 need not comply.

Exception No. 2: The thickness of cross-linked synthetic polymer, polytetrafluoroethylene or fluorinated ethylene propylene insulation shall not be less than 0.015 inch (0.38 mm).

16.2.3 The effects of vibration, impact, and exposure are to be considered for wires smaller than 24 AWG (0.21 mm^2).

16.2.4 Wiring that is subject to motion, including the opening of the door for servicing, and any supplementary insulation provided on the wire, may need to be subjected to a flexing test to determine its acceptability for the application. See the Internal Wiring Flexing Test, Section 42.

16.2.5 Impregnated or unimpregnated cotton- or asbestos-insulated wire shall not be used.

16.3 Protection of wiring

16.3.1 Metal clamps and guides used for routing stationary internal wiring shall have smooth, well-rounded edges.

16.3.2 Wires shall be located or protected so that they cannot contact sharp edges, screw threads, burrs, fins, moving parts, and the like that may abrade the insulation on the wires.

16.3.3 Auxiliary mechanical protection that is not electrically conductive shall be provided:

a) Under a clamp at which pressure is exerted on a conductor having thermoplastic insulation less than 1/32 inch (0.8 mm) thick and no overall braid and

b) On any wire or wires that are subject to motion.

16.3.4 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 well-rounded bushing or shall have smooth, well-rounded surfaces upon which the wire may bear, to avoid abrasion of the wire insulation.

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

16.4 High-voltage wiring

16.4.1 The high-voltage wiring of a neon tube shall comply with the high-voltage wiring requirements in the Standard for Electric Signs, UL 48.

17 Splices and Connections

17.1 Each splice and connection shall be mechanically secure and shall provide reliable electrical contact. Consideration shall be given to vibration and the like when judging the use of an electrical connection. A mechanical splicing device shall be of a type intended for the purpose.

17.2 Aluminum conductors, insulated or uninsulated, used as internal wiring, such as for interconnections between current-carrying parts or in a component winding, shall be terminated at each end by a method intended for the combination of metals involved at the connection points.

17.3 With reference to 17.2, a wire binding screw or a pressure wire conductor used as a terminating device shall be intended for use with aluminum under the conditions involved – for example, temperature, heat cycling, and vibration.

17.4 A soldered connection shall be made mechanically secure before being soldered if breaking or loosening of the connection may result in a risk of fire, electric shock, or injury to persons.

17.5 In an appliance in which excessive vibration is likely to occur, such as a motor driven amusement ride, the requirement in 17.1 will necessitate the use of lock washers or other means to prevent wire-binding screws and nuts from loosening.

17.6 A splice shall be provided with insulation that has been determined to be acceptable if required spacing between the splice and other metal parts may not be maintained.

17.7 If the voltage involved is less than 250 volts, insulation consisting of two layers of insulating thermoplastic tape, two layers of friction tape, or one layer of friction tape and one layer of rubber tape, that has been determined to be acceptable for the purpose may be used on a splice. Thermoplastic tape wrapped over a sharp edge shall not be used.

17.8 In determining if splice insulation consisting of coated fabric, thermoplastic, or another type of tape or tubing may be used, consideration is to be given to its properties, such as electrical (dielectric), mechanical, flammability, and moisture-resistance.

17.9 Splicing devices such as pressure wire connectors may be used if they provide mechanical security that has been determined to be acceptable and insulation rated for the voltage and temperature to which they are subjected.

17.10 The means of connecting stranded internal wiring to a wire-binding screw shall be such that loose strands of wire cannot contact other uninsulated conductive parts. This may be accomplished by use of a pressure terminal connector, a soldering lug, a crimped eyelet, or by any other reliable means.

17.11 Open-end connectors are not to be used unless they are provided with upturned ends that will hold the connector in place if the screw becomes slightly loose.

17.12 A nominal 0.110-, 0.125-, 0.187-, 0.205-, or 0.250-inch wide quick-connect terminal shall comply with the Standard for Electrical Quick-Connect Terminals, UL 310. Other sizes of quick-connect terminals shall be investigated with respect to crimp pullout, engagement-disengagement forces of the connector and tab, and temperature rise; all tests shall be conducted in accordance with UL 310.

18 Separation of Circuits

18.1 An insulated conductor that may touch any uninsulated live part operating at a potential higher than the potential at which the conductor itself operates shall be provided with insulation rated for the highest voltage involved.

18.2 Insulated conductors shall be separated or segregated from uninsulated live parts connected to different circuits.

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

18.4 Field-wiring terminals for secondary circuits shall not be in a wiring compartment, box, or other area with terminals for other circuits. Field-installed conductors shall be segregated or separated by barriers or partitions so as not to contact uninsulated live parts, field-installed wiring, and factory-installed wiring of any other circuit unless the conductors of both circuits are or will be insulated for the maximum voltage of either circuit.

Exception No. 1: In an appliance for which field connections for some applications are different from the connections for other applications, a removable solid partition or nonremovable partition in which there are holes for the passage of conductors may be provided. Instructions for use of such a removable or pierced partition are to be a permanent part of the appliance.

Exception No. 2: Instead of a partition, a wiring diagram may be provided on or with the appliance if such routing is clearly and completely shown by the diagram, and if complete wiring instructions accompany the diagram.

18.5 Separation of field-installed conductors connected to one circuit from other field-installed conductors and from uninsulated live parts connected to different circuits can be accomplished by arranging the location of openings in the enclosure for the various conductors (with respect to the terminals or other uninsulated live parts) so that, after installation, the conductors or parts of different circuits will not be intermingled. If no more openings are provided in the enclosure than are necessary for wiring of the appliance and each opening is opposite a set of terminals, it is to be assumed in determining compliance with this requirement that conductors entering the enclosure through any such opening will be connected only to the terminals opposite that opening. If more openings are provided in the enclosure than are necessary for wiring of the appliance, it is to be assumed in determining compliance with this requirement that conductors will enter the enclosure through openings that are not opposite the terminals to which they are intended to be connected and touch insulated conductors and uninsulated live parts of circuits other than their own.

18.6 In determining whether an appliance complies with the requirements in 17.3, the appliance is to be wired in the manner in which it would be wired in the field. A reasonable amount of slack is to be left in each conductor within the enclosure, and not more than average care is to be used in stowing the slack in the compartment.

18.7 A barrier or partition used to provide separation between the wiring of different circuits shall be grounded metal or rigid insulating material and shall be firmly secured in place.

19 Transformers

19.1 A transformer or power supply provided for a neon tube shall comply with the Standard for Neon Transformers and Power Supplies, UL 2161.

20 Motors

20.1 A motor shall be of a type that has been determined acceptable for the particular application.

20.2 A motor winding shall resist the absorption of moisture and shall be formed and assembled in an manner that has been determined to be acceptable for the application.

20.3 A brush cap shall be secured or located so as to be protected from mechanical damage that may result during normal use.

21 Overcurrent Protection

21.1 Each general-use receptacle circuit and each lampholder circuit included in the appliance shall be provided with overcurrent protection, as part of the appliance, rated at not more than 20 amperes. The overcurrent protection shall be provided by a circuit breaker or a fuse rated for use on a branch circuit.

Exception: An appliance that would be properly connected to a branch circuit rated 20 amperes or less need not have additional overcurrent protection.

21.2 A fuseholder or circuit breaker shall be intended for the application and shall not be accessible from outside the appliance without opening a door or cover.

Exception: The operating handle of a circuit breaker may project outside the enclosure.

21.3 If the handle of a circuit breaker is operated vertically rather than rotationally or horizontally, the up position of the handle shall be the on position.

21.4 A motor or a power transformer in an appliance rated more than 20 amperes shall be protected by an overcurrent device having a maximum ampere rating in accordance with the National Electrical Code, ANSI/NFPA 70. Such overcurrent protection shall be provided as a part of the appliance unless it can be determined that equivalent overcurrent protection would be incorporated as the branch-circuit protective device.

22 Motor-Overload Protection

22.1 Each motor shall be provided with overload protection.

Exception No. 1: A motor that is used for air handling only – direct drive blower or ventilating fan – is considered to have overload protection if it is protected under locked-rotor conditions only.

Exception No. 2: A single-coil shaded-pole motor having a 2 to 1 or less current ratio between locked-rotor current and no-load current is considered to have overload protection if it is protected under locked-rotor conditions only.

22.2 The overload protection required by 22.1 shall consist of one of the following:

a) Thermal protection complying with the requirements in the Standard for Overheating Protection for Motors, UL 2111;

b) Impedance protection complying with the requirements for such protection in UL 2111;

c) Other protection that is shown by tests to be equivalent to the protection specified in (a).

d) Compliance with the Secondary Circuit Motor Test, Section 46, for motors connected in secondary circuits and rated less than 100 volts or less than 200 volt-amperes.

22.3 A device providing overload protection for a motor shall be intended for use on a branch circuit to which the appliance may be connected, or additional protection shall be provided in the appliance.

22.4 The functioning of an overload-protective device provided for a motor as part of an appliance, whether or not such a device is required, shall not result in a risk of fire, electric shock, or injury to persons. See 30.7.1.

23 Capacitors

23.1 The materials and construction of a capacitor, its enclosure, or both shall be such that emission of flame from the enclosure during malfunction of the capacitor cannot occur.

23.2 A capacitor provided as a part of a capacitor 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 that will protect the plates against mechanical damage and that will prevent the emission of flame or molten material resulting from malfunction of the capacitor. The container shall be metal providing strength and protection not less than that of uncoated steel having a thickness of 0.020 inch (0.51 mm).

Exception: The container of a capacitor may be of sheet steel thinner than 0.020 inch (0.51 mm) or of other intended material if the capacitor is mounted in an enclosure that houses other parts of the appliance and if such a box, case, or the like is intended for the enclosure of live parts.

23.3 An electrolytic capacitor shall be vented.

23.4 If the charge stored in a capacitor 1 minute after it has been disconnected from its source of energy is sufficiently high that the potential measured between the terminals of the capacitor is 50 volts or more, or if the stored energy is 20 joules or more as determined from the following equation, a marking as indicated in 54.24 shall be provided.

$$J = 5 \times 10^{-7} CV^2$$

in which:

J is the stored energy, in joules,

C is the capacitance, in microfarads, and

V is the potential, in volts.

23.5 The voltage rating of a capacitor other than a motor-starting or motor-running capacitor shall equal or exceed the maximum steady-state potential to which the capacitor is subjected during operation of the appliance at the rated voltage.

23.6 A capacitor using a liquid dielectric medium more combustible than askarel shall be tested in accordance with the applicable performance requirements in this standard, including faulted-overcurrent conditions based on the branch circuit in which it is used; dielectric medium shall not be expelled.

24 Receptacles

24.1 A receptacle provided on an appliance shall be of a grounding type and shall be bonded to the frame of the appliance.

Exception No. 1: A receptacle on a double-insulated appliance shall not be of the grounding type.

Exception No. 2: A receptacle located within an enclosure need not be of the grounding type if it is dedicated for use in an application that does not warrant bonding to the grounding conductor.

24.2 The face of a receptacle shall either:

a) Be flush with or project beyond a nonconductive surrounding surface or

b) Project at least 0.015 inch (0.38 mm) beyond a conductive surrounding surface.

24.3 The white or silver terminal of each 2-pole receptacle nominally rated 120 volts shall be connected to the grounded (neutral) supply conductor.

Exception: A receptacle supplied from a secondary winding of an isolating transformer that is located in an appliance need not comply.

25 Switches and Controllers

25.1 Each switch or other control device shall be intended for the application and shall have a rating not less than that of the load it controls.

25.2 The rated ampacity of a switch that controls a solenoid, magnet, transformer, electric-discharge-lamp ballast, or other inductive load shall not be less than twice the rated full-load current of the component that is controlled unless the switch is rated for the application.

25.3 A switch that controls a lampholder for an incandescent lamp other than a 15-watt or smaller pilot or indicating lamp shall have a tungsten-filament lamp load-rating at least equal to the load it controls.

25.4 The operation of a device, such as a switch, that is intended to adapt the appliance to different supply voltages and that is accessible to the user or maintenance person without the use of tools shall not result in a risk of fire, electric shock, or injury to persons. See 41.5(a).

25.5 Each switch provided to de-energize the appliance for servicing shall disconnect all ungrounded conductors of the circuit when placed in the off position.

25.6 A motor controller shall be provided in a cord-connected appliance using a motor rated more than 1/3 horsepower (249 W output).

26 Secondary Circuits

26.1 A secondary circuit may be connected to the frame of an appliance.

26.2 If the frame is used as a current-carrying part, a hinge or other movable part shall not be relied upon as a current-carrying means.

26.3 All safety circuits are to be investigated for compliance with the requirements for primary circuits. All other secondary circuits, except as specified in 26.4 – 26.10, are to be investigated for compliance with the applicable requirements in this standard.

Exception No. 1: Deleted Effective May 1, 2012.

Exception No. 2: A circuit supplied from a Class 2 transformer rated at 30 volts rms sinusoidal or less need not be investigated. Printed-wiring boards and insulated wire used in such circuits shall be types that have been determined to be acceptable for the application. See 16.2.1, 27.1, and 27.2.

Exception No. 3: A circuit supplied by a single source consisting of an isolating transformer, or a power supply that includes an isolating transformer, with an open circuit potential or no-load output of the supply of 30 volts rms (42.4 volts peak) or less need not be investigated from the point at which the current and voltage are limited so that the current under any condition of load including short circuit is not more than 8 amperes after 1 minute of operation. Printed-wiring boards and insulated wire used in such circuits shall be types that have been determined to be acceptable for the application. See 16.2.1, 27.1, and 27.2.

26.4 With reference to the voltage limit specified in Exception No. 3 to 26.3, a measurement is to be made with the appliance, the power supply, or the transformer primary connected to the voltage specified in 32.3 and with all loading circuits disconnected from the transformer or power supply under test. Measurements may be made at the output terminals of the transformer or power supply. If a tapped transformer winding is used to supply a full-wave rectifier, voltage measurement is to be made from either end of the winding to the tap.

26.5 If the power supply mentioned in Exception No. 3 to 26.3 is not limited as to available short-circuit current by the construction of the transformer but the circuit includes either a fixed impedance, a fuse, a nonadjustable manual-reset circuit-protective device, or a regulating network, the circuits in which the current is limited in accordance with 26.6 or 26.8 need not be investigated.

26.6 A fuse or circuit-protective device used to limit the current in accordance with 26.5 shall be rated or set at not more than the values specified in Table 26.1.

Table 26.1
Rating for secondary fuse or circuit protector

Open-circuit voltage (peak)	Current rating, amperes
0 – 21.2	5.0
21.3 – 42.4	3.2

26.7 If an interchangeable fuse – a fuse is interchangeable if any fuse of a higher current rating will fit the fuseholder – is used, a marking as described in 54.14 shall be provided.

26.8 A fixed impedance or a regulating network used to limit the current in accordance with 26.5 shall be such that the current under any condition of load, including short circuit, does not exceed 8 amperes measured after 1 minute of operation.

26.9 If a regulating network is used to limit the voltage or current in accordance with 26.3 – 26.8, and the performance may be affected by malfunction, either short circuit or open circuit, of any single component in the network, the risk of such malfunction occurring shall be determined by an investigation of that component.

26.10 In a circuit of the type described in 26.5, the secondary winding of the transformer, the fuse or circuit-protective device, or the regulating network, and all wiring up to the point at which the current and voltage are limited are to be investigated for compliance with the applicable requirements in this standard.

27 Printed-Wiring Boards

27.1 A printed-wiring board used in a primary circuit and in a secondary circuit where separation of the bond between the conductor and the base material might result in contact with an uninsulated primary circuit part shall comply with the Standard for Printed-Wiring Boards, UL 796.

27.2 All printed-wiring boards shall have a flammability rating of V-2 or less in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

Exception: Printed-wiring boards located outside an enclosure shall have a minimum flammability rating of HB.

28 Spacings

28.1 The spacings between field-wiring terminals of opposite polarity and the spacings between a field-wiring terminal and any other uninsulated metal part (dead or live) of the opposite polarity shall not be less than indicated in Table 28.1.

Table 28.1
Minimum spacings at field-wiring terminals

Potential involved, volts	Between field-wiring terminals (through air or over surface),[a]		Between field-wiring terminals and other uninsulated parts not always of the same polarity[a]			
			Over surface,		Through air,	
	inch	(mm)	inch	(mm)	inch	(mm)
0 – 50	1/8	3.2	1/8	3.2	1/8	3.2
51 – 250	1/4	6.4	1/4	6.4	1/4	6.4
251 – 600	1/2[b]	12.7[b]	1/2[b]	12.7[b]	3/8	9.5

[a] These spacings apply to the sum of the spacings involved wherever an isolated dead metal part is interposed.

[b] A spacing of not less than 3/8 inch (9.5 mm) over the surface or through the air may be used at wiring terminals in a wiring compartment or terminal box that is integral with a motor.

28.2 In primary circuits, other than at field-wiring terminals, the spacing between uninsulated live parts of opposite polarity and between an uninsulated live part and a dead metal part shall not be less than the value specified in Table 28.2. 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 located near an uninsulated live part, the construction shall be such that at least the minimum intended spacings shall be maintained regardless of the position of the movable part.

Exception No. 1: A spacing at closed-in points on heating elements only, such as the screw-and-washer construction of an insulated terminal mounted in metal, shall not be less than 3/64 inch (1.2 mm).

Exception No. 2: The inherent spacings of a component of the appliance, such as a switch, are judged on the basis of the requirements for that component.

Exception No. 3: Motor spacings shall comply with the spacing requirements in the Standard for Rotating Electrical Machines – General Requirements, UL 1004-1.

Exception No. 4: See 26.5.

Exception No. 5: Spacings are not specified between parts of opposite polarity if one or both of the following conditions exist:

a) There are 10,000 ohms or more of series impedance in a circuit in which the voltage is 125 volts or less.

b) There are 20,000 ohms or more of series impedance in a circuit in which the voltage is 125 – 250 volts.

Table 28.2
Minimum primary-circuit spacings elsewhere than at field-wiring terminals and in motors

Potential involved in volts,		Over surface,		Through air,	
rms	(peak)	inches	(mm)	inches	(mm)
0 – 50	0 – 70.7	3/64[a]	1.2[a]	3/64[a]	1.2[a]
51 – 125	72.1 – 176.8	1/16[a,b]	1.6[a,b]	1/16[a,b]	1.6[a,b]
126 – 250	178.2 – 353.5	3/32[a,b]	2.4[a,b]	3/32[a,b]	2.4[a,b]
251 – 600	364.9 – 848.4	1/2[a,c]	12.7[a,c]	3/8[a,c]	9.5[a,c]
601 – 3000	849.8 – 4242.0	3/4[a,d,e]	19.0[a,d,e]	3/4[a,d,e]	19.0[a,d,e]
3001 – 5000	4243.4 – 7070.0	1[d,e]	25.4[d,e]	1[c,e]	25.4[d,e]
5001 – 10000	7071.4 – 14140.0	1-1/2[d]	38.1[d]	1-1/2[d]	38.1[d]
		1-1/8[e]	28.6[e]	1-1/8[e]	28.6[e]
10001 – 15000	14141.4 – 21210.0	1-1/2[d,e]	38.1[d,e]	1-1/2[d,e]	38.1[d,e]

[a] On printed-wiring boards, their connectors and board-mounted electrical components, wired on the load side of line filters or similar-voltage-peak-reduction networks and/or components, a minimum spacing of 0.023 inch (0.58 mm) plus 0.0002 inch (0.005 mm) per volt peak shall be maintained over the surface and through air between uninsulated live parts and any other uninsulated conductive part (live or dead) not of the same polarity.

[b] Film-coated wire is to be considered as if it were an uninsulated live part. However, spacings not smaller than 3/32 inch (2.4 mm) over surface and through air may be used between dead metal parts and film coated wire that is rigidly supported and held in place on a coil.

[c] A spacing of not less than 3/32 inch (2.4 mm) over surface and through air may be used between a dead metal part and film-coated wire that is rigidly supported and held in place on a coil.

[d] Between uninsulated high-voltage parts and uninsulated high-voltage parts of opposite polarity or different potentials, earth-grounded metal parts, and uninsulated primary-circuit parts.

[e] Between uninsulated high-voltage parts and insulated primary-circuit parts, and insulated high-voltage parts of opposite polarity or of different potentials.

28.3 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 minimum spacings specified in Tables 28.1 and 28.2 will be maintained.

28.4 Primary-circuit spacings apply in all secondary circuits supplied by a transformer winding of a 200 volt-ampere or greater capacity (maximum available power) at a potential greater than 100 volts. The spacings in all other secondary circuits are to be judged on the basis of the Dielectric Voltage-Withstand Test, Section 37, and Table 37.1.

28.5 The spacings specified in Table 28.2 as the minimum intended do not apply to snap switches and other intended components of an appliance. For components, the spacings apply that are specified in the requirements for the particular component.

28.6 At terminal screws and studs to which connection may be made in the field by means of wire connectors, eyelets, and the like, the spacings shall not be less than those specified in Table 28.1 with the connectors, eyelets, and the like, in such position that the minimum spacings specified in Tables 28.1 and 28.2 – opposite polarity and to dead metal – exist.

28.7 An insulating liner or barrier of vulcanized fiber or similar material used in lieu of spacings shall not be less than 1/32 inch (0.8 mm) thick for up to 600 volts and shall be located or of such material so that it will not be adversely affected by arcing. However, vulcanized fiber not less than 1/64 inch (0.4 mm) thick may be used in conjunction with an additional air spacing of not less than 50 percent of the spacing required for air alone. Separators shall be held in place by a means more secure than friction between surfaces. The elasticity of tubing shall not be depended upon to hold the tubing in place, but dilated or heat-shrunk tubing may be used.

Exception: Insulating material having a thickness less than that specified may be used if upon investigation it is determined to be acceptable for the application.

28.8 The spacing requirements of neon tubes shall comply with neon tubing and electrode receptacles and other spacing requirements as specified in the Standard for Electric Signs, UL 48.

29 Coin, Currency, and Credit Mechanisms

29.1 A coin, currency, or credit mechanism shall be acceptable for the temperatures involved and for controlling the intended load. The mechanism shall be installed in the appliance at the factory.

Exception: A coin, currency, or credit mechanism may be installed in the field if the construction complies with the requirements in 29.2 – 29.6 and 54.28 – 54.30.

29.2 The installation of a coin, currency, or credit mechanism shall be by means of receptacle and plug-in connectors.

29.3 Bonding for grounding shall be accomplished automatically by normal mounting of the mechanism in the appliance, or a separate bonding conductor shall be provided in the receptacle and plug-in connector.

29.4 A strain-relief means shall be provided for the wiring in the mechanism if stress may be transmitted to terminal connections during installation.

29.5 A coin or credit mechanism is to be trial-installed to determine that its installation is feasible and that the instructions are detailed and correct. A risk of electric shock shall not be present during installation of a mechanism unless the marking required by 54.28 is provided. Following installation, the use of a mechanism shall not result in a risk of fire, electric shock, or injury to persons.

29.6 An appliance without a coin or credit mechanism is to be evaluated for accessibility of live or moving parts capable of causing injury to persons, without the mechanism installed and with the enclosure of the appliance open to the extent permitted by the absence of the coin or credit mechanism.

30 Protection Against Risk of Fire, Electric Shock, or Injury to Persons

30.1 General

30.1.1 If the normal operation of an appliance involves a risk of fire, electric shock, or injury to persons, means shall be provided to reduce such a risk.

30.1.2 Whether a guard, a safety release, a pressure relief valve, 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 fire, electric shock, or injury to persons resulting from a cause other than gross negligence.

30.1.3 With reference to the requirement in 30.1.2, the degree of protection required of an enclosure depends upon the general construction and intended use of the appliance. The factors to be taken into consideration in evaluating the acceptability of exposed moving parts are:

a) The degree of exposure;

b) The sharpness of the moving parts;

c) The risk of unintentional contact with the moving parts;

d) The speed of movement of these parts; and

e) The risk of fingers, arms, hair, or clothing being drawn into the moving parts, such as at points where gears mesh or where belts travel onto a pulley or where moving parts close in a pinching or shearing action.

30.2 Sharp edges

30.2.1 An edge, a projection, a corner, an opening, a frame, a guard, a handle, or the like shall be smooth and not be sufficiently sharp to constitute a risk of injury to persons during intended use or servicing of the appliance.

Exception: This requirement does not apply to a part or portion of a part that is sharp in order to perform a working function.

30.2.2 Whenever referee measurements are necessary to determine if a part as mentioned in 30.2.1 is sufficiently sharp to constitute a risk of injury to persons, the method described in the Standard for Tests for Sharpness of Edges on Equipment, UL 1439, is to be used.

30.3 Interlocks and protective devices

30.3.1 A safety interlock (a means relied upon to prevent access to an area involving a risk of electric shock or injury to persons) shall be of a type or in such a location that it is not likely to be unintentionally operated. In order to bypass a safety interlock, an intentional operation shall be necessary.

30.3.2 An interlock provided for the purpose of protecting personnel against risk of electric shock shall open all current-carrying conductors of cord-connected appliances and all ungrounded conductors of permanently-connected appliances.

Exception: An interlock switch that opens all current-carrying conductors in the area in which the interlock is intended to provide protection may be used even though conductors outside the protected area are left live.

30.3.3 A bypass means shall be such that the safety interlock function is self-restoring when the appliance is returned to intended operation.

30.3.4 A safety interlock operated by a door or panel shall function before any opening resulting from movement of the door or panel is large enough to provide access to parts involving a risk of electric shock or injury to persons as determined by application of the probes as described in 10.3 and 10.4.

30.3.5 If a safety interlock system is used that employs solid state devices and the performance of the system may be affected by malfunction – either by short circuit or open circuit – of any single solid state component in the system, the intended use of the system is to include an investigation of that component.

30.3.6 Additional requirements for a safety interlock system are not specified but are to be determined from a study of the entire appliance, its construction, operating characteristics, intended function, and possible misuse. In the case of an interlock system that is not reliable, an investigation of the system and its components is to include consideration of the frequency of operation and the nature of the risk involved in non-operation, and is to include an endurance test based on these factors. In general, the endurance test for interlocks involving service personnel is 6,000 operations and the test for interlocks involving a maintenance person or user is 100,000 operations.

30.4 Protection of maintenance and service personnel

30.4.1 The requirements in 30.4.2 – 30.5.1 apply only to appliances of such size and complexity that it may be necessary for maintenance or service personnel to reach over, under, across, or around uninsulated electrical parts or moving parts to make adjustments or measurements while the appliance is energized.

30.4.2 An uninsulated part that involves a risk of electric shock at more than 42.4 volts peak AC or 60 volts DC shall be located or protected so that unintentional contact with the part is not likely during service operations involving other parts of the appliance.

30.4.3 Moving parts that may cause injury to persons and that must be in motion during servicing operations not involving the moving parts shall be located or protected so that unintentional contact with the moving parts is not likely.

30.5 Electric shock

30.5.1 A risk of electric shock is considered likely to occur at any part if the potential between the part and earth ground or any other accessible part is more than 42.4 volts peak and the continuous current flow through a 1500-ohm resistor connected across the potential exceeds 5.0 milliamperes.

30.6 Injury to persons

30.6.1 A risk of injury to persons is considered to exist if one or more of the conditions in (a) – (d) applies:

a) A power-operated moving part such as a gear and linkage is accessible during intended operation and can cause a cut or laceration;

b) A sharp edge, burr, or projection is present that can cause injury during intended use or maintenance;

c) The stability of an appliance is such that it can cause injury to persons (see the Physical Stability Test, Section 39); and

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

30.6.2 With reference to 30.6.1, the accessibility of power-operated moving parts such as gears and linkages is to be investigated using the applicable accessibility requirements in 10.1 – 10.4.

30.6.3 If a moving part involving a risk of injury to persons is accessible through a maintenance access door, means shall be provided so that when the door or panel is opened, the movement of the part is reduced within 5 seconds to a speed that will not involve a risk of injury to persons.

30.6.4 If complete guarding of a moving part involving a risk of injury to the maintenance person is not possible without defeating the intended function of the appliance, a switch or other control device to de-energize the part shall be provided at a readily accessible location on the appliance.

30.6.5 A manually-operated control for moving parts located in a maintenance area that may result in injury to persons shall be:

a) Located or guarded that it is unlikely to be switched on unintentionally and

b) Capable of being switched off by a single, straight-line motion.

30.7 Switches and controllers

30.7.1 If an automatically-reset protective device is used in an appliance, automatic restarting of the motor shall not result in a risk of injury to persons.

30.7.2 The requirement in 30.7.1 may necessitate the use of an interlock in the appliance if moving parts or the like may create a risk of injury upon automatic restarting of the motor.

30.7.3 An automatically-reset protector shall not be used on an amusement ride.

31 Covers and Guards

31.1 A lid or a cover that may cause injury upon unintentional closing shall be:

a) Counterweighted;

b) Spring-loaded;

c) Provided with an automatic latch to retain it in the open position; or

d) In the case of the playing field of a pinball machine, provided with a mechanical rod fitting into a recess that cannot be readily knocked out.

The action members of the latches shall be enclosed or guarded.

31.2 A guard shall be provided over a part that is in motion during servicing and that presents a risk of injury, such as pinching, snagging, cutting, or the like, to maintenance or service personnel when a cover, door, panel, or other closure is opened or removed during servicing.

PERFORMANCE

32 General

32.1 An appliance with one frequency rating is to be tested at that frequency. An appliance with a dual frequency rating or frequency range is to be tested at 60 hertz if 60 hertz is within the rating, and may also be tested at a second frequency if such testing is warranted.

32.2 Insulation resistance is to be measured using a voltmeter having an internal resistance of 30,000 ohms and a 250-volt direct-current circuit.

32.3 In tests where maximum rated voltage is specified, the appliance is to be connected to a source of supply of maximum rated voltage except that the voltage of the test circuit is to be 120 volts for an appliance rated between 110 and 120 volts and is to be 240 volts for an appliance rated between 220 and 240 volts. At any other voltage rating, the appliance is to be tested at its marked voltage rating. If agreeable with all parties concerned, a different voltage may be used. An appliance that is rated for use at more than one voltage or for a range of voltages and contains a tapped transformer or other means of being adapted to different supply voltages is to be tested while connected in accordance with the manufacturer's instructions.

33 Starting Current Test

33.1 An appliance shall start and operate as intended according to the test described in 33.2 while connected to a branch circuit protected by a fuse, other than a time-delay type, that has a current rating corresponding to that of the branch circuit to which the appliance is intended to be connected. The fuse shall not open, and no overload protective device provided as part of the appliance shall trip.

Exception: This requirement does not apply if:

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

b) The appliance starts and operates normally on a circuit protected by a time-delay fuse.

33.2 To determine whether an appliance complies with the requirement in 33.1, the appliance is to be started three times from standstill. The appliance is to be at room temperature at the beginning of the test. The test is to be conducted at the voltage and frequency specified in 32.3. 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 an automatic appliance), and any motor is to be allowed to come to rest and other thermal components are to cool between successive starts.

34 Leakage Current Test

34.1 The leakage current of a cord-connected appliance rated for a nominal 250 volts or less supply when tested in accordance with 34.2 – 34.9 shall not be more than:

a) 0.75 milliampere when the grounding conductor is connected and switch S1 of the measurement circuit illustrated in Figure 34.1 is closed;

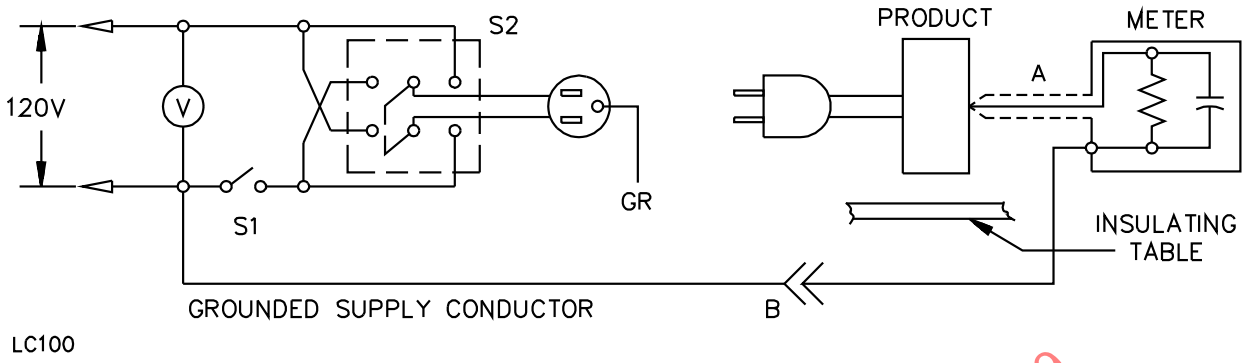
b) 1.0 milliampere when the grounding conductor is opened and switch S1 is closed or with the grounding conductor connected and switch S1 is opened; and

c) 2.0 milliamperes when the grounding conductor and switch S1 are both open.

Exception No. 1: If an appliance has a grounding conductor detector-interrupter that de-energizes the appliance when the connection opens between accessible conductive parts of the appliance and the service equipment ground, the leakage currents shall be not more than 3.5 milliamperes.

Exception No. 2: The measurement in (a) only refers to accessible surfaces that are not grounded.

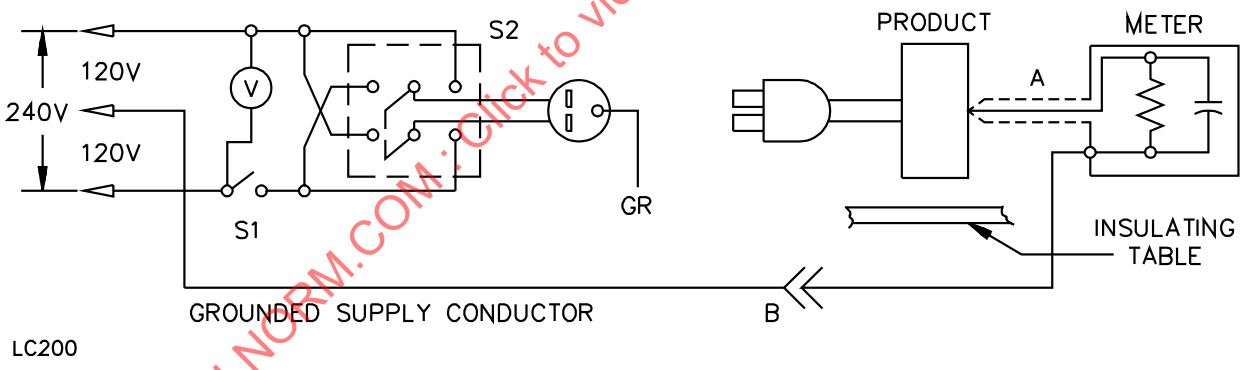
Figure 34.1
Leakage current measurement circuit



LC100

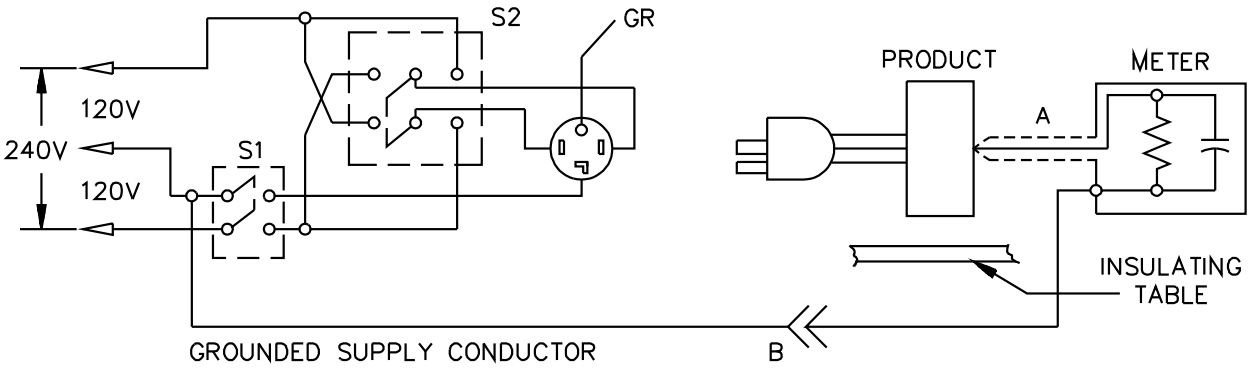
Appliance intended for connection to a 120-volt power supply.

Figure 34.1 (Cont.)



LC200

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



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

A – Probe with shielded lead.

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

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

34.3 All exposed conductive surfaces are to be tested for leakage currents. The 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 as specified in Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts, Section 10. 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.

34.4 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 metal foil with an area of 4 by 8 inches (10 by 20 centimeters) in contact with the surface. If the surface is less than 4 by 8 inches, 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 appliance.

34.5 The measurement circuit for leakage current shall be as illustrated in Figure 34.1. The measurement instrument is defined in (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. The meter used need not have all of 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 not to have an error of more than 5 percent.

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

34.7 A sample appliance is to be prepared and conditioned for leakage-current measurement as follows:

a) The sample is to be representative of the wiring methods, routing, components, component location and installation, and the like, of the production unit.

b) The grounding conductor is to be open at the attachment plug and the sample isolated from ground.

c) The sample is to be conditioned for not less than 8 hours in an ambient temperature of 21 – 27°C (70 – 80°F) with a relative humidity of approximately 50 percent.

d) The test is to be conducted at the ambient conditions specified in (c).

e) The supply voltage is to be adjusted to rated voltage.

34.8 The test sequence, with reference to the measuring circuit, Figure 34.1, is to be as follows:

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

c) The leakage current is to be monitored until thermal stabilization is obtained. Both positions of switch S2 are to be used in determining this measurement. Thermal stabilization is to be obtained by operation as in the temperature test.

34.9 The complete leakage current test program as described in 34.8, is to be conducted without interruption for other tests. However, with the concurrence of those concerned, the leakage current tests may be interrupted for the purpose of conducting other nondestructive tests.

35 Input Test

35.1 The current or power input to an appliance shall not be more than 110 percent of the rated value when the appliance is operated under the condition of maximum normal load while connected to a supply circuit of maximum rated voltage and rated frequency. The input of an amusement ride for children is to be measured with a 150 pound (68 kg) load applied in such a position as to simulate as nearly as possible the load imposed by the human body.

36 Temperature Test

36.1 When tested under the conditions of maximum normal load as described in 36.12, an appliance shall not attain a temperature at any point sufficiently high to:

a) Result in a risk of fire;

b) Adversely affect any materials used in the appliance; or

c) Exceed the temperature rises specified in Table 36.1. See 36.3.

Table 36.1
Maximum temperature rises

Materials and components	°C	(°F)
A. MOTORS		
1. Class 105 (formerly Class A) insulation systems on coil windings of AC motors having a frame diameter not larger than 7 inches (178 mm) (not including universal motors) and on vibrator coils:		
a) In open motors and on vibrator coils (thermocouple or resistance method):	75[a]	135[a]
b) In totally enclosed motors (thermocouple or resistance method):	80[a]	144[a]
2. Class 105 (formerly Class A) insulation systems on coil windings of AC motors having a frame diameter larger than 7 inches (178 mm) and of DC motors and universal motors:		
a) In open motors:		
Thermocouple method	65[a]	117[a]
Resistance method	75[a]	135[a]
b) In totally enclosed motors:		
Thermocouple method	70[a]	126[a]
Resistance method	80[a]	144[a]
3. Class 130 (formerly Class B) insulation systems on coil windings of AC motors having a frame diameter not larger than 7 inches (178 mm) (not including universal motors) and on vibrator coils:		
a) In open motors and on vibrator coils (thermocouple or resistance method):	95[a]	171[a]
b) In totally enclosed motors (thermocouple or resistance method):	100[a]	180[a]
4. Class 130 (formerly Class B) insulation systems on coil windings of AC motors having a frame diameter larger than 7 inches (178 mm) and of DC motors and universal motors:		
a) In open motors:		
Thermocouple method	85[a]	153[a]
Resistance method	95[a]	171[a]
b) In totally enclosed motors		
Thermocouple method	90[a]	162[a]
Resistance method	100[a]	180[a]
5. Class F insulation systems on coil windings of AC motors having a frame diameter not larger than 7 inches (178 mm), not including universal motors, and on vibrator coils:		
a) In open motors and on vibrator coils (thermocouple or resistance method)	120	216
b) In totally enclosed motors (thermocouple or resistance method)	125	225

Table 36.1 Continued on Next Page

Table 36.1 Continued

Materials and components	°C	(°F)
6. Class F insulation systems on coil windings of AC motors having a frame diameter larger than 7 inches (178 mm) and of DC motors and universal motors:		
a) In open motors		
Thermocouple method	110	198
Resistance method	120	216
b) In totally enclosed motors		
Thermocouple method	115	207
Resistance method	125	225
7. Class H insulation systems on coil windings of AC motors having a frame diameter not larger than 7 inches (178 mm) and on vibrator coils:		
a) In open motors and on vibrator coils (thermocouple or resistance method)	135	243
b) In totally enclosed motors (thermocouple or resistance method)	140	252
8. Class H insulation systems on coil windings of AC motors having a frame diameter larger than 7 inches (178 mm) and of DC motors and universal motors:		
a) In open motors		
Thermocouple method	125	225
Resistance method	135	243
b) In totally enclosed motors		
Thermocouple method	130	234
Resistance method	140	252
B. COMPONENTS		
1. Capacitors – On surface of casing:		
Electrolytic	40[b]	72[b]
Other types	65[c]	117[c]
2. Fuses	65	117
3. Transformers with Class 105 insulation systems:		
Thermocouple method	65[a]	117[a]
Resistance method	75[a]	135[a]
4. Transformers with Class 130 insulation systems:		
Thermocouple method	85[a]	153[a]
Resistance method	95[a]	171[a]
5. Transformers with Class 155 insulation systems:		
Thermocouple method	110	198
Resistance method	120	216
6. Transformers with Class 180 insulation systems:		
Thermocouple method	125	225
Resistance method	135	243
7. Wood and similar material	65	117
8. At any point on or within a terminal box on a stationary unit (see 54.15)	65	117
C. INSULATED CONDUCTORS		
1. Rubber- or thermoplastic-insulated wires and cords	35[d,e]	63[d,e]
D. SURFACES		
1. A surface upon which a permanently wired unit might be mounted in service, and surfaces that might be adjacent to the unit when it is so mounted	65	117
E. ELECTRICAL INSULATION – GENERAL		
1. Fiber used as electrical insulation	65	117
2. Phenolic composition used as electrical insulation or as a part whose malfunction may result in a risk of fire, electric shock, injury to persons, or electrical – high current levels	125[d]	225[d]
3. Varnished-cloth insulation	60	108

Table 36.1 Continued on Next Page

Table 36.1 Continued

Materials and components	°C	(°F)
[a] See 36.5.		
[b] A capacitor operating at a temperature rise higher than 40°C (72°F) may be investigated on the basis of its marked temperature rating or, if not marked with a temperature rating, may be investigated to determine its acceptability at the higher temperature. The temperature rise of a capacitor that is integral with or attached to a motor shall not be more than 65°C (117°F).		
[c] A capacitor that operates at a temperature rise of more than 65°C (117°F) may be investigated on the basis of its marked temperature limit.		
[d] The limitations on phenolic composition and on rubber and thermoplastic insulations do not apply to compounds that are investigated and determined to have heat-resistant properties.		
[e] Rubber-insulated conductors within a motor having a Class 105 (formerly Class A) insulation system, rubber-insulated motor leads, and a rubber-insulated flexible cord entering a motor can be subjected to a temperature rise of more than 35°C (63°F) if an acceptable braid is used on the conductor of other than a flexible cord. This does not apply to thermoplastic-insulated wires or cords.		

36.2 During the test, a thermal or overcurrent (overload) protective device shall not operate.

36.3 Each value of temperature rise in Table 36.1 is based on an assumed ambient temperature of 25°C (77°F). Tests are to be conducted at any room ambient temperature within the range of 10 – 40°C (50 – 104°F).

36.4 During normal use, the temperature of a surface that may be contacted by persons shall not be more than the value given in Table 36.2. If the test is conducted at a room temperature other than 25°C (77°F), the results are to be corrected to that temperature.

Exception: Other than a handle or knob, a surface that is accessible to service personnel may exceed the surface temperature values in Table 36.2 if the surface is marked in accordance with 54.20.

Table 36.2
Maximum surface temperatures

Location	Composition of surface[a]			
	Metal,		Nonmetallic,	
	°C	(°F)	°C	(°F)
Handles, knobs, or surfaces that are grasped for lifting, carrying, or holding	56	131	75	167
Handles or knobs that are contacted, but do not involve lifting, carrying, or holding, and surfaces subject to contact during intended use or maintenance	60	140	85	185
Other surfaces	70	158	95	203
[a] A handle, knob, or the like made of nonmetallic material that is plated or clad with metal having a thickness of 0.005 inch (0.13 mm) or less is considered to be a nonmetallic part.				

36.5 Coil and winding temperatures are to be measured by thermocouples located on exposed surfaces, except that the resistance method may be used for a coil that is inaccessible for mounting thermocouples because the coil is, for example, immersed in sealing compound, wrapped with thermal insulation, or wrapped with more than two layers of material such as cotton, paper, or rayon more than 1/32 inch (0.8 mm) thick. For a thermocouple-measured temperature of a coil in an alternating-current motor, other than a universal motor, having a frame diameter of 7 inches (178 mm) or less, the thermocouple is to be mounted on the integrally-applied insulation of the coil wire. For a thermocouple-measured temperature of a coil of any other motor, the thermocouple is to be mounted as described, or it may be separated from the conductor by no more than the insulation on the conductor itself and the intended coil-wire wrap.

36.6 At a point on the surface of a coil where the temperature is affected by an external source of heat, the temperature rise measured by means of a thermocouple may be higher by the amount specified in Table 36.3 than the maximum indicated in Table 36.1 if the temperature rise of the coil measured by the resistance method is not greater than that specified in Table 36.1.

Table 36.3
Maximum temperature rise where an external source of heat is a factor

Reference in Table 36.1	Additional thermocouple rise,	
	°C	(°F)
Subitem (1)(a) to item (A)	5	9
Subitem (2)(a) to item (A)	15	27
Subitem (2)(b) to item (A)	20	36
Subitems (1)(b) and (6)(b) to item (A)	10	18

36.7 With reference to the test described in 36.15 that is to be continued until constant temperatures are attained, thermal equilibrium is considered to be attained when three successive readings, taken at intervals of 10 percent of the previously elapsed duration of that test, but not less than 5 minutes, indicate no change.

36.8 Rubber and other material subject to deterioration is to be removed from feet and other supports of the appliance if absence of the material might result in the appliance attaining higher temperatures.

36.9 Thermocouples are to consist of wires no larger than 24 AWG (0.21 mm^2). When thermocouples are used to determine the temperatures in connection with the heating of electrical devices, it is common practice to use thermocouples consisting of 30 AWG (0.05 mm^2) iron and constantan wires and a temperature-type indicating instrument. Such equipment is to be used whenever referee temperature measurements by thermocouples are necessary.

36.10 The thermocouples and related instruments are to be accurate and calibrated in accordance with good laboratory practice. The thermocouple wire is to conform to the requirements for Special Tolerances thermocouples as listed in the Tolerances on Initial Values of EMF versus Temperature tables in the Standard Specification and Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples, ANSI/ASTM E230/E230M.

36.11 A thermocouple junction and adjacent thermocouple lead wire are to be held in secure, held in good thermal contact with the surface of the material being measured. Secure thermal contact may be achieved by securely taping or cementing the thermocouple in place. If a metal surface is involved, brazing or soldering the thermocouple to the metal may be necessary.

36.12 In testing an appliance, maximum normal load is considered to be the load that approximates as closely as possible the most severe conditions of normal use. It is not a deliberate overload except as the conditions of actual use can be more severe than the maximum load conditions that are recommended by the manufacturer of the appliance. A test that has been determined to be a close approximation of the most severe conditions of normal use is indicated in 36.15 for an amusement ride. However, appliances having features not contemplated in this test procedure may be tested as necessary to meet the intent of these requirements.

36.13 An appliance that is provided with internal or external receptacle connectors for the installation of accessories is to be subjected to the normal temperature test with such connectors loaded to their maximum rated output.

36.14 The test is to be conducted simulating the most severe installation the construction permits. Installation in an alcove, in a right-angle corner of a room, or against a wall is to be simulated if the appliance lends itself to such placement.

36.15 The temperature test for an amusement ride is to consist of continuous operation with a 150-pound load, applied in such a position so as to simulate as nearly as possible the load imposed by the human body, until constant temperatures are attained.

37 Dielectric Voltage-Withstand Test

37.1 Primary circuits

37.1.1 An appliance shall withstand for 1 minute without breakdown the application of an essentially sinusoidal potential at a frequency within the range of 40 – 70 hertz with the appliance at the maximum operating temperature reached in normal use:

a) Successively applied between each different type of primary circuit and earth ground (dead metal parts) with all other primary circuits connected to the earth ground.

b) Applied between any live or current-carrying part of the primary circuit of an isolating-type power transformer and each secondary circuit of that transformer.

c) Applied between terminals of opposite polarity on capacitors that are connected across the line.

37.1.2 The test potential is to be:

a) One thousand volts for an appliance using a motor rated 1/2 horsepower (373 W output) or less and 250 volts or less or

b) One thousand volts plus twice the rated voltage for an appliance using a motor rated more than 1/2 horsepower or more than 250 volts, or an appliance applied directly to persons. A handle, joystick, or an appliance that persons may ride are not considered to be applied directly to persons.

37.1.3 If an autotransformer is in the circuit, an essentially sinusoidal potential of 1250 volts plus twice the rated voltage at a frequency in the range of 40 – 70 hertz is to be applied to all wiring involving more than 250 volts.

37.1.4 The primary of the autotransformer is to be disconnected and the test potential is to be applied directly to the wiring that involves the higher potentials.

37.1.5 To determine whether an appliance complies with the requirement in 37.1.1, the appliance is to be tested using a 500 volt-ampere or larger capacity transformer, the output voltage of which 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 value for 1 minute, except in case of breakdown. The increase in applied potential is to be at a substantially uniform rate as rapid as is consistent with correct indication of its value by a voltmeter.

37.1.6 If the current leakage across the line, or from line to earth ground, is large enough to make it impossible to maintain the required AC test potential, the appliance may be subjected to a DC test potential of 1.414 times the applicable AC voltage. The DC test potential is to be maintained for 1 minute, except in case of breakdown.

37.2 Maximum-voltage measurements

37.2.1 The maximum voltage used as a basis for the calculation of the dielectric voltage-withstand potentials specified in Table 37.1 is to be determined in accordance with 37.2.2 – 37.2.5.

Table 37.1
Test potential for secondary circuits

Maximum voltage (rms) in the circuit[a]	Test potential
30 or less (42.4 peak)	No test
More than 30 but not more than 333.3 (471.3 peak)	Ten times maximum voltage in circuit (maximum of 1000 V rms)
More than 333.3 (471.3 peak) but not more than 1000	Three times maximum voltage in circuit 1000 (1414 peak)
More than 1000 (1414 peak)	1750 V plus 1.25 times voltage in circuit
[a] If the peak voltage is greater than 120 percent of 1.414 times the rms voltage, the circuit is to be tested as if the voltage were peak voltage divided by 1.414.	

37.2.2 Voltages are to be measured with and without any accessories or kits. In each case, all operating controls and all maintenance area controls are to be adjusted to produce the maximum voltage.

37.2.3 An automatic voltage-regulating device is to be rendered inoperative unless, upon investigation, it is determined that it can be relied upon to reduce the risk of an increase in voltage. The investigation is to take into consideration any likely malfunctions or breakdown of either the regulating device or the appliance and the possibility of the device being disconnected if it is not permanently connected in the circuit.

37.2.4 A connector or comparable part that is likely to be disconnected during intended use or maintenance is to be both connected and disconnected during the test in order that the maximum voltage can be obtained.

37.2.5 If a complex voltage is present, the peak value of the voltage is to be measured.

37.3 Secondary circuits

37.3.1 Each secondary circuit shall withstand for 1 minute without breakdown the application of a test potential between:

a) Primary and secondary circuits,

b) Secondary circuits and grounded metal with any grounding connections disconnected,

c) Secondary circuit current-carrying parts that are isolated from each other after all common ground connections are disconnected, and

d) Isolated secondary windings of transformers.

The appliance shall be at normal operating temperature during the test. The test potential shall be as indicated in Table 37.1 and 37.3.2.

Exception: Circuits derived from isolation transformers that are powered by a secondary circuit that does not involve a risk of electric shock need not be tested.

37.3.2 The test potential may be obtained from any convenient source having a capacity to maintain the potential indicated in Table 37.1, except in case of breakdown. The output voltage of the test apparatus is to be monitored. Starting at zero, the applied potential is to be increased at a rate of approximately 200 volts per second until the required test value is reached and is to be held at that value for 1 minute. A DC source or an AC source with a peak value equal to the DC value may be used for testing a DC circuit.

37.3.3 Printed-wiring assemblies and other electronic circuit components that would be damaged by application of the test potential or that would short-circuit the test potential are to be removed, disconnected, or otherwise rendered inoperative before the dielectric voltage-withstand tests are conducted. A representative subassembly may be tested instead of an entire appliance. Rectifier diodes in the power supply may be individually shunted before the test is conducted to avoid destroying them in the case of a malfunction elsewhere in the secondary circuit.

37.4 Induced potential

37.4.1 When at operating temperature, each power transformer shall operate without breakdown while a potential indicated in Table 37.1 is induced for 1 minute in each secondary winding that furnishes power at a higher potential than the primary windings.

Exception: A winding of a transformer that does not serve a prime power-supply function (such as a resonant winding of a constant-voltage transformer) need not be subjected to this test.

37.4.2 An essentially sinusoidal source is to be used, and the frequency of the source may be in the range of 180 – 1000 hertz if necessary to prevent saturation of the core.

37.4.3 Primary- and secondary-circuit wiring connected to a transformer is to be disconnected for the test mentioned in 37.4.1.

38 Spill Test

38.1 Each apparatus with a horizontal playing surface, a surface that could be used to support glasses of liquid, or other surfaces on the front of a unit with joints, shall be constructed to prevent the entrance of liquids into parts of enclosures that house electrical components. One liter of water shall be poured at a rate of 1 L/min over each surface where water is likely to enter. The enclosure shall be examined for an hour after each spill has been simulated, and the apparatus shall comply with the dielectric voltage-withstand test of 37.1 – 37.3. The apparatus may be tilted up to 5 degrees in any direction from the vertical during the test.

39 Physical Stability Test

39.1 Under all conditions of servicing and intended use after installation, a fully assembled appliance shall not become physically unstable to the degree that it may result in a risk of injury to users, maintenance, or service personnel.

39.2 An appliance shall not tip over when tilted 10 degrees from its intended upright position while all doors, covers, gates, drawers, and the like are in place and closed.

39.3 The requirements in 39.4 – 39.9 apply only to freestanding appliances. A freestanding appliance is one that is floor standing and not intended to be secured to other appliances or to the floor or other parts of the building.

39.4 In conducting the tests described in 39.5 – 39.7, all casters and jacks are to be placed in their most unfavorable position and wheels are to be locked or blocked. However, if casters are being used only to transport the appliance and jacks are lowered after installation, then the jacks (and not the casters) are to be used in the most unfavorable position for the test, consistent with reasonable leveling of the appliance.

39.5 A freestanding appliance that has an external ledge at a height not exceeding 39-3/8 inches (1 meter) from the floor and that is likely to be stepped on or sat upon shall not tip over when a continuous downward force of 180 lbf (800 N) is applied to that surface at the point of maximum moment. For this test all doors, covers, gates, drawers, and the like are to be in place and closed.

39.6 With regard to the requirement in 39.5, delicate parts such as control panels and video monitors are not considered likely to be stepped on or sat upon.

39.7 A freestanding appliance more than 39-3/8 inches (1 meter) high and weighing more than 55.1 lb (25 kg) shall not tip over when a force equal to one-fifth the weight of the appliance, but not more than 56.2 pounds-force (250 newtons) is applied in any horizontal direction, at a height not exceeding the position of the user controls (joysticks, push buttons, steering wheels, and similar items). An additional force is to be applied to the most unfavorable point on the appliance at a height not exceeding 78.7 inches (2 meters) above floor level. This force F, in Newtons, is calculated according to the following equation:

$$F = (250/x)$$

in which

x is the height of the test point in meters.

39.8 A freestanding appliance shall not tip over when tilted 10 degrees from its intended upright position. For this test, all doors, drawers, frames, and similar parts that can be opened for maintenance or service personnel servicing are to be opened and in the most unfavorable position. Separate tests may be performed when maintenance and service extensions are different or when stabilizers are used in accordance with 39.9.

39.9 A stabilizing means may be used to improve stability when doors, drawers, and the like are opened. The stabilizing means shall be automatic in operation or interlocked when associated with maintenance. For service personnel, where it is not automatic in operation, a conspicuous marking shall be provided on its use. See 54.18.

39.10 The stability of an amusement ride for children shall be such that it cannot be overturned by a 150-pound (68-kg) person, getting on, getting off, or while on the ride in any position.

40 Handle Test

40.1 A handle or handles tested as described in 40.2 shall not result in breakage of the handle, its securing means, or that part of the appliance to which the handle is attached.

40.2 To determine compliance with 40.1, a force four times the weight of the appliance is to be applied uniformly in the intended carrying direction over a 2-5/16-inch (75-mm) length at the center of the handle. Starting at zero, the applied force is to be gradually increased so that the required test value is attained in 5 to 10 seconds and then maintained for 1 minute. If more than one handle is provided, the test force is to be determined by the percentage of the appliance weight sustained by each handle with the appliance in the intended carrying position. If an appliance weighing less than 55 pounds (25 kg) is provided with more than one handle but can be carried by using only one of the handles, each handle is to be capable of withstanding a force based on the total weight of the appliance.

41 Abnormal Operation Tests

41.1 If the conditions of intended operation are not representative of the abnormal conditions possible during intended use, an appliance shall not present a risk of fire, electric shock, or injury to persons while operated under such abnormal conditions. Only one abnormal condition is to be simulated at a time.

41.2 An appliance operated continuously under abnormal conditions that are likely to occur shall not emit flame or molten metal other than drops of melted solder, or cause glowing or flaming of combustible material upon which the appliance may be placed or, for a permanently installed appliance, combustible material that may be in proximity to the appliance as installed. The fuse in the grounding circuit shall not open. After having been subjected to an abnormal test, the insulation resistance of a cord-connected appliance shall not be less than 50,000 ohms.

41.3 To determine whether an appliance complies with the requirements in 41.2, a separate burnout or abnormal test is to be conducted with the appliance operating continuously until the ultimate result has been determined. A cord-connected appliance is to be connected to a circuit as described in 33.1, and tested on white tissue paper on a softwood surface. A single layer of cheesecloth is to be draped loosely over the appliance. The test is to be conducted with the applied voltage and method of mounting in accordance with Performance, General, Section 32 and 36.14 and with a 3-ampere fuse connected between the frame and earth ground.

41.4 An unacceptable condition is considered to exist when:

a) Flame is emitted from the overall enclosure of the appliance;

b) The single layer of cheesecloth or the tissue paper glows or flames; or

c) The 3-ampere ground fuse opens.

41.5 Malfunction of components and likely misuses of the equipment that could present an unacceptable condition are to be simulated during the abnormal tests mentioned in 40.1. Examples are as follows:

a) Improper connection or internal adjustment of an appliance that is rated for use at more than one voltage or for a range of voltages and contains a tapped transformer or other means of being adapted to different supply voltages.

Exception No. 1: This test is not conducted if the internal adjustments are intended to be made by service personnel.

Exception No. 2: This test need not be conducted if all three of the following conditions apply:

i) A clear, permanent marking adjacent to the cord or supply compartment warns the maintenance person that internal adjustments must be made when the appliance is installed or moved.

ii) Detailed instructions clearly showing the adjustments that must be made for various voltages are permanently attached to the appliance. These instructions may be on the outside or inside of the overall enclosure of an appliance where visible at the point at which adjustments for supply voltage must be made.

iii) The means provided for adjusting for different voltages comply with the requirements for wiring terminals in 14.2.3.1 – 14.2.3.10.

b) If supplied with a selecting means located in a maintenance area, the appliance is to be tested at the worst case(s) of voltage applied and voltage setting means combination(s).

c) Malfunction of a fan or blower. During these tests the fan or blower motors are to be disconnected.

d) Overloading of power supplies through maintenance area connectors or unused printed wiring board receptacles as described in 41.7.

e) Malfunction of electronic components as described in 41.8 – 41.10.

Exception: The tests described in 41.8 – 41.10 may be omitted if one of the following conditions exists:

1) There are 10,000 ohms or more of additional series impedance in a circuit in which the voltage is 125 volts or less.

2) There are 20,000 ohms or more of additional series impedance in a circuit in which the voltage is greater than 250 volts.

3) The component is located within a secondary circuit that complies with either Exception No. 2 or Exception No. 3 of 26.3.

41.6 Each abnormal condition simulated for the tests described in 41.1 and 41.4 usually will manifest itself as a condition of risk within 1 hour after it occurs; hence the tests usually are limited to 1 hour. If at the end of 1 hour there is no indication of the abnormal condition and it appears possible that a condition of risk will result eventually, the test is to be continued until ultimate results are obtained – usually 7 hours. Operation of an overcurrent protective device before any condition of risk results is to be considered an acceptable conclusion of a test.

41.7 With regard to overloading of low-voltage connectors and printed wiring board receptacles, or both, as mentioned in 41.5(d), the connectors or receptacles, or both, are to be connected to a resistive load that draws the maximum available output current. The maximum available output current is considered to be the lower of (a) – (c). The trip point of overcurrent protective devices is considered to be 110 percent of their current rating.

a) The short-circuit current; or

b) The current that is just below the trip point of any overcurrent or overtemperature protective device; or

c) The current that is just below the point at which the power supply circuitry limits the output current.

41.8 With regard to the malfunction of electronic components as mentioned in 41.5(e), the appliance, circuit diagrams, and component specifications should be examined to determine those fault conditions that may reasonably occur. Examples are short circuits and open circuits of transistors, rectifiers, diodes, and capacitors (particularly electrolytic capacitors); faults causing continuous dissipation in resistors constructed for intermittent dissipation, and internal faults in integrated circuits causing excessive dissipation.

41.9 The tests mentioned in 41.8 are to be applied one at a time. Short circuits are to be applied only between two terminals of a multiterminal device at one time. Simulated circuits may be used, but, if the tests performed on simulated circuits indicate likely damage to other parts of the appliance to the extent that the safety of the appliance may be affected, the tests are to be repeated in the appliance.

41.10 If the circuit is interrupted by the opening of a component, the test is to be repeated twice, using new components as necessary.

42 Internal Wiring Flexing Test

42.1 Wiring from an appliance to components mounted on a door is to be tested as described in 42.2. Following the test, the appliance is to be subjected to the Dielectric Voltage-Withstand Test, Section 37. The wiring shall not be damaged by the test.

42.2 The flexing test is to be conducted by opening the door as far as possible and then closing it for 6000 cycles of operation. Restraints such as chains are to remain in place.

43 Strain Relief Test

43.1 The strain relief means for a supply cord is to be tested as described in 43.2. At the point of disconnection of the conductors, there shall be no movement of the cord to indicate that stress may result on the electrical connections.

43.2 To determine that a cord-connected appliance complies with the requirement in 43.1, the cord connections within the appliance are to be disconnected. A 35-pound (15.9-kg) weight is then to be suspended from the cord and supported by the appliance for 1 minute so that the strain-relief means will be stressed from any angle that the construction of the appliance permits.

44 Grounding Impedance Test

44.1 The impedance of the grounding path shall not exceed 0.1 ohm when measured from the grounding means of the product to the conductive part that is required to be grounded.

44.2 The impedance is to be determined by measuring the voltage when a current of 25 A derived from a 60-Hz source with a no-load voltage not exceeding 12 V is passed between the product grounding means (point on the product where the cord grounding conductor is attached) and the grounded conductive part. The impedance in ohms is to be calculated by dividing the drop in potential in volts by the current in amperes passing between the two points. The power-supply cord is to be excluded.

45 Tests for Enclosures, Guards, and Maintenance Area Barriers

45.1 Elevated temperature test for nonmetallic guards and maintenance area barriers

45.1.1 A guard or maintenance area barrier of nonmetallic material shall not be damaged (see 45.1.3) when exposed for 7 hours to a temperature not less than 10°C (18°F) higher than the maximum temperature attained during intended operation, but not less than 70°C (158°F) in any case.

Exception: Guards and barriers of rigid thermosetting materials or of low-pressure, molded, foamed plastic need not be tested.

45.1.2 In performing the test mentioned in 45.1.1, it is preferable that the complete guard or barrier be used. If this is impractical because of size, a section may be used. This section is to be selected to represent the complete guard or barrier with regard to thickness of material and mechanical support provided by any metal frame members.

45.1.3 A material that has any cracks, splits, or other openings after removal from the oven and after cooling to room temperature is acceptable if after the material is reinstalled, the appliance complies with the requirements in Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts, Section 10.

45.2 Impact test for nonmetallic enclosures and guards

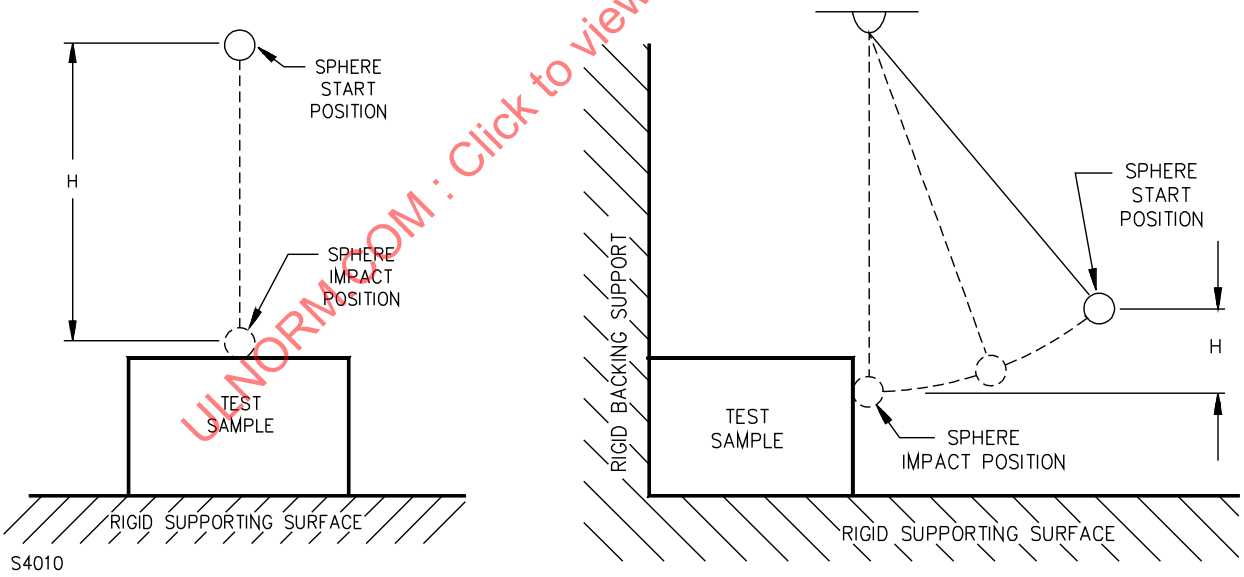
45.2.1 Enclosures and guards shall withstand the impact described in 45.2.2 and 45.2.3 without developing cracks or other openings such that the appliance does not comply with the accessibility requirements in 10.1 – 10.4.

45.2.2 Test samples may consist of the complete enclosure or guard, or a section thereof representing the largest unreinforced area of the thinnest wall section that is likely to be subjected to impacts during intended use.

45.2.3 Each of three samples is to be subjected to a single impact on any surface that may be exposed to a blow during intended use. The impact is to be produced by dropping a steel sphere 2 inches (50.8 mm) in diameter and weighing 1.18 pounds (0.54 kg) from a height of 51 inches (1.30 m). For surfaces other than the top of an enclosure, the steel sphere is to be suspended by a cord and swung as a pendulum, dropping through a vertical distance of 51 inches. See Figure 45.1.

Exception: Fewer samples may be tested if a total of three intended impacts are made.

Figure 45.1
Ball impact tests



45.3 Mechanical strength tests for metal enclosures and guards

45.3.1 The external enclosure and guards of an appliance, if of metal, shall withstand a force of 50 pounds (222 N) applied by means of a hemisphere 1/2 inch (12.7 mm) in diameter for 1 minute without:

a) Permanent distortion to the extent that spacings are reduced below the values specified in Spacings, Section 28;

b) Transient distortion that results in contact with live parts; and

c) Development of openings such that the appliance does not comply with the accessibility requirements in 10.1 – 10.4.

45.3.2 The external enclosure and guards of an appliance, if of metal, shall withstand an impact of 5 foot-pounds (6.8 J) without:

a) Permanent distortion to the extent that spacings are reduced below the values specified in Spacings, Section 28;

b) Transient distortion that results in contact with live parts; and

c) Development of openings such that the appliance does not comply with the accessibility requirements in 10.1 – 10.4.

45.3.3 The impact mentioned in 45.3.2 is to be applied by means of a smooth, solid steel sphere 2 inches (50.8 mm) in diameter and having approximately 1.18 pounds (0.54 kg) mass. The sphere is to fall freely from rest through a vertical distance of 51 inches (1.3 m).

45.4 Mechanical strength test for enclosures, guards, and maintenance area barriers

45.4.1 Enclosures, guards, and maintenance area barriers shall withstand a push force of 6.75 pounds-force (30 N) without development of cracks or other openings such that the appliance does not comply with the accessibility requirements in 10.1 – 10.4. The force is to be applied by means of a hemisphere 1/2 inch (12.7 mm) in diameter. Additionally, if of metal, the enclosure, guard, or barrier shall not permanently distort to the extent that spacings are reduced below the values specified in Spacings, Section 28, and shall not exhibit transient distortion that results in contact with live parts.

46 Secondary Circuit Motor Test

46.1 Motors rated less than 100 volts or less than 200 volt-amperes in secondary circuits shall not ignite tissue paper or cheesecloth when tested as described in 46.2.

46.2 The motor is to be placed on a wooden board that is covered with a single layer of tissue paper, and the motor in turn covered with a single layer of bleached cotton cheesecloth of approximately 40 grams per square meter. The motor is to be operated at its working voltage and with the rotor locked for 7 hours or until steady conditions are established, whichever is longer.

47 Resistance to Moisture

47.1 Humidity conditioning

47.1.1 An appliance intended for outdoor use or for use in a protected location, using insulating material that may be adversely affected by moisture under conditions of normal use, is to be conditioned as described in 47.1.2. After the conditioning:

a) A cord-connected appliance rated 250 volts or less shall comply with the requirements in 34.1 in a repeated leakage-current test, except that the test is to be discontinued when leakage current stabilizes.

b) An appliance other than as mentioned in (a) shall have an insulation resistance of not less than 50,000 ohms between live parts and interconnected dead metal parts.

47.1.2 With regard to 47.1.1, the appliance is to be conditioned for 24 hours in moist air having a relative humidity of 85 ±5 percent at a temperature of 32 ±2°C (90 ±4°F).

47.2 Rain conditioning

47.2.1 An appliance intended for outdoor use or use in a protected location is to be conditioned as described in 47.2.2 – 47.2.3. After the conditioning:

a) A cord-connected appliance rated 250 volts or less shall comply with the requirements in 34.1 in a repeated leakage-current test, except that the test is to be discontinued when the leakage current stabilizes.

b) An appliance other than as mentioned in (a) shall have an insulation resistance not less than 50,000 ohms between live parts and interconnected dead metal.

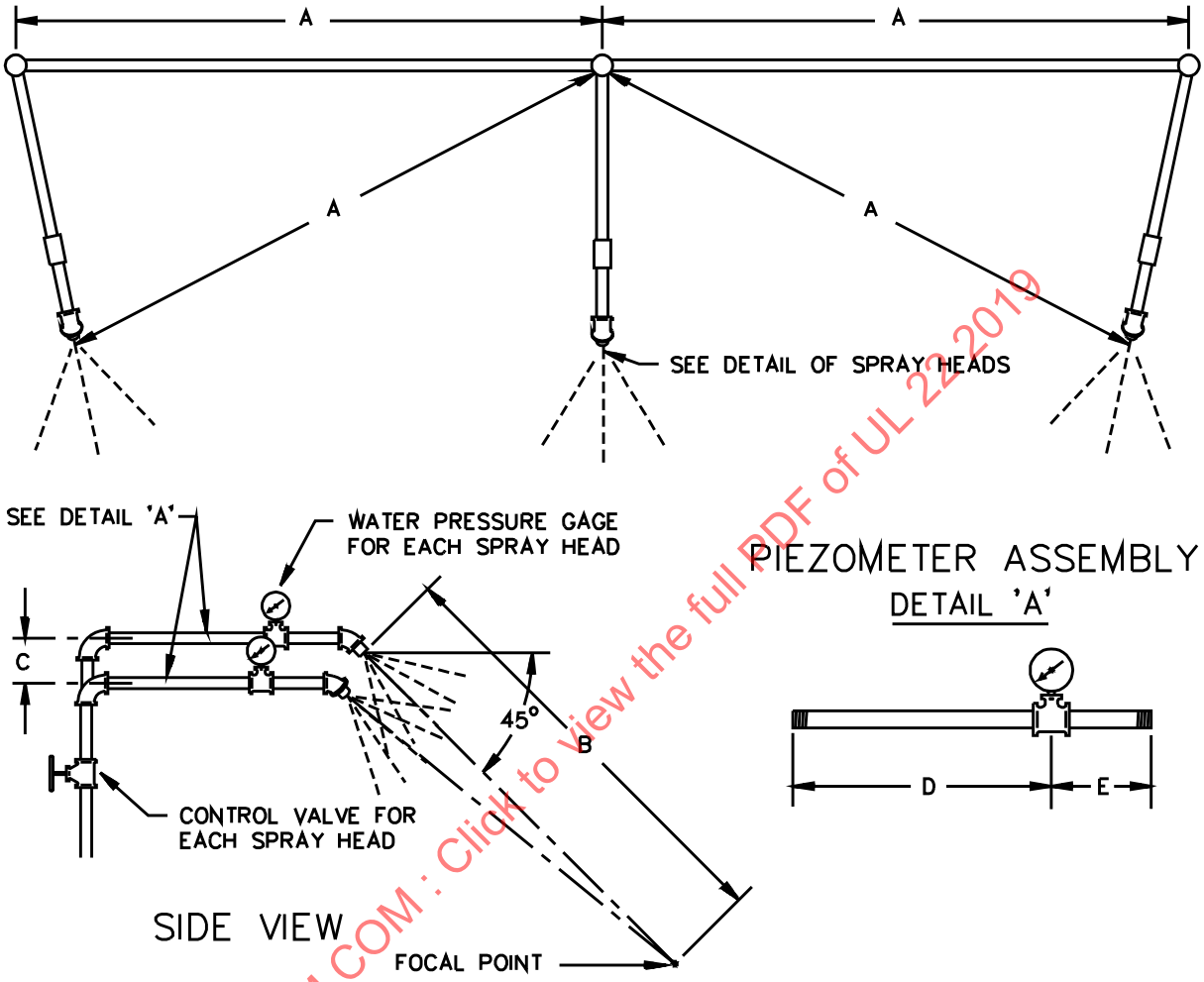
c) The appliance shall comply with the requirements in 37.1.1 in a repeated dielectric voltage-withstand test.

d) There shall be no wetting of uninsulated live parts except that motor windings may be judged by insulation-resistance and dielectric voltage-withstand tests provided the motors are constructed, located, or shielded so that the windings are not directly exposed to water during the test.

47.2.2 To determine whether an appliance complies with the requirement in 47.2.1, the appliance is to be positioned and leveled in accordance with the manufacturer's instructions. An appliance intended for use in a protected location is to be provided with a representative shelter, such as a roof, a canopy, marquee, or the like, that is to be positioned over the appliance, in accordance with the manufacturer's instructions. An appliance intended for outdoor use is to be tested without a shelter. The appliance is to be subjected to a water spray as described in 47.2.3.

47.2.3 The water spray apparatus is to consist of three spray heads constructed in accordance with the details illustrated in Figure 47.1 and mounted in a water supply pipe rack as illustrated in Figure 47.2. The water pressure for all tests is to be maintained at 5 psi (34 kPa) at each spray head. The distance between the center nozzle and the appliance is to be approximately 5 feet (1.5 m). The appliance is to be brought into the focal area of the three spray heads in such a position and under such conditions as are most likely to result in entrance of water into the appliance. The spray is to be directed at a 45-degree angle to the vertical toward the appliance. The total exposure is to be for 1 hour.

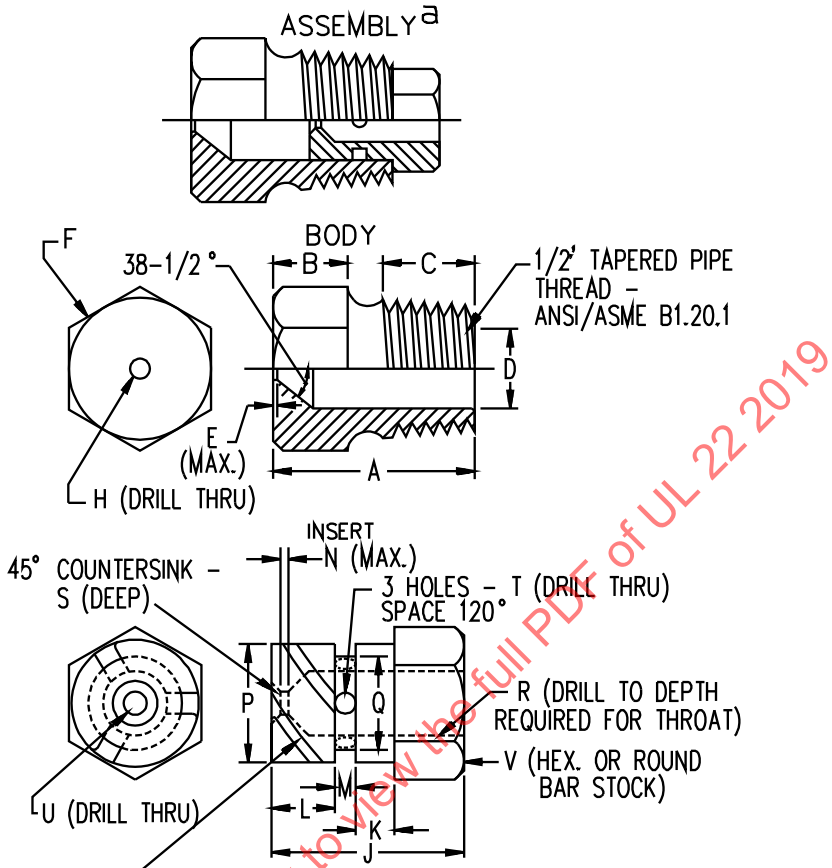
Figure 47.1
Spray head



Item	inch	mm
A	28	710
B	55	1400
C	2–1/4	55
D	9	230
E	3	75

RT101D

Figure 47.2
Spray head pipe rack



Item	inch	mm	Item	inch	mm
A	1-7/32	31.0	N	1/32	0.80
B	7/16	11.0	P	.575	14.61
C	9/16	14.0		.576	14.63
D	.578	14.68	Q	.453	11.51
	.580	14.73		.454	11.53
E	1/64	0.40	R	1/4	6.35
F	c	c	S	1/32	0.80
G	.06	1.52	T	(No. 35) [b]	2.80
H	(No.9) [b]	5.0	U	(No. 40) [b]	2.50
J	23/32	18.3	V	5/8	16.0
K	5/32	3.97	W	0.06	1.52
L	1/4	6.35			
M	3/32	2.38			

[a] Nylon Rain-Test Spray Heads are available from Underwriters Laboratories

[b] ANSI B94.11M Drill Size

[c] Optional - To serve as a wrench grip.

RT100E

48 Metallic Coating Thickness Test

48.1 With reference to 11.8, the solution to be used for the test to determine the thickness of cadmium and zinc coatings is to be made from distilled water and is to contain 200 grams per liter of American Chemical Society (ACS) reagent grade chromic acid (CrO_3) and 50 grams per liter of ACS reagent grade concentrated sulfuric acid (H_2SO_4). The latter is equivalent to 27 milliliters per liter of ACS reagent grade concentrated sulfuric acid, specific gravity 1.84, containing 96 percent of H_2SO_4.

48.2 The test solution is to be contained in a glass vessel such as a separatory funnel with the outlet equipped with a stopcock and a capillary tube having an inside bore of 0.025 inch (0.64 mm) and a length of 5.5 inches (140 mm). The lower end of the capillary tube is to be tapered to form a tip which releases drops of about 0.025 milliliter each. To preserve an effectively constant level, a small glass tube is to be inserted in the top of the funnel through a rubber stopper and its position is to be adjusted so that when the stopcock is opened, the drop rate is 100 ±5 drops per minute. If desired, an additional stopcock may be used in place of the glass tube to control the rate of dropping.

48.3 The sample and the test solution are to be in the test room long enough to acquire the temperature of the room, which is to be noted and recorded. The test is to be conducted at a room temperature of 21.1 – 32.2°C (70.0 – 90.0°F).

48.4 Each sample is to be cleaned before testing. All grease, lacquer, paint and other nonmetallic coatings are to be removed by using solvents. Samples are then to be thoroughly rinsed in water and dried with clean cheesecloth. Care should be exercised to avoid contact of the cleaned surface with the hands or any foreign material.

48.5 The sample to be tested is to be supported 0.7 – 1.0 inch (17.8 – 25.4 mm) below the orifice, so that the drops of solution strike the point to be tested and run off quickly. The surface to be tested should be inclined approximately 45 degrees from the horizontal.

48.6 The stopcock is to be opened and the time (in seconds) until the dropping solution dissolves the protective metal coating exposing the base metal is to be measured. The end point is the first appearance of the base metal recognizable by a change in color.

48.7 Each sample of a test lot is to be subjected to the test at three or more points, excluding cut, stenciled, and threaded surfaces, on the inside surface and at an equal number of points on the outside surface, at places where the metal coating may be expected to be the thinnest. On an enclosure made from precoated sheets, the external corners that are subjected to the greatest deformation are likely to have thin coatings.

48.8 To calculate the thickness of the coating being tested, select from Table 48.1 the thickness factor appropriate for the temperature at which the test was conducted, multiply it by the time in seconds required to expose base metal described in 48.6, and multiply the result by 10^{-5} inch (3×10^{-4} mm).