UL 1238

STANDARD FOR SAFETY

Control Equipment for Use with Flammable Liquid and LP-Gas Dispensing Devices

UL Standard for Safety for Control Equipment for Use with Flammable Liquid and LP-Gas Dispensing Devices, UL 1238

Seventh Edition, Dated January 19, 2022

Summary of Topics

This new edition of ANSI/UL 1238 dated January 19, 2022 includes the following changes:

- ***– UL 1238 title change;***
- ***– Addition of zone designations; 1.2, 5.7 and 49.1***
- ***– Addition of reference to NFPA 30A; 1.2 and 6.3***
- ***– Revision to the Glass Panel Test; 7.6.7***
- ***– Clarification to Table 7.1, Table 7.2 and 10.1;***
- ***– Clarification of requirements for components used to make an enclosure rainproof or raintight; 8.6, 38.1 and 38.3***
- ***– Clarification of requirements for motors; 19.1 and 19.3***
- ***– Revision to secondary circuit requirements; 23.3***
- ***– Editorial clarification; 39.1.1***
- ***– Revision to the Flammability Test; 41.3.5***
- ***– Rain Test clarification; 43.3***
- ***– Typo correction; 45.1***
- ***– Updates to Appendix A***

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated November 19, 2021.

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UL 1238

Standard for Control Equipment for Use with Flammable Liquid and LP-Gas Dispensing Devices

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The most recent designation of ANSI/UL 1238 as an American National Standard (ANSI) occurred on January 19, 2022. 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 equipment used for the control and monitoring of flammable liquid and LP-Gas dispensing devices rated 600 volts or less. Such control equipment is intended to be installed in ordinary locations in accordance with the National Electrical Code, NFPA 70.

1.2 These requirements also cover electrical control equipment that is capable of being installed in or over a hazardous area as defined by the Flammable and Combustible Liquids Code, NFPA 30, and Code for Motor Fuel Dispensing Facilities and Repair Garages, NFPA 30A. Electrical control equipment for installation in a Class I, Zone 1, or Zone 2 Class I, Division 1 or Division 2 hazardous area shall comply with the applicable requirements for the Hazardous Location protection method employed. See Appendix A for a list of appropriate standards.

1.3 These requirements cover general-use field-installed equipment. They also cover controls intended to be factory installed on or in certain devices as operating controls. Typical devices covered by these requirements include:

a) Communication Units – Visual, pulse, or audio devices which complies with the transmittal of data or information. Such devices include audio or visual systems between the service station attendant and the customer, and data processing systems between the service station and a remote data processing terminal.

b) Control Consoles – Prepay, post-pay, remote totalizing, or remote actuating and monitoring devices located indoors or within a structure some distance from the dispensing device.

c) Credit Acceptance Units – Dollar bill, coin, token, pulse, or credit card activated devices which are capable of being installed on, adjacent to, or away from the dispensing device.

d) Electric Computer Resets – Electrically authorized or electrically operated devices which reset a mechanical computer.

1.4 These requirements do not cover safety or emergency controls which automatically or manually interrupt the operation of a dispensing device.

1.5 The term "device" refers to any equipment covered by this standard.

1.6 These requirements do not cover purely mechanical systems such as hose nozzle attachments and pneumatic or hydraulic actuators.

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.

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.

2.5 Except for portable equipment, provision shall be made for securely mounting control equipment in position. Bolts, screws, or other parts used for mounting equipment shall be independent of those used for securing components of the equipment to the frame, base, or panel.

3 Units of Measurement

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

3.2 Unless otherwise indicated, 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 Glossary

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

5.2 ABBREVIATIONS – For the purpose of this standard, the following definitions apply:

AC – Alternating Current

AWG – American Wire Gage

DC – Direct Current

GSG – Galvanized Sheet Gage

Hz – hertz

MSG – Manufacturers Standard Gage

NEC – National Electrical Code, NFPA 70

psig – Pounds per square inch gauge

rms – Root-mean-square

5.3 BRANCH CIRCUIT – That portion of the building wiring system beyond the final overcurrent device on the power-distribution panel protecting the circuit to the field-wiring terminals in a permanently connected device or to the receptacle outlet for cord-connected devices.

5.4 CIRCUITS, ELECTRICAL –

a) Class 2 (Low-Voltage) – A circuit involving a potential of not more than 42.4 volts peak supplied by:

1) An energy-limiting Class 2 transformer;

2) A nonenergy-limiting Class 2 transformer and an overcurrent protective device that has been evaluated for limiting energy to Class 2 levels;

3) The combination of an isolated transformer secondary winding and a fixed impedance or reliable regulating network which complies with the applicable performance requirements for an energy-limiting Class 2 transformer;

4) A dry cell battery having output characteristics no greater than those of an energy-limiting Class 2 transformer; or

5) The combination of a rechargeable battery and a fixed impedance or reliable regulating network which complies with the applicable performance requirements for an energy-limiting Class 2 transformer.

b) Line-Voltage – Any field connected source of supply other than battery power, nominally 50 – 60 Hz, 115, 208, or 230 volts, is classified as a line-voltage circuit.

c) Secondary – Those circuits supplied from transformer output windings which are electrically isolated, i.e., insulated from ground.

5.5 CORD- AND PLUG-CONNECTED DEVICE – A device intended for connection to the branch-circuit power line by means of a supply cord. Such a device is intended to be moved for reasons of interchange or servicing.

5.6 GENERAL PURPOSE ENCLOSURE – A metallic or nonmetallic enclosure that is not required to be explosion proof.

5.7 HAZARDOUS (CLASSIFIED) LOCATIONS – Locations where fire or explosion hazards may exist due to flammable gases, flammable liquid-produced vapors, combustible liquid-produced vapors, combustible dusts, or ignitable fibers/flyings. Commonly abbreviated as "HazLoc".

5.8 LIMITED CURRENT CIRCUIT – A circuit which is so designed and protected that, under both normal conditions and a likely fault condition, the current which can be drawn is not at levels that are considered hazardous. See Limited Current Test, Section 40, for limits.

6 Instructions

6.1 A copy of the operating and installation instructions intended to accompany each device, or equivalent information, is to be used as a reference in the examination and test of the device. For this purpose, a printed edition is not required.

6.2 The instructions shall include such directions and information as deemed by the manufacturer to be adequate for the proper installation, maintenance, and use of the device.

6.3 For products marked in accordance with 49.1(f)(4), the following statements shall be included in the installation instructions.

a) A statement to the effect that the equipment is to be installed and used in accordance with the National Electrical Code, NFPA 70, and the Flammable and Combustible Liquids Code, NFPA 30, and Code for Motor Fuel Dispensing Facilities and Repair Garages, NFPA 30A.

b) Detailed information showing hook-up and/or ratings associated with each terminal, lead, or connector in the interconnection box or other device to which field connections are to be made.

c) Information necessary to determine that the junction box in the dispenser has sufficient volume for the application. See 20.13 and 20.14 and Table 20.2 in the Standard for Power-Operated Dispensing Devices for Petroleum Products, UL 87.

d) Wiring diagrams showing typical dispenser-control system connections.

CONSTRUCTION

7 Frame and Enclosure

7.1 General

7.1.1 Control equipment shall be so fabricated and assembled that it has the strength and rigidity required to resist the abuses to which it is capable of being subjected, without increasing the risk of fire, explosion, electric shock, or injury to persons due to total or partial collapse resulting in reduction of spacings, loosening or displacement or parts, or other serious defects.

7.1.2 The equipment shall be provided with an enclosure of material evaluated for use in this application which shall house all electrical parts that are capable of presenting a risk of fire, electric shock, or injury to persons under any condition of use.

7.1.3 A portion of an overall enclosure can be omitted when the equipment is intended to be installed in conjunction with other equipment where the latter completes the enclosure, and installation instructions are provided.

7.1.4 For equipment with electrical circuits that will be located over a classified area such as field island terminals that extend to grade, a metal plate shall be provided as a secondary bottom enclosure. The plate shall comply with all of the following:

a) The plate shall comply with all other enclosure requirements in this standard, such as material requirements and thickness requirements;

b) The plate shall have no openings following installation, such that any flaming particles or drops that fall downward will be contained by the plate with no particles or drops falling below the plate; and

c) The plate shall be located at a height of 18 inches minimum from the base of the product, such that the plate is located over the Classified area as well.

7.2 Covers

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

7.2.2 Sheet-metal screws threading directly into metal shall not be used to attach a cover, door, or other part removed to install field wiring or for operation of the equipment. Sheet-metal screws can thread into sheet-metal nuts that are permanently mounted and suitably protected against corrosion. Machine screws and self-tapping machine screws can thread directly into sheet-metal walls.

7.2.3 Sheet-metal screws mounting internal components that are not removed for installation or operation can thread directly into metal.

7.2.4 A snap-on cover that gives access to exposed live parts and that does not require a tool for removal shall comply with the tests in Snap-On Covers, Section 42.

7.2.5 The continuity of the bonding means for a snap-on or fastener-attached cover shall comply with the requirements in 15.1.1 – 15.1.4, 15.2.1, and 15.2.2.

7.2.6 An enclosure cover shall be hinged when it gives access to a fuse, thermal cutout, or any other overload-protective device, the normal functioning of which requires renewal, or when it is required to open the cover in connection with the normal operation of the device.

7.2.7 A door or cover giving access to a fuse or thermal cutout in other than a low-voltage circuit shall shut closely against a 1/4 inch (6.4 mm) rabbet or strips that have been determined to be equivalent, or shall have either turned flanges for the full length of four edges or angle strips fastened to it. Flanges or angle strips shall fit closely with the outside of the walls of the box proper and shall overlap the edges of the box not less than 1/2 inch (12.7 mm). An appropriate construction that affords protection that has been determined to be equivalent or a combination of flange and rabbet is permissible.

7.2.8 Strips used to provide rabbets, or angle strips fastened to the edges of a door shall be secured at not less than two points, not more than 1-1/2 inches (38 mm) from each end of each strip and at points between these end fastenings not more than 6 inches (152 mm) apart.

7.2.9 A hinged cover shall be provided with a spring latch or catch, and not depend solely upon screws or other similar means requiring the use of a tool to hold it closed. For a hinged cover that is provided, although not required, a hasp, sliding latch, or other means for holding the cover closed can be employed.

7.3 Cast metal

7.3.1 Cast metal for a general purpose enclosure shall be at least 1/8 inch (3.2 mm) thick at every point, of greater thickness at reinforcing ribs and door edges, and not less than 1/4 inch (6.4 mm) thick at tapped holes for conduit; except that, other than at plain or threaded conduit holes, die-cast metal shall not be less than 3/32 inch (2.4 mm) thick for an area greater than 24 square inches (155 cm^2) or having any dimension greater than 6 inches (152 mm), and shall not be less than 1/16 inch (1.6 mm) thick for an area of 24 square inches (155 cm^2) or less and not having dimensions greater than 6 inches. The area limitation for metal 1/16 inch thick complying with the provision of reinforcing ribs subdividing a larger area. Die-cast metal of 0.035 inch (0.9 mm) minimum thickness can be employed in lieu of 1/16 inch thick die-cast metal when the enclosure will not be used as a splice box and when the voltage rating of the complete control is such that the voltage between any two conductors does not exceed 250 volts ac or dc; and die-cast metal of 0.028 inch (0.71 mm) minimum thickness can be employed in lieu of 1/16 inch thick die-cast metal for an enclosure housing only low-voltage circuits.

7.4 Sheet metal

7.4.1 The thickness of a sheet-metal enclosure shall be as indicated in Table 7.1 and Table 7.2, except that steel shall be not less than 0.032 inch (0.81 mm) (No. 20 MSG) thick [0.034 inch (0.86 mm) (No. 20 GSG) thick when zinc coated] and nonferrous metal shall be not less than 0.045 inch (1.14 mm) (No. 18 GSG) thick at points where a wiring system is to be connected.

Table 7.1
Minimum Thickness of Sheet Metal for Enclosures Carbon Steel or Stainless Steel

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]				Minimum thickness uncoated,		Minimum thickness metal coated,	
Maximum width,[b]		Maximum length,[c]		Maximum width,[b]		Maximum length,		inch	(mm)	inch	(mm)
inches	(cm)	inches	(cm)	inches	(cm)	inches	(cm)	[MSG]		[GSG]	
4.0	(10.2)	Not limited		6.25	(15.9)	Not limited		0.020[d]	(0.51)	0.023[d]	(0.58)
4.75	(12.1)	5.75	(14.6)	6.75	(17.1)	8.25	(21.0)	[24]		[24]	
6.0	(15.2)	Not limited		9.5	(24.1)	Not limited		0.026[d]	(0.66)	0.029[d]	(0.74)
7.0	(17.8)	8.75	(22.2)	10.0	(25.4)	12.5	(31.8)	[22]		[22]	
8.0	(20.4)	Not limited		12.0	(30.5)	Not limited		0.032	(0.81)	0.034	(0.86)
9.0	(22.9)	11.5	(29.2)	13.0	(33.0)	16.0	(40.6)	[20]		[20]	
12.5	(31.8)	Not limited		19.5	(49.5)	Not limited		0.042	(1.07)	0.045	(1.14)
14.0	(35.6)	18.0	(45.7)	21.0	(53.3)	25.0	(63.5)	[18]		[18]	
18.0	(45.7)	Not limited		27.0	(68.6)	Not limited		0.053	(1.34)	0.056	(1.42)
20.0	(50.8)	25.0	(63.5)	29.0	(73.7)	36.0	(91.4)	[16]		[16]	
22.0	(55.9)	Not limited		33.0	(83.8)	Not limited		0.060	(1.53)	0.063	(1.61)
25.0	(63.5)	31.0	(78.7)	35.0	(89.0)	43.0	(109.2)	[15]		[15]	
25.0	(63.4)	Not limited		39.0	(99.1)	Not limited		0.067	(1.70)	0.070	(1.78)
29.0	(73.7)	36.0	(91.4)	41.0	(104.1)	51.0	(129.5)	[14]		[14]	

[a] A supporting frame is a structure of angle or channel or a folded rigid section of sheet metal which is rigidly attached to and has the same outside dimensions as the enclosure surface and which has torsional rigidity to resist the bending moments which is capable of being applied via the enclosure surface when it is deflected. Construction that is determined to have equivalent reinforcing can be accomplished by constructions that produce a structure which is as rigid as one built with a frame of angles or channels. Construction determined to be without supporting frame includes:

1) Single sheet with single formed flanges (formed edges);

2) A single sheet which is corrugated or ribbed; and

3) An enclosure surface loosely attached to a frame, for example, with spring clips.

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

[c] For panels which are not supported along one side, for example, side panels of boxes, the length of the unsupported side shall be limited to the dimensions specified unless the side in question is provided with a flange at least 1/2 inch (12.7 mm) wide.

[d] Sheet metal for an enclosure intended for outdoor use shall comply with 8.6, 8.7 and Section 10.

Table 7.2
Minimum Thickness of Sheet Metal for Enclosures Aluminum, Copper, or Brass

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]				Minimum thickness,	
Maximum width,[b]		Maximum length,[c]		Maximum width,[b]		Maximum length,			
inches	(cm)	inches	(cm)	inches	(cm)	inches	(cm)	inches [AWG]	(mm)
3.0	(7.6)	Not limited		7.0	(17.8)	Not limited		0.023[d]	(0.58)
3.5	(8.9)	4.0	(10.2)	8.5	(21.7)	9.5	(24.1)	[22]	
4.0	(10.2)	Not limited		10.0	(25.4)	Not limited		0.029	(0.74)
5.0	(12.7)	6.0	(15.2)	10.5	(26.7)	13.5	(34.2)	[20]	
6.0	(15.2)	Not limited		14.0	(35.6)	Not limited		0.036	(0.91)
6.5	(16.5)	8.0	(20.4)	15.0	(38.1)	18.0	(45.7)	[18]	
8.0	(20.4)	Not limited		19.0	(48.3)	Not limited		0.045	(1.14)
9.5	(24.1)	11.5	(29.2)	21.0	(53.3)	25.0	(63.5)	[16]	
12.0	(30.5)	Not limited		28.0	(71.1)	Not limited		0.058	(1.47)
14.0	(35.6)	16.0	(40.6)	30.0	(76.2)	37.0	(94.0)	[14]	
18.0	(45.7)	Not limited		42.0	(106.7)	Not limited		0.075	(1.91)
20.0	(50.8)	25.0	(63.4)	45.0	(114.3)	55.0	(139.7)	[12]	
25.0	(63.4)	Not limited		60.0	(152.4)	Not limited		0.095	(2.41)
29.0	(73.7)	36.0	(91.4)	64.0	(162.6)	78.0	(198.1)	[10]	

[a] A supporting frame is a structure of angle or channel or a folded rigid section of sheet metal which is rigidly attached to and has the same outside dimensions as the enclosure surface and which has torsional rigidity to resist the bending moments which are capable of being applied via the enclosure surface when it is deflected. Construction that is determined to have equivalent reinforcing can be accomplished by constructions that produce a structure which is as rigid as one built with a frame of angles or channels. Construction determined to be without supporting frame includes:

1) Single sheet with single formed flanges (formed edges);

2) A single sheet which is corrugated or ribbed; and

3) An enclosure surface loosely attached to a frame, for example, with spring clips.

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

[c] For panels which are not supported along one side, for example, side panels of boxes, the length of the unsupported side shall be limited to the dimensions specified unless the side in question is provided with a flange at least 1/2 inch (12.7 mm) wide.

[d] Sheet metal for an enclosure intended for outdoor use shall comply with 8.6, 8.7 and Section 10.

7.5 Nonmetallic

7.5.1 A nonmetallic material can be used for part or all of a general purpose enclosure when it complies with the requirements in 7.5.2 – 7.5.5.

7.5.2 A nonmetallic enclosure or enclosure part shall have mechanical strength and durability and be so formed that operating parts are protected against damage, and shall resist the abuses that will be encountered during installation and normal use and service. The enclosure or enclosure part shall protect persons from shock hazard, and the material shall not create or contribute to a hazardous condition.

7.5.3 A nonmetallic enclosure shall comply with the following:

a) Flammability test, 41.3;

Exception: Parts that are molded from materials that are classed as 5VA, 5VB, V-0, V-1, or V-2 by the vertical burning test described in the Standard for Tests for Flammability of Plastic Materials for

Parts in Devices and Appliances, UL 94, need not be subjected to the flammability test described in 41.3.

b) Elevated temperature test, 41.4; and

c) Impact test, 41.5.

The material is not to display a loss of these properties beyond its minimum intended level as a result of aging.

7.5.4 Temperatures shall be monitored on the enclosure during the Normal Temperature Test, Section 34. If any part of the enclosure is subjected to a temperature rise greater than 40 °C, the enclosure shall be conditioned in accordance with 41.2, prior to the tests outlined in 7.5.3.

7.5.5 A metallized coating provided on a nonmetallic part, shall comply with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, and shall be suitable for the application to the appropriate surface material.

7.6 Glass panels

7.6.1 Glass, laminated glass and glass with protective coatings covering an observation opening shall be secured in place so that it cannot be readily displaced in service, and shall provide the required mechanical protection for the enclosed parts.

7.6.2 Any size laminated glass or glass with protective coatings shall comply with 7.6.5 or 7.6.6. Glass for an opening not more than 4 inches (102 mm) in any dimension shall not be less than 1/16 inch (1.6 mm) thick.

7.6.3 Glass for a larger opening not more than 144 square inches (929 cm^2) in area and not having a dimension greater than 12 inches (305 mm), shall not be less than 1/8 inch (3.2 mm) thick.

7.6.4 Glass larger than 144 square inches (929 cm^2) in area and having a dimension greater than 12 inches (305 mm) area shall not be less than 1/8 inch thick and shall comply with 7.6.5 or 7.6.6.

7.6.5 The glass shall be of a nonshattering or tempered type that, when broken, shall comply to the performance specifications noted in the Methods of Test for Safety Glazing Material Used in Buildings, ANSI Z97.1-2009.

7.6.6 The glass shall withstand a 2-1/2 foot-pound (3.39 J) impact from a 2 inch (50.8 mm) diameter, 1.18 pound (0.54 kg) steel sphere without cracking or breaking to the extent that a piece is released or dropped from its normal position.

7.6.7 If an adhesive is used to hold a gasket or glass cover in place, and failure of the adhesive would allow rain to enter the enclosure or allow access to hazardous circuits or parts, the combination shall be subjected to the Adhesion Test in the Standard for Gaskets and Seals, UL 157 or the Adhesive-Specialized Applications Test in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

7.7 Openings

7.7.1 The electrical enclosure shall be constructed to prevent the risk of emission of flame, sparks, molten metal, flaming or glowing particles, or flaming drops. The size of openings permitted for drainage, ventilation, etc., shall be reduced or shall be baffled or screened where required to comply with this requirement. See 7.9.1 and 7.9.2.

7.7.2 When the failure of any part that contains, conducts, or otherwise contacts a liquid or vapor results in a hazardous condition, the part shall be resistant to the liquid or vapor involved under any conditions of use.

7.7.3 When a liquid, powder, or other material that must be replenished, removed, or replaced is present in the equipment, spilled material shall be prevented from contacting live parts, and any other hazardous condition that results from filling, emptying, storage, normal movement of the equipment, or similar activities, shall be prevented from occurring.

7.8 Ventilating openings

7.8.1 For ventilating openings the following requirements shall apply:

a) A compartment or that part of an enclosure that contains field-wiring splices in the line-voltage circuit shall not be provided with ventilating openings.

b) The nearest portion of a ventilating opening shall be above the bottom of the enclosure and away from any wall mounting surface by a distance equal to one-quarter of the enclosure height and depth, respectively, or 1 inch (25.4 mm) whichever is the least.

c) There shall not be emission of flame or molten material, or manifestation of fire hazard, during the normal tests, as well as during abnormal tests such as transformer burnout and burnout of relays with blocked armature, on the control.

d) Unless the construction of a device provided with forced ventilation is such that there is not direct path between live parts and the outlet opening, burnout tests, in addition to those specified in (c) shall be conducted to determine that there is not emission of flame or molten material through that opening.

e) Air from a ventilating opening, either forced or otherwise, shall not be directed into a duct or into a concealed space in a building, shall not be directed against the mounting surface, and shall not be directed so that a disturbance is propagated to other equipment.

7.9 Other openings

7.9.1 The smaller dimension (width) of an opening in an enclosure around a dial, adjusting knob, lever, handle, pointer, and similar parts shall not be more than 1/8 inch (3.2 mm) for any setting or position of the dial, knob, or similar part.

7.9.2 Except as permitted for ventilating openings or in 7.9.1, the enclosure shall not have open holes other than:

a) Not more than four unused holes intended for mounting various components inside the enclosure. The largest dimension of each such opening shall not be more than 3/16 inch (4.8 mm).

b) Not more than four holes 1/8 inch (3.2 mm) or less in diameter for the escape of air or drainage of paint during the painting process if they are located as close to the corners of the enclosure as possible, preferably at the rear of the enclosure.

c) The drainage opening in a rainproof enclosure shall not exceed 1/4 by 1/4 inch (6.4 by 6.4 mm).

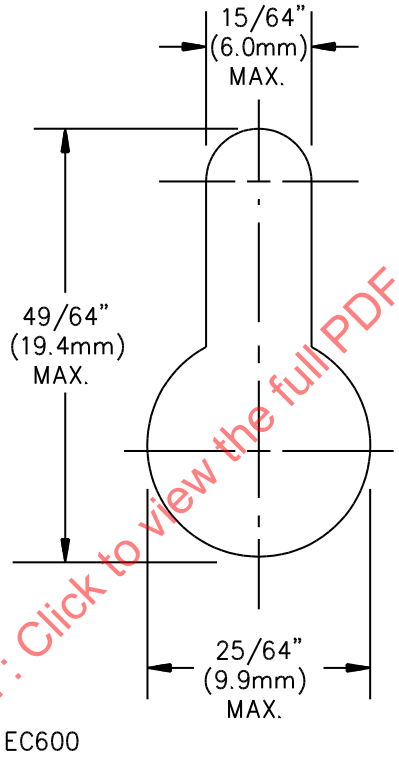
d) Not more than four enclosure mounting holes shall be provided for an enclosure having a maximum dimension of 18 inches (457 mm). Six holes can be provided for an enclosure with a maximum dimension more than 18 inches, and less than 48 inches (122 cm). Eight holes can be provided for an enclosure with a maximum dimension of 48 inches or more. Four of the holes for an enclosure with a maximum dimension of 12 inches (305 mm) can be keyhole slots having the

configuration illustrated in Figure 7.1. The dimensions shown in Figure 7.1 can vary when the area is determined to be equivalent. Four of the holes for a larger enclosure can be keyhole slots, the dimensions of which are not specified and shall be judged with respect to the enclosure dimensions and configuration.

e) An opening for passage of a tube, pipe, or other required mechanism shall result in an unclosed portion of the opening not larger than 1/16 inch (1.6 mm).

Figure 7.1

Keyhole Slot



7.9.3 A plate or plug for an unused conduit opening shall have a thickness not less than 0.014 inch (0.36 mm) for steel or 0.019 inch (0.48 mm) for nonferrous metal for a hole having a 1/4 inch (6.4 mm) maximum dimension, and 0.027 inch (0.69 mm) steel or 0.032 inch (0.81 mm) nonferrous metal for a hole having a 1-3/8 inch (34.9 mm) maximum dimension. A closure for a larger hole shall have a thickness equal to that required for the enclosure of the device or a standard knockout seal shall be used. Such plates or plugs shall be securely mounted.

7.9.4 In a small device where the indentation of a guard or enclosure will not alter the clearance between uninsulated, movable, live parts and grounded metal, so as to adversely affect performance or reduce spacings below the minimum values given in Table 29.1, 0.020 inch (0.51 mm) expanded metal mesh [0.023 inch (0.58 mm) when zinc coated] can be employed, as long as:

a) The exposed mesh on any one side or surface of the device so protected has an area of not more than 72 square inches (465 cm^2) and has no dimension greater than 12 inches (305 mm) or

b) The width of an opening so protected is not greater than 3-1/2 inches (88.9 mm).

7.10 Wiring openings

7.10.1 When threads for the connection of conduit are tapped all the way through a hole in an enclosure wall, or when a construction that has been determined to be equivalent is employed, there shall be not less than three nor more than five threads in the metal, and the construction of the device shall be such that a conduit bushing intended for use with the equipment is capable of being properly attached. When threads for the connection of conduit are not tapped all the way through a hole in an enclosure wall, conduit hub, or similar part, there shall be not less than 3-1/2 threads in the metal and there shall be a smooth well-rounded inlet hole for the conductors which shall afford protection to the conductors equivalent to that provided by a standard conduit bushing and which shall have an internal diameter the same as that of the corresponding trade size of rigid conduit.

7.10.2 An enclosure threaded for support by rigid conduit shall provide at least five full threads for engaging the conduit.

7.10.3 Except as noted in 7.10.6, a conduit hub or nipple attached to the enclosure of a pressure switch or similar equipment by swaging, staking, or similar means shall be capable of withstanding, without turning or pulling apart, a direct pull of 200 pounds (890 N), a bending moment of 600 pound-inches (67.74 N·m), and a torque of 600 pound-inches (67.74 N·m), each applied for 5 minutes.

7.10.4 For the pullout test, the equipment is to be supported by a rigid conduit in the intended manner and is to support a weight of 200 pounds (91 kg).

7.10.5 For the bending and twisting tests, the equipment is to be rigidly supported by means other than the conduit fittings. In the bending test, the force is to be applied to the conduit at right angles to its axis, and the lever arm is measured from the wall of the enclosure in which the hub or stud is located to the point of application of the bending force. In the torsion test, the force is to be applied to the conduit in a direction tending to tighten the connection, and the lever arm is to be measured from the center of the conduit.

7.10.6 With regard to 7.10.4 and 7.10.5, some distortion of the enclosure under test is capable of occurring. The test can be discontinued when noticeable distortion occurs.

7.10.7 Clamps and fasteners for the attachment of conduit, electrical metallic tubing, metal-clad cable, nonmetallic flexible tubing, nonmetallic-sheathed cable, service cable, and similar parts, which are supplied as a part of an enclosure shall comply with the requirements for outlet boxes and fittings.

7.10.8 A knockout in a sheet-metal enclosure shall be reliably secured and shall be capable of being removed without undue deformation of the enclosure.

7.10.9 A knockout shall be provided with a flat surrounding surface adequate for proper seating of a conduit bushing, and shall be located so that installation of a bushing at any knockout that is capable of being used during installation will not result in spacing between uninsulated live parts and the bushing of less than the requirements in this standard.

7.10.10 For an enclosure not provided with conduit openings or knockouts, spacings not less than the minimum required in this standard shall be provided between uninsulated live parts and a conduit bushing installed at any location that is capable of being used during installation. A permanent marking on the enclosure, a template, or a full-scale drawing furnished with the device is not prohibited from being used to limit such a location.

7.10.11 In measuring a spacing between an uninsulated live part and a bushing installed in the knockout referred to in 7.10.9 and 7.10.10, it is to be assumed that a bushing having the dimensions indicated in Table 7.3 is in place, in conjunction with a single locknut installed on the outside of the enclosure.

7.10.12 No wires other than those leading to a part mounted on the door or cover shall be brought out through the door or cover of an enclosure.

Table 7.3
Dimensions of Bushings

Trade size of conduit, inches	Bushing dimensions			
	Overall diameter,		Height,	
	inches	(mm)	inches	(mm)
1/2	1	(25.4)	3/8	(9.6)
3/4	1-15/64	(31.4)	27/64	(10.7)
1	1-19/32	(40.5)	33/64	(13.1)
1-1/4	1-15/16	(49.2)	9/16	(14.3)
1-1/2	2-13/64	(56.0)	19/32	(15.1)
2	2-45/64	(68.7)	5/8	(17.9)
2-1/2	3-7/32	(81.8)	3/4	(19.1)
3	3-7/8	(98.5)	13/16	(20.7)
3-1/2	4-7/16	(112.7)	15/16	(23.9)
4	4-31/32	(126.3)	1	(25.4)
4-1/2	5-35/64	(140.9)	1-1/16	(27.0)
5	6-7/32	(158.0)	1-3/16	(30.2)
6	7-7/32	(183.4)	1-1/4	(31.8)

7.11 Speaker openings

7.11.1 A speaker provided as part of an electrical enclosure on outdoor use equipment, shall be required to prevent rain from entering the electrical enclosure in the same manner as the enclosure itself.

7.11.2 In accordance with 7.11.1, an electrical enclosure shall be subjected to the Rain Test, Section 43, with the speaker in place.

Exception: For multiple electrical enclosure constructions where the speaker is the only difference, the speaker may be subjected to the Water Penetration Test, Section 44, as an alternate test method.

8 Raintight and Rainproof Enclosures

8.1 An enclosure designated rainproof shall be constructed to prevent the entrance of a beating rain at a level higher than the lowest live part within the enclosure, in accordance with the Rain Test, Section 43.

8.2 An enclosure designated raintight shall comply with 8.1, except that it shall be constructed to prevent the entrance of a beating rain at any point within the enclosure.

8.3 The enclosure shall be provided with external means for mounting, except that internal means for mounting can be employed when constructed to prevent water from entering the enclosure. Hinges and other attachments shall be resistant to corrosion. Metals shall not be used in combinations that result in galvanic action which adversely affects any part of the device.

8.4 To determine that an enclosure complies with the requirements specified in 8.1 or 8.2, the complete enclosure is to be mounted with conduit connections as in actual service and subjected to the Rain Test, Section 43.

8.5 For a raintight enclosure, all openings for conduit shall be threaded. For a rainproof enclosure, all openings shall be threaded, unless they are located wholly below the lowest terminal lug or other live part within the enclosure, and there shall be provision for drainage of the enclosure when knockouts or unthreaded holes are provided.

8.6 A component (such as a gasket, printer door or lock cover) of an elastomeric or thermoplastic material, or a composition gasket utilizing an elastomeric material employed to make an enclosure rainproof or raintight, shall be resistant to aging. See 38.2 and 38.3. If an adhesive is used to hold the gasket in place, the gasket and adhesive shall be subjected to the Adhesion Test in the Standard for Gaskets and Seals, UL 157.

8.7 A raintight or rainproof enclosure of sheet steel having an average thickness less than 0.120 inch (3 mm) (No. 10 MSG) shall be:

a) Galvanized by the hot-dip process after forming and assembly,

b) Made from hot-dipped sheets,

c) Provided with a metallic coating that has been evaluated as at least the equivalent of zinc applied by the hot-dip process, or

d) Protected from corrosion by some other finish that has been evaluated as equivalent protection.

8.8 A raintight or rainproof enclosure made of sheet steel having an average thickness of 0.120 inch (3 mm) (No. 10 MSG) or more can be formed from either hot-dipped or electroplated sheets, or can be protected from corrosion by some other finish that has been evaluated as equivalent protection. A cadmium coating shall not be less than 0.001 inch (0.03 mm) thick.

9 Operating Mechanism

9.1 The operating mechanism of control equipment shall be such that it is not adversely affected by the vibration of normal operation. When screws and nuts serve to attach operating parts to movable members, they shall be upset or otherwise locked to prevent loosening under the conditions of actual use. The operating mechanism shall not subject manually operated switch parts to undue stress.

9.2 If the position of an operating handle is not readily apparent, the position shall be marked in accordance with 49.14.

9.3 Control equipment involving electronic control circuits shall be investigated under conditions of actual service to determine when it complies with all applicable requirements.

10 Corrosion Protection

10.1 For enclosures for outdoor use only, iron and steel parts, except bearings, thermal elements, etc., where such protection is impracticable, shall be protected against corrosion by enameling, galvanizing, sherardizing, plating, or other means that has been determined to be equivalent.

10.2 The requirement of 10.1 applies to all enclosing cases whether of sheet steel or cast iron, and to all springs and other parts upon which proper mechanical operation depends. It does not apply to small minor parts of iron or steel such as washers, screws, bolts, and similar parts which are not current-carrying, when the failure of such unprotected parts would probably not result in a hazardous condition; however the protection of all such parts is recommended. Parts made of stainless steel (properly polished or treated when required) do not require additional protection against corrosion.

10.3 Metallic parts that are protected against corrosion by the following methods comply with the intent of 10.1:

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

b) Coatings which have been determined to be equivalent to G90 under the requirements of the Standard for Organic Coatings for Steel Enclosures for Outdoor Use Electrical Equipment, UL 1332.

11 Protection of User and Service Personnel

11.1 When the normal operation of a device involves accident hazards or involves hazards resulting from the presence of toxic or flammable chemicals, and similar materials, protection shall be provided for the reduction of such hazards to a level that does not result in an injury to the operator. Operators shall be protected during operator servicing.

11.2 There shall be a plainly marked “Off” position on or adjacent to a switch of other than a momentary-contact type when the switch controls parts that results in injury to persons.

11.3 When an automatic reset type of protective device is employed in a device, the automatic restart shall not result in any condition of hazard to persons.

11.4 The requirement in 11.3 necessitates the use of a reliable interlock in the device when moving parts are capable of being hazardous upon the automatic restarting of the motor.

12 Field Wiring Connections

12.1 Permanently connected devices

12.1.1 Control equipment intended to be permanently wired shall be provided with field-wiring terminals or leads for the connection of the power supply or other conductors, and with means for the connection of a wiring system as required by the National Electrical Code, NFPA 70.

12.1.2 For the purpose of these requirements, a field-wiring terminal is determined to be a terminal to which a power supply or control connection is made in the field when the equipment is installed.

12.1.3 When provided, an opening or a knockout not having rounded edges and intended to be used for the entry of field installed conductors of a low-voltage Class-2 circuit shall be provided with a reliable insulating bushing. The bushing can be mounted in place in the opening or can be within the enclosure so that it is properly mounted when the device is installed. Only the number of bushings required to properly wire the device is required to be provided. When the opening is capable of accommodating an NEC, Class I wiring system and the installation instructions specify such a wiring system, bushings are not required to be provided.

12.1.4 A bushing of rubber or rubber-like material provided in accordance with 12.3 shall be 1/8 inch (3.2 mm) or more thick, except that it shall not be less than 1/16 inch (1.6 mm) thick [with a minus tolerance of 1/64 inch (0.4 mm)] when the metal around the hole is eyeleted or similarly treated to ensure smooth edges. A bushing shall be located so that it will not be exposed to oil, grease, oily vapors, or other substances having a deleterious effect on the material of the bushing. A hole in which a bushing is mounted shall be free from sharp edges, burrs, projections, and similar conditions, which are capable of damaging the bushing.

12.1.5 The space within the enclosure shall provide ample room for the distribution of wires and cables required for the proper wiring of the device.

12.1.6 In determining the adequacy of wiring space, the device shall be wired as intended in service. A reasonable amount of slack is to be left in each conductor within the enclosure, and not more than average care is to be exercised in stowing this slack into the enclosure. Consideration is then to be given to the relative location of the conduit opening to parts operating at temperatures in excess of the permissible temperature limit of the field installed wiring and splices, moving parts which are capable of abrading insulation or be fouled by field installed wiring to prevent their normal operation, or sharp stationary parts over which wires are capable of being routed or against which slack is capable of being stowed. These considerations apply whether connections are to be made at terminals or by splices to leads.

12.2 Terminal compartments

12.2.1 A terminal compartment that is intended for connection of a supply raceway and is capable of being positioned to suit a particular installation, shall be provided with a means for attachment to the control equipment to prevent turning both during and after installation.

12.2.2 An outlet or terminal box in which connections to the power supply circuit are to be made shall be located so that, after the equipment has been installed as intended, the connections are readily accessible for inspection. The compartment cover shall be independent of the means for the connection of the wiring system.

12.2.3 The compartment shall be located so that during conduit connections thereto, internal wiring and electrical components shall not be exposed to physical abuse or strain. Temporary removal or relocation of factory wiring shall not be required to accomplish field wiring.

12.3 Wiring terminals and leads

12.3.1 The wiring terminals or leads shall be appropriate for the connection of field-installed conductors having an ampacity, as required for the device, in accordance with the National Electrical Code, NFPA 70.

12.3.2 When the control equipment is intended to be adapted upon installation for either of two different supply voltages (such as, 120 volts, two wire or 120/240 volts, three wire), it shall be provided with means by which the appropriate connections are capable of being made during field installation, without the necessity of changing or disrupting internal wiring or connections other than at the point of field connection. This requirement does not apply to equipment which is factory wired internally for a specific voltage and so marked on the nameplate.

12.3.3 A wiring terminal shall have a pressure wire connector evaluated for use with the component, firmly bolted or held by a screw; except that a wire-binding screw can be employed at a wiring terminal intended to accommodate at 8 AWG (8.4 mm^2) or smaller conductor when upturned lugs or parts that have been determined to be equivalent are provided to hold the wire in position.

12.3.4 A wiring terminal shall be prevented from turning.

12.3.5 A wire-binding screw shall thread into metal.

12.3.6 A wire-binding screw at a wiring terminal shall not be smaller than No. 8 (4.2 mm diameter) except that a No. 6 (3.5 mm diameter) screw can be used for a terminal to which a 14 AWG (2.1 mm^2) wire or smaller is normally connected.

12.3.7 A wire-binding screw at a wiring terminal supplied from circuits which are judged to be low-voltage Class-2, shall not be smaller than a No. 5 (3.2 mm diameter) machine screw.

12.3.8 A terminal plate tapped for a wire-binding screw shall be of metal not less than 0.050 inch (1.27 mm) thick, except that a plate not less than 0.030 inch (0.76 mm) thick is permissible when the tapped threads are determined to have the required strength. There shall be two or more full threads in the metal, which are to be extruded, when required, to provide the threads.

12.3.9 Upturned lugs, a cupped washer, or a part that has been determined to be equivalent shall retain a conductor under the head of the screw or the washer.

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

12.3.11 The surface of a lead intended for connection of a grounded power supply conductor shall be white or grey, and shall be readily distinguishable from the other leads.

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

12.3.13 A lead intended for field connection and exiting from the control equipment through a conduit hub shall be at least 18 inches (457 mm) in length measured from the point of exit of the control equipment to the connection end of the lead.

12.3.14 A lead intended to be connected to field-installed wiring shall not be smaller than 18 AWG (0.82 mm^2).

12.4 Cord- and plug-connected devices

12.4.1 Portable equipment and fixed or stationary equipment requiring cord connection to facilitate removal or disconnection for maintenance and repair can be provided with a flexible cord and an attachment plug for connection to the supply source.

12.4.2 When more than one supply cord is provided on a unit, the construction shall be such that physical disconnection of any one power-supply cord shall automatically result in de-energization of all circuits within the unit supplied by other cords.

12.4.3 The cords that remain connected, a terminal strip, circuit breaker, or both, when used, and parts of a unit on the line side of a disconnect device can remain energized when they are enclosed or otherwise protected against unintentional contact by service personnel performing service functions not involving these parts.

12.4.4 A supply cord shall be of a type that is capable of being used with the product. It shall be evaluated for use at a voltage not less than the rated voltage of the unit, and its ampacity, as given in the National Electrical Code, NFPA 70, shall not be less than the current rating of the unit.

12.4.5 The length of a supply cord measured from the outside surface of the enclosure of a unit to the plane of the face of the attachment-plug cap shall not exceed 15 feet (4.6 m).

12.4.6 For equipment provided with a polarized attachment-plug cap, one of the circuit conductors in the flexible cord shall be identified for connection of the grounded supply conductor when the unit is rated at 125 volts or less or at 125/250 volts or less (3 wires) 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 and 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).

12.4.7 An attachment-plug cap supplied with a supply cord shall be evaluated for its intended use, with a current rating not less than 125 percent of the rated current of the unit, and a voltage rating not less than the rated voltage of the unit.

12.4.8 Strain relief means shall be provided to prevent a mechanical stress on a supply cord from being transmitted to terminals, splices, or interior wiring.

12.4.9 Clamps of material, metal or otherwise, can be used on cords without varnished-cloth insulating tubing or a part that has been determined to be equivalent under the clamp unless it is judged that the tubing or the equivalent item is required to prevent the clamp from damaging the cord.

12.4.10 Means shall be provided to prevent the supply cord from being pushed into the unit through the cord-entry hole when such displacement:

a) Subjects the cord to mechanical damage or to exposure to a temperature higher than that for which the cord is rated, or

b) Is capable of reducing spacings, such as to a metal strain-relief clamp, below the minimum values.

12.4.11 When tested in accordance with 12.4.12, the strain-relief means provided on the supply cord shall be capable of withstanding for 1 minute without displacement, a pull of 35 pounds (156 N) applied to the cord with the connections within the unit disconnected.

12.4.12 A 35 pound (15.88 kg) weight is to be suspended on the cord and so supported by the unit that the strain-relief means is stressed from any angle that the construction of the unit permits. The strain relief shall not be used when, at the point of disconnection of the conductors, there is movement of the cord as to indicate that stress would result on the cord connections.

12.4.13 At each point at which a supply cord passes through an opening in a metal or other wall, barrier, or enclosing case, a smooth, well-rounded surface against which the cord is capable of resting shall be provided to protect the cord against damage. A bushing used to comply with this requirement shall be substantial and reliably secured in place.

13 Internal Wiring

13.1 General

13.1.1 The wiring and connections between parts within control equipment shall be adequately protected or enclosed. See 13.4.1 – 13.4.5 for interconnecting cords and cables.

13.2 Wires

13.2.1 The internal wiring of control equipment shall consist of wires of a type(s) that are capable of being used when evaluated with respect to the temperature and voltage to which the wiring is capable of being subjected, with respect to exposure, oil or grease, and other conditions of service to which the wiring can be subjected. The requirements relating to color coding for identification do not apply to internal wiring that is not visible in a wiring compartment in which field connections are to be made.

13.2.2 Particular care is to be taken to consider the effects of vibration, impact, and handling during operator servicing for wires smaller than 24 AWG (0.21 mm^2).

13.2.3 Wiring that is subject to motion and any supplementary insulation provided on the wire is not prohibited from being subjected to a flexing test.

13.2.4 Metal clamps, items integral to the equipment, such as channels, barriers, and similar parts, and components that have been investigated for routing stationary internal wiring shall be provided with smooth, well-rounded edges. Adequate auxiliary nonconducting mechanical protection shall be provided 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.

13.2.5 Wires shall be reliably routed away from sharp edges, screw threads, burrs, fins, moving parts, and similar parts, that are capable of abrading the wires.

13.2.6 A hole through which insulated wires pass through a sheet-metal wall within the overall enclosure shall be provided with a smooth, well-rounded bushing or shall have smooth, well-rounded surfaces upon which the wire is capable of resting, to prevent abrasion of the wire.

13.2.7 Attention is to be paid to possible inductive heating where wires carrying large currents are involved.

13.2.8 Except as noted in 23.7 – 23.9, the frame or enclosure shall not be used to carry current.

13.3 Splices and connections

13.3.1 All splices and connections shall be mechanically secured and shall provide adequate and reliable electrical continuity. A soldered connection shall be made mechanically secure before being soldered, when breaking or loosening of the connection results in any hazardous condition. Consideration shall be given to vibration, etc., when evaluating electrical connections. Mechanical splicing devices are permitted.

13.3.2 A splice shall be provided with suitable insulation that is capable of being used in this application when permanence of spacing between the splice and other metal parts is not ensured.

13.3.3 In determining whether or not splice insulation consisting of coated-fabric, thermoplastic, or another type of tape or tubing is capable of being used, consideration is to be given to such factors as mechanical strength, dielectric properties, heat and moisture-resistant characteristics, etc. Thermoplastic tape shall not be wrapped over a sharp edge.

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

13.4 Interconnecting cords and cables

13.4.1 Flexible-cord or cable assemblies used for external interconnection between sections of equipment shall be provided with bushings and strain relief that has been evaluated for use in this application.

13.4.2 Inserting a male connector in a female connector other than the one intended to receive it, misalignment of male and female connectors, and other manipulations of parts that are accessible to the operator shall not result in a hazard.

13.4.3 When either or each end of an external interconnecting cable terminates in a connector on which there are one or more contacts:

a) Not more than 42.4 volts peak open-circuit potential shall exist between ground and any contact that is exposed on either the connector or its receptacle while the connector is out of its receptacle or

b) Not more than 5.0 milliamperes of current shall flow through a 1500-ohm noninductive resistor connected between ground and any exposed contact.

13.4.4 Inclusion of an interlock circuit in the cable to de-energize the exposed contacts whenever an end of the cable is disconnected constitutes compliance with the requirement in 13.4.3. In the absence of such an interlock, compliance, or the lack thereof, is to be determined by means of the procedure indicated in 13.4.5.

13.4.5 While the interconnected units are operating normally, the cable connectors specified in 13.4.3 are to be disengaged from their receptacles one at a time. The open-circuit voltages are to be measured between each of the exposed contacts and grounded metal. The 1500-ohm resistor is to be connected between each of the exposed contacts and grounded metal and the current through the resistor is to be measured in each position.

13.4.6 The length of a cable containing line-voltage conductors shall be limited to 4 feet (1.2 m) unless the cable has been evaluated for extra hard service.

14 Grounding

14.1 Cord-connected control equipment and all permanently connected equipment shall have provision for the grounding of all exposed dead-metal parts that are capable of becoming energized.

14.2 In permanently-connected equipment, the provision of a knockout or other opening in the enclosure can be used for grounding when the knockout or other opening is required for the connection of one of the wiring systems that, in accordance with the National Electrical Code, NFPA 70 is appropriate for the equipment. In cord-connected equipment the provision of a multiple-conductor flexible cord having one conductor connected to the enclosure or frame of the equipment can be used for grounding.

14.3 A wire-binding screw intended for the connection of an equipment-grounding conductor shall have a green colored head that is hexagonal-shaped, 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," "GROUND," "GROUNDING," a similar designation, or by a similar marking designation on a wiring diagram provided on the equipment. The wire-binding screw or pressure wire connector shall be located so that it will not be removed during normal servicing of the unit.

14.4 A terminal for connection of an equipment-grounding conductor shall be capable of securing a conductor of the intended size in accordance with the National Electrical Code, NFPA 70.

14.5 A soldering lug, a push-in (screwless) connector, or a quick-connect or similar friction-fit connector, shall not be used for the grounding terminal.

14.6 An insulated grounding conductor of a flexible cord shall be green or green with one or more yellow stripes. No other lead shall be so identified.

14.7 The insulated grounding conductor of the power supply cord of a cord-connected device shall be attached to the grounding blade of an attachment-plug cap of the grounding-type, and shall be connected within the confines of the frame or enclosure by means of a screw that is not to be removed during servicing not involving the power supply cord. The grounding conductor shall be arranged so an external pull on the power-supply cord will not transmit stress to the grounding connection on the frame or enclosure before the line-voltage connections are broken.

14.8 The grounded-circuit conductor shall not be grounded at or in conjunction with control equipment.

15 Bonding of Internal Parts

15.1 General

15.1.1 All exposed dead-metal parts that are capable of becoming energized, and all dead-metal parts within the enclosure that are exposed to contact during operator servicing and that are capable of becoming energized, shall be reliably connected together and to the grounding means.

15.1.2 Exempted from the requirements in 15.1.1 are small internal assembly screws, or other small fasteners, such as rivets, and relay and contactor magnets and armatures.

15.1.3 Uninsulated live parts and wiring shall be maintained away from moving parts, such as relay and contactor magnets and armatures, by clamping, routing, or other means that have been determined to be equivalent that ensure permanent separation.

15.1.4 When two or more pieces of control equipment are electrically or mechanically connected to one another and one of them is grounded:

a) All exposed dead-metal parts that are capable of becoming energized shall be grounded on all of the devices and

b) Each unit of the system that has a separate supply cord shall have a grounding-type cord.

When the control equipment is interconnected electrically and one of them is grounded, they shall be bonded together, such as by means of a discrete conductor included in an interconnecting cable that has been evaluated for use in this manner.

15.2 Construction and connections

15.2.1 A separate component bonding conductor shall be of copper, a copper alloy, or other material capable of being used as an electrical conductor. A ferrous-metal part in the grounding path shall be suitably protected against corrosion by enameling, galvanizing, plating, or other means that have been determined to be equivalent. A separate bonding conductor or strap:

a) Shall be protected from mechanical damage or shall be located within the confines of the outer enclosure or frame and

b) Shall not be secured by a removable fastener used for any purpose other than bonding unless the bonding conductor would not to be omitted after removal and replacement of the fastener. The ends of the bonding conductor shall be in metal-to-metal contact with the parts to be bonded.

15.2.2 The size of a separate conductor or strap used for bonding of a motor frame or component within the device enclosure shall be the same as that specified in Table 15.1 or shall be the same as that of the conductor supplying the motor or component, whichever is the smaller.

Table 15.1
Bonding Conductor Size

Rating of overcurrent devices, amperes	Size of bonding conductor[a]					
	Copper wire,		Aluminum wire,		Rigid conduit or pipe, inch	Electrical metallic tubing, inch
	AWG	(mm^2)	AWG	(mm^2)		
20[b]	12	(3.3)	10	(5.3)	1/2	1/2
30	10	(5.3)	8	(8.3)	1/2	1/2
40	10	(5.3)	8	(8.3)	1/2	1/2
60	10	(5.3)	8	(8.3)	1/2	1/2
100	8	(8.3)	6	(13.4)	1/2	1/2

[a] Or a cross-sectional area that has been determined to be equivalent.

[b] For a cord-connected device, the grounding wire in the cord can be the same size as the current-carrying conductors.

ELECTRICAL COMPONENTS

16 Switching Devices

16.1 A switch or other control device shall be rated for the application or shall be tested according to the requirements in 36.2.1, 36.2.2, and 36.3.1.

16.2 The rating of a switch shall not be less than the rating of the load that the switch controls.

16.3 The current rating of a switch that controls a solenoid, magnet, transformer, electric-discharge-lamp ballast, or other inductive load is to be at least twice the rated full-load current of the component that is controlled unless the switch is capable of being used in this application.

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

16.5 The operation of a control (such as a switch intended to adapt the equipment to different supply voltages) that is accessible to the operator without the use of tools shall not result in a hazard.

16.6 When equipment that is intended for connection to the branch-circuit supply by means of a flexible cord and an attachment-plug cap contains a motor rated at more than 1/3 horsepower (245 W), a motor-control device that has been evaluated for use in this application shall be provided in the equipment.

16.7 A control switch, lampholder, attachment-plug receptacle, or plug connector provided as a part of control equipment shall be mounted securely and shall be prevented from turning by means other than friction between surfaces.

16.8 A lock washer intended for use in this application, properly applied, can be used as a means to prevent turning of a control switch.

17 Capacitors

17.1 The materials and construction of a capacitor, its enclosure, or both shall ensure against emission of flame from the enclosure of the control equipment in the event of failure of the capacitor.

17.2 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 equipment at rated voltage.

17.3 A capacitor shall employ such materials and shall be constructed so that it will not constitute an undue fire hazard. It shall not be affected adversely by the temperatures attained by the device under the most severe conditions of normal use. A paper capacitor shall be impregnated or reliably enclosed to exclude moisture. An electrolytic or other special type of capacitor and a capacitor intended for connection directly across the line shall be evaluated for use in this application.

18 Transformers

18.1 A transformer intended to furnish power to a low-voltage Class-2 or secondary circuit shall be of the two-coil or insulated type.

18.2 A transformer shall be housed within its own enclosure, or within the main enclosure of the equipment, or within a combination thereof.

18.3 The transformer shall be evaluated for use in its intended environment and shall operate under normal conditions without introducing hazardous conditions.

18.4 The transformer winding shall resist the absorption of moisture.

19 Motors

19.1 Each motor shall be evaluated for use in its intended environment and shall be capable of driving its "maximum normal load" during operation of the equipment without introducing hazardous conditions. A motor intended for use in a Division 1 Classified area shall comply with the requirements in the Standard for Electric Motors and Generators for Use in Division 1 Hazardous (Classified) Locations, UL 674. Motors for use in unclassified areas shall comply with the Standard for Rotating Electrical Machines – General Requirements, UL 1004-1. Motors for use in Division 2 Hazardous (Classified) Locations shall comply with the Outline of Investigation for Electric Motors and Generators for Use in Class I, Division 2, Class I, Zone 2, Class II, Division 2 and Zone 22 Hazardous (Classified) Locations, UL 1836.

19.2 A motor winding shall resist the absorption of moisture.

19.3 A continuous-duty motor in permanently connected control equipment, an automatically controlled fractional-horsepower motor in equipment, the motor of equipment intended to be operated remotely or unattended, a motor whose operation or failure to operate will not be evident to the operator, and a continuous-duty integral-horsepower motor shall be provided with overcurrent (overload) protection. Except as specified in 19.6, the protection provided is to be as indicated in 19.5. For a multispeed motor, the protection is to be effective at all speed settings.

Exception: This requirement does not apply to motors powered by Class 2 equivalent power sources.

19.4 When overloading, stalling, etc., of a motor results from normal operation of the equipment, that motor shall be provided with overcurrent (overload) protection as described in 19.5.

19.5 The overcurrent (overload) protection required in 19.3 is to consist of one of the following:

a) Thermal protection complying with either the Standard for Overheating Protection for Motors, UL 2111, or the Standard for Thermally Protected Motors, UL 1004-3;

b) Impedance protection complying with the requirements for motor-operated equipment when tested as used in the application; and

c) Other protection that tests show is equivalent to the protection mentioned in (a).

19.6 A motor that drives only a blower or fan is determined to have the intended overcurrent (overload) protection when it is protected against locked-rotor conditions only.

19.7 A motor having a difference of one ampere or less between no-load and locked-rotor currents and having a 2:1 or smaller ratio between locked-rotor and no-load currents is to be determined to have the intended overcurrent (overload) protection when it is protected against locked-rotor conditions only.

19.8 A thermal or overcurrent (overload) protective device shall not open the circuit during normal use of the equipment.

19.9 The functioning of an overcurrent (overload) protective device provided for a motor as part of control equipment, whether or not such a device is required, shall not result in a risk of fire, electric shock, or injury to persons.

20 Heaters

20.1 If a device is provided with a heater, the heater shall be subjected to the Heater Maximum Temperature Test, Section 46. If the temperatures measured during this test exceeds 90 °C, then the heater shall be:

a) Located or guarded such that it is not accessible to the user during normal operation or during user maintenance and

b) Located or guarded such that it is not contacted by wiring or other parts.

20.2 If temperatures measured on the heater exceed 60 °C, but they do exceed 90 °C, then the product shall be marked as indicated in 49.16. If the temperatures measured do not exceed 60 °C, then the heater can be located without restriction.

21 Insulating Material

21.1 A material that is used for the direct support of an uninsulated live part shall comply with the Relative Thermal Index (RTI), Hot Wire Ignition (HWI), High-Current-Arc Resistance to Ignition (HAI), and Comparative Tracking Index (CTI) values indicated in Table 21.1. A material is in direct support of an uninsulated live part when:

a) It is in direct physical contact with the uninsulated live part and

b) It serves to physically support or maintain the relative position of the uninsulated live part with respect to spacing requirements.

Exception: A generic material provided in the thickness indicated in Table 21.2 complies with 21.1 without additional evaluation.

Table 21.1
Minimum Material Characteristics for the Direct Support of Uninsulated Live Parts

Flame class	RTI Elec	Maximum performance level category (PLC)		
		HWI[b,c]	HAI[d, e]	CTI[f,g,h]
HB	a	2	1	3
V-2, VTM-2	a	2	2	3
V-1, VTM-1	a	3	2	3
V-0, VTM-0	a	4	3	3

Relative Thermal Index (RTI)

[a] The electrical Relative Thermal Index (RTI) value of a material is to be determined in accordance with the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B, by test or by use of the generic RTI table. This material characteristic is dependent upon the minimum thickness at which the material is being used. The RTI shall not be exceeded during the Normal Temperature Test, Section 34.

Hot Wire Ignition (HWI)

[b] The Hot Wire Ignition (HWI) value of a material is to be determined by test in accordance with the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A. This material characteristic is dependent upon the minimum thickness at which the material is being used. When the thickness of an insulating material is less than the minimum specified thickness corresponding to a HWI value, the material is evaluated as in footnote c.

[c] A material without an HWI Performance Level Category (PLC) value or with a HWI PLC value greater (worse) than the value required by Table 21.1 shall be subjected to the end-product Abnormal Overload Test or the Glow Wire End-Product Test specified in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

High Current Arc Resistance to Ignition (HAI)

[d] The HAI value of a material is to be determined by test in accordance the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A. This material characteristic is dependent upon the minimum thickness at which the material is being used. When the thickness of an insulating material is less than the minimum specified thickness corresponding to a HAI value, the material is evaluated as in footnote e.

[e] A material without an HAI PLC value or with an HAI PLC value greater (worse) than the value required by Table 21.1 shall be subjected to the end-product Arc Resistance Test specified in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

Comparative Tracking Index (CTI)

[f] The Comparative Tracking Index (CTI) PLC value of a material is to be determined by test in accordance with the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A. This material characteristic is not dependent upon the minimum thickness at which the material is being used. When the thickness of an insulating material is less than the minimum specified thickness corresponding to a CTI value, the material is evaluated as having the same CTI value found for the greater thickness. The CTI value applies to insulating materials used in Pollution Degree 3 environments for voltages of 600 V or less. For equipment where Pollution Degree 1 or 2 is maintained, an insulating material shall have a CTI PLC of 4 or less. For equipment rated 601 – 1500 volts, see footnote h.

[g] A material without a CTI PLC value or with a CTI PLC value greater (worse) than the value required by Table 21.1 shall have a proof tracking index of 175 when used in Pollution Degree 3 environment or a proof tracking index of 100 when used in Pollution Degree 1 or 2 environment as determined by the end-product Proof Tracking Test specified in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

[h] For equipment rated 601 – 1500 volts, the insulating material shall not track beyond one inch in less than 60 minutes using the time to track method of the Inclined Plane Tracking Test specified in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A. The voltage for the Inclined Plane Tracking Test shall be not less than the rated voltage of the equipment.

Table 21.2
Generic Materials for Direct Support of Uninsulated Live Parts

Generic material	Thickness, Inch	(mm)	RTI, °C
Diallyl Phthalate	0.028	(0.71)	105
Epoxy	0.028	(0.71)	105
Melamine	0.028	(0.71)	130
Melamine-Phenolic	0.028	(0.71)	130
Phenolic	0.028	(0.71)	150
Unfilled Nylon	0.028	(0.71)	105
Unfilled Polycarbonate	0.028	(0.71)	105
Urea Formaldehyde	0.028	(0.71)	100
Ceramic, Porcelain, and Slate	No limit		No limit
Beryllium Oxide	No limit		No limit

NOTE – Each material shall be used within its minimum thickness and its Relative Thermal Index (RTI) value shall not be exceeded during the Normal Temperature Test, Section 34.

21.2 Insulating material– such as a relay dust cover, transformer bobbin, printed wiring broad (PWB) insulating sheet, encapsulation, or the like – that is used as a barrier in lieu of the required over surface or through air spacings (or both) shall comply with the requirements in Insulating Barriers, Section 22.

21.3 An insulating material used for direct support as in 21.1, shall comply with the requirements for regrinds, co-molding, and recycled plastics in the Standard for Polymeric Materials – Fabricated Parts, UL 746D, when:

a) More than 25 percent by weight of regrind thermoplastic is included;

b) Any amount of regrind thermoset material, such as phenolic, or melamine, is included;

c) The part is co-molded, using two different plastics in the same mold for a part; or

d) Made from any amount of recycled plastic.

22 Insulating Barriers

22.1 When a barrier is used to comply with spacing requirements, the insulating material used shall comply with at least one of the following criteria:

a) Be a generic direct support material provided in the thickness indicated in Table 21.2;

b) Be a generic barrier material provided in the thickness indicated in Table 22.1 when the insulating barrier does not physically support or maintain the relative position of the uninsulated parts involved; or

c) Comply with the direct support requirements in Table 22.1 at a thickness that meets at least one of the following:

1) Not less than 0.028 inch (0.71 mm) thick;

2) Not less than 0.013 inch (0.33 mm) thick plus one-half required clearance spacings when the barrier is provided in lieu of required clearance distance only; or

3) Capable of withstanding the 5000V ac Dielectric Strength Test in accordance with the internal barrier requirements in the Standard for Polymeric Materials – Use In Electrical Equipment Evaluations, UL 746C.

Exception: When the barrier is provided in lieu of clearance distance only, is not within 1/32 inch (0.8 mm) of uninsulated live parts, and does not physically support or maintain the relative position of uninsulated parts involved, the insulating material is only required to comply with the RTI and HAI values in Table 21.1.

Table 22.1
Generic Materials Suitable as a Barrier

Generic material	Minimum thickness, inch	(mm)	RTI, °C
Aramid paper	0.010	(0.25)	105
Cambric	0.028	(0.71)	105
Electrical grade paper	0.028	(0.71)	105
Epoxy	0.028	(0.71)	105
Mica	0.006	(0.15)	105
Mylar (PETP)	0.007	(0.18)	105
RTV	0.028	(0.71)	105
Silicone	0.028	(0.71)	105
Treated cloth	0.028	(0.71)	105
Vulcanized fiber	0.028	(0.71)	105

NOTE – Each material shall have at least the minimum thickness specified and its Relative Thermal Index (RTI) value shall not be exceeded during the Normal Temperature Test, Section 34.

23 Secondary Circuits

23.1 Except as specified in 37.2, a secondary circuit is not required to be investigated when it is supplied by a Class-2 transformer rated 30 volts rms, 42.4 volts peak, or less.

23.2 Except as specified in 23.5 and 37.3, a secondary circuit is not required to be investigated when both of the conditions outlined below are met:

a) The circuit is supplied by an isolating transformer with a sinusoidal open-circuit potential of 30 volts rms, 42.4 volts peak, or less and

b) The power is limited to the levels specified for a Class-2 transformer by one of the following means:

1) A reliable, fixed impedance;

2) A noninterchangeable fuse;

3) A nonadjustable, manual-reset circuit-protective device; and

4) A reliable regulating network.

23.3 A fuse or circuit protective device used to limit the power as specified in 23.2 shall be rated or set at not more than 3.2 amperes for a circuit operating between 15 and 30 volts and at not more than 5.0 amperes for a 0 – 15 volt circuit. When an impedance or regulating network is used to limit the current, it

shall be such value or construction as to limit the current under short-circuit conditions to not more than 8.0 amperes measured after 1 minute.

Exception: A power supply that complies with any of the following is considered to comply with this requirement without test:

a) Power supplies evaluated to the Standard for Information Technology Equipment – Safety – Part 1: General Requirements, UL 60950-1 that are SELV, Non-energy hazardous and provided with a fused output in accordance with the fuse values given in 23.3;

b) Power supplies evaluated to the Standard for Class 2 Power Units, UL 1310, that are marked as Class 2, Limited Power Source, or LPS;

c) Power supplies evaluated to the Standard for Electrical Equipment for Measurement, Control, and Laboratory Use; Part 1: General Requirements, UL 61010-1; or

d) Power supplies evaluated to the Standard for Audio/Video, Information and Communication Technology Equipment – Part 1: Safety Requirements, UL 62368-1, that are marked ES1 and PS1 or ES1 and PS2.

23.4 When a regulating network is used to limit the power in accordance with 23.2 and 23.3, the performance shall not be adversely affected by failure, either by short circuit or open circuit between any two terminals, or any single rectifier, capacitor, transistor, or similar component in the network in accordance with Component Faults, Section 45.

23.5 In a circuit of the type described in 23.2, the following components are to be judged under the requirements for line-voltage circuits:

a) The secondary of the transformer;

b) The impedance, fuse, circuit protective device, or regulating network; and

c) The wiring between (a) and (b).

23.6 Secondary circuits can be connected to the frame of the control equipment. Except as noted in 23.7 and 23.8, the connection shall be made at only one point in the equipment or system.

23.7 The frame can be used as the return for a secondary circuit supplied as indicated in 23.1 or 23.2.

23.8 A grounding bus of adequate ampacity that is used as the return for a secondary circuit other than as covered by 23.7 can be anchored (connected) to the frame at more than one point.

23.9 When any secondary circuit of more than 42.4 volts peak is connected to the frame of the equipment, all exposed dead-metal parts are capable of becoming energized and all dead-metal parts within the enclosure that are capable of being touched by a person during operator servicing and that are capable of becoming energized shall be reliably connected together.

24 Separation of Circuits

24.1 A factory-installed conductor shall be separated by a barrier or segregated as specified in 24.2 from a factory-installed conductor and from an uninsulated live part used in a different circuit.

Exception: Conductors provided with insulation rated for the highest voltage involved are not required to comply with this requirement.

24.2 Segregation of a conductor shall be accomplished by clamping, routing, or equivalent means that provides permanent separation from a conductor or an uninsulated live part of a different circuit.

24.3 The equipment shall be constructed so that a field-installed conductor of any circuit is segregated as specified in 24.5, or separated by a barrier (see 24.4) from:

a) A field-installed conductor connected to any other circuit, unless:

1) Both circuits are Class 2 or Class 3, or both circuits are other than Class 2 or Class 3 and

2) The conductors of both circuits are insulated for the maximum voltage of either circuit.

b) An uninsulated live part of any other circuit.

Exception No. 1: Field-installed conductors that come into contact with the wiring terminals of other circuits complies with the intent of this requirement when provided with marked instructions that specify the use of Type RH, TW, RFH-2, or conductors that have been determined to be equivalent in accordance with the National Electrical Code, NFPA 70.

Exception No. 2: Field-installed conductors having insulation less than that provided with the wires specified in Exception No. 1, and that come into contact with low-voltage wiring terminals comply with the intent of this requirement when the short-circuiting of such terminals does not result in a risk of fire or electric shock.

c) Any part that is sharp or exceeds the temperature rating of the field-installed conductor and is capable of damaging the field-installed conductor. See 12.1.6 and 40.4.

d) A factory-installed conductor connected to any other circuit, unless the conductors of both circuits are installed for the maximum voltage of either circuit.

Exception: The field-installed conductors are not required to be separated by a barrier when installation instructions are included that explain the proper procedure for maintaining separation and which, upon investigation, are found to achieve the required separation.

24.4 With regard to 24.3, when the intended uses of the device are such that in some applications a barrier is required while in other applications no barrier is required, a removable barrier, or one having openings for the passage of conductors, is not prohibited from being employed. Instructions for the use of such a barrier are to be a permanent part of the device.

24.5 Field-installed conductors are not prohibited from being segregated from each other, and from uninsulated live parts or factory-installed conductors connected to different circuits of the device. This segregation is to be achieved by arranging the location of openings in an enclosure for the various field-installed conductors with respect to the terminals or other uninsulated live parts and factory- or field-installed conductors so that a minimum 1/4 inch (6.4 mm) permanent separation is provided.

24.6 With regard to 24.5, when the number of openings in the enclosure does not exceed the minimum required for the intended wiring of the device, and when such openings are located opposite a set of terminals, it is to be assumed that a conductor entering an opening is to be connected to the terminals opposite that opening. When more than the minimum number of openings are provided, the possibility of a conductor entering an opening other than that opposite the terminal to which it is to be connected and contacting insulated conductors or uninsulated live parts connected to a different circuit is to be investigated in accordance with 12.1.6.

25 Low-Voltage Class-2 Circuits

25.1 Except as noted in 25.2, the output of a transformer device supplying a circuit classified as a low-voltage Class-2 circuit, provided as a part of the equipment, shall not be interconnected with the output of another such transformer device.

25.2 With respect to 25.1, the output of two or more such transformer devices provided as a part of the equipment can be interconnected when the voltage and current measurements at the output terminals are within the values for a single low-voltage Class-2, 30 volt or less transformer device.

25.3 Two or more transformer devices supplying circuits classified as low-voltage Class-2 circuits, provided as a part of the equipment, shall be treated as two separate circuits each having its own separate wiring compartment, and the output of each circuit shall be marked to warn that the separation shall be maintained.

26 Limited Current Circuits

26.1 Secondary circuits that operate at hazardous voltage levels shall not be accessible to the user unless the circuit complies with the Limited Current Test, Section 40.

26.2 Limited current circuits shall be so designed that the limits specified in Limited Current Test, Section 40, are not exceeded under normal operating conditions or in the event of a single fault.

26.3 In accordance with 26.2, if a single fault condition results in other faults, which are a direct consequence of the single fault, then those subsequent faults are allowed.

27 Barriers

27.1 When a barrier is used to provide separation between the wiring of different circuits, it shall be of metal or insulating material, and shall be held in place. Openings in a barrier for the passage of conductors shall not be larger than 1/4 inch (6.4 mm) in diameter and shall not exceed in number, on the basis of one opening per conductor, the number of wires which are required to pass through the barrier. The closure for any other opening shall present a smooth surface wherever an insulated wire is in contact with it and the area of any such opening, with the closure removed, shall not be larger than required for the passage of the required wires.

27.2 A barrier used to provide separation between the field wiring of one circuit and the wiring or uninsulated live parts of another shall be spaced not more than 1/16 inch (1.6 mm) from the enclosure walls and from interior mechanisms and component-mounting panels, etc., which serve to provide segregated compartments.

27.3 A metal barrier shall have a thickness required by Table 7.1 and Table 7.2 based on the dimensions of the barrier. A barrier of insulating material shall be not less than 1/32 inch (0.8 mm) nominal [minimum 0.028 inch (0.71 mm) thick] and shall be of greater thickness when its deformation is readily accomplished so as to defeat its purpose.

28 Printed-Wiring Boards

28.1 Printed-wiring boards used in primary circuits, and in secondary circuits shall be rated for the intended application.

28.2 A resistor, capacitor, inductor, transformer, or other part that is mounted on a printed-wiring board to form a printed-wiring assembly shall be secured so that it cannot be displaced enough by any forces that

are capable of being exerted on it to result in a shock or fire hazard during assembly of the unit, normal operation, or operator or other servicing.

28.3 Consideration is to be given to the mechanical protection and electrical insulation afforded to the part by a barrier or partition.

SPACINGS

29 General

29.1 Live screwheads or nuts on the underside of a base shall be countersunk not less than 1/8 inch (3.2 mm) in the clear, and then covered with a waterproof, insulating, sealing compound that will not melt at a temperature 15 °C (27 °F) higher than the normal operating temperature of the device, and at not less than 65 °C (149 °F) in any case, except that when such parts are staked, upset, or otherwise reliably prevented from loosening, they are not required to be recessed, and they can be insulated from the mounting surface by material other than sealing compound or by the provision of spacings through air and over surface as required in this standard.

29.2 The spacing at wiring terminals is to be measured with appropriate wires in place and connected to the terminals as in actual service.

29.3 All uninsulated live parts connected to different circuits shall be spaced from one another as though they were parts of opposite polarity and shall be judged on the basis of the highest voltage involved.

29.4 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) not of the same polarity shall not be less than indicated in Table 29.1.

Table 29.1
Spacings at Field-Wiring Terminals

Potential involved in volts	Minimum spacings[a]					
	Between field-wiring terminals through air, over surface,		Between terminals and other uninsulated parts not always of the same polarity			
			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)
250 – 600	1/2[b]	(12.7)	1/2[b]	(12.7)	3/8	(9.5)
Over 600	See Table 29.2		See Table 29.2		See Table 29.2	

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

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

29.5 In primary circuits, other than at field-wiring terminals, the spacings between uninsulated live parts of opposite polarity, and between an uninsulated live part and a dead-metal part shall be not less than indicated in Table 29.2 and Table 29.3. When an uninsulated live part is not rigidly fixed in position by means other than friction between surfaces, or when a movable dead-metal part is in proximity to an uninsulated live part, the construction shall be such that at least the minimum permissible spacing is capable of being maintained with the movable part in any position.

Table 29.2
Primary-Circuit Spacings, Other Than at Field-Wiring Terminals and in Motors

Potential involved in volts	Over surface,		Through air,	
	inch	(mm)	inch	(mm)
0 – 50	3/64	(1.2)	3/64	(1.2)
51 – 125	1/16	(1.6)	1/16	(1.6)
126 – 250	3/32	(2.4)	3/32	(2.4)
251 – 600	1/2[a]	(12.7)	3/8[a]	(9.5)
601 – 3000	3/4[b,c]	(19.1)	3/4[b,c]	(19.1)

[a] Enamel-insulated wire is to be considered as if it were an uninsulated live part. However, 3/32-inch (2.4 mm) and greater spacings over the surface and through the air can be between dead-metal parts and enamel-insulated wire that is rigidly supported and held in place on a coil.

[b] Between uninsulated high-voltage parts and:

1) Uninsulated high-voltage parts of opposite polarity or of different potentials,

2) Grounded metal parts, and

3) Uninsulated primary-circuit parts.

[c] Between uninsulated high-voltage parts and:

1) Insulated primary-circuit parts and

2) Insulated high-voltage parts of opposite polarity or of different potentials.

29.6 Primary-circuit spacings apply in all secondary circuits supplied by a transformer winding of 200 volt-amperes or a higher capacity (maximum available power) at a potential higher than 100 volts. The spacings in all other secondary circuits are judged on the basis of the dielectric withstand test described in 37.3.

29.7 The spacings in Table 29.2 and Table 29.3 do not apply to the inherent spacings of a component of the control equipment, such as a snap switch. The acceptability of spacings on a component is based on the requirements that cover the component. For a repulsion motor, a repulsion-induction motor, or a repulsion-start induction motor, the spacings in Table 29.3 do not apply to the commutator, the brush assembly, or the jumpers that short-circuit the brushes. Any uninsulated conductor in the rotor circuit is regarded as a dead-metal part with respect to the stator circuit, and the appropriate spacing is required between the uninsulated stator and rotor conductors.

29.8 Vulcanized fiber or a similar material employed where spacings are otherwise insufficient shall comply with Insulating Barriers, Section 22.

Exception: Vulcanized fiber can be used at one-half the thickness indicated in Section 22 when it is used in conjunction with at least 50 percent of the required air spacing for air alone.

Table 29.3
Primary-Circuit Spacings Within Motors at Other Than Wiring Terminals

Potential involved in volts	Parts involved	Minimum spacings, inch (mm)							
		Motor diameter 7 inches (178 mm) or less[a]				Motor diameter more than 7 inches (178 mm)[a]			
		Over surface		Through air		Over surface		Through air	
0 – 125	Between commutator bars or collector rings of a motor and the motor shaft and laminations	1/16	(1.6)	1/16	(1.6)	3/16[b]	(4.7)	1/8[b]	(3.2)
	Elsewhere in the motor	3/32[c]	(2.4)	3/32[c]	(2.4)	1/4[b,d]	(6.4)	1/8[b,d]	(3.2)
126 – 250	Between commutator bars or collector rings of a motor and the motor shaft and laminations	1/16	(1.6)	1/16	(1.6)	3/16[b]	(4.7)	3/16[b]	(4.7)
	Elsewhere in the motor	3/32	(2.4)	3/32	(2.4)	1/4[b,d]	(6.4)	3/16[b,d]	(4.7)
251 – 600	Between commutator bars or collector rings and live parts of the brush rigging of a motor and the motor shaft and laminations	1/4	(6.4)	1/8	(3.2)	3/8	(9.5)	1/4	(6.4)
	Elsewhere in the motor	1/2[d]	(12.7)	3/8[d]	(9.5)	1/2[d]	(12.7)	3/8[d]	(9.5)

[a] This is the diameter, measured in the plane of the laminations, of the circle circumscribing the stator frame, excluding lugs, boxes, etc., used solely for motor mounting, assembly, or connection.

[b] Spacings of not less than 3/32 inch (2.4 mm) are permitted throughout a universal motor.

[c] For a motor rated at 1/3 horsepower (2.5 W) or less, these spacings shall be not less than 1/16 inch (1.6 mm).

[d] Enamel-insulated wire is determined to be an uninsulated live part. However, a spacing of not less than 3/32 inch (2.4 mm) (over surface and through air) is permitted between enamel-insulated wire, rigidly supported and held in place on a coil, and a dead-metal part.

29.9 As an alternative approach to the spacing requirements in this section, over surface spacings (creepage distances) can be evaluated in accordance with the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, as described in 29.10.

Exception: The creepage distance at field-wiring terminals shall be in accordance with the requirements in 29.4.

29.10 In conducting evaluations in accordance with the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, the following guidelines shall be used:

a) When encapsulation or a coating is intended to be used to achieve pollution degree 1, in addition to complying with the requirements in UL 840, the material shall also be resistant to the vapors to which it is capable of being be exposed.

b) A coating which complies with the requirements for conformal coating in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, shall be determined to comply with the requirements for coatings for printed-wiring boards used to achieve Pollution Degree 1 in accordance with UL 840.

c) Evaluation of creepage distances shall be conducted in accordance with the requirements in UL 840 for creepage distances.

d) Any printed-wiring board which complies with the Standard for Printed-Wiring Boards, UL 796, shall be determined to provide a Comparative Tracking Index (CTI) of 100; and when it further

complies with the requirements for direct support in UL 796, it shall be determined to provide a CTI of 175.

PERFORMANCE

30 General

30.1 Test voltage

30.1.1 Unless otherwise indicated, control equipment shall be subjected to the tests described in Sections 30 – 41. The order of tests, as far as applicable, shall be as presented below.

30.1.2 Unless otherwise indicated, the tests shall be conducted at rated frequency and at the voltage indicated in Table 30.1.

Table 30.1
Test Voltage

Voltage rating of device[a]	Test potential in volts
110 – 120 Vac	120 Vac
110 – 125 Vdc	125 Vdc
208 Vac	208 Vac
220 – 240 Vac	240 Vac
220 – 250 Vdc	250 Vdc
265 – 277 Vac	277 Vac
440 – 480 Vac	480 Vac
550 – 600 Vac	600 Vac

[a] When the rating of the equipment does not fall within any of the indicated voltage ranges, it is to be tested at its rated voltage.

30.1.3 Equipment having a multiple rating can be tested at any of the ratings to ensure that tests are conducted under the most adverse conditions.

30.2 Additional tests

30.2.1 Additional performance requirements are specified in 7.10.3 – 7.10.5, 8.1 – 8.8, 12.4.11 – 12.4.13, 19.5, and Section 42.

31 Input Measurement Test

31.1 Except as indicated in 31.2, the power input shall not exceed the marked rating of the control equipment by more than 10 percent when it is operated under the conditions of normal use and with the equipment connected to a supply circuit as indicated in Table 30.1.

31.2 A device rated 20 watts or less can have an input of not more than 25 percent above its marked rating.

32 Output Measurement Test

32.1 The open circuit voltage and short circuit current shall be measured at the output terminals, when provided. These values are to be used as the basis for establishing the connection and marking requirements as indicated elsewhere in this standard. In the power circuits, the output can be measured with assumed failures of electronic components. However, only one failure is to be introduced at a time.

33 Maximum Voltage Output Measurement Test

33.1 Unless evident from the other tests conducted, measurements are to be made at various points to determine the maximum voltage within the control equipment. These voltage measurements are to be used as a basis for determining the voltages employed in the Dielectric Voltage-Withstand Test, Section 37.

34 Normal Temperature Test

34.1 When tested under the conditions described in 34.2 – 34.9, the control equipment shall not attain a temperature at any point that constitutes a risk of fire or damages any materials employed in the device, nor show temperature rises at specific points greater than those indicated in Table 34.1.

34.2 With reference to the items in Table 34.1, the temperature rise observed by means of a thermocouple on the surface of a coil, where Class 105 and 130 insulation is involved and where the temperature at that point is affected by an external source of heat, can be 15 °C (27 °F) higher than that indicated in the table, as long as the temperature rise by the resistance method for the item in question is not more than that specified in the table.

34.3 All values for temperature rises given in Table 34.1 apply to equipment intended for use in ambient temperature normally prevailing in occupiable spaces, which usually are not higher than 25 °C (77 °F) and are capable of being as high as 40 °C (104 °F) occasionally and for brief periods. Tests of a device for service with such ambient temperatures can be conducted (without correction) and with any ambient temperature in the range of 10 – 40 °C (50 – 104 °F). When the equipment is intended specifically for use in a prevailing ambient constantly more than 25 °C, the test is to be conducted at such higher ambient temperature, and the permissible temperature rises specified in the table are to be reduced by the difference between the higher ambient temperature and 25 °C.

Table 34.1
Maximum Temperature Rises

Material and components	°C	(°F)
A. MOTORS		
1. Class A insulation systems on coil windings of DC and universal motors:		
a) In open motors:		
Thermocouple method	65	(117)
Resistance method	75	(135)
b) In totally enclosed motors:		
Thermocouple method	70	(126)
Resistance method	80	(144)
2. Class A insulation systems on coil windings of AC motors:		
a) In open motors:		
Thermocouple or resistance method	75	(135)
b) In totally enclosed motors:		
Thermocouple or resistance method	80	(144)
3. Class B insulation systems on coil windings of DC and universal motors:		
a) In open motors:		
Thermocouple method	85	(153)

Table 34.1 Continued on Next Page

Table 34.1 Continued

Material and components	°C	(°F)
Resistance method	95	(171)
b) In totally enclosed motors:		
Thermocouple method	90	(162)
Resistance method	100	(180)
4. Class B insulation systems on coil windings of AC motors:		
a) In open motors and on vibrator coils:		
Thermocouple or resistance method	95	(171)
b) In totally enclosed motors:		
Thermocouple or resistance method	100	(180)
B. COMPONENTS		
1. Capacitors		
a) Electrolytic[a]	40	(72)
b) Other types[b]	65	(117)
2. Fuses	65	(117)
3. Rectifiers		
a) Selenium[c]	50	(90)
b) Silicon[c]	75	(135)
4. Relay, solenoid, magnets and other coils with:		
a) Class 105 insulated winding:		
Thermocouple method	65	(117)
Resistance method	85	(153)
b) Class 130 insulated winding:		
Thermocouple method	85	(153)
Resistance method	105	(189)
5. Sealing Compound	40 °C (104 °F) less than melting point	
6. Transformer windings:		
a) Class 105 insulation:		
Thermocouple method	65	(117)
Resistance method	75	(135)
b) Class 130 insulation:		
Thermocouple method	85	(153)
Resistance method	95	(171)
7. Wood and other combustible material	65	(117)
C. ELECTRICAL INSULATION		
1. Fiber employed as electrical insulation	65	(117)
2. Phenolic composition as electrical insulation or as a part whose failure results in a hazardous condition:		
a) Molded composition[c]	125	(225)
b) Laminated composition[c]	100	(180)
3. Rubber- or thermoplastic-insulated wires and cords[c,d]	35	(63)

Table 34.1 Continued on Next Page

Table 34.1 Continued

Material and components	°C	(°F)
4. Varnished-cloth insulation	60	(108)
D. GENERAL		
1. Any point on or within a terminal box on a stationary unit.	65	(117)
2. A surface upon which a permanently wired unit is capable of being mounted in service, and surfaces that are capable of being adjacent to the unit when it is so mounted.	65	(117)
3. Operating knobs, handles, levers:		
a) Metal	25	(45)
b) Nonmetal	35	(63)

[a] For an electrolytic capacitor that is physically integral with or attached to a motor, the temperature rise on insulating material integral with the capacitor enclosure is not to be higher than 65 °C (117 °F).

[b] A capacitor that operates at a temperature rise of more than 65 °C (117 °F) is permitted to be judged on the basis of its marked temperature limit.

[c] This limitation does not apply to an insulated conductor, a rectifier, or a material, which has been investigated and accepted for a higher temperature.

[d] Rubber-insulated conductors within a motor having a Class A insulation system, rubber-insulated motor leads, and a rubber-insulated flexible cord entering a motor are permitted to be subjected to a temperature rise of more than 35 °C (63 °F) when a suitable braid is employed on each individual conductor. This does not apply to thermoplastic-insulated wires or cords.

34.4 Coil or winding temperatures are to be measured by thermocouples mounted on the outside of the coil wrap. When the coil is inaccessible for mounting thermocouples (e.g., a coil immersed in sealing compound) or when the coil wrap includes thermal insulation, such as asbestos or more than 1/32 inch (0.8 mm) of cotton, paper, rayon, or similar materials, the resistance method is to be used. For a thermocouple-measured temperature of a coil of a motor, the thermocouple is to be mounted on the integrally applied insulation of the conductor.

34.5 The resistance method consists of the determination of the temperature of a winding by comparing the resistance of the winding at the temperature to be determined with the resistance of the winding at a known temperature, according to the formula:

$$T_1 = \frac{R}{r}(K + t_2) - K$$

in which:

T_1 is the temperature in degrees C to be determined;

R is the resistance in ohms at the temperature to be determined;

r is the resistance in ohms at the known temperature;

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

t_2 is the known temperature in degrees C.

34.6 Temperatures are to be measured by thermocouples consisting of wires not larger than 24 AWG (0.21 mm^2) and not smaller than 30 AWG (0.06 mm^2), except that a coil temperature is to be determined by the resistance method when the coil is inaccessible for mounting thermocouples. See 34.4. When thermocouples are used in determining temperatures in electrical equipment, it is standard practice to employ thermocouples consisting of 30 AWG (0.06 mm^2) iron and constantan wire and a potentiometer-type indicating instrument. Such equipment is to be used whenever referee temperature measurements by

thermocouples are required. The thermocouple wire is to comply with 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. A temperature is determined to be constant when three successive readings, taken at intervals of 10 percent of the previously-elapsed duration of the test, and not less than 5 minute intervals, indicate no change.

34.7 A thermocouple junction and the adjacent thermocouple lead wire are to be securely held in thermal contact with the surface of the material whose temperature is being measured. In most cases, adequate thermal contact results from securely taping or cementing the thermocouple in place. However, when a metal surface is involved, alternative methods of securing the thermocouple to the surface, such as brazing or soldering, are not prohibited from being used.

34.8 The temperature rise attained by the motor of a timing device, when stalled and while connected to a supply circuit as indicated in Table 30.1, shall not exceed the limits given in Table 34.1, when stalling the motor is part of the normal operation.

34.9 To determine when the equipment complies with the requirements of 34.1 – 34.8, the device is to be operated under normal conditions, unless otherwise indicated. The potential of the supply circuit is to be in accordance with Table 30.1.

35 Operation

35.1 An electromagnet (e.g., relay, solenoid) provided on the equipment shall be able to withstand 10 percent above the test voltage for the equipment, in accordance with Table 30.1, continuously without damage to the operating coil and to operate successfully at 15 percent less than the rated voltage. This does not apply to a force coil intended to produce a modulated force as a function of current.

35.2 For the operation at minimum voltage, the equipment is to be subjected to the normal test voltage per Table 30.1 until constant temperature is reached, and the electromagnet is then tested immediately for closing at the minimum voltage.

36 Overload and Endurance Test

36.1 General

36.1.1 Unless it has been tested and found capable of being used in this application, a contact device shall acceptably complete the test program outlined in 36.2.1, 36.2.2, and 36.3.1.

36.2 Overload

36.2.1 A contact device shall be capable of performing successfully for 50 cycles of operation when the device is connected to a supply circuit having a potential of 110 percent of the voltage specified in 30.1.1. There shall be neither electrical nor mechanical failure of the control, nor undue burning, pitting, or welding of the contacts.

36.2.2 In a test to determine whether or not a contact device complies with the requirements in 36.2.1, the device is to be connected to a grounded supply circuit; the enclosure of the device, when made of metal, is to be connected to ground through a 3-ampere fuse; and the control, when single-pole, is to be connected in an ungrounded conductor of the circuit. The control is to be operated at the rate of 6 cycles per minute, except that a faster rate of operation can be employed. The performance is unacceptable when the fuse in the grounding connection is ruptured during the test.

36.3 Endurance

36.3.1 A contact device shall be capable of withstanding an endurance test which shall consist of 6000 cycles of operation. The contact shall make and break the expected load in the equipment while connected to a circuit of rated voltage. There shall be neither electrical nor mechanical failure of the device, nor undue burning, pitting, or welding of the contacts.

37 Dielectric Voltage-Withstand Test

37.1 A device shall be capable of withstanding for 1 minute without breakdown the application of a 60 Hz alternating potential of 1000 volts plus twice maximum rated test voltage of the following circuits, when applicable:

a) Between line-voltage live parts and grounded exposed-metal parts or the enclosure with the contacts open and closed;

b) Between line-voltage live parts of opposite polarity with the contacts closed;

c) Between live parts of line-voltage and secondary circuits; and

d) Between live parts of different line-voltage circuits.

37.2 Low-Voltage Class-2 circuits shall be capable of withstanding the application of a 60 Hz alternating potential of 500 volts for 1 minute without breakdown. The potential shall be applied between live parts of opposite polarity and between live parts and the enclosure, grounded dead-metal parts, or exposed, isolated (insulated) parts.

Exception: Low-Voltage, Class 2 circuits that are mounted on printed wiring boards with a flame rating of V-1 or better, do not need to be tested for dielectric between the Low Voltage, Class 2 circuit and the enclosure.

37.3 Secondary circuits shall be capable of withstanding the application of 60 Hz rms potential equal to three times the maximum peak voltage of the circuit, and not less than 500 volts rms for 1 minute without breakdown. The potential shall be applied between live parts of different circuits between live parts of opposite polarity, and between live parts and grounded dead-metal parts, or exposed, isolated (insulated) parts.

Exception: Secondary circuits that are mounted on printed wiring boards with a flame rating of V-1 or better, do not need to be tested for dielectric between the secondary circuit and the enclosure.

37.4 When the low-voltage Class-2 or secondary circuit is grounded at one or more points, the grounding points shall be removed for the test covered in 34.2 and 34.3.

37.5 The test potentials specified in 37.1 – 37.3 are to be obtained from a 500 volt-ampere or larger testing transformer, the output voltage of which is essentially sinusoidal and can be regulated. Starting at zero, the applied potential is to be increased gradually until the required test value is reached or until breakdown occurs. The increase in the applied potential is to be at a substantially uniform rate and as rapid as is consistent with its value being correctly indicated by the voltmeter.

Exception: The test potentials specified in 37.1 – 37.3 may be replaced be a dc voltage potential which is equal to 1.414 times the required ac potential.

38 Aging Test

38.1 A component (such as a gasket, printer door or lock cover) employed to make an enclosure rainproof shall be subjected to the accelerated aging test described in 38.2 or shall be subject to the requirements of 38.3, based upon the component composition.

38.2 A gasket of rubber or neoprene or a composition thereof intended for use at 60 °C (140 °F) or less is to be exposed for 70 hours in an air oven at 100 ±2 °C (212 ±3.6 °F). Gaskets for use at over 60 °C (140 °F) are to be subjected to other appropriate aging tests. The gasket is determined to be resistant to aging when there is no visible evidence of deterioration such as softening, hardening, or cracking after flexing.

38.3 A component (such as a gasket, printer door or lock cover) of thermoplastic material, or a combination thereof, is to be accepted after consideration of the effects of heat aging, distortion under conditions of use, and the means of securing the gasket to the cover or enclosure.

39 Low-Voltage Class-2 Transformer Test

39.1 General

39.1.1 Three representative samples of the transformer shall be subjected to tests in the following order:

a) Open-circuit secondary voltage;

b) Current output or volt-ampere capacity;

c) Burnout; and

d) Dielectric withstand.

Based on the test results, the transformer is to be classified as indicated in Table 39.1.

Table 39.1
Classification of Transformers

Transformer classification	Maximum secondary output		
	Open circuit, volts	Short circuit, amperes	Capacity, volt-amperes
Low-voltage, energy-limiting, Class-2	30	8.0	–
Low-voltage, nonenergy-limiting, Class-2	30	–	100

39.2 Open-circuit secondary voltage

39.2.1 With the primary of a low-voltage Class-2 transformer connected to a supply circuit as indicated in Table 30.1 at rated frequency, the open-circuit secondary voltages shall not exceed the values indicated in Table 39.1.

39.3 Current output

39.3.1 Under any noncapacitive condition of loading, including short-circuit, the secondary current of a low-voltage Class-2 energy-limiting transformer shall not be more than 8 amperes 1 minute after the primary is energized from a supply circuit as indicated in Table 30.1 at rated frequency.