UL 773A

STANDARD FOR SAFETY

Nonindustrial Photoelectric Switches for Lighting Control

UL Standard for Safety for Nonindustrial Photoelectric Switches for Lighting Control, UL 773A

Sixth Edition, Dated January 19, 2016

Summary of Topics

This revision of ANSI/UL 773A dated June 26, 2020 incorporates the Addition of Requirements for Manufacturer's Recommended Field Wiring Terminal Tightening torque to Clause 8.1.13 and Table 42.1.

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

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated November 15, 2019.

No Text on This Page

Association of Standardization and Certification
NMX-J-715-ANCE
First Edition

CSA Group
CSA C22.2 No. 284-16
First Edition

Underwriters Laboratories Inc.
UL 773A
Sixth Edition

Nonindustrial Photoelectric Switches for Lighting Control

January 19, 2016

(Title Page Reprinted: June 26, 2020)

ANSI/UL 773A-2020

Commitment for Amendments

This standard is issued jointly by the Association of Standardization and Certification (ANCE), the Canadian Standards Association (operating as "CSA Group"), and Underwriters Laboratories Inc. (UL). Comments or proposals for revisions on any part of the standard may be submitted to ANCE, CSA Group, or UL at anytime. Revisions to this standard will be made only after processing according to the standards development procedures of ANCE, CSA Group, and UL. CSA Group and UL will issue revisions to this standard by means of a new edition or revised or additional pages bearing their date of issue. ANCE will incorporate the same revisions into a new edition of the standard bearing the same date of issue as the CSA Group and UL pages.

ISBN 978-1-77139-732-2 © 2016 Canadian Standards Association

This Standard is subject to review five years from the date of publication, and suggestions for its improvement will be referred to the appropriate committee. To submit a proposal for change, please send the following information to inquiries@csagroup. org and include "Proposal for change" in the subject line: Standard designation (number); relevant clause, table, and/or figure number; wording of the proposed change; and rationale for the change.

This ANSI/UL Standard for Safety consists of the Sixth Edition including revisions through June 26, 2020. The most recent designation of ANSI/UL 773A as an American National Standard (ANSI) occurred on June 26, 2020. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page (front and back), or the Preface.

The Department of Defense (DoD) has adopted UL 773A on June 13, 1989. The publication of revised pages or a new edition of this Standard will not invalidate the DoD adoption.

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.

To purchase UL Standards, visit UL's Standards Sales Site at http://www. shopulstandards. com/HowToOrder.aspx or call toll-free 1-888-853-3503.

CONTENTS

MANUFACTURING AND PRODUCTION TESTS

RATINGS, MARKINGS AND INSTRUCTIONS

No Text on This Page

PREFACE

This is the harmonized ANCE, CSA Group, and UL standard for Nonindustrial Photoelectric Switches for Lighting Control. It is the first edition of NMX-J-715-ANCE, the first edition of CSA-C22.2 No. 284-16, and the sixth edition of UL 773A. This edition of UL 773A supersedes the previous edition published on February 10, 2006. This harmonized standard has been jointly revised on June 26, 2020. For this purpose, CSA Group and UL are issuing revision pages dated June 26, 2020, and ANCE is issuing a new edition dated June 26, 2020.

This harmonized standard was prepared by the Association of Standardization and Certification, (ANCE), CSA Group and Underwriters Laboratories Inc. (UL). The efforts and support of the Technical Harmonization Subcommittee, on the Harmonization of Electrotechnical Standards of the Nations of the Americas (CANENA), are gratefully acknowledged.

The CSA Group standard also replaces the following Technical Information Letters (T.I.L.), for products covered in this Standard:

– TIL No. A-15 Photo-electric switches

This standard is considered suitable for use for conformity assessment within the stated scope of the standard.

The present Mexican standard was developed by the CT 23 Electrical Accesries from the Comite de Normalizacion de la Asociacion de Normalizacion y Certificacion, A.C., CONANCE, with the collaboration of the Electrical of manufactures, manufacturers and users.

This standard was reviewed by the CSA Integrated Committee on Wiring Devices, under the jurisdiction of the CSA Technical Committee on Wiring Products and the CSA Strategic Steering Committee on requirements for Electrical Safety, and has been formally approved by the CSA Technical Committee. This standard has been developed in compliance with Standards Council of Canada requirements for National Standards of Canada. It has been published as a National Standard of Canada by CSA Group.

Application of Standard

Where reference is made to a specific number of samples to be tested, the specified number is to be considered a minimum quantity.

Note: Although the intended primary application of this standard is stated in its scope, it is important to note that it remains the responsibility of the users of the standard to judge its suitability for their particular purpose.

Level of Harmonization

This standard is published as an identical standard for ANCE, CSA Group and UL.

An identical standard is a standard that is exactly the same in technical content except for national differences resulting from conflicts in codes and governmental regulations. Presentation is word for word except for editorial changes.

Reasons for Differences From IEC

There is no corresponding IEC standard.

Interpretations

The interpretation by the standards development organization of an identical or equivalent standard is based on the literal text to determine compliance with the standard in accordance with the procedural rules of the standards development organization. If more than one interpretation of the literal text has been identified, a revision is to be proposed as soon as possible to each of the standards development organizations to more accurately reflect the intent.

INTRODUCTION

1 Scope

1.1 Requirements contained in this Standard cover controls of the light-sensitive or presence-sensitive types, or both; for indoor or outdoor service; intended for the control of indoor or outdoor loads up to a maximum of 20 A and maximum 347 V; intended for installations on 50 Hz or 60 HZ systems or DC up to 60 V (for US); and DC up to 42.4 V (for Canada); and intended to be installed in accordance with the National Electrical Code (NEC), NFPA 70, the Canadian Electrical Code (CE Code) Part I, CSA C22.2 No. 0, and NOM 001 SEDE.

1.2 These requirements do not cover controls intended to be used under the following conditions:

a) Devices that are locking type, used for area or roadway lighting fixtures;

b) Devices that monitor or control safety critical loads or personal protection circuits;

c) Devices intended to be installed in areas designated hazardous locations;

d) Devices intended to be installed for manufacturing process control.

2 General

2.1 Components

2.1.1 A component of a product covered by this standard shall comply with the requirements for that component. A component shall be used in accordance with its rating established for the intended conditions of use.

2.1.2 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.

2.1.3 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.

2.2 Units of measurement

2.2.1 Values stated without parentheses are the requirement. Values in parentheses are explanatory or approximate information. SI (metric) units shall be normative, except for trade sizes.

2.3 Undated references

2.3.1 For undated references to Standards, such reference shall be considered to refer to the latest edition and all revisions to that edition up to the time when this Standard was approved.

2.4 Normative references

2.4.1 Products covered by this Standard shall comply with the referenced installation codes and standards noted in this Clause.

CSA Group Standards

Note: For products intended for use in Canada, general requirements are given in CSA-C22.2 No. 0

C22.1-15
Canadian Electrical Code (CE Code), Part I

CSA C22.2 No. 0
General requirements – Canadian Electrical Code, Part II

CSA 22.2 No. 0.2
Insulation Coordination

CSA 22.2 No. 0.17
Evaluation of Properties of Polymeric Materials

CSA 22.2 No. 42
General Use Receptacles, Attachment Plugs, and Similar Wiring Devices

CSA C22.2-111
General-Use Snap Switches

CSA 18.1
Metallic Outlet Boxes

CSA 66.1
Low Voltage Transformers – Part 1: General Requirements

CSA 66.3
Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers

CSA 223
Power Supplies With Extra-Low-Voltage Class 2 Outputs

UL Standards

UL 498
Attachment Plugs and Receptacles

UL 60730-1
Automatic Electrical Controls for Household and Similar Use, Part 1: General Requirements

UL 1414
Capacitors and Suppressors for Radio- and Television-Type Appliances

UL 1310
Class 2 Power Units

UL 61810-1
Electromechanical Elementary Relays – Part 1: General Requirements

UL 157
Gaskets and Seals

UL 20
General-Use Snap Switches

UL 508
Industrial Control Equipment

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

UL 5085-3
Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers

UL 5085-1
Low Voltage Transformers – Part 1: General Requirements

UL 514A
Metallic Outlet Boxes

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

UL 746A
Polymeric Materials – Short Term Property Evaluations

UL 746C
Polymeric Materials – Use in Electrical Equipment Evaluations

UL 796
Printed-Wiring Boards

UL 244A
Solid-State Controls for Appliances

UL 1472
Solid-State Dimming Controls

UL 1449
Surge Protective Devices

ANCE Standards

ANCE NMX-J-005

ANCE NMX-J-023/1

ANCE NMX-J-412

2.5 Definitions

2.5.1 **Enclosure**– The part of the device that:

a) Renders inaccessible all or any parts of the device that may present a risk of electric shock; and

b) Retards propagation of fire initiated from within the device

2.5.2 **Outlet-box device**– A device intended to be installed in an electrical box, with or without a cover plate.

2.5.3 **Snap-on cover** – A cover that is held in place by friction-fit and not requiring the use of a tool for removal.

2.6 Suitability for control of loads

2.6.1 A device suitable for control of receptacles shall have a rating equivalent to the rating (amps, hp) of the receptacle(s) it is intended to control.

2.6.2 A device intended for pilot duty loads shall be tested for the specific load and so marked.

2.7 Grounding/Bonding Conductor

– a conductor that is defined in the National Electrical Code (NEC) as an Equipment Grounding Conductor, and a conductor that is defined in the Canadian Electrical Code (CE Code), Part I, as a Bonding Conductor.

CONSTRUCTION

3 Enclosures

3.1 General

3.1.1 The enclosure of a unit shall be strong and rigid so as to resist the abuses likely to be encountered in the operation of the unit. The degree of resistance inherent in the unit shall preclude total or partial collapse with the attendant reduction of spacings, loosening or displacement of parts, and other serious defects which alone or in combination may increase the risk of fire, electric shock, or injury to persons.

3.1.2 Devices rated for outdoor use or wet locations shall comply with the Rain Test, Clause 27.

3.2 Metal Enclosures

3.2.1 A cast-metal enclosure shall be at least 3.2 mm (1/8 in) thick at every point, more than 3.2 mm (1/8 in) thick at reinforcing ribs and door edges, and not less than 6.4 mm (1/4 in) thick at tapped holes for conduit.

3.2.2 Other than at plain or threaded conduit holes, die-cast metal may be:

a) Not less than 2.4 mm (3/32 in) thick for an area greater than 155 cm^2 (24 in^2) or having any dimensions more than 152 mm (6 in); and

b) Not less than 1.6 mm (1/16 in) thick for an area of 155 cm^2 (24 in^2) or less and having no dimensions more than 152 mm (6 in). The area limitation may be obtained by the provision of reinforcing ribs subdividing a larger area.

3.2.3 The cast-metal enclosure described in 3.2.1 or an enclosure of sheet metal having the construction indicated in Table 3.1 or Table 3.2 will generally be considered to have an acceptable level of the factors indicated in Clause 3, Enclosures.

Table 3.1
Minimum thickness of sheet metal for enclosures – carbon steel or stainless steel

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]				Minimum thickness			
Maximum width[b]		Maximum length of supported edge[c]		Maximum width[b]		Maximum length		Thickness Uncoated		Minimum thickness metal coated	
cm	(inches)	cm	(inches)	cm	(inches)	cm	(inches)	cm	(inches)	cm	(inches)
10.2	(4.0)	Not limited		15.9	(6.25)	Not limited					
12.1	(4.75)	14.6	(5.75)	17.1	(6.75)	21.0	(8.25)	0.51	(0.020[d])	0.58	(0.023[d])
15.2	(6.0)	Not limited		24.1	(9.5)	Not limited					
17.8	(7.0)	22.2	(8.75)	25.4	(10.0)	31.8	(12.5)	0.66	(0.026[d])	0.74	(0.029[d])
20.3	(8.0)	Not limited		30.5	(12.0)	Not limited					
22.9	(9.0)	29.2	(11.5)	33.3	(13.0)	40.6	(16.0)	0.81	(0.032)	0.86	(0.034)
31.8	(12.5)	Not limited		49.5	(19.5)	Not limited					
35.6	(14.0)	45.7	(18.0)	53.3	(21.0)	63.5	(25.0)	1.07	(0.042)	1.14	(0.045)
45.7	(18.0)	Not limited		68.6	(27.0)	Not limited					
50.8	(20.0)	63.5	(25.0)	73.7	(29.0)	91.4	(36.0)	1.35	(0.053)	1.42	(0.056)
55.9	(22.0)	Not Limited		83.8	(33.0)	Not Limited					
63.5	(25.0)	78.7	(31.0)	88.9	(35.0)	109.2	(43.0)	1.52	(0.060)	1.60	(0.063)
63.5	(25.0)	Not Limited		99.1	(39.0)	Not Limited					
73.7	(29.0)	91.4	(36.0)	104.1	(41.0)	129.5	(51.0)	1.70	(0.067)	1.78	(0.070)
83.8	(33.0)	Not Limited		129.5	(51.0)	Not Limited					
96.5	(38.0)	119.4	(47.0)	137.2	(54.0)	167.6	(66.0)	2.03	(0.080)	2.13	(0.084)
106.7	(42.0)	Not Limited		162.6	(64.0)	Not Limited					
119.4	(47.0)	149.9	(59.0)	172.7	(68.0)	213.4	(84.0)	2.36	(0.093)	2.46	(0.097)
132.1	(52.0)	Not Limited		203.2	(80.0)	Not Limited					
152.4	(60.0)	188.0	(74.0)	213.4	(84.0)	261.6	(103.0)	2.74	(0.108)	2.82	(0.111)
160.0	(63.0)	Not Limited		246.4	(97.0)	Not Limited					
185.4	(73.0)	228.6	(90.0)	261.6	(103.0)	322.6	(127.0)	0.123	(0.123)	3.20	(0.126)

[a] See 3.2.5 for description of supporting frame and method for accomplishing equivalent reinforcing.

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

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

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

Table 3.2
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			
cm	(inches)	cm	(inches)	cm	(inches)	cm	(inches)	mm	(inch)
7.6	(3.0)	Not limited		17.8	(7.0)	Not limited			
8.9	(3.5)	10.2	(4.0)	21.6	(8.5)	24.1	(9.5)	0.58	(0.023[d])
10.2	(4.0)	Not limited		25.4	(10.0)	Not limited			
12.7	(5.0)	15.2	(6.0)	26.7	(10.5)	34.3	(13.5)	0.74	(0.029)
15.2	(6.0)	Not limited		35.6	(14.0)	Not limited			
16.5	(6.5)	20.3	(8.0)	38.1	(15.0)	45.7	(18.0)	0.91	(0.036)
20.3	(8.0)	Not limited		48.3	(19.0)	Not limited			
24.1	(9.5)	29.2	(11.5)	53.3	(21.0)	63.5	(25.0)	1.14	(0.045)
30.5	(12.0)	Not limited		71.1	(28.0)	Not limited			
35.6	(14.0)	40.6	(16.0)	76.2	(30.0)	94.0	(37.0)	1.47	(0.058)
45.7	(18.0)	Not limited		106.7	(42.0)	Not limited			
50.8	(20.0)	63.5	(25.0)	114.3	(45.0)	139.7	(55.0)	1.91	(0.075)
63.5	(25.0)	Not limited		152.4	(60.0)	Not limited			
73.7	(29.0)	91.4	(36.0)	162.6	(64.0)	198.1	(78.0)	2.41	(0.095)
94.0	(37.0)	Not limited		221.0	(87.0)	Not limited			
106.7	(42.0)	134.6	(53.0)	236.2	(93.0)	289.6	(114.0)	3.10	(0.122)
132.1	(52.0)	Not limited		312.4	(123.0)	Not limited			
152.4	(60.0)	188.0	(74.0)	330.2	(130.0)	406.4	(160.0)	3.89	(0.153)

[a] See 3.2.5 for description of supporting frame and method for accomplishing equivalent reinforcing.

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

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

[d] Sheet copper, brass, or aluminum for an enclosure intended for outdoor use – raintight or rainproof – shall not be less than 0.74 mm (0.029 inch) thick.

3.2.4 Table 3.1 and Table 3.2 are based on a uniform deflection of the enclosure surface for any given load concentrated at the center of the surface regardless of metal thickness.

3.2.5 With reference to Table 3.1 and Table 3.2, a supporting frame is a structure of angle or channel or folded rigid section of sheet metal that is rigidly attached to and has essentially the same outside dimensions as the enclosure surface and that has sufficient torsional rigidity to resist the bending moments that may be applied by the enclosure surface when it is deflected. Construction that is considered to have equivalent reinforcing may be accomplished by designs that will produce a structure that is as rigid as one built with a frame of angles or channels. Construction considered to be without supporting frame includes:

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

b) A single sheet that is corrugated or ribbed;

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

d) An enclosure surface having an unsupported edge.

3.3 Polymeric enclosure

3.3.1 A polymeric (non-metallic) enclosure shall comply with the requirements of Clause 15, Polymeric Materials.

3.4 Snap-on covers

3.4.1 Snap-on covers shall not permit access to live parts as described in 4.7. When snap on covers are required for compliance with other sections of this standard, they shall be evaluated to the Snap-On Cover Test, Clause 39.

3.4.2 The enclosure shall have provision for the connection of a wiring system suitable for the application.

4 Accessibility of Uninsulated Live Parts

4.1 Construction shall be such that uninsulated live parts that may involve a risk of electric shock shall not be accessible to contact by user under conditions of normal use including use as described in 4.7.

4.2 A live part is considered to involve a risk of electric shock unless it is in one of the following circuits:

a) A circuit supplied by one or more isolated secondary windings of a transformer or equivalent power supply in which the maximum possible open circuit voltage at the transformer is less than:

1) 30 V (42.4 V peak) where wet contact is not likely to occur; and

2) 15 V (21.2 V peak) where wet contact is likely to occur

b) A circuit derived from a source other than that described in (a) in which the available current is limited to 0.5 mA, regardless of supply polarity. The current shall be measured between accessible points and from these points to earth ground through a 1500-Ω resistor. If circuit impedance is used to limit the current, the circuitry shall comply with the requirements specified in 4.3 and 4.4.

c) A dry-cell battery having output characteristics not greater than those of an energy-limiting Class 2 transformer or power source;

d) A combination of a rechargeable battery and a fixed impedance that complies with all of the performance requirements for an energy-limiting Class 2 transformer or power source; or

e) Terminals or conductors intended to extend in the building wiring that are part of a Class 2 circuit and comply with Class 2 power supply requirements.

4.3 Class 2 transformers shall comply with performance and marking requirements in the Standard for Low Voltage Transformers: General Requirements, UL 5085-1/CSA 66.1; and the Standard for Low Voltage Transformers: Class 2 Transformers, UL 5085-3/CSA 66.3. Class 2 power units shall comply with performance and marking requirements in the Standard for Class 2 Power Units, UL 1310 and CSA 223.

4.4 Power supply circuits having accessible live parts shall comply with 4.3. Power supply circuits having accessible live parts complying with the tests of Clause 33, Power Supply Abnormal Tests, shall be considered to comply with the performance requirements of 4.3.

4.5 The circuit impedance described in 4.2 (b) shall be provided by two independent means. Either independent means shall limit the available leakage current to less than 0.5 mA.

4.6 With respect to 4.3, the following components can be used for the application:

a) Metal film, carbon film, wire wound, and metal glazed resistors;

b) Metallized polyester film capacitors;

c) Antenna-coupling capacitors, and line-by-pass capacitors that comply with the Standard for Capacitors and Suppressors for Radio- and Television-Type Appliances, UL 1414; and

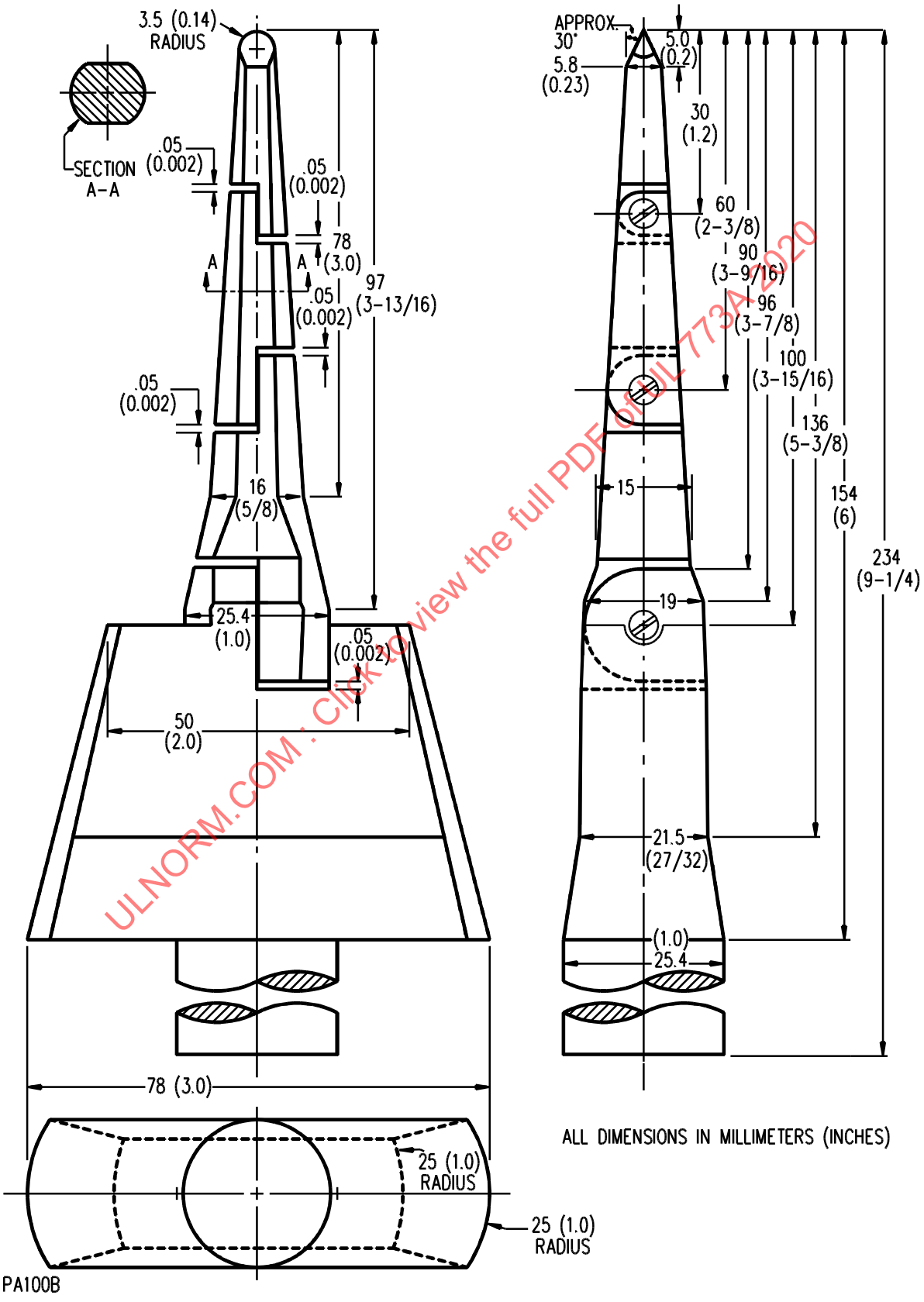
d) Other components, if investigated and found acceptable for the application.

4.7 For supplies of circuits of the types specified in 4.2 (b), the minimum spacings shall be in accordance with Spacings, Clause 12, or Alternate Spacings – Clearances and Creepage Distances, Clause 13.

4.8 The probe illustrated in Figure 4.1, when inserted through an opening in an enclosure, guard, or operator accessible barrier, shall not touch any uninsulated live part that involves a risk of electric shock. See 4.9. The probe shall be rotated with the movable sections straight or in any possible position resulting from bending one or more sections in the same direction. The maximum force applied to the probe shall not exceed approximately 10 N.

Figure 4.1

Articulate probe with web stop



4.9 If any part of the enclosure must be opened or removed as part of energized set-up, normal operation, regular adjustment, or regular or required maintenance (set point adjustment, timer or time of day clock adjustment, battery replacement, or similar maintenance) with or without the use of tools, or can be opened or removed without the use of tools, the accessibility probe shall be applied without the part in place. The maximum force applied to the probe shall be 20 N (4.5 lb).

4.10 If a marking or an operating instruction refers a user to a hole or opening in an enclosure through which a tool is to be inserted for adjustment or a similar purpose, it shall not be possible to contact an uninsulated live part through the hole or opening with a 1.6-mm (1/16-inch) diameter rod. Maximum force shall not be greater than 10 N.

5 Openings in Enclosure

5.1 Openings in an enclosure shall not have any dimensions large enough to permit the entrance of a 25.4 mm (1 in) diameter rod, and shall comply with 5.2 – 5.6. The maximum force applied to the probe shall be 20 N (4.5 lb).

5.2 An opening shall not be provided in a compartment or part of an enclosure intended for field-wiring connections in a line-voltage circuit.

5.3 Openings in the mounting surface shall be limited to the following:

a) A mounting opening that complies with Provision for Mounting, Clause 6.

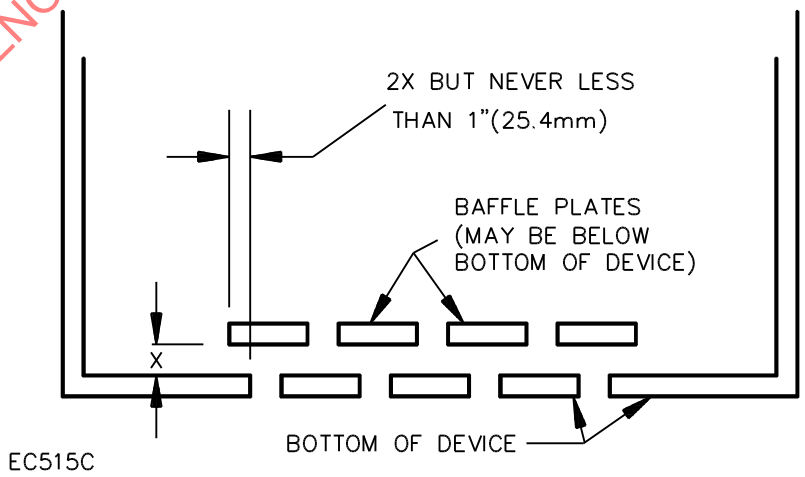
b) A maximum of four openings provided for the escape of air or paint during a painting process. The maximum dimension of such an opening shall not exceed 3.2 mm (1/8 in).

c) A maximum of four unused holes provided for mounting of internal components. The maximum dimension of such an opening shall not exceed 4.8 mm (3/16 in).

5.4 An opening may be provided in the bottom surface of an enclosure if the opening does not permit materials to fall directly out from the interior of the unit. Figure 5.1 illustrates a construction that meets this requirement.

Figure 5.1

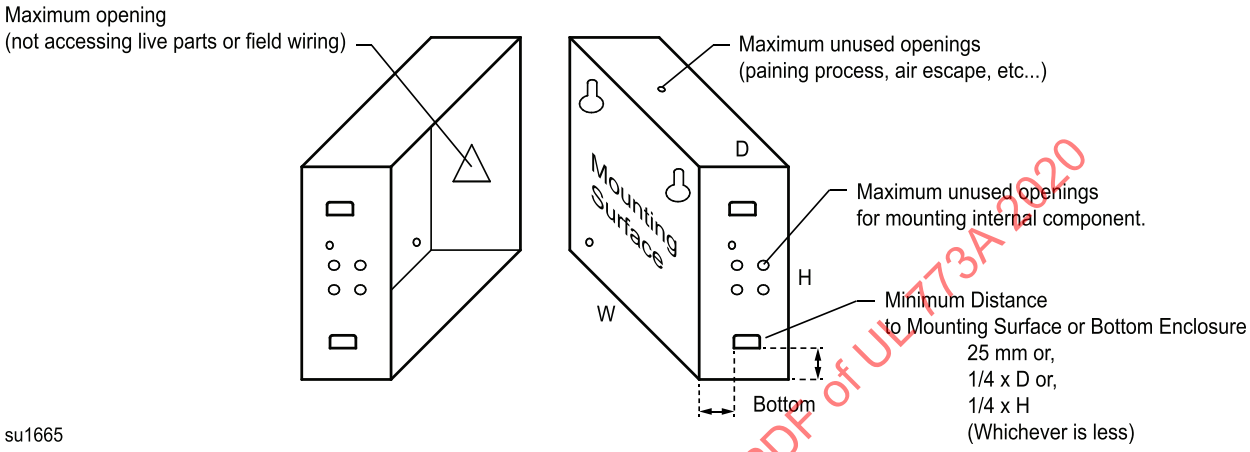
Bottom surface opening of an enclosure



5.5 The shortest distance between an opening and the bottom of an enclosure or a wall-mounting surface shall be at least one-quarter of the enclosure height or depth, respectively, or 25.4 mm (1 in), whichever is less – see Figure 5.2.

Figure 5.2

Examples of Shortest Distances from Enclosure Openings



5.6 There shall be no emission of flame or molten material through an opening, or manifestation of risk of fire, during normal tests or during abnormal tests, such as transformer burnout.

5.7 Knockouts

If a knockout is provided, it shall comply with Table 5.1 and Clause 36, Knockout Test.

Table 5.1
Knockout diameters and width of flat surface surrounding knockouts

Trade size of conduit (metric designator)		Minimum width of flat surface surrounding knockout, mm (in)		Knockout diameters, mm (in)					
				Minimum		Nominal		Maximum	
1/2	(16)	3.38	(0.133)	21.84[a]	(0.860)	22.23	(0.875)	22.61	(0.890)
3/4	(21)	3.68	(0.145)	27.79[b]	(1.094)	28.17	(1.109)	28.96	(1.140)
1	(27)	4.72	(0.186)	34.52	(1.359)	34.93	(1.375)	35.71	(1.406)
1-1/4	(35)	6.45	(0.254)	43.66	(1.719)	44.04	(1.734)	44.83	(1.765)
1-1/2	(41)	7.80	(0.307)	49.73	(1.958)	50.39	(1.984)	51.20	(2.016)
2	(53)	8.97	(0.353)	61.80	(2.433)	62.71	(2.469)	63.50	(2.500)

[a] In Canada, a reduced diameter of 21.46 mm (0.8 in) on a multiple knockout shall be allowed.

[b] In Canada, a reduced diameter of 27.05 mm (1.065 in) on a multiple knockout shall be allowed.

6 Provision for Mounting

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

6.2 Bolts, screws, or other parts used for assembling the unit shall be independent of those used for securing component parts of the unit to the frame, base, or panel.

6.3 There shall be no more than four holes for mounting.

6.4 A cord-connected unit shall not include means for permanent mounting. One or two keyhole slots for wall hanging may be provided if the hanging screws, nails, and similar means, are not accessible for tightening, and if long nails, hooks, or screws for hanging will not be likely to touch internal wiring, the operating mechanism, or live parts and will not result in spacings less than those required in 12.1. Blind key hole slots are considered suitable to fulfill this requirement.

7 Protection Against Corrosion

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

7.2 Thermal elements, magnet pole faces, and hardened and polished parts such as latching surfaces, and similar parts where such protection is impractical need not be protected.

7.3 The metal enclosure of an indoor switch need not be protected.

7.4 Phosphate treatment with an oil or wax coating is acceptable as corrosion protection for magnets and armatures; oil treatment is acceptable as corrosion protection for steel springs; and stainless steel is acceptable without additional protection, if polished or treated.

7.5 All surfaces of a raintight metal enclosure, and all attached metal parts of such an enclosure, shall be protected against corrosion by one of the coatings described in 7.6 and 7.7, unless the metal is inherently resistant to corrosion. Metals used in combinations shall be galvanically compatible.

7.6 A sheet steel enclosure shall be protected against corrosion as specified in (a) – (d).

a) Hot-dipped mill-galvanized sheet steel conforming with the coating Designation G90 in the Weight (Mass) of Coating Requirements table in the Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process, ASTM A653/A653M, with not less than 40 percent of the zinc on any side, based on the minimum single spot test requirement in this ASTM specification. The weight of the zinc coating may be determined by any method; however, in case of question the weight of coating shall be established in accordance with the Standard Test Method for Weight [Mass] of Iron or Steel Articles with Zinc or Zinc-Alloy Coatings, ASTM A90.

b) A zinc coating, other than that provided on hot-dipped mill-galvanized sheet steel, uniformly applied to an average thickness of not less than 0.015 mm (0.00061 in) on each surface with a minimum thickness of 0.014 mm (0.00054 in). An annealed coating shall comply with 7.7.

c) A zinc coating conforming with (1) or (2) and with one coat of an organic finish of the epoxy or alkyd-resin type or other outdoor paint on both surfaces after forming. The acceptability of the paint may be determined by consideration of its composition or by corrosion tests if these are considered necessary.

1) Hot-dipped mill-galvanized sheet steel conforming with the coating Designation G60 or A60 in the Weight (Mass) of Coating Requirements table in the Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process, ASTM A653/A653M, with not less than 40 percent of the zinc on any side, based on the minimum single spot test requirement in this ASTM specification. The weight

of zinc coating may be determined by the method; however, in case of question the weight of coating shall be established in accordance with the Standard Test Method for Weight [Mass] of Coating on Iron or Steel Articles with Zinc or Zinc-Alloy Coatings, ASTM A90.

2) A zinc coating, other than that provided on hot-dipped mill galvanized sheet steel, uniformly applied to an average thickness of not less than 0.010 mm (0.00041 in) on each surface with a minimum thickness of 0.009 mm (0.00034 in).

d) Other finishes, including paints, metallic finishes, or combinations of the two may be accepted when comparative tests with galvanized sheet steel – without annealing, wiping or other surface treatment – conforming with (a), indicate they provide equivalent protection. Among the factors that are taken into consideration when judging the acceptability of such coating systems are exposure to salt spray, moist carbon-dioxide/sulphur-dioxide/air mixtures, moist hydrogen-sulphide/air mixtures, ultraviolet light, and water.

7.7 An annealed zinc coating that is bent or similarly formed after annealing and that is not otherwise required to be painted shall be painted in the bent or formed area if the bending or forming process damages the zinc coating, except that such areas on the inside surface of an enclosure that are not exposed to water during the rain test need not be painted. The zinc coating is considered to be damaged if flaking or cracking of the zinc coating at the outside radius of the bent or formed section is visible at 25 power magnification. Simple sheared or cut edges and punched holes are not considered to be formed.

8 Supply Connections

8.1 Permanently connected units

8.1.1 Leads, except for bare bonding/grounding leads, shall have insulation of a type rated for the purpose and have following minimum characteristics:

a) Minimum free length of a lead shall be 100 mm (4 in).

b) Field connections shall be copper.

c) Ampacity of the lead be in accordance with Table 8.1.

d) Leads for Class 2 shall not be less than 22 AWG.

e) Insulation except for bare ground lead.

f) Insulation

Where leads are to be run through a strain relief, hub, nipple, tubing or conduit, insulation shall be suitable for raceway installation.

g) Lead color

Green coloring, with or without one or more yellow stripes shall be used only for bonding/grounding conductors. White or gray shall be used only for grounded (identified) conductors). Colors other than indicated above may be used for conductors other than grounding and grounded.

h) Solder shall not be relied upon to be the only means of securement for leads.

Table 8.1
Minimum size of leads

Lead rating (A)	Leads	
	AWG	(mm^2)
0 – 6	18	(0.82)
6.1 – 10	16	(1.3)
10.1 – 15	14	(2.1)
15.1 – 20	12	(3.3)

8.1.2 Lead sizes smaller than the ones shown in Table 8.1 are permitted if in compliance with the Temperature Test in Clause 22 and marking requirements in Table 42.1, item 26, but shall not be smaller than 18 AWG.

8.1.3 For a unit provided with field-wiring terminals, a field-wiring terminal shall be rated for the application. The terminal shall be rated for connection of a conductor as follows:

a) A terminal intended to conduct 12 A or less shall be rated for connection of a 14 AWG (2.1 mm^2) minimum supply conductor; and

b) A terminal intended to conduct more than 12 A and up to 20 A shall be rated for connection of a 12 AWG (3.3 mm^2) minimum supply conductor.

8.1.4 A terminal connector shall be prevented from moving so as to strain factory connections or reduce spacings to unacceptable values. Friction alone is not acceptable to prevent such movement.

8.1.5 Terminal parts by which connections are made shall maintain connections even under hard usage. For 8 AWG (8.4 mm^2) and larger wires, pressure wire connectors shall be used. For 10 AWG (5.3 mm^2) and smaller wires, the parts to which the wiring connections are made may consist of clamps or binding screws with terminal plates having upturned lugs or the equivalent to hold the wires in position.

8.1.6 A wiring terminal shall be prevented from turning.

8.1.7 A wire-binding screw to which field-wiring connections are made shall not be smaller than No. 8 (4.2 diameter) except that a No. 6 (3.5 mm diameter) screw may be used for a terminal to which only 14 AWG (2.1 mm^2) wire would be connected.

8.1.8 A terminal plate tapped for a wire-binding screw shall be of metal not less than 1.27 mm (0.050 in) thick and shall have not less than two full threads in the metal. A plate less than 1.27 mm (0.050 in) but not less than 0.76 mm (0.030 in) thick may be acceptable if the tapped threads have appropriate mechanical strength.

8.1.9 A terminal plate formed from stock having the minimum required thickness, as specified in 8.1.8, may have the metal extruded at the tapped hole for the binding screw so as to provide two full threads.

8.1.10 A wire-binding screw shall thread into metal.

8.1.11 If threads for the connection of conduit are tapped all the way through a hole in an enclosure wall, or if an equivalent construction is used, there shall be no less than three threads in the metal, and the construction of the unit shall be such that a conduit bushing can be attached as intended.

8.1.12 Unplated iron or steel shall not be used for wire-binding screws and terminals. Stainless steel, or steel that is protected against corrosion by zinc plating or the equivalent coating may be used, if the steel parts are not depended upon to carry current.

8.1.13 A Non Industrial Photoelectric switch employing field wiring terminals shall be provided with the manufacturers recommended terminal tightening torque. These instructions shall appear on the device where visible during installation, on the smallest unit container, or on an information sheet packed in the smallest unit container in accordance with Table 42.1 Ref. 4a.

8.2 Outlet-box-mounted units

8.2.1 In addition to the requirements in 8.1.1 – 8.1.12, an outlet-box-mounted unit shall comply with 8.2.2 – 8.2.5.

8.2.2 Wiring terminals and other live parts and sharp-edged grounded or dead metal parts of a unit intended for mounting on an outlet box or similar enclosure shall be located or protected so that they will not be forced against wiring in the box during installation.

8.2.3 With reference to 8.2.2, back wiring terminals may be employed if they are recessed or are protected by close-fitting barriers of insulating material or the equivalent so that contact with wiring installed in the box will not occur.

8.2.4 Terminals that do not project into a box beyond the plane of the front edge of the box are acceptable.

8.2.5 With reference to 8.2.3, guards provided alongside terminals and extending at least 6.4 mm (1/4 in) beyond the terminals before wiring, with a corresponding guard between double-pole switching mechanisms, are acceptable.

8.3 Cord-connected or direct plug-in units

8.3.1 A cord-connected unit shall be provided with a multi-conductor flexible cord or cable. The cord or cable shall:

a) Be sized in accordance with Table 8.3 corresponding to the electrical rating of the equipment but shall not be smaller than 18 AWG (0.82 mm^2). Higher ampacities shall not be used unless the cord and product assembly has been tested and complies with Clause 22, Temperature Test. Temperature measurements of the cord, and adjacent components shall be monitored to demonstrate that they do not exceed their thermal ratings.

b) If the unit is intended for indoor use only, the cord or cable shall be rated "Not Hard" usage with an overall insulation thickness of 1.14 mm (0.45 in) or greater (such as Type SPT-2 cord), or "Hard usage" or "Extra hard usage" and shall be rated for the conditions of use.

c) If the unit is intended for outdoor use, the cord or cable shall be rated for "Hard usage" or "Extra hard usage" and for the conditions of use. The outdoor-use cord or cable shall be marked in accordance with Table 42.1, ref 27.

d) Be provided with strain-relief that complies with 35.1.

Table 8.3
Sizing of flexible supply cords and cables

Wire size, AWG (mm^2)	Three conductor cord[a], amp	Two conductor cord[b], amp
18 (0.82)	0 – 7	0 – 10
16 (1.3)	10	13
14 (2.1)	15	18
12 (3.3)	20	25

[a] Maximum current for supply cords with 3 current carrying conductors.

[b] Maximum current for supply cords with 2 current carrying conductors.

8.3.2 An attachment plug for a cord-connected or direct plug-in unit shall be a 3-wire, bonding/grounding type or a 2-wire, polarized type and shall comply with the Standard for Attachment Plugs and Receptacles, UL 498, CSA C22.2 No. 42, or NMX-J-412-ANCE. The ampere rating of the attachment plug shall not be less than 125 % of the ampere rating of the unit.

8.4 Receptacles Incorporated in Equipment

8.4.1 A receptacle shall comply with the Standard for Attachment Plugs and Receptacles, UL 498, CSA C22.2 No. 42, and NMX-J-412.

8.4.2 The bonding/grounding contact of the receptacle shall be electrically connected to dead metal that will be grounded when the unit is in use.

8.4.3 The face of a receptacle shall:

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

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

8.4.4 A receptacle provided onto portable equipment shall have the same voltage and current rating as the attachment plug.

8.4.5 A bonding/grounding type receptacle shall only be permitted if the attachment plug is of the bonding/grounding type.

8.4.6 A receptacle of the 5-15R configuration shall be permitted if the attachment plug is of the 5-20P configuration.

8.4.7 A receptacle of the 1-15R configuration shall be permitted if the attachment plug is of the 1-15P, 5-15P or 5-20P configurations.

8.5 Direct Plug-in

8.5.1 Outlets on direct plug-in devices shall comply with the requirements in 8.4.

8.5.2 The moment, center of gravity, and dimensions of a direct plug-in unit, see Figure 8.1, shall comply with each of the following:

a) The quotient of WY/Z shall not exceed 1.36 kg (48 oz);

b) The quotient of WY/S shall not exceed 1.36 kg (48 oz);

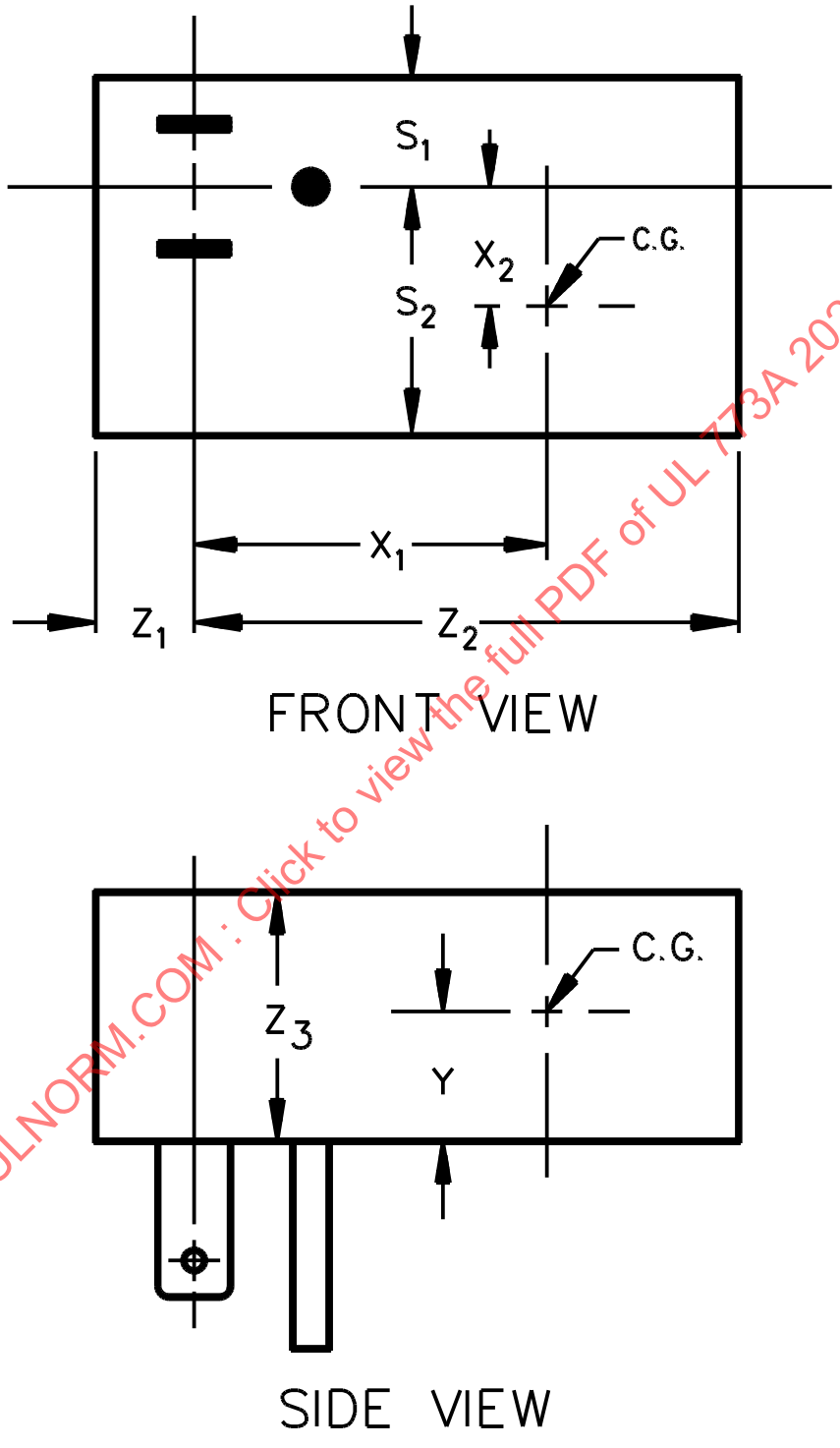
c) The product of WX shall not exceed 0.56 N·m (80 oz-in);

d) The dimension Z3 shall not exceed 82.6 mm (3-1/4 in); and

e) The dimensions S_1, S_2, Z_1, and Z_2 shall not exceed 127 mm (5 in).

Figure 8.1

Plug-in limits of dimensions



C.G. = Center of Gravity

8.5.3 Definitions for the symbols used in 8.5.2 are as follows:

a) W is the weight of the unit in kg (oz);

b) Y is in mm (inches);

c) Z is the smaller of Z_1 or Z_2 in mm (inches);

d) S is the smaller of S_1 or S_2 in mm (inches); and

e) X is the larger of X_1 or X_2 in mm (inches).

8.6 Strain relief

8.6.1 Strain relief shall be provided so that mechanical stress on a flexible supply cord will not be transmitted to terminals, splices, or interior wiring.

8.6.2 A strain-relief device shall be subjected to the test described in Clause 35, Strain Relief and Lead Securement Tests.

8.6.3 A surface, against which a knot in a flexible cord that serves as strain relief may bear or which a flexible cord may contact, shall be free from projections, sharp edges, burrs, fins, and similar formations, that may abrade the insulation on conductors.

8.7 Bushings

8.7.1 Where a flexible cord passes or is intended to pass through an opening in a wall, barrier, or enclosing case, there shall be a substantial bushing or the equivalent that is reliably secured in place, and has a smoothly rounded surface against which the cord may bear. An insulating bushing shall be provided for a cord lighter than Type SJ that passes through a wall or barrier of metal if the construction is such that the cord may be subjected to stress or motion.

8.7.2 A cord hole with a smoothly rounded surface through wood, porcelain, phenolic composition, or other acceptable nonconductive material, is considered to be the equivalent of a bushing.

8.7.3 A soft-rubber bushing shall not be less than 1.2 mm (3/64 in) thick and shall be located so that it will not be exposed to oil, grease, oily vapor, or other substance having a deleterious effect on rubber. A hole in metal in which a soft-rubber bushing is employed shall be free from sharp edges, burrs, projections, and similar formations that may cut into the rubber.

8.7.4 Insulating material in an insulated metal grommet employed in lieu of an insulating bushing shall not be less than 0.8 mm (1/32 in) thick and shall completely fill the space between the grommet and the metal in which it is mounted.

9 Bonding/Grounding

9.1 There shall be provision for bonding/grounding all dead metal parts that are exposed or that are likely to be touched by a person during normal operation or adjustment and that are likely to become energized through electrical malfunction.

9.2 To determine whether a part is likely to become energized, such factors as construction, the proximity of wiring, a dielectric voltage-withstand test conducted after the appropriate overload, endurance, and burnout tests shall be evaluated.

9.3 With respect to 9.1, a means for connection to an equipment bonding/grounding conductor for a permanently connected unit shall be provided by an uninsulated copper wire, an insulated wire (see 8.1.1), or a bonding/grounding terminal. A bonding/grounding terminal may be a wire-binding screw if the construction complies with 8.1.6 – 8.1.12. For a 3-wire cord-connected unit, equipment bonding/grounding shall be provided by the equipment bonding/grounding conductor in the flexible cord, and the bonding/grounding pin of a bonding/grounding attachment plug.

9.4 A terminal intended for the connection of an equipment bonding/grounding conductor shall be identified by:

a) Use of a wire-binding screw with a green-colored head that is hexagonal or slotted, or both;

b) Use of a threaded stud with a green-colored hexagonal nut;

c) Use of a green-colored pressure terminal connector;

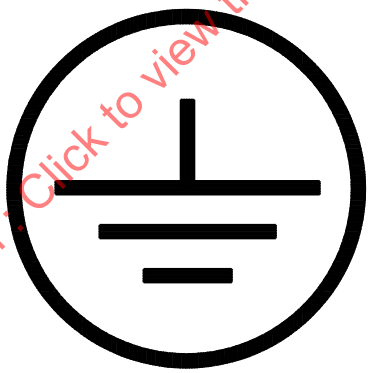
d) Being marked "G," "GR," "GND," "Ground," "Grounding," or the like;

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

f) The bonding/grounding symbol shown in Figure 9.1 (IEC Publication 417, Symbol No. 5019) on or adjacent to the terminal or on a wiring diagram provided on the product.

Figure 9.1

Grounding symbol



IEC417, Symbol 5019

9.5 The bonding/grounding terminal shall be provided with upturned lugs, a cupped washer, or the equivalent capable of retaining a 14 AWG (2.1 mm^2) or larger solid conductor, based on the product's rating, even though the screw or nut may become slightly loose.

9.6 A flush-type unit intended for mounting in a flush-device box shall be so constructed that a metal faceplate will be bonded to ground when installed in the intended manner.

9.7 Bonding/Grounding lead requirements

9.7.1 The size of a bonding/grounding lead shall be:

a) In accordance with Table 8.1 but not less than the size of the supply or load conductor; or

b) Of a size in compliance with the tests in 30.2.

9.8 Bonding/Grounding lead securement

9.8.1 A bonding/grounding lead smaller than 18 AWG (0.824 mm^2) shall comply with the test in 30.2.

10 Current-Carrying Parts

10.1 Current-carrying parts shall have appropriate mechanical strength and ampacity for the intended use and shall be of metal that has been investigated and found acceptable for the application.

10.2 Uninsulated live parts shall be prevented from turning or shifting in position by methods other than friction between surfaces if such motion may result in reduction of spacings to less than as indicated in 12.1. A properly applied lock washer may be acceptable.

10.3 The security of contact assemblies shall be such that the alignment of contacts will be maintained.

11 Internal Wiring

11.1 Internal wiring shall consist of general use wire, or appliance wiring material that has been investigated and found acceptable for the application, when considered with respect to the temperature, voltage, and conditions of service to which the wiring is likely to be subjected.

11.2 Internal wiring shall be supported or routed so that contact with moving parts or parts having sharp edges or burrs, that may cause abrasion of conductor insulation, will not be likely.

11.3 A bare conductor, including leads and coil leads, shall be supported so that the spacings specified in 12.1 will be maintained.

11.4 All joints and connections shall be mechanically secure and shall provide positive contact without strain on connections and terminals.

11.5 A splice shall be provided with insulation equivalent to the voltage of the circuits for the wires involved.

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

11.7 With reference to 11.6, a wire-binding screw or a pressure wire connector used as a terminating device shall be acceptable for use with aluminum under the conditions involved – for example, temperature, heat cycling, vibration, and similar conditions.

12 Spacings

12.1 Spacings between any uninsulated live part and an uninsulated live part of opposite polarity or an accessible or grounded dead metal part other than the enclosure, shall be not less than 1.6 mm (1/16 in) for 0 – 300V, and 3.2 mm (1/8 in) for 301 – 600V, through air and over surface. Spacing between any uninsulated live parts and the enclosure shall be not less than 6.4 mm (1/4 in) through air and over surface.

12.2 Insulating material used in lieu of the required spacing through air shall be of a type that has been investigated and found to be acceptable for sole support of live parts and shall not be less than 0.71 mm (0.028 in) thick.

12.3 Insulating material not less than 0.13 mm (0.005 in) and of appropriate mechanical strength for the application is acceptable in heater-bimetal constructions if:

a) The insulating material is not subjected to temperatures greater than its established temperature limit under all conditions of operation; and

b) The insulating material withstands the Dielectric Voltage-Withstand Test, Clause 23.

13 Alternate Spacings – Clearances and Creepage Distances

13.1 As an alternative to the requirements in Spacings, Clause 12, the following shall be applied:

a) Class 2 Isolated transformer output: no spacing requirements are needed.

b) Alternate spacings based on the Standard for UL 840/CSA 22.2 No. 0.2 Insulation coordination. See 13.2.

c) Alternate Spacings based Limited power point determination (15W or 50W) see 13.4.

d) Abnormal PWB trace faults. See 13.5.

13.2 The spacing requirements in Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840/CSA 22.2 No. 0.2, shall not be used for spacings between field wiring terminals, or between uninsulated live parts and a metal enclosure.

13.3 The spacing requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840/CSA 22.2 No. 0.2 shall be amended as follows:

Surge protective devices or systems rated above 120V nominal are permitted to have Maximum Continuous Operating Voltage (MCOV) equal to or greater than the line-to-neutral voltage.

13.4 Limited power point determination

13.4.1 Spacings within a portion of a circuit or within the entire circuit, less than the specified values required in Clause 12, Spacings, are allowed when the tests of 13.3, as applicable, are completed with compliant results.

13.4.2 The device shall be tested under the following conditions:

a) Supplied by rated branch circuit protection at the rated voltage and frequency;

b) Metal parts are connected to ground through a ground arc indicating fuse;

c) On a soft wood surface covered with white tissue paper;

d) By a single layer of cheesecloth;

e) Adjusted to all possible operation settings; and

f) If a user replaceable fuse in the device opens during the test, the fuse shall be shorted so that it cannot open and the test repeated.

13.4.3 The maximum permitted wattage under normal operation shall be determined to be less than either (a) or (b):

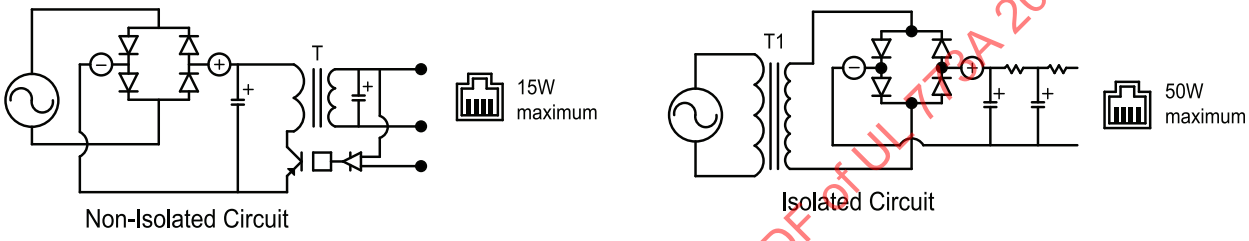
a) 15W – Circuits supplied from non- isolated sources.

b) 50W – Circuits supplied from Isolated sources.

Note: Isolation is determined by dielectrics and examination of the circuit. Transformers with bridging components are not considered to be isolating unless the components are evaluated for the purpose such as opto-isolators or capacitors with reinforced isolation.

Figure 13.1

Examples of typical non-isolated and isolated circuits



su1666

13.4.4 The location where the limited wattage begins shall be determined using the method below.

a) Starting at the input to the circuit, the maximum wattage available to the limited circuit under consideration shall be measured by connecting a variable resistive load between the load side point of each component in line with the source and the supply return. The variable resistance shall be adjusted, beginning with a maximum resistance, down to a short circuit to determine if the component will maintain no greater than the required maximum watts (15W or 50W) as measured by a wattmeter. Each component capable of maintaining the required watts or higher for a period of 5 seconds shall be identified as a critical primary circuit component.

b) Components relied upon to maintain the required impedance shall provide the required spacings, in accordance with Clause 12, across the terminals, and have reliable and suitable electrical stress factor as follows:

1) The stress factor shall be no greater than 0.5 during all conditions of normal operation; or

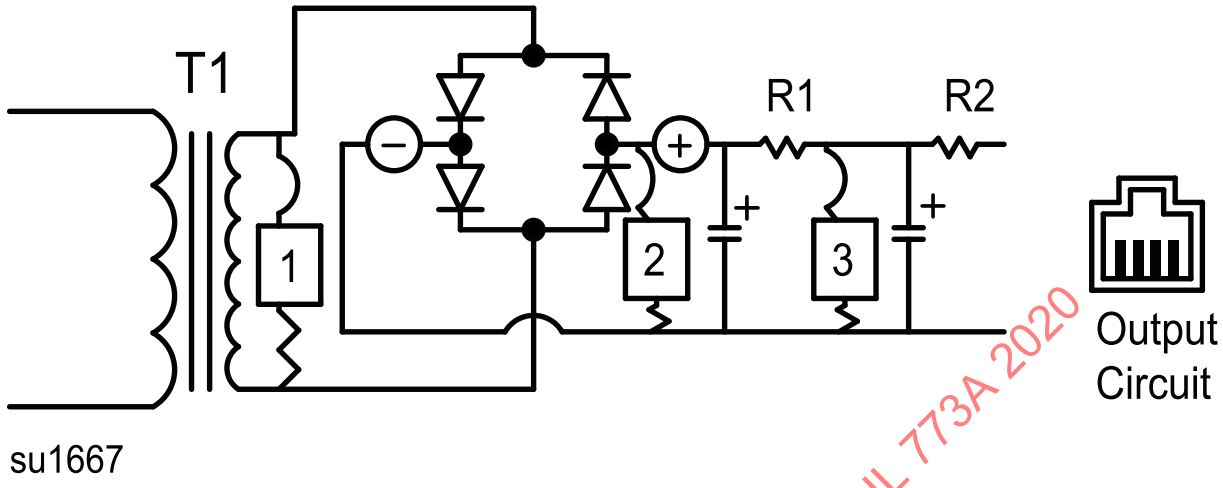
2) The stress factor shall not be greater than 1.0 after single component failure with respect to rated voltage, current and dissipated wattage.

3) The component shall under no condition change in value to the extent that the specified power limit is exceeded.

Note: The electrical stress factor is defined as ratio of applied electrical characteristic to rated electrical characteristic (applied current to rated amps).

Figure 13.2

Illustration for determining component stress



13.4.5 Switch mode power supplies – The location where the limited wattage begins shall be determined using the method below.

a) Starting at the output capacitor, the maximum wattage available to the limited circuit under consideration shall be measured by connecting a variable resistive load between the positive and negative supply (across the capacitor) and adjusted as quickly as possible. If necessary, it is further adjusted after 1 minute to maintain the applicable overload. No further adjustments are permitted.

b) If no overcurrent protection or foldback is provided, the maximum overload is the maximum VA obtainable.

c) In the case of voltage foldback, as in a switching power supply, the overload shall be slowly increased to the point that causes the output voltage to collapse (greatly reduce towards zero). The overload shall then occur at the point where the output voltage recovers, and shall be held for the duration of the test (minimum of 1 hour or until constant results or temperature is reached).

13.4.6 With the circuit in the most onerous condition, user accessible surfaces, output circuits shall not experience a risk of shock including the following:

a) Linear power supplies are shorted at the load side of the limiting component.

b) Switch mode power supply output is connected to an external adjustable resistor and set to obtain the worst case downstream impedance.

13.4.7 Compliance criteria shall be the following:

a) The ground arc indicating fuse of 3 A or less shall not open.

b) Any accessible circuit shall not exceed 30 V rms, or leakage current greater than 0.5 mA, after 5 seconds.

13.4.8 With the circuit in the shorted condition, the device shall not present a risk of fire and there shall not be ignition of the tissue paper, wood, or cheesecloth.

13.4.9 There shall not be dielectric breakdown in accordance with Dielectric Voltage-Withstand Test, Clause 23.

13.4.10 With the circuit in the shorted condition, the device shall not open the branch circuit protection.

13.5 Printed-wiring board abnormal operation test

13.5.1 To determine whether spacings at specific points on printed-wiring boards are required to comply with the spacings requirements, each point of the printed-wiring board so identified shall be tested as described in 13.5.2 – 13.5.5 with adjacent printed circuit paths short-circuited one at a time until the operation of an integral protective device, the opening of a component as described in 13.5.2, or until thermal conditions have stabilized, up to a maximum of 7 hours.

13.5.2 Operation of an overcurrent protection device, other than the branch circuit overcurrent protection device, before any abnormal condition results is acceptable. When a wire or a printed wiring board trace opens, the gap shall be electrically shorted and the test continued. This applies to each occurrence. When the circuit is interrupted by the opening of a component, the test shall be repeated twice, using new components as necessary.

13.5.3 A sample of the device employing the printed-wiring board shall be wired as intended to an electrical supply circuit sized and protected to simulate end-use conditions.

13.5.4 A 3 Amp fuse shall be connected between device dead metal parts and the ground path ground.

13.5.5 The device shall be placed on a white-tissue-paper covered softwood surface.

13.5.6 Compliance with the test shall be verified as follows:

a) The overcurrent protection in the branch circuit to which the device is connected shall not open;

b) The cheesecloth or tissue paper shall not glow or flame; and

c) The 3 A fuse connected in the device bonding/grounding circuit shall not open.

13.6 When applying specific requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, NMX-J-597/1-ANCE, or CSA C22.2 No. 0.2, it is anticipated that the degrees of pollution expected or controlled will be as indicated in Table 13.1.

Table 13.1
Degrees of pollution

Pollution degree	Equipment Examples
1	Hermetically sealed or encapsulated equipment or printed wiring boards with protective coating.[a]
2	Equipment for ordinary locations and indoor use, such as residential controls, commercial controls for use in a clean environment, controls for installation on or in appliances.
3	Equipment for outdoor use, and equipment influenced by surrounding environment.
4	Equipment open to the environment.

[a] Tested in accordance with the protective coating test in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840.

13.7 When applying specific requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, it is anticipated that the equipment will be identified by overvoltage categories as indicated in Table 13.2.

Table 13.2
Overvoltage categories

Equipment	Overvoltage category
Permanently wired	III
Plug connected	II
Isolated power-limited such as Class 1 and Class 2	I

13.8 In order to evaluate clearances where the levels of overvoltage are controlled, control of overvoltage shall be achieved by providing an overvoltage device or system as an integral part of the product. The equipment shall be evaluated for the rated impulse withstand voltage specified in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840.

13.9 Printed-wiring boards constructed of Types XXXP, XXXPC, G-10, FR-2, FR-3, FR-4, or FR-5 industrial laminates in accordance with the Standard for Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used in Printed Wiring Boards, UL 746E, are considered to have a minimum comparative tracking index of 100 without further investigation.

13.10 Printed wiring boards that comply with the requirements for direct support of live parts in the Standard for Printed-Wiring Boards, UL 796, are considered to have a minimum comparative tracking index of 100 without additional investigation.

13.11 Printed-wiring boards constructed of Types CEM-1, CEM-3, GPO-2, or GPO-3 industrial laminates in accordance with the Standard for Polymeric Materials – Industrial Laminates, Filament Wound Tubing, Vulcanized Fibre, and Materials Used in Printed Wiring Boards, UL 746E, are considered to have a minimum comparative tracking index of 175 without additional investigation.

14 Bonding of Internal Parts for Bonding/Grounding

14.1 General

14.1.1 An exposed noncurrent-carrying metal part that is likely to become energized through electrical fault on equipment required to be grounded – see 14.1.5 – shall be reliably bonded to the point of connection of the field-equipment bonding/grounding means.

14.1.2 A metal part, such as an adhesive-attached metal-foil marking, a screw, or a handle need not comply with this requirement if it is:

a) Located on the outside of an enclosure or cabinet and isolated from electrical components and wiring by grounded metal parts so that it is not likely to become energized; or

b) Separated from wiring and spaced from uninsulated live parts as if it were a grounded part.

14.1.3 A small internal assembly screw, or other small fastener, such as a rivet, or a magnet or armature of a relay need not be bonded.

14.1.4 A metal panel or cover need not be bonded if it:

a) Is insulated from electrical components and wiring by an insulating barrier of vulcanized fiber, varnished cloth, phenolic composition, or other moisture-resistant material not less than 0.8 mm (1/32 in) thick and reliably secured in place;

b) Does not enclose uninsulated live parts, and wiring is positively separated from the panel or cover so that it is not likely to become energized; or

c) Is isolated from live parts and wiring by grounded or bonded interposing metal so that the interposing metal would be subject to an electrical fault before the isolated metal part panel or cover.

14.1.5 To determine whether a part is likely to become energized, such factors as construction, the proximity of wiring, a dielectric voltage-withstand test after the appropriate overload, and endurance tests shall be evaluated.

14.1.6 A guard, baffle, or cover that can be removed without a tool shall be removed when determining whether a part is exposed to contact by the user.

14.1.7 Circuitry shall be arranged such that an equipment-grounding connection or conductor, an equipment-bonding connection or conductor, an enclosure, a frame, a component mounting panel, or a similar component does not carry current.

14.1.8 A single point reference ground connection for a Class 2 circuit, a Class 3 circuit, or an isolated secondary circuit shall be permitted.

In Canada this requirement applies only to Class 2 Circuits.

14.1.9 Current of a Class 2 circuit, a Class 3 circuit, or a 50-W maximum power isolated secondary circuit through an enclosure, a frame, or a panel including bolted joints, shall be permitted.

14.1.10 Such current shall not be conducted by the field equipment-grounding means, a metallic raceway, or other power-supply bonding/grounding means.

14.1.11 A current not exceeding 0.5 mA conducted through an equipment-grounding or the equipment-bonding conductor or connection shall be permitted and marked in accordance with item 25 in Table 42.1. The maximum available current along the equipment-grounding or equipment-bonding conductors or connection shall be verified and measured in accordance with 31.5 – 31.10 as described for leakage current, except S2 described in 31.9, need not be switched to the second position for this measurement. Switch S2 shall be maintained in the normal power setting for normal operation for this measurement.

14.1.12 Uninsulated metal parts such as cabinets, electrical enclosures and covers, controller mounting frames and brackets, transformer cores, and other electrical components, shall be electrically bonded together if they may be contacted by a user or service person. See 14.1.13.

14.1.13 A part on the back side of a component mounting panel and a part located so as to require major disassembly by using tools are not considered to be exposed to the user; such parts are not considered to be exposed to a service person unless it is likely that servicing will be performed while the equipment is energized after disassembly.

14.1.14 Uninsulated live parts and wiring shall be held away from moving parts, such as relay and contactor magnets and armatures, by clamping, routing, or equivalent means that will provide permanent separation.

14.1.15 A flush-type unit intended for mounting in a flush-device box shall be provided with a means for bonding/grounding a metallic faceplate to ground when the unit is installed in the intended manner. The bonding/grounding means shall be provided whether or not a metallic faceplate is provided with the unit.

14.2 Construction and connection

14.2.1 Parts shall be bonded by metal-to-metal contact or by a separate bonding/grounding jumper in accordance with 14.2.2 – 14.2.9.

14.2.2 A bonding/grounding conductor shall be copper, a copper alloy, or other material acceptable for use as an electrical conductor. A ferrous metal part in a bonding/grounding path shall be protected against corrosion by enameling, galvanizing, plating, or other equivalent means.

14.2.3 A bonding/grounding conductor may be a bare or insulated wire, printed wiring foil, a clamp, a strap, or the like, and shall be so installed that it is protected from mechanical damage.

14.2.4 A separate bonding/grounding conductor or strap:

a) Shall be protected from mechanical damage or shall be located within an outer enclosure or frame; and

b) Shall not be secured by a removable fastener used for any purpose other than bonding/grounding unless the bonding/grounding conductor is unlikely to be omitted after removal and replacement of the fastener.

14.2.5 The size of a bonding/grounding conductor shall be based on the rating of the overcurrent protective device of the branch circuit to which the unit will be connected in accordance with the National Electrical Code, NFPA 70, NOM-001-SEDE, or Table 16 of the Canadian Electrical Code, Part I. A conductor noted in 14.2.2 of a type other than a wire shall have a cross-sectional conducting area equal to or greater than that of the required wire size.

14.2.6 The bonding/grounding conductor for a component may be reduced to, but not smaller than, the size of the conductors supplying power to the component. However, consideration should be given to the likelihood of energization under normal and abnormal conditions of the dead metal of the component by external wiring in proximity to the component in question.

14.2.7 The bonding/grounding conductor for a dead metal part that is not part of a component (for example, an enclosure or a partial enclosure, or a bracket) need not be larger than the conductors supplying power to components in proximity to or within the part. However, consideration should be given to the likelihood of energization under normal and abnormal conditions of the part by such conductors.

14.2.8 A smaller conductor may be used if the smaller conductor does not open when subjected to the overcurrent test in Bonding/Grounding Connection Tests, Clause 30.

14.2.9 A splice shall not be employed in a wire used for bonding/grounding purposes.

14.2.10 An internal connection for bonding/grounding internal parts to an enclosure for bonding/grounding, but not for a field-installed grounding conductor or for the bonding/grounding wire in a supply cord, may employ a quick-connect terminal provided:

a) The connector is not likely to be displaced;

b) The terminal has the dimensions specified in Table 14.1; and

c) The component is limited to use on a circuit having a branch-circuit protective device as specified in Table 14.1.

Table 14.1
Quick-connect bonding/grounding terminals for internal parts

Nominal size of terminal, mm (in)						Rating of branch-circuit protective device, A
Width		Thickness		Length		
4.7	(0.187)	0.5	(0.020)	6.35	(1/4)	20 or less
4.7	(0.187)	0.8	(0.032)	6.35	(1/4)	20 or less
5.2	(0.205)	0.8	(0.032)	6.35	(1/4)	20 or less
6.4	(0.250)	0.8	(0.032)	7.94	(5/16)	60 or less

14.2.11 A connection for bonding/grounding conductor shall be by a positive means providing reliable metal-to-metal contact, such as by clamping, riveting, a bolted or screwed connection, brazing, or welding. The bonding/grounding connection shall reliably penetrate nonconductive coatings, such as paint, enamel, or varnish. Solder alone shall not be used to maintain a bonding/grounding connection.

14.2.12 A bolted or screwed connection that incorporates a star washer under the screwhead, a serrated screwhead, or the equivalent is acceptable for penetrating nonconductive coatings as specified in 14.2.11. A serrated-edged ring terminal constructed of copper or copper alloy is not considered an acceptable means of penetrating a nonconductive coating.

14.2.13 If the connecting means depends upon screw threads, two or more screws or two full threads of a single screw engaging metal is considered to comply with 14.2.11.

14.2.14 If the adequacy of a bonding/grounding connection cannot be determined by examination, the bonding/grounding connection shall not open, when tested as prescribed in 30.2.1.

14.2.15 If continuity of a bonding/grounding system relies on dimensional integrity of a nonmetallic material, the dimensional stability of the material shall be considered in addition to such factors as mechanical strength, thermal aging characteristics, moisture-absorptive properties, combustibility, and resistance to impact, distortion, arcing, and ignition. The material shall be subjected to the Bonding/Grounding Connection Tests, Clause 30.

15 Polymeric Materials

15.1 Polymeric materials shall comply to the requirements in Table 15.1.

Table 15.1
Polymeric Materials

Installation	Flammability [a]	RTI [c]	UV	CTI [d]
Class 2 [b]	HB or better	50C	g	none
Portable Equipment	V-2	60C – Elec 60C – imp 60C – str	g	CTI of 175 V (PLC 3)
Self-contained permanently wired equipment	5V	80C – Elec 60C – imp 80C – str	g	CTI of 175 V (PLC 3)
Part of the enclosure which is inside the outlet box, or part of an outlet box	HB	80C – Elec 60C – imp 80C – str	g	CTI of 175 V (PLC 3)

Table 15.1 Continued on Next Page

Table 15.1 Continued

Installation	Flammability [a]	RTI [c]	UV	CTI [d]
mounted device that is inside the outlet box				
Part of the enclosure outside the outlet box (with an opening in the cover plate of 335 mm^2 or less)	HB	80C – Elec 60C – imp 80C – str	g	CTI of 175 V (PLC 3)
Part of the enclosure outside the outlet box (with an opening in the cover plate greater than 335 mm^2)	V-2	80C – Elec 60C – imp 80C – str	g	CTI of 175 V (PLC 3)
Barrier used in place of the enclosure behind the coverplate [e, f]	V-2	60C Elec	none	CTI of 175 V (PLC 3)
Barrier used inside the enclosure for insulation [f]	HB	60C Elec	none	CTI of 175 V (PLC 3)
Lens	none	none	h, I	none
Polymeric parts – in direct support of current carrying components	V-2	80C – Elec 60C – imp 80C – str	none	CTI of 175 V (PLC 3)

a) Flammability minimum requirements are based on the materials flammability rating at a reference thickness of 1.6 mm (0.06 in).
b) Class 2 equipment as defined in the National Electrical Code, NFPA 70, NOM-001-SEDE, or Canadian Electrical Code, Part I limited to 42.4 V peak or 60 V DC, or 42.4 V peak or dc as per Canadian Electrical Code, Part I.
c) RTI at higher ratings may be required in a specific application based on the results obtained for the Temperature Test, Clause 22.
d) CTI – Insulating materials used for direct support of live parts (as defined in Clause 4.2) shall have a CTI of 175 V min.(PLC 3).
e) Barrier minimum dimensions shall be minimum barrier dimensions shall be 84.0 mm by 44.5 mm. (3.3 by 1.75 in); and maximum total openings in the barrier shall not exceed 335 mm^2 (0.52 in^2) (excluding openings for metal mounting screws). A metal yoke thickness shall be minimum 1.0 mm (0.039 in).
f) Barriers of electrical grade paper not less than 0.33 mm (0.013 inch) thick or mica not less than 1.65 mm (0.065 inch) thick may be used in conjunction with a through-air spacing of not less than 50 percent of the through-air spacing without additional investigation.
g) UV – Outdoor devices shall have critical enclosure material rated suitable for Ultraviolet exposure, demonstrated by an F1 rating or testing.
h) Lenses that do not provide access to live parts as determined in Clause 4, for indoor or outdoor use, and comply with the Rain Test, Clause 27, with the lens removed, are not required to comply with the UV requirements of the standard.
i) Lenses that provide access to live parts as determined in Clause 4, for outdoor use, shall comply with the UV requirements of the standard.

15.2 As an alternate to flammability ratings indicated above, a polymeric part that complies with either the 12 mm (0.47 in) or 20 mm (0.79 in) the end-product flame test described in the Standard for Polymeric Materials - Use in Electrical Equipment Evaluations, UL 746C and C22.2 No. 0.17, which may be used as a substitute for V-0, V-1, V-2, or HB flammability rating, need not have a flammability class rating. A polymeric part that complies with the 127 mm (5 in) end product flame test described in the Standard for Polymeric Materials - Use in Electrical Equipment Evaluations, UL 746C, and C22.2 No. 0.17, which may be used as a substitute for the 5V flammability rating, need not have a flammability class rating.

15.3 Mold stress testing shall be conducted for polymeric materials with use temperatures of 50°C and greater, when measured during normal temperature testing, see 30.1.

Note: Class 2 devices are not required to complete Mold Stress testing.

15.4 Portable devices shall be tested for resistance to crush according to 37.2.

15.5 Devices shall be tested for resistance to impact according to 37.1.

15.6 The enclosure shall have provision for the connection of a wiring system suitable for the application.

15.7 Parts that can be removed without exposing the user to a risk of shock or fire and not required during environmental testing are not required to be rated for ultraviolet exposure.

16 Coil Windings

16.1 Coil windings of relays shall be such as to resist the absorption of moisture. This may be accomplished by impregnating, dipping, or brushing with varnish, or by other equivalent means.

17 Air-Gap Switches

17.1 Devices that are marked “OFF” shall completely disconnect all ungrounded conductors in the load circuit when in the “OFF” (open) position. Devices that do not disconnect all ungrounded conductors, including devices that incorporate in-line components, such as neon indicators, that pass current through the load when the switch is in the open position, shall not be marked “OFF”.

17.2 The actuating means of an air-gap switch that performs the on/off function shall be readily available to the user, and not depend on the use of tools for operation.

PERFORMANCE

18 General

18.1 Performance shall be investigated by subjecting a representative sample or samples to the applicable tests specified in Clauses 19 – 40.

18.2 Testing is completed at the rated voltage and frequency, unless specifically indicated. When a range is declared such as 50 – 60 Hz, testing shall be completed at the worst case.

18.3 The operating characteristics of any unit shall be determined from analysis of design and the intended operation, prior to subjecting it to the test program.

18.4 Consideration shall be given to such inherent characteristics, of each unit, as effects of varying light levels – dusk and dawn twilight effects for units intended to be operated by sunlight – and speed of the on-off switch function – snap-action or slow-make, slow-break characteristics – of the control unit.

18.5 From the investigation of the inherent operating characteristics of the unit, the maximum operating rate representing the normal operation of the unit, but not exceeding one operation every 10 seconds (6 cycle per minute, 1 second on, 9 seconds off), shall be used for cycling tests – operation, overload, and endurance. The test may be conducted at a faster rate if agreeable to all concerned parties and a minimum on time of 1 second.

18.6 If analysis of design and the intended operation indicates that a cycling rate based on increasing the light level from zero until the normal switching function is complete and then decreasing the light level is more applicable to the operation of the unit than is the 6 cycle of load interruption and restoration per minute rate, then the unit shall be cycled at the rate determined, but the rate shall not to exceed 6 cycle per minute.

18.7 The testing sequence shall be as follows:

a) Overload Test, Clause 20;

b) Endurance Test, Clause 21;

c) Temperature Test, Clause 22; and

d) Dielectric Voltage-Withstand Test, Clause 23.

19 Overload and Endurance Testing – General

19.1 General

19.1.1 For each electrical rating, 3 specimens shall be subjected to the following sequence of tests unless 22.8 applies in which case one specimen shall be used: Overload Test, Clause 20, Endurance Test, Clause 21, Temperature Test, Clause 22 and Dielectric Voltage-Withstand Test, Clause 23. A new set of 3 specimens shall be used for each electrical rating unless indicated otherwise.

19.1.2 The power supply shall deliver an open-circuit voltage not to be less than 100 percent, or more than 110% of maximum rated voltage. The voltage is 60 Hz unless indicated otherwise or DC.

19.1.3 The cycle rate shall be 6 to 10 cycles per minute, unless indicated otherwise, with an on time not less than 1 second. Specimens with a slower cycle rated shall be cycled as quickly as possible. Specially prepared specimens may be used provided the entire power and switching circuit are connected to demonstrate the normal operation.

19.1.4 A unit with grounded metal parts shall be tested with a fuse connected between the metal parts and ground. The fuse shall be 3 A nonrenewable, non time-delay, having a voltage rating not less than the voltage rating of the unit being tested. The ground fuse shall be the only path to ground and includes leads, terminals and all ground connections.

19.1.5 Reactive components of the test load may be paralleled, if of the air-core type, but no reactances shall be connected in parallel with resistances, except that an air-core reactor may be shunted by resistance, the loss in which is approximately 1 % of the total power consumption in that phase, calculated in accordance with the formula:

$$R_{SH} = 100\left(\frac{1}{PF} - PF\right)\frac{E}{I}$$

in which:

R_{SH} is the shunt resistance;

PF is the power factor;

E is the closed-circuit phase voltage; and

I is the phase current.

19.1.6 Circuit characteristics shall be determined using laboratory-type meters. It is not necessary that the device to be tested be in the circuit when making the circuit determination. The test current required shall be the rms symmetrical current value.

19.1.7 An AC General Use rating shall be tested with 6 samples and reference the Standard for General-Use Snap Switches, UL 20/ CSA C22.2 No 111-10 / ANCE NMX-J-005 according to Table 20.1.

19.1.8 Pilot Duty ratings, may be represented by hp rating testing under the following conditions:

a) The hp overload amps are 150% of the required pilot duty inrush current at the same voltage;

b) For Codes A, B, and C, and for devices with ratings not expressed using codes, the pilot-duty inrush current (make) is ten times the steady state current value (break); and

c) For Codes D and E, the pilot-duty inrush current (make) is 6 times the steady state current value (break).

The relationship between horsepower ratings and equivalent control circuit contact ratings is shown in Table 19.1.

Table 19.1
Relationship between hp testing and Pilot duty codes

Switch rating single phase horsepower (hp)	Maximum rating of coil, volt-amperes	Title	Equivalent control circuit contact rating code
1	720	746 W	A150, A300, A600
1/2	360	373 W	B150, B300, B600
1/8	180	93 W	C150, C300
1/10	72	75 W	D150, D300

19.2 Air-gap switch used in series with solid state switching devices

19.2.1 Three as-received samples shall be tested at rated load for 100 cycles with a short circuit across the control circuitry (power semiconductor) so that the air-gap switch contacts control the load directly.

19.2.2 As a result of the test, there shall not be electrical or mechanical breakdown of the device, undue burning or pitting of the contacts, or welding of the contacts.

20 Overload Test

20.1 Samples shall withstand 50 cycles, unless indicated otherwise, of the overload condition make and break indicated, according to load, in Table 20.1. Separate samples may be used for testing different types of loads.

20.2 For Pilot duty ratings, the required load shall be measured at the rated voltage. Without re-adjusting the load, the voltage shall then be increased to the value in Table 21.3 or Table 21.4. The duration of the inrush (make) amps shall be at least 2 cycles at 50 or 60 Hz (40 ms to 33 ms).

Note: For Mexico the system frequency is 60 Hz.

20.3 For a motor load identified as “hp” horse power or “W” watts, the test values in Table 21.2 shall be used. A motor load not tested with the FLA or LRA values indicated in Table 21.2, shall not be marked “hp” or “W” watts and shall indicate the specific LRA and FLA test values.

20.4 For General Use ratings, one overload test of 100 cycles is completed followed by the endurance tests indicated in Endurance Test, Clause 21.

20.5 Compliance shall be determined at the end of the overload cycles by the following:

a) No electrical or mechanical breakdown of the specimen.

b) The ground arc indicating fuse shall not be open.

c) No welding of the contacts. Sticking of the contacts, which self-clears before the next operation of the switch, shall not be considered to diminish the usefulness and reliability of the switch.

Table 20.1
Methods for determining currents for overload / endurance tests by types of loads

	Load Type	Overload (a)	Endurance (a, b)	Marking example
1	AC Tungsten-filament Lamps	Amp = 1.5 x rated PF = 0.75 – 0.8 (or) Load = Tungsten lamp	Amp = 1.0 x rated Load = Tungsten lamp	“Incand”, “Incandescent” ”Tung”, “Tungsten”; “Inc”
2	AC Electric-Discharge Lamp Ballast (Magnetic)	Amp = 3.0 x rated PF = 0.4 – 0.5	Amp = 2.0 x rated PF = 0.4 – 0.5 (a)	“Std Bal”, “Magnetic Ballast”; “Mag Bal” “Standard Ballast” “HID”; “Fluorescent”
3	AC Transformer (Magnetic)	Amp = 3.0 x rated PF = 0.4 – 0.5	Amp = 2.0 x rated PF = 0.4 – 0.5 (a)	“Mag Xfmr”; “MLV”; “Magnetic Low Voltage”; “Magnetic Transformer” “M. BAL.”; “MAG.BAL.”;
4	AC Transformer (Electronic)	Amp = 1.5 x rated Load = Tungsten lamp	Amp = 1.0 x rated Load = Tungsten lamp	“Electronic Low Voltage”; “ELV”
5	AC Externally ballasted Fluorescent and LED Lamps (electronic)	Amp = 1.5 x rated Load = Tungsten lamp	See Table 21.5 below	“Elect Bal”; “e-ballast”; “Electronic Ballast”; “E. BAL.” “EL. BAL.” “EFL”
6	AC Integrally ballasted Fluorescent and LED Lamps	Amp = 1.5 x rated Load = Tungsten lamp	See Table 21.5 below	“Self-ballasted Lamps” “Integral Ballasted Lamp”; “I.BAL”; “INT. BAL”
7	AC Resistance	Amp = 1.5 x rated PF = 0.9 –1.0	Amp = 1.0 x rated PF = 0.9 –1.0	“Res” “Resistance”
8	AC Motor	Amp = 6 x FLA (c) PF = 0.4 – 0.5	Amp = 1.0 x FLA (c) PF = 0.75 – 0.8	"W", “HP”, “FLA”, “LRA”(d); “Motor”
9	Pilot Duty	Volt = 1.1 x Rated Amp = Table x (e) PF = 0 – 0.35	Volt = 1.0 x Rated Amp = Table x (e) PF = 0 – 0.35	Volts, Amperes and the words pilot duty or PD or pilot duty codes
10	AC General Use	See UL 20/CSA C22.2-111/ ANCE NMX-J-005 5.2.10 b) 100 cycles Amp = 4.8 x rated current (15A or 20A)= 72A or 96A PF = 0.4 – 0.5	See UL 20 /CSA C22.2-111/ ANCE NMX-J-005 5.2.10 c), d) and e) -10 000 cycles at rated current (15A or 20A) PF = 0.9 – 1.0 -10 000 cycles at rated current (15A or 20A) PF = 0.75 – 0.8 - 10 000 cycles at rated current (15A or 20A) Load = Tungsten lamp	General Use, suitable to control type of specified load within its amperage rating
11	347 Vac General Use	100 cycles Amp = 22.5A for 15 A or 25A for 20A rated current PF= 0.75 – 0.80	10 000 cycles at rated current (15A or 20A) PF = 0.9 – 1.0 -20 000 cycles at rated current (15A or 20A) PF = 0.75 – 0.8	347 Vac general use

a) Test with the rated voltage unless indicated otherwise.

b) For units intended for operation once a day or by sunlight and having inherent time-delay response, the current may be reduced to rated current for the break portion of the cycle.

c) FLA (Full Load Amperage) of a motor load is the steady state amperage, see Table 21.2.

d) LRA (Locked Rotor Amperage) of a motor load is the peak current created by the rotor not moving, see Table 21.2.

e) Pilot duty ratings other than indicated in the table shall have a make amp ratings 10 times the break amp rating.

21 Endurance Test

21.1 Following the overload test, the samples shall withstand the endurance cycles indicated below unless indicated otherwise, operating the load indicated in Table 20.1:

a) 3650 cycles for units intended for operation only once a day; or

b) 6000 cycles for other types, unless otherwise indicated.

21.2 For pilot duty ratings, the load shall be as described in Table 21.3 or Table 21.4. The duration of the inrush (make) amps shall be at least 2 cycles at 50 or 60 Hz (40 ms to 33 ms).

21.3 For tungsten lamp loads, a tungsten lamp or equivalent simulated (synthetic) load shall be used.

21.4 Tungsten lamp load "on" and "off" times shall be 1 second "on" and 6 – 10 operating cycles per minute. The operating cycle shall be such that the lamps are off for at least 55 seconds of each test cycle. Simulated (Synthetic) loads shall be verified to ensure the operating cycles provide adequate recovery time and provide a reliable inrush.

21.5 Tungsten lamps used as the test load shall be the smallest possible number of lamps having standard ratings. When the load is above 500 W, the largest possible number of 500-W lamps shall be used. A tungsten-filament lamp larger than 500 W shall be permitted.

21.6 Simulated (synthetic) loads shall provide the following minimum characteristics:

a) The inrush current shall be at least ten times the normal current.

b) The current shall not be less than half the required inrush current at 1/60 s (17 ms) and not less than twice the steady-state current at 7/120 s (58 ms) after the circuit is closed. The current in a straight resistance load shall be the full inrush value for a minimum of 15 ms after the circuit is closed.

c) For AC General Use synthetic loads see table below.

Table 21.1
Lamp load

Switch Rating	Overload Inrush		Overload Steady		Endurance inrush		Endurance steady	
	A rms	(A p)	A rms	(A p)	A rms	(A p)	A rms	(A p)
1	19.1	(27.0)	1.50	(2.12)	12.7	(18.0)	1.00	(1.41)
2	36.1	(51.0)	3.00	(4.24)	24.8	(35.0)	2.00	(2.83)
3	50.2	(71.0)	4.50	(6.36)	36.1	(51.0)	3.00	(4.24)
4	64.4	(91.0)	6.00	(8.49)	46.0	(65.0)	4.00	(5.66)
5	78.5	(111.0)	7.50	(10.61)	55.2	(78.0)	5.00	(7.07)
6	91.9	(130.0)	9.00	(12.73)	65.1	(92.0)	6.00	(8.49)
7	104.0	(147.0)	10.50	(14.85)	74.3	(105.0)	7.00	(9.90)
8	115.3	(163.0)	12.00	(16.97)	82.7	(117.0)	8.00	(11.32)
9	125.9	(178.0)	13.50	(19.09)	99.7	(130.0)	9.00	(12.73)
10	135.1	(191.0)	12.50	(17.68)	108.2	(141.0)	10.00	(14.14)

Table 21.1 Continued on Next Page

Table 21.1 Continued

Switch Rating	Overload Inrush		Overload Steady		Endurance inrush		Endurance steady	
	A rms	(A p)	A rms	(A p)	A rms	(A p)	A rms	(A p)
11	127.3	(180.0)	13.75	(19.45)	115.3	(153.0)	11.00	(15.56)
12	135.1	(191.0)	15.00	(21.22)	122.3	(163.0)	12.00	(16.97)
13	142.1	(201.0)	16.25	(22.98)	129.4	(173.0)	13.00	(18.39)
14	149.2	(211.0)	17.50	(24.75)	135.1	(183.0)	14.00	(19.80)
15	152.1	(215.0)	18.75	(26.52)	140.7	(191.0)	15.00	(21.22)
16	159.8	(226.0)	20.00	(28.29)	140.7	(199.0)	16.00	(22.63)
17	162.7	(230.0)	21.25	(30.06)	146.4	(207.0)	17.00	(24.05)
18	169.0	(239.0)	22.50	(31.82)	151.3	(214.0)	18.00	(25.46)
19	171.9	(243.0)	23.75	(33.59)	155.6	(220.0)	19.00	(26.87)
20	174.7	(247.0)	25.00	(35.36)	159.8	(226.0)	20.00	(28.29)

Notes:

1 – All values are minimums.

2 – (peak amps are represented in parentheses) where A(peak) = A(rms) / 1.414

21.7 For a motor load identified as “hp” horse power or “W” watts, the test values in Table 21.2 shall be used. A motor load not tested with the FLA or LRA values indicated in Table 21.2 shall not be marked “hp” or “W” watts, and shall indicate the specific LRA and FLA test values.

21.8 For General Use ratings, the same samples that completed the overload test shall be subjected to the endurance tests consecutively, 30 000 cycles total.

a) 15A or 20A Resistive, PF = 0.9 – 1.0, 10 000 cycles.

b) 15A or 20A Inductive, PF = 0.75 – 0.8, 10 000 cycles.

c) 15A or 20A Tungsten, Load = tungsten lamp, 10 000 cycles.

21.9 Compliance shall be checked at the end of the endurance cycles by the following:

a) No electrical or mechanical breakdown of the specimen.

b) The ground arc indicating fuse shall not be open.

c) No welding of the contacts. Sticking of the contacts, which self-clears before the next operation of the switch, shall not be considered to diminish the usefulness and reliability of the switch.

Table 21.2
Motor currents corresponding to various ac power ratings

AC Power		Locked-rotor motor currents (LRA) for overload test					Full-load motor-running currents (FLA) for endurance test					
		125	250	250	277	480	125	250	250	277	480	480
hp	(W)	Single phase	Single phase	Two phase[a]	Single phase	Two phase[a] or 3 phase	Single phase	Single phase	Single phase	Single phase	Two phase[a]	Three phase
1/10	(75)	18	9.0	–	7.5	–	3.0	1.5	–	1.2	–	–
1/8	(93)	22.8	11.4	–	9.5	–	3.8	1.9	–	1.6	–	–
1/6	(119)	26.4	13.2	–	11.0	–	4.4	2.2	–	1.8	–	–
1/4	(186)	34.8	17.4	–	14.4	–	5.8	2.9	–	2.4	–	–
1/3	(246)	43.2	21.6	–	17.9	–	7.2	3.6	–	3.0	–	–
1/2	(373)	58.8	29.4	20	24.4	10	9.8	4.9	2.2	4.1	1.0	1.1
3/4	(559)	82.8	41.4	25.0	34.4	12.5	13.8	6.9	3.2	5.7	1.2	1.6
1	(746)	96.0	48.0	30	39.8	15	16.0	8.0	4.2	6.6	1.6	2.1
1-1/2	(1.12	120	60	40	49.8	20	20.0	10.0	6.0	8.3	2.3	3.0
2	(1.5)	144	72	50	59.8	25	24.0	12.0	6.8	10.0	3.0	3.4

[a] Two Phase connections are considered to be 4 wire.

Note: Conversion base: 1 hp = 745.66272 W

Table 21.3
Pilot Duty
Standard loads for control-circuit devices

Normal potential	Standard duty codes B & P		Heavy duty codes A & N	
	Normal current	Current inrush	Normal current	Current inrush
110 – 120 Vac [a]	3.0	30	6.0	60
220 – 240 Vac [a]	1.5	15	3.0	30
440 – 480 Vac [a]	0.75	7.5	1.5	15
550 – 600 Vac [a]	0.6	6	1.2	12
115 – 125 Vdc [b]	1.1	–	2.2	–
230 – 250 Vdc [b]	0.55	–	1.1	–
550 – 600 Vdc [b]	0.2	–	0.4	–

[a] Power factor 0.35 or less.

[b] The duration of the inrush (make) amps shall be at least 2 cycles at 50 or 60 Hz (40 ms to 33 ms). For Mexico the system frequency is 60 Hz.

Table 21.4
Pilot Duty
Rating codes for a-c control-circuit contacts at 50 and 60 Hz

Contact rating code designation [a]	Thermal continuous test current amperes	Maximum make or break [b, c] current, amperes								Maximum volt-amperes	
		120 Volt		240 Volt		480 Volt		600 Volt			
		Make	Break	Make	Break	Make	Break	Make	Break	Make	Break
A150	10	60	6	–	–	–	–	–	–	7200	720
A300	10	60	6	30	3	–	–	–	–	7200	720
A600	10	60	6	30	3	15	1.5	12	1.2	7200	720
B150	5	30	3	–	–	–	–	–	–	3600	360
B300	5	30	3	15	1.5	–	–	–	–	3600	360
B600	5	30	3	15	1.5	7.5	0.75	6	0.6	3600	360
C150	2.5	15	1.5	–	–	–	–	–	–	1800	180
C300	2.5	15	1.5	7.5	0.75	–	–	–	–	1800	180
C600	2.5	15	1.5	7.5	0.75	3.75	0.375	3.0	0.3	1800	180
D150	1.0	3.60	0.6	–	–	–	–	–	–	432	72
D300	1.0	3.60	0.6	1.8	0.3	–	–	–	–	432	72
E150	0.5	1.80	0.3	–	–	–	–	–	–	216	36

[a] The numerical suffix designates the maximum voltage design values, which are to be 600, 300, and 150 volts for suffixes 600, 300, and 150, respectively. The test voltage is to be 600, 240, or 120 volts.

[b] For maximum ratings at voltages between the maximum design value and 120 volts, the maximum make and break ratings are to be obtained by dividing the volt-amperes rating by the application voltage. For voltages below 120 volts, the maximum make current is to be the same as for 120 volts, and the maximum break current is to be obtained by dividing the break volt-amperes by the application voltage, but these currents shall not exceed the thermal continuous test current.

[c] Power factor 0.35 or less.

Table 21.5
Electronic ballast

Steady state current (A)	Peak current (A) 120 Vac	Pulse Width 120 Vac (ms) See Note 2	I_2t (A2 sec) 120 Vac See Note 1	Peak current (A) 277 Vac	Pulse Width 277 Vac (ms) See Note 2	I_2t (A2 sec) 277 Vac See Note 1
0.5	75	0.34	11	77	0.50	11
1	107	0.48	24	131	0.71	27
2	144	0.70	41	205	0.85	76
3	166	0.89	51	258	0.98	111
5	192	1.20	74	320	1.20	205
8	221	1.25	98	370	1.25	274
10	230	1.50	106	430	1.50	370
12	235	1.80	110	440	1.80	387
15	239	2.00	114	458	2.00	420
16	242	2.10	117	480	2.10	461

Notes:

1 – The values used to calculate I_2t are the peak current shown in the above table and a pulse duration of 2 ms (t).

2 – Pulse widths are shown in the above table and will provide adequate performance with electronic devices having pulse widths up to 2 ms, in accordance with ANSI C82.11 or ANSI C82.14.
Note: For Mexico the reference ANSI C82.11 or ANSI C82.14 are informative.

21.10 The synthetic load described in 21.11 and 21.12 shall be used as the load for testing. The endurance test shall be completed with that load.

21.11 The series coil values shall be adjusted based on the input line characteristics to achieve the peak currents listed in Table 21.5 , Electronic ballast, and Table 21.6, Controls rated 347 VAC. The series coil shall be sized such that it does not saturate during testing and shall be able to handle the resulting power dissipation with less than 10°C temperature rise. Peak current and pulse width are illustrated in Figure 21.1.

21.12 The circuit shall provide a method to discharge the capacitor bank in between test cycles without influencing the performance of the device under test. This is accomplished by S2 and R2 in Figure 21.2. S2 should be switched alternately with S1 and R2 should be sized to allow for complete discharge of C during the period that S1 is open.

Table 21.6
Controls rated 347 VAC

Steady State Current (A)	Peak Current (A) 347 VAC	Pulse Width 347 VAC (ms)	I_2t (A2 sec) 347 VAC See Note 1
0.5	198	0.34	92
1	270	0.47	173
2	354	0.70	294
3	396	0.86	369
5	450	1.15	476
8	492	1.50	569
10	508	1.67	606
12	529	1.66	658
15	550	2.05	711
16	552	2.10	716

Note 1 – The values used to calculate I_2t are the peak current shown in the table above and pulse duration of 2.35 ms (t).

Figure 21.1

Waveform per synthetic measurement of pulse width and peak current

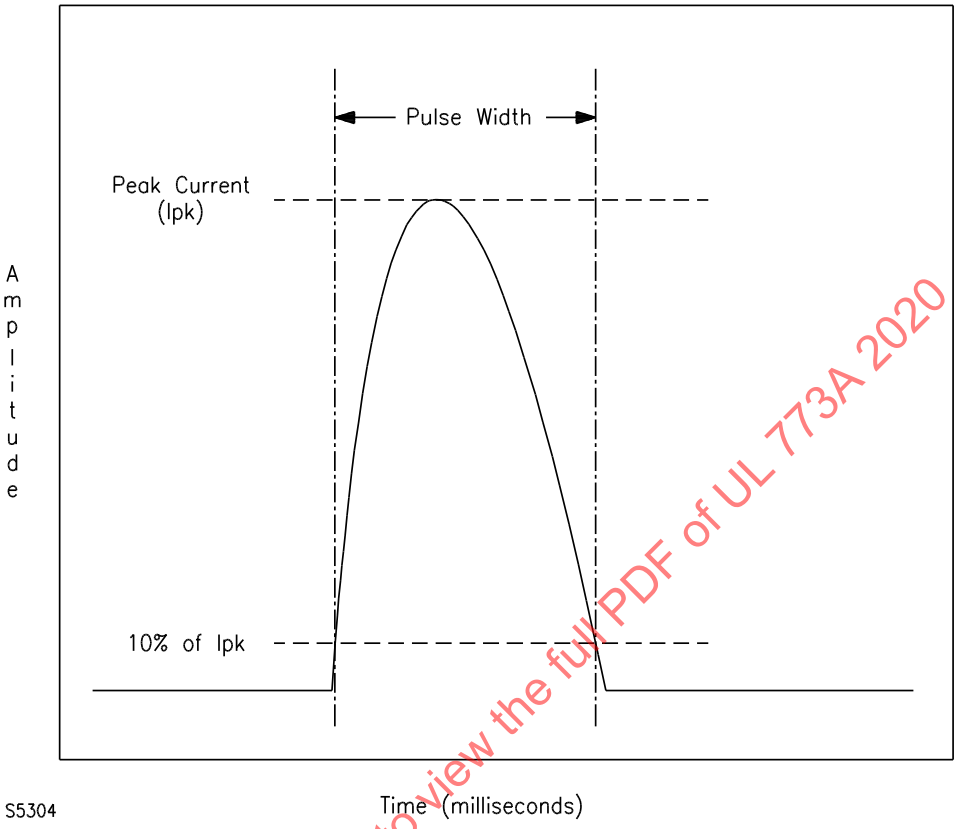
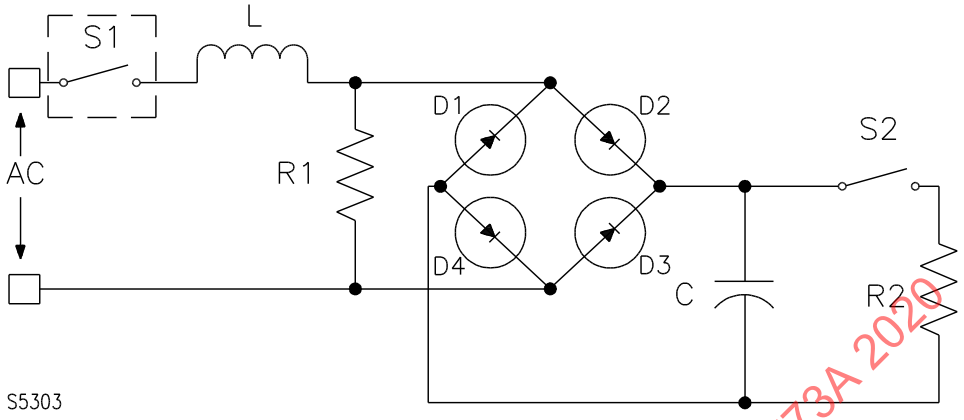


Figure 21.2

Typical test circuit diagram



Reference	Description
AC	Test voltage is either 347 VAC, 277 VAC or 120 VAC
S1	Device Under Test
L	Series Inductor, its value of inductance (L) and resistance (R) are selected. When combined with the AC line source impedance it provides the specified Reference Waveforms
R1	AC synthetic load resistor, value to provide desired continuous current. (e.g., 5A, 8A, . . . 16A)
D1 through D4	Bridge rectifier
C	Capacitor load bank, design value to provide 125 mF for each continuous amp of load current at a test voltage of 347 VAC or 277 VAC, and 175 mF for each continuous amp of load current at a test voltage of 120 VAC.
S2	Capacitor discharge switch
R2	Bleeder resistor, value to provide appropriate capacitor load bank discharge rate

22 Temperature Test

22.1 The devices that have completed the overload and endurance tests shall be subjected to a temperature test. Temperatures measured during the test shall not exceed the temperature limits specified in Table 22.1.

22.2 To determine if the device complies with the temperature test requirements, it shall be operated under normal conditions at its maximum rated current at the specified voltage until temperatures are constant.

22.3 A temperature shall be considered to be constant when three successive readings, taken at 5-minute intervals, indicate no change greater than ± 2°C.

22.4 For devices incorporating photo-sensing detection, the temperature test shall be started in the operating condition with the maximum current (photo-sensing device in saturated condition) in the monitoring circuit and the load "off".

22.5 Specimens for surface mounting, mounted to rigid conduit, or enclosures shall be mounted according to the manufacturers' instructions and in the most unfavorable position permitted.

22.6 Specimens for outlet box mounting shall be mounted according to the manufacturers' instructions and be tested in a metallic box mounted in the test wall according to Figure 22.1. If the device cannot physically fit in a box of 63 mm (2.5 in) depth and 75 mm (3 in) height, it shall be tested in a box identified in the manufacturer's installation instructions.

22.7 Devices shall be tested for single, double (2) and triple (3) gang installation as indicated below.

22.8 Devices incorporating air-gap switches directly controlling the load shall not be required to be tested in multiple gang installation.

22.9 Temperature test set-ups as illustrated in Figure 22.1 shall be constructed with a single-, a double-, and a triple-unit box, as appropriate. The box or boxes shall be centered in the test wall.

22.10 One sample shall be mounted in a single-unit configuration, two samples shall be mounted in a double-unit ganged configuration, and 3 samples shall be mounted in a triple-unit ganged configuration. The devices shall be connected as intended, and shall control a load in accordance with 22.2 and the derating factor provided by the manufacturer. Temperature test set-ups as illustrated in Figure 22.1 shall be constructed with a single-, a double-, and a triple-gang box, as appropriate. The set-up can be modified to use the minimum number of outlet boxes needed to install the devices in each configuration. A device not provided with an integral cover plate shall be mounted with a nonmetallic flush-device cover plate or equivalent in position over the device and marked according to Clause 44 for the required box size.

22.11 The temperature limits specified in Table 22.1 are maximum temperatures. However, tests may be conducted at any ambient temperature within the range of 10 – 40°C (50 – 104°F). If tested at other than 25C (77°F), the measured temperatures shall be normalized to 25°C (77°F).

22.12 Temperatures rated above 40° C (104° F) shall be tested in an oven at the marked rated temperature +/-2 °C or tested at room temperatures and normalized to the rated temperature.

22.13 Temperatures shall be measured by thermocouples consisting of wires not larger than 0.21 mm^2 (24 AWG) and not smaller than 0.05 mm^2 (30 AWG). When thermocouples are used in determining temperatures in electrical equipment, it is common practice to employ thermocouples consisting of 0.05 mm^2 (30 AWG) iron and constantan wire and a potentiometer-type instrument. Such equipment shall be used whenever referee temperature measurements by thermocouples are necessary.

22.14 A thermocouple used for determining the temperature of a coil or winding shall be located on the outer surface of the coil or winding or the coil enclosure.

22.15 A device shall be tested with a minimum of 1.2 m (4 ft) of wire attached to each field-wiring terminal. The wire shall be single solid copper conductor and sized as follows:

a) 14 AWG for 0-15A; or

b) 12 AWG for greater than 15A

22.16 Devices incorporating dimmers intended to control dimmable AC integrally ballasted fluorescent and LED lamps (self-ballasted lamps) shall be tested in accordance with the Standard for Solid State Dimming Controls, UL 1472, NMX-J-374-ANCE, CSA C22.2 No. 184 or CSA C22.2 No. 184.1 and the requirements for wall-box dimmer switch for use with LED lamp with integral driver light source.

Table 22.1
Maximum temperature limits

	Materials and components	°C
1	Fuses	90
2	Fiber employed as electrical insulation	90
3	Materials other than fiber employed as electrical insulation or as a part whose failure would result in a hazardous condition	RTI (Relative Thermal Index)
4	Wood and other combustible material	90
5	Surfaces likely to contact the insulation of field wiring	75 [a,b]
6	A surface upon which a permanently wired unit might be mounted in service and surfaces that might be adjacent to the unit when it is so mounted, including the yoke.	90
7	Class 105 insulation systems	80
	Class 120(E) insulation systems	90
	Class 130(B) insulation systems	100
	Class 155(F) insulation systems	110
	Molded phenolic composition	150[c]
	Rubber or thermoplastic-insulated wires and cords	60[c]
	Surfaces accessible during normal operation	60 [g]
	Semiconductor case	d
	Electrolytic capacitor	65 [e]
	Printed-wiring boards	f
	Solid and build-up contacts, busses and connecting straps	90[h]
	Capacitors	I

[a] Any part of the device or box more than 6.4 mm (1/4 in) behind the mounting yoke shall be considered a part that can be contacted by field wiring unless specific barriers or construction features do not provide room for field wiring to access these areas.

[b] Devices that are intended for use with 75°C (167°F) or greater field wiring shall be allowed to obtain a maximum of 90°C (194°F) where contact with field wiring is possible. See item 26 of Table 42.1 for marking requirements.

[c] The limitations on phenolic composition and on rubber and thermoplastic insulations do not apply to compounds that have been found suitable for higher temperature.

[d] The maximum acceptable temperature of a semiconductor case cannot exceed the manufacturer's rating for the semiconductor.

[e] A capacitor operating at a higher temperature may be accepted on the basis of its marked temperature rating.

[f] Printed-wiring boards shall be used at temperatures equal to or less than their temperature rating.

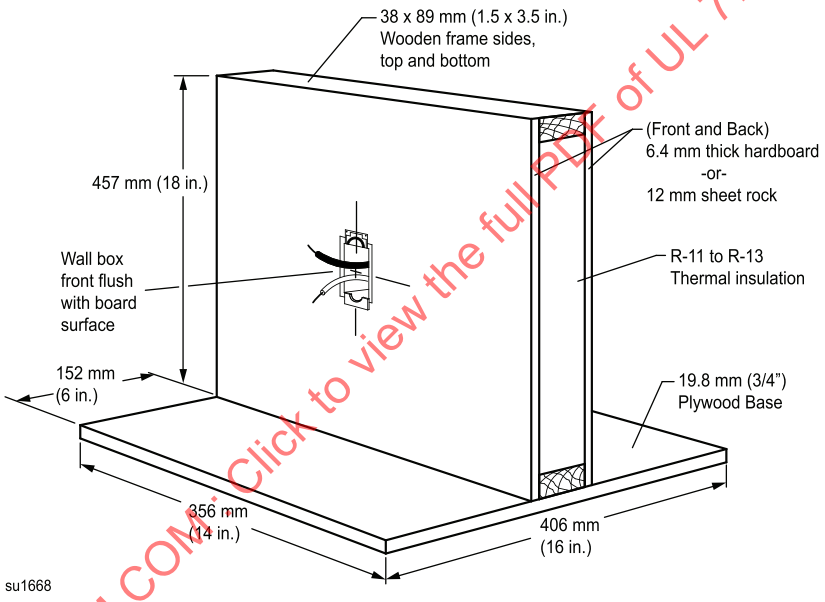
Table 22.1 Continued on Next Page

Table 22.1 Continued

Materials and components	°C
[g] Does not apply to a screw head. A heat sink located behind the plane of the face plate and exposed not more than 19 mm (3/4 inch) shall not exceed 90°C (194°F).	
[h] If contacts of any metal and their supporting blades, busses, and connecting bars attain a temperature greater than 90°C (194°F) where a higher than nominal room ambient temperature or other external temperature prevails, or where affected by a bimetal heater or other heat source in the assembly, the control shall perform acceptably when subjected to overload and endurance tests conducted at the high temperatures involved. *Note: Contacts of silver or a silver alloy that do not attain a temperature higher than 100°C need not be subjected to overload and endurance tests conducted at the higher temperature.*	
[I] For a capacitor the maximum temperature is the marked temperature minus an assumed ambient of 40°C (104°F) unless a higher ambient is declared.	

Figure 22.1

Temperature test setup



1. The dimensions in the figure represent standard building material dimensions and are minimum requirements (i.e. 2 x 4 wood frame is a planed 1.5 x 3.5 in).

2. The insulation shall completely fill the wall cavity.

23 Dielectric Voltage-Withstand Test

23.1 A unit that has been subjected to the tests described in Temperature Test, Clause 22, Operation Test, Clause 24, and Endurance Test, Clause 21, shall withstand for 60 seconds without breakdown the application of a 50 or 60 Hz alternating potential of 1000 V plus twice the maximum rated voltage between:

a) Line-voltage parts and grounded or exposed metal parts or the enclosure with the contacts open and then closed;

b) Line-voltage parts of opposite polarity with the contacts closed;

Note: This test is not required for circuit poles that are intentionally bridged by electronic components, such as transformers or across-the-line capacitors.

c) Live parts of a line-voltage circuit and a Class 2 circuit, a Class 3 circuit, a 50-W maximum power isolated secondary circuit or 15W non-isolated circuit.

d) Live parts of different line-voltage circuits; and

e) Live parts of different secondary circuits.

23.2 Compliance with the requirement in 23.1 shall be determined by means of a 500 VA, or larger capacity, transformer, the output voltage of which can be varied. The output potential shall be essentially sinusoidal and shall be increased from zero to the required test value, and shall be held at that value for 1 minute. The increase in the applied potential shall be at a uniform rate and as rapid as is consistent with its value being correctly indicated by a voltmeter.

24 Operation Test

24.1 A unit shall withstand 110 % of its rated voltage continuously, without damage, and shall operate acceptably at 85 % of its rated voltage, under full-load conditions.

24.2 Compliance with the requirements in 24.1 shall be determined by increasing the supply voltage to the unit to 110 % of its rated voltage. The unit shall be operated in the off mode at the increased voltage until constant temperatures are attained. The unit shall be capable of operating at the increased voltage, after temperatures have stabilized.

24.3 Following operation at increased voltage, the supply voltage to the unit shall be decreased to 100 % of rated voltage and the unit allowed to operate in the off mode until temperatures stabilize. The supply voltage shall then be reduced to 85 % of rated voltage. The unit shall be capable of operating at the reduced voltage.

24.4 With regard to the operation of the unit described in 24.2 and 24.3, consideration shall be given to varying light levels and the speed of the on-off switching function – see 18.3 – 18.5. The unit shall cycle at its normal rate and the light level shall be increased from zero until the mechanism completes its switching function. The operation test shall be conducted in a manner simulating actual service conditions.

25 Abnormal Switching Test

25.1 Unless tested for functional safety, controls incorporating electronic circuitry to trigger the switching device during a more advantageous electrical condition, such as at zero crossing, shall be subjected to this abnormal switching test when the following conditions apply:

a) Loads and circuits are non-safety; and

b) Switching components are used beyond their ratings.

25.2 Two test samples shall be prepared and connected as follows:

a) The trigger circuit of the switching device shall be removed or modified to allow random switching.

b) A ground arc indicating fuse shall be connected to accessible dead metal of the control. The ground arc detection fuse shall be rated not greater than 3 A and not less than the working voltage.

c) The control shall be covered in a single layer of cheesecloth except the mounting surface, and then placed on a softwood surface that has been covered with white tissue paper. The cheesecloth shall be bleached untreated cotton cloth running 26 – 28 m^2/kg (14 – 15 square yards per pound)

and for any square inch a count of 32 threads in one direction and 28 in the other direction (for any square centimeter, 13 threads in one direction and 11 in the other direction).

d) The rated supply shall be connected through a branch circuit protection device sized according to installation requirements, and

e) The control shall be connected to its rated electrical load.

25.3 The prepared test samples shall be operated in accordance with the endurance test requirements specifying the number of operating cycles and on/off periods using random switching. The test samples shall be operated until either the required number of endurance test cycles are achieved or until ultimate results are demonstrated for 1 hour stabilized duration.

25.4 Immediately after each abnormal switching test, each control shall be subjected to the Dielectric Voltage-Withstand Test, Clause 23.

Note: The dielectrics test does not reduce the need to measure the clearance and creepage of a switching device used at a higher voltage rating. The distance between the coil or gate and power live parts are especially critical when the increase in voltage is above 300V.

25.5 The control shall either operate as intended in accordance with the endurance test requirements, or demonstrate an end-of-life fail safe condition with no evidence of an imminent electrical shock, fire or injury to persons. There shall be:

a) No opening of the ground arc detection fuse;

b) No burning of the cheesecloth;

c) No opening of the branch circuit protection device; or

d) No breakdown during the post-dielectric withstand testing.

26 Limited Short-Circuit Test for Solid-State Switching Control

26.1 Six samples of a control in the as-received condition shall be tested in series with a 30 A nonrenewable, non-time delay, cartridge fuse rated for branch circuit overcurrent protection on an alternating-current circuit of rated voltage capable of delivering 1000 A rms when the system is short-circuited at the testing terminals. A load with a 0.98 – 1.00 power-factor shall be used to limit the current. There shall be no ignition of the cotton, the 3 A fuse shall not open, and the terminals or leads of the control shall not be visibly damaged. The control need not be operable after the test.

26.2 Each sample shall be installed in a metal flush-device box mounted in the test fixture illustrated in Figure 22.1, and covered with a metal flush-device cover plate, unless a non-interchangeable cover is provided with the control. A cord-connected control shall be connected to the supply circuit through a 600 mm length of the largest gauge flexible cord that the device will accept. The enclosure and any other exposed dead metal shall be connected to ground through a 3 A nonrenewable, non-time delay, cartridge fuse rated for branch circuit overcurrent protection. Cotton shall be draped over the entire exposed surface of the control after installation in the test fixture. The short circuit shall connect the control output to the opposite polarity conductor of the supply circuit.

26.3 The first set of three samples shall have the short-circuit open at the start of the test. The test shall be conducted by closing the short-circuit on the control. The second set of three samples shall have the short circuit closed at the start of the test.

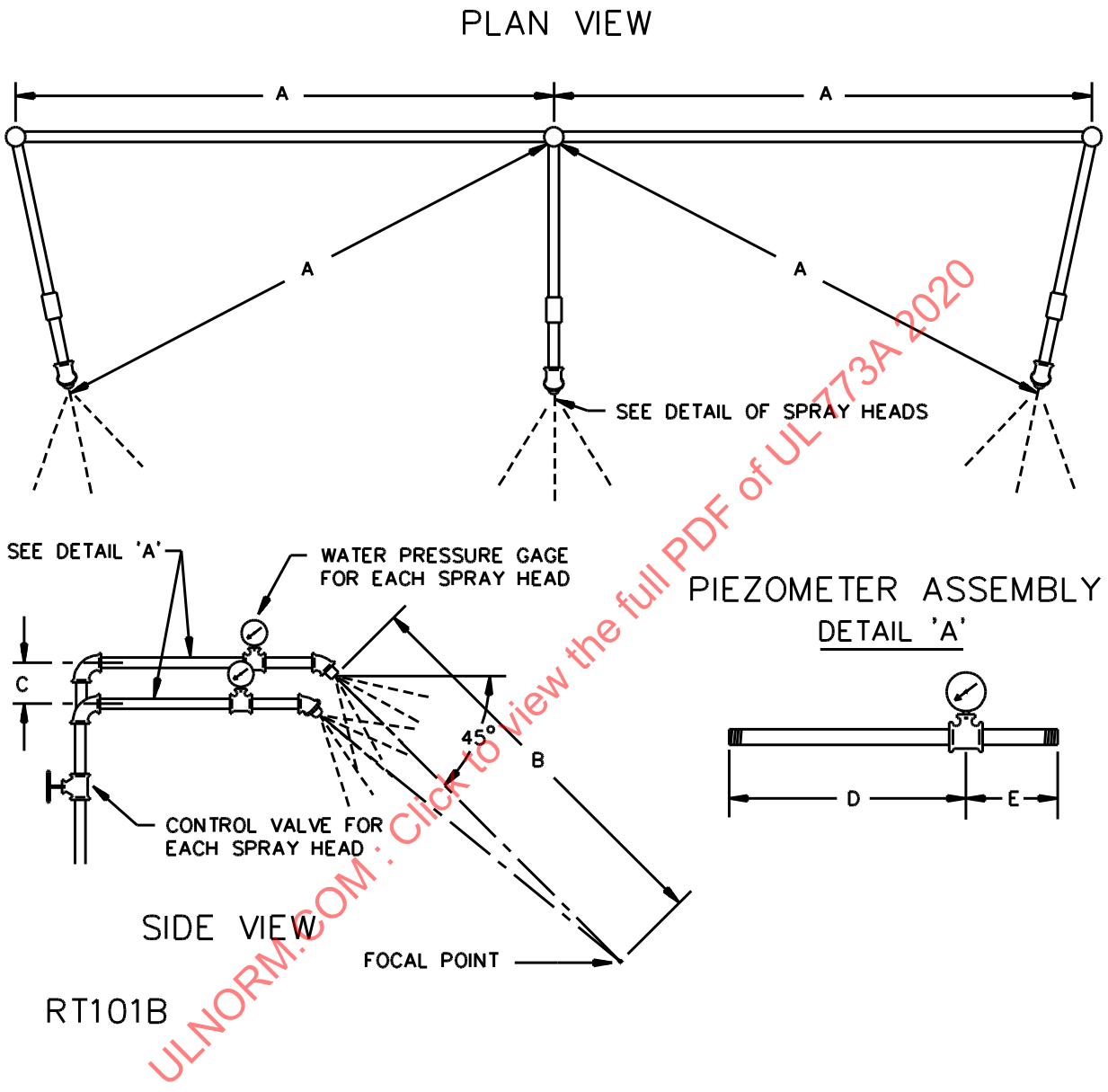
27 Rain Test

27.1 A unit rated "Raintight", “outdoor”, or “wet locations” shall be constructed so that it will exclude the entrance of any water to the interior space of its enclosure when subjected to the water spray described in 27.2.

27.2 A unit shall be mounted as specified in the manufacturer's instructions, and the water spray shall be applied to the top front of the unit at an angle of 45 degrees to the vertical. The unit shall be positioned in the focal area of the three spray heads. The water pressure shall be maintained at 34.5 kPa (5 psig) at each spray head for 1 hour. Figure 27.1 and Figure 27.2 depict the spray head piping and nozzle construction.

Figure 27.1

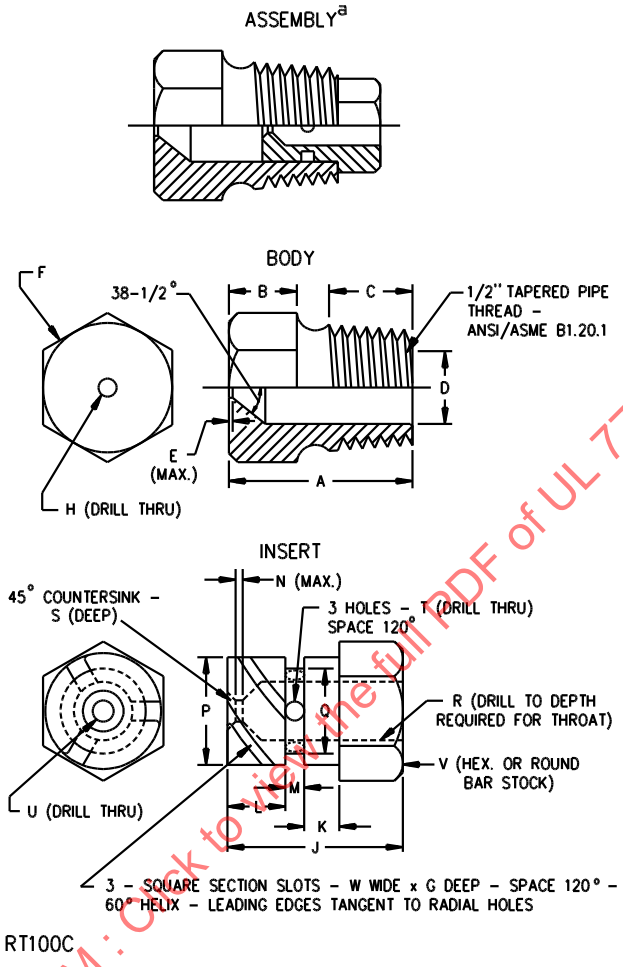
Rain-test spray-head piping



Item	mm	(in)
A	710	(28)
B	1400	(55)
C	55	(2-1/4)
D	230	(9)
E	75	(3)

Figure 27.2

Rain-test spray head



Item	mm	(in)	Item	mm	(in)
A	31.0	(1-7/32)	N	0.80	(1/32)
B	11.0	(7/16)	P	14.61	(0.575)
C	14.0	(9/16)		14.63	(0.576)
D	14.68 14.73	(0.578) (0.580)	Q	11.51 11.53	(0.453) (0.454)
E	0.40	(1/64)	R	6.35	(1/4)
F	c	c	S	0.80	(1/32)
G	1.52	(0.06)	T	2.79	(No. 35)[b]
H	5.0	(No. 9)[b]	U	2.49	(No. 40)[b]
J	18.3	(23/32)	V	16.0	(5/8)
K	3.97	(5/32)	W	1.52	(0.06)
L	6.35	(1/4)			
M	2.38	(3/32)			

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

[b] ANSI B94.11 Drill Size.

[c] Optional – To serve as wrench grip.

27.3 Within 5 minutes after completion of the spray test, the unit shall be tested in accordance with Dielectric Voltage-Withstand Test, Clause 23.

27.4 A gasket provided to prevent the entrance of water shall have the following properties when tested as specified in the Standard for Gaskets and Seals, UL 157:

a) The gasket shall be resistant to aging. There shall not be any visible evidence of deterioration such as softening, distortion, hardening or cracking after air-oven aging as specified in UL 157. The maximum service temperature used to determine the oven time and temperature for oven aging shall be the maximum temperature attained on the gasket during the test prescribed in Temperature Test, Clause 22, but not less than 60°C.

b) The adhesive or cement used to secure the gasket shall be resistant to aging as determined by exposing a sample of the enclosure, with the gasket secured in place, to 70 hours at 87° C, as specified in UL 157. If the gasket attains a maximum service temperature higher than 60°C in use, the time and temperature shall be the same as determined for oven aging. The adhesive or cement is considered to be resistant to aging if there is no visible evidence of the gasket to peel off, or to be dislodged from the original position of the gasket during and after the conditioning.

28 Exposure to Humid Atmospheres

28.1 A unit rated "Raintight", “outdoor”, or “wet locations” shall resist the absorption of moisture when subjected to a humid atmosphere for not less than 168 hours by exposing a unit, to air at a relative humidity of 96 ±2 %, at a temperature of 50 ±2°C (122 ±4°F). The sample shall then be removed from the humidity chamber and, within 1 minute of removal, subjected to the Dielectric Voltage-Withstand Test, Clause 23.

29 Permanence of Marking Tests

29.1 Requirements for pressure sensitive labels

29.1.1 Unless previously investigated for the application, a pressure sensitive label that is required to be permanent shall be tested as described in 29.1.2.

29.1.2 After being subjected to the conditions described in 29.2 – 29.5, a pressure-sensitive label or a label secured by cement or adhesive is considered to be permanent if immediately following removal from each test medium, and after being exposed to room temperature for 24 hours following removal from each medium:

a) Each sample demonstrates good adhesion and the edges are not curled;

b) The label resists defacement or removal as demonstrated by scraping across the test panel with a flat metal blade 1/32 in (0.8 mm) thick, held at right angles to the test panel; and

c) The printing is legible and is not defaced by rubbing with thumb or finger pressure.

29.2 Oven-aging test

29.2.1 Three samples of the label applied to test surfaces as in the intended application shall be conditioned for 240 hours in an air oven maintained at the temperature specified in Table 29.1.

Table 29.1
Oven-aging test temperature

Maximum temperature during normal temperature test of surface to which applied		Oven temperature	
°C	(°F)	°C	(°F)
60 or less	(140 or less)	87	(189)
80 or less	(176 or less)	105	(221)
100 or less	(212 or less)	121	(250)
125 or less	(257 or less)	150	(302)
150 or less	(302 or less)	180	(356)
Over 150	(Over 302)	a	a

[a] A label applied to a surface attaining a temperature greater than 150°C (302°F) during the normal temperature test shall be oven-aged at a temperature representative of the temperatures attained during normal and abnormal operation.

29.3 Immersion test

29.3.1 Three samples of the label applied to test surfaces as in the intended application shall be conditioned for 24 hours in a controlled atmosphere maintained at a temperature of 23.0 ±2.0° C (73.4 ±3.6° F) and a relative humidity of 50 ±5 percent. The samples shall then be immersed for 48 hours in water at a temperature of 21.0 ±2.0°C (69.8 ±3.6°F).

29.4 Standard-atmosphere test

29.4.1 Three samples of the label applied to test surfaces as in the intended application shall be conditioned for 72 hours in a controlled atmosphere maintained at a temperature of 23.0 ±2.0° C (73.4 ±3.6°F) and a relative humidity of 50 ±5 percent.

29.5 Unusual-conditions exposure test

29.5.1 If the labels are exposed to unusual conditions in service three samples of the label applied to test surfaces as in the intended application shall be conditioned for 24 hours in a controlled atmosphere maintained at a temperature of 23.0 ±2.0° C (73.4 ±3.6° F) and a relative humidity of 50 ±5 percent. The samples shall then be immersed for 48 hours in a solution representative of service use maintained at the temperature the solution would attain in service, but not less than 23.0 ±2.0°C (73.4 ±3.6°F).

30 Bonding/Grounding Connection Tests

30.1 Creep and mold stress relief

30.1.1 Creep and mold stress-relief tests shall be conducted in accordance with the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A, and the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, followed by an overcurrent test as specified in 30.2.1.

30.1.2 There shall be no softening, cracking, or other distortion of the material or damage to the bonding/grounding connection, and no change in the voltage drop through the bonding/grounding path when the unit is subjected to the tests specified in 30.2 and 30.3.

30.1.3 A separate set of three samples shall be subjected to the tests specified in 30.2, Overcurrent test, and 30.3, Impedance test.

30.2 Overcurrent tests

30.2.1 A current of 40 A shall pass through the bonding path for 2 minutes. Compliance is checked by the conductor not opening during the testing.

30.2.2 Three samples in the as-received condition shall be tested in series with a 20-ampere nonrenewable, non-time delay, cartridge fuse rated for branch circuit overcurrent protection on an a-c circuit at rated voltage capable of delivering 1000 amperes peak when the system is short-circuited at the testing terminals. A load with a 0.98 – 1.00 power factor shall be used to limit the current. One test shall be performed on the bonding/grounding lead, bonding conductor, or both the bonding/grounding lead and the bonding conductor of each dimmer sample.

30.3 Impedance test

30.3.1 The test shall be conducted with the bond at normal operating temperature.

Note: For some equipment, e.g., an electric range, normal operating temperature is achieved by allowing the equipment to heat up in the usual manner until a stable temperature is attained.

30.3.2 The impedance test shall be conducted by passing a 60 Hz current from a part to be bonded to the bonding/grounding terminal means and measuring the potential drop between them at the end of the period. The current shall be as specified in 30.2.1.

30.3.3 The current used for the measurement specified in 30.3.3 shall have the following characteristics:

a) For cord-connected equipment, twice the rating of the attachment plug cap, but not less than 40 A;

b) For equipment for permanent connection to the supply, twice the rating of the fuse that is required by the National Electrical Code, NFPA 70, Part I of the CE Code or NOM-001-SEDE for the branch circuit to which the equipment is connected, up to 250 A; and

c) 500 A for equipment for permanent connection to the supply when a branch circuit fused at over 250 A is required.

30.3.4 The following additional requirements shall apply:

a) For test currents up to 500 A, the measured potential drop shall not exceed 4 V;

b) For equipment that requires branch circuit fusing over 250 A, the measured potential drop multiplied by the required fusing and divided by 250 shall not exceed 4 V; and

c) There shall be no melting of any metal in the bond and no heating or burning that is likely to create a risk of fire.

31 Leakage Current Test

31.1 Equipment rated "Raintight", “outdoor”, or “wet locations” shall be humidity conditioned as specified in Clause 32 before the leakage current test.

31.2 The leakage current of a fixed wired device provided with a bonding/grounding conductor but not a grounded (neutral) conductor, regardless of the rated voltage or current path, when tested in accordance with 31.5 – 31.10 shall not be more than 0.5 mA.

31.3 The leakage current of a cord-connected unit rated for a nominal 120-, 208-, or 240-V supply when tested in accordance with 31.5 – 31.10 shall not be more than 0.5 mA.

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

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

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

31.7 The measurement circuit for leakage current shall be as illustrated in Figure 31.1. The measurement instrument is defined in (a) – (c). The meter that is actually used for a measurement need only indicate the same numerical value for a particular measurement as would the defined instrument; it need not have all the attributes of the defined instrument.

a) The meter shall have an input impedance of 1500 Ω resistive shunted by a capacitance of 0.15 µf.

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

c) Over a frequency range of 0 – 100 kHz, the measurement circuitry shall have a frequency response – ratio of indicated to actual value of current – that is equal to the ratio of the impedance of a 1500-Ω resistor shunted by a 0.15-µf capacitor to 1500 Ω. At an indication of 0.5 mA the measurement is to have an error of not more than 5 percent at 60 Hz.

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

31.9 A sample of the equipment shall be tested for leakage current starting with the as received condition – the as received condition being without prior energization except as may occur as part of the production-line testing. The bonding/grounding conductor, if any, is to be open at the attachment plug. The supply voltage shall be in accordance with 32.1. The test sequence, with reference to the measuring circuit, Figure 31.1, shall be as follows:

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

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

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

31.10 Normally the complete leakage-current-test program as described in 31.9 is to be conducted without interruption for other tests. However, with the concurrence of those concerned, the leakage current test may be interrupted to conduct other nondestructive tests.