UL 810

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Capacitors

Underwriters Laboratories Inc. (UL)
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UL Standard for Safety
for
Capacitors, UL 810

Fifth Edition, Dated May 4, 1995

Revisions: This Standard contains revisions through and including August 24, 1998. UL is in the process of converting its Standards for Safety to the Standard Generalized Markup Language (SGML). SGML – an international standard (ISO 8879-1986) – is a descriptive markup language that describes a document's structure and purpose, rather than its physical appearance on the page. Significant benefits that will result from UL's use of SGML are increased productivity, reduced turnaround times, and data and information consistency, reusability, shareability, and portability. The changes noted in these revised pages are needed to modify the format and layout of this Standard to allow it to be converted to SGML. These editorial changes are now in effect.

A change is indicated by a note following the affected item. The note is preceded and followed by an asterisk.

The new and/or revised requirements are substantially in accordance with UL's Bulletin on this subject dated December 17, 1997. The bulletin is now obsolete and may be discarded.

The revisions dated August 24, 1998 include a reprinted title page (page 1) for this Standard.

The revisions dated April 11, 1996 were issued to include Type W cords as an alternative to W-A cords for outside use.

As indicated on the title page (page 1), this UL Standard for Safety is an American National Standard. Attention is directed to the note on the title page of this Standard outlining the procedures to be followed to retain the approved text of this ANSI/UL Standard.

The master for this Standard at UL's Northbrook Office is the official document insofar as it relates to a UL service and the compliance of a product with respect to the requirements for that product and service, or if there are questions regarding the accuracy of this Standard.

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The requirements in this Standard are now in effect, except for those paragraphs, sections, tables, figures, and/or other elements of the Standard having future effective dates as indicated in the note following the affected item. The prior text for requirements that have been revised and that have a future effective date are located after the Standard, and are preceded by a "SUPERSEDED REQUIREMENTS" notice.

New product submittals made prior to a specified future effective date will be judged under all of the requirements in this Standard including those requirements with a specified future effective date, unless the applicant specifically requests that the product be judged under the current requirements. However, if the applicant elects this option, it should be noted that compliance with all the requirements in this Standard will be required as a condition of continued Listing, Recognition, and Follow-Up Services after the effective date, and understanding of this should be signified in writing.

This Standard consists of pages dated as shown in the following checklist:

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MAY 4, 1995
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American National Standard

ANSI/UL 810-1998

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UL 810

Standard for

Capacitors

First Edition – November, 1953
Second Edition – May, 1973
Third Edition – June, 1976
Fourth Edition – September, 1981

Fifth Edition

May 4, 1995

Approval as an American National Standard (ANSI) covers the numbered paragraphs on pages dated May 4, 1995 and August 24, 1998. These pages should not be discarded when revised or additional pages are issued if it is desired to retain the ANSI approved text.

An effective date included as a note immediately following certain requirements is one established by Underwriters Laboratories Inc.

Approved as ANSI/UL 810-1998, June 15, 1998

Revisions of this standard will be made by issuing revised or additional pages bearing their date of issue. A UL Standard is current only if it incorporates the most recently adopted revisions, all of which are itemized on the transmittal notice that accompanies the latest set of revised requirements.

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FOREWORD

A. This Standard contains basic requirements for products covered by Underwriters Laboratories Inc. (UL) under its Follow-Up Service for this category within the limitations given below and in the Scope section of this Standard. These requirements are based upon sound engineering principles, research, records of tests and field experience, and an appreciation of the problems of manufacture, installation, and use derived from consultation with and information obtained from manufacturers, users, inspection authorities, and others having specialized experience. They are subject to revision as further experience and investigation may show is necessary or desirable.

B. The observance of the requirements of this Standard by a manufacturer is one of the conditions of the continued coverage of the manufacturer's product.

C. A product which complies with the text of this Standard will not necessarily be judged to comply with the Standard if, when examined and tested, it is found to have other features which impair the level of safety contemplated by these requirements.

D. A product employing materials or having forms of construction differing from those detailed in the requirements of this Standard may be examined and tested according to the intent of the requirements and, if found to be substantially equivalent, may be judged to comply with the Standard.

E. UL, in performing its functions in accordance with its objectives, does not assume or undertake to discharge any responsibility of the manufacturer or any other party. The opinions and findings of UL represent its professional judgment given with due consideration to the necessary limitations of practical operation and state of the art at the time the Standard is processed. UL shall not be responsible to anyone for the use of or reliance upon this Standard by anyone. UL shall not incur any obligation or liability for damages, including consequential damages, arising out of or in connection with the use, interpretation of or reliance upon this Standard.

F. Many tests required by the Standards of UL are inherently hazardous and adequate safeguards for personnel and property shall be employed in conducting such tests.

INTRODUCTION

1 Scope

1.1 The requirements in Part I of this Standard apply to enclosed capacitors with integral protection intended to reduce the risk of rupture and venting of the capacitor enclosure under internal fault conditions. These requirements apply to oil-filled capacitors rated 5 kilovolts or less, and dry-type capacitors rated 2 kilovolts or less that are intended for use with appliances, lighting equipment, air conditioning and refrigeration equipment, motors, and the like, that comply with the requirements for such appliances and equipment.

1.2 The requirements in Part II of this Standard apply to general-use power-factor-correction units rated 600 volts maximum, intended for power-factor correction of circuits in accordance with the National Electrical Code, ANSI/NFPA 70.

1.2 revised August 24, 1998

1.2.1 A component capacitor used in a power factor correction unit as described in Part II of this Standard has been evaluated for across-the-line applications in accordance with Part I of this Standard.

1.2.1 added August 24, 1998

1.3 A capacitor that complies with the requirements in Part I of this standard is intended to be mounted within an appliance or within equipment for which an acceptable outer enclosure is provided.

1.4 The requirements in Part I and Part II do not apply to capacitors covered by the Standard for Across-the-Line, Antenna Coupling, and Line-by-Pass Capacitors for Radio- and Television-Type Appliances, UL 1414.

1.5 Other types of capacitors may be investigated to establish compliance with these requirements, and with such additional test criteria as may be found necessary.

1.6 A product that contains features, characteristics, components, materials, or systems new or different from those covered by the requirements in this standard, and that involve a risk of fire, electric shock, or injury to persons, shall be evaluated using the appropriate additional component and end-product requirements as determined necessary to maintain the acceptable level of safety as originally anticipated by the intent of this standard. A product whose features, characteristics, components, materials, or systems conflict with specific requirements or provisions of this standard cannot be judged to comply with this standard. Where considered appropriate, revision of requirements shall be proposed and adopted in conformance with the methods employed for development, revision, and implementation of this standard.

2 Glossary

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

2.2 CAPACITOR ROLL – The layered and rolled interior windings of a capacitor, which is also known as the element.

2.2.1 COMPONENT CAPACITOR – Refers to a capacitor evaluated to Part I of the Standard. A component capacitor is also referred to as "capacitor."

2.2.1 added August 24, 1998

2.3 CONTROLLED ENVIRONMENT – An environment that is relatively free of conductive contaminants, such as carbon dust and the like, that may result from the end-use equipment in which a capacitor or power-factor correction unit is installed or due to the location of the end-use equipment, and that is provided with protection against humidity and the formation of condensation.

2.4 ENCLOSURE – In Part I enclosure refers to the capacitor element housing. In Part II enclosure refers to the ultimate housing.

2.5 FIELD-WIRING TERMINALS – Terminals to which supply, control, output, or other permanent connections are made when the unit is installed.

2.6 HAZARDOUS LIVE PARTS – A live part having a potential greater than 30 volts rms (42.4 volts peak) between the part and ground or a grounded part, or between adjacent live parts.

2.7 INTERNAL PROTECTION BRIDGE – A device used with oil-filled capacitors that aids in the expansion of the capacitor enclosure in a direction that will interrupt the circuit, also referred to as a pressure interrupter.

2.8 ISOLATED LIMITED-ENERGY CIRCUIT – A circuit derived from an isolated secondary winding of a transformer having a maximum capacity of 100 volt-amperes and an open-circuit secondary voltage rating not exceeding 1000 volts. A circuit derived from a line-voltage source of supply by connecting resistance in series with the supply circuit as a means of limiting the voltage and current is not considered to be an isolated limited-power circuit or a low-voltage limited-energy circuit as described in 2.9.

2.9 LOW-VOLTAGE LIMITED-ENERGY CIRCUIT – A circuit involving a potential of not more than 30 volts rms (42.4 volt peak) and supplied by a primary battery, a Class 2 transformer, or a combination of a transformer and a fixed impedance that as a unit complies with all the performance requirements for a Class 2 transformer and limited energy as specified in 31.3.

2.10 POLE LEAST LIKELY TO STRIKE TO GROUND – A pole that, by its position or potential or both relative to other poles of a capacitor or power-factor correction unit, considered to be less likely than any other to strike to ground. In a three pole device, this pole would usually be the middle pole. It is possible for several poles to be equally least likely to strike to ground. In this case any pole may be used for the test.

2.11 POWER FACTOR – The ratio of the actual power of an a-c power producing product as measured by a wattmeter to the apparent power as measured by an ammeter and a voltmeter.

2.12 POWER-FACTOR CORRECTION – Addition of capacitors to an inductive circuit in order to increase the power factor by making the total current more nearly in phase with the applied voltage.

2.13 POWER-FACTOR CORRECTION UNIT – A group of capacitors housed in one enclosure that are connected ahead of an induction load (such as large motor driven equipment) to correct the power factor of that individual load. Also referred to as a unit in this standard.

2.13.1 PRESSURE SENSITIVE INTERRUPTER – An integral protection device that assists in the expansion process by providing resistance to internal pressure caused by a build-up of gases. Also referred to as an internal protection bridge.

2.13.1 added August 24, 1998

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

2.15 SECONDARY CIRCUIT – A circuit conductively connected to the secondary winding of an isolating power supply transformer.

2.16 SUPPLY CIRCUIT – The circuit supplying electrical energy to the product from a branch circuit or battery feed.

3 General

3.1 Components

3.1.1 Except as indicated in 3.1.2, a component of an appliance covered by this standard shall comply with the requirements for that component. See Appendix A for a list of standards covering components generally used in the products covered by this standard.

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3.1.2 A component need not comply with a specific requirement that:

a) Involves a feature or characteristic not needed in the application of the component in the appliance covered by this standard; or

b) Is superseded by a requirement in this standard.

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

3.1.4 Specific components are recognized as being 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 for which they have been recognized.

3.2 Units of measurement

3.2.1 If a value for measurement is followed by a value in other units in parentheses, the second value may be only approximate. The first stated value is the requirement.

PART I – CAPACITORS

CONSTRUCTION

4 Enclosure

4.1 General

4.1.1 A capacitor shall be provided within an enclosure that houses all live parts other than the supply leads, terminals, or discharge resistor.

4.2 Metallic

4.2.1 A metal enclosure shall be 0.010 inch (0.25 mm) thick minimum, if of steel, and 0.016 inch (0.41 mm) thick minimum, if of aluminum, brass, or copper.

4.3 Nonmetallic

4.3.1 A polymeric material used as part or all of an enclosure shall comply with the applicable requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

4.3.2 A polymeric material used as part or all of an enclosure shall:

a) Comply with the flammability test – 3/4-inch (19.1-mm) flame, specified in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C; or

b) Be classed V-2 minimum in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

4.3.2 revised August 24, 1998

4.3.3 Among the factors that shall be taken into consideration when investigating the acceptability of a nonmetallic material with respect to its intended application are:

a) Mechanical strength;

b) Moisture-absorbent properties;

c) Combustibility;

d) Compatibility with dielectric mediums;

e) Resistance to arcing;

f) Dielectric strength;

g) Aging characteristics; and

h) Resistance to distortion at maximum temperatures to which the enclosure may be subjected under conditions of normal or abnormal use.

4.3.4 With regard to mechanical strength and resistance to distortion at maximum temperatures of operation described in 4.3.3 (a) and (h), a polymeric material used as an enclosure shall have a relative mechanical temperature index without impact of at least 70EC (158EF) or the marked temperature rating, whichever is greater, in accordance with the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B.

4.3.5 A nonmetallic enclosure material that also functions as an insulator shall comply with Insulating Material, Section 6.

5 Internal Protection Bridge

5.1 A polymeric material used as an internal protection bridge or pressure interrupter shall have a relative mechanical temperature index without impact in accordance with the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B, at least equal to that of the capacitor enclosure. See 4.3.4.

6 Insulating Material

6.1 A material used for the mounting of uninsulated capacitor terminals shall be a material rated for the application, and shall comply with the requirements specified in Table 6.1.

Exception No. 1: A polymeric material that is not rated for, or does not comply with, the hot wire ignition or high current arc resistance to ignition requirements in Table 6.1 shall not be used unless the part fabricated with the polymeric material complies with the applicable requirements for materials used in stationary equipment as prescribed in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

Exception No. 2: Products that have a minimum 1/2 inch (12.7 mm) over surface spacing from terminal-to-terminal are not required to comply with Table 6.1.

6.1 revised August 24, 1998

Table 6.1
Polymeric insulating material

Application	Properties				
		Resistance to ignition		Electrical	
		Hot wire (HWI)[b]	High current (HAI)[b]	Dielectric breakdown strength[b]	Comparative tracking index (CTI)[b]
	Minimum flammability class[a]	Maximum performance level category	Maximum performance level category	Minimum volts	Maximum performance level category
Contact with insulated live parts[c]	V-0	4	3	–	–
	V-1	4	2		
	V-2	4	2		
Contact with uninsulated live parts[d]	V-0	4	3	5000	5
	V-1	3	2	5000	5
	V-2	2	2	5000	5

[a] The flammability classification is to be determined by the tests described in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

[b] Tests are to be conducted in accordance with the Standard for Polymeric Materials – Short Term Property Evaluation, UL 746A. Requirements for each test are specified in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

[c] Also applies to a nonmetallic enclosure in contact with insulated current-carrying live parts and where there are no uninsulated current carrying parts.

[d] Also applies to a nonmetallic enclosure in contact with uninsulated live parts or where the enclosure is within 1/32 inch (0.8 mm) of uninsulated live parts.

Table 6.1 revised August 24, 1998

6.2 Internal insulating materials shall comply with the requirements for the Dielectric Voltage-Withstand Test, Section 11.

6.3 A capacitor having a metal enclosure shall have an insulating liner of nonmoisture-absorbent material between the capacitor roll and the metal enclosure. In addition, the capacitor shall:

a) Resist the absorption of moisture by having the capacitor roll completely immersed in a sealing compound or other material that may be used for the purpose; and

b) The insulating liner shall have a minimum dielectric strength of 5000 volts, and a volume resistivity of 10 megohm-centimeters after 90 percent humidity exposure in accordance with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

7 Leads and Terminals

7.1 A lead of a capacitor shall be rated for the voltage and current involved. The temperature rating of the insulation of the lead shall not be less than the temperature rating of the capacitor.

7.2 The connection of a lead inside a capacitor shall be secure. Strain relief shall be provided that complies with the Pull-Out Test, Section 9.

7.3 A wiring terminal of a capacitor shall be provided with a soldering lug, pressure terminal connector, wire-binding screw, or quick-connect terminal rated for securing the size of the conductor to be connected. The terminal material shall be at least 0.020 inch (0.51 mm) thick and shall be of copper, copper alloy, tin plated steel, or other metal rated for the application.

7.4 A quick-connect terminal shall be provided with a detent, such as a dimple (depression) or hole in a tab that acts to engage a raised portion on the connector providing a latching means for the mating parts.

8 Spacings

8.1 The electrical spacing between an uninsulated live part, and an uninsulated live part of opposite polarity, or a grounded-metal part shall not be less than the applicable value specified in Table 8.1.

Exception: Electrical spacings are not specified for those parts that are inside the enclosure and that are surrounded by a dielectric medium. See 6.3.

Table 8.1
Spacings

Capacitor rating, volts	Minimum spacings, inch (mm)			
	Through air		Over surface	
0 – 150	1/8	(3.2)	1/4	(6.4)
151 – 300	1/4	(6.4)	3/8	(9.5)
301 – 660	3/8	(9.5)	1/2	(12.7)
661 – 2000	3/4	(19.1)	3/4	(19.1)
2001 – 5000	1	(25.4)	3/4	(19.1)

PERFORMANCE

9 Pull-Out Test

9.1 With reference to 7.2, the connection for a capacitor lead shall withstand the pull-out test described in 9.2 without any evidence of lead pull out.

9.2 Six samples of a capacitor are to be subjected to a gradual force applied to each lead for 1 minute in a direction perpendicular to the plane of the surface at which the lead enters the capacitor. The force shall be:

a) 20 pounds (89 N) for No. 18 AWG (0.82 mm^2) and larger leads; or

b) 8 pounds (36 N) for leads smaller than No. 18 AWG.

10 Fault-Current Test

10.1 General

10.1.1 When tested under the induced fault conditions specified in this section:

a) For an oil-filled capacitor, the enclosure shall not vent, leak, or rupture expelling the dielectric medium; or

b) For a dry-type capacitor, there shall not be ignition of the cotton prescribed in 10.1.10.

10.1.2 Under test conditions the expansion of an expansion-type capacitor shall not exceed 0.5 inch (12.7 mm).

10.1.3 The manufacturer shall specify the maximum voltage and the maximum available fault current – excluding transients of the capacitor. See Table 10.1.

Table 10.1
Current for fault-current test

Intended application	Number of test samples[a]	Current, amperes[b]								
		10,000	5000	1000	200	60	30	15	5	2.5
General application, across-the-line or in series with other impedance	42 per fault 84 total	X	X	X	X	X	X		X	
Air conditioning or refrigeration and motor applications	30 per fault 60 total		X		X	X	X		X	
HID ballast, across-the-line applications	36 per fault 72 total		X	X	X	X		X	X	
HID ballast (secondary or extended primary) applications	24 per fault 48 total				X	X		X	X	
Fluorescent ballast, across-the-line applications	30 per fault 60 total			X	X	X			X	X
Fluorescent ballast, secondary applications	18 per fault 36 total					X			X	X

[a] Test samples for Type A and Type B faults specified in 10.2.1;

a) Three for each fault type with the capacitor having the maximum enclosure height and base size; and

b) Three for each fault type with the capacitor having the minimum enclosure height and base size.

[b] Values of fault-test currents other than those specified may be used for specific conditions or applications.

10.1.4 The test-circuit voltage is to be the highest rated voltage of the circuit to which the capacitor is intended to be connected or the voltage across the capacitor, whichever is higher. The enclosure is to be connected to the live pole that is determined to be least likely to strike to ground in service. The open-circuit voltage of the test circuit is not to be less than 100 percent nor more than 105 percent of the rated voltage.

Exception: A voltage more than 105 percent of the rated voltage may be employed if agreeable to those concerned.

10.1.5 The test circuit power factor is to be the highest available for the circuit, unless a lower power factor is required for the intended application of the capacitor. The power factor is not specified when the available fault current is 1000 amperes or more; however, the power factor of the circuit is to be recorded.

10.1.6 The test circuit is to have sufficient capacity to deliver the fault currents specified in Table 10.1 with the test terminals short-circuited with a copper bar that is not more than 12 inches (305 mm) long and that has a cross-sectional area of at least 3 square inches (19.4 cm^2).

10.1.7 A branch-circuit fuse is not to be employed in the test circuit as protection for a capacitor.

10.1.8 Representative production samples of the minimum and maximum enclosure sizes – minimum base size and minimum height, maximum base size and maximum height – are considered to represent the intermediate enclosure sizes. If one combination of base size and height of a capacitor represents another, only the representative capacitor need be tested. The number of samples to be employed in the test program is to be as specified in 10.2 and Table 10.1.

10.1.9 For oil-filled capacitors, the samples are to be filled with the oil that will be used in production and sealed. If use of an alternate dielectric medium is desired, the test program is to be repeated using the alternate medium. Each capacitor is to be marked or coded to indicate the type of fault and the type of medium.

10.1.10 For dry type capacitors, the enclosure is to be wrapped in cotton.

10.2 Sample preparation

10.2.1 Capacitors with foil electrodes

10.2.1.1 The required number of samples, as indicated in Table 10.1, to complete each test are to be prepared. For paper and foil windings, a fault is to be induced by removal of a section of the paper dielectric between the foil layers at the top margin, to a depth of 1/2 inch (12.7 mm) and a width of approximately 1/2 inch, at the following locations:

a) Type A – In a layer of the capacitor roll within fifteen layers from the outer end of the roll; and

b) Type B – In a layer of the roll within fifteen layers from the inner end of the roll or, at the manufacturer's option, a short circuit consisting of no paper between foils for the first 6 inches (152 mm) of the roll.

Exception: Other methods of inducing faults that produce representative protector actuation are not prohibited from being used. Among these are contaminated dielectric, elevated ambient temperature, and increased test-circuit voltage.

10.2.1.1 revised August 24, 1998

10.2.2 Capacitors with metallized electrodes

10.2.2.1 A sufficient number of samples as indicated in Table 10.1 to complete each test is to be prepared. The samples are to be faulted by applying a high-voltage d-c potential with a current not more than 300 mA, sufficient to cause breakdown.

10.2.2.2 Prior to the test, the samples are to be conditioned for 2 hours in an oven at the rated temperature of the capacitor. If necessary, to defeat the rehealing of a capacitor (that is, self-clearing of a fault), a higher temperature may be used if agreeable to those concerned.

10.3 Test method

10.3.1 Three samples of each size with induced faults, prepared in accordance with 10.2.1 and 10.2.2, are to be subjected to the rated maximum fault-test current, and to lower levels of fault-test currents specified in Table 10.1. When the protective device does not function at the lowest current level specified in Table 10.1, the current is to be increased by increments of 2.5 amps. Quick-connect terminals are not prohibited from being used in circuits in which the available fault current is 200 amperes or less. The enclosure is to be connected to the live pole of the capacitor that is least likely to strike to ground in service.

10.3.1 revised August 24, 1998

10.3.2 A total of three samples are to be tested. One sample is to be mounted in one of each of the following three positions:

a) With the major axis of the capacitor vertical and the terminals on top;

b) With the major axis of the capacitor horizontal and, when the capacitor is oval-shaped, with the minor axis of the oval horizontal; and

c) With major axis of the capacitor vertical and the terminals on the bottom.

Exception: Capacitors employing a protection means other than a pressure sensitive interrupter are required to be tested in only one position.

10.3.2 revised August 24, 1998

10.3.3 Leads connected to the test terminals are to be No. 12 AWG (3.3 mm^2) or larger, and are not to be longer than 2 feet (0.61 m).

10.3.4 The application of the voltage is to be continued for not less than 1 minute after interruption of the fault current. If there has not been reestablishment of current or any indication of a tendency to restrike (unusual heating, internal arcing, or the like) before the end of the 1-minute interval, the performance is acceptable. If evidence of a tendency to restrike has been noted, the voltage is to be applied until it is definitely determined that complete and permanent interruption of the circuit has occurred, or until the ultimate effect on the capacitor has been determined, but not longer than 2 hours. Reestablishment of the circuit that results in venting or enclosure rupture is not acceptable.

10.3.5 If the protective device does not function after the circuit has been energized for at least 2 hours, the sample may be replaced by a substitute sample of the same construction and fault condition, and the test is to be repeated.

10.4 Restrike test (oil-filled only)

10.4.1 When tested as described in 10.4.2 there shall be no venting or rupture of the enclosure of an oil-filled capacitor.

10.4.2 One capacitor out of three (that is, one capacitor from each of the samples tested at each current level for each fault-current test) in which the protective device has actuated during the fault-current test is to be connected in a circuit of voltage equal to that of the fault-current test circuit, and positioned in the same manner as in the fault-current test for that sample. The samples chosen are to be those with the least amount of swelling, or those for which minor restrikes were noted during the fault-current test. This test is to be conducted for at least 48 hours.

11 Dielectric Voltage-Withstand Test

11.1 General

11.1.1 All samples that have been subjected to the Fault-Current Test, Section 10, shall be subjected to a dielectric voltage-withstand test as described in 11.2 and 11.3. There shall be no dielectric breakdown of any sample.

11.1.2 To determine if a capacitor complies with the requirements in 11.1.1, the capacitor is to be tested using a 500 volt-ampere or larger capacity transformer, the output voltage of which can be varied. The applied potential is to be increased from zero until the required test level is reached, and is to be held at that level for 1 minute. The increase in applied potential is to be at a substantially uniform rate as rapid as is consistent with correct indication of its value by a voltmeter.

11.1.3 As an alternative, a d-c potential equal to 1.4 times the a-c potential specified in 11.2.1 and 11.3.1 may be used.

11.2 Oil-filled capacitor

11.2.1 An oil-filled capacitor shall withstand for 1 minute, the application of a 60 Hz alternating potential of 1-1/2 times the maximum rated voltage:

a) Between terminals of opposite polarity; and

b) Between the terminals and the enclosure.

11.3 Dry-type capacitor

11.3.1 A dry-type capacitor shall withstand for 1 minute the application of a 60 Hz alternating potential of:

a) One thousand volts plus twice the rated voltage between all live parts and all dead metal parts; and

b) One and a half times the maximum rated voltage between terminals of opposite polarity.

Exception: Momentary short-circuiting between terminals is acceptable.

11.3.2 A capacitor with a nonmetallic enclosure is to be tested by applying the voltage between the terminals and a metal foil tightly wrapped around and contacting all surfaces other than the surface on which the terminals are attached.

MANUFACTURING AND PRODUCTION TESTS

12 Dielectric Voltage-Withstand Test

12.1 Each capacitor shall withstand without electrical breakdown, as a routine production-line test, the application of a 40 – 70 Hz potential as specified in 11.2.1(b) for oil-filled capacitors and 11.3.1(a) for dry-type capacitors.

Exception: The test potential application time may be reduced to 1 second if the test potential is 3.0 times the maximum rated voltage for oil-filled capacitors or 1200 volts plus 2.4 times the rated voltage for dry-type capacitors.

12.2 The test equipment shall include a transformer having an essentially sinusoidal output, a means of indicating the test potential, an audible or visual indicator of electrical breakdown, and either a manually reset device to restore the equipment after electrical breakdown or an automatic reject feature of any unacceptable capacitor.

12.3 If the output of the test equipment transformer is less than 500 volt-amperes, the equipment shall include a voltmeter in the output circuit to directly indicate the test potential.

12.4 If the transformer output is 500 volt-amperes or larger, the test potential may be indicated:

a) By a voltmeter in the primary circuit or in a tertiary-winding circuit;

b) By a selector switch marked to indicate the test potential; or

c) For equipment having a single test potential output, by a marking in a readily visible location to indicate the test potential.

12.5 If a marking is used without an indicating voltmeter as described in 12.4 (b) or (c), the equipment shall include a positive means, such as an indicator lamp, to indicate that the manually reset switch has been reset following a dielectric breakdown.

12.6 Test equipment other than those described in 12.2 – 12.5 may be used if equivalent.

MARKINGS

13 General

13.1 Each capacitor shall be legibly and permanently marked with:

a) The manufacturer's name, trade name, or trademark;

b) The date or other dating period of manufacture not exceeding any three consecutive months;

c) A distinctive catalog number or the equivalent;

d) The capacitance in microfarads;

e) The voltage rating;

f) The frequency in hertz;

g) The temperature rating when the capacitor is rated over 70EC (158EF);

h) The maximum fault current; and

i) When provided with the marking in (h), the capacitor is not prohibited from being additionally marked "Internally Protected" or "Protected."

Exception No. 1: When the manufacturer's identification is provided in a traceable code, the product shall be identified by the brand or trademark owned by a private labeler.

Exception No. 2: When the date of manufacture is abbreviated or in a nationally accepted conventional code, or in a code affirmed by the manufacturer, the code:

a) Shall not repeat in less than 20 years; and

b) Shall not require reference to the production records of the manufacturer to determine when the product was manufactured.

13.1 revised August 24, 1998

PART II – POWER-FACTOR CORRECTION UNITS

GENERAL

14 Terminology

14.1 The term "unit" as used in these requirements refers to all power-factor correction units or any part of a unit covered by these requirements unless specifically noted otherwise.

CONSTRUCTION

15 Frame and Enclosure

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

15.2 A unit shall be provided with an enclosure that houses all parts that may present a risk of fire, electric shock, or injury to persons under intended conditions of use.

15.3 A unit shall have a means for securely mounting it in position. Bolts, screws, and other parts used for mounting the unit shall be independent of those used for securing components.

15.4 Mounting instructions shall be furnished with each unit. If special hardware is required, it shall be provided by the manufacturer. A mounting means shall comply with Static Load Test, Section 43.

15.5 If the breakage or damage of a part such as an enclosure, a frame, a guard, or the like, might result in a risk of injury to persons, the material of the part shall have properties such that the part meets the demand of expected conditions of operation and use.

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

Exception: This requirement does not apply to a sharp edge that might be exposed to enable the unit to perform its intended function.

15.7 If an electrical instrument, such as a meter, forms part of the enclosure, the face or the back of the instrument housing, or both together, shall comply with the requirements for an enclosure.

Exception: An electrical instrument connected in a secondary circuit need not comply, if damage or deterioration of the materials comprising the housing will not result in a risk of fire or electric shock.

15.8 Material supporting terminals or used as internal electrical insulation of an electrical instrument shall comply with Insulating Materials, Section 25.

Exception: An electrical instrument connected in a secondary circuit need not comply, if damage to or deterioration of the materials will not result in a risk of fire or electric shock.

15.9 A compartment or part of an enclosure that contains field-wiring splices for other than low-voltage circuits shall not be provided with ventilating openings.

15.10 A sheet-metal enclosure or part of an enclosure shall have a thickness not less than that specified in Table 15.1.

Exception: A part of an enclosure that complies with the Compression Test, Section 40, and the Deflection Test, Section 42, need not comply with Table 15.1.

15.11 An enclosure, frame, or cover of a material other than steel shall have a thickness not less than that specified in Table 15.2.

15.12 With reference to Tables 15.1 and 15.2, 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. A structure that is as rigid as one built with a frame of angles or channels is considered to have equivalent reinforcing. Constructions considered to be without supporting frame include:

a) 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.

Table 15.1
Thickness of sheet metal for enclosures – carbon steel or stainless steel

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

[a] See 15.12.

[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 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 1/2 inch (12.7 mm) or fastened to adjacent surfaces not normally removed in use.

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

Table 15.2
Thickness of sheet metal for electrical enclosures – aluminum, copper, or brass

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

[a] See 15.12.

[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 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 1/2 inch (12.7 mm) or fastened to adjacent surfaces not normally removed in use.

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

15.13 A polymeric enclosure or polymeric part of an enclosure shall comply with the requirements for fixed or stationary equipment in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluation, UL 746C.

Exception No.1: A polymeric part (such as a reset knob, a lever, or a button) protruding through a hole in the enclosure need only be made of a material classified V-0, V-1, or V-2 in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, when the area of the hole is 0.6 square inch (3.9 cm^2) or less.

Exception No. 2: When the part is removed and there are no hazardous live parts (see 2.4) or moving parts accessible to the user as determined by the Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts, Section 16, the part is not required to comply with 15.13.

15.13 revised August 24, 1998

15.14 A polymeric material enclosure, having in any single unbroken area, a projected surface area greater than 10 square feet (0.93 m^2) or a single linear dimension greater than 6 feet (1.83 m) shall have a flame-spread rating of 50 or less when tested in accordance with the:

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

b) Radiant-panel furnace method in the Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source, ASTM E162-1990.

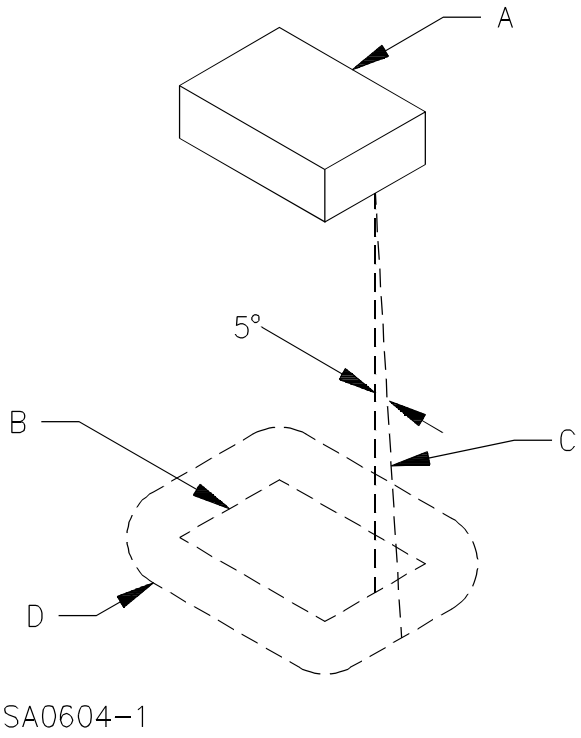
Exception: A polymeric material with a flame-spread rating greater than 50 may be used as the exterior finish or covering on any portion of the enclosure if the flame-spread rating of the combination of the base material and finish or covering has a flame-spread rating of 50 or less when tested in accordance with (a) or (b).

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

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

15.16 The enclosure of a unit shall reduce the risk of molten metal, burning insulation, flaming particles, or the like from falling on combustible materials, including the surface upon which the unit is supported. A barrier shall be horizontal, be located as illustrated in Figure 15.1, and shall have an area in accordance with the figure. Openings for drainage, ventilation, and the like may be employed in the barrier if such openings would not permit molten metal, burning insulation, or the like, to fall on combustible material.

Figure 15.1
Location and extent of barrier



NOTES

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

B – Projection of outline of component on horizontal plane.

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

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

Figure 15.1 revised August 24, 1998

15.17 The requirement in 15.16 necessitates that, a switch, a relay, a solenoid, or the like, be completely and individually enclosed, except for terminals, unless it can be shown that:

a) Malfunction of the component would not result in a risk of fire; or

b) There are no openings in the enclosure through which molten metal, burning insulation, flaming particles, or the like could fall.

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

16.1 No opening in the enclosure of a unit shall permit entrance of a 1-inch (25.4-mm) diameter rod. An opening smaller than 1-inch diameter is acceptable only if a probe as illustrated in Figure 16.1, when inserted through the opening in accordance with 16.2, cannot be made to touch any uninsulated live part or film-coated wire that may involve a risk of electric shock, or any moving part that may involve a risk of injury to persons.

16.2 The probe illustrated in Figure 16.1 is to be applied to any depth that the opening will permit and with a force not greater than 1 pound (4.4 N), and is to be rotated or angled before, during, and after insertion through the opening to any position that is necessary to examine the unit. The probe is to be applied in any possible configuration, and, if necessary, the configuration is to be changed after insertion through the opening.

16.3 Glass or thermoplastic covering an opening for user servicing, such as replacing a pilot lamp, and enclosing live parts that are guarded in accordance with 17.1.4 shall be reliably retained in place.

16.4 An uninsulated live part that may involve a risk of electric shock shall be located or enclosed so that protection against unintentional contact is provided.

16.5 A door or cover that provides access to a live part that may involve a risk of electric shock shall be securely held in place so that it can be opened or removed only by using a tool.

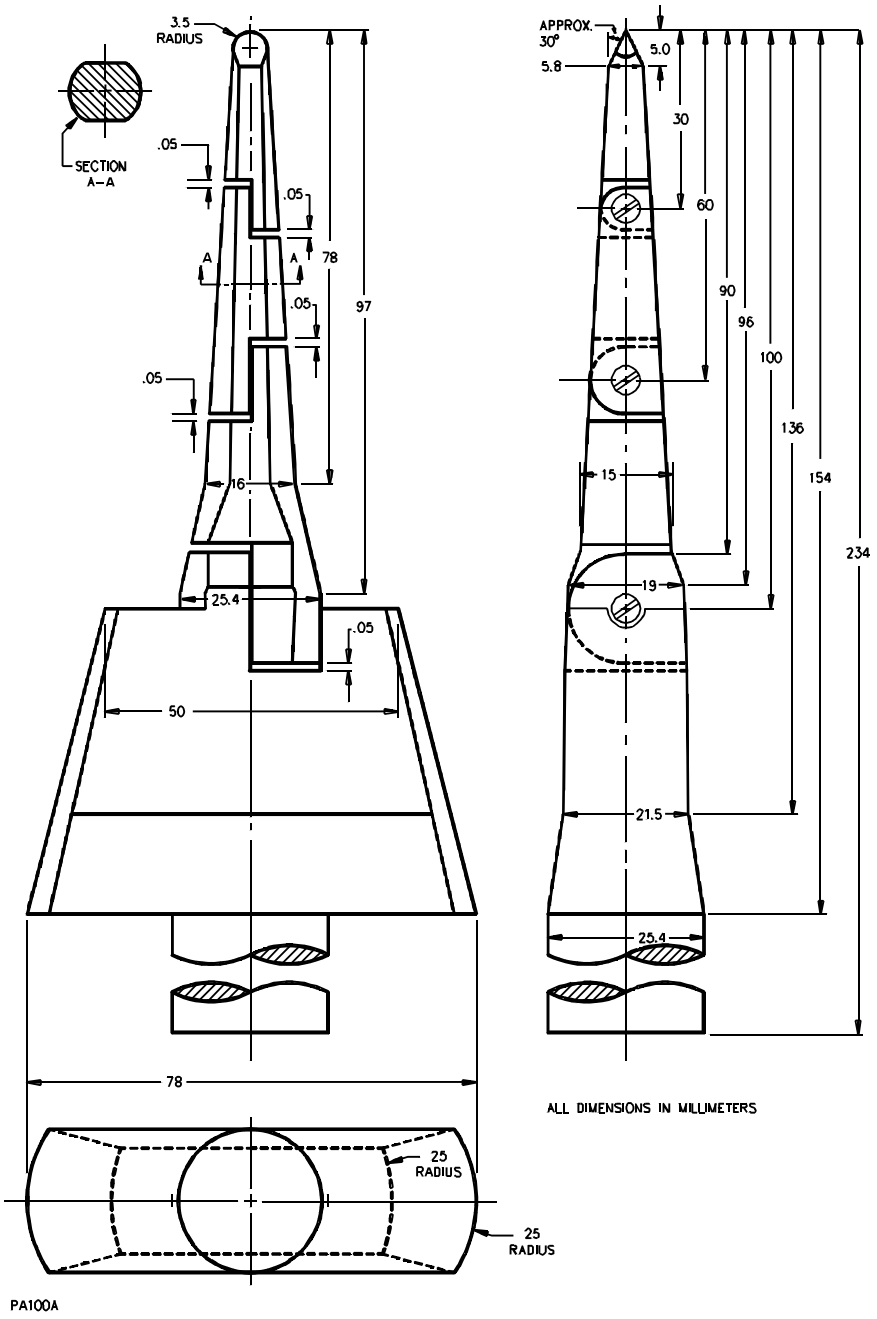
Exception: A door or cover that provides access to a live part that does not involve risk of electric shock shall be securely held in place, but need not be secured so that it is necessary to use a tool to open or remove it.

16.6 A door or cover of an enclosure shall be hinged or attached in an equivalent manner if it provides access to an overload-protective device the intended functioning of which requires renewal, or if it is necessary to open the cover in connection with the intended operation of the protective device. A door or cover providing access to a fuseholder shall be tight-fitting, and shall be positively held closed.

Exception: A hinged cover is not required if the only overload-protective devices enclosed are supplementary fuses in control circuits, provided the fuses and the circuit loads are within the same enclosure, supplementary fuses rated 2 amperes or less for loads not exceeding 100 volt-amperes, extractor fuses having an integral enclosure, or fuses connected in a low-voltage circuit.

16.7 The operating handle of a circuit breaker, the operating button of a manually-operable protector, the capped portion of an extractor-type fuseholder, or a similar part may project outside the enclosure.

Figure 16.1
Articulate probe with web stop



17 Protection Against Risks of Electric Shock and Injury to Persons

17.1 General

17.1.1 These requirements apply to live parts in circuits other than low-voltage limited-energy circuits, and to moving parts.

Exception: Electrical components in accordance with 17.5.3 need not comply.

17.1.2 An uninsulated live part involving a risk of electric shock, and a moving part involving a risk of injury to persons shall be located, guarded, or enclosed so as to reduce the risk of unintentional contact with such part by persons while changing a lamp or fuse, adjusting a control, or performing other like operations, including those performed only at the time of installation or during servicing procedures.

17.1.3 If operation, maintenance, or reasonably foreseeable misuse of a unit by the user involves a risk of injury to persons, protection shall be provided to reduce such risk.

17.1.4 With reference to 17.1.2, a part that is within the enclosure of a unit, and that cannot be contacted from outside the enclosure, see 16.1, by the probe illustrated in Figure 16.1 is considered to be acceptably guarded. An opening in a guard shall not permit the entrance of a probe with a diameter of 1 inch (25.4 mm).

17.1.5 A guard, baffle, or cover that can be removed without using a tool is to be removed when determining if a part is accessible to the user. A part that can be contacted by the probe illustrated in Figure 16.1, when inserted through an opening in a permanently-attached guard or baffle, is considered to be accessible to persons.

17.1.6 A part on the back of a component mounting panel, and a part located so as to require major disassembly by using a tool are not considered to be accessible to the user. Such parts are not considered accessible to service personnel unless it is likely that servicing will be done while the parts are energized after disassembly.

17.2 Live parts

17.2.1 Live parts shall be so arranged, and covers so located as to reduce a risk of electric shock while covers are being removed and replaced.

17.2.2 A live part such as a heat sink for a solid-state component, a live relay frame, and the like shall comply with the requirements in 17.4.2 and 17.5.1. Such a part shall also either be guarded against unintentional contact by persons or be marked in accordance with 46.3.

17.2.3 With reference to 17.2.2, the size, shape, material, and color give a heat sink or relay-frame the appearance of a dead metal part. Other live parts that can be mistaken for dead metal are to be similarly investigated, and guarded or marked.

17.3 Moving parts

17.3.1 The rotor of a motor, a fan blade, a pulley, a belt, a gear or other moving part that could cause injury to persons, shall be enclosed or provided with other means to reduce the likelihood of unintentional contact.

17.3.2 A rotating or moving part that might result in a risk of injury to persons if it should become disengaged, shall be provided with a positive means to retain it in place under intended conditions of use.

17.4 Mechanical servicing

17.4.1 The requirements in 17.4.2 and 17.4.3 are intended to provide a reasonable degree of protection to service personnel performing mechanical functions on energized equipment. Such functions do not in themselves require exposure to live parts involving a risk of electric shock or to moving parts involving a risk of injury to persons, but it is usually necessary to perform them with the equipment energized.

17.4.2 An uninsulated live part involving a risk of electric shock, and a moving part involving a risk of injury to persons shall be located, guarded, or enclosed so as to reduce the risk of unintentional contact by service personnel adjusting or resetting controls, and the like, or performing mechanical service functions that may be performed with the equipment energized, such as lubricating a motor, adjusting the setting of a control with or without marked dial settings, resetting a trip mechanism, or operating a manual switch.

17.4.3 Unless guarded, an adjustable or resettable electrical control or manual switching device may be located or oriented with respect to uninsulated live parts so that manipulation of the mechanism for adjustment, resetting, or operation can be accomplished in the normal direction of access if uninsulated live parts are not located in the direction of access of the mechanism, and are not located near any side or behind the mechanism.

17.5 Electrical servicing

17.5.1 An electrical component that may require examination, adjustment, servicing, or maintenance while energized shall be located and mounted with respect to other components, and with respect to grounded metal parts so that it is accessible for electrical service functions without subjecting service personnel to a risk of electric shock or injury to persons. Access to components in a unit is not to be impeded by other components or by wiring in the direction of access.

17.5.2 Protection against the risk of electric shock and injury to persons may be obtained by mounting control components so that unimpeded access to each component is provided by an access cover or panel in the outer cabinet.

17.5.3 The electrical components referred to in 17.5.1 and 17.5.2 include the following: fuses, adjustable or resettable overload relays, magnetically operated relays, manual-switching devices, clock timers, and incremental voltage taps. Such components in a low-voltage limited energy circuit as defined in 2.9 shall comply with the requirements in 17.2 and 17.3 with respect to uninsulated hazardous live parts, and to moving parts involving a risk of injury to persons.

17.5.4 The following are not considered to be uninsulated live parts: coils and windings of relays, solenoids, and transformers that are provided with insulating overwraps at least 1/32 inch (0.8 mm) thick rated for the application, or the equivalent; enclosed motor windings; terminals and splices with insulation rated for the application, and insulated wire.

18 Assembly

18.1 An uninsulated live part shall be secured to the base or surface so that the likelihood of the part rotating or shifting in position as the result of stresses is reduced if such movement might result in a reduction of spacings below the minimum acceptable values.

18.2 Friction between surfaces shall not be used as a means to reduce the likelihood of shifting or turning of a live part, but a properly applied lock washer or the like may be used.

18.3 A component such as a rectifier element, a control switch, a lampholder, an attachment-plug receptacle, or a plug connector shall be mounted securely, and the likelihood of the component turning shall be reduced by means other than friction between surfaces.

Exception No. 1: A switch need not be restricted from turning, if all of the following conditions are met:

a) The switch is a plunger or other type that does not tend to rotate when operated (a toggle switch is considered to be subject to forces that tend to turn the switch);

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

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

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

Exception No. 2: A lampholder of the type in which the lamp cannot be replaced, such as a sealed neon pilot or indicator light need not be restricted from turning, if rotation is unlikely to reduce spacings below the minimum acceptable value.

18.4 The likelihood that a small stem-mounted device having a single-hole mounting means may rotate may be reduced by a properly applied lock washer.

19 Protection Against Corrosion

19.1 Iron and steel parts shall be protected against corrosion by enameling, painting, galvanizing, plating, or an equivalent means. For outdoor-use units, see the corrosion protection requirements specified in 49.2, and Metallic Coating Thickness Test, Section 52.

Exception No. 1: Bearings, laminations, and other minor parts of iron or steel, such as washers and screws, need not be protected against corrosion.

Exception No. 2: A part the corrosion of which would not result in a risk of fire, electric shock, or injury to persons need not be protected against corrosion.

20 Supply Connections

20.1 A unit shall have provision for the connection of a wiring system.

20.2 A knockout in a sheet-metal enclosure shall be secured, and shall be removable without undue deformation of the enclosure.

20.3 A knockout shall be surrounded by a flat surface to accommodate seating of a conduit bushing or locknut of the appropriate size.

20.4 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 employed, there shall not be less than 3 nor more than 5 full threads in the metal, and the construction of the device shall be such that a conduit bushing can be attached in the intended manner.

20.5 If threads for the connection of conduit are not tapped all the way through a hole in an enclosure wall, conduit hub, or the like, there shall not be less than 3-1/2 threads in the metal and there shall be a smooth, rounded inlet hole for the conductors. The hole shall afford protection to the conductors equivalent to that provided by a standard conduit bushing and shall have an internal diameter approximately the same as that of the corresponding trade size of rigid conduit.

20.6 For an enclosure not provided with conduit openings or knockouts, spacings not less than the minimum required in Section 30, Spacings, shall be provided between uninsulated live parts and a conduit bushing installed at any location likely to be used during installation. Permanent marking on the enclosure, a template, or a full-scale drawing furnished with the device may be used to specify locations that may be used.

20.7 A field-wiring compartment in which supply connections are to be made shall be located so that the connections will be accessible for inspection after the unit is installed as intended.

20.8 A field-wiring compartment intended for connection of a wiring system shall be attached to the unit so that the likelihood of turning is reduced.

20.9 An outlet box, terminal box, wiring compartment, or the like in which connections to the supply circuit will be made in the field shall be free from any sharp edges, including screw threads, a burr, a fin, a moving part, or the like, that may abrade the insulation on conductors or otherwise damage the wiring.

20.10 Flexible cord of the extra hard usage type, such as Type S, ST, SO, and the like, may be used as external interconnection from a unit to the field wiring compartment.

21 Wiring Terminals and Leads

21.1 A field-wiring terminal or lead shall be rated for the connection of a conductor or conductors having an ampacity of 135 percent of the rating of the unit.

21.2 A wiring terminal shall be provided with a pressure terminal connector.

Exception No.1: A pressure terminal connector need not be provided if the following conditions are met:

a) A terminal assembly rated for the application shall be:

1) Supplied by the manufacturer – installed or shipped separately; or

2) Specified in a marking on the unit in accordance with 46.7 and 46.8;

b) A fastening device, such as a stud, nut, bolt, spring or flat washer, or the like, as required for an effective installation, shall either be provided as part of the terminal assembly specified in (a) or be mounted on or separately packaged with the unit;

c) The installation of the terminal assembly specified in (a) shall not involve the loosening or disassembly of parts other than a cover or other part giving access to the terminal location;

d) The means for securing the terminal connectors shall be readily accessible for tightening before and after installation of conductors;

e) If a pressure terminal connector provided in a terminal assembly requires the use of a special tool for securing the conductor, any necessary instructions shall be included in the assembly package or with the unit (see 46.9); and

f) After installation of the pressure terminal connector in the intended manner, the unit shall comply with the requirements in this standard.

Exception No. 2: A wire-binding screw may be employed at a wiring terminal intended for connection of a No. 10 AWG (5.3 mm^2) or smaller conductor. See 21.4 – 21.7.

Exception No. 3: A wiring terminal need not be provided with a pressure terminal connector if the terminal is intended for connection of a No. 8 AWG (8.4 mm^2) or larger conductor, and the unit complies with the requirements in Exception No. 1.

21.3 A wiring terminal shall be restricted from turning or shifting in position by a means other than friction between surfaces. This may be accomplished by two screws or rivets; by square shoulders or mortises; by a dowel pin, lug, or offset; by a connecting strap or clip fitted into an adjacent part, or by an equivalent method.

21.4 A wire-binding screw at a field-wiring terminal shall not be smaller than No. 10 and shall be rated for connection of a No. 10 AWG (5.3 mm^2) or smaller conductor.

Exception No. 1: A No. 8 screw may be used at a terminal intended only for the connection of a No. 14 AWG (2.1 mm^2) conductor.

Exception No. 2: A No. 6 screw may be used for the connection of a No. 16 AWG (1.3 mm^2) or No. 18 AWG (0.82 mm^2) control-circuit conductor.

21.5 A wire-binding screw shall thread into metal.

21.6 A terminal plate tapped for a wire-binding screw shall be of metal not less than 0.050 inch (1.27 mm) thick and shall be tapped to provide at least two full threads. The metal may be extruded at the tapped hole to provide two full threads.

Exception No. 1: A plate not less than 0.030 inch (0.76 mm) thick may be used if the tapped threads have adequate mechanical strength when subjected to the Tightening Torque Test, Section 42.

Exception No. 2: Two full threads are not required for a terminal in a low-voltage limited-energy or isolated limited-energy circuit if a lesser number of threads results in a secure connection in which the threads will not strip when subjected to the Tightening Torque Test, Section 42.

21.7 Upturned lugs, a cupped washer, or the equivalent shall be capable of retaining a conductor of the size specified in 21.4 under the head of the screw or washer.

21.8 The free length of a lead inside an outlet box or wiring compartment shall be 6 inches (152 mm) or more if the lead is intended for supply connection.

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

21.10 A terminal for connection of a grounded supply conductor shall be made of, or plated with, metal substantially white in color and shall be readily distinguishable from other terminals.

Exception: Identification of the grounded supply terminal may be clearly shown in some other manner, such as on an attached wiring diagram.

21.11 The insulation on a lead for the connection of a grounded supply conductor shall be white or natural gray, and shall be readily distinguishable from the other leads.

22 Current-Carrying Parts

22.1 A current-carrying part shall be of silver, copper, a copper alloy, or other material rated for the application.

22.2 Aluminum used as a current-carrying part shall be acceptable with respect to heating, oxidation, and connection of dissimilar metals. A wire terminal or connector between aluminum and a dissimilar metal in which corrosion can occur shall be evaluated by the heat-cycling test specified in the Standard for Wire Connectors for Use With Aluminum Conductors, UL 486B.

22.3 Plated iron or steel may be used for a current-carrying part if:

a) Acceptable in accordance with 3.1;

b) Within a motor, or associated governor; or

c) In a secondary circuit rated 42.4 volts peak – 30 volts rms – or less.

22.4 Stainless steel and other corrosion-resistant alloys may be used for current-carrying parts.

22.5 A live screwhead or nut on the back of a base or panel shall be recessed not less than 1/8 inch (3.2 mm), and covered with a waterproof, insulating sealing compound that will not melt at a temperature 15EC (27EF) higher than the normal operating temperature of the compound, but not less than 65EC (149EF).

Exception: A part that is staked, upset, or otherwise reliably restricted from loosening need not be recessed, but:

a) Shall be insulated from the mounting surface by material other than sealing compound; or

b) Shall comply with the spacing requirements specified in Table 30.2.

23 Internal Wiring

23.1 General

23.1.1 The internal wiring of a unit shall be rated for the application. Among the factors to be considered are temperature, voltage, current, and the need for mechanical protection.

23.1.2 Thermoplastic-, neoprene-, and rubber-insulated wire used for internal wiring shall be rated for the application, and shall comply with the requirements in Table 23.1.

Exception: Thermoplastic-insulated wire connected in an isolated limited-energy circuit' located where it is not subjected to mechanical damage and segregated from other circuits, may have an insulation thickness not less than 0.013 inch (0.33 mm). Wiring in such a circuit may be grouped in supplementary tubing rated for the application to provide the segregation from other circuits and protection against mechanical damage. See 23.1.4

Table 23.1
Characteristics of internal wiring

Insulation	Nominal thickness inch	(mm)	Braid or jacket required	Nominal thickness of braid or jacket, inch	(mm)
Thermoplastic or neoprene	1/32[a]	(0.8)	No[a]	–	
Rubber	1/32[b]	(0.8)	Yes[b]	1/64[b]	(0.4)
Cross-linked synthetic polymer	1/64	(0.4)	No	–	

[a] The thickness may be 1/64 inch (0.4 mm) if the wire is provided with an additional braid or jacket having a thickness of not less than 1/64 inch.

[b] For heat-resistant rubber, other than a silicone type, the wall thickness shall not be less than 3/64 inch (1.2 mm). No braid is required.

23.1.3 If the use of a short length of insulated conductor, such as a short coil lead, is not practical, insulating tubing may be used on a conductor. The tubing shall be subjected to sharp bends, tension, compression, or repeated flexing, or contact with sharp edges, projections, or corners during intended use. See 23.1.4.

Exception: Tubing shall not be used if the unit is intended for use in wet locations.

23.1.4 Polyvinyl chloride tubing shall not be less than 0.017 inch (0.43 mm) thick at any point. For insulating tubing of other materials, the thickness of the tubing shall provide the mechanical strength to withstand abrasion; and properties such as cut-through resistance, flame resistance, dielectric properties, and heat- and moisture-resistant characteristics that are equivalent to 0.017 inch thick polyvinyl chloride tubing.

23.2 Protection of wiring

23.2.1 Wires, including accessible and internal wiring (see 16.1), within an enclosure, compartment, raceway, or the like shall be located or protected to reduce the likelihood of contact with any sharp edge, burr, fin, moving part, or the like that can damage the conductor insulation.

Exception: Accessible internal wiring need not be protected if it is located and secured within the enclosure so that it is not likely to be subjected to stress or mechanical damage.

23.2.2 A hole through which insulated wires pass in a sheet metal wall within the overall enclosure of a unit shall be provided with smooth, rounded surfaces upon which the wires may bear, to reduce the likelihood of abrasion of the insulation.

23.3 Electrical connections

23.3.1 An insulated or uninsulated aluminum conductor used as internal wiring, such as for interconnection between current-carrying parts or in a component winding, shall be terminated at each end by a method rated for the combination of metals involved at the connection points.

23.3.2 With reference to 23.3.1, a pressure wire connector used as a terminating device shall be rated for use with aluminum conductors under the conditions involved – for example, temperature, heat cycling, and vibration.

23.3.3 A splice or connection shall be mechanically secure and shall make reliable electrical contact.

23.3.4 A soldered connection shall be mechanically secured before being soldered. A hand-soldered connection shall be mechanically secured, by a means such as bending or the equivalent, prior to being soldered.

Exception: A wave- or lap-solder connection to a printed-wiring board need not have additional mechanical security before soldering.

23.3.5 A splice shall be provided with insulation equivalent to that of the wires involved unless permanent spacings will be maintained between the splice and other metal parts. An acceptable splice may consist of:

a) A splicing device, such as a pressure wire connector, may be employed if insulated for the voltage and temperature involved; or

b) Two layers of thermoplastic tape, two layers of friction tape, or one layer of friction tape and one layer of rubber tape rated for the application may be used on a splice if the voltage involved is less than 250 volts. Thermoplastic tape shall not be wrapped over a sharp edge.

Exception: Splices within coil windings need not be provided with equivalent insulation.

23.3.6 If internal wiring is stranded, loose strands of wire shall not contact other uninsulated live parts of opposite polarity or dead metal parts. At a wire-binding screw, this may be accomplished by using upturned ends or lugs, a cupped washer, barriers, soldering all strands of wire together, or other equivalent means to hold the wires under the head of the screw. Other acceptable means of retaining the loose stranded internal wiring in position are use of a pressure terminal connector, a soldering lug, or a crimped eyelet.

23.3.7 An open-end spade lug is not acceptable unless an additional means, such as upturned ends on the lug, or bosses or shoulders on the terminal, is provided to hold the lug in place if the binding screw or nut loosens.

24 Separation of Circuits

24.1 General

24.1.1 Insulated conductors of different circuits – see 24.1.3 – within a unit, including wires in a terminal box or compartment, shall be separated by barriers or shall be segregated, and shall, in any case, be separated or segregated from uninsulated live parts connected to different circuits.

Exception: For insulated conductors of different circuits, if each conductor is provided with insulation rated for the highest of the circuit voltages, no barrier or segregation is necessary.

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

24.1.3 For the purpose of the requirement in 24.1.1, different circuits include:

a) Circuits connected to the primary and secondary windings of an isolation transformer;

b) Circuits connected to different isolated secondary windings of a multi-secondary transformer; and

c) Circuits connected to secondary windings of different transformers.

24.2 Separation barriers

24.2.1 A barrier used to provide separation between the wiring of different circuits shall be grounded metal or insulating material:

a) Classed V-2 or less flammable in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94;

b) No less than 0.028 inch (0.71 mm) thick; and

c) Supported so that it is not readily deformed so as to defect its purpose.

24.2.1 revised August 24, 1998

24.2.2 A barrier used to provide separation between field wiring of one circuit and field or factory wiring or uninsulated live parts of another circuit shall be spaced no more than 1/16 inch (1.6 mm) from the enclosure walls and interior mechanisms, component-mounted panels, and other parts that serve to provide separated compartments.

24.3 Field wiring

24.3.1 A unit shall be constructed so that a field-installed conductor of a circuit shall be segregated as specified in 24.3.2 or separated by barriers as specified in 24.2.1 and 24.2.2 from:

a) Factory-installed conductors connected to any other circuit, unless the conductors of both circuits will be insulated for the maximum voltage of either circuit;

b) An uninsulated live part of another circuit and from an uninsulated live part if short circuit with it could result in a risk of fire, electric shock, electrical energy involving high circuit levels, or injury to persons; and

c) Field-installed conductors connected to any other circuit unless both circuits are Class 2 or Class 3 or both circuits are other than Class 2 or Class 3, and both circuits will be insulated for the maximum voltage of either circuit.

Exception: A field-installed conductor need not be separated from a field wiring terminal of a different circuit if the field wiring will be insulated for the maximum voltage of either circuit and both circuits are Class 2 or Class 3 or both circuits are other than Class 2 or Class 3.

24.3.2 Segregation of a field-installed conductor from other field-installed conductors and from an uninsulated live part connected to another circuit may be accomplished by locating an opening in the enclosure for the conductor opposite to the conductor terminals so that, when the installation is complete, the conductors and parts of different circuits are separated by a minimum of 1/4 inch (6.4 mm). In determining if a unit having such openings complies with this requirement, the unit is to be wired as in service including 6 inches (152 mm) of slack in each conductor within the enclosure. Not more than average care is to be exercised in routing the wiring and stowing the conductor slack into the wiring compartment.

24.3.3 With reference to 24.3.2, if the number of openings in the enclosure does not exceed the minimum required for the proper wiring of the unit, and if each opening is located opposite a set of terminals, it is to be assumed that a conductor entering an opening will be connected to the terminal opposite that opening. If more than the minimum number of openings are provided, the possibility of a conductor entering an opening other than the one opposite the terminal to which it is intended to be connected and the likelihood of it contacting insulated conductors or uninsulated current-carrying parts connected to a different circuit is to be investigated.

25 Insulating Materials

25.1 A barrier or integral part, such as an insulating washer or bushing, and a base or a support for mounting live parts shall be moisture-resistant material that is rated for the temperature and stresses to which it will be subjected under conditions of use.

25.2 An insulating material shall be rated for the application. Materials such as mica, some molded compounds, and certain refractory materials may be used for the sole support of live parts. With respect to acceptable ratings, consideration is to be given to:

a) The material's mechanical strength, resistance to ignition, dielectric strength, insulation resistance, and heat-resistant qualities, in both the aged and unaged conditions;

b) The degree to which it is enclosed; and

c) Any other feature affecting the risk of fire, electric shock, or injury to persons.

Exception: A polymeric material complying with UL 746C, the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, may be used.

25.3 Ordinary vulcanized fiber may be used for insulating bushings, washers, separators, and barriers, but shall not be used as the sole support for uninsulated live parts.

26 Switches and Controls

26.1 A switch or other control device shall have current and voltage ratings not less than those of the circuit that it controls when the unit is operated in its intended manner.

26.2 A primary-circuit switch that controls an inductive load with a power factor less than 75 percent, such as a transformer or some ballasts, and that does not have an inductive rating shall be either:

a) Rated not less than twice the maximum load current under normal operating conditions; or

b) Investigated for the application.

26.3 A switch that controls a tungsten-filament lamp shall have a tungsten-filament-lamp current rating in accordance with the Standard for Special-Use Switches, UL 1054, not less than the maximum current it will control.

Exception: A switch not having a tungsten-filament-lamp current rating and rated 3 amperes or more may be used to control a 15-watt or smaller lamp.

26.4 If unintentional operation of a switch can result in a risk of injury to persons, the actuator of the switch shall be located or guarded so that such operation is unlikely. The actuator may be guarded by recessing, ribs, barriers, or the like.

26.5 An on-off switch, provided to de-energize a unit, shall have a marked off position so that the operator can readily determine by visual inspection if the unit is de-energized.

27 Overload-Protective Devices

27.1 An overload-protective device, the intended functioning of which requires renewal, replacement, or resetting, shall be readily accessible. See 16.6.

Exception: An overload-protective device that would ordinarily be unknown to the user because of its location and omission of reference to the device in the operating instructions, circuit diagrams, and other instructional materials provided with the unit need not be readily accessible.

27.2 With reference to 27.1, a control-circuit fuse is not considered to require renewal as a result of it's intended function if the fuse and the load are contained within the same enclosure.

27.3 A circuit breaker connected in the supply circuit shall simultaneously open all ungrounded conductors.

27.4 A protective device shall be inaccessible from outside a unit without opening a door or cover, and resetting shall not require exposure of protected or enclosed live parts.

Exception: The operating handle of a circuit breaker, the operating button of a manually operable motor protector, and similar parts may project outside the enclosure.

28 Fuses and Fuseholders

28.1 A fuse and a fuseholder shall be rated for the voltage and current of the circuit in which they are connected. A fuseholder shall be of the enclosed-cartridge, plug, or extractor type. Plug fuses shall not be used in a unit rated more than 125 volts or 125/250 volts, 3 wire.

28.2 The screw shell of a plug-type fuseholder and an extractor-type fuseholder shall be connected to, and ahead of the load.

29 Printed Wiring

29.1 A printed-wiring board shall comply with the requirements in the Standard for Printed-Wiring Boards, UL 796, and shall be classed V-0, V-1, or V-2 in accordance with the requirements in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94. The use of material classed V-2 requires a closed bottom in the equipment beneath the material or the use of an equivalent barrier.

29.1 revised August 24, 1998

29.2 A resistor, capacitor, inductor, or other part that is mounted on a printed-wiring board to form a printed-wiring assembly shall be secured so that a force likely to be exerted on it during assembly, intended operation, or servicing of the unit will not result in a risk of electric shock or fire.

29.3 A barrier or a partition that is part of the unit, and that provides mechanical protection and electrical insulation of a component connected to the printed-wiring board shall comply with 24.2.1 and 24.2.2.

30 Spacings

30.1 General

30.1.1 The spacings at field-wiring terminals shall not be less than specified in Table 30.1:

a) Between terminals of opposite polarity;

b) Between terminals and inaccessible uninsulated dead metal parts not always of the same polarity; and

c) Between terminals and the enclosure or other accessible dead metal parts not always of the same polarity, including a fitting for conduit or armored cable.

Table 30.1
Spacings at field-wiring terminals

Potential involved, volts	Minimum spacings, inch (mm)			
	Through air		Over surface	
0 – 150	1/4	(6.4)	1/4	(6.4)
151 – 300	1/4	(6.4)	3/8[a]	(9.5)
301 – 600	3/8	(9.5)	1/2	(12.7)

NOTE – The spacing at a field-wiring terminal is measured with a wire of the rated ampacity installed.

[a] 1/4 inch (6.4 mm) at control-circuit terminals.

30.1.2 Spacings, other than at field-wiring terminals, between live parts of opposite polarity, and between live and dead metal parts shall not be less than specified in Table 30.2 or 30.3, whichever applies. If an uninsulated live part is not rigidly secured in position by means other than friction between surfaces, or if a movable dead metal part is in proximity to an uninsulated live part, the construction shall be such that the minimum spacings will be maintained.

Exception No. 1: The spacing requirements in Tables 30.2 and 30.3 do not apply to the inherent spacings of a component, such as a switch rated for the application. Such spacings shall comply with the requirements for the component. See 3.1.2.

Exception No. 2: The spacing requirements in Tables 30.2 and 30.3 do not apply to the spacings between coil windings and an uninsulated live part. These spacings shall comply with 30.1.4

Exception No. 3: If liners and barriers are used, the spacings may comply with 30.3.1.

Exception No. 4: As an alternative to the spacing requirements in Table 30.2 and Table 30.3, spacings may comply with 30.2.

Exception No. 5: The spacing requirements in Tables 30.2 and 30.3 do not apply to spacings for controlled environment applications. These spacings shall comply with 30.4.

Table 30.2
Spacings at other than field-wiring terminals

Potential involved, volts	Minimum spacings, inch (mm)			
	Through air		Over surface	
50 or less	1/16	(1.6)	1/16	(1.6)
51 – 150	1/8	(3.2)	1/4	(6.4)
151 – 300	1/4	(6.4)	3/8	(9.5)
301 – 600	3/8	(9.5)	1/2	(12.7)

Table 30.3
Spacings between an uninsulated live part, and a metal enclosure or other accessible dead metal part including a fitting for conduit or armored cable

Potential involved, volts	Minimum spacings through air and over surface, inch (mm)	
50 or less	1/16	(1.6)
51 – 150	1/4	(6.4)
151 – 600	1/2	(12.7)

30.1.3 Enameled or film-coated wire is considered to be an uninsulated live part with respect to requirements for spacings.

30.1.4 The spacings between a magnet-coil winding, and an uninsulated live part or grounded dead metal part shall be as specified in 30.1.1, or the coil shall be provided with an insulating barrier that complies with the requirements in 30.3.2.

30.1.5 A slot in a molded bobbin for guiding the crossover- or start-lead – unspliced at the windings – of a magnet-coil is an acceptable crossover-lead insulation, if the slot provides a graduated through-air spacing to the winding, increasing to the end turns.

30.1.6 Spacings between uninsulated live parts of opposite polarity, and between such parts and dead metal that may be grounded in service are not specified for parts of a low-voltage limited-energy circuit.

30.1.7 Spacings between uninsulated live parts of opposite polarity, and between such parts and dead metal that may be grounded in service are not specified for parts of an isolated limited-energy circuit. Spacings are to be subjected to the dielectric voltage-withstand test specified in 39.1(a).

30.1.8 The acceptability of spacings between live parts and dead metal parts connected to the enclosure within a device, such as a meter, shall be determined in accordance with the Dielectric Voltage-Withstand Test, Section 40.

30.1.9 Spacings in a motor shall comply with the spacing requirements in the Standard for Electric Motors, UL 1004.

30.2 Alternative spacings

30.2.1 As an alternative to the spacing requirements of Table 30.2 or Table 30.5, as appropriate, the spacing requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances For Electrical Equipment, UL 840, may be used. The spacing requirements of UL 840 shall not be used for field wiring terminals, or spacings to a dead metal enclosure. In determining the pollution degree and overvoltage category, the end-use application is to be considered, and may require characteristics different than those indicated in 30.2.2 and 30.2.3.

30.2.2 It is anticipated that the level of pollution expected or controlled for indoor use equipment will be pollution degree 2. For outdoor use equipment, pollution degree 3 is expected. Hermetically sealed or encapsulated enclosures, or coated printed wiring boards in compliance with the printed wiring board coating performance test in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, are considered pollution degree 1.

30.2.3 It is anticipated that a unit will be rated overvoltage category I and overvoltage category II as defined in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840.

30.2.4 In order to apply Clearance B (controlled overvoltage) clearances, control of overvoltage shall be achieved by providing an overvoltage device or system as an integral part of the product.

30.2.5 All printed wiring boards are considered to have a minimum comparative tracking index of 100 without further investigation.

30.3 Insulating liners or barriers

30.3.1 A barrier or the equivalent may be used to reduce the likelihood of wall-mounting screws from projecting into a compartment containing electrical parts and reducing spacings to less than that specified in 30.1.2.

30.3.2 An insulating liner or barrier of material, such as vulcanized fiber or thermoplastic employed in place of required spacings, shall not be less than 0.028 inch (0.71 mm) thick, and shall be so located or of such material that it will not be adversely affected by arcing.

Exception No. 1: Vulcanized fiber not less than 0.013 inch (0.33 mm) thick or mica not less than 0.0065 inch (0.165 mm) thick may be used:

a) In conjunction with an air spacing of not less than 50 percent of the minimum acceptable through-air spacing;

b) In a single-plate rectifier element of an isolated secondary circuit rated 50 volts rms or less; or

c) Between a heat sink and a metal mounting surface, including the enclosure, of an isolated secondary circuit rated 50 volts rms or less.

Exception No. 2: An insulating material having a thickness less than that specified may be used if, upon investigation, it is found to be acceptable for the application.

Exception No. 3: This requirement does not apply to insulation between a Class 2 secondary crossover lead, and the secondary winding to which the crossover lead is connected, the metallic enclosure, or the core of a transformer.

30.4 Controlled environment applications

30.4.1 The requirements in 30.4.2 – 30.4.6 and Tables 30.4 and 30.5 apply to units that are intended for use in controlled environment applications. See 2.3.

30.4.2 Spacings between field-wiring terminals of opposite polarity, and the spacings between a field-wiring terminal, and any uninsulated live or dead metal part not of the same polarity shall not be less than specified in Table 30.4.

Table 30.4
Spacings at field-wiring terminals
for controlled environment applications

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

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

Table 30.5
Primary-circuit spacings at other than field-wiring terminals and in motors
for controlled environment applications

Potential involved in volts rms (peak)		Minimum spacings, inch (mm)			
		Over surface		Through air	
0 – 50	(0 – 70.7)	3/64	(1.2)[b]	3/64	(1.2)[b]
51 – 125	(72.1 – 176.8)	1/16	(1.6)[b]	1/16	(1.6)[b]
126 – 250	(178.2 – 353.5)	3/32	(2.4)[b]	3/32	(2.4)[b]
251 – 600	(354.9 – 848.4)	1/2	(12.7)[a,b]	3/8	(9.5)[b]

[a] Film-coated wire is considered to be an uninsulated live part. However, a spacing of not less than 3/32 inch (2.4 mm) over surface and through air is acceptable between a dead metal part and film-coated wire that is rigidly supported and held in place on a coil.

[b] On printed-wiring boards, their connectors, and board-mounted electrical components, wired on the load side of line filters or similar voltage peak reduction networks and components, a minimum spacing of 0.0230 inch (0.580 mm) plus 0.0002 inch (0.005 mm) per volt peak shall be maintained over surface and through air between uninsulated live parts and any other uninsulated live or dead conductive parts not of the same polarity.

30.4.3 In primary circuits other than at field-wiring terminals, the spacings between an uninsulated live part and any live or dead uninsulated metal part not of the same polarity shall not be less than specified in Tables 30.4 and 30.5. If an uninsulated live part is not rigidly fixed in position by means other than friction between surfaces or if a movable dead metal part is in proximity to an uninsulated live part, the construction shall be such that the minimum spacings specified in Tables 30.4 and 30.5 will be maintained regardless of the position of the movable part.

Exception: A unit that complies with the requirements in 30.2 for alternative spacings need not comply with the spacings specified in Tables 30.4 and 30.5.

30.4.4 Primary-circuit spacings in controlled environment applications apply in all secondary circuits that are safety circuits and in all secondary circuits supplied by a transformer winding of a 200 volt-ampere or greater capacity – maximum available power – at a potential greater than 100 volts. The spacings in all other secondary circuits that are not safety circuits are investigated on the basis of the dielectric voltage-withstand test described in 39.1. See 30.4.6.

30.4.5 Primary-circuit spacings in controlled environment applications do not apply in an isolated internal secondary circuit starting at any point beyond:

a) An impedance that limits the available power to less than 200 volt-amperes under all conditions; or

b) A fuse or other overcurrent-protective device other than an automatically reset type having a current rating in amperes not exceeding

$$\frac{100\ Va}{V_{max}}$$

in which V_{max} is the open-circuit voltage of the secondary in question in volts rms with the primary connected to maximum rated voltage.

30.4.6 With respect to 30.4.4, maximum available power is to be measured using a variable resistor connected in place of the circuit in question. For a transformer having multiple secondary windings, all measurements on one secondary-winding circuit are to be made with all other windings unloaded.

31 Secondary Circuits

31.1 All safety circuits and all other secondary circuits in units that are intended for use in controlled environmental applications shall comply with the requirements for primary circuits.

Exception: Circuits that comply with 30.2 for alternative spacings, and 31.2 – 31.8 need not comply with the requirements for primary circuits.

31.2 A circuit supplied from a Class 2 transformer rated 30 volts rms need not be investigated.

31.3 Printed wiring assemblies and secondary circuits that do not involve a risk of electric shock need not be investigated. However, power supplies and power distribution components such as bus bars, wiring, connectors and similar parts up to and including printed wiring receptacles and connectors shall be investigated. Printed wiring boards and insulated wire used in such circuits shall be rated for the application.

31.4 Circuits supplied by an isolating transformer need not be investigated if the open-circuit potential at the point of connection to the supply is not more than 42.4 volts a-c peak, and the energy available to the circuit is limited:

a) So that the current under any condition of loading including short circuit is not more than 8 amperes measured as specified in the Open-Circuit Potential Test, Section 37, after 1 minute of operation by the isolating transformer, or the value of a fixed impedance or reliable regulating network; or

b) By a fuse or nonadjustable manually reset circuit protective device that is rated or set at not more than the value specified in Table 31.1.

Table 31.1
Rating for fuse or circuit protector

Open-circuit potential, volts peak	Current rating, amperes
0 – 21.2	5
21.3 – 42.4	3.2

31.5 If the performance of a regulating network used to limit the voltage or current in accordance with 31.4(a) may be adversely affected by either a short circuit or open circuit of any single component in the network, the likelihood of such an occurrence shall be determined by investigation of that component.

31.6 In a circuit of the type described in 31.4, the secondary winding of the transformer, the fuse or circuit-protective device, or the regulating network and all wiring up to the point at which the current and voltage are limited are to be investigated under the applicable requirements for internal wiring, spacings, and the like, in this standard.

31.7 Low-voltage limited-energy circuits rated not more than 0.5 mA may be connected to the frame of the unit.

31.8 If the frame is used as a current-carrying part of a secondary circuit, a hinge or other movable part shall not be relied upon to carry current.

32 Grounding Connections

32.1 A unit shall comply with the grounding requirements specified in 32.2 – 32.10.

32.2 A unit shall be provided with a terminal or lead for grounding all dead metal parts that are exposed or are likely:

a) To be touched by a person during operation or adjustment of the unit; and

b) To become energized as a result of an electrical fault.

32.3 To determine if a part is likely to become energized, factors, such as the proximity of wiring, the results of a dielectric voltage-withstand test after a test such as the overload or the endurance test, and the results of appropriate burnout tests are to be evaluated.

32.4 A grounding terminal or lead shall be located so that it is unlikely to be removed during normal servicing, and the connection to the part to be grounded shall penetrate any nonconductive coating, such as paint or vitreous enamel, on the part.

32.5 A wire-binding screw for the connection of a field-installed equipment grounding conductor shall have a green colored head that is either hexagonal, slotted, or both. A pressure wire connector intended for connection of such a conductor shall be plainly identified by being marked "G," "GR," "GND," "Ground," "Grounding," or the like, or by a marking on a wiring diagram attached to the unit.

32.6 The grounding terminal shall be rated for securing a conductor of a size rated for the application in accordance with Table 33.2.

32.7 A soldering lug, a screwless (push-in) connector, a quick-connect, or other friction-fit connector shall not be used as a grounding terminal.

32.8 A grounding lead shall be a size specified in Table 33.2 or larger. A grounding lead shall have a free length of at least 6 inches (152 mm) and the surface of the insulation shall be green with or without one or more yellow stripes. No other lead in a field-wiring compartment or visible to the installer shall be so identified.

32.9 A grounding connection, grounding conductor, enclosure, frame, component mounting panel, or any other part connected to earth ground shall not carry current except during an electrical fault.

Exception: Low-voltage limited-energy circuits rated not more than 0.5 mA that comply with 31.7 may be used.

32.10 A grounded (neutral) circuit conductor shall not be connected to any grounding or bonding circuit or device in a unit.

33 Bonding of Internal Parts

33.1 With reference to 32.2, an exposed dead metal part that is likely to become energized by an electrical fault shall be bonded to the point of connection of the equipment-grounding means. See 32.3 and 32.4.

33.2 Uninsulated dead metal parts such as a cabinet, component enclosure, and cover shall be electrically bonded together if contact by the user or service personnel is likely.

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

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

b) Not likely to become energized because uninsulated live parts are enclosed and wiring is positively separated from the panel or cover; or

c) Separated from live parts and wiring by a grounded or bonded interposing metal barrier or part such that the metal barrier will be the first to be subjected to an electrical fault.

33.3 A metal part, such as an adhesive-attached metal marking plate, a screw, or a handle, located on the outside of an enclosure or cabinet, need not be bonded if it is isolated from electrical components and wiring by a grounded metal part so that it is not likely to become energized, or it is separated from wiring and spaced from uninsulated live parts as if it were a grounded part. Other parts not required to be bonded are small internal assembly screws, rivets, or other small fasteners, a handle for a disconnect switch, and a relay or contactor magnet and armature.

33.4 Uninsulated live parts and wiring shall be separated from a moving or movable part, such as a relay or contactor armature, a panel, or a cover by clamping, positioning, or an equivalent means that will maintain permanent separation.

33.5 An internal connection for bonding an internal part to the enclosure may employ a quick-connect terminal of the dimensions specified in Table 33.1 if the connector is not likely to be displaced, and the component is limited to use in a circuit having a branch-circuit protective device rated 20 amperes or less. A quick-connect terminal shall not be used for a connection to be made in the field.

Table 33.1
Dimensions for quick-connect bonding terminal

Terminal dimensions, inch (mm)
0.020 (0.51) by 0.187 (4.75) by 0.250 (6.35)
0.032 (0.81) by 0.187 (4.75) by 0.250 (6.35)
0.032 (0.81) by 0.205 (5.21) by 0.250 (6.35)
0.032 (0.81) by 0.250 (6.35) by 0.313 (7.95)

33.6 Bonding shall be accomplished by a metal-to-metal contact of parts or by a separate bonding conductor specified in 33.9 – 33.11.

33.7 A bonding conductor shall be copper, copper alloy, or other material rated for the application.

33.8 Ferrous metal in the grounding path shall be protected against corrosion by enameling, galvanizing, plating, or other equivalent means.

Exception: Corrosion protection need not be provided at electrical connections.

33.9 A separate bonding conductor shall be protected from mechanical damage or located within an outer enclosure, and shall not be secured by a removable fastener used for a purpose in addition to bonding unless the bonding conductor is not likely to be omitted if the fastener is removed and replaced as intended. A bonding conductor shall be in metal-to-metal contact with the parts to be bonded.

33.10 A splice shall not be employed in a bonding conductor.

33.11 A separate bonding conductor shall not be smaller than the size specified in Table 33.2, or smaller than the conductor supplying the component.

Exception: A separate bonding conductor need not comply with the sizes in Table 33.2 if it complies with 33.12.

Table 33.2
Grounding/bonding conductor size

Maximum rating or setting of branch circuit overcurrent device in circuit, amperes	Size of grounding/bonding conductor[a]					
	Copper wire		Aluminum wire		Rigid conduit or pipe trade size, inch	Electrical metallic tubing, trade size, inch
	AWG	(mm^2)	AWG	(mm^2)		
15	14	(2.1)	12	(3.3)	1/2	1/2
20	12	(3.3)	10	(5.3)	1/2	1/2
30	10	(5.3)	8	(8.4)	1/2	1/2
40	10	(5.3)	8	(8.4)	1/2	1/2
60	10	(5.3)	8	(8.4)	1/2	1/2
100	8	(8.4)	6	(13.3)	1/2	1/2
200	6	(13.3)	4	(21.2)	1/2	1
300	4	(21.2)	2	(33.6)	3/4	1-1/4
400	3	(26.7)	1	(42.4)	3/4	1-1/4
500	2	(33.6)	1/0	(53.5)	3/4	1-1/4
600	1	(42.4)	2/0	(67.4)	3/4	1-1/4
800	1/0	(53.5)	3/0	(85.0)	1	2
1000	2/0	(67.4)	4/0	(107.2)	1	2
1200	3/0	(85.0)	250 MCM	(127.0)	1	2

[a] Or equivalent cross-sectional area

33.12 If more than one size of branch-circuit overcurrent-protective device is used, the size of a component-bonding conductor is to be based on the rating of the overcurrent-protective device providing protection for that component. For a component individually protected by an overcurrent-protective device rated less than the overcurrent-protective device used in the supply circuit, a bonding conductor is to be sized on the basis of the component overcurrent-protective device rating individually protecting the component.

PERFORMANCE

34 General

34.1 A representative sample of a unit is to be subjected to the tests described in Sections 35 – 43. Unless otherwise specified, all tests are to be conducted at the applicable voltage specified in Table 34.1, and at rated frequency. A unit rated 50 – 60 hertz is to be tested at 60 hertz.

Table 34.1
Values of test voltages

Rated voltages	Test voltages
110 – 120	120
121 – 219	Rated voltage
220 – 240	240
241 – 253	Rated voltage
254 – 277	277
278 – 439	Rated voltage
440 – 480	480
481 – 525	Rated voltage
550 – 600	600

34.2 A unit having primary or secondary voltage adjustment taps shall comply at any setting including the maximum and intermediate positions.

35 Power Input Test

35.1 The amperage or wattage input to a unit shall not be more than 115 percent of the rated value when the unit is connected to a supply adjusted to the test voltage specified in Table 34.1.

36 Draining of Charge Test

36.1 The difference of potential between the supply terminals of a unit shall not be more than 50 volts one minute after the unit has been disconnected from the supply circuit.

37 Open-Circuit Potential Test

37.1 With reference to 31.4(a), the open-circuit voltage of a transformer is to be measured with the primary of the unit connected to the voltage specified in Table 34.1 and all load circuits disconnected from the unit under test. The measurement may be made at the output terminals of the transformer or unit. If a tapped transformer winding is used to supply a full-wave rectifier, the voltage measurement is to be made from each end of the winding to the tap.

38 Temperature Test

38.1 A unit shall not reach a temperature at any point high enough to result in a risk of fire, to damage any material used, or to exceed the temperature rises specified in Table 38.1. The unit shall be mounted as intended in service and connected as described in 34.1.

Table 38.1
Maximum temperature rises

Materials and components	EC	EF
1. Wood and other combustible materials	65	117
2. Rubber- or thermoplastic- insulated wire and cord	35[a,b]	63[a,b]
3. Other types of insulated wire	c	c
4. Fuses (miniature)	65	117
5. Capacitor:		
Electrolytic	40[d]	72[d]
Other than electrolytic	65[d]	117[d]
6. Sealing compound	e	e
7. Selenium rectifier	50[f,g]	90[f,g]
8. Silicon rectifier	75[g]	135[g]
9. Class 105 transformer insulation systems:		
Thermocouple method	65[h]	117[h]
Resistance method	75	126
10. Class 130 transformer insulation systems		
Thermocouple method	85[h]	153[h]
Resistance method	95	171
11. Class 155 transformer insulation systems		
Thermocouple method	110	198
Resistance method	115	207
12. Class 180 transformer insulation systems		
Thermocouple method	125	225
Resistance method	135	243
13. Class 200 transformer insulation systems		
Thermocouple method	140	252
Resistance method	150	270
14. Class 220 transformer insulation systems		
Thermocouple method	155	279
Resistance method	165	297
15. Field wiring terminals	50	90

[a] The temperature limits on phenolic composition and on rubber and thermoplastic insulation do not apply to a compound that has been investigated and found to have the required heat-resistant properties.

[b] A short length of rubber- or thermoplastic-insulated flexible cord inside the unit is not prohibited from being exposed to a temperature of more than 60EC (140EF) when supplementary insulation rated for the measured temperature and having the required dielectric properties is employed on each individual exposed conductor.

[c] For insulated conductors, reference is to be made to the National Electrical Code ANSI/NFPA 70-1996. The maximum temperature rise is not to exceed 25EC (45EF) less than the temperature limit of the wire except as in note b.

(Continued)

Table 38.1 (Cont'd)

[d] A capacitor that operates at a temperature rise of more than 40EC (72EF) for electrolytic and more than 65EC (117EF) for other types is to be investigated on the basis of its marked temperature limit. In any case, the measured temperature shall not exceed the temperature rating of the capacitor based on a 25EC (77EF) ambient temperature.

[e] The temperature on a wiring terminal or less is measured at the point most likely to be contacted by the insulation of a conductor installed as in actual service. Unless a thermosetting compound, the maximum sealing compound temperature, when corrected to a 25EC (77EF) ambient temperature, is 15EC (27EF) less than the softening point of the compound as determined in accordance with the Test for Softening Point by the Ball and Ring Apparatus ASTM, E28-67(1982).

[f] A temperature rise of 60EC (108EF) is acceptable when the stack assembly is insulated with phenolic composition or other insulating material suitable for a temperature of 150EC (302EF).

[g] The limitation does not apply to material rated for a higher temperature limit.

[h] At a point on the surface of a coil where the temperature is affected by an external source of heat, the temperature rise is to be measured by means of a thermocouple and may be 5EC (9EF) higher than that specified when the temperature rise of the coil as measured by the resistance method is not more than that specified.

Table 38.1 revised August 24, 1998

38.2 All values for temperature rises in Table 38.1 are based on an assumed ambient temperature of 25EC (77EF). However, tests may be conducted at any ambient temperature within the range of 10 – 40EC (50 – 104EF).

38.3 A protective device shall not operate during the temperature test.

38.4 A unit intended for mounting or support in more than one position, or in a confined location is to be tested in the position representing the most severe conditions. An adjacent mounting or supporting surface is to consist of 1-inch (25.4-mm) thick minimum soft-pine boards.

38.5 A supporting means formed of soft rubber or rubberlike material is to be removed prior to the temperature test. If the supporting means has a metal insert, such as a screw or rivet, the test is to be conducted with the unit supported by the metal insert. At the request of the manufacturer, the test may be conducted without any means of support.

38.6 A thermocouple junction and the adjacent thermocouple lead wires are to be held securely in thermal contact with the surface of which the temperature is being measured. Usually, adequate thermal contact will result from securely taping or cementing the thermocouple in place, but, if a metal surface is involved, brazing or soldering the thermocouple to the metal may be necessary.

38.7 Coil and winding temperatures are to be measured by thermocouples located on exposed surfaces. In an alternating-current motor, the thermocouples are to be attached to the integrally-applied insulation of the coil wire.

Exception: The change-of-resistance method may be used for a coil that is inaccessible for attaching thermocouples, such as a coil immersed in sealing compound, wrapped with thermal insulation such as asbestos, or wrapped with more than two layers of material such as cotton, paper, or rayon that is more than 1/32 inch (0.8 mm) thick.

38.8 With reference to the Exception to 38.7, the temperature rise of a winding is to be determined by the change-of-resistance method by comparing the resistance of the winding at a temperature determined by calculation with the resistance at a known temperature using the formula:

$$t = \frac{R}{r}(k + t_1) - (k + t_2)$$

in which:

t is the temperature rise of the winding in degrees C;

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

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

t_1 is the room temperature in degrees C at the beginning of the test;

t_2 is the room temperature in degrees C at the end of the test; and

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

38.9 The winding is to be at room temperature at the start of the test.

38.10 Thermocouples are to consist of wires not larger than No. 24 AWG and not smaller than No. 30 AWG. When thermocouples are used in determining temperatures in electrical equipment, it is common practice to employ thermocouples consisting of No. 30 AWG iron and constantan wire and a potentiometer type instrument. Such equipment is to be used whenever referee temperature measurements by thermocouples are necessary. The thermocouples and related instruments are to be accurate and calibrated in accordance with standard laboratory practice. The thermocouple wire is to comply with the requirements for special thermocouples as listed in the table of limits of error of thermocouples in Temperature Measurement Thermocouples, ANSI MC96.1-1982.

38.11 A temperature is considered to be constant when three successive readings taken at intervals of 10 percent of the previously elapsed duration of the test, but not less than 15 minutes, indicate no further increase.

39 Dielectric Voltage-Withstand Test

39.1 While still in a heated condition, a unit shall withstand for 1 minute without breakdown the application of a 60-hertz essentially sinusoidal potential of:

a) One thousand volts plus twice the maximum rated voltage between the primary circuit and dead metal parts, and the primary and secondary circuits;

b) One thousand volts between live and dead metal parts of a motor;

c) Five hundred volts between a secondary circuit operating at 50 volts or less and dead metal parts; and

d) 1000 volts plus twice the maximum rated secondary circuit voltage between a secondary circuit operating at more than 50 volts and dead metal parts.

39.2 To determine if a unit complies with the requirements in 39.1, the unit is to be tested using a 500 volt-ampere or larger capacity transformer, the output voltage of which can be varied. The applied potential is to be increased from zero until the required test level is reached, and is to be held at that level for 1 minute. The increase in applied potential is to be at a substantially uniform rate as rapid as is consistent with correct indication of its value by a voltmeter.

40 Compression Test

40.1 When subjected to the test described in 40.2, an enclosure that is thinner than that specified in Tables 15.1 or 15.2 shall be constructed so that its deflection is not more than that of a sheet-metal enclosure of the maximum length and width and having the required thickness.

40.2 Force is to be applied to the end, side, and rear walls of each enclosure. The value of force and limit of deflection are not specified, but the force on each wall of both the test and reference enclosures is to be sufficient to result in a measurable deflection of the test enclosure. For the test, the enclosure is to rest on a smooth, solid, horizontal surface. A vertical force is to be applied to any point on the end, side or rear wall of the enclosure, through a rod having a 1/2-inch (12.7-mm) square, flat steel face.

41 Deflection Test

41.1 A drawn, embossed, flanged, or similarly strengthened door, front, or cover made of metal having a thickness less than that specified in Table 15.1 or 15.2 shall not deflect inward more than 1/4 inch (6.4 mm) when a vertical force of 100 pounds (445 N) is applied at any point on the door, front, or cover. The force is to be applied through a rod having a 1/2-inch (12.7-mm) square, flat steel face. The enclosure is to rest on its back on a smooth, solid, horizontal surface with the door closed and the front or cover secured as intended. If more than one test is necessary, separate samples may be used for additional tests.

41.2 If a flange on the upper edge of a telescoping door or cover is reduced in depth or is omitted, the door or cover shall not deflect more than 3/8 inch (9.5 mm) when subjected to a force of 100 pounds (445 N) applied at any point 1 inch (25.4 mm) from the edges. The test is to be conducted with the door or cover mounted on the enclosure in the intended manner, and the enclosure placed with its back on a smooth, solid, horizontal surface. The force is to be applied through the end of a rod having a 1/2-inch (12.7-mm) square, flat steel face.

42 Tightening Torque Test

42.1 With respect to Exception No. 2 of 21.6, the threads of a terminal plate shall not strip when subjected to the tightening torques specified in Table 42.1.

Table 42.1
Tightening torque for wire-binding screws

Size of terminal screw	Wire sizes to be tested, AWG[a]	Tightening torque		
		Pound-inches	(N•m)	(kg•m)
No. 6	16 – 22 (ST)	12	(1.4)	(0.14)
No. 8	14 (S)	16	(1.8)	(0.18)
	16 – 22 (ST)			
No. 10	10 – 14 (S)	20	(2.3)	(0.23)
	16 – 22 (ST)			

[a] ST – stranded wire; S – solid wire.

43 Static Load Test

43.1 A mounting means for a unit shall withstand the load test described in 43.2 without permanent deformation, breakage, or cracking of the mounting supports, the securing means, or that portion of the unit to which it is attached.

43.2 When mounted as recommended by the manufacturer, the mounting means of a unit shall support a static load of four times the load supported by the mounting means but not less than 20 pounds (9.1 kg):

a) Applied through the center of gravity of the unit in the downward direction; or

b) Applied evenly over the horizontal plane of the unit.

MANUFACTURING AND PRODUCTION TESTS

44 Dielectric Voltage-Withstand Test

44.1 Each unit shall withstand without electrical breakdown, as a routine production-line test, the application of a 40 – 70 Hz potential as specified in 39.1(a).

Exception: The test potential may be 3.0 times the voltage applied in 39.1(a) for 1 second.

44.2 The unit may be in a heated or unheated condition for the test.

44.3 The test is to be conducted when the unit is completely assembled. It is not intended that the unit be unwired, modified, or disassembled for the test.

Exception No.1: Parts such as snap covers or friction-fit knobs that would interfere with performing the test need not be in place.

Exception No 2: The test may be performed before final assembly if the test represents that for the completed unit.

44.4 The test equipment shall include a transformer having an essentially sinusoidal adequate output, a means of indicating the test potential, an audible or visual indicator of electrical breakdown, and either a manually reset device to restore the equipment after electrical breakdown or an automatic reject feature of any unacceptable unit.

44.5 If the output of the test equipment transformer is less than 500 volt-amperes, the equipment shall include a voltmeter in the output circuit to directly indicate the test potential.

44.6 If the transformer output is 500 volt-amperes or larger, the test potential may be indicated:

a) By a voltmeter in the primary circuit or in a tertiary-winding circuit;

b) By a selector switch marked to indicate the test potential; or

c) By a marking in a readily visible location to indicate the test potential of equipment having a single test potential output. If marking is used without an indicating voltmeter, the equipment shall include a positive means, such as an indicator lamp, to indicate that the manually reset switch has been reset following a dielectric breakdown.

44.7 Test equipment other than those described in 44.4 – 44.6 may be used if found to accomplish the intended factory control.

44.8 During the test, the primary switch or circuit breaker is to be in the on position and both sides of the primary circuit of the unit are to be connected together and to one terminal of the test equipment, and the second test-equipment terminal is to be connected to accessible dead metal.

RATINGS

45 Details

45.1 A unit shall have the following ratings:

a) Input voltage;

b) Number of phases for input;

c) Input frequency; and

d) Input amperes or kvar.

MARKINGS

46 General

46.1 A unit shall be plainly and permanently marked where it will be readily visible after installation with the following:

a) The manufacturer's name, trade name, or trademark;

b) A distinctive catalog number or the equivalent;

c) The voltage, frequency, and amperes or kvar;

d) The date or other dating period of manufacture not exceeding any three consecutive months;

e) The number of phases if the product is intended for use on a polyphase circuit. The symbol "Ø" may be used in place of the word "phase;" and

f) The amount of dielectric liquid, if any, in gallons.

Exception No. 1: The manufacturer's identification may be in a traceable code if the unit is identified by a brand or trademark owned by a private labeler.

Exception No. 2: The date of manufacture may be abbreviated or may be in a nationally accepted conventional code or in a code affirmed by the manufacturer provided that the code:

a) Does not repeat in less than 20 years; and

b) Does not require reference to the production records of the manufacturer to determine when the product was manufactured.

46.2 If a manufacturer produces or assembles a unit at more than one factory, each unit shall have a distinctive marking – which may be in code – by which it may be identified as the product of a particular factory.

46.3 A live heat sink or other part that is likely to be mistaken for dead metal, is at a potential that exceeds 30 volts rms (42.4 volts peak), and is not guarded as specified in 17.2.2 shall be permanently marked with the signal word "CAUTION," and with the following or equivalent: "Risk of Electric Shock – Plates (or other word describing the type of part) are live. Disconnect unit before servicing." The marking shall be located on the live part so as to make the risk of electric shock known before the part is likely to be touched. See 46.4 and 46.5.

46.4 A marking shall be located adjacent to the part being guarded to indicate that the cover or guard is to be replaced before operation of the unit.

46.5 A cautionary marking shall be permanent and shall be prefixed by the signal word "CAUTION" in letters not less than 1/8 inch (3.2 mm) high. The remaining letters shall not be less than 1/16 inch (1.6 mm) high.

46.6 A marking that is required to be permanent shall be molded, die-stamped, paint-stenciled; stamped or etched metal that is permanently secured; or indelibly stamped on a pressure-sensitive label secured by adhesive that, upon investigation, is found to comply with the requirements in the Standard for Marking and Labeling Systems, UL 969. Ordinary usage, handling, storage, and the like, of the unit are to be considered in determining whether a marking is permanent.

46.7 In accordance with Exception No. 1(a)(2) to 21.2, if a pressure terminal connector is not provided with a unit as shipped, the unit shall be marked to indicate which pressure terminal connector or terminal assembly package is to be used with the unit. This marking may be provided on the unit or on a tag attached to the unit.

46.8 The terminal assembly package mentioned in 46.7 shall be marked with an identifying marking, wire size, manufacturer's name, and trade mark or other descriptive marking by which the organization responsible for the product may be identified.

46.9 With reference to Exception No.1(e) to 21.2, if a pressure terminal connector provided with a unit (or in a terminal assembly) for a field installed conductor requires the use of a special tool for securing the conductor, necessary instructions for using the tool shall be provided. The instructions shall be included in a readily visible location such as on the connector, on a wiring diagram, on a tag secured to the connector, or in an assembly package provided with the unit.

46.10 With reference to the Exception to 17.3.3, a unit may be provided with a marking located adjacent to the part being guarded, to instruct the user that the cover or guard should be replaced before resuming operation of the unit.

46.11 A unit that exceeds the temperature limits specified in the third item in Table 39.1 – see the Exception to 39.1 – shall be legibly marked where readily visible after installation with the signal word "CAUTION" and the following or the equivalent: "Hot surfaces – To reduce the risk of burns – Do not touch."

47 Installation Instructions

47.1 Instructions for mounting shall be provided with each unit intended for permanent mounting.

47.2 The manufacturer's instructions provided with a unit that exceeds the temperature limits in the third item of Table 39.1 – see Exception to 39.1 – shall specify that the unit is to be installed so that it is not likely to be contacted.

OUTDOOR-USE UNITS

48 General

48.1 The requirements in Sections 48 – 53 supplement, and in some cases modify, the general requirements in Part II – Power Factor Correction Units.

49 Construction

49.1 General

49.1.1 The enclosure of an outdoor unit shall be protected against outdoor exposure in accordance with the requirements in this section.

49.1.2 Metals shall not be used in combination such as to cause galvanic action that may adversely affect an enclosure.

49.1.3 Hinges and other attachments shall be resistant to corrosion.

49.1.4 The requirements specified in 49.1.6 and 49.2 do not apply to a part, such as a decorative part, that is not required to form a part of the enclosure.

49.1.5 A nonmetallic enclosure is to be investigated for the effect of exposure to water and ultraviolet light in accordance with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

49.1.6 When a flexible cord is used as external interconnection in accordance with 20.10, the flexible cord shall be marked "W-A" in accordance with the Standard for Flexible Cord and Fixture Wire, UL 62.

Exception: The marking "W" is an acceptable alternative designation for "W-A."

49.1.6 revised April 11, 1996

49.2 Corrosion protection

49.2.1 A metallic enclosure shall be protected against corrosion as specified in 49.2.2 – 49.2.7.

Exception: Aluminum , stainless steel, polymeric materials, copper, bronze, or brass containing at least 80 percent copper may be used without additional protection against corrosion.

49.2.2 An enclosure of cast iron or malleable iron at least 1/8 inch (3.2 mm) thick shall be protected against corrosion by:

a) A 0.00015 inch (0.0038 mm) thick coating of zinc, cadmium, or the equivalent, on the outside surface and a visible coating of such metal on the inside surface; or

b) One coat of an organic finish of the epoxy or alkyd-resin type or other outdoor paint on each surface. The acceptability of the paint may be determined by consideration of its composition or, if necessary, by corrosion tests.

49.2.3 An enclosure of sheet steel having a thickness less than 1/8 inch (3.2 mm) if zinc-coated or 0.123 inch (3.12 mm) if uncoated shall be protected against corrosion by one of the following means or by other metallic or nonmetallic coatings that have been found to give equivalent protection as described in 49.2.5.

a) Hot-dipped mill-galvanized sheet steel conforming with the coating Designation G90 in Table I of the Specification for General Requirements for Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, ASTM Designation A525-1991b, with not less than 40 percent of the zinc on any side, based on the minimum single-spot-test requirement in this ASTM designation. The weight of zinc coating may be determined by any suitable method; however, in case of question, the weight of coating shall be established in accordance with the Test Method for Weight of Coating on Zinc-Coated (Galvanized) Iron or Steel Articles, ASTM Designation A90-81.

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 0.00061 inch (0.0155 mm) on each surface with a minimum thickness of 0.00054 inch (0.0137 mm). Thickness of the coating shall be established by the metallic-coating thickness test described in 52.1 – 52.7. An annealed coating shall also comply with 49.2.7.

c) A zinc coating complying with 49.2.4 (a) or (c) with one coat of an organic finish of the epoxy or alkyd-resin type or other outdoor paint on each surface. The suitability of the paint shall be determined by consideration of its composition or, if necessary, by corrosion tests.

d) A cadmium coating not less than 0.001 inch (0.03 mm) thick on both surfaces. The thickness of coating shall be established in accordance with the metallic-coating thickness test described in 52.1 – 52.7.

e) A cadmium coating not less than 0.00075 inch (0.0191 mm) thick on both surfaces with one coat of outdoor paint on both surfaces, or not less than 0.0005 inch (0.013 mm) thick on both surfaces with two coats of outdoor paint on both surfaces. The thickness of the cadmium coating shall be established in accordance with the metallic-coating thickness test described in 52.1 – 52.7 and the paint shall be as specified in (c).

49.2.4 An enclosure of sheet steel 0.126 inch (3.20 mm) thick or more if zinc-coated or 0.123 inch (3.12 mm) thick or more if uncoated shall be protected against corrosion by one of the following means or by other metallic or nonmetallic coatings that have been shown to provide equivalent protection as described in 49.2.5.

a) Hot-dipped mill-galvanized sheet steel conforming with the coating Designation G60 or A60 in Table I of the Specification for General Requirements for Steel Sheet, Zinc-Coated (Galvanized) by the Hot-Dip Process, ASTM Designation A525-1991b with not less than 40 percent of the zinc on any side, based on the minimum single-spot-test requirement in this ASTM designation. The weight of zinc coating may be determined by any suitable method; however, in case of question, the weight of coating shall be established in accordance with the Test Method for Weight of Coating on Zinc-Coated (Galvanized) Iron or Steel Articles, ASTM Designation A90-81. An A60 (alloyed) coating shall also comply with 49.2.7

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 0.00041 inch (0.0104 mm) on each surface with a minimum thickness of 0.00034 inch (0.0086 mm). The thickness of the coating shall be established by the metallic-coating thickness test described in 52.1 – 52.7. An annealed coating shall also comply with 49.2.7.

c) Two coasts of an organic finish of epoxy or alkyd resin or other outdoor paint on each surface. The suitability of the paint may be determined by consideration of its composition or, if necessary, by corrosion tests.

d) Any one of the means specified in 49.2.3.

49.2.5 With reference to 49.2.3 and 49.2.4, other finishes, including paint, special metallic finishes, and combinations of the two may be accepted when comparative tests with galvanized sheet steel – without annealing, wiping, or other surface treatment – complying with 49.2.3(a) or 49.2.4(a), as applicable, indicate they provide equivalent protection. Among the factors that are taken into consideration when judging the suitability of such coating systems are exposure to salt spray, moist carbon-dioxide/sulfur-dioxide air mixtures, moist hydrogen-sulfide air mixtures, ultraviolet light, and water. See Supplement B to the Standard for Industrial Control Equipment, UL 508, for Investigation of Component Coatings.

49.2.6 Test specimens of a finish as described in 49.2.2 or 49.2.5, 49.2.3(c), or 49.2.4(c), if the paint is tested, are to be consistent with the finish that is to be used in production with respect to the base metal, cleaning or pretreatment method, application method, number of coats, curing method, thickness, and the like.

49.2.7 A hot-dipped mill-galvanized A60 (alloyed) coating or 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 at the outside radius of the bent or formed section visible at 25 power magnification. Simple sheared or cut edges and punched holes are not considered to be formed.

50 Rain Test

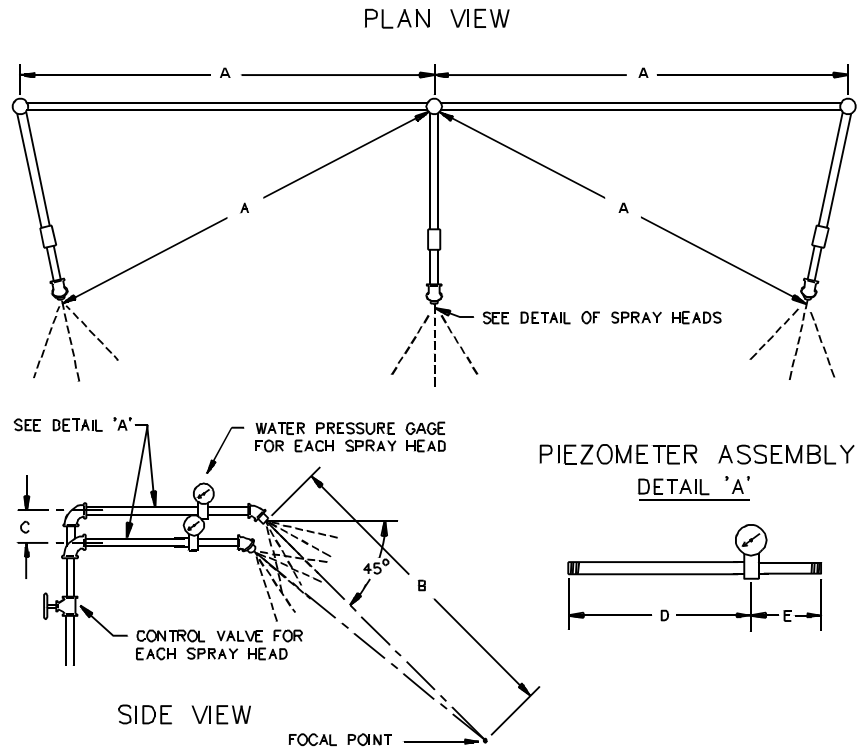
50.1 An outdoor-use unit is to be subjected to a rain test in the energized condition as described in 50.2 and 50.3. After being subjected to the rain test, an outdoor-use unit shall have no entrance of water into the enclosure.

Exception: Water may enter the unit if the unit is provided with two drain holes with a minimum diameter of 1/8 inch (3.2 mm) to a maximum diameter of 3/16 inch (4.8 mm) in the bottom of the unit, and there is no wetting of live parts.

50.2 The complete enclosure with conduit connected – without pipe thread compound – is to be mounted as intended. The tightening torque for rigid conduit threaded into an opening in the enclosure is to be 800 pound-inches (90 N•m) for 3/4-inch and smaller trade sizes, and 1000 pound-inches (113 N•m) for 1, 1-1/4, and 1-1/2 inch trade sizes, and 1600 pound-inches (180 N•m) for 2-inch and larger trade sizes.

50.3 The water spray apparatus is to consist of three spray heads mounted in a pipe rack as illustrated in Figure 50.1. Spray heads are to be constructed in accordance with the details shown in Figure 50.2. The water pressure for all tests is to be maintained at 5 psi (34 kPa) at each spray head. The distance between the center nozzle and the equipment is to be approximately 5 feet (1.5 m). The spray is to be directed at an angle of 45 degrees from vertical toward the louvers or other openings, handles, unsealed screws, and the like nearest current-carrying parts. A water spray is then to be applied to the enclosure from the top and sides for 1 hour.

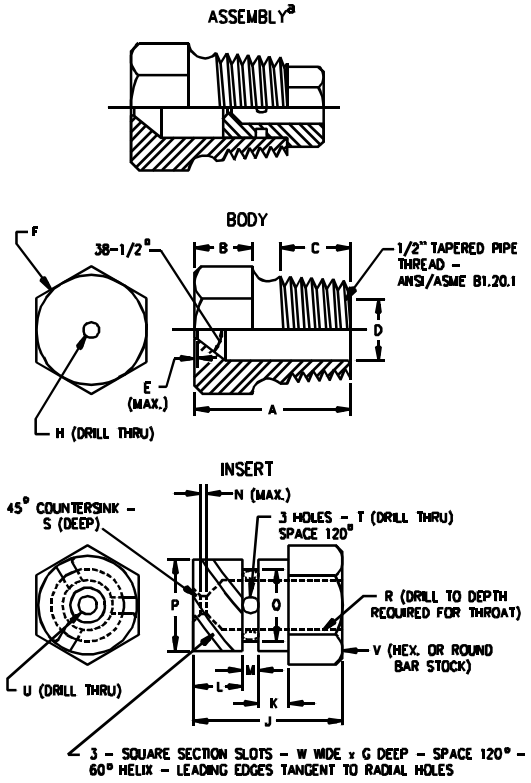
Figure 50.1
Rain-test spray-head piping



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

RT101E

Figure 50.2
Rain-test spray head



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

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

[b] ANSI B94.11M Drill Size

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

RT100E

51 Gasket Tests

51.1 Samples of a gasket of an elastomeric or thermoplastic material, or a composition gasket utilizing an elastomeric material that is employed to comply with the requirements in 50.1 is to be subjected to the tests specified in 51.2. At the conclusion of the tests, there shall be no visible deterioration, deformation, melting, or cracking of the material and the material shall not harden as determined by normal hand flexing.

51.2 A sample of a gasket is to be conditioned at a temperature of 69 – 70EC (156 – 158EF) in circulating air for 168 hours before being subjected to the tensile strength and elongation tests in accordance with the Standard for Gaskets and Seals, UL 157. The conditioned sample shall have a tensile strength of not less than 75 percent and an elongation of not less than 60 percent of values determined for an unconditioned sample.

Exception: Neoprene rubber is acceptable for 60EC (140EF) and silicone rubber is acceptable for 105EC (221EF) without being subjected to the test.

52 Metallic Coating Thickness Test

52.1 With reference to 49.2.3 (b), (d), and (e), and 49.2.4(b), the method of determining the thickness of a zinc or cadmium coating is described in 52.2 – 52.7

52.2 The solution to be used for this test is to be made from distilled water and is to contain 200 grams per liter of reagent grade chromic acid (CrO_3); and 50 grams per liter of reagent grade concentrated sulfuric acid (H_2SO_4). The latter is equivalent to 27 milliliters per liter of reagent grade concentrated sulfuric acid, specified gravity 1.84, containing 96 percent of H_2SO_4.

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

52.4 The sample and the test solution are to be kept in the test room long enough to stabilize at room temperature. The room temperature is to be recorded. The test is to be conducted at an ambient temperature of 21.1 – 32.2EC (70 – 90EF).

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

52.6 The sample to be tested is to be supported 0.7 – 1 inch (18 – 25 mm) below the orifice, so that the drops of solution strike the point to be tested and run off quickly. The surface to be tested is to be inclined about 45 degrees from horizontal.

52.7 The stopcock is to be opened and the time in seconds is to be measured until the dropping solution dissolves the protective metallic coating, exposing the base metal. The end point is to be the first appearance of the base metal recognizable by the change in color at that point.

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

52.9 To calculate the thickness of the coating being tested, the thickness factor from Table 52.1 applicable for the temperature at which the test was conducted is to be multiplied by the time in seconds required to expose base metal as noted in 52.7.

Table 52.1
Thickness factors

Temperature		Thickness factors, 0.00001 inches (0.00025 mm) per second	
EF	(EC)	Cadmium platings	Zinc platings
70	(21.1)	1.331	0.980
71	(21.7)	1.340	0.990
72	(22.2)	1.352	1.000
73	(22.8)	1.362	1.010
74	(23.3)	1.372	1.015
75	(23.9)	1.383	1.025
76	(24.4)	1.395	1.033
77	(25.0)	1.405	1.042
78	(25.6)	1.416	1.050
79	(26.1)	1.427	1.060
80	(26.7)	1.438	1.070
81	(27.2)	1.450	1.080
82	(27.8)	1.460	1.085
83	(28.3)	1.470	1.095
84	(28.9)	1.480	1.100
85	(29.4)	1.490	1.110
86	(30.0)	1.501	1.120
87	(30.6)	1.513	1.130
88	(31.1)	1.524	1.141
89	(31.7)	1.534	1.150
90	(32.2)	1.546	1.160

53 Markings

53.1 An outdoor-use unit shall be marked "Suitable for Wet Locations." See 50.1.

APPENDIX A

Standards for Components

Standards under which components of the products covered by this standard are evaluated include the following:

Title of Standard – UL Standard Designation

Control Equipment, Industrial – UL 508
Enclosures for Electrical Equipment – UL 50
Flammability of Plastic Materials for Parts in Devices and Appliances, Tests for – UL 94
Fuseholders – UL 512
Fuses for Supplementary Overcurrent Protection – UL 198G
Fuses, Plug – UL 198F
Gaskets and Seals – UL 157
Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment – UL 840
Marking and Labeling Systems – UL 969
Motors, Electric – UL 1004
Polymeric Materials – Long Term Property Evaluations – UL 746B
Polymeric Materials– Use in Electrical Equipment Evaluations – UL 746C
Printed – Wiring Boards – UL 796
Surface Burning Characteristics of Building Materials, Tests for – UL 723
Switches, Special-Use – UL 1054
Terminals, Electrical Quick-Connect – UL 310
Terminals for Use with Aluminum and/or Copper Conductors, Equipment Wiring – UL 486E
Transformers, Class 2 and Class 3 – UL 1585
Transformers, Specialty – UL 506
Tubing, Extruded Insulating – UL 224
Wire Connectors and Soldering Lugs for Use With Copper Conductors – UL 486A
Wire Connectors for Use With Aluminum Conductors – UL 486B
Wire Connectors, Splicing – UL 486C

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