UL 810

STANDARD FOR SAFETY

Capacitors

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UL Standard for Safety for Capacitors, UL 810

Sixth Edition, Dated October 29, 2019

Summary of Topics

This revision of ANSI/UL 810 dated August 22, 2023 is being issued to incorporate the following requirements:

> ***– Addition of requirements for medium voltage power banks in a new Part III; 1.5A, 1.8, Sections 57 – 76***
>
> ***– Miscellaneous revisions throughout the Standard; 1A – 1C, Section 3, 31.1 and Annex A***

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

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated June 2, 2023.

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The most recent designation of ANSI/UL 810 as an American National Standard (ANSI) occurred on August 22, 2023. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

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

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No Text on This Page

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CONTENTS

ULNORM.COM : Click to view the full PDF of UL 810 2023

CONSTRUCTION

PERFORMANCE

ULNORM.COM : Click to view the full PDF of UL 810 2023

MANUFACTURING AND PRODUCTION TESTS

RATINGS

MARKINGS

OUTDOOR-USE UNITS

PART III – MEDIUM VOLTAGE POWER FACTOR CORRECTION CAPACITOR BANKS

GENERAL

CONSTRUCTION

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PERFORMANCE

RATINGS

MARKINGS AND INSTRUCTIONS

Supplement SA – Electrolytic Capacitors

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ULNORM.COM : Click to view the full PDF of UL 810 2023

No Text on This Page

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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 capacitors with expansion type protection rated 5 kV or less, and capacitors with segmented film type protection rated 2 kV 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 of Part I may also be used to evaluate the construction only of these types of capacitors with ratings greater than the values noted in 1.1 but no greater than 7.2 kV. Capacitors employing polymeric enclosures or capacitors employing a partial metallic enclosure (i.e. remainder of enclosure such as the cap/cover which is not crimped to the case) that are not provided with internal protection and intended to be located in circuits not requiring fault current protection may be evaluated using only the construction requirements of Part I.

1.3 The requirements in Part II of this standard apply to general-use power-factor-correction units consisting of one or more capacitors with or without protective fusing or overloads, with or without a switch or other disconnect device all within a protective enclosure; rated 600 V maximum and intended for power-factor correction of circuits in accordance with the National Electrical Code, NFPA 70. This equipment is intended for installation in ordinary locations, in accordance with the National Electrical Code, NFPA 70, where the ambient temperature does not exceed 40°C (104°F) maximum. See 1.4.

1.4 The requirements of Part II of this standard do not apply to power factor correction units containing automatic or other circuit monitoring/conditioning controls or automatic systems of multiple connected power factor correction units. Power factor correction units with these additional features shall be evaluated to the Standard for Industrial Control Panels, UL 508A as an industrial control panel.

1.5 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 and has been evaluated for a minimum fault current rating of 10k AFC.

1.5A The requirements in Part III cover equipment having ac voltage ratings above 1000 V, up to 46 kV, intended to provide power factor correction for AC power systems. The power factor correction banks covered by Part III of this Standard are metal-enclosed assemblies consisting of one or more shunt power capacitor(s), with or without additional controls and switching devices necessary to provide control of the power factor of the system to which the equipment is connected. The power factor correction equipment covered by Part III of this Standard may be rated for indoor or outdoor use, and cover equipment intended for use in ordinary locations in accordance with the National Electrical Code.

1.6 The requirements of Supplement SA apply to electrolytic capacitors for motor start or similar applications including dc circuits rated 600 V or less.

1.7 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.

1.8 The requirements in Part I, Part II, and Part III do not apply to capacitors covered by the Standard for Fixed Capacitors for Use in Electronic Equipment – Part 14: Sectional Specification: Fixed Capacitors for Electromagnetic Interference Suppression and Connection to the Supply Mains, UL 60384-14.

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

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1A Components

1A.1 A component of a product covered by this Standard shall:

a) Comply with the requirements for that component as specified in this Standard;

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

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

NOTE: See Annex A for a list of additional standards covering components generally used in the products covered by this Standard.

1A.2 A component of a product covered by this Standard is not required to comply with a specific component requirement that:

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

b) Is superseded by a requirement in this Standard; or

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

1A.3 Specific components are incomplete in construction features or restricted in performance capabilities. Such components are intended for use only under limited conditions, such as certain temperatures not exceeding specified limits, and shall be used only under those specific conditions.

1A.4 A component that is also intended to perform other functions such as overcurrent protection, ground-fault circuit-interruption, surge suppression, any other similar functions, or any combination thereof, shall comply additionally with the requirements of the applicable UL Standard(s) that cover devices that provide those functions.

1B Units of Measurement

1B.1 Values stated without parentheses are the requirement. Values in parentheses are explanatory or approximate information.

1C Referenced Publications

1C.1 Any undated reference to a code or standard appearing in the requirements of this standard shall be interpreted as referring to the latest edition of that code or standard.

1C.2 The following publications are referenced in this Standard:

ASTM A90/A90M, *Standard Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings*

ASTM A653/A653M, *Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process*

ASTM E162, *Standard Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source*

ASTM E230/E230M, *Standard Specification and Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples*

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IEEE 4, *Techniques for High-Voltage Testing*

IEEE No. 18, *Shunt Power Capacitors*

IEEE C37.04, *Ratings and Requirements for AC High-Voltage Circuit Breakers with Rated Maximum Voltage Above 1000 V*

IEEE C37.09, *Standard Test Procedures for AC High-Voltage Circuit Breakers with Rated Maximum Voltage Above 1000 V*

IEEE C37.24, *Guide for Evaluating the Effect of Solar Radiation on Outdoor Metal-Enclosed Switchgear*

IEEE C37.20.3, *Metal-Enclosed Interrupter Switchgear (1 kV–38 kV)*

IEEE 386, *Separable Insulated Connector Systems for Power Distribution Systems above 600 Volts*

ANSI/NEMA CC1, *Electric Power Connection for Substations*

NFPA 70, *National Electrical Code*

UL 50, *Enclosures for Electrical Equipment, Non-Environmental Considerations*

UL 50E, *Enclosures for Electrical Equipment, Environmental Considerations*

UL 62, *Flexible Cords and Cables*

UL 94, *Tests for Flammability of Plastic Materials for Parts in Devices and Appliances*

UL 224, *Tubing, Extruded Insulating*

UL 347, *Medium-Voltage AC Contactors, Controllers, and Control Centers*

UL 248-1, *Low-Voltage Fuses – Part 1: General Requirements*

UL 248-11, *Low-Voltage Fuses – Part 11: Plug Fuses*

UL 486A-486B, *Wire Connectors*

UL 508A, *Industrial Control Panels*

UL 723, *Test for Surface Burning Characteristics of Building Materials*

UL 746A, *Polymeric Materials – Short Term Property Evaluation*

UL 746B, *Polymeric Materials – Long Term Property Evaluations*

UL 746C, *Polymeric Materials – Use in Electrical Equipment Evaluations*

UL 796, *Printed Wiring Boards*

UL 810A, *Electrochemical Capacitors*

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

UL 969, *Marking and Labeling Systems*

UL 1059, *Terminal Blocks*

UL 1332, *Organic Coatings for Steel Enclosures for Outdoor Use Electrical Equipment*

UL 4248-1, *Fuseholders – Part 1: General Requirements*

UL 60384-14, *Fixed Capacitors for Use in Electronic Equipment – Part 14: Sectional Specification: Fixed Capacitors for Electromagnetic Interference Suppression and Connection to the Supply Mains*

UL 61058-1, *Switches for Appliances – Part 1: General Requirements*

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.

2.3 CLASS 2 CIRCUIT – A circuit supplied by a Class 2 source in accordance with Article 725 of the National Electrical Code, NFPA 70.

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

2.5 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.

2.6 DRY TYPE CAPACITOR – A capacitor that contains no liquid and utilizes a solid dielectric medium other than wax.

2.7 ELECTRODE, FOIL TYPE – Capacitor plates consisting of thin metal or “foil” separated by a dielectric.

2.8 ELECTRODE, METALLIZED – Capacitor plates consisting of dielectric material covered with metallic deposits such as aluminum on the surface. This type of electrode has a tendency to self restore or "re-heal" after local breakdown of the dielectric.

2.9 ELECTROLYTE – Current conducting solution (liquid, gel, or solid) between two electrodes or plates of an electrolytic capacitor at least one of which is covered by a dielectric film.

2.10 ELECTROLYTIC CAPACITOR – A capacitor consisting of two conducting electrodes whose anode has a metal oxide film. The oxide film acts as the dielectric or insulating medium. The electrode without the film and the electrolyte serve as the cathode. Electrolytic capacitors may be provided with either a solid or liquid electrolyte and may or may not be polarized.

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

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

2.13 HAZARDOUS LIVE PARTS – A live part having a potential greater than 30 Vrms (42.4 Vpeak) or 60 Vdc between the part and ground or a grounded part, or between adjacent live parts.

2.14 INTERNAL PROTECTION BRIDGE – A device that aids in the expansion of the capacitor enclosure in a direction that will interrupt the circuit, also referred to as a pressure interrupter.

2.15 LEAD – An insulated wire provided as the electrical connection to the capacitor.

2.16 LIMITED-POWER CIRCUIT – A circuit involving a potential of not more than 30 Vrms (42.4 Vpeak) or 60 Vdc and supplied by a limited power 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 limited power source as specified in Exception No. 2 of 34.1.1.

2.17 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.

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

2.19 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.

2.20 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.

2.21 PRESSURE SENSITIVE INTERRUPTER (EXPANSION TYPE PROTECTION) – 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.

2.22 PRIMARY CIRCUIT – A circuit that is directly connected to the AC main supply, for example, the means for connections to the AC supply, the primary windings of transformers, motors and other loading devices.

2.23 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.

2.24 SAFETY EXTRA LOW-VOLTAGE (SELV) CIRCUIT – A secondary circuit which is designed and protected so that under normal and single fault conditions voltages do not exceed 30 Vrms (42.4 Vpeak) or 60 Vdc.

2.25 SECONDARY CIRCUIT – A circuit conductively connected to the secondary winding of an isolating power supply transformer. A secondary circuit has no direct physical connection to a primary circuit, but is coupled to the primary by electromagnetic induction only.

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2.26 SEGMENTED METALLIZED ELECTRODE (SEGMENTED FILM TYPE PROTECTION) – An integral protection means where the metallized type electrode disconnects, similar to the way a fuse operates, due to a surge in current under a fault condition.

2.27 SEPARATOR – A liner provided to insulate the contents of the electrolytic capacitor from the external metal can.

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

2.29 VENTING MECHANISM – The means employed within an electrolytic capacitor to relieve pressure when the contents of the capacitor overheat due to a fault condition.

3 General

3.1 Components

3.1.1 *Deleted*

3.1.2 *Deleted*

3.1.3 *Deleted*

3.1.4 *Deleted*

3.2 Units of measurement

3.2.1 *Deleted*

3.3 Undated references

3.3.1 *Deleted*

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-in (0.25-mm) thick minimum, if of steel, and 0.016-in (0.41-mm) thick minimum, if of aluminum, brass, or copper.

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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-in (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.

4.3.3 The following are among the factors that shall be taken into consideration when using the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, to judge the acceptability of a nonmetallic material with respect to its intended application:

a) Mechanical strength;

b) Moisture-absorbent properties;

c) Combustibility;

d) Compatibility with dielectric mediums;

e) Dielectric strength;

f) Aging characteristics; and

g) 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, aging characteristics, and resistance to distortion at maximum temperatures of operation described in 4.3.3 (a), (f) and (g), a polymeric material used as an enclosure shall have a relative mechanical temperature index without impact of at least 70°C (158°F) or the marked temperature rating, whichever is greater, in accordance with the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B. With regard to the moisture-absorbent and dielectric strength properties described in 4.3.3 (b) and (e), a polymeric material shall meet the requirements for dielectric strength as described in Table 6.1 of the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C. The compatibility with dielectric mediums is addressed with the Dielectric Voltage-Withstand Test of Section 13.

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.

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Exception No. 1: A polymeric insulating 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 testing requirements outlined in the "additional consideration for materials not meeting pre-selection test performance levels" as prescribed in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, Table 6.2.

Exception No. 2: Products that have a minimum 1/2-in (12.7-mm) over surface spacing from terminal-to-terminal are not required to comply with the polymeric insulating material requirements of Table 6.1.

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, V	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	5,000	5
	V-1	3	2	5,000	5
	V-2	2	2	5,000	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 in (0.8 mm) of uninsulated live parts.

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6.2 Internal insulating materials shall comply with the requirements for the Dielectric Voltage-Withstand Test, Section 13. Internal insulating materials shall have a relative mechanical temperature index without impact of at least 70°C (158°F) or the marked temperature rating marked on the capacitor, whichever is greater, in accordance with the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B.

Exception: Internal insulating materials for capacitors not subjected to the Fault-Current Test, Section 12, shall comply with the following requirements:

a) Shall be classified HB minimum in accordance with the Standard for Tests Flammability of Plastic Material for Parts in Devices and Appliances, UL 94, or comply with the flammability – 12 mm flame test specified in the Standard for Polymeric Materials – Use in Electrical Equipment, UL 746C;

b) Shall have a relative mechanical temperature index without impact of at least 70°C (158°F) or the marked temperature rating marked on the capacitor, whichever is greater, in accordance with the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B; and

c) Shall comply with the requirements for dielectric strength criteria as described in Table 6.1 of the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

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

7 Leads, Terminals and Internal Wiring

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.

Exception: Bare leads provided for securing the capacitor to a printed wiring board need not comply with the Pull-Out Test of Section 9. Bare leads provided for this purpose shall comply with the material and minimum thickness requirements outlined in 7.5.

7.3 An integral terminal connector or terminal block employed for making electrical connections to a capacitor shall be mechanically secured to the capacitor to prevent movement that would result in reduced spacings and/or damage to connections. A terminal block shall be rated for the application and comply with the Standard for Terminal Blocks, UL 1059.

Exception: A terminal connector or terminal block may alternatively be evaluated to the requirements outlined in 7.4.

7.4 A terminal connector or terminal block shall comply with the following:

a) The insulation criteria for contact with uninsulated parts as outlined in Table 6.1;

b) The spacings criteria of Section 8;

c) The requirements of 7.5 and if intended for connection of copper wiring, be limited to copper, copper alloy or other suitable material found to prevent galvanic corrosion when in contact with the intended connection wiring (see Figure 7.1); and

d) The mold stress test of Section 11 and if provided with screw terminals, the torque test of Section SA5.3.

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Figure 7.1

Metal compatibility chart

Magnesium, magnesium alloys	Zinc, zinc alloys	80 tin/20 Zn on steel, Zn on iron or steel	Aluminium	Cd on steel	Al/Mg alloy	Mild steel	Duralumin	Lead	Cr on steel, soft solder	Cr on Ni on steel, tin on steel, 12% Cr stainless steel	High Cr stainless steel	Copper, copper alloys	Silver solder, austenitic stainless steel	Ni on steel	Silver	Rh on Ag on Cu, silver/gold alloy	Carbon	Gold, platinum	
0	0.05	0.55	0.7	0.8	0.85	0.9	1.0	1.05	1.1	1.15	1.25	1.35	1.4	1.45	1.6	1.65	1.7	1.75	Magnesium, magnesium alloys
	0	0.05	0.2	0.3	0.35	0.4	0.5	0.55	0.6	0.65	0.75	0.85	0.9	0.95	1.1	1.15	1.2	1.25	Zinc, zinc alloys
		0	0.15	0.25	0.3	0.35	0.45	0.5	0.55	0.6	0.7	0.8	0.85	0.9	1.05	1.1	1.15	1.2	80 tin/20 Zn on steel, Zn on iron or steel
			0	0.1	0.15	0.2	0.3	0.35	0.4	0.45	0.55	0.65	0.7	0.75	0.9	0.95	1.0	1.05	Aluminium
				0	0.05	0.1	0.2	0.25	0.3	0.35	0.45	0.55	0.6	0.65	0.8	0.85	0.9	0.95	Cd on steel
					0	0.05	0.15	0.2	0.25	0.3	0.4	0.5	0.55	0.6	0.75	0.8	0.85	0.9	Al/Mg alloy
						0	0.1	0.15	0.2	0.25	0.35	0.45	0.5	0.55	0.7	0.75	0.8	0.85	Mild steel
							0	0.05	0.1	0.15	0.25	0.35	0.4	0.45	0.6	0.65	0.7	0.75	Duralumin
								0	0.05	0.1	0.2	0.3	0.35	0.4	0.55	0.6	0.66	0.7	Lead
									0	0.05	0.15	0.25	0.3	0.35	0.5	0.55	0.6	0.65	Cr on steel, soft solder
										0	0.1	0.2	0.25	0.3	0.45	0.5	0.55	0.6	Cr on Ni on steel, tin on steel, 12% Cr stainless steel
											0	0.1	0.15	0.2	0.35	0.4	0.45	0.5	High Cr stainless steel
												0	0.05	0.1	0.25	0.3	0.35	0.4	Copper, copper alloys
													0	0.05	0.2	0.25	0.3	0.35	Silver solder, austenitic stainless steel
														0	0.15	0.2	0.25	0.3	Ni on steel
															0	0.05	0.1	0.15	Silver
																0	0.05	0.1	Rh on Ag on Cu, silver/gold alloy
																	0	0.05	Carbon
																		0	Gold, platinum

Ag = Silver
Al = Aluminium
Cr = Chromium
Cd = Cadmium
Cu = Copper
Mg = Magnesium
Ni = Nickel
Rh = Rhodium
Zn = Zinc

NOTE. – Corrosion due to electrochemical action between dissimilar metals which are in contact is minimized if the combined electrochemical potential is below about 0.6V. In the following table the combined electrochemical potentials are listed for a number of pairs of metals in common use; combinations above the dividing line should be avoided.

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7.5 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-in (0.51-mm) thick and shall be of copper, copper alloy, tin plated steel, or other metal rated for the application. Wire-binding screws shall be limited to connections with 10 AWG (5.26 mm^2) or smaller conductors.

Exception: For capacitors rated over 5,000 V, a terminal plate tapped for a wire-binding screw shall be of metal not less than 0.030-in (0.76-mm) thick for a 14 AWG (2.1 mm^2) or smaller wire and not less than 0.050-in (1.27-mm) thick for a wire larger than 14 AWG (2.1 mm^2). There shall be sufficient threads to provide two full threads engagement with the screw.

7.6 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.

Exception: Capacitors employing terminal forks for securement of the capacitor to a printed wiring board are not required to be provided with a detent. The terminal fork shall comply with the material and minimum thickness requirements outlined in 7.5.

7.7 Insulated conductors serving as internal wiring and sleeving serving as insulation for uninsulated internal conductors shall be rated for the voltage, temperature, and other conditions of use to which they are subjected in the intended application and in accordance with the applicable component standard. See Section 1A for component requirements.

Exception: Insulated sleeving employed for internal conductors and/or connections molded from a thermoplastic material not previously evaluated in accordance with an applicable component standard as outlined in Section 1A may alternatively be evaluated to the Conductor Insulation Test of Section 10.

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 No. 1: Electrical spacings are not specified for those parts that are inside the enclosure and that are surrounded by a dielectric medium. See 6.3.

Exception No. 2: As an alternative to the spacing requirements of Table 8.1, the spacing requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances For Electrical Equipment, UL 840, may be used. See Section 33.2 for details. 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 33.2.2 and 33.2.3.

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Table 8.1
Spacings

Capacitor rating V	Minimum spacings			
	Through air		Over surface	
	in	(mm)	in	(mm)
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)

Table 8.1 Continued on Next Page

Table 8.1 Continued

Capacitor rating V	Minimum spacings			
	Through air		Over surface	
	in	(mm)	in	(mm)
661 – 2000	3/4	(19.1)	3/4	(19.1)
2001 – 5000	3/4	(19.1)	1	(25.4)
5001 – 7200	2	(50.8)	3-1/2	(88.9)

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 min in a direction perpendicular to the plane of the surface at which the lead enters the capacitor. The force shall be:

a) 20 lbf (89 N) for 18 AWG (0.82 mm^2) and larger leads; or

b) 8 lbf (36 N) for leads smaller than 18 AWG (0.82 mm^2).

10 Conductor Insulation Test

10.1 Fifteen samples of the tubular style insulation employed in capacitors are to be conditioned in accordance with Table 10.1. The fifteen samples are to be 4-in (102-mm) diameter or square in the minimum thickness used or are to be of a size representative of the end-use and subjected to the following test outlined in 10.2 and 10.3.

10.2 Following the conditioning, each sample is to be subjected to a dielectric voltage within a test chamber. The electrodes of the dielectric equipment shall be placed on opposite sides and in the center of the sample. The voltage is to be applied at a uniform rate of 500 V/s until breakdown occurs. When physical evidence of dielectric breakdown is not apparent, the voltage is to be reapplied until a more positive indication is produced.

10.3 As a result of this test, the average breakdown value for each set of samples shall be no less than 5000 V. In addition, the average breakdown value for all 10 conditioned samples (subjected to either oven conditioning or moist air conditioning) shall be no less than one-half the value of the as-received samples. For example, when the as-received samples had a breakdown of 15000 V, then the conditioned samples shall not have a breakdown less than 7500 V.

Table 10.1
Conductor insulation conditioning

Number of Samples	Conditioning
5	As received
5	Oven exposure at 100 ±2°C (212 ±3.6°F) for 72 h, or the rated temperature of the capacitor, if rated higher than 100°C (212°F)
5	Exposure to moist air (90% ± 5% RH) at a temperature of 30 ±2°C (86 ±3.6°F) for 24 h

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11 Mold Stress Relief Test (Terminals Blocks/Terminal Connectors)

11.1 A terminal block and terminal connector evaluated in accordance with 7.4 shall be conditioned in an air-circulating oven for 7 h at a temperature of 10°C (18°F) plus the maximum rated temperature of the intended capacitor. At the conclusion of the conditioning, the terminal block shall be examined for damage such as cracking, warping or loosening of contacts.

11.2 As a result of the conditioning, there shall be no sign of damage to the terminal connection device such as cracking, warping or loosening of contacts.

12 Fault-Current Test

12.1 General

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

a) For a capacitor with expansion type protection, the enclosure shall not vent, leak, or rupture expelling the dielectric medium; or

b) For a capacitor with segmented film type protection, there shall not be ignition of the cotton prescribed in 12.1.10.

12.1.2 Under test conditions the expansion of a capacitor with expansion type protection shall not exceed 0.5 in (12.7 mm) except that capacitors intended for power factor correction applications only can exceed the 0.5 in (12.7 mm) expansion limit if sufficient space can be provided in the end use application. Because of the large size of many power factor correction capacitors, additional expansion space may be necessary to allow for safe expansion as a result of overheating from an abnormal condition.

12.1.3 The manufacturer shall specify the maximum voltage and the maximum available fault current – excluding transients of the capacitor. See Table 12.1.

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Table 12.1
Current for fault-current test

Intended application	Number of test samples (metallized electrode)[c]	Number of test samples (foil electrode)[a]	Current[b]								
			10,000 A	5,000 A	1,000 A	200 A	60 A	30 A	15 A	5 A	2.5 A
General application, and power factor correction applications, across-the-line or in series with other impedance	42 total	42 per fault 84 total	X	X	X	X	X	X		X	
Air conditioning or refrigeration and motor applications	30 total	30 per fault 60 total		X		X	X	X		X	
HID ballast, across-the-line applications	36 total	36 per fault 72 total		X	X	X	X		X	X	

Table 12.1 Continued on Next Page

Table 12.1 Continued

Intended application	Number of test samples (metallized electrode)[c]	Number of test samples (foil electrode)[a]	Current[b]								
			10,000 A	5,000 A	1,000 A	200 A	60 A	30 A	15 A	5 A	2.5 A
HID ballast (secondary or extended primary) applications	24 total	24 per fault 48 total				X	X		X	X	
Fluorescent ballast, across-the-line applications	30 total	30 per fault 60 total			X	X	X			X	X
Fluorescent ballast, secondary applications	18 total	18 per fault 36 total					X			X	X

[a] Test samples for Type A and Type B faults specified in 12.2.1: three samples for each fault type and current with the capacitors having the maximum and minimum enclosure height and base size.

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

[c] Three samples for each fault current with the capacitors having the maximum and minimum enclosure height and base size.

Note: The fault current test is intended to address protection of the capacitor from available fault currents over the life of the capacitor. The capacitor is intentionally internally faulted to represent dielectric breakdown that would occur within the capacitor over time. The maximum fault current test levels represent a complete internal dielectric breakdown in the capacitor with the maximum fault current available. The lower fault current test levels represent the various stages of internal dielectric breakdown during the life of the capacitor where the available fault current will be less.

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12.1.4 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% nor more than 105% of the rated voltage.

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

12.1.5 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 1,000 A or more; however, the power factor of the circuit is to be recorded.

12.1.6 The test circuit is to have sufficient capacity to deliver the fault currents specified in Table 12.1 with the test terminals short-circuited with a copper bar that is not more than 12-in (305-mm) long and that has a cross-sectional area of at least 3 in^2 (19.4 cm^2).

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

12.1.8 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 12.2 and Table 12.1.

12.1.9 For capacitors with expansion type protection, 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.

12.1.10 For capacitors with segmented film type protection, the enclosure is to be wrapped in cotton.

12.2 Sample preparation

12.2.1 Capacitors with foil electrodes

12.2.1.1 The required number of samples, as indicated in Table 12.1, to complete each test are to be prepared. For paper and foil windings, an internal 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 in (12.7 mm) and a width of approximately 1/2 in (12.7 mm), 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 in (152 mm) of the roll.

Exception: Other methods of inducing internal 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.

12.2.2 Capacitors with metallized electrodes

12.2.2.1 A sufficient number of samples as indicated in Table 12.1 to complete each test is to be prepared. For capacitors with expansion type protection, the samples are to be internally faulted by applying a high-voltage DC potential with a current not more than 300 mA, sufficient to cause breakdown.

12.2.2.2 Prior to the test, the samples are to be conditioned for a minimum of 2 h 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.

12.3 Test method

12.3.1 Capacitors with internal pressure interruption mechanisms

12.3.1.1 Three samples of each size with induced faults, prepared in accordance with 12.2.1 or 12.2.2 as applicable, are to be subjected to the rated maximum fault-test current, and to lower levels of fault-test currents specified in Table 12.1.

12.3.1.2 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.

12.3.1.3 When the protective device does not function at the lowest current level specified in Table 12.1, the current is to be increased by increments of 2.5 A. Quick-connect terminals are not prohibited from

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being used in circuits in which the available fault current is 200 A 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.

12.3.1.4 Leads connected to the test terminals are to be 12 AWG (3.3 mm^2) or larger, and are not to be longer than 2 ft (0.61 m).

12.3.1.5 The application of the voltage is to be continued for not less than 1 min 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-min 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 h. Re-establishment of the circuit that results in venting or enclosure rupture is not acceptable.

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

12.3.1.7 At the conclusion of the test, the dielectric withstand test is conducted.

12.3.2 Capacitors with segmented metallized electrode protection (no internal pressure interruption mechanism)

12.3.2.1 Three samples of each size for each fault current, with induced faults prepared in accordance with 12.2.2, are subjected to the rated maximum fault-test current and to the lower levels of fault test currents specified in Table 12.1. See Table 12.1 for samples required. The test method shall consist of cycling the capacitors between a DC voltage used to break the capacitors down and the AC fault-test current. In order to cycle the samples, they are connected to a circuit as outlined in Figure 12.1.

12.3.2.2 A single cycle consists of:

a) The AC fault current at specified voltage is applied to the test sample capacitor(s) for 5 s.

b) The connection between the AC fault current circuit and test capacitor is then opened and the test capacitor is discharged for 30 to 60 s through a 3 MΩ resistor.

c) After the discharge, the test capacitor is connected to a DC voltage supply of 2,000 V (limited to 300 mA) for 2 s to induce an internal fault. This value may be adjusted if determination is made that the voltage levels are not adequately inducing internal faults.

d) The connection between the DC voltage supply and the test capacitor is then opened and the test capacitor is discharged for 30 to 60 s through a 3 MΩ resistor.

12.3.2.3 The above cycle shall be repeated until the test sample capacitance loss measures 5% of its original reading or ultimate results occurs.

12.3.2.4 When the protective mechanism does not function at the lowest current level specified in Table 12.1, the current is to be increased by increments of 2.5 A. Quick-connect terminals are not prohibited from being used in circuits in which the available fault current is 200 A 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.

12.3.2.5 Leads connected to the test terminals are to be 12 AWG (3.3 mm^2) or larger, and are not to be longer than 2 ft (0.61 m).

12.3.2.6 At the conclusion of the test, the dielectric withstand test is conducted.

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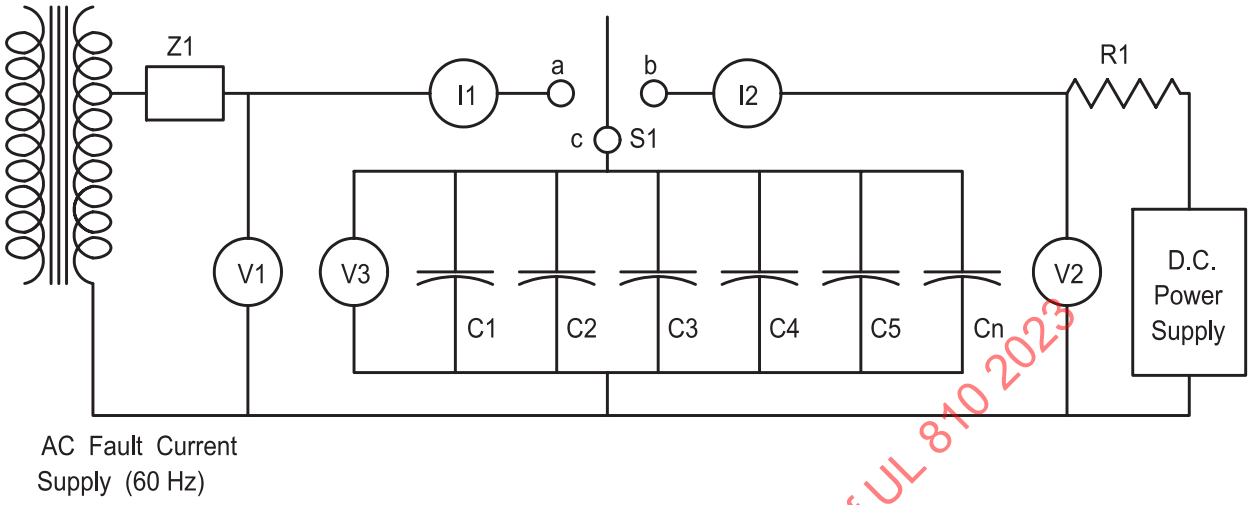
Figure 12.1

Cycling test circuit for testing segmented metallized electrode type capacitors



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Current and voltage monitoring points:

V1 – open circuit voltage

I1 – AC test current

V2 – DC breakdown voltage

I2 – DC breakdown current

V3 – Capacitor voltage

Components for the circuit:

An AC supply capable of providing the required short circuit current or AFC and the required open circuit voltage or test voltage.

A small DC power supply capable of obtaining the desired breakdown voltage.

Z1 – The impedance added to the circuit impedance to achieve the desired fault current at the test voltage.

R1 – A resistor sized to limit the peak DC current to 1% of the normal peak current for the capacitors under test.

S1 – A switch where the "a" contact is capable of switching the AC fault current and the "b" contact is capable of switching the DC breakdown current.

C1 through Cn – The capacitors under test.

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12.4 Restrike test (expansion type protection only)

12.4.1 When tested as described in 12.4.2 there shall be no venting or rupture of the enclosure of a capacitor with expansion type protection.

12.4.2 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 h.

13 Dielectric Voltage-Withstand Test

13.1 All samples that have been subjected to the Fault-Current Test, Section 12, shall be subjected to a dielectric voltage-withstand test as described in 13.2. There shall be no dielectric breakdown of any sample.

Exception: Capacitors not subjected to the Fault-Current Test, Section 12, shall be subjected to an as-received dielectric voltage-withstand test between terminals and enclosure only as outlined in 13.4.

13.2 To determine if a capacitor complies with the requirements in 13.1, the capacitor is to be tested using a 500 VA 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 min. 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.

13.3 As an alternative, a DC potential equal to 1.4 times the AC potential specified in 13.4 may be used.

13.4 The test voltage applied shall consist of a 60 Hz alternating potential of 1,000 V plus twice the rated voltage applied between terminals and enclosure.

13.5 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

14 Dielectric Voltage-Withstand Test

14.1 Each capacitor shall withstand without electrical breakdown, as a routine production-line test, the application of a 40 – 70 Hz potential between terminals and enclosure as specified in 13.4. As an alternative, a DC potential equal to 1.4 times the AC potential specified in 13.4 may be used.

Exception No. 1: The test potential application time may be reduced to 1 s if the test potential is 1,200 V plus 2.4 times the rated voltage.

Exception No. 2: This test is not necessary if the capacitor enclosure is made entirely of insulating material for capacitors.

14.2 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

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reset device to restore the equipment after electrical breakdown or an automatic reject feature of any unacceptable capacitor.

14.3 If the output of the test equipment transformer is less than 500 VA, the equipment shall include a voltmeter in the output circuit to directly indicate the test potential.

14.4 If the transformer output is 500 VA 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.

14.5 If a marking is used without an indicating voltmeter as described in 14.4 (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.

14.6 Test equipment other than those described in 14.2 – 14.5 may be used if equivalent.

MARKINGS

15 General

15.1 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 and tolerance as a percentage;

e) The voltage rating;

f) The frequency in hertz;

g) The temperature rating when the capacitor is rated over 70°C (158°F); and

h) Capacitors complying with the fault current test of Section 12, shall be marked with the maximum fault current and the words "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.

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Exception No. 3: Capacitors not subjected to fault current testing per Section 12 shall not be marked as required in (h) above, nor shall any literature or packaging provided with the capacitors indicate that they have been evaluated for fault current protection in accordance with Section 12.

Exception No. 4: Capacitors intended for use in power factor correction units may be marked in KVAR rather than microfarads.

PART II – POWER-FACTOR CORRECTION UNITS

GENERAL

16 Terminology

16.1 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

17 Frame and Enclosure

17.1 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.

17.2 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.

17.3 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.

17.4 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 46.

17.5 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.

17.6 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.

17.7 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.

17.8 Material supporting terminals or used as internal electrical insulation of an electrical instrument shall comply with Insulating Materials, Section 28.

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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.

17.9 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.

17.10 A sheet-metal enclosure or part of an enclosure shall have a thickness not less than that specified in Table 17.1.

Exception: A part of an enclosure that complies with the Compression Test, Section 43, and the Deflection Test, Section 44, need not comply with Table 17.1.

17.11 An enclosure, frame, or cover of a material other than steel shall have a thickness not less than that specified in Table 17.2.

17.12 With reference to Table 17.1 and Table 17.2, 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.

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Table 17.1
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			
Maximum width[b]		Maximum length[c]		Maximum width[b]		Maximum length		Uncoated		Metal coated	
in	(cm)	in	(cm)	in	(cm)	in	(cm)	in	(mm)	in	(mm)
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)				

Table 17.1 Continued on Next Page

Table 17.1 Continued

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		Uncoated		Metal coated	
in	(cm)	in	(cm)	in	(cm)	in	(cm)	in	(mm)	in	(mm)
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 17.12.

[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 in (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-in (0.86-mm) thick if zinc coated and not less than 0.032-in (0.81-mm) thick if uncoated.

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Table 17.2
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			
in	(cm)	in	(cm)	in	(cm)	in	(cm)	in	(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)		

Table 17.2 Continued on Next Page

Table 17.2 Continued

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			
in	(cm)	in	(cm)	in	(cm)	in	(cm)	in	(mm)
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 17.12.

[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 in (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-in (0.74-mm) thick.

17.13 A polymeric enclosure or polymeric part of an enclosure shall comply with the requirements of Path III of Table 4.1 (i.e. applicable to non-portable 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 in^2 (3.9 cm^2) or less.

Exception No. 2: When the part is removed and there are no hazardous live parts (see 2.11) or moving parts accessible to the user as determined by the Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts, Section 18, the part is not required to comply with 17.13.

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

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

b) The Standard Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source, ASTM E162.

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).

17.15 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.

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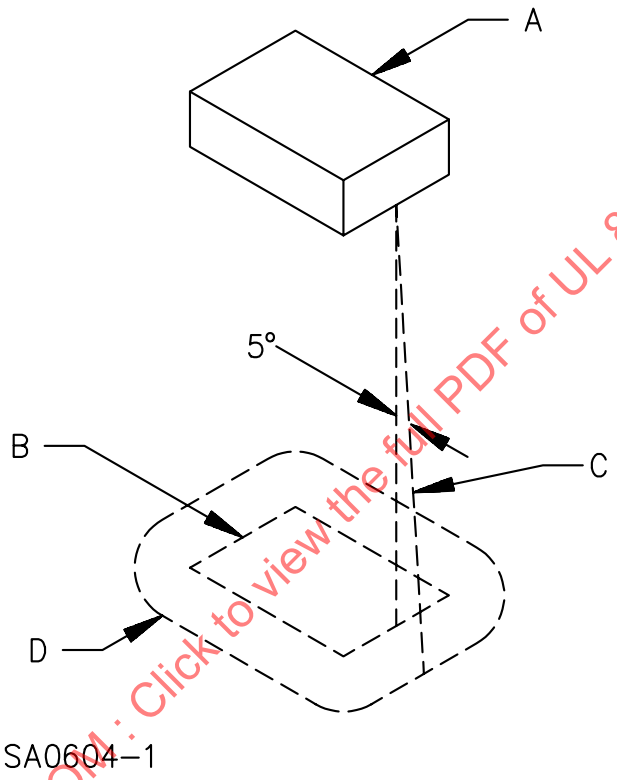
17.16 The enclosure of a unit shall reduce the risk of molten metal, burning insulation, flaming particles, or the like from falling on combustible materials, including the surface upon which the unit is supported. A barrier shall be horizontal, be located as illustrated in Figure 17.1, and shall have 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 17.1

Location and extent of barrier



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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° 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.

17.17 The requirement in 17.16 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.

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

18.1 No opening in the enclosure of a unit shall permit entrance of a 1-in (25.4-mm) diameter rod. An opening smaller than 1-in diameter is acceptable only if a probe as illustrated in Figure 18.1, when inserted through the opening in accordance with 18.2, 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.

18.2 The probe illustrated in Figure 18.1 is to be applied to any depth that the opening will permit and with a force not greater than 1 lbf (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.

18.3 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 19.1.4 shall be reliably retained in place.

18.4 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.

18.5 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.

18.6 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 A or less for loads not exceeding 100 VA, extractor fuses having an integral enclosure, or fuses connected in a low-voltage circuit.

18.7 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.

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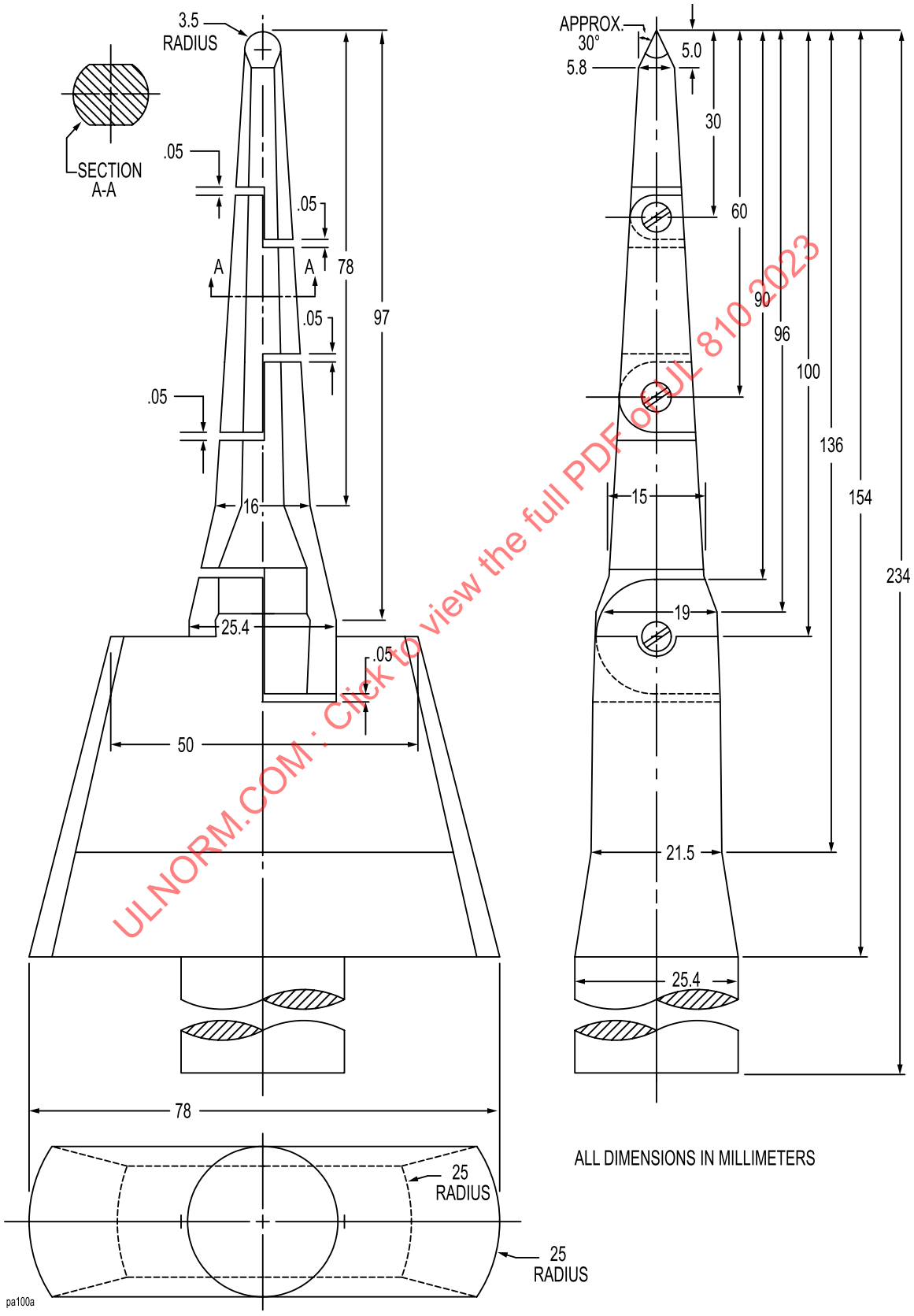
Figure 18.1

Articulate probe with web stop



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19 Protection Against Risks of Electric Shock and Injury to Persons

19.1 General

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

Exception: Electrical components in accordance with 19.5.3 need not comply.

19.1.2 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.

19.1.3 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.

19.1.4 With reference to 19.1.2, a part that is within the enclosure of a unit, and that cannot be contacted from outside the enclosure, see 18.1, by the probe illustrated in Figure 18.1 is considered to be acceptably guarded. An opening in a guard shall not permit the entrance of a probe with a diameter of 1 in (25.4 mm).

19.1.5 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 18.1, when inserted through an opening in a permanently-attached guard or baffle, is considered to be accessible to persons.

19.1.6 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.

19.2 Live parts

19.2.1 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.

19.2.2 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 19.4.2 and 19.5.1. Such a part shall also either be guarded against unintentional contact by persons or be marked in accordance with 49.4.

19.2.3 With reference to 19.2.2, 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.

19.3 Moving parts

19.3.1 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.

19.3.2 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.

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19.4 Mechanical servicing

19.4.1 The requirements in 19.4.2 and 19.4.3 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.

19.4.2 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.

19.4.3 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.

19.5 Electrical servicing

19.5.1 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.

19.5.2 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.

19.5.3 The electrical components referred to in 19.5.1 and 19.5.2 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 2.16 shall comply with the requirements in 19.2 and 19.3 with respect to uninsulated hazardous live parts, and to moving parts involving a risk of injury to persons.

19.5.4 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-in (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.

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20 Assembly

20.1 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.

20.2 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.

20.3 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.

20.4 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.

21 Protection Against Corrosion

21.1 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 52.2, and Metallic Coating Thickness Test, Section 55.

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.

22 Supply Connections

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

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

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

22.4 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.

22.5 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.

22.6 For an enclosure not provided with conduit openings or knockouts, spacings not less than the minimum required in Section 33, shall be provided between uninsulated live parts and a conduit bushing

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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.

22.7 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. The bending space within the field wiring compartment shall be in accordance with Section 24.

22.8 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.

22.9 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.

22.10 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. External cords shall be supplied with a suitable means of strain relief (i.e. strain relief bushing) rated to accommodate the gauge and type of cord.

23 Wiring Terminals and Leads

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

23.2 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 49.8 and 49.9;

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 49.10); 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 10 AWG (5.3 mm^2) or smaller conductor. See 23.4 – 23.7.

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

23.3 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.

23.4 A wire-binding screw at a field-wiring terminal shall not be smaller than No. 10 and shall be rated for connection of a 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 14 AWG (2.1 mm^2) conductor.

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

23.5 A wire-binding screw shall thread into metal.

23.6 A terminal plate tapped for a wire-binding screw shall be of metal not less than 0.050-in (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-in (0.76-mm) thick may be used if the tapped threads have adequate mechanical strength when subjected to the Tightening Torque Test, Section 45.

Exception No. 2: Two full threads are not required for a terminal in a limited-power 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 45.

23.7 Upturned lugs, a cupped washer, or the equivalent shall be capable of retaining a conductor of the size specified in 23.4 under the head of the screw or washer.

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

23.9 A unit rated 125 or 125/250 V (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.

23.10 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.

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

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24 Wire Bending Space

24.1 The distance between the end of a pressure wire connector or terminal block for connection of a field installed wire and the wall of the enclosure toward which the wire is to be directed shall be in accordance with Table 24.1.

Table 24.1
Wire bending space at field wiring terminals

Size of wire		Minimum bending space, terminal to wall							
		Wires per terminal[a]							
		1		2		3		4 or more	
AWG or MCM	(mm^2)	in	(mm)	in	(mm)	in	(mm)	in	(mm)
14 – 10	(2.1 – 5.3)	Not specified		a		a		a	
8 – 6	(8.4 – 13.3)	1.5	(38)	a		a		a	
4 – 3	(21.2 – 26.7)	2	(51)	a		a		a	
2	(33.6)	2.5	(64)	a		a		a	
1	(42.4)	3	(75)	a		a		a	
1/0	(53.5)	5	(127)	5	(127)	7	(178)	–	
2/0	(67.4)	6	(152)	6	(152)	7.5	(191)	–	
3/0	(85.0)	7	(178)	7	(178)	8	(203)	–	
4/0	(107.2)	7	(178)	7	(178)	8.5	(216)	–	
250	(127)	8	(203)	8	(203)	9	(229)	10	(254)
300	(152)	10	(254)	10	(254)	11	(279)	12	(305)
350	(177)	12	(305)	12	(305)	13	(330)	14	(356)
400	(203)	12	(305)	12	(305)	14	(356)	15	(381)
500	(253)	12	(305)	12	(305)	15	(381)	16	(406)
600	(304)	14	(356)	16	(406)	18	(457)	22	(559)
700	(356)	14	(356)	16	(406)	20	(508)	22	(559)
750 – 800	(380 – 405)	18	(457)	19	(483)	22	(559)	24	(610)
900	(456)	18	(457)	19	(483)	24	(610)	24	(610)
1000	(506)	20	(508)	–	–	–	–	–	–
1250	(663)	22	(559)	–	–	–	–	–	–
1500 – 2000	(760 – 1013)	24	(610)	–	–	–	–	–	–

Note: " – " indicates no value established

[a] Conductors smaller than 1/0 AWG (53.5 mm^2) shall not be connected in parallel.

24.2 Upon leaving the lug or connector, the distance specified in 24.1 shall be measured in a straight line from the center of the opening in the connector, in the direction in which the wire leaves the terminal, perpendicular to the enclosure wall.

24.3 When a wire is restricted by barriers or other means from being bent where it leaves the connector, the distance required by Table 24.1 shall be measured from the end of the barrier.

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24.4 The required bending space is dependent on the size of the anticipated field wiring to the bank in accordance with the National Electrical Code, NFPA 70.

25 Current-Carrying Parts

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

25.2 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, UL 486A-486B.

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

a) Acceptable in accordance with Section 1A;

b) Within a motor, or its associated controller; or

c) In a secondary circuit rated 42.4 Vpeak – 30 Vrms or 60 Vdc – or less.

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

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

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 33.2.

26 Internal Wiring

26.1 General

26.1.1 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.

26.1.2 Thermoplastic-, neoprene-, and rubber-insulated wire used for internal wiring shall be rated for the application, and shall comply with the requirements in Table 26.1.

Exception: Thermoplastic-insulated wire connected in an isolated limited-power 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 in (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 26.1.4.

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Table 26.1
Characteristics of internal wiring

Insulation	Nominal thickness in	Nominal thickness (mm)	Braid or jacket required	Nominal thickness of braid or jacket, in	Nominal thickness of braid or jacket, (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 in (0.4 mm) if the wire is provided with an additional braid or jacket having a thickness of not less than 1/64 in.

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

26.1.3 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 26.1.4.

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

26.1.4 Polyvinyl chloride tubing shall not be less than 0.017-in (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-in (0.43-mm) thick polyvinyl chloride tubing.

26.2 Protection of wiring

26.2.1 Wires, including accessible and internal wiring (see 18.1), 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.

26.2.2 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.

26.3 Electrical connections

26.3.1 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.

26.3.2 With reference to 26.3.1, 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.

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

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26.3.4 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.

26.3.5 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 V. Thermoplastic tape shall not be wrapped over a sharp edge.

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

26.3.6 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.

26.3.7 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.

27 Separation of Circuits

27.1 General

27.1.1 Insulated conductors of different circuits – see 27.1.3 – 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.

27.1.2 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.

27.1.3 For the purpose of the requirement in 27.1.1, 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.

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27.2 Separation barriers

27.2.1 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-in (0.71-mm) thick; and

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

27.2.2 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 in (1.6 mm) from the enclosure walls and interior mechanisms, component-mounted panels, and other parts that serve to provide separated compartments.

27.3 Field wiring

27.3.1 A unit shall be constructed so that a field-installed conductor of a circuit shall be segregated as specified in 27.3.2 or separated by barriers as specified in 27.2.1 and 27.2.2 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.

27.3.2 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 in (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 in (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.

27.3.3 With reference to 27.3.2, 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.

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28 Insulating Materials

28.1 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.

28.2 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 insulation requirements outlined in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, may be used.

28.3 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.

29 Switches and Controls

29.1 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.

29.2 A primary-circuit switch that controls an inductive load with a power factor less than 75%, 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.

29.3 A switch that controls a tungsten-filament lamp shall have a tungsten-filament-lamp current rating in accordance with the Standard for Switches for Appliances – Part 1: General Requirements, UL 61058-1, not less than the maximum current it will control.

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

29.4 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.

29.5 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.

30 Overload-Protective Devices

30.1 An overload-protective device, the intended functioning of which requires renewal, replacement, or resetting, shall be readily accessible. See 18.6.

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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.

30.2 With reference to 30.1, a control-circuit fuse is not considered to require renewal as a result of its intended function if the fuse and the load are contained within the same enclosure.

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

30.4 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.

31 Fuses and Fuseholders

31.1 A fuse and a fuseholder shall comply with UL 248-1 and UL 4281-1 and 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 comply with UL 248-11 and shall not be used in a unit rated more than 125 V or 125/250 V, 3-wire.

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

32 Printed Wiring

32.1 A printed-wiring board shall comply with the requirements in the Standard for Printed-Wiring Boards, UL 796, and shall be classed V-1 minimum in accordance with the requirements in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

Exception: A material classed V-2 may be employed, if a closed bottom in the equipment beneath the material is provided or an equivalent barrier is provided.

32.2 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.

32.3 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 27.2.1 and 27.2.2.

33 Spacings

33.1 General

33.1.1 The spacings at field-wiring terminals shall not be less than specified in Table 33.1:

a) Between terminals of opposite polarity;

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

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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 33.1
Spacings at field-wiring terminals

Potential involved V	Minimum spacings			
	Through air		Over surface	
	in	(mm)	in	(mm)
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 in (6.4 mm) at control-circuit terminals.

33.1.2 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 33.2 or Table 33.3, 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 Table 33.2 and Table 33.3 do not apply to the inherent spacings of a component. Such spacings shall comply with the requirements for the component. See 3.1.2.

Exception No. 2: The spacing requirements in Tables Table 33.2 and Table 33.3 do not apply to the spacings between coil windings and an uninsulated live part. These spacings shall comply with 33.1.4.

Exception No. 3: If liners and barriers are used, the spacings may comply with 33.3.1.

Exception No. 4: As an alternative to the spacing requirements in Table 33.2 and Table 33.3, spacings may comply with 33.2.

Exception No. 5: The spacing requirements in Table 33.2 and Table 33.3 do not apply to spacings for controlled environment applications. These spacings shall comply with 33.4.

Exception No. 6: The spacing requirements in Table 33.2 and Table 33.3 do not apply to spacings in circuits supplied by a Class 2 power source in accordance with the National Electric Code or a limited power source as defined in Section 34 or SELV secondary circuits as defined in 2.24.

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Table 33.2
Spacings at other than field-wiring terminals

Potential involved V	Minimum spacings			
	Through air		Over surface	
	in	(mm)	in	(mm)
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 33.3
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 V	Minimum spacings through air and over surface	
	in	(mm)
50 or less	1/16	(1.6)
51 – 150	1/4	(6.4)
151 – 600	1/2	(12.7)

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

33.1.4 The spacings between a magnet-coil winding, and an uninsulated live part or grounded dead metal part shall be as specified in 33.1.1, or the coil shall be provided with an insulating barrier that complies with the requirements in 33.3.2.

33.1.5 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.

33.1.6 All secondary circuits that are not SELV circuits in accordance with 2.24 or safety circuits, shall comply with the spacing requirements in Table 33.2 or Table 33.3 as applicable.

33.1.7 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 a limited-power circuit.

33.1.8 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 42.

33.1.9 Spacings between circuits supplied by an NEC Class 2 source or a limited power source in accordance with Section 34, and live parts of primary circuits or secondary circuits that are not SELV circuits, shall be twice the required values noted in Table 33.3.

33.2 Alternative spacings

33.2.1 As an alternative to the spacing requirements of Table 33.2 or Table 33.5, 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 33.2.2 and 33.2.3.

33.2.2 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.

33.2.3 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.

33.2.4 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.

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

33.2.6 Spacings between circuits supplied by an NEC Class 2 source or a limited power source in accordance with Section 34, and live parts of primary circuits or secondary circuits that are not SELV circuits, shall be twice the required values determined in accordance with Table 33.2.

33.3 Insulating liners or barriers for the reduction of spacings

33.3.1 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 33.1.2.

33.3.2 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-in (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-in (0.33-mm) thick or mica not less than 0.0065-in (0.165-mm) thick may be used:

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

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

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

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33.4 Spacings for controlled environment applications

33.4.1 The requirements in 33.4.2 – 33.4.5 and Table 33.4 and Table 33.5 apply to units that are intended for use in controlled environment applications. See 2.5.

33.4.2 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 33.4.

Table 33.4
Spacings at field-wiring terminals for controlled environment applications

Potential involved V	Minimum spacings					
	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	
	in	(mm)	in	(mm)	in	(mm)
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 33.5
Primary-circuit spacings at other than field-wiring terminals and in motors for controlled environment applications

Potential involved in Vrms (peak)		Minimum spacings			
		Over surface		Through air	
		in	(mm)	in	(mm)
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 in (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 in (0.580 mm) plus 0.0002 in (0.005 mm) per Vpeak 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.

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33.4.3 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 Table 33.4 and Table 33.5. 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 Table 33.4 and Table 33.5 will be maintained regardless of the position of the movable part.

Exception: A unit that complies with the requirements in 33.2 for alternative spacings need not comply with the spacings specified in Table 33.4 and Table 33.5.

33.4.4 Primary-circuit spacings in controlled environment applications apply in all secondary circuits that are safety circuits and in all non-safety secondary circuits that are not SELV circuits per 2.24, or supplied by a Class 2 or limited power source per 34.2.

33.4.5 Spacings in controlled environments between circuits supplied by an NEC Class 2 source or a limited power source in accordance with Section 34, and live parts of primary circuits or secondary circuits that are not SELV circuits, shall be twice the required values determined in accordance with Table 33.4 and Table 33.5 as applicable.

34 Secondary Circuits

34.1 General

34.1.1 All safety circuits located in secondary circuits and all secondary circuits that are intended for use in controlled applications shall be evaluated as a primary circuits.

Exception No. 1: Circuits that comply with 33.2 for alternative spacings and 34.2 need not comply with the requirements for primary circuits.

Exception No. 2: A circuit supplied from a Class 2 transformer or limited power source rated 30 Vrms (42.4 V peak) or 60 Vdc or a limited power battery rated 60 Vdc or less need not be investigated.

Exception No. 3: Printed wiring assemblies and secondary circuits that do not involve a risk of electric shock (i.e. SELV circuits) 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.

34.2 Limited power sources

34.2.1 Circuits need not be investigated if they are supplied by a limited power source complying with the following:

a) The output is inherently limited in compliance with Table 34.1; or

b) An impedance limited to the output in compliance with Table 34.1; or

c) An overcurrent protective device is used and the output is limited in compliance with Table 34.2; or

d) A regulating network limits the output in compliance with Table 34.1, both under normal operating conditions and after any single fault condition in the network (i.e. open circuit or short circuit); or

e) A regulating network limits the output in compliance with Table 34.1 under normal operating conditions, and an overcurrent protective device limits the output in compliance with Table 34.2 after any single fault condition in the regulating network (open or short circuit).

34.2.2 Where an overcurrent protective device is used, it shall be a fuse or a non-adjustable, non-autoreset, electromechanical device.

34.2.3 A limited power source operated from a primary supply or a battery-operated limited power source that is recharged for a primary supply while supplying the load, shall incorporate an isolating transformer.

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34.2.4 Compliance is checked by inspection and measurement and where appropriate, by examination of the manufacturer's data for batteries. Batteries shall be fully charged when conducting the measurements for U_{oc} and I_{sc} according to Table 34.1 and Table 34.2.

34.2.5 The load referenced in items 2) and 3) of Table 34.1 and Table 34.2 is adjusted to develop maximum current and power transfer respectively. Single faults in a regulating network are applied under these maximum current and power conditions.

Table 34.1
Limits for inherently limited power sources

Output Voltage[1] (U_{oc})		Output current[2] (I_{sc})	Apparent power[3] (S)
Vac	Vdc	A	VA
< 20	< 20	< 8.0	< 5 x U_{oc}
20 < U_{oc} < 30	20 < U_{oc} < 30	< 8.0	< 100
–	30 < U_{oc} < 60	< 150/U_{oc}	< 100

1) U_{oc}: Maximum output voltage measured with all load circuits disconnected. Voltages are for substantially sinusoidal AC and ripple free DC. For non-sinusoidal AC and DC with ripple greater than 10% of the peak, the peak voltage shall not exceed 42.4 V.

2) I_{sc}: Maximum output current with any non-capacitor load, including a short circuit, measured 60 s after application of the load.

3) S (VA): Maximum output VA with any non-capacitor load measured 60 s after application of the load.

Table 34.2
Limits for power sources not inherently limited (overcurrent protective device required)

Output Voltage[1] (U_{oc})		Output current[2] (I_{sc})	Apparent power[3] (S)	Currrent rating of overcurrent protective device[4]
V ac	V dc	A	VA	A
< 20	< 20	< 1000/U_{oc}	< 250	< 5.0
20 < U_{oc} < 30	20 < U_{oc} < 30	< 1000/U_{oc}	< 250	< 100/U_{oc}
–	30 < U_{oc} < 60	< 1000/U_{oc}	< 250	< 100/U_{oc}

1) U_{oc}: Maximum output voltage measured with all load circuits disconnected. Voltages are for substantially sinusoidal AC and ripple free DC. For non-sinusoidal AC and DC with ripple greater than 10% of the peak, the peak voltage shall not exceed 42.4 V.

2) I_{sc}: Maximum output current with any non-capacitor load, including a short circuit, measured 60 s after application of the load. Current limiting impedances in the equipment remain in the circuit during measurement but overcurrent protective devices are bypassed.

3) S (VA): Maximum output VA with any non-capacitor load measured 60 s after application of the load. Current limiting impedances in the equipment remain in the circuit during measurement, but overcurrent protective devices are bypassed.

NOTE: The reason for making measurements with overcurrent protective devices bypassed is to determine the amount of energy that is available to cause possible overheating during the operating time for the overcurrent protective devices.

4) The current ratings of overcurrent protective devices are based on fuses and circuit breakers that break the circuit within 120 s with a current equal to 210% of the current rating specified in the table.

34.2.6 Limited-power circuits rated not more than 0.5 mA may be connected to the frame of the unit.

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

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35 Grounding Connections

35.1 A unit shall comply with the grounding requirements specified in 35.2 – 35.10.

35.2 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.

35.3 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.

35.4 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.

35.5 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:

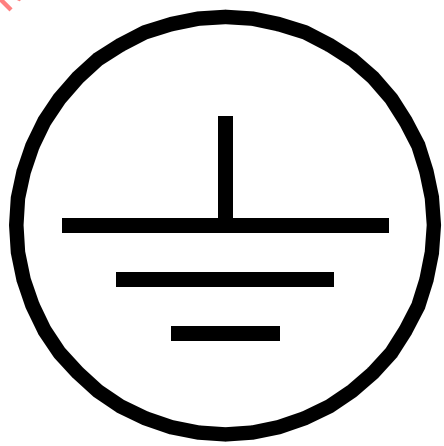
a) A marking such as G," "GR," "GND," "Ground," "Grounding," or the like;

b) A marking on a wiring diagram attached to the unit;

c) The grounding symbol illustrated in Figure 35.1 on or adjacent to the terminal or on a wiring diagram provided on the product.

Figure 35.1

Grounding symbol



IEC 60417, DB: 5019

35.6 The grounding terminal shall be rated for securing a conductor of a size rated for the application in accordance with Table 36.2.

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

35.8 A grounding lead shall be a size specified in Table 36.2 or larger. A grounding lead shall have a free length of at least 6 in (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.

35.9 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: Limited-power circuits rated not more than 0.5 mA that comply with 34.2.6 may be used.

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

36 Bonding of Internal Parts

36.1 With reference to 35.2, 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 35.3 and 35.4.

36.2 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-in (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.

36.3 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.

36.4 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.

36.5 A sheet metal screw shall not be used as a means to secure bonding conductors to the enclosure. An internal connection for bonding an internal part to the enclosure may employ a quick-connect terminal of the dimensions specified in Table 36.1 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 A or less. A quick-connect terminal shall not be used for a connection to be made in the field.

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Table 36.1
Dimensions for quick-connect bonding terminal

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

36.6 Bonding shall be accomplished by a metal-to-metal contact of parts or by a separate bonding conductor specified in 36.9 – 36.11.

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

36.8 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.

36.9 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.

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

36.11 A separate bonding conductor shall not be smaller than the size specified in Table 36.2, or smaller than the conductor supplying the component.

Exception: A separate bonding conductor need not comply with the sizes in Table 36.2 if it complies with 36.12.

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Table 36.2
Grounding/bonding conductor size

Maximum rating or setting of branch circuit overcurrent device in circuit A	Size of grounding/bonding conductor[a]					
	Copper wire		Aluminum wire		Rigid conduit or pipe trade size in	Electrical metallic tubing, trade size in
	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

Table 36.2 Continued on Next Page

Table 36.2 Continued

Maximum rating or setting of branch circuit overcurrent device in circuit A	Size of grounding/bonding conductor[a]					
	Copper wire		Aluminum wire		Rigid conduit or pipe trade size in	Electrical metallic tubing, trade size in
	AWG	(mm^2)	AWG	(mm^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

36.12 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

37 General

37.1 A representative sample of a unit is to be subjected to the tests described in Sections 38 – 46. Unless otherwise specified, all tests are to be conducted at the applicable voltage specified in Table 37.1, and at rated frequency. A unit rated 50 – 60 Hz is to be tested at 60 Hz.

Table 37.1
Values of test voltages

Rated voltages V	Test voltages V
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

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

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38 Power Input Test

38.1 The amperage or wattage input to a unit shall not be more than 115% of the rated value when the unit is connected to a supply adjusted to the test voltage specified in Table 37.1.

39 Draining of Charge Test

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

40 Secondary Circuit Evaluations

40.1 SELV determination

40.1.1 A secondary circuit is determined to be SELV when, under all conditions of loading including open circuit, the maximum voltage measured after 60 s does not exceed 30 Vrms (42.4 V peak) or 60 Vdc under normal and single fault conditions.

40.1.2 Single faults shall be applied one at a time. A single fault shall consist of a single failure (either short circuit or open circuit) of any component. The equipment, circuit diagrams and component specifications are examined to determine those fault conditions that might reasonably be expected to occur. Examples include:

a) Short circuits and open circuits of semiconductor devices and capacitors (other than power factor capacitors).

b) Faults causing continuous dissipation in resistors designed for intermittent dissipation.

c) Internal faults in integrated circuits causing excessive dissipation.

40.2 Limited power determination

40.2.1 A limited power source shall comply with the requirements outlined in 34.2. Limited power determination shall be made under normal and single fault conditions as outlined in 40.1.2.

41 Temperature Test

41.1 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 41.1. The unit shall be mounted as intended in service and connected as described in 37.1.

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Table 41.1
Maximum temperature rises

Materials and components	°C	(°F)
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:		

Table 41.1 Continued on Next Page

Table 41.1 Continued

Materials and components	°C	(°F)
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)
16. Temperature Limits on Accessible Surfaces[i]	Maximum Limits	
Metal	70	(158)
Nonmetallic	80	(176)

[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 60°C (140°F) 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, NFPA 70. The maximum temperature rise is not to exceed 25°C (45°F) less than the temperature limit of the wire except as in note b.

[d] A capacitor that operates at a temperature rise of more than 40°C (72°F) for electrolytic and more than 65°C (117°F) 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 25°C (77°F) 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 25°C (77°F) ambient temperature, is 15°C (27°F) less than the softening point of the compound as determined in accordance with the Standard Test Methods for Softening Point of Resins Derived from Pine Chemicals and Hydrocarbons, by Ring-and-Ball Apparatus, ASTM E28.

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

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

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Table 41.1 Continued on Next Page

Table 41.1 Continued

Materials and components	°C	(°F)
[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 5°C (9°F) higher than that specified when the temperature rise of the coil as measured by the resistance method is not more than that specified.		
[i] See 49.11 and 50.2 for when marking and installation instructions are required.		

41.2 All values for temperature rises in Table 41.1 are based on an assumed ambient temperature of 25°C (77°F). However, tests may be conducted at any ambient temperature within the range of 10 – 40°C (50 – 104°F).

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

41.4 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-in (25.4-mm) thick minimum soft-pine boards.

41.5 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.

41.6 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.

41.7 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-in (0.8-mm) thick.

41.8 With reference to the Exception to 41.7, 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 °C;

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

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

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

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t_2 is the room temperature in °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.

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

41.10 Thermocouples are to consist of wires not larger than 24 AWG (0.25 mm^2) and not smaller than 30 AWG (0.05 mm^2). When thermocouples are used in determining temperatures in electrical equipment, it is common practice to employ thermocouples consisting of 30 AWG (0.05 mm^2) 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 Tolerances on Initial Values of EMF versus Temperature tables in the Standard Specification and Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples, ASTM E230/E230M.

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

42 Dielectric Voltage-Withstand Test

42.1 While still in a heated condition, a unit shall withstand for 1 min without breakdown the application of a 60-Hz 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 V or less and dead metal parts;

d) One thousand volts plus twice the maximum rated secondary circuit voltage between a secondary circuit operating at more than 50 V and dead metal parts; and

e) Twice the value outlined in (a), between primary and Class 2 or limited power secondary circuits.

42.2 To determine if a unit complies with the requirements in 42.1, the unit is to be tested using a 500 VA 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 min. 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.

43 Compression Test

43.1 When subjected to the test described in 43.2, an enclosure that is thinner than that specified in Table 17.1 or Table 17.2 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.

43.2 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-in (12.7-mm) square, flat steel face.

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44 Deflection Test

44.1 A drawn, embossed, flanged, or similarly strengthened door, front, or cover made of metal having a thickness less than that specified in Table 17.1 or Table 17.2 shall not deflect inward more than 1/4 in (6.4 mm) when a vertical force of 100 lbf (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-in (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.

44.2 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 in (9.5 mm) when subjected to a force of 100 lbf (445 N) applied at any point 1 in (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-in (12.7-mm) square, flat steel face.

45 Tightening Torque Test

45.1 With respect to Exception No. 2 of 23.6, the threads of a terminal plate shall not strip when subjected to the tightening torques specified in Table 45.1.

Table 45.1
Tightening torque for wire-binding screws

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

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

46 Static Load Test

46.1 A mounting means for a unit shall withstand the load test described in 46.2 without permanent deformation, breakage, or cracking of the mounting supports, the securing means, or that portion of the unit to which it is attached.

46.2 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 lbs (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

47 Dielectric Voltage-Withstand Test

47.1 Each unit shall withstand without electrical breakdown, as a routine production-line test, the application of a 40 – 70 Hz potential as specified in 42.1(a).

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Exception: The test potential may be 1,200 V plus 2.4 times the maximum rated voltage applied for 1 s.

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

47.3 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.

47.4 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.

47.5 If the output of the test equipment transformer is less than 500 VA, the equipment shall include a voltmeter in the output circuit to directly indicate the test potential.

47.6 If the transformer output is 500 VA 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.

47.7 Test equipment other than those described in 47.4 – 47.6 may be used if found to accomplish the intended factory control.

47.8 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.

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RATINGS

48 Details

48.1 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

49 General

49.1 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.

49.2 Units marked with a fault current rating shall employ capacitors and components with greater than or equal fault current ratings. See Supplement on Short Circuit Current Ratings for Industrial Control Panels, in the Standard for Industrial Control Panels, UL 508A, for guidance on component short circuit current ratings.

49.3 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.

49.4 A live heat sink or other part that is likely to be mistaken for dead metal, is at a potential that exceeds 30 Vrms (42.4 Vpeak), and is not guarded as specified in 19.2.2 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 49.5 and 49.6.

49.5 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.

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

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49.7 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.

49.8 In accordance with Exception No. 1(a)(2) to 23.2, 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.

49.9 The terminal assembly package mentioned in 49.8 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.

49.10 With reference to Exception No.1(e) to 23.2, 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, or a tag secured to the connector, or in an assembly package provided with the unit.

49.11 A unit that exceeds the maximum temperature limits specified in Table 41.1 (item 16) 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.″

50 Installation Instructions

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

50.2 The manufacturer's instructions provided with a unit that exceeds the maximum temperature limits in Table 41.1 (item 16) shall specify that the unit is to be installed so that it is not likely to be contacted.

OUTDOOR-USE UNITS

51 General

51.1 The requirements in Sections 51 – 56 supplement, and in some cases modify, the general requirements in Part II – Power Factor Correction Units.

52 Construction

52.1 General

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

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

52.1.3 Hinges and other attachments shall be resistant to corrosion.

52.1.4 The requirements specified in 52.1.6 and 52.2 do not apply to a part, such as a decorative part, that is not required to form a part of the enclosure.

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52.1.5 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.

52.1.6 When a flexible cord is used as external interconnection in accordance with 22.10, the flexible cord shall be marked "W-A " in accordance with the Standard for Flexible Cords and Cables, UL 62.

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

52.2 Corrosion protection

52.2.1 A metallic enclosure shall be protected against corrosion as specified in 52.2.2 – 52.2.7.

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

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

a) A 0.00015-in (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.

52.2.3 An enclosure of sheet steel having a thickness less than 1/8 in (3.2 mm) if zinc-coated or 0.123 in (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 52.2.5.

a) Hot-dipped mill-galvanized sheet steel conforming with the coating Designation G90 in the Weight (Mass) of Coating Requirements table in the Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process, ASTM A653, with not less than 40% 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 Standard Test Method for Weight [Mass] of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings, ASTM A90/A90M.

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 in (0.0155 mm) on each surface with a minimum thickness of 0.00054 in (0.0137 mm). Thickness of the coating shall be established by the metallic-coating thickness test described in 55.1 – 55.7. An annealed coating shall also comply with 52.2.7.

c) A zinc coating complying with 52.2.4 (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-in (0.03-mm) thick on both surfaces. The thickness of coating shall be established in accordance with the metallic-coating thickness test described in 55.1 – 55.7.

e) A cadmium coating not less than 0.00075-in (0.0191-mm) thick on both surfaces with one coat of outdoor paint on both surfaces, or not less than 0.0005-in (0.013-mm) thick on both surfaces with two coats of outdoor paint on both surfaces. The thickness of the cadmium coating shall be

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established in accordance with the metallic-coating thickness test described in 55.1 – 55.7 and the paint shall be as specified in (c).

52.2.4 An enclosure of sheet steel 0.126-in (3.20-mm) thick or more if zinc-coated or 0.123-in (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 52.2.5.

a) Hot-dipped mill-galvanized sheet steel conforming with the coating Designation G60 or A60 in the Weight (Mass) of Coating Requirements table in the Standard Specification for Steel Sheet, Zinc-Coated (Galvanized) or Zinc-Iron Alloy-Coated (Galvannealed) by the Hot-Dip Process, ASTM A653/A653M, with not less than 40% 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 Standard Test Method for Weight (Mass) of Coating on Iron and Steel Articles with Zinc or Zinc-Alloy Coatings, ASTM A90/A90M. An A60 (alloyed) coating shall also comply with 52.2.7.

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 in (0.0104 mm) on each surface with a minimum thickness of 0.00034 in (0.0086 mm). The thickness of the coating shall be established by the metallic-coating thickness test described in 55.1 – 55.7. An annealed coating shall also comply with 52.2.7.

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 52.2.3.

52.2.5 With reference to 52.2.3 and 52.2.4, 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 52.2.3(a) or 52.2.4(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 the Salt Spray Fog Test, the Moist Carbon-Dioxide/Sulfur-Dioxide Air Test, and the Light and Water Test for Clear Coatings in accordance with the Stnadard for Organic Coatings for Steel Enclosures for Outdoor Use Electrical Equipment, UL 1332.

52.2.6 Test specimens of a finish as described in 52.2.2 or 52.2.5, 52.2.3(c), or 52.2.4(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.

52.2.7 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.

53 Rain Test

53.1 An outdoor-use unit is to be subjected to a rain test in the energized condition as described in 53.2 and 53.3. After being subjected to the rain test, an outdoor-use unit shall have no entrance of water into the enclosure.

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

53.2 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 lbf·in (90 N·m) for 3/4-in and smaller trade sizes, and 1000 lbf·in (113 N·m) for 1, 1-1/4, and 1-1/2 in trade sizes, and 1,600 lbf·in (180 N·m) for 2-in and larger trade sizes.

53.3 The water spray apparatus is to consist of three spray heads mounted in a pipe rack as illustrated in Figure 53.1. Spray heads are to be constructed in accordance with the details shown in Figure 53.2. 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 ft (1.5 m). The spray is to be directed at an angle of 45° 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 h.

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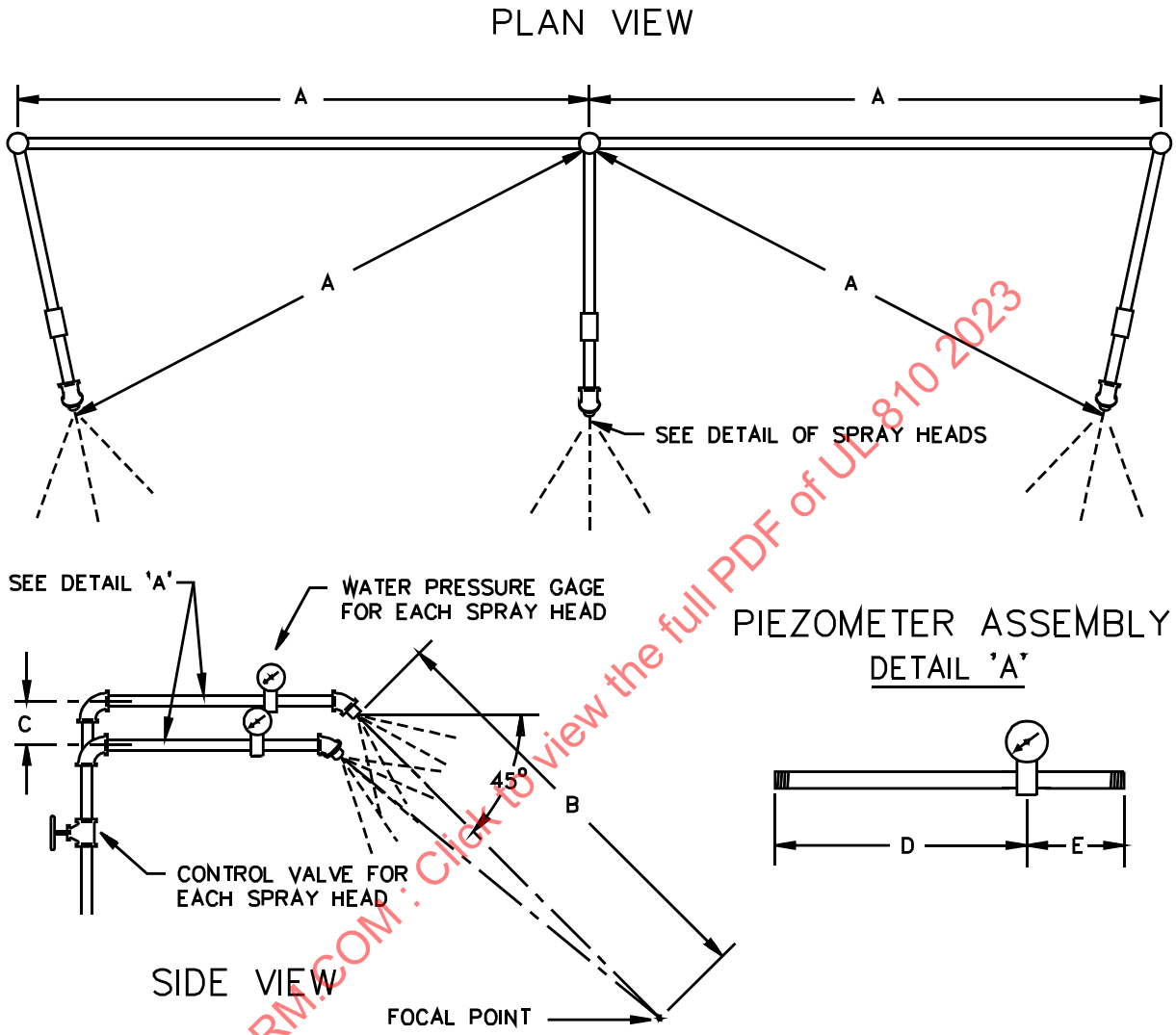
Figure 53.1

Rain-test spray-head piping



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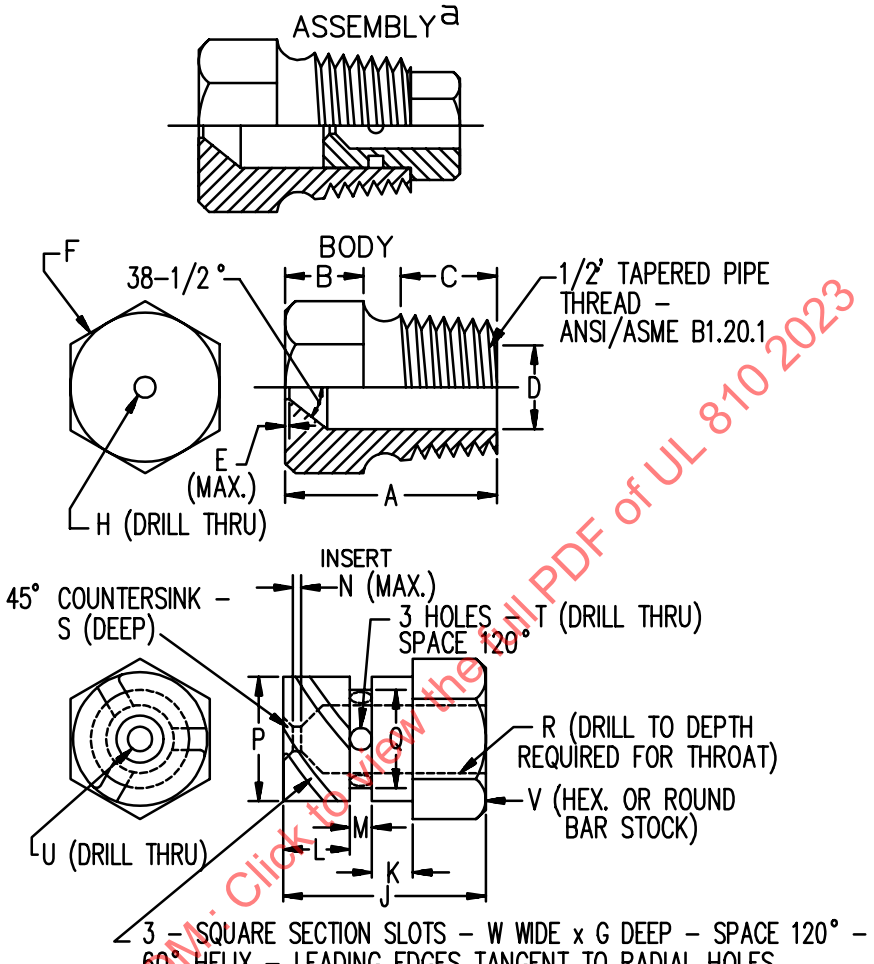
Item	inch	mm
A	28	710
B	55	1400
C	2–1/4	55
D	9	230
E	3	75

RT101E

Figure 53.2

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

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54 Gasket Tests

54.1 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 53.1 is to be subjected to the tests specified in 54.2. 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.

54.2 A sample of a gasket is to be conditioned at a temperature of 69 – 70°C (156 – 158°F) in circulating air for 168 h 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% and an elongation of not less than 60% of values determined for an unconditioned sample.

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

55 Metallic Coating Thickness Test

55.1 With reference to 52.2.3 (b), (d), and (e), and 52.2.4(b), the method of determining the thickness of a zinc or cadmium coating is described in 55.2 – 55.7.

55.2 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 g/L of reagent grade concentrated sulfuric acid (H_2SO_4). The latter is equivalent to 27 mL/L of reagent grade concentrated sulfuric acid, specified gravity 1.84, containing 96% of H_2SO_4.

55.3 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 in (0.64 mm) and a length 5.5 in (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 mL 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.

55.4 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 – 32.2°C (70 – 90°F).

55.5 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.

55.6 The sample to be tested is to be supported 0.7 – 1 in (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° from horizontal.

55.7 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.

55.8 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

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from precoated sheets, the external corners that are subjected to the greatest deformation are likely to have thin coatings.

55.9 To calculate the thickness of the coating being tested, the thickness factor from Table 55.1 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 55.7.

Table 55.1
Thickness factors

Temperature		Thickness factors, 0.00001 in (0.00025 mm) per second	
°F	(°C)	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

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56 Markings

56.1 An outdoor-use unit shall be marked "Suitable for Wet Locations." See 53.1. Units not evaluated for outdoor use in accordance with this standard shall not include any markings indicating suitability for outdoor exposure unless employing an enclosure rated for outdoor exposure with all exposed fittings and components rated for outdoor exposure in accordance with the Standard for Industrial Control Panels, UL 508A.

PART III – MEDIUM VOLTAGE POWER FACTOR CORRECTION CAPACITOR BANKS

GENERAL

57 Normal and Special Service Conditions

57.1 Normal service conditions

57.1.1 Apparatus within the scope of this Part shall be capable of operation within its performance specifications under the following conditions:

a) For equipment that is cooled by air, either ventilated or nonventilated, the temperature of the air outside of the enclosure and the ambient temperature is above 0 °C (32 °F) but does not exceed 40 °C (104 °F), and its average value, measured over a period of 24 h, does not exceed 35 °C (95 °F); and

b) The equipment is located where:

1) The influence of solar radiation is not significant, such as indoors or similarly protected locations;

2) The altitude does not exceed 3300 ft (1000 m);

3) The ambient air is not significantly polluted by dust, smoke, corrosive and/or flammable gases, vapors, or salt; and

4) The average value of the relative humidity, measured over a period of 24 h, does not exceed 95 % non-condensing.

57.2 Special service conditions

57.2.1 Altitude

57.2.1.1 Installation at altitudes above 3300 ft (1000 m) up to 9843 ft (3000 m) is also recognized in this part. Variations in the design will in some cases be required. For example, considerations should be made for temperature rise, insulation level, and mechanical parameters affected by lower ambient pressures. Manufacturers should be prepared to supply any de-rating factors to be applied to the normal service condition ratings and any necessary setting adjustments.

NOTE: Special conditions are in some cases also necessary for some types of operating mechanisms.

57.2.2 Solar radiation

57.2.2.1 If the effects of solar radiation are significant, the principles stated in IEEE C37.24, may be used for guidance.

57.2.3 Evaluations and exceptions

57.2.3.1 Conditions that equipment will experience should be evaluated in terms of the manufacturer's designated ratings and limitations. Service conditions that are outside the limits described in 57.2.1.1 should be called to the controller manufacturer's attention, since special construction or protection will in some cases be required.

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58 Glossary

58.1 General

58.1.1 For the purpose of this Part, the following definitions apply.

58.1.2 CLEARANCE – The distance between two conductive parts along a string stretched the shortest way between these conductive parts.

58.1.3 COVER – An unhinged portion of an enclosure that covers an opening.

58.1.4 CREEPAGE DISTANCE – The shortest distance along the surface of an insulating material between two conductive parts.

58.1.5 DISRUPTIVE DISCHARGE – The phenomena associated with the failure of insulation under electric stress; these include a collapse of voltage and the passage of current. The term applies to electrical breakdown in solid, liquid, and gaseous dielectrics, and combinations of these dielectrics.

58.1.6 DOOR – A hinged portion of an enclosure that covers an opening, that is intended to be opened during routine maintenance, operations, and adjustments.

58.1.7 ENCLOSURE – A surrounding case constructed to provide a degree of protection to personnel against incidental contact with the enclosed equipment and to provide a degree of protection to the enclosed equipment against specified environmental conditions.

58.1.8 MEDIUM-VOLTAGE – For this standard, ac voltage in the range of 1501 V to 15 kV.

58.1.9 MEDIUM-VOLTAGE COMPARTMENT – A compartment containing one or more medium-voltage components.

58.1.10 LOW-VOLTAGE – For this Part, ac voltage in the range of 50 V to 1500 V.

58.1.11 LOW-VOLTAGE CONTROL COMPARTMENT – A compartment containing only low-voltage components.

58.1.12 PANEL, HINGED – A portion of an enclosure that has hinges, but no hand-operable latching system, secured in the closed position by multiple bolts or other hardware requiring a tool other than a key to operate.

NOTE: Hinged panels are not intended to be opened during normal operation, routine adjustment, or simple maintenance operations such as replacement of fuses.

58.1.13 POWER FACTOR CORRECTION BANK (PFC BANK) – An assembly consisting of one or more shunt power capacitor(s), with or without additional controls and switching devices necessary to provide control of the power factor of the system to which the equipment is connected.

58.1.14 PROSPECTIVE CURRENT – The current that would flow in the circuit if each pole of the circuit were replaced by a conductor of negligible impedance.

NOTE: For testing, the prospective current is determined by calibrating the test circuit with a short circuit placed directly across the incoming terminals of the test specimen.

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58.2 Equipment characteristics

58.2.1 RATED CONTINUOUS CURRENT (I_{th}) – The rated continuous current is the maximum current carried on a continuous basis.

58.2.2 RATED DURATION OF SHORT-TIME (t_k) – The rated duration of short-time withstand current is the interval of time for which the equipment can carry a current equal to its rated short-time withstand current (I_k).

58.2.3 RATED FREQUENCY (f_r) – The rated frequency is the supply frequency for which the PFC bank is designed and to which the other characteristic values correspond. The standard values of the rated frequency are 50 Hz and 60 Hz. The preferred rated frequency is 60 Hz.

58.2.4 RATED INSULATION LEVEL (U_d), (U_p) – The rated insulation level is the impulse test voltage (BIL) (U_p) and the power-frequency withstand test voltage (U_d) from Table 68.1 that the PFC bank is expected to withstand.

58.2.5 RATED MAXIMUM VOLTAGE (U_r) – The rated maximum voltage indicates the upper limit of the highest voltage of the system voltage for which the PFC bank is intended.

NOTE: Standard values of rated voltages are 2.5 kV, 3.6 kV, 5.0 kV, 7.2 kV, 12.0 kV, 15.0 kV, 27kV, 38 kV, and 46 kV.

58.2.6 RATED SHORT-TIME WITHSTAND CURRENT (I_k) – The rated short-time withstand current is the maximum symmetrical rms value of the short-circuit current that equipment can withstand for the rated duration (t_k).

CONSTRUCTION

59 Enclosure

59.1 Requirements in other standards

59.1.1 In addition to the following, when an enclosure is marked with an environmental type designation, the enclosure construction requirements of UL 50 and UL 50E apply. If there is a conflict between the requirements in this Part and UL 50 or UL 50E, the requirements in this standard apply.

59.2 General requirements

59.2.1 Enclosures shall be metallic and suitably supported. Barriers between medium voltage and low voltage compartments shall be not less than MSG 11 [nominal thickness of 0.118 in (3 mm)]. All other doors, covers, panels and barriers shall be not less than MSG 14 [nominal thickness of 0.075 in (1.9 mm)].

59.2.2 The minimum thickness requirements of 59.2.1 are based on the use of steel. Materials other than steel may be used if they provide equivalent strength and resistance to deflection.

59.2.3 When devices are installed in doors or panels, an increase in thickness or additional strengthening shall be provided to support the devices. The additional strengthening shall provide equivalent resistance to deflection as a door or panel of the same dimensions without any openings for installed devices.

59.2.4 External parts of the enclosure may be of insulating material, provided that all medium-voltage parts are completely enclosed by grounded metallic partitions or grounded shutters meeting the thickness requirements of 59.2.1.

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59.2.5 The enclosure shall comply with the rod entry test of Section 71.

59.2.6 Enclosures shall be supplied with a bottom plate unless marked in accordance with 74.7.

59.3 Complete equipment

59.3.1 PFC banks shall be substantially complete when shipped by the manufacturer with necessary bus splices, instructions, and hardware for field connecting to provide a completed PFC bank.

59.3.2 PFC banks shall be designed with provisions for lifting, handling, storage, and installation.

59.4 Exterior doors, covers, and similar parts of enclosures

59.4.1 A part of the enclosure, such as a door, a cover, or a tank, shall be provided with means, such as latches, locks, interlocks, or screws, for firmly securing it in place.

59.4.2 If bare live parts are exposed by the opening of such doors or covers, means requiring the use of a tool to open them or provision for locking them shall be provided to secure them in the closed position. If parts operating above 600 V are exposed by the opening of covers or doors, a warning marking shall also be provided in accordance with 74.8.

59.4.3 Doors shall be provided with a latch or with a captive fastener. Such fasteners shall be located or used in multiples so as to hold the cover closed over its entire length. A door more than 4 ft (1220 mm) long on the hinged side shall have at least a two-point latch operated by a single knob or handle, or shall have two or more separate latches or captive fasteners.

59.4.4 Doors of compartments containing medium-voltage components that can be opened without the use of a tool other than a key shall be mechanically interlocked in accordance with the following:

a) Interlocks shall prevent the opening of a door to a medium-voltage compartment when the isolating means is closed;

b) Interlocks shall prevent the isolating means from being closed when the door of any medium-voltage compartment of the controller is open; and

c) Where a controller is being back fed by other power source(s), such as a bypass contactor or an isolating contactor for adjustable speed drive applications, interlocks shall be provided to prevent opening of a door to a medium-voltage compartment when the isolating means of the back-fed power source is closed, and to prevent closing of the isolating means of the back-fed power source when a door to a medium-voltage compartment is open.

NOTE: Key interlocking schemes are considered to meet this requirement.

59.4.5 A hinged panel covering a compartment containing medium-voltage components need not be mechanically interlocked when all the following conditions are met:

a) The door is not provided with handles or latches;

b) The door is bolted on all unhinged sides with a minimum of two bolts per side;

c) No bolts are operable by hand, without the use of a tool;

d) All bolts are captive fasteners;

e) The door does not provide access to withdrawable elements or fuses; and

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f) The door is marked in accordance with 74.9.

59.4.6 Covers of compartments containing medium-voltage components shall be bolted closed.

59.4.7 Where a door must be opened for maintenance of equipment or removal of drawout elements, low-voltage energized uninsulated live parts mounted on the door shall be effectively guarded or enclosed, to provide protection against unintentional contact.

59.4.8 All doors shall be capable of being opened to a minimum of 90° from the closed position.

59.4.9 Low-voltage control compartments required to be opened during normal operation, thus exposing bare live parts, shall:

a) Be of clear safety-type glass or wire-reinforced glass or another clear material found suitable with respect to flammability and UV resistance in accordance with UL 746C;

b) Be secured in such a manner that it cannot be removed without tools; and

c) Meet the requirements of impact and pressure tests for viewing panes specified in 71.2 and 71.3.

NOTE: The replacement of fuses is not considered a normal operation with respect to controllers, but the resetting of overload devices, repeated adjustment of timers or switches, etc., are considered normal operations.

59.5 Inspection windows

59.5.1 A transparent material covering an observation opening and forming a part of the enclosure shall:

a) Be of clear safety-type glass or wire-reinforced glass or another clear material found suitable with respect to flammability and UV resistance in accordance with UL 746C;

b) Be secured in such a manner that it cannot be removed without tools; and

c) Meet the requirements of impact and pressure tests for viewing panes specified in 71.2 and 71.3.

59.5.2 When provided, infrared inspection ports shall comply with UL 50V, Outline of Investigation for Infrared Viewports, in addition to 59.5.1 (b) and (c).

59.6 Ventilating openings, vent outlets (openings in enclosures)

59.6.1 Ventilation openings, including perforations, louvers, and openings protected by means of wire screening, expanded metal, or a perforated cover, shall comply with the rod entry test specified in Section 71.

59.6.2 Barriers shall be provided behind all ventilating openings into medium-voltage compartments. The barrier shall be effectively secured in place and shall prevent drawing a straight line from any point outside the enclosure to any medium voltage live part, including insulated parts such as cables (other than shielded cables).

59.6.3 The diameter of the wires of a screen shall be not less than 0.050 in (1.3 mm) if the screen openings are 0.497 in^2 (320 mm^2) or less in area, and shall be not less than 0.081 in (2.06 mm) for larger screen openings.

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59.6.4 Perforated sheet steel and sheet steel employed for expanded metal mesh shall be not less than 0.042 in (1.07 mm) thick for mesh openings or perforations 0.497 in^2 (320 mm^2) or less in area, and shall be not less than 2.03 mm (0.080 in) thick for larger openings.

59.6.5 Any ventilation opening in the top of the enclosure shall be covered by a hood or protective shield spaced above the opening to prevent the entry of water or objects falling vertically downward, both with and without any cooling system or fans operating.

59.7 Protection against corrosion

59.7.1 Enclosures shall be designed so that aluminum will not contact a concrete mounting pad when installed in accordance with the manufacturer's instructions.

59.7.2 All metal surfaces are to be provided with corrosion protection, in accordance with the requirements of IEEE C37.20.3.

59.8 External operating handles and control devices

59.8.1 Control, instrument, switch, and operator handles or external handles and pushbuttons shall be located in accordance with the following:

a) Pushbuttons, control switch handles, and transfer switch handles shall be located in a readily accessible location at an elevation above the mounting surface not in excess of 79 in (2 m);

b) Operating handles requiring more than 50 lbf (222 N) to operate shall not be higher than 66 in (1.7 m) in either the open or closed position; and

c) Operating handles for infrequently operated devices, such as reset devices, drawout fuses, fused voltage transformer or CPT primary disconnects, and bus transfer switches, need not comply with (a) and (b) above.

59.8.2 In determining compliance with the requirements of 59.8.1, measurements shall be made from the mounting surface to the center of the handle grip with the handle in its highest possible position. If the handle grip is not clearly defined, the center of the handle grip shall be considered to be at a point 3 in (76 mm) in from the end of the handle.

59.8.3 If the mechanism of a switching device is such that operation of a remote or automatic tripping device will permit sudden movement of an operating handle, the motion of the handle shall be restricted or the handle shall be guarded.

59.9 Barriers

59.9.1 When access is required to a compartment that contains energized medium-voltage parts, barriers shall be provided to:

a) Prevent unintentional contact with energized parts;

b) Prevent tools or other equipment from being dropped on energized parts; and

c) Protect against contact with live parts of adjacent functional units.

59.9.2 Any barrier intended to be removed during routine maintenance or servicing (such as barriers required to be removed for replacement of fuses or the examination of contacts) shall be marked in accordance with 74.10.

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59.10 Environmental enclosure considerations

59.10.1 The following requirements shall apply to all outdoor enclosures:

a) External hinged doors or covers for equipment intended for use outdoors shall be provided with stops to hold them in the open position;

b) An enclosure intended for use outdoors shall be subjected to the Driven Rain test described in Section 69;

c) Enclosures intended for outdoor use shall have provisions for locking to prevent access to medium-voltage compartments; and

d) Consideration should be given to prevention of condensation and entry of snakes, rodents, etc.

59.10.2 Enclosures may also be evaluated to specific enclosure types as specified in UL 50E. Enclosures rated with an outdoor type environmental rating shall be subjected to the driven rain test described in Section 69, in addition to the appropriate tests in UL 50E for the assigned type rating(s).

60 Field-Wiring Connections

60.1 Medium voltage conductors

60.1.1 Wire bending space shall be such that, during installation, medium voltage field-installed conductors need not be bent to a radius:

a) Less than 8 times the overall diameter for non-shielded conductors; or

b) Less than 12 times the overall diameter for shielded or lead-covered conductors.

60.1.2 With respect to 60.1.1, construction shall take into account the type and size of wire, optional use of stress cones for field terminations, and other instructions provided in accordance with 75.3.9. The minimum size field-wiring conductors to be used for calculating wire bending space shall be determined based on use of MV-90 conductors with an ampacity no less than 135% of the rated current of the capacitor bank using Tables 310.60©(73) and 310.60(C)(74) of NFPA 70 for copper and aluminum conductors, respectively.

60.1.3 PFC banks rated over 2.5 kV shall be provided with wire bending space based on the use of shielded conductors.

NOTE: Section 310.10 of NFPA 70 provides details for the use of shielded conductors.

60.1.4 Terminals for field connection of medium voltage conductors shall conform to any one of the following:

a) Bus bars provided with hole patterns meeting the requirements of ANSI/NEMA CC1;

b) Connectors complying with UL 486A-486B, rated for the conductor size required based on the rated ampacity of the PFC bank; or

c) Separable connectors complying with IEEE 386, rated for the ampacity of the PFC bank.

60.1.5 There shall be provisions for bonding of conductor shields to the ground bus. These provisions shall be located such that the shield bonding conductor need not exceed 3.3 ft (1 m).

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60.2 Low voltage conductors

60.2.1 When field connection of low voltage conductors is expected, wire bending space for low voltage conductors shall meet the requirements for field wiring conductors as specified in 60.2.2 through 60.2.4. The minimum size field-wiring conductors to be used for calculating wire bending space shall be determined based on use of conductors with an ampacity no less than 135 % of the rated current of the capacitor bank, using the ampacities shown in Table 310.15(B)(16) of NFPA 70 for 75 °C (167 °F) rated conductors.

60.2.2 The space between the end of the pressure wire connector for the connection of field-installed wire and the wall of the enclosure toward which the wire will be directed upon leaving the connector shall be at least that specified in Table 60.1.

Table 60.1
Wire bending space at the low-voltage terminals of PFC Banks

Size of wire[a]		Minimum bending space, terminal to wall							
		Wires per terminal							
		1		2		3		4 or more	
AWG or kcmil	(mm^2)	in	(mm)	in	(mm)	in	(mm)	in	(mm)
4 – 3	(21.2 – 26.7)	2	(51)	–		–		–	
2	(33.6)	2-1/2	(64)	–		–		–	
1	(42.4)	3	(76)	–		–		–	
1/0	(53.5)	5	(127)	5	(127)	7	(178)	–	
2/0	(67.4)	6	(152)	6	(152)	7-1/2	(191)	–	
3/0	(85.0)	7	(178)	7	(178)	8	(203)	–	
4/0	(107.2	7	(178)	7	(178)	8-1/2	(216)	–	
250	(127	8	(203)	8	(203)	9	(229)	10	(254)
300	(152	10	(254)	10	(254)	11	(279)	12	(305)
350	(177)	12	(305)	12	(305)	13	(330)	14	(356)
400	(203)	12	(305)	12	(305)	14	(356)	15	(381)
500	(253)	12	(305)	12	(305)	15	(381)	16	(406)
600	(304)	14	(356)	16	(406)	18	(457)	19	(483)
700	(355)	14	(356)	16	(406)	20	(508)	22	(559)
750 – 800	(380 – 405)	18	(457)	19	(483)	22	(559)	24	(610)
900	(456)	18	(457)	19	(483)	24	(610)	24	(610)

[a] The wire size is to be based on 60.2.1.

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60.2.3 The space specified in 60.2.2 is to be the length of a straight line extending from the end of the pressure wire connector where the wire would be connected toward and perpendicular to the enclosure wall toward which the wire would be initially directed.

60.2.4 If a wire is restricted by barriers or other means from being bent where it leaves the connector, the distance required by 60.2.2 and Table 60.1 is to be measured from the end of the barrier. A terminal connector that is not prevented from turning is to be repositioned anywhere within the limits to obtain the shortest distance for measurement.

60.2.5 Terminals for field connection of low voltage conductors shall be suitable for connection of conductors having an ampacity of no less than 135 % of the rated current of the circuit to be connected, or 14 AWG (2.1 mm^2), whichever is larger.

60.3 Separation of circuits

60.3.1 Field wiring terminals shall be located such that low voltage field-wiring conductors will be separated from medium voltage wiring or components and medium voltage field-wiring conductors will be separated from low voltage wiring or components.

60.3.2 For the purpose of 60.3.1, the conductors shall be separated by a distance no less than the clearance required between uninsulated medium voltage parts and ground as shown in Table 65.1.

60.3.3 Field-wiring conductors for circuits having voltages above 7.2 kV shall be isolated from all low-voltage conductors and components by grounded metal barriers.

61 Bus Bars

61.1 Bus insulation is optional. When provided, the following requirements shall apply:

a) Bus joints, other than at shipping joints, shall be completely covered by insulating materials at the factory. For interconnecting bus joints that must be made in the field, insulating material shall be supplied for application in accordance with the manufactu'er's instructions;

b) A representative sample of insulated bus shall withstand without breakdown the test for bus bar insulation described in 67.6. This test is required on one insulated bus bar test sample for each rated voltage; and

c) The bus bar insulation shall be rated 94 V-0 or better.

61.2 All joints between bus bars shall be tin or silver plated on both mating surfaces.

62 Internal Wiring

62.1 Conductors

62.1.1 Insulated conductors shall be suitable for the service intended with respect to voltage, temperature, and grouping. Conductors shall be not smaller than 24 AWG (0.205 mm^2), and the temperature rating shall be not less than 90 °C (194 °F) unless shown suitable with appropriate temperature rise testing.

NOTE: These requirements apply only to the wiring furnished on or in PVC banks as a part of the equipment. They do not apply to the supply wiring run to control equipment, to loads, or to other apparatus.

62.1.2 Conductors smaller than 24 AWG (0.205 mm^2) may be used for wiring of printed circuit boards and interconnecting wiring between electronic modules and subassemblies.

62.1.3 Conductors in sizes 1/0 AWG (53.5 mm^2) and larger may be run in parallel if the arrangement is such as to provide equal division of total current among all conductors involved.

62.1.4 Conductors that are in contact with each other, or bundled together shall all be insulated for the highest voltage normally occurring on any of the conductors.

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