

UL 810

Capacitors





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UL Standard for Safety for Capacitors, UL 810

Fifth Edition, Dated May 4, 1995

Revisions: This Standard contains revisions through and including March 3, 2008.

Summary of Topics

The revisions dated March 3, 2008 were issued to incorporate the following:

- *Inclusion of fault current testing capacitors that rely on segmented metallized electrodes to open the circuit under fault conditions rather than an expansion/pressure mechanism;*
- *Revised requirements for low voltage circuits and limited power (formerly limited energy) circuits;*
- *Revised production line testing values;*
- *Added new Supplement SA to include requirements for electrolytic capacitors;*
- *New option to allow use of IEC grounding symbol;*
- *Wire bending space; and*
- *Miscellaneous revisions.*

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Text that has been changed in any manner is marked with a vertical line in the margin. Changes in requirements are marked with a vertical line in the margin and are followed by an effective date note indicating the date of publication or the date on which the changed requirement becomes effective.

The following table lists the future effective dates with the corresponding item.

Future Effective Date	References
May 21, 2012	1.1.1, 1.2, 7.3, 12.1, 20.7, 33.5, 44.1, 46.1.1, and 53.1

The new and/or revised requirements are substantially in accordance with UL's Proposal(s) on this subject dated July 13, 2007 and October 12, 2007.

The revisions dated March 3, 2008 include a reprinted title page (page1) for this Standard.

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

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

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Page	Date
1-18F.....	March 3, 2008
19.....	May 4, 1995
20.....	March 3, 2008
21-22.....	August 24, 1998
23-24B.....	March 3, 2008
25-26.....	May 4, 1995
27-30B.....	March 3, 2008
31.....	May 4, 1995
32.....	August 24, 1998
33.....	May 4, 1995
34-43.....	March 3, 2008
44.....	May 4, 1995
45-50.....	March 3, 2008
51.....	May 4, 1995
52-52B.....	March 3, 2008
53.....	May 4, 1995
54-56.....	March 3, 2008
57-59.....	May 4, 1995
60-62.....	March 3, 2008
SA1-SA6.....	March 3, 2008
A1-A2.....	March 3, 2008
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1

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Standard for Capacitors

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May 4, 1995

The most recent designation of ANSI/UL 810 as an American National Standard (ANSI) occurred on March 3, 2008. The ANSI approval for this standard does not include the Cover Page, Transmittal Pages, or Title Page.

This ANSI/UL Standard for Safety, which consists of the Fifth Edition including revisions through March 3, 2008, is under continuous maintenance, whereby each revision is ANSI approved upon publication.

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CONTENTS

INTRODUCTION

1 Scope	5
2 Glossary	6
3 General	7
3.1 Components	7
3.2 Units of measurement	7
3.3 Undated references	7

PART I – CAPACITORS

CONSTRUCTION

4 Enclosure	8
4.1 General	8
4.2 Metallic	8
4.3 Nonmetallic	8
5 Internal Protection Bridge	9
6 Insulating Material	9
7 Leads and Terminals	10
8 Spacings	11

PERFORMANCE

9 Pull-Out Test	12
10 Fault-Current Test	12
10.1 General	12
10.2 Sample preparation	14
10.3 Test method	15
10.3A Test method	15
10.4 Restrike test (oil-filled only)	18
11 Dielectric Voltage-Withstand Test	18
11A Dielectric Voltage-Withstand Test	18

MANUFACTURING AND PRODUCTION TESTS

12 Dielectric Voltage-Withstand Test	18A
--	-----

MARKINGS

13 General	18B
------------------	-----

PART II – POWER-FACTOR CORRECTION UNITS

GENERAL

14 Terminology	18C
----------------------	-----

CONSTRUCTION

15	Frame and Enclosure	18C
16	Accessibility of Uninsulated Live Parts, Moving Parts, and Film-Coated Wire	22
17	Protection Against Risks of Electric Shock and Injury to Persons	24
17.1	General	24
17.2	Live parts	24
17.3	Moving parts	24A
17.4	Mechanical servicing	25
17.5	Electrical servicing	25
18	Assembly	25
19	Protection Against Corrosion	26
20	Supply Connections	26
21	Wiring Terminals and Leads	28
21A	Wire Bending Space	30
22	Current-Carrying Parts	30A
23	Internal Wiring	30B
23.1	General	30B
23.2	Protection of wiring	31
23.3	Electrical connections	31
24	Separation of Circuits	32
24.1	General	32
24.2	Separation barriers	32
24.3	Field wiring	33
25	Insulating Materials	33
26	Switches and Controls	34
27	Overload-Protective Devices	35
28	Fuses and Fuseholders	35
29	Printed Wiring	35
30	Spacings	36
30.1	General	36
30.2	Alternative spacings	38
30.3	Insulating liners or barriers for the reduction of spacings	38
30.4	Spacings for controlled environment applications	39
31	Secondary Circuits	40
31A	Secondary Circuits	40
31A.1	General	40
31A.2	Limited power sources	41
32	Grounding Connections	42A
33	Bonding of Internal Parts	42C

PERFORMANCE

34	General	44
35	Power Input Test	45
36	Draining of Charge Test	45
37	Open-Circuit Potential Test	45
37A	Secondary Circuit Evaluations	45
37A.1	SELV determination	45
37A.2	Limited power determination	46
38	Temperature Test	46
39	Dielectric Voltage-Withstand Test	47
40	Compression Test	47

41 Deflection Test	48
42 Tightening Torque Test	48
43 Static Load Test	49

MANUFACTURING AND PRODUCTION TESTS

44 Dielectric Voltage-Withstand Test	49
--	----

RATINGS

45 Details	51
------------------	----

MARKINGS

46 General	51
47 Installation Instructions	53

OUTDOOR-USE UNITS

48 General	53
49 Construction	53
49.1 General	53
49.2 Corrosion protection	54
50 Rain Test	56
51 Gasket Tests	59
52 Metallic Coating Thickness Test	59
53 Markings	61

SUPPLEMENT SA - Electrolytic Capacitors

SA1 Scope	SA1
SA2 Glossary	SA1
SA3 General	SA1
SA4 Construction	SA1
SA4.1 Enclosure	SA1
SA4.2 Internal protection bridge	SA1
SA4.3 Insulating material	SA1
SA4.4 Electrolyte	SA2
SA4.5 Leads and terminals	SA2
SA4.6 Spacings	SA2
SA5 Performance	SA2
SA5.1 General	SA2
SA5.2 Pull-out test	SA3
SA5.3 Torque test (screw terminals)	SA3
SA5.4 Heating (sealing) test	SA3
SA5.5 Reverse polarity test	SA4
SA5.6 Pressure relief test	SA4
SA5.7 Dielectric voltage-withstand test	SA4
SA6 Markings	SA5
SA6.1 General	SA5
SA6.2 Instructions	SA6

APPENDIX A

Standards for Components.....	A1
-------------------------------	----

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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 oil-filled capacitors rated 5 kilovolts or less, and dry-type capacitors rated 2 kilovolts or less that are intended for use with appliances, lighting equipment, air conditioning and refrigeration equipment, motors, and the like, that comply with the requirements for such appliances and equipment.

1.1.1 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 kilovolts. Dry type capacitors intended to be located in circuits not requiring fault current protection may be evaluated using only the construction requirements of Part I.

Added 1.1.1 effective May 21, 2012

1.2 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 volts maximum and intended for power-factor correction of circuits in accordance with the National Electrical Code, ANSI/NFPA 70. This equipment is intended for installation in ordinary locations, in accordance with the National Electrical Code, ANSI/NFPA 70, where the ambient temperature does not exceed 40°C (104°F) maximum.

Exception: 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.

Revised 1.2 effective May 21, 2012

1.2.1 A component capacitor used in a power factor correction unit as described in Part II of this Standard has been evaluated for across-the-line applications in accordance with Part I of this Standard and has been evaluated for a minimum fault current rating of 10K AFC.

1.2.1 revised March 3, 2008

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

1.2.2 added March 3, 2008

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

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

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

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

1.6 revised March 3, 2008

2 Glossary

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

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

2.2.0 CLASS 2 CIRCUIT – A circuit supplied by a Class 2 source in accordance with Article 725 of the National Electrical Code (NEC).

2.2.0 added March 3, 2008

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

2.2.1 added August 24, 1998

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

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

2.3.1 added March 3, 2008

2.3.2 ELECTRODE, FOIL TYPE – Capacitor plates consisting of thin metal or "foil" separated by a dielectric.

2.3.2 added March 3, 2008

2.3.3 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.

2.3.3 added March 3, 2008

2.3.4 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.

2.3.4 added March 3, 2008

2.3.5 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.

2.3.5 added March 3, 2008

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

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

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

2.6 revised March 3, 2008

2.7 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.

2.7 revised March 3, 2008

2.8 Deleted March 3, 2008

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

2.8.1 added March 3, 2008

2.9 LIMITED-POWER CIRCUIT – A circuit involving a potential of not more than 30 volts rms (42.4 volt peak) 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 31A.1.1.

2.9 revised March 3, 2008

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

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

2.11 revised March 3, 2008

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

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

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

2.13.1 added August 24, 1998

2.13.2 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.

2.13.2 added March 3, 2008

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

2.14.1 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 V peak) or 60 Vdc.

2.14.1 added March 3, 2008

2.15 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.

2.15 revised March 3, 2008

2.15.1 SEGMENTED METALLIZED ELECTRODE – 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.

2.15.1 added March 3, 2008

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

2.15.2 added March 3, 2008

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

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

2.17 added March 3, 2008

3 General

3.1 Components

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

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

- a) Involves a feature or characteristic not required in the application of the component in the product covered by this standard, or
- b) Is superseded by a requirement in this standard.

3.1.2 revised March 3, 2008

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

3.1.3 revised March 3, 2008

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

3.1.4 revised March 3, 2008

3.2 Units of measurement

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

3.2.1 revised March 3, 2008

3.3 Undated references

3.3 added March 3, 2008

3.3.1 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.

PART I – CAPACITORS

CONSTRUCTION

4 Enclosure

4.1 General

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

4.2 Metallic

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

4.3 Nonmetallic

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

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

- a) Comply with the flammability test– 3/4-inch (19.1-mm) flame, specified in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C; or
- b) Be classed V-2 minimum in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

4.3.2 revised August 24, 1998

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

- a) Mechanical strength;
- b) Moisture-absorbent properties;
- c) Combustibility;
- d) Compatibility with dielectric mediums;
- e) Resistance to arcing;
- f) Dielectric strength;
- g) Aging characteristics; and
- h) Resistance to distortion at maximum temperatures to which the enclosure may be subjected under conditions of normal or abnormal use.

4.3.4 With regard to mechanical strength and resistance to distortion at maximum temperatures of operation described in 4.3.3 (a) and (h), a polymeric material used as an enclosure shall have a relative mechanical temperature index without impact of at least 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.

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

5 Internal Protection Bridge

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

6 Insulating Material

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

Exception No. 1: A polymeric 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 inch (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.

6.1 revised March 3, 2008

Table 6.1
Polymeric insulating material

Table 6.1 revised August 24, 1998

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

Table 6.1 Continued

Application	Properties				
	Minimum flammability class ^a	Resistance to ignition		Electrical	
		Hot wire (HWI) ^b	High current (HAI) ^b	Dielectric breakdown strength ^b	Comparative tracking index (CTI) ^b
		Maximum performance level category	Maximum performance level category	Minimum volts	Maximum performance level category
^a The flammability classification is to be determined by the tests described in the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94. ^b Tests are to be conducted in accordance with the Standard for Polymeric Materials – Short Term Property Evaluation, UL 746A. Requirements for each test are specified in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C. ^c Also applies to a nonmetallic enclosure in contact with insulated current-carrying live parts and where there are no uninsulated current carrying parts. ^d Also applies to a nonmetallic enclosure in contact with uninsulated live parts or where the enclosure is within 1/32 inch (0.8 mm) of uninsulated live parts.					

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

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

6.3 revised March 3, 2008

7 Leads and Terminals

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

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

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 7.3.

7.2 revised March 3, 2008

7.3 A wiring terminal of a capacitor shall be provided with a soldering lug, pressure terminal connector, wire-binding screw, or quick-connect terminal rated for securing the size of the conductor to be connected. The terminal material shall be at least 0.020 inch (0.51 mm) thick and shall be of copper, copper alloy, tin plated steel, or other metal rated for the application. Wire-binding screws shall be limited to connections with 10 AWG or smaller conductors.

Exception: For capacitors rated over 5000 V, a terminal plate tapped for a wire-binding screw shall be of metal not less than 0.030 inch (0.76 mm) thick for a 14 AWG (2.1 mm²) or smaller wire and not less than 0.050 inch (1.27 mm) thick for a wire larger than 14 AWG. There shall be sufficient threads to provide two full threads engagement with the screw.

Revised 7.3 effective May 21, 2012

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

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 7.3.

7.4 revised March 3, 2008

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 30.2 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 30.2.2 and 30.2.3.

8.1 revised March 3, 2008

Table 8.1
Spacings

Table 8.1 revised March 3, 2008

Capacitor rating, volts	Minimum spacings, inch (mm)			
	Through air		Over surface	
0 – 150	1/8	(3.2)	1/4	(6.4)
151 – 300	1/4	(6.4)	3/8	(9.5)
301 – 660	3/8	(9.5)	1/2	(12.7)
661 – 2000	3/4	(19.1)	3/4	(19.1)
2001 – 5000	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 minute in a direction perpendicular to the plane of the surface at which the lead enters the capacitor. The force shall be:

- a) 20 pounds (89 N) for 18 AWG (0.82 mm²) and larger leads; or
- b) 8 pounds (36 N) for leads smaller than 18 AWG.

9.2 revised March 3, 2008

10 Fault-Current Test

10.1 General

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

- a) For an oil-filled capacitor, the enclosure shall not vent, leak, or rupture expelling the dielectric medium; or
- b) For a dry-type capacitor, there shall not be ignition of the cotton prescribed in 10.1.10.

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

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

Table 10.1
Current for fault-current test

Table 10.1 revised March 3, 2008

Intended application	Number of test samples (metallized electrode) ^c	Number of test samples (foil electrode) ^a	Current, amperes ^b								
			10,000	5000	1000	200	60	30	15	5	2.5
General application, across-the-line or in series with other impedance	42 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	

Table 10.1 Continued

Intended application	Number of test samples (metallized electrode) ^c	Number of test samples (foil electrode) ^a	Current, amperes ^b								
			10,000	5000	1000	200	60	30	15	5	2.5
HID ballast, across-the-line applications	36 total	36 per fault 72 total		X	X	X	X		X	X	
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 10.2.1: 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.											

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

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

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

10.1.6 The test circuit is to have sufficient capacity to deliver the fault currents specified in Table 10.1 with the test terminals short-circuited with a copper bar that is not more than 12 inches (305 mm) long and that has a cross-sectional area of at least 3 square inches (19.4 cm²).

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

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

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

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

10.2 Sample preparation

10.2.1 Capacitors with foil electrodes

10.2.1.1 The required number of samples, as indicated in Table 10.1, to complete each test are to be prepared. For paper and foil windings, 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 inch (12.7 mm) and a width of approximately 1/2 inch, at the following locations:

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

Exception: Other methods of inducing 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.

10.2.1.1 revised March 3, 2008

10.2.2 Capacitors with metallized electrodes

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

10.2.2.1 revised March 3, 2008

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

10.2.2.2 revised March 3, 2008

10.3 Test method

Section 10.3 revised and relocated as Section 10.3A March 3, 2008

10.3A Test method

Section 10.3 revised and relocated as Section 10.3A March 3, 2008

10.3A.1 Capacitors with internal pressure interruption mechanisms

10.3A.1.1 Three samples of each size with induced faults, prepared in accordance with 10.2.1 or 10.2.2 as applicable, are to be subjected to the rated maximum fault-test current, and to lower levels of fault-test currents specified in Table 10.1.

10.3A.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.

10.3A.1.3 When the protective device does not function at the lowest current level specified in Table 10.1, the current is to be increased by increments of 2.5 amps. Quick-connect terminals are not prohibited from being used in circuits in which the available fault current is 200 amperes or less. The enclosure is to be connected to the live pole of the capacitor that is least likely to strike to ground in service.

10.3A.1.4 Leads connected to the test terminals are to be 12 AWG (3.3 mm²) or larger, and are not to be longer than 2 feet (0.61 m).

10.3A.1.5 The application of the voltage is to be continued for not less than 1 minute after interruption of the fault current. If there has not been reestablishment of current or any indication of a tendency to restrike (unusual heating, internal arcing, or the like) before the end of the 1-minute interval, the performance is acceptable. If evidence of a tendency to restrike has been noted, the voltage is to be applied until it is definitely determined that complete and permanent interruption of the circuit has occurred, or until the ultimate effect on the capacitor has been determined, but not longer than 2 hours. Reestablishment of the circuit that results in venting or enclosure rupture is not acceptable.

10.3A.1.6 If the protective device does not function after the circuit has been energized for at least 2 hours, the sample may be replaced by a substitute sample of the same construction and fault condition, and the test is to be repeated.

10.3A.1.7 At the conclusion of the test, the dielectric withstand test is conducted.

10.3A.2 Capacitors with segmented metallized electrode protection (no internal pressure interruption mechanism)

10.3A.2.1 Three samples of each size for each fault current, with induced faults prepared in accordance with 10.2.2, are subjected to the rated maximum fault-test current and to the lower levels of fault test currents specified in Table 10.1. See Table 10.1 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 10.3A.1.

10.3A.2.2 A single cycle consists of:

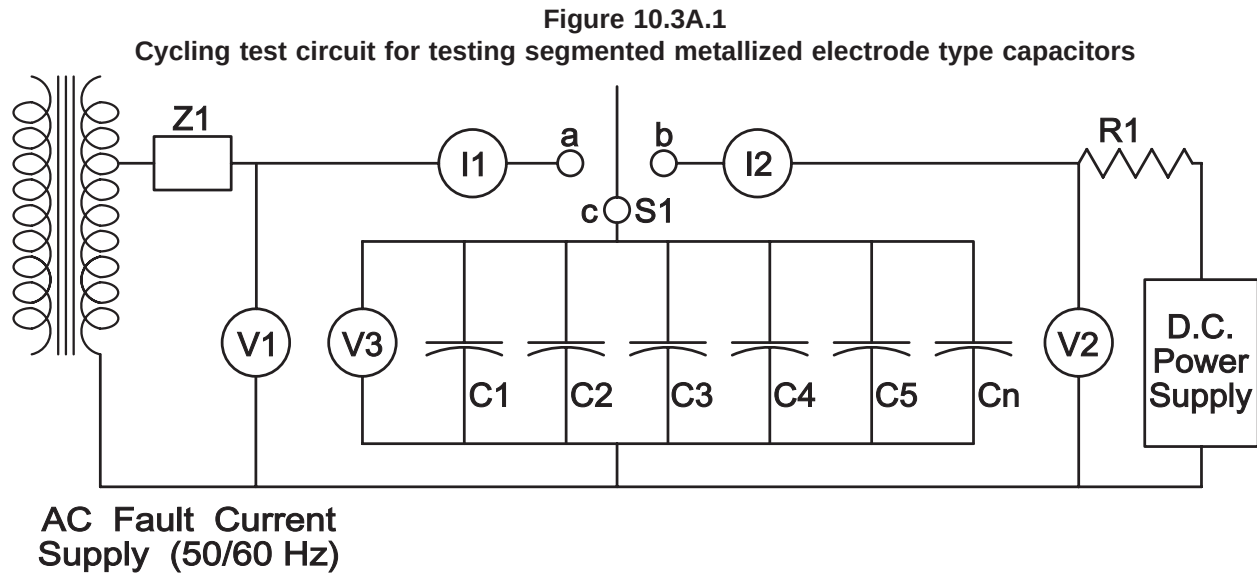
- a) The AC fault current at specified voltage is applied to the test sample capacitor(s) for 5 seconds.
- b) The connection between the AC fault current circuit and test capacitor is then opened and the test capacitor is discharged for 30 to 60 seconds through a 3 Meg-ohm resistor.
- c) After the discharge, the test capacitor is connected to a DC voltage supply of 2000 V (limited to 300 mA) for 2 seconds 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 seconds through a 3 Meg-ohm resistor.

10.3A.2.3 The above cycle shall be repeated until the test sample capacitance loss measures 5 percent of its original reading or ultimate results occurs.

10.3A.2.4 When the protective mechanism does not function at the lowest current level specified in Table 10.1, the current is to be increased by increments of 2.5 amps. Quick-connect terminals are not prohibited from being used in circuits in which the available fault current is 200 amperes or less. The enclosure is to be connected to the live pole of the capacitor that is least likely to strike to ground in service.

10.3A.2.5 Leads connected to the test terminals are to be 12 AWG (3.3 mm²) or larger, and are not to be longer than 2 feet (0.61 m).

10.3A.2.6 At the conclusion of the test, the dielectric withstand test is conducted.



S5438

Current and voltage monitoring points:

- 1) V1 – open circuit voltage
- 2) I1 – AC test current
- 3) V2 – DC breakdown voltage
- 4) I2 – DC breakdown current
- 5) V3 – Capacitor voltage

Components for the circuit:

- 1) An AC supply capable of providing the required short circuit current or AFC and the required open circuit voltage or test voltage.
- 2) A small DC power supply capable of obtaining the desired breakdown voltage.
- 3) Z1 – The impedance added to the circuit impedance to achieve the desired fault current at the test voltage.
- 4) R1 – A resistor sized to limit the peak DC current to 1 percent of the normal peak current for the capacitors under test.
- 5) 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.
- 6) C1 through Cn – The capacitors under test.

10.4 Restrike test (oil-filled only)

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

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

11 Dielectric Voltage-Withstand Test

Section 11 revised and relocated as Section 11A March 3, 2008

11A Dielectric Voltage-Withstand Test

Section 11 revised and relocated as Section 11A March 3, 2008

11A.1 All samples that have been subjected to the Fault-Current Test, Section 10, shall be subjected to a dielectric voltage-withstand test as described in 11A.2. There shall be no dielectric breakdown of any sample.

11A.2 To determine if a capacitor complies with the requirements in 11A.1, the capacitor is to be tested using a 500 volt-ampere or larger capacity transformer, the output voltage of which can be varied. The applied potential is to be increased from zero until the required test level is reached, and is to be held at that level for 1 minute. The increase in applied potential is to be at a substantially uniform rate as rapid as is consistent with correct indication of its value by a voltmeter.

11A.3 As an alternative, a DC potential equal to 1.4 times the AC potential specified in 11A.4 may be used.

11A.4 The test voltage applied shall consist of a 60 Hz alternating potential of:

- a) One thousand volts plus twice the rated voltage applied between all live parts and all dead metal parts; and
- b) One and a half times the maximum rated voltage applied between terminals of opposite polarity.

11A.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

12 Dielectric Voltage-Withstand Test

12.1 Each capacitor shall withstand without electrical breakdown, as a routine production-line test, the application of a 40 – 70 Hz potential between live parts and dead metal parts as specified in 11A.4(a). As an alternative, a DC potential equal to 1.4 times the AC potential specified in 11A.4(a) may be used.

Exception: The test potential application time may be reduced to 1 second if the test potential is 1200 volts plus 2.4 times the rated voltage.

Revised 12.1 effective May 21, 2012

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

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

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

- a) By a voltmeter in the primary circuit or in a tertiary-winding circuit;
- b) By a selector switch marked to indicate the test potential; or
- c) For equipment having a single test potential output, by a marking in a readily visible location to indicate the test potential.

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

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