UL 2237

STANDARD FOR SAFETY

Multi-Point Interconnection Power Cable Assemblies for Industrial Machinery

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UL Standard for Safety for Multi-Point Interconnection Power Cable Assemblies for Industrial Machinery, UL 2237

First Edition, Dated April 16, 2019

Summary of Topics

This revision of ANSI/UL 2237 dated August 11, 2023 includes the addition of requirements for environmental rating of "4 or 4X Indoor Use Only": 17.3 and 49.3A.

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 requirements are substantially in accordance with Proposal(s) on this subject dated April 21, 2023 and June 23, 2023.

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ANSI/UL 2237-2023

1

UL 2237

Standard for Multi-Point Interconnection Power Cable Assemblies for Industrial Machinery

First Edition

April 16, 2019

This ANSI/UL Standard for Safety consists of the First Edition including revisions through August 11, 2023.

The most recent designation of ANSI/UL 2237 as an American National Standard (ANSI) occurred on August 11, 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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CONTENTS

INTRODUCTION

CONSTRUCTION

PERFORMANCE

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MANUFACTURING AND PRODUCTION TESTS

RATINGS

MARKINGS

Appendix A

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INTRODUCTION

1 Scope

1.1 This standard covers multi-point interconnection power cable assemblies. They may consist of power cable assemblies, male or female power cable fittings, panel-mounted power cable/conductor fittings and feeder-tap power cable fittings, referred to as the device in this standard, used with industrial machinery in accordance with the National Fire Protection Association Electrical Standard for Industrial Machinery, NFPA 79 that have system voltages up to and including 1,000 V.

1.2 These interconnection power cable assemblies may be used in an industrial environment to distribute the power to feeder and branch circuits, including motor branch circuits, of industrial machinery.

1.3 Devices covered under this standard are only intended for indoor use, unless otherwise identified.

1.4 Devices covered under this standard are rated 1,000 V or less. Each device is rated in volts and amperes. The electrical ratings are marked, on each device or on a flag label affixed to each individual power cable assembly.

1.5 The cable assembly fittings and panel-mount fittings are intended to be installed in accordance with the manufacturer's installation instructions. The cable assembly fittings are intended to be assembled or molded on flexible cord. The power cable assemblies and mating fittings are not intended to be used as a substitute for the fixed wiring of the building or structure. The power cable assemblies and mating fittings may be connected to the fixed wiring of the building or structure; using a feeder tap fitting or male/female cable fitting.

1.6 Power cable assemblies and fittings covered under this standard are not intended to make or interrupt current under load conditions. These power cable assemblies and fittings have been investigated to their marked short-circuit current rating. Power cable assemblies and fittings may specify a maximum ampere rating, type of overcurrent protective device, or both. Unless otherwise marked, the power cable assemblies and fittings are intended to be supplied from an overcurrent protective device of the maximum ampere rating permitted by the Relationship Between Conductor Size and Maximum Rating or Setting of Short-Circuit Protective Device for Power Circuits Table, Table 7.2.10.4, of the National Fire Protection Association Electrical Standard for Industrial Machinery, NFPA 79.

1.7 This standard does not cover male-to-male cable assemblies or multi-outlet fittings.

1.8 These devices are intended for use only with the manufacturer's same line of products covered under this standard.

1.9 These devices are not intended for disconnecting means under load conditions and are marked as described in 48.3.

Exception: Devices may be investigated for use as a disconnecting means under load conditions, if so requested and the device complies with the overload, temperature, resistance to arcing and dielectric voltage withstand testing as described in Table 19.1.

2 Glossary

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

2.2 CONNECTOR (CABLE CONNECTOR) – A portable receptacle that is intended to provide power, with means for attachment of flexible cord or cable and not intended for permanent mounting.

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2.3 FEEDER-TAP CABLE FITTING – A fitting intended for feed-through termination to tray cable or other appropriate cable together with either a female interconnection device to terminate to a cable assembly or to connect to a flexible cord or cable suitable for hard use that is the same size and ampacity as the feeder cable.

2.4 FEED-THROUGH FITTING – A male and female device directly connected through the pins or contacts. This device is not assembled on a flexible cord, cable or AWM.

2.5 GROUNDED CONDUCTOR – The circuit conductor that is identified and intended for connection to the grounded (neutral circuit conductor) circuit.

2.6 GROUNDING-CONDUCTOR – The circuit conductor that is identified and intended for connection to the grounding (protective earth conductor) circuit.

2.7 GROUNDING-CONDUCTOR PATH – A path between the grounding pin or contact and/or terminal to the grounding conductor.

2.8 INLET – A permanently mounted plug intended to receive power from a cable connector.

2.9 MALE OR FEMALE CABLE FITTING – A fitting intended to be either molded-on or field-assembled to flexible cord or cable with either a male or female insert.

2.10 PANEL-MOUNTED CABLE/CONDUCTOR FITTING – A fitting consisting of a panel-mounted assembly with either a male or female insert. Each assembly is provided with a means to secure to an enclosure, a panel, of the industrial machinery.

2.11 PLUG (ATTACHMENT PLUG) – A device intended to receive power when inserted in a receptacle or connector, which establishes connection between conductors of the attached flexible cord or cable and the conductors connected to the receptacle or cable connector.

2.12 POLARIZED DEVICE – A device intended to receive power when inserted in a receptacle or connector, which establishes connection between conductors of the attached flexible cord or cable and the conductors connected to the receptacle or cable connector.

2.13 POWER CABLE ASSEMBLIES – Cable assemblies consist of a length of cable or flexible cord with a molded-on or assembled-on male or female power cable fitting on at least one end of the cable.

2.14 RECEPTACLE (OUTLET) – A device that is intended to provide power to an inserted plug, and that is installed as a fixed outlet or on equipment.

2.15 SPLITTER – A male fitting that terminates in two or more female fitting which may or may not be cord connected.

2.16 SYSTEM VOLTAGE – The rated supply or line voltage to which the end product will be connected.

2.17 TERMINAL, CRIMP TYPE – A terminal in which an electro-mechanical connection is made between the terminal lug, pin or contact and a conductor by compressing the lug, pin or contact onto the conductors.

2.18 TERMINAL, INSULATION-DISPLACEMENT – A terminal having a contacting member that forces the conductor insulation aside and presses to contact the current-carrying conductor.

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2.19 TERMINAL, PIN TYPE (INSULATION-PIERCING) – A terminal having a contact pin that punctures the conductor insulation to contact the current-carrying conductor.

2.20 TERMINAL, PRESSURE WIRE – A terminal that establishes a connection between one or more conductors and a terminal plate by means of mechanical pressure without the use of solder. The terminal is one of the following types:

a) Clamp-type – A terminal in which the conductor is held under a pressure plate or saddle clamp by one or more screws. This type of terminal may be provided in combination with a wire-binding screw terminal.

b) Setscrew-type – A terminal in which the pressure is applied by the end of the screw bearing on the conductor, either directly or through a wire-protecting pad.

2.21 TERMINAL, WIRE-BINDING SCREW – A terminal in which the conductor is bent around the screw and is clamped directly under the head of the screw when it is tightened.

2.22 UNIT CONTAINER – The smallest carton, package, or container, in which a fitting is packaged. A unit container may contain more than one fitting if the devices are not intended to be removed from the container for individual sale.

3 Components

3.1 Except as indicated in 3.2, a component of a product covered by this standard shall comply with the requirements for that component. See Appendix A for a list of standards covering components used in the products covered by this standard.

3.2 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.

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

3.4 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.

4 Units of Measurement

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

5 Undated References

5.1 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.

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CONSTRUCTION

6 Accessibility of Uninsulated Live Parts

6.1 Uninsulated live parts, other than exposed wiring terminals, and internal wiring shall not be accessible to contact by the probe illustrated in Figure 6.1. The probe is to be applied with a force of 3 lbf (13.3 N). The probe is to be rotated, changed in configuration, or angled; before, during, and after application.

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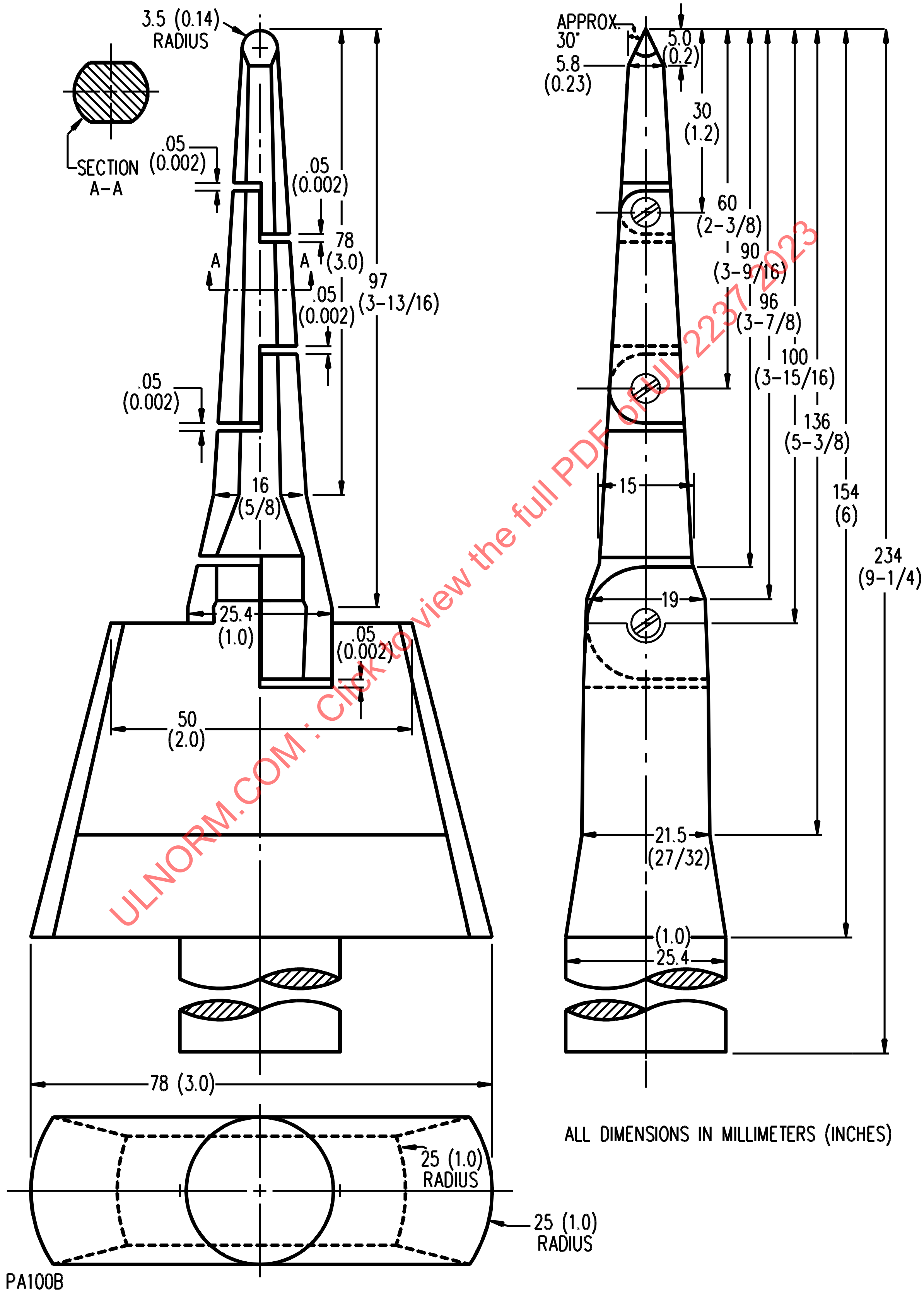
Figure 6.1

Accessibility probe



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6.2 The probe is to be used as a measuring instrument to investigate the accessibility and not as an instrument to determine the strength of a material.

7 Insulating Materials

7.1 General

7.1.1 For the purpose of this standard, an insulation material is defined as a material which is in contact with or within 1/32 in (0.8 mm) to either uninsulated live parts of opposite polarity, or uninsulated live parts and either metal parts that are capable of being grounded in service, or any surface exposed to contact.

7.2 Insulating materials for devices rated 600 V or less

7.2.1 General

7.2.1.1 A part that functions as electrical insulation or as an enclosure of a device shall be made of insulating material rated for the particular application.

7.2.1.2 Vulcanized fiber shall not be used as the sole support of live parts. Vulcanized fiber is acceptable for insulating washers, separators, and barriers. Vulcanized fiber shall comply with Moisture Absorption Test, Section 21.

7.2.1.3 Tubing used to enclose live parts shall have a flammability rating of VW-1 in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94. The tubing shall be rated for voltage and temperature for the conditions of use.

7.2.2 Flammability

7.2.2.1 A polymeric material used for electrical insulation or enclosure of live parts shall have a flammability classification of HB, V-2, V-1, V-0, VTM-2, VTM-1, VTM-0, 5VA, or 5VB in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94. The flame class rating of the material shall be determined at the minimum thickness employed at the walls and barriers in the device, which are critical to the functioning of the insulation or enclosure of the device.

Exception No. 1: This requirement does not apply to a small part:

a) With a volume that does not exceed 0.122 in^3 (2 cm^3),

b) With no dimension exceeding 1.18 in (3 cm), and

c) That is located such that the part does not propagate flame from one area to another or act as a bridge between a source of ignition and other ignitable parts.

Exception No. 2: This requirement does not apply to fiber or similar material that is 0.010 in (0.25 mm) or less thick.

Exception No. 3: A polymeric material that complies with either the 12 mm or 20 mm (3/4-in) flame flammability test described in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, need not have a flammability class rating.

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7.2.3 Electrical properties

7.2.3.1 General

7.2.3.1.1 A polymeric material used for electrical insulation or enclosure of live parts shall comply with 7.2.3.2, 7.2.3.3, and 7.2.3.4.

Exception No. 1: The requirements in 7.2.3.2, 7.2.3.3, and 7.2.3.4 do not apply to devices rated 8 A or less and 30 V (42 Vpeak) or less.

Exception No. 2: Small parts that are made from polymeric or epoxy type materials that does not come into contact with live parts or are totally encapsulated due to their design and do not track between parts of opposite polarity and/or any other uninsulated parts of different polarities do not have to comply with the requirements of 7.2.3.2, 7.2.3.3, and 7.2.3.4. A small part is considered to be not more than 0.122 in^3 (2 cm^3) in volume.

7.2.3.2 Comparative tracking index (CTI)

7.2.3.2.1 A polymeric material used for electrical insulation or enclosure of live parts shall have a comparative tracking index (CTI) performance level category (PLC) rating of 0, 1, 2, or 3 determined in accordance with the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A.

Exception: A polymeric material used for electrical insulation or enclosure of live parts is not required to comply with this requirement if it complies with the Comparative Tracking Index (CTI) Test, 45.2 or the Proof Tracking Test in accordance with the Method for the Determination of the Proof and the Comparative Tracking Indices of Solid Insulating Materials, IEC 60112.

7.2.3.3 Hot wire ignition (HWI)

7.2.3.3.1 A polymeric material used for electrical insulation of live parts shall have a hot wire ignition (HWI) performance level category (PLC) rating not less than specified in Table 7.1 determined in accordance with the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A. For a material with other than a VTM flammability classification, the acceptability of the material shall be determined using the material thickness employed in the end-use product or a nominal 1/8-in (3.2-mm) thickness, whichever is greater.

Exception No. 1: A polymeric material used in an enclosure of a molded-on fitting is not required to comply with this requirement.

Exception No. 2: A polymeric material used for electrical insulation or enclosure of live parts is not required to comply with this requirement if it complies with the Glow Wire Test, 45.1.

Table 7.1
Hot-wire ignition (HWI) ratings

Flammability classification[a]	HWI[b]	
	Mean ignition time[c] s	PLC[d]
V-0, VTM-0	7 and up to 15	4
V-1, VTM-1, 5VA, 5VB	15 and up to 30	3

Table 7.1 Continued on Next Page

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Table 7.1 Continued

Flammability classification[a]	HWI[b]	
	Mean ignition time[c] s	PLC[d]
V-2, VTM-2	30 and up to 60	2
HB	30 and up to 60	2

[a] Flammability classification – Determined in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

[b] HWI – Hot wire ignition (HWI) determined in accordance with the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A.

[c] Mean number of arcs to cause.

[d] PLC – performance level category.

7.2.3.4 High-current arc ignition (HAI)

7.2.3.4.1 A polymeric material used for electrical insulation or enclosure of live parts shall have a high-current arc ignition (HAI) performance level category (PLC) rating not less than specified in Table 7.2 as determined in accordance with the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A. For a material with other than a VTM flammability classification, the acceptability of the material shall be determined using the material thickness employed in the end-use product or a nominal 1/8-in (3.2-mm) thickness, whichever is greater.

Exception No. 1: This requirement does not apply to:

a) A polymeric material used in over-mold applications to form the enclosure of live parts; and

b) A polymeric material used within contact with live parts not to exceed 0.04 in^2 (26 mm^2) of contact area.

Exception No. 2: A polymeric material used for electrical insulation or enclosure of live parts is not required to comply with this requirement if it complies with the High-Current Arc Resistance to Ignition Test in 45.3.

Table 7.2
High-ampere arc ignition (HAI) ratings

Flammability classification[a]	HAI[b]	
	Mean number of arcs[c]	PLC[d]
V-0, VTM-0	15 and up to 30	3
V-1, VTM-1, 5VA, 5VB	30 and up to 60	2
V-2, VTM-2	30 and up to 60	2
HB	60 or more	1

[a] Flammability classification – Determined in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94.

[b] HAI – High-current arc ignition (HAI) determined in accordance with the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A.

[c] Mean number of arcs to cause ignition.

[d] PLC – Performance level category.

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7.2.4 Thermal properties

7.2.4.1 A polymeric material used for electrical insulation or enclosure of live parts shall have the relative thermal index ratings shown in Table 7.3 for the specific application of the insulating material. For materials with other than VTM flammability classifications, the material shall be evaluated using the specimen thickness employed in the end product or nominal 1/8-in (3.2-mm) thickness, whichever is greater.

Exception No. 1: The following generic materials having readings of 65 or less on the Shore Durometer D scale [when measured for 5 s at an ambient temperature of 73.4 ±3.6°F (23.0 ±2.0°C)] are acceptable for use at 140°F (60°C) based on their successful completion of the appropriate accelerated aging test described in the Accelerated Aging Tests, Section 44:

a) Ethylene/Propylene/Diene (EPDM)

b) Natural Rubber (NR)

c) Neoprene (Chloroprene Butadiene) Rubber (CBR)

d) Nitrile Rubber (NBR)

e) Polyvinyl Chloride (PVC) and its copolymers

f) Silicone Rubber (SIR)

g) Styrene (Butadiene) Rubber (SBR)

h) Thermo Elastomeric [TEE; includes Thermoplastic Elastomers (TPE) and Ethylene Propylene Thermoplastic Rubber (EPTR)]

Exception No. 2: A polymeric material that does not have a RTI value, see the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B Table for "Relative Thermal Indices Based Upon Past Field-Test Performance and Chemical Structure" for generic thermal index.

Exception No. 3: A polymeric material used in over-mold applications to form the enclosure of live parts or within contact with live parts not to exceed 0.04 in^2 (26 mm^2) of contact area shall not require a comparative tracking index (CTI) rating.

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Table 7.3
Minimum relative thermal indices (RTI)

Application	Minimum RTI [a]		
	Electrical °F (°C)	Mechanical with impact[b] °F (°C)	Mechanical without impact °F (°C)
Permanently-wired devices, panel-mounted fittings, multi-outlet fittings	176 (80)	140 (60)	176 (80)
Cord and cable fittings (including multi-outlet fittings, splitters, and feed-through fitting)	140 (60)	140 (60)	140 (60)

[a] RTI – The relative thermal index determined in accordance with the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B.

[b] For industrial laminates, vulcanized fiber, and similar polymeric materials, the material's minimum RTI for mechanical with impact shall comply with the values specified for mechanical without impact.

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7.3 Insulating materials for devices rated 601 – 1,000 V

7.3.1 A device rated 601 – 1,000 V shall comply with the applicable construction requirements in this standard in addition to the general requirements for Insulating Materials in 7.1 – 7.2.

7.3.2 An insulating material used as direct or indirect support of an uninsulated live part shall comply with 7.1 – 7.2 and the Inclined Plane Tracking Test specified in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A. The insulating material shall not track beyond one inch in less than 60 min using the time to track method. The voltage for the Inclined Plane Tracking Test shall be not less than the rated voltage of the device.

7.3.3 Insulation material shall be subjected to the Mold Stress-Relief Distortion Test, Section 20.

Exception: The Mold Stress-Relief Distortion Test is not required for rigid thermosetting insulating materials, such as phenolic.

8 Live Parts

8.1 Iron or steel, plated or unplated, shall not be used for a current-carrying part. Stainless steel is acceptable for a current-carrying part that is not subject to arcing.

8.2 A current-carrying part shall be restrained from turning relative to the surface on which the part is mounted if such turning affects the performance of the device.

8.3 Uninsulated live parts shall be secured in place so that the spacings are not reduced below those specified in 12.1.1, 12.2 or 12.3 as appropriate.

9 Grounding and Dead-Metal Parts

9.1 Grounding parts shall be copper or a copper-base alloy.

9.2 Steel or its equivalent is acceptable for a rivet, bolt, or clamp that is used to secure parts in the grounding path if the rivet, bolt, or clamp is not a conductor in the grounding path.

9.3 A copper-base alloy rivet that is used to secure parts in the grounding path, and forms a part of the grounding path, shall not contain less than 80% copper.

9.4 The requirements in 9.1 – 9.3 apply to the entire grounding-conductor path between the grounding pin or contact and the grounding terminal.

9.5 Grounding parts and dead-metal parts shall be secured in place so that the spacings are not reduced below those specified in 12.1.1, 12.2 or 12.3 as appropriate.

9.6 A dead-metal part of a grounding device shall be conductively connected to the grounding-conductor path by means of the device unless the dead-metal part is isolated from current-carrying parts and wiring other than a complete flexible cord. A flexible cord is not complete if two insulated conductors of a parallel-type cord are split apart or where the jacket of a jacketed-type cord is removed from the insulated conductors.

9.7 The grounding path of a device fitting shall be located and formed in such a manner that makes grounding first and breaks the grounding circuit last.

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9.8 The AWG sizing of the grounding conductor shall be the same or larger, as the other terminal conductors.

10 Terminals

10.1 When a device is intended for connection by conductors, the means for connection shall be a wiring terminal of the wire-binding screw construction, or pressure wire terminal construction that utilizes positive screw pressure on a bared conductor, or a factory assembled conductor attached by means of soldering, welding, riveting, or crimping.

Exception: Other forms of conductor connection meet the intent of the requirement if the mechanical features and current-carrying capability are equivalent to those of one of the connections described.

10.2 Each conductor shall be fastened to the terminals of fittings in a manner that:

a) Prevents strands of any conductor from contacting uninsulated live parts of opposite polarity or dead-metal parts,

b) Provides mechanical security in accordance with Conductor Secureness Test, Section 24,

c) Provides ampacity for compliance with Temperature Test, Section 27, and

d) Prevents strands from surfacing in a molded-on fitting.

10.3 A setscrew type terminal shall not be employed in other than a pressure wire connector as specified in 10.7.

10.4 A wire-binding screw shall thread into metal. The thickness of the metal shall provide two full threads for the screw.

10.5 Wire binding screws used in making electrical connections shall not be smaller than indicated in Table 10.1. The minimum size for a wire-binding screw shall be as indicated in Table 10.1.

Table 10.1
Minimum sizes of wire-binding screws

Contact rating A	Minimum size of screw	Minimum head diameter in (mm)	Maximum number of threads per inch
20 or less	No. 6 (M3.5)[a]	0.275 (7.0)	36
up to 35	No. 8 (M4)[b]	0.315 (8.0)	32

[a] A No. 6 (M3) terminal screw, minimum head diameter of 1/4 in (6.3 mm), may be used on devices not intended for permanent installation and rated 15 A.

[b] A No. 8 (M4) or larger screw having more than the number of threads per inch indicated may be used for terminals if the assembly is capable of withstanding a tightening torque of 16 lbf·in (1.8 N·m) applied to the wire-binding screw without stripping either the screw threads or the terminal plate threads, or damaging the slot in the head of the screw.

10.6 A direct-bearing, setscrew pressure wire connector shall comply with the applicable requirements in the Standard for Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors, UL 486E.

10.7 The tightening torque for a field-wiring terminal shall be specified by the device manufacturer and the device shall be marked in accordance with 48.7. The tightening torque shall not be less than 90% of the value required for the Static Heating Test in the Standard for Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors, UL 486E, for the maximum wire size corresponding to the ampere rating of the device.

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Exception: A lesser torque value meets the intent of the requirement if the connector complies with the Standard for Wire Connectors, UL 486A-486B, or the Standard for Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors, UL 486E, using the lesser torque value.

11 Strain Relief and Cord Entries

11.1 A strain-relief means shall be provided in a device intended for connection to a flexible cord so that a pull on the flexible cord is not transmitted to the binding-screw terminals, or connection between the conductors and the pins or contacts as determined in accordance with Strain-Relief Test, Section 25.

11.2 The cord-entry hole for a flexible cord in a metal enclosure shall be provided with an insulating bushing of porcelain, phenolic, cold-molded composition, or other insulating material with equivalent properties.

12 Spacings

12.1 Spacing for devices rated 600 V or less

12.1.1 The spacings maintained through air or over surface shall be a minimum 3/64 in (1.2 mm) for a device rated 250 V or less, and a minimum 1/8 in (3.2 mm) for a device rated more than 250 V, between the following:

a) Uninsulated live parts of opposite polarity,

b) An uninsulated live part and a dead-metal part that is likely to be grounded or exposed to contact by persons when the device is installed as intended, including a metal surface on which the device is mounted in the intended manner or a metal face plate used with a flush receptacle.

12.1.2 In measuring a spacing, an isolated dead-metal part interposed between live parts of opposite polarity, or between a live part and a grounded or exposed dead-metal part, is considered to reduce the spacing by an amount equal to the dimension of the isolated dead-metal part in the direction of the measurement.

12.2 Spacings for devices rated 601 – 1,000 V

12.2.1 Other than as noted in 12.3, Alternate spacings – clearance and creepage distances, the electrical spacings in cable assemblies and fittings rated 601 – 1,000 V shall not be less than the applicable value specified in Table 12.1.

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Table 12.1
Minimum spacings for cable assemblies and fittings rated 601 – 1,000 V

Application	Potential involved	Minimum spacings between uninsulated live parts of opposite polarity; and between an uninsulated live part and a grounded part including any mounting surface or exposed metal part			
		Through air		Over surface	
	V	in	(mm)	in	(mm)
Rated 601 – 1,000 V	601 – 1,000	0.55	(14.0)	0.85	(21.6)

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12.3 Alternate spacings – clearance and creepage distances

12.3.1 As an alternative to the specified spacing requirements of Section 12, Spacings, the spacing requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, are applicable.

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

a) For evaluating clearances:

1) A device which operates in the direct line of the source of power to the load device shall be evaluated for Overvoltage Category III.

Exception: Overvoltage category II can be applied if the device is marked as indicated in 48.13.

2) The Phase-to-Ground Rated System Voltage used in the determination of Clearances shall be the device rated supply voltage rounded to the next higher value (in the table for determining clearances for the device). The test is only required if using equivalency requirements.

b) For evaluation of creepage:

1) Any printed wiring board which complies with the requirements in the Standard for Printed Wiring Boards, UL 796, provides a Comparative Tracking Index (CTI) of 100, and when it complies with the requirements for Direct Support in UL 796, then it provides a CTI of 175;

2) A device shall be evaluated for pollution degree 3, but may be evaluated for pollution degree 2 when instructions are provided with the device indicating that it shall be installed in a pollution degree 2 macro-environment;

3) Printed wiring boards are evaluated as pollution degree 2 when adjacent conductive material is covered by any coating, such as a solder mask, which provides an uninterrupted covering over at least one side and the complete distance up to the other side of conductive material;

4) Printed wiring boards shall be evaluated as pollution degree 1 under one of the following conditions:

i) A coating which complies with the requirements for Conformal Coatings in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C; or

ii) At a specific printed wiring board location by application of at least a 1/32-in (0.79-mm) thick layer of silicone rubber or through potting, without air bubbles, in epoxy or potting material.

13 Assembly

13.1 General

13.1.1 An assembled-on or panel-mounted device shall be easily wired as intended so that the wires are not damaged.

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13.1.2 Electrical contact shall be reliably maintained at any point at which a connection is made between current-carrying parts.

13.1.3 A live part of an outlet or cord connected device shall be protected against exposure to contact by persons when the device is assembled and installed as intended.

13.1.4 Where internal connections exist corresponding contacts of individual outlets shall be connected together.

13.1.5 A device having female contacts shall be constructed so that a mating attachment plug seats without exposure of the contacts of the plug between the plane of the face of the plug and the plane of the rim of the female device.

13.1.6 The insulation and braid on the individual conductors of a cord shall be removed only to the extent required to make the proper wire connection.

13.1.7 A fitting intended for securement to conduit shall also comply with the requirements contained in the Standard for Fittings for Cable and Conduit, UL 514B, as appropriate.

13.2 Polarization

13.2.1 A device shall be constructed so that the grounding member of the corresponding fitting plug or connector is not able to be inserted by hand into any outlet or inlet slot respectively to touch a live contact.

13.2.2 A device consisting of two or more pieces shall be such that any foreseeable assembly during installation does not defeat polarization.

13.3 Mating and interchangeability

13.3.1 A device shall be constructed so that electrical continuity between respective and similarly marked terminals is established automatically when the mating plug and outlet device are connected together.

13.3.2 An outlet shall not accommodate an attachment plug other than one that is specifically intended for use with the outlet.

13.4 Terminal identification

13.4.1 A terminal of a cable assembly, which is identified for the connection of either a grounded (neutral) conductor or a grounding (protective earth) conductor, shall be connected to the corresponding identified conductor of the cord.

13.4.2 A terminal of a cable fitting or panel-mount fitting intended as a grounded conductor or a grounding conductor shall be identified in accordance with Table 13.1. No other terminals shall be so identified.

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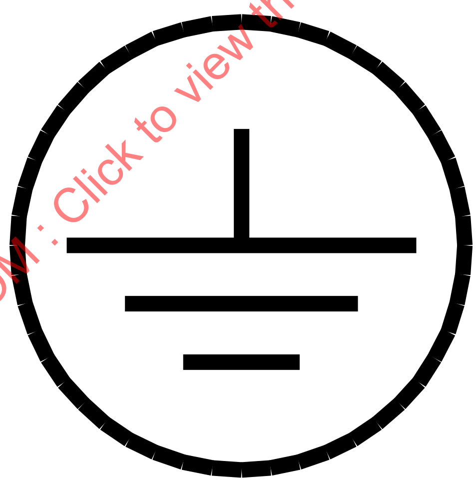
Table 13.1
Identification of wiring terminals

Identification	Grounded (neutral) terminal	Grounding (protective earth) terminal
Wire-binding screw	White metal or plating on circular screw head	Hexagonal, green-colored nut or slotted screw head where screw is not readily removable
Pressure wire terminal, visible	White metal or plating on terminal	Green colored terminal, screw or appendage that is not readily removable
Terminal, concealed	Distinct white-colored area adjacent to wire entrance hole or the word "White" or letter "W" distinctively marked adjacent to wire entrance hole	Distinct green-colored area adjacent to wire entrance hole or the word "Green" or "Ground" distinctively marked adjacent to wire entrance hole, or the letters "G," "GR," or "GND", or the grounding symbol shown in Figure 13.1 distinctively marked adjacent to wire entrance hole in letters not less than 1/16 in (1.6 mm) high
Terminal plate (where all terminal screws are the same color)	White metal or plating	–
Insulating enclosure or terminal	The word "White" marked on or directly adjacent to terminal, or white metal or plating on terminal	The word "Green" marked on or directly adjacent to terminal, or green-colored terminal

Figure 13.1

Grounding symbol



13.4.3 A wire lead of a panel-mount fitting intended for field wiring to either a grounded conductor or a grounding conductor shall be identified in accordance with Table 13.2.

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Table 13.2
Identification of conductor leads

Identification	Grounded (neutral) conductor	Grounding (protective earth) conductor	All other conductors
Color of braid[b]	Solid white or gray (without tracer)	Not applicable	White or gray with tracer in braid or solid color other than white, gray, or green[a] (without tracer)
	Color other than white, gray or green[a], with tracer in braid	Not applicable	Solid color other than white, gray, or green[a] (without tracer)
Color of insulation[b]	Solid white or gray; stripe, white or gray, on contrasting color other than green[a]	Green with or without one or more yellow stripes	Solid color other than white, gray, or green[a]
Color of separator[b]	Solid white or gray	Not applicable	Solid color other than white, gray, or green[a]

[a] A green wire, with or without one or more yellow stripes, shall be used only as an equipment-grounding conductor.

[b] Where color of braid, insulation, or separator is used for identification, all conductors shall be untinned.

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14 Enclosure

14.1 A cable fitting shall be provided with a complete enclosure that:

a) Encloses or completes the enclosure of current-carrying parts other than those on the face of the male cable fitting; or

b) Encloses or completes the enclosure of the flexible cord from which the jacket has been removed for wiring.

14.2 With reference to 14.1, a part that performs no function other than to provide strain relief is not required for the operation of the device.

15 Flexible Cord, Cable or Wiring

15.1 A flexible cord or cable shall also comply with the requirements contained in the Standard for Flexible Cord and Cables, UL 62, or the Standard for Electrical Power and Control Tray Cables with Optional Optical-Fiber Members, UL 1277, as appropriate.

15.2 Appliance Wiring Material (AWM) shall comply with the requirements in the Standard for Appliance Wiring Material, UL 758 and may be used if suitable for the application.

15.3 The flexible cord, cable or wiring shall be rated for the conditions of use and shall have electrical ratings not less than the provided or identified fittings.

16 Mounting

16.1 A panel-mounted device shall be provided with means for mounting.

17 Environmental Rating

17.1 A device intended or identified for use in either outdoor or wet locations or marked with an environmental type enclosure rating, shall comply with Environmental Enclosure Tests, Section 33.

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17.2 Molded on devices for use in either outdoor use or wet locations shall exclude moisture or the alike. Compliance is determined by the Adhesion Test, Section 32.

17.3 A Type 4 or 4X enclosure intended for Indoor Use Only and marked in accordance with 49.3A:

a) Need not be subjected to the External Icing Test in the Standard for Enclosures for Electrical Equipment, Environmental Considerations, UL 50E; and

b) For a polymeric enclosure, need not have a material which is resistant to ultraviolet light weathering in accordance with the Standard for Polymeric Materials – Use in Electrical Equipment Evaluation, UL 746C.

18 Outdoor Use

18.1 Devices intended for outdoor use shall employ flexible cord, cable or wiring suitable for the application.

18.2 A polymeric material serving as the enclosure of a device intended for outdoor use shall comply with the applicable requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, concerning ultraviolet light exposure.

Note: An f1 rating signifies compliance; an f2 rating requires further investigation into its suitability.

18.3 A device for outdoor use shall have an outdoor environmental type enclosure rating in accordance with the Standard for Enclosures for Electrical Equipment, Environmental Considerations, UL 50E.

PERFORMANCE

19 General

19.1 Refer to Table 19.1 for sample requirements for each test.

Table 19.1
Summary of tests

Section	Test	Number of Devices	Details
20	Mold Stress-Relief Distortion	3	
21	Moisture Absorption	3	Only applies to devices employing vulcanized fiber.
22	Dielectric Voltage-Withstand	3	
23	Insulation Resistance	1	Conducted on devices employing rubber or similar materials that contain enough free carbon to render the material grey or black in color.
24	Conductor Secureness	3	Crimped connections only.
25	Strain-Relief	6	
26	Overload	3	For devices 600 V or less and intended for current interruption under load conditions.

Table 19.1 Continued on Next Page

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Table 19.1 Continued

Section	Test	Number of Devices	Details
27	Temperature	3	Mated pairs. For devices 600 V or less and intended for current interruption under load conditions same 3 previously subjected to Overload testing are used.
28	Resistance to Arcing	Same 3	For devices 600 V or less and intended for current interruption under load conditions are used.
29	Current-Cycling and Vibration	6	Conducted on insulation piercing or insulation displacement type terminals. Mated pairs.
30	Jacket Retention	3	Molded-on devices
31	Polarization	1	
32	Adhesion	1	Outdoor or wet location molded-on device construction
33	Environmental Enclosure		See the Standard for Enclosures for Electrical Equipment, Non-Environmental Considerations, UL 50 for details
34	Grounding (Bonding) Path Current	1	Mated pairs
35	Cable Pullout	3	Assembled-on devices
36	Creep	3	Assembled-on devices
37	Short-Circuit Withstand	2	Mated pairs
38	Humidity Conditioning	1	Mated device
39	Crush	1	
40	No-Load Endurance	1	Mated pair
41	Impact	3	
42	Abnormal Overload	3	Mated pairs
43	Resistance to Corrosion	3	Ferrous parts
44	Accelerating Aging	3	Parts molded of rubber, EPDM and TEE or PVC compounds
45.1	Glow Wire	3	Material to be evaluated in accordance with Exception No. 2 of 7.2.3.3.1
45.2	Comparative Tracking Index	3	Material to be evaluated in accordance with Exception of 7.2.3.2.1
45.3	High-Current Arc Resistance to Ignition	3	Material to be evaluated in accordance with Exception No. 2 of 7.2.3.4.1

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20 Mold Stress-Relief Distortion Test

20.1 As a result of the conditioning specified in 20.3, nonmetallic parts of a device shall not warp, shrink, or distort to the extent that results in any of the following:

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a) Making uninsulated live parts, other than exposed wiring terminals, or internal wiring accessible to contact as determined in accordance with Accessibility of Uninsulated Live Parts, Section 6.

b) Defeating the integrity of the enclosure so that mechanical protection is not afforded to the internal parts of the device.

c) Interference with the operation, function, or installation of the device. The outlet slot openings of a female device shall be capable of receiving a fully inserted attachment plug of the intended configuration.

d) A reduction of spacings below the values specified in Spacings, Section 12.

e) A condition that results in the device not complying with Dielectric Voltage-Withstand Test, Section 22.

f) Any other evidence of damage that results in a risk of fire or electric shock.

20.2 For field assembled devices, they are to be wired and assembled in accordance with the manufacturer's instructions, and any part(s), that can be opened or removed by the user without using a tool is to be opened or removed.

20.3 The devices are to be placed in a full-draft circulating-air oven for 7 h at the highest temperature to which the nonmetallic part is exposed as determined in accordance with Temperature Test, Section 26, plus 18°F (10°C) but not less than 158 ±1.8°F (70 ±1°C). The devices are to be removed from the oven and cooled to room temperature before determining compliance with 20.1 (a) – (f).

21 Moisture Absorption Test

21.1 Vulcanized fiber as specified in 7.2.1.2 shall not absorb more than 6% of water by weight as a result of the conditioning described in 21.2.

Exception: Compliance may be determined using the Test Method for Water Absorption of Plastics, ASTM D 570 specified in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A.

21.2 The material is to be:

a) Dried at 221.0 ±9.0°F (105 ±5°C) for 1 h,

b) Weighed, (W_1),

c) Immersed in distilled water at 73.4 ±1.8°F (23 ±1°C) for 24 h,

d) Removed from the distilled water and the excess surface moisture wiped off, and

e) Reweighed, (W_2).

21.3 With reference to 21.1, the percent of water absorbed by the material is to be calculated as:

$$\frac{W_2 - W_1}{W_1} \times 100\,\%$$

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22 Dielectric Voltage-Withstand Test

22.1 A device shall withstand without breakdown a voltage potential according to Table 22.1. The test voltage shall be applied as described in 22.1 and 22.3 for one minute between live parts, between live parts of opposite polarity, and between live parts and grounding or dead-metal parts.

Table 22.1
Dielectric Voltage Withstand Potentials

Device rating	Test potential based on test equipment used	
	ac equipment (50 – 60 Hz)	**dc equipment**
0 – 600 Vac	(1,000 + 2 Vac)	(1,000 + 2 Vac)*1.414
0 – 600 Vdc	(1,000 + 2 Vdc)/1.414	(1,000 + 2 Vdc)
0 – 600 Vac/dc	(1,000 + 2 Vac) for ac rating (1,000 + 2 Vdc)/1.414 for dc rating higher potential of the two shall be used	(1,000 + 2 Vac)*1.414 for ac rating (1,000 + 2 Vdc) for dc rating higher potential of the two shall be used
601 – 1,000 Vac	(2,000 + 2.25 Vac)	(2,000 + 2.25 Vac)*1.414
601 – 1,000 Vdc	(2,000 + 2.25 Vdc)/1.414	(2,000 + 2.25 Vdc)
601 – 1,000 Vac/dc	(2,000 + 2.25 Vac) for ac rating (2,000 + 2.25 Vdc)/1.414 for dc rating higher potential of the two shall be used	(2,000 + 2.25 Vac)*1.414 for ac rating (2,000 + 2.25 Vdc) for dc rating higher potential of the two shall be used

22.2 All devices rated 600 V or less shall be capable of withstanding the application of an alternating-current test potential of 1,000 V plus 2 times the rated voltage. All devices rated 601 – 1,000 V shall be capable of withstanding the application of an alternating-current test potential of 2,000 V plus 2.25 times rated voltage, and a direct-current test potential shall be 1.414 times the alternating-current test potential specified in this paragraph. See Table 22.1.

Exception No. 1: A test potential of 500 V is to be applied to a device rated 30 V_{rms} *(42.4* V_{peak}*) or less.*

Exception No. 2: The equivalent dc potential may be substituted if necessary due to components employed in the circuitry.

22.3 The device is to be tested by means of a 500 VA or larger capacity transformer whose output voltage is sinusoidal and variable. 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 one minute. The increase in the applied potential is to be at a uniform rate and as rapid as is consistent with its value being correctly indicated by a voltmeter.

Exception: When the output of the test-equipment transformer is less than 500 VA, the equipment is to include a voltmeter in the output circuit to indicate the test potential directly.

23 Insulation Resistance Test

23.1 As a result of the test described in 23.2 – 23.5, the insulation resistance of a fitting shall not be less than 100 MΩ between:

a) Live parts of opposite polarity,

b) Live parts and dead-metal parts that are exposed to contact by persons or that may be grounded in service, and

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c) Live parts and any surface of insulating material that is exposed to contact by persons or that may be in contact with ground in service.

23.2 The insulation resistance measurement is to be made on rubber and polymeric materials of any color that may contain carbon (usually black and gray).

23.3 All parts are to be maintained at room temperature for not less than 48 h before being subjected to the test.

23.4 Each device is tightly wrapped in metal foil on surfaces so that the foil serves as an electrode in contact with the surface to which the test is to be applied.

23.5 The insulation resistance is to be measured by a magneto megohmmeter which has an open-circuit output of 500 V or by equivalent equipment.

24 Conductor Secureness Test

24.1 Where a conductor of a flexible cord or cable is crimped to the terminal of a device before the crimped terminal has been assembled into the device, the connection before the crimped terminal has been assembled into the device shall not break as a result of a pull applied for 1 min between the crimped terminal and the conductor. A force as specified in Table 24.1 is to be applied. The angle between the crimped terminal and the conductor is to be that used in the completely assembled device. The force is to be applied gradually.

Table 24.1
Conductor secureness test values

Wire Size AWG (mm^2)	Pull Force lbf (N)
30 (0.05)	1 (4.4)
28 (0.08)	2 (8.9)
26 (0.14)	4 (17.8)
24 (0.21)	6 (26.7)
22 (0.34)	8 (35.6)
20 (0.52)	10 (44.5)
18 (0.82)	20 (89)
14 (2.1)	20 (89)
12 (3.3)	20 (89)
10 (5.3)	20 (89)
8 (8.4)	20.5 (90)
6 (13.3)	21 (94)
4 (21.2)	30 (133)
3 (26.7)	35 (156)
2 (33.6)	42 (186)
1 (42.4)	53 (236)
1/0 (53.5)	64 (285)
2/0 (67.4)	64 (285)

Table 24.1 Continued on Next Page

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Table 24.1 Continued

Wire Size AWG (mm^2)	Pull Force lbf (N)
3/0 (85)	79 (351)
4/0 (107)	96 (427)
250 (127)	96 (427)
300 (152)	99 (441)
350 (177)	113 (503)
400 (203)	113 (503)
500 (253)	130 (578)
600 (304)	130 (578)
700 (355)	145 (645)
750 (380)	155 (690)
800 (405)	155 (690)
900 (456)	158 (702)
1,000 (507)	175 (778)
1,250 (633)	217 (965)
1,500 (760)	264 (1174)
1,750 (887)	303 (1347)
2,000 (1010)	342 (1521)

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25 Strain-Relief Test

25.1 Cord-to-fitting test

25.1.1 The assembly of a cord to a device shall be subjected to a straight pull force as specified in 25.1.2 and Table 25.1 applied between the fitting and the cord. As a result of the test, the force shall not be transmitted to the terminals of the device. There shall be no movement of the cord with respect to the strain relief.

Table 25.1
Strain-relief test values

Type of Device	Wire Size AWG (mm^2)	Pull Force lbf (N)
Cord-to-device	18 – 3 (0.82 – 26.7)	35 (156)
	2 (33.6)	42 (186)
	1 (42.4)	53 (236)
	1/0 (53.5)	64 (285)
	2/0 (67.4)	64 (285)
	3/0 (85)	79 (351)

25.1.2 The device is to be securely supported by a rigid, flat plate mounted horizontally. The plate is to have a hole just large enough for the supply cord to pass through. A pull force as specified in Table 25.1 is to be applied for 1 min to the flexible cord, in a direction perpendicular to the plane of the cord-entry hole.

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25.2 Feeder-tap cable systems test

25.2.1 With the device supported securely, a force as specified in Table 25.2 is to be applied on a cord having conductors the size specified in Table 25.1. The force is to be applied for 1 min in a direction perpendicular to the plane of the cord entry hole of the device. As a result of the test, the force shall not be transmitted to the terminals of the device. There shall be no movement of the cord with respect to the strain relief.

Table 25.2
Strain-relief test values for feeder-tap cable systems

Type of Device	Wire Size AWG (mm^2)	Pull Force lbf (N)
Feeder-tap cable system	18 – 16 (0.82 – 1.3)	35 (156)
	14 (2.1)	50 (222)
	12 (3.3)	50 (222)
	10 (5.3) or larger	100 (445)

26 Overload Test

26.1 A female device rated 600 V or less, shall perform acceptably when subjected to an overload test as described in 26.2 – 26.11. There shall not be any electrical or mechanical failure of the device nor pitting or burning of the contacts that would affect the intended function. The grounding fuse shall not open during the test.

Exception No. 1: A device that is intended not for current interruption, and is marked in accordance with 48.3 need not be subjected to this test.

Exception No. 2: A device rated more than 600 V is not permitted be subjected to overload testing and is marked in accordance with 48.3.

26.2 A mating device is to be inserted and withdrawn either manually or by machine while connected to a suitable load. The equipment grounding contact is to be connected to ground through a fuse.

26.3 For ac applications, the test current shall be 6 times device full-load current with a power factor of 0.4 – 0.5.

26.4 For dc applications the test current shall be 10 times device full-load current with a non-inductive resistive load.

26.5 The full load current (FLA) shall be based upon the device voltage rating and Hp rating assigned by the manufacturer. See the Standard for Industrial Control Equipment, UL 508, the Full-load Motor-running Currents in Amperes Corresponding to Various a-c Horsepower Ratings Table and the Full-load Motor-running Currents in Amperes Corresponding to Various d-c Horsepower Ratings Table for details.

26.6 The potential of the test circuit closed voltage is to be from 100 – 110% of the rating of the device in volts.

26.7 Each device shall be subjected to 50 cycles of operation at a rate not higher than 10 cycles/min. The device is to be rigidly supported. For devices that employ multiple circuits, all circuits at their given ampacity are to be tested simultaneously. Exposed metal parts and any pole that is not part of the test circuit are to be connected through a fuse to ground of the test circuit.

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26.8 The fuses in the test circuit shall be non-time-delay, general use, cartridge type fuses. The fuse in the grounding (bonding) conductor circuit shall have a 15-A rating if the device under test is rated at 30 A or less. If the device under test is rated at more than 30 A the grounding fuse shall have a rating of 30 A. For the line fuse, the next higher commercial fuse rating than the value of the test current in the test circuit shall be used.

26.9 A previously untested male contact device is to be used for each overload test.

Exception: One device may be used for all of the overload tests if agreeable to all concerned.

26.10 Contacts of the device are not to be adjusted, lubricated, or otherwise conditioned before or during the test.

26.11 After this test, the device shall be subjected to the Dielectric Voltage-Withstand Test in Section 22.

27 Temperature Test

27.1 A device tested as described in 27.2 – 27.7 shall not attain a temperature at any point sufficiently high:

a) To constitute a risk of fire;

b) To adversely affect any material employed in the device; or

c) To exceed a temperature rise more than 30°C when the device is carrying its maximum rated current. This temperature rise is based on devices intended to be wired with conductors rated 60°C. A temperature rise of 45°C shall be permitted when the device is intended to be wired with conductors rated 75°C or higher, and so marked. See 48.6.

27.2 The temperature test shall be performed following the overload test, if applicable, on the same test samples.

27.3 If the tests are conducted at an ambient temperature of other than 25°C, the results shall be adjusted to an ambient temperature of 25°C by adding the appropriate variation between 25°C and the recorded ambient temperature.

27.4 The temperature measurement shall be made on the wiring terminals of the device, if they are accessible for mounting thermocouples. If the device has no wiring terminals or if they are inaccessible, temperatures shall be measured on the stripped conductor (bare conductor) as close to the terminal of the device under test as possible.

27.5 The temperature test is to continue until stabilized temperatures are attained but no less than 4 h. Stabilization is determined by three consecutive readings, taking at 5-min intervals; indicate no further rise above the ambient temperature. The generation of heat from sources, other than the female contacts is to be minimized as much as practicable. The contacts of the device are to be connected together by means of a male cable fitting inserted therein. The male cable fitting is to have the same configuration as the device under test. The male cable fitting is to be factory wired or wired as specified by the manufacturer. The leads of the male and female fittings are to be wired in series by means of 6-in (150-mm) lengths of wires or shorter. For assembled-on devices, the terminals are to be tightened to the marked torque limit as specified by the manufacturer.

27.6 Each current-carrying conductor of the device is to be wired in series and caused to carry continuously a current equal to the current rating of the device. For devices with groups of contacts with

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multiple circuits, each circuit shall be wired as a separate series circuit and carry continuously a current equal to the current rating of each circuit concurrently.

27.7 Temperature readings are to be obtained by means of thermocouples. Thermocouples are to consist of wires not larger than 24 AWG (0.21 mm^2) and not smaller than 30 AWG (0.05 mm^2). Whenever referee temperature measurements by thermocouples are necessary, thermocouples consisting of 30 AWG (0.05 mm^2) iron and constantan wire and a potentiometer-type instrument are to be used. The thermocouple wire is to conform to the requirements for special thermocouples Special Tolerances thermocouples as listed in the Tolerances on Initial Values of EMF versus Temperature tables in the Standard Specification and Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples, ANSI/ASTM E230/E230M.

27.8 After this test, the device shall be subjected to the Dielectric Voltage Withstand Test in Section 22.

28 Resistance to Arcing Test

28.1 The same samples previously subjected to overload, temperature, dielectric voltage withstand testing shall be subjected to an additional 150 cycles of operation under the overload test conditions.

28.2 The mating device (plug portion) used for this test may be changed after every 50 operations. There shall not be any sustained flaming of the material in excess of five seconds duration. There shall not be any electrical tracking or the formation of a permanent carbon conductive path which results in a dielectric breakdown, as determined by the Dielectric Voltage-Withstand Test, Section 22, applied for one minute between live parts of opposite polarity and between live parts and dead metal parts.

29 Current-Cycling and Vibration Test (For Pin Type or Insulation Displacement Type Terminals)

29.1 General

29.1.1 Following the current-cycling and vibration tests described in this section, each device having pin-type (insulation-piercing) or insulation displacement terminals shall comply with the thermal stability criteria specified in 29.1.2.

29.1.2 As a result of current cycling before and after vibration conditioning as described in 29.2, 29.3, and 29.4, a device employing pin-type (insulation-piercing) or insulation-displacement terminals on the fitting terminals shall comply with the following:

a) The thermal stability shall be such that none of the 11 data points deviate above the average temperature by more than 18°F (10°C) as determined in accordance with 29.5.1;

b) There shall not be a temperature rise of more than 180°F (100°C); and

c) There shall not be a temperature rise greater than 180°F (100°C) on any feeder-tap cable system.

29.1.3 Six previously untested samples shall be tested. Following the manufacturer's instructions, three of the six representative devices are to be assembled on the wire of the size and type specified by the manufacturer. Solid copper wire is to be used unless otherwise specified in the instructions.

29.1.4 The devices are to be connected with 24 to 27 in (610 to 666 mm) of cable between each device and wired in series so that the test current passes through the connection point of the entering conductor, the internal structure of the device, and the exiting conductor.

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29.1.5 The remaining three of the six devices are to be mounted to a test rack constructed of cast-iron angles not smaller than 1/8 by 1-1/4 by 1-1/4 in (3.2 by 31.8 by 31.8 mm) welded to form a rigid assembly. Mounting holes are to be provided for attachment of the test rack to a vibration platform.

29.2 Current-cycling before vibration test

29.2.1 Each current cycle is to consist of 1-1/2 h "on" time and 1/2 h "off" time with a total of 500 cycles on each device. The test current is to be 200% of the current rating of the device.

29.2.2 Temperature rises are to be measured using thermocouples placed on the pins of the male fitting, as close as possible to the face of the fitting.

29.2.3 Temperature readings are to be obtained by means of thermocouples described in 27.7.

29.2.4 The temperature of the connection is to be recorded at 25, 50, 75, 100, and 125 cycles.

29.3 Vibration test

29.3.1 Following 125 cycles of current cycling as described in 29.2.1 – 29.3.2, the three devices mounted to the test rack are to be disconnected from the circuit and subjected to vibration testing as described in 29.3.2.

29.3.2 The test rack is to be fastened to a vibration platform and subjected to the following conditioning:

a) Simple harmonic motion of amplitude 0.03 in (0.76 mm), 0.06 in (1.52 mm) peak-to-peak, with the frequency varied uniformly in one minute from 10 cps to 55 cps and back to 10 cps.

b) Vibration applied for 2 h in each of three mutually perpendicular directions for a total of 6 h of testing.

29.3.3 At the conclusion of the vibration, each device is to be reconnected to the current cycling test circuit to complete the 375 remaining cycles of the Current Cycling Test, as described in 29.4.1, for a total of 500 cycles.

29.4 Current-cycling after vibration test

29.4.1 After vibration, six additional data points for each device are to be obtained at 170, 215, 260, 340, 420, and 500 cycles of current cycling. The test method is to be as specified in 29.2.1 – 29.2.3.

29.5 Calculations

29.5.1 The thermal stability for each thermocouple location is to be determined as follows:

a) Determine the average temperature rise for all 11 data points obtained in accordance with 29.2.4 and 29.4.1; and

b) Determine the deviation of each of the 11 data points from the calculated average.

30 Jacket Retention Test

30.1 For devices molded onto jacketed flexible cord or cable, there shall not be fillers, separators, insulation, or bare conductors visible at the point where the cord enters the fitting as a result of the test described in 30.2 – 30.5. An attachment plug or cord connector of a cable assembly shall retain the jacket of the flexible cord to which it is molded.

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30.2 Six previously untested samples, with 12 in (305 mm) of flexible cord or cable attached, are to be used for this test. The cord jacket of each of the samples is to be slit for a short distance at a point 6 in (152 mm) from the point of cord entry to the fitting. All internal conductors, conductor insulation, fillers, and separators are to be severed.

30.3 Samples are then to be secured by the body of the fitting so that the flexible cord or cable jacket is hanging vertically. A pull of 15 lbf (67 N) is to be applied for 2 min at a point 8 in (203 mm) from where the cord enters the fitting.

30.4 Each molded-on fitting is then to be connected by the body to a test apparatus having a vertical assembly capable of rotating through 360° and securing the fitting so that the cord exits the fitting being tested with the longitudinal axis of the cord in a horizontal direction, perpendicular to the plate face.

30.5 A weight of 3 lbf (14 N) is to be suspended at a point 8 in (203 mm) from where the cord enters the fitting for 15 s. With the weight still attached, the test apparatus mounting plate then is to be rotated 360° about the horizontal axis of the cord exit (from the fitting) in 15 s, during which time the cord-body interface is to be visually examined to determine compliance with 30.1.

31 Polarization Test

31.1 Compliance with 13.3.2 is to be determined by using the device assembled in its intended housing. With the axis of the mating devices aligned, the devices shall not be able to mate in any manner that energizes the grounding feature of the device. The polarization of the device shall not be defeated.

32 Adhesion Test

32.1 To determine compliance with 17.2, the adhesion between a cord and the body of a fitting, the cord is to be bent sharply to an angle of 90° with the plane of the cord entry and visually examined for openings into the body.

32.2 If from the visual examination specified in 32.1 there is reason to suspect that an acceptable seal does not exist, the assembly is to be cut apart for examination. The adhesion is acceptable if the examination of the inner construction reveals a positive seal at all points around the periphery of the cord.

33 Environmental Enclosure Tests

33.1 A device with an environmental enclosure rating shall comply with the Standard for Enclosures for Electrical Equipment, Non-Environmental Considerations, UL 50. For type designation and marking see 48.1 – 48.7.

33.2 When a panel-mounted device is tested, it is to be mounted in accordance with the manufacturer's instructions on a panel of the appropriate enclosure type.

34 Grounding (Bonding) Path Current Test

34.1 The assembly of mating grounding devices shall comply with the short time test as described in the Standard for Grounding and Bonding, UL 467. The test current shall be based on the equipment grounding size conductor.

35 Cable Pullout Test (For Pin Type or Insulation Displacement Type Terminals)

35.1 As a result of the test in 35.2, there shall not be:

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a) Visible indication of conductor pullout;

b) Damage to the cable insulation; or

c) Loosening of the assembly that enables the cable to be removed by flexing or bending following the removal of the test force.

35.2 Six devices that are provided with assembled on cable are to be installed on each size and type of cable with which the device is intended to be used. The cable installation is to be in accordance with the manufacturer's instructions. Wiring terminals having a screw-actuated clamping means are to be tightened to the manufacturer’s specified torque and then loosened one full turn before application of the test force. Each cable is then to be subjected to a pull force of 60 lbf (267 N) applied perpendicular to the plane of the cable entrance (along the wire) for 5 min. The devices are to be rigidly supported during testing in such a manner that movement of the cable is not restricted.

36 Creep Test (For Pin Type or Insulation Displacement Type Terminals)

36.1 A cable assembly device shall comply with Cable Pullout Test, Section 35, following the oven conditioning described in 36.2.

36.2 The devices are to be assembled as intended on each type of cable of the maximum AWG size conductor intended for use. Three samples are to be assembled midway on the cable and three are to be assembled onto the end of the cable. Each device is then to be conditioned in an air-circulating oven for 300 h at 194°F (90°C).

37 Short-Circuit Withstand Test

37.1 General

37.1.1 A device shall be subjected to the tests in accordance with 37.2.6 – 37.2.17 when protected by a fuse or circuit breaker as specified in 37.2.1 and 37.2.2. The overcurrent protective device used shall have an interrupting rating at least equal to the test current. See 48.9 and 48.11. Figure 37.1 depicts typical set-up.

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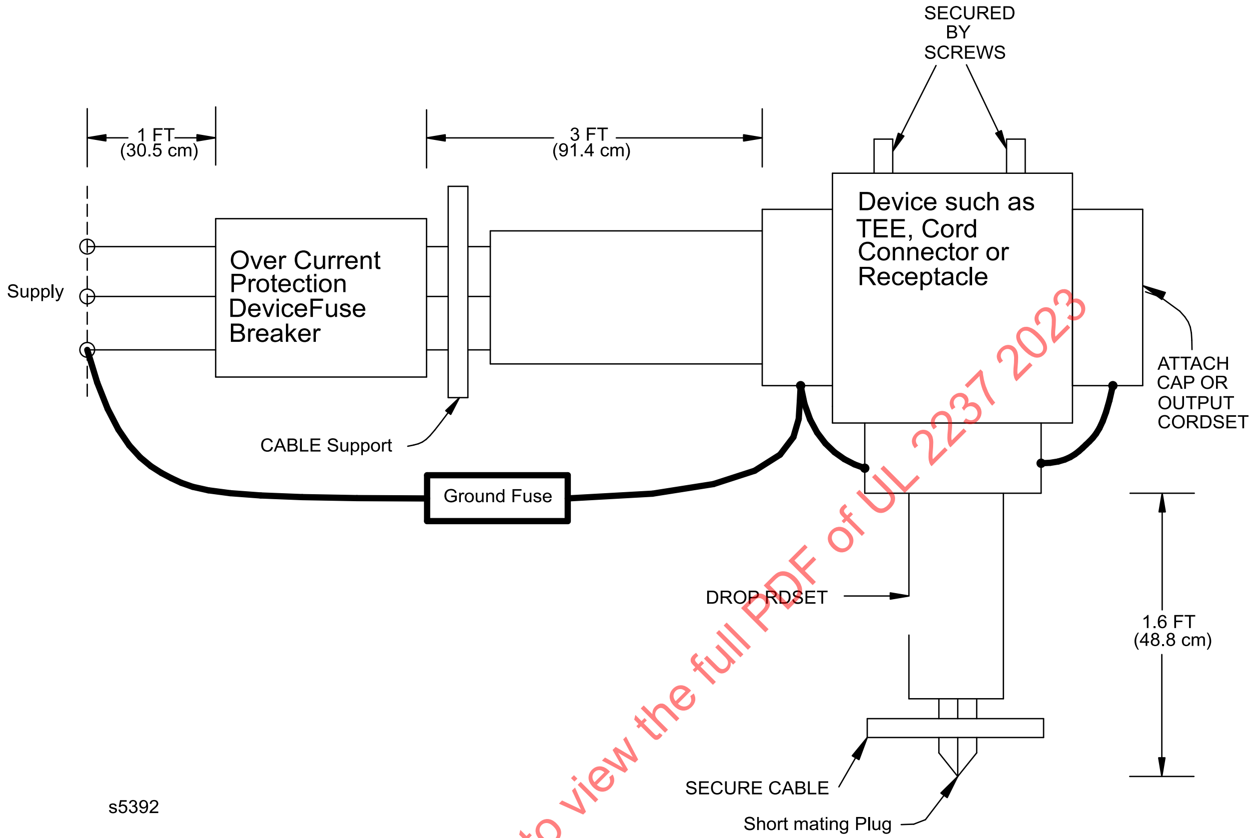
Figure 37.1

Typical short-circuit withstand capability test set-up



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37.1.2 If such equipment is marked to limit protection to fuses only, it shall not be considered as intended for use in a circuit protected by an inverse-time circuit breaker.

37.1.3 Testing with inverse-time circuit breakers shall not be required if it is shown that the clearing time of the inverse-time circuit breakers will be less than that of the fuse with which the product has been tested. Testing with inverse-time circuit breakers is not required when it is shown that the let-through energy (I^2t) and peak let-through current (I_p) of the inverse-time circuit breakers is less than that of the fuse with which the product has been tested.

37.2 Protective devices

37.2.1 The fuses used for the tests shall be specified as follows:

a) For a device intended for use on general purpose branch circuits, the rating of the fuse used shall be the ampere rating of the device.

b) For a device intended for use on motor branch circuits, the fuses used for the tests shall be specified by the manufacturer in accordance with Table 37.1.

Table 37.1
Ratings of fuses used for test

Type of fuse[a]	Maximum percent of device rated current[b]	Fuse Current (Amp) marking required[h]	Fuse Type (Class) marking required[i]
Nontime delay	400[c,d]	No	Yes
Nontime delay	< 400 but ≥ 300[e]	Yes	Yes
Nontime delay	< 300 but > 225[f]	Yes	Yes
Time delay	≤ 225[g]	Yes	Yes

[a] Tests with 225% full load ampere time delay fuses are not representative of tests with 400% full load ampere non-time delay fuses.

[b] These values are to be used when the manufacturer does not specify fuse sizes and refers to a maximum percent level, such as "Fuse not to exceed 300% of motor full load amps."

[c] For non-time delay fuses, if the calculated value of the fuse is between two standard ratings as specified in 37.2.3, a fuse of the nearest standard rating but not more than four times the full-load motor-current rating is to be used.

[d] Tests with 400% non-time delay fuses cover use with 225% time delay fuses.

[e] Tests with non-time delay fuses rated less than 400%, and equal to or greater than 300 percent cover use with 175% time delay fuses.

[f] Tests with less than 300% non-time delay fuses requires additional testing with 225% (or as marked) time delay fuses.

[g] The product is marked to indicate the level of protection and that the branch-circuit protective device is able to be of the time-delay type.

[h] When the fuse size employed for the short circuit test requires a marking, the device shall be marked as specified in Section 48.

[i] For Fuse Type (Class) see Section 48, Markings.

37.2.2 Standard ampere ratings for fuses are 1, 3, 6, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 601, 700, 800, 1000, 1200, 1600, 2000, 2500, 3000, and 4000.

37.2.3 Testing shall be conducted with Class RK5 fuses.

Exception: Other class of fuses may be used, if the device is marked to indicate the Class Type of fuse. See marking in 48.10.

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37.2.4 For a device intended to be used with fuses and short circuit rating greater than 5,000 A, the protective devices used for the test are to be sized in accordance with 37.2.1 and are to be selected as follows:

a) Fuses specified for branch-circuit protection devices rated greater than 5,000 A shall be limited to high-interrupting capacity, current-limiting types – for example, Class CC, G, J, L, R, and T.

b) A device that is required to be used with RK1 or RK5 fuses is to be tested with fuses having I^2t and Ip characteristics for Class RK5 fuses. All references to Class R fuses are intended to mean fuses with energy let-through (I^2t), characteristics of Class RK5 fuses.

Exception: A device that is marked to restrict its use to RK1 fuses is able to be tested with fuses having energy let-through characteristics of a Class RK1 fuse.

c) A Class CC, G, J, L, R, or T fuse, or motor short-circuit protector is to be selected such that, when tested on a single-phase circuit, the peak let-through current and clearing I^2t are not less than the maximum value established for the fuse – see the UL 248-1 series of standards – or motor short-circuit protector rating that is intended to be used with the controller being tested. For a fuse with I_p and I^2t limits established for several different short-circuit current levels, the test fuse is to be selected to have at least the maximum values of the current corresponding to the marked short-circuit current rating of the motor control device.

Exception: A test limiter is able to be used in place of the fuses.

37.2.5 An inverse-time circuit breaker used for the test described in 37.2.8 – 37.2.19 and Table 37.2 shall be specified by the manufacturer in accordance with (a), (b), or (c):

a) For a device intended for use on general purpose branch circuits, the rating of the inverse time circuit breaker shall be the ampere rating of the device.

b) For a device intended for use on motor branch circuits, the inverse-time circuit breaker may be rated four times the device rating for currents of 100 A or less or three times the device rating for full-load currents greater than 100 A. If the calculated value of the circuit breaker is between two standard ratings as specified in 37.2.6, a circuit breaker of the nearest standard rating less than the calculated value shall be used. If the calculated value of the circuit breaker is less than 15 A, a circuit breaker rated 15 A shall be used. No marking of the circuit breaker rating is required on the product.

c) The inverse-time circuit breaker mentioned above may have a rating less than that specified in (b) if the product is marked to indicate the limit of protection.

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Table 37.2
Standard short circuit test values

Device amperage rating A	Test current A[a]	Power factor[c]
0 – 50	5,000[b]	0.70 – 0.80
51 – 200	10,000	0.70 – 0.80
201 – 400	18,000	0.25 – 0.30

[a] Symmetrical rms amperes.

[b] 10,000 A at manufacturer's option.

[c] Lower power factors may be used.

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37.2.6 Standard ampere ratings for inverse-time circuit breakers are 1, 3, 6, 10, 15, 20, 25, 30, 35, 40, 45, 50, 60, 70, 80, 90, 100, 110, 125, 150, 175, 200, 225, 250, 300, 350, 400, 450, 500, 600, 700, 800, 1000, 1200, 1600, 2000, 2500, 3000, and 4000.

37.2.7 The marking referred to in 37.1.1, 37.2.5, and Table 37.1 may alternatively be located in the installation instructions.

37.2.8 A device shall be tested in an enclosure representative of that likely to be encountered in service.

37.2.9 A device shall be wired to each of the testing terminals by no more than 4 ft (1.2 m) of wire per pole as shown in Figure 37.1. The wire shall be as specified by the manufacturer.

37.2.10 The grounding (bonding) conductor shall be installed as intended. For this test:

a) A male device shall be assembled to a 2-ft (0.6-m) length of flexible cord or cable. The male device was inserted into the mating female device. The load conductors shall be shorted together.

b) A female device shall be assembled to a length of flexible cord or cable wired at one end to the testing terminals. The total conductor length between supply terminals and fitting shall not exceed 4 ft (1.2 m). See Figure 37.1.

37.2.11 The test conductors including flexible cord or cable may exceed the specified length as shown in Figure 37.1 if they are in the test circuit during calibration.

37.2.12 The grounding (bonding) conductor and the metal enclosure shall be connected through a non-time-delay, 30-A cartridge fuse to the electrical supply live pole judged least likely to arc to ground. The fuse referred to in 37.1.1 shall be connected in series with the pole judged most likely to strike ground. The connection shall be made to the load side of the limiting impedance by a 10 AWG (5.3 mm^2) copper wire that is 4 to 6-ft (1.2 to 1.8-m) long.

37.2.13 The connection may be made with 12 or 14 AWG (3.3 or 2.1 mm^2) copper wire if the branch-circuit conductors the equipment is intended to be connected to are 12 or 14 AWG (3.3 or 2.1 mm^2).

37.2.14 During the test, surgical cotton shall be placed at all openings, covers, flanges, joints, and the like, on the outside of the enclosure.

37.2.15 Equipment rated for direct current shall be tested using a direct current electrical source; alternating-current equipment shall be tested on a 60 Hz essentially sinusoidal current electrical source. The open-circuit voltage of the test circuit shall be 100 – 105% of the voltage rating of the device, except that the voltage may exceed 105% of the rated voltage with the concurrence of those concerned. The test circuit shall be capable of delivering the current specified in Table 37.2 for a given motor rating when the system is short-circuited at the testing terminals to which the device under test is connected, and this shall be verified by means of an oscillograph.

37.2.16 For devices requiring a higher fault current rating, see the Standard for Industrial Control Equipment, UL 508 for short circuit test values.

37.2.17 Fuses specified for branch-circuit protection for a motor control device rated over 10,000 A shall be limited to high-interrupting capacity, current-limiting types – for example, Class CC, G, J, L, R, and T.

37.2.18 For all test operations, the test circuit shall be closed on the mated devices. Two devices shall be tested.

Exception: One device may be tested twice when agreeable to those concerned.

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37.2.19 If a group of devices having different ratings are of the same construction and material and are intended for use with one size of fuse, tests on the highest ratings may be considered to be representative of that group.

37.2.20 After the protective device has cleared the fault, the device shall comply with the following:

a) There shall not be any discharge of parts. The contacts shall not disintegrate, evaporate, or weld. There shall not be any damage to the device, the wiring terminals or other parts that would impair the function of the device.

b) There shall not be any breakage of insulating bases or supports to the extent that the integrity of the mounting or insulation of live parts is impaired.

c) There shall not be any ignition of the cotton or cord insulation, or any other risk of a fire, and the circuit breaker or the fuse in the test circuit shall operate when the test circuit is closed.

d) The fuse connected between the live pole and the grounding (bonding) conductor or the enclosure shall not open.

37.3 Calibration of test circuits

37.3.1 Circuit characteristics

37.3.1.1 Equipment rated for direct current is to be tested using a direct current electrical source; alternating-current equipment is to be tested on a 60-Hz essentially sinusoidal current electrical source. The open-circuit voltage of the test circuit is to be 100 – 105% of the voltage rating of the overload relay, except that the voltage may exceed 105% of the rated voltage with the concurrence of those concerned. The test circuit is to be capable of delivering the specified current when the system is short-circuited at the testing terminals to which the device under test is to be connected, and this is to be verified by means of an oscillograph.

37.3.1.2 For available fault current circuits, air core type reactors are to be employed in the line to obtain the power factor in accordance with Table 37.2. The reactors may be connected in parallel, but no reactor is to be connected in parallel with a resistor; except that a reactor in any phase may be shunted by a resistor if the power consumed by the resistor is in the range between 0.55 – 0.65% of the reactive volt-amperes in the reactor in that phase. The minimum value of the shunting resistance used with a reactor having negligible resistance is to be calculated from the equation:

$$R = 167\frac{E}{I}$$

in which:

E is the voltage across the reactor with current I flowing as determined by oscillographic measurement during the short circuit calibration or by proportion from meter measurements at some lower current.

37.3.2 Alternating-current circuits

37.3.2.1 General

37.3.2.1.1 The available current capacity of the circuit is to be at least the value required for the short-circuit-current rating of the motor control device. The frequency of the test circuit is to be 60 ±12 Hz for an alternating-current circuit.

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37.3.2.1.2 The available rms symmetrical current is to be determined at the device terminals. If the available current is determined at the test-station terminal and the physical arrangement in the test station requires leads longer than 8 ft (2.4 m) per terminal, the additional length of leads is to be included in the circuit calibration.

Exception No. 1: For a circuit rated 25,000 A or less, the available current may be determined at the test-station terminals.

Exception No. 2: The available current may be determined at the test-station terminals if for a circuit having a maximum available short-circuit current:

a) Between 25,001 – 50,000 A, the available current is determined to be 5% higher than the required test current; or

b) Between 50,001 – 200,000 A, the available current is determined to be 10% higher than the required test current.

37.3.2.2 Available current of 10,000 A or less

37.3.2.2.1 For an alternating-current circuit intended to deliver 10,000 A or less, the current and power factor shall be determined as follows:

a) For a 3-phase test circuit, the current shall be determined by averaging the rms values of the first complete cycle of current in each of the three phases; the voltage to neutral shall be used to determine the power factor.

b) For a single-phase test circuit, the current shall be the rms value of the first complete cycle (See Figure 37.2) when the circuit is closed to produce an essentially symmetrical current waveform. The direct-current component shall not be added to the value obtained when measured as illustrated. To obtain the desired symmetrical waveform of a single-phase test circuit, controlled closing is recommended although random closing methods may be used. The power factor shall be determined by referring the open-circuit voltage wave to the two adjacent zero points at the end half of the first complete current cycle by transposition through a suitable timing wave. The power factor shall be computed as an average of the values obtained by using these two current zero points.

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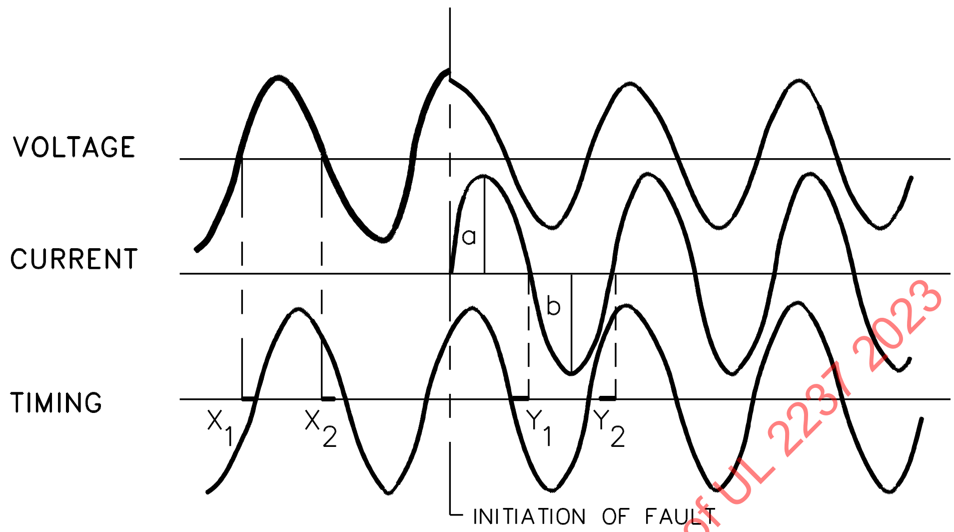
Figure 37.2

Determination of current and powerfactor for circuits of 10,000 A and less



$$Current = \frac{a+b}{2} \text{ rms calibration of instrument element}$$

$$Power\ Factor = \frac{Cos\left[(Y_1 + X_1) \times 180°\right]}{2} + \frac{Cos\left[(Y_2 + X_2) \times 180°\right]}{2}$$

Where X and Y values are fractions of the 1/2–cycle distance in which they occur.

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37.3.2.3 Available current more than 10,000 A

37.3.2.3.1 For circuits intended to deliver more than 10,000 A, the current and power factor shall be determined in accordance with the requirements in 37.3.2.3.2 – 37.3.2.3.8. Instrumentation used to measure test circuits of over 10,000 A shall comply with the requirements in 37.2.5 – 37.3.4.5.

37.3.2.3.2 The rms symmetrical current shall be determined, with the supply terminals short-circuited by measuring the alternating-current component of the wave at an instant 1/2 cycle – on the basis of the test frequency timing wave – after the initiation of the short circuit. The current shall be calculated in accordance with the Short-Line Fault TRV with Time Delay Figure in the Standard Test Procedure for AC High-Voltage Circuit Breakers Rated on a Symmetrical Current Basis, ANSI/IEEE C37.09.

37.3.2.3.3 For a 3-phase test circuit, the rms symmetrical current shall be the average of the currents in the three phases. The rms symmetrical current in any one phase is not to be less than 90% of the required test current.

37.3.2.3.4 In 3-phase circuits, the symmetrical alternating component of current of all three phases shall be averaged. The test circuit and its transients shall be such that:

a) Three cycles after initiation of the short circuit, the symmetrical alternating component of current will not be less than 90% of the symmetrical alternating component of current at the end of the first 1/2 cycle; or

b) The symmetrical alternating component of current at the time at which the over current protective device will interrupt the test circuit is at least 100% of the rating for which the device is being tested.

37.3.2.3.5 The power factor shall be determined at an instant 1/2 cycle – on the basis of the test frequency timing wave – after the short circuit occurs. The total asymmetrical rms amperes shall be measured in accordance with 37.3.2.3.2 and the ratio M_A or M_M shall be calculated as follows: Using ratio M_A or M_M, the power factor shall be determined from Table 37.3.

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Table 37.3
Short-circuit power factor

Short-circuit power factor %	Ratio M_M	Ratio M_A	Short-circuit power factor %	Ratio M_M	Ratio M_A
0	1.732	1.394	30	1.130	1.066
1	1.696	1.374	31	1.121	1.062
2	1.665	1.355	32	1.113	1.057
3	1.630	1.336	33	1.105	1.053
4	1.598	1.318	34	1.098	1.049
5	1.568	1.301	35	1.091	1.046
6	1.540	1.285	36	1.084	1.043
7	1.511	1.270	37	1.078	1.039
8	1.485	1.256	38	1.073	1.036
9	1.460	1.241	39	1.068	1.033
10	1.436	1.229	40	1.062	1.031
11	1.413	1.216	41	1.057	1.028
12	1.391	1.204	42	1.053	1.026

Table 37.3 Continued on Next Page

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Table 37.3 Continued

Short-circuit power factor %	Ratio M_M	Ratio M_A	Short-circuit power factor %	Ratio M_M	Ratio M_A
13	1.372	1.193	43	1.049	1.024
14	1.350	1.182	44	1.045	1.022
15	1.330	1.171	45	1.041	1.020
16	1.312	1.161	46	1.038	1.019
17	1.294	1.152	47	1.034	1.017
18	1.277	1.143	48	1.031	1.016
19	1.262	1.135	49	1.029	1.014
20	1.247	1.127	50	1.026	1.013
21	1.232	1.119	55	1.015	1.008
22	1.218	1.112	60	1.009	1.004
23	1.205	1.105	65	1.004	1.002
24	1.192	1.099	70	1.002	1.001
25	1.181	1.093	75	1.0008	1.0004
26	1.170	1.087	80	1.0002	1.00005
27	1.159	1.081	85	1.00004	1.00002
28	1.149	1.075	100	1.00000	1.00000
29	1.139	1.070			

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37.3.2.3.6 The power factor of a 3-phase circuit may be calculated by using controlled closing so that upon subsequent closings a different phase will be caused to have maximum asymmetrical conditions. The power factor of each phase could then be determined using the method described for single-phase circuits in 37.3.2.3.5. The power factor of the 3-phase circuit shall be considered to be the average of the power factors of each of the phases.

37.3.2.3.7 The recovery voltage shall be at least equal to the rated voltage of the device. The peak value of the recovery voltage within the first complete half cycle after clearing and for the next five successive peaks shall be at least equal to 1.414 times the rms value of the rated voltage of the device. Each of the peaks shall not be displaced by more than ±10 electrical degrees from the peak values of the open-circuit recovery voltage – that is, the displacement of the peak from its normal position on a sinusoidal wave. The average of the instantaneous values of recovery voltage each of the first six, half cycles measured at the 45° and 135° points on the wave shall be not less than 85% of the rms value of the rated voltage of the device. The instantaneous value of recovery voltage measured at the 45° and 135° points of each of the first six, half cycles shall not be less than 75% of the rms value of the rated voltage of the device.

37.3.2.3.8 If there is no attenuation or phase displacement of the first full cycle of the recovery voltage wave when compared with the open-circuit secondary voltage wave before current flow in a circuit that employs secondary closing, the detailed measurement of recovery voltage characteristics as indicated in 37.3.2.3.7 shall not be required.

37.3.2.4 Instrumentations for test currents above 10,000 A

37.3.2.4.1 The galvanometers in a magnetic oscillograph employed for recording voltage and current during circuit calibration and while testing shall be of a type having a flat (±5%) frequency response from 50 – 1200 Hz. For fast acting fuses, current limiters, or motor-short-circuit protectors, a galvanometer may need to have a flat frequency response from 50 – 9000 Hz, or an oscilloscope may be needed to obtain accurate values of peak current, (I_p), and energy let-through, (I^2t).

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37.3.2.4.2 Galvanometers shall be calibrated as described in 37.3.2.4.3 – 37.3.2.4.5. When a shunt is used to determine the circuit characteristics, a direct-current calibrating voltage is normally used. The voltage applied to the oscillograph galvanometer circuit is to result in a deflection of the galvanometer approximately equivalent to that which is expected when the same galvanometer circuit is connected to the shunt and the nominal short-circuit current is flowing. The voltage shall be applied to cause the galvanometer to deflect in both directions. Additional calibrations shall be made using approximately 50% and approximately 150% of the voltage used to obtain the deflection indicated above, except that if the anticipated maximum deflection is less than 150%, such as a symmetrically closed single-phase circuit, any other suitable calibration point shall be chosen. The sensitivity of the galvanometer circuit in volts per millimeter (or volts per inch) shall be determined from the deflection measured in each case, and the results of the six trials averaged. The peak amperes per millimeter (or amps per inch) shall be obtained by dividing the sensitivity by the resistance of the shunt. This multiplying factor shall be used for the determination of the rms current as described in 37.3.2.3.2.

37.3.2.4.3 A 60 Hz sine-wave potential may be used for calibrating the galvanometer circuit, using the same general method described in 37.3.2.4.2. The resulting factor shall be multiplied by 1.414.

37.3.2.4.4 When a current transformer is used to determine the circuit characteristics, an alternating current shall be used to calibrate the galvanometer circuit. The value of current applied to the galvanometer circuit shall result in a deflection of the galvanometer approximately equivalent to that which is expected when the same galvanometer is connected to the secondary of the current transformer and nominal short circuit current is flowing in the primary. Additional calibrations shall be made at approximately 50% and approximately 150% of the current used to obtain the deflection indicated above except that if the anticipated maximum deflection is less than 150%, such as in a symmetrically closed single-phase circuit, any other suitable calibration point shall be chosen. The sensitivity of the galvanometer circuit in rms amperes per millimeter (or amps per inch) shall be determined in each case and the results averaged. The average sensitivity shall be multiplied by the current-transformer ratio and by 1.414 to obtain peak amperes per millimeter (or amps per inch). This constant shall be used for the determination of the rms current as described in 37.3.2.3.2.

37.3.2.4.5 All the galvanometer elements employed shall line-up properly in the oscillograph, or the displacement differences shall be noted and used as needed.

37.3.2.4.6 The sensitivity of the galvanometers and the recording speed shall be such that the values of voltage, current, and power factor can be determined accurately. The recording speed shall be at least 60 in/s (1.5 m/s).

37.3.2.4.7 With the test circuit adjusted to provide the specified values of voltage and current, and with a noninductive (coaxial) shunt that has been found acceptable for use as a reference connected into the circuit, the tests described in 37.3.2.4.8 and 37.3.2.4.9 shall be conducted to verify the accuracy of the manufacturer's instrumentation.

37.3.2.4.8 With the secondary open-circuited, the transformer shall be live and the voltage at the test terminals observed to see if rectification is occurring making the circuit unacceptable for test purposes because the voltage and current will not be sinusoidal. Six random closings shall be made to demonstrate that residual flux in the transformer core will not cause rectification. If testing is done by closing the secondary circuit, this check can be omitted providing testing is not commenced before the transformer has been live for approximately 2 s, or longer if an investigation of the test equipment shows that a longer time is necessary.

37.3.2.4.9 With the test terminals connected together by means of a copper bar, a single-phase circuit shall be closed as nearly as possible at the moment that will produce a current wave with maximum offset. The short circuit current and voltage shall be recorded. The primary voltage shall be recorded if primary closing is used. The current measured by the reference shunt shall be within 5% of that measured using

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the manufacturer's instrumentation, and there shall be no measurable variation in phase relationship between the traces of the same current. Controlled closing is not required for polyphase circuits.

37.3.2.4.10 When the verification of the accuracy of the manufacturer's instrumentation is completed, the reference coaxial shunt shall be removed from the circuit. The reference coaxial shunt shall not be used during the final calibration of the test circuit nor during the testing of devices.

37.3.3 Direct current circuits

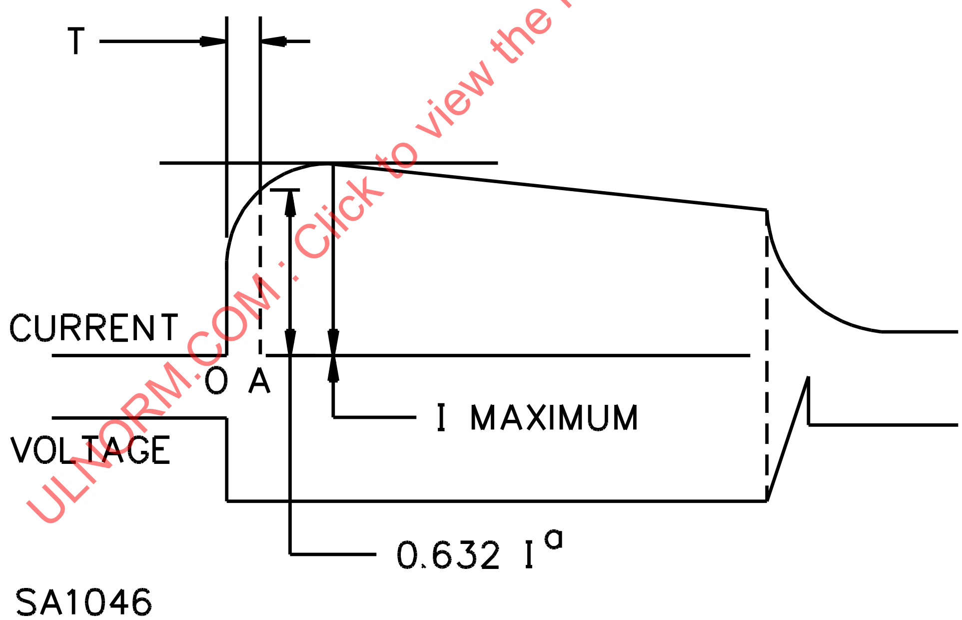
37.3.3.1 An equipment intended for use on a dc system is to be tested with dc and with the equipment connected so that the frame and enclosure will be positive in potential with regard to the nearest arcing point.

37.3.3.2 Oscillograph recordings, or an equivalent method, are to be used to determine circuit characteristics.

37.3.3.3 For a dc source, the requirements of 37.3.3.4 – 37.3.3.8 are to be applied. The time constant of the test circuit is to be determined by the method shown in Figure 37.4 and is to be no less than the value shown in Table 37.4.

Figure 37.4

Determination of the short circuit test constant (oscillograph method) of direct-current circuits



[a] The value of the time constant is given by the abscissa OA corresponding to the ordinate 0.632I of the oscillograph of calibration of the circuit.

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Table 37.4
Time constant of test circuit

Rated interrupting current A	Minimum time constant s
10,000 or less	0.003
Over 10,000	0.008

37.3.3.4 The dc open circuit voltage measurement mentioned in 37.3.1.1 is to be made with a voltmeter. In addition, the open circuit voltage, as determined by the arithmetic average of the maximum and minimum values of the voltage wave read from the oscillograph, is to be within 99% and 105% of the rated voltage of the equipment, except that a higher voltage may be used if agreeable to all concerned.

37.3.3.5 The minimum point on the dc voltage wave is to be no less than 90% of the rated voltage of the equipment.

37.3.3.6 The available dc capacity of the circuit is to be no less than the value as required for the rating of the device as indicated in Table 37.4, as appropriate. The prospective current is to be determined with the supply terminals short circuited by measuring the maximum displacement on an oscillogram at a time, after the start of current, of no less than 4 times the required time constant. Any overshot above time-current curve (exponential curve) is not to be considered.

37.3.3.7 The time constant of the circuit is the time measured on the oscillogram where the current is 63.2% of the prospective current.

37.3.3.8 If the current source has a ripples, measurements are to be made from the midpoint of the ripple.

37.3.4 Calibration characteristics for protective device

37.3.4.1 To obtain the required values specified in 37.3.2.2.1, it may be necessary to employ a fuse, current limiter, or motor short-circuit protector larger than that specified for use with the device being tested; or a commercially available test fuse designed and calibrated to exhibit I^2t and I_p characteristics at least equal to the maximum permitted limits for the fuse, current limiter, or motor short-circuit protector rating. The let-through characteristics are to be determined in accordance with 37.3.2.4.2.

37.3.4.2 Fuses, current limiters, or motor short-circuit protectors used for tests are to be selected from a batch from which two samples have been selected. The value of the I_p and I^2t determined for the two selected samples is to be equal to or greater than the required values. These determinations are to be made in accordance with 37.3.4.3 and 37.3.4.4.

37.3.4.3 Figure 37.5 is typical of oscillogram obtained during the test of a fuse, current limiter, or motor short-circuit protectors on an alternating-current circuit; and represents a circuit that opened before the current could reach its first major peak. The peak let-through current I_p is to be determined as illustrated.

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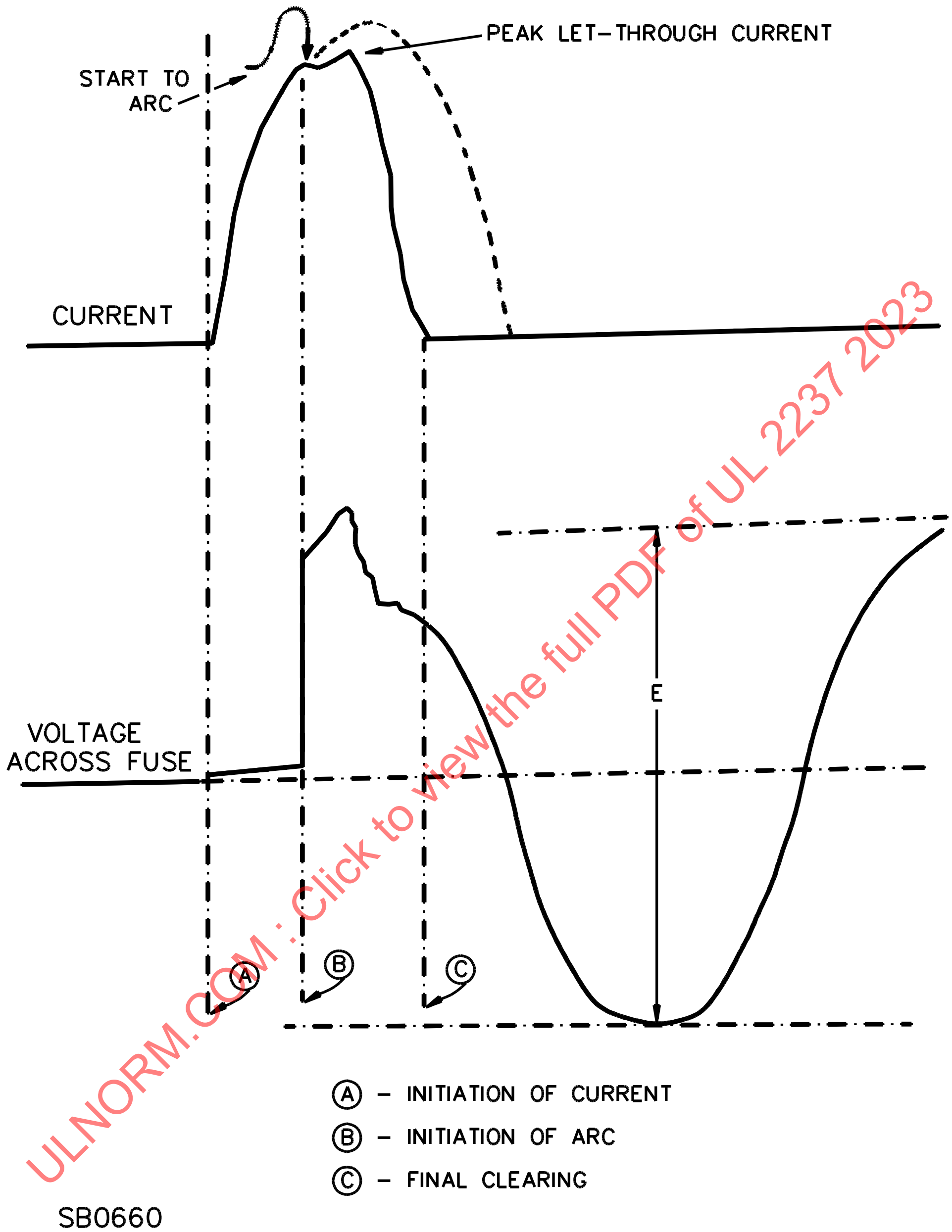
Figure 37.5

Peak let-through current



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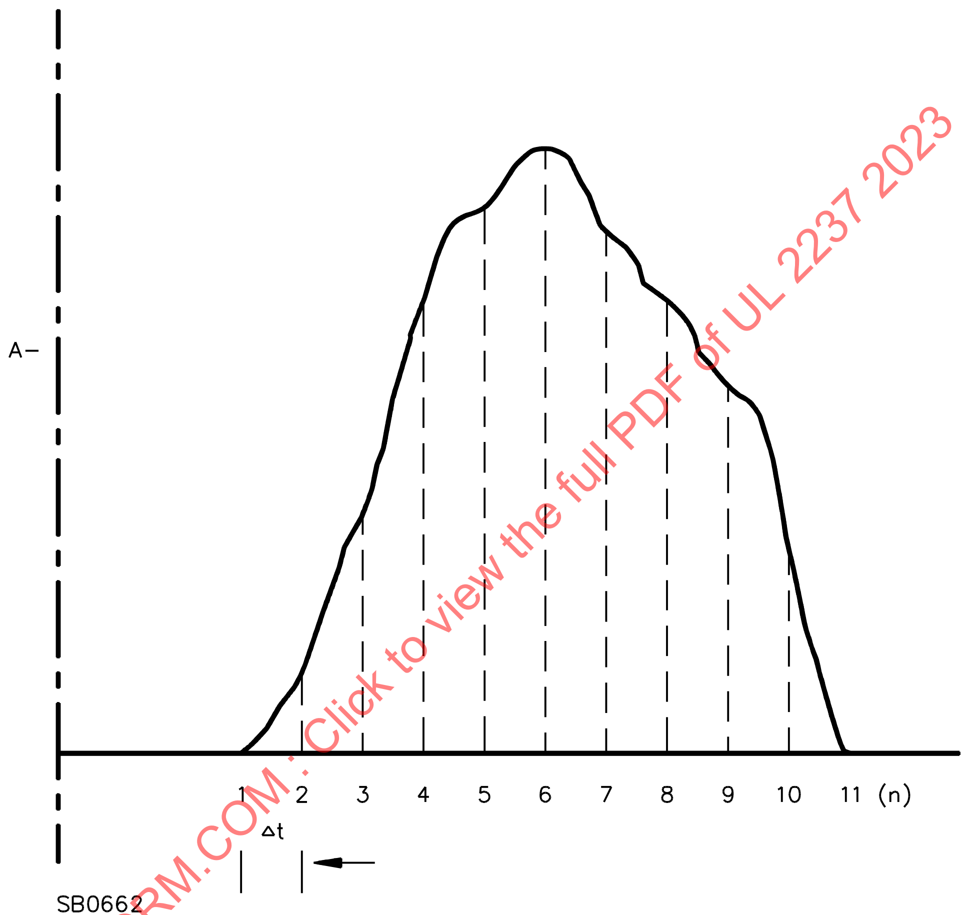
37.3.4.4 The let-through energy (I^2t) is to be determined from an oscillogram showing a current trace during the interruption of the circuit by the fuse, current limiter, or motor short-circuit protectors. The determination is to be made by the application of Simpson's rule illustrated in Figure 37.6 or the use of an integrating planimeter.

Figure 37.6

Application of Simpson's Rule to fuse current oscillogram to obtain let-through I^2t



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1. Odd numbers of ordinates (n) are to be chosen evenly spaced (Δt). The more uneven the curve, the more ordinates.

2. Each ordinate is to be measured, multiplied by ampere scale (indicated by A in this figure), and squared.

3. I^2t is calculated as follows:

$$I^2t = (\Delta t / 3)[(I_1{}^2 + I_n{}^2) + 4(I_2{}^2 + I_4{}^2 + I_6{}^2 ... I_{(n-1)}{}^2) + 2(I_3{}^2 + I_5{}^2 + I_7{}^2 ... I_{(n-2)}{}^2)]$$

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