JOINT CANADA-UNITED STATES
NATIONAL STANDARD

# ANSI/CAN/UL 2808:2020

# STANDARD FOR SAFETY

## Energy Monitoring Equipment



Approved American National Standard

ANSI/UL 2808-2020

Standards Council of Canada
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UL Standard for Safety for Energy Monitoring Equipment, ANSI/CAN/UL 2808

First Edition, Dated July 22, 2020

***Summary of Topics***

***This First Edition of ANSI/CAN/UL 2808 has been issued to reflect the latest ANSI and SCC approval dates, and covers submetering equipment and open and enclosed type current sensors intended for factory or field installation within distribution and control equipment such as panelboards, switchboards, industrial control equipment, and energy monitoring/management equipment. Installation is in accordance with the National Electrical Code, ANSI/NFPA 70 and the Canadian Electrical Code (CE Code), CSA C22.1. These requirements also cover "Service Entrance" enclosed-type current sensors intended for indoor and outdoor use.***

The new requirements are substantially in accordance with Proposal(s) on this subject dated August 16, 2019, December 20, 2019 and March 6, 2020.

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ANSI/UL 2808-2020

JULY 22, 2020



# ANSI/CAN/UL 2808:2020

## Standard for Energy Monitoring Equipment

**First Edition**

**July 22, 2020**

This ANSI/CAN/UL Safety Standard consists of the First Edition.

The most recent designation of ANSI/UL 2808 as an American National Standard (ANSI) occurred on May 5, 2020. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, Title Page, Preface or SCC Foreword.

This standard has been designated as a National Standard of Canada (NSC) on July 22, 2020.

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**ANNEX A (INFORMATIVE) SAFETY MARKING TRANSLATIONS**

# Preface

This is the First Edition of ANSI/CAN/UL 2808, Standard for Energy Monitoring Equipment.

UL is accredited by the American National Standards Institute (ANSI) and the Standards Council of Canada (SCC) as a Standards Development Organization (SDO).

This Standard has been developed in compliance with the requirements of ANSI and SCC for accreditation of a Standards Development Organization.

This ANSI/CAN/UL 2808 Standard is under continuous maintenance, whereby each revision is approved in compliance with the requirements of ANSI and SCC for accreditation of a Standards Development Organization. In the event that no revisions are issued for a period of four years from the date of publication, action to revise, reaffirm, or withdraw the standard shall be initiated.

In Canada, there are two official languages, English and French. All safety warnings must be in French and English. Attention is drawn to the possibility that some Canadian authorities may require additional markings and/or installation instructions to be in both official languages.

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



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This Edition of the Standard has been formally approved by the UL Standards Technical Panel (STP) on Retrofit Energy Monitoring Equipment, STP 2808.

This list represents the STP 2808 membership when the final text in this standard was balloted. Since that time, changes in the membership may have occurred.

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This Standard is intended to be used for conformity assessment.

The intended primary application of this standard is stated in its scope. It is important to note that it remains the responsibility of the user of the standard to judge its suitability for this particular application.

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## INTRODUCTION

### 1 Scope

1.1 These requirements cover submetering equipment and open and enclosed type current sensors intended for factory or field installation within the wiring space of enclosures for switches or overcurrent devices. Installation is in accordance with the National Electrical Code, ANSI/NFPA 70 and the Canadian Electrical Code (CE Code), CSA C22.1. These requirements also cover "Service Entrance" enclosed-type current sensors intended for indoor and outdoor use.

1.2 These current sensors are rated for use in a maximum 250 V, 600 V, or 1000 V line-to-line circuit or in a maximum 1500 Vdc circuit. The frequency measurement capability of the sensors is governed by the stated frequency.

1.3 Current sensor conductor leads under the scope of this standard are considered a Class 1 circuit, as defined by the National Electrical Code, ANSI/NFPA 70, and the Canadian Electrical Code (CE Code), CSA C22.1 and are intended to be installed with NFPA 70 Chapter 3, wiring methods and CE Code Section 12, wiring methods.

1.4 This standard does not include investigation of the function of the controlled equipment.

1.5 These current sensors have not been evaluated for accuracy or use with emergency control systems where the function of the control could affect safety.

1.6 These current sensors are intended for use in an ambient temperature of 0 – 40°C (32 – 104°F) unless specifically indicated for use in other conditions.

1.7 These current sensors are intended for use at altitudes up to 2000 m (6562 ft) and in a humidity tolerance of 0 – 95 percent, unless indicated for use in other conditions.

1.8 Unless specifically evaluated and marked “Service Entrance”, these current sensors are evaluated for installation within equipment on the load side of the service equipment overcurrent device.

### 2 Components

2.1 Except as indicated in 2.2, a component of a product covered by this standard of Investigation shall comply with the requirements for that component.

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

a) Involves a feature or characteristic not required in the application of the component in the product covered by this standard, or

b) Is superseded by a requirement in this standard.

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

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

## 3 Units of Measurement

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

3.2 The voltage designations used throughout this standard are defined as follows:

- V – A voltage rating that is either ac or dc. Ac voltage is rms, peak is specifically designated Vpeak.
- VAC – A voltage rating that is exclusively ac only.
- VAC/VDC – A voltage rating that is explicitly ac and dc.
- VDC – A voltage rating that is exclusively dc only.

## 4 Undated References

4.1 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.

## 5 Normative References

5.1 The following standards are referenced in this standard, and portions of these referenced standards may be essential for compliance.

### ASTM Standards

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

### CSA Standards

CSA C22.1, *Canadian Electrical Code, Part I Safety Standard for Electrical Installations*

CAN/CSA C22.2 No. 0, *General Requirements – Canadian Electrical Code, Part II*

CSA C22.2 No. 0.15, *Adhesive Labels*

CAN/CSA C22.2 No. 0.17, *Evaluation of Properties of Polymeric Materials*

CAN/CSA C22.2 No. 94, *Special Purpose Enclosures*

CSA C22.2 No. 94.1, *Enclosures for Electrical Equipment, Non-Environmental Considerations*

CSA C22.2 No. 94.2, *Enclosures for Electrical Equipment, Environmental Considerations*

CSA C22.2 No. 158, *Terminal Blocks*

CSA C22.2 No. 182.3, *Special Use Attachment Plugs, Receptacles and Connectors*

CSA C22.2 No. 61010-1, *Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use – Part 1: General Requirements*

CSA C22.2 No. 61010-2-030, *Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use – Part 2-030: Particular Requirements for Testing and Measuring Circuits*

CSA C22.2 No. 61010-2-32, *Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use – Part 2-032: Particular Requirements for Hand-Held and Hand- Manipulated Current Sensors for Electrical Test and Measurement*

CSA C22.2 No. 182.3, *Special Use Attachment Plugs, Receptacles and Connectors*

CSA C22.2 No. 158, *Terminal Blocks*

**IEC Standards**

IEC 60364, *Low-voltage Electrical Installations – Part 1: Fundamental Principles, Assessment of General Characteristics*

IEC 60664-1, *Insulation Coordination for Equipment within Low-Voltage Systems – Part 1: Principles, Requirements and Tests*

IEC 61010, *Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory use – Part 1: General Requirements*

**NEMA Standards**

NEMA 250, *Enclosures for Electrical Equipment (1000 Volts Maximum)*

**NFPA Standards**

NFPA 70, *National Electrical Code*

**UL Standards**

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

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

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

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

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

UL 969, *Marking and Labeling Systems*

UL 1059, *Terminal Blocks*

UL 1446, *Systems of Insulating Materials – General*

UL 2238, *Cable Assemblies and Fittings for Industrial Control and Signal Distribution*

UL 61010-1, *Electrical Equipment for Measurement, Control, and Laboratory Use; Part 1: General Requirements*

UL 61010-2-030, *Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use – Part 2-030: Particular Requirements for Testing and Measuring Circuits*

UL 61010-2-32, *Safety Requirements for Electrical Equipment for Measurement, Control, and Laboratory Use – Part 2-032: Particular Requirements for Hand-Held and Hand- Manipulated Current Sensors for Electrical Test and Measurement*

## 6 Glossary

6.1 For the purposes of this standard, the following definitions apply.

6.2 BURDEN COMPONENT – A resistor or other component that limits open circuit voltage of the current sensor.

6.3 CLASS 1 CIRCUIT – The portion of the wiring system between the load side of the overcurrent device or power-limited supply and the connected equipment.

6.4 CLASS 2 CIRCUIT – The portion of the wiring system between the load side of a Class 2 power source and the connected equipment.

6.5 CONTROLLED ENVIRONMENT – Also known as Pollution Degree 2. Indicates current sensors are intended for installation in an environment where only non-conductive pollution occurs, except that occasionally a temporary conductivity caused by condensation is expected.

6.6 CURRENT SENSOR – A sensor for measuring primary current that outputs a signal or data. Current sensors include, but are not limited to, Instrument Transformers, Shunts, Rogowski Coils and their associated signal level processor, combiner and/or multiplexer board accessories thereto, or other measurement technologies.

6.7 ENCLOSED-TYPE CURRENT SENSOR – A device that is provided with a complete enclosure and may be installed outside of a separate end-product enclosure.

6.8 OPEN-TYPE CURRENT SENSOR– A device that is not provided with a complete enclosure and is intended to be placed in a suitable end-product enclosure.

6.9 SERVICE ENTRANCE – That portion of the installation between the service point and the line side of the service equipment.

Note: Service entrance correlates with Overvoltage Category IV, or CAT IV, as defined in IEC 60364 and IEC 60664-1.

6.10 SUBMETER – A meter or meter system downstream of the master meter. Submeters provide details of energy and associated quantities for monitoring or revenue submetering.

## CURRENT SENSORS CONSTRUCTION

## 7 General

7.1 In order to reduce the likelihood of creating a risk of electric shock, all metallic parts shall be completely encased or otherwise recessed within an insulating material and comply with the spacing requirements within this standard.

7.2 Unless otherwise noted, all insulating materials shall be rated with an Electrical Relative Thermal Index (RTI Elec) of 105°C (221°F), minimum.

7.3 These current sensors shall be evaluated for installation within equipment having a maximum line-to-line voltage of 250 Vac, 600 Vac, 1000 Vac, or 1500 Vdc.

7.4 These current sensors shall not contain any radio signal generators or other intentional signal emitters.

## 8 Case and Potting Materials

8.1 Materials for a molded insulating case shall comply with Table 8.1.

**Table 8.1**
**Material characteristics for current sensor case and exposed potting**

| Flame class | RTI elec[a] | Performance level category (PLC) | | |
|---|---|---|---|---|
| | | HWI[b,c,h] | HAI[d,e,h] | CTI[f,g] |
| V-2, VTM-2 | Min. 105°C (221°F) | 0, 1 or 2 | 0, 1 or 2 | 0, 1, 2 or 3 |
| V-1, VTM-1 | Min. 105°C (221°F) | 0, 1, 2 or 3 | 0, 1 or 2 | 0, 1, 2 or 3 |
| V-0, VTM-0 or 5V | Min. 105°C (221°F) | 0, 1, 2, 3 or 4 | 0, 1, 2 or 3 | 0, 1, 2 or 3 |

**Relative Thermal Index (RTI)**

[a] The Electrical Relative Thermal Index (RTI) value of a material is to be determined in accordance with UL 746B and CAN/CSA C22.2 No. 0.17, by test or by use of the generic RTI table. This material characteristic is dependent upon the minimum thickness at which the material is being used. The RTI shall not be exceeded during the Temperature Test.

**Hot Wire Ignition (HWI)**

[b] The Hot Wire Ignition (HWI) value of a material is to be determined by test in accordance with UL 746A and CAN/CSA C22.2 No. 0.17. This material characteristic is dependent upon the minimum thickness at which the material is being used. When the thickness of an insulating material is less than the minimum specified thickness corresponding to a HWI value, the material is evaluated as in footnote c.

[c] A material without an HWI Performance Level Category (PLC) value or with a HWI PLC value greater (worse) than the value required by Table 8.1 shall be subjected to the Glow Wire End-Product Test specified in UL 746C and CAN/CSA C22.2 No. 0.17.

**High Current Arc Resistance to Ignition (HAI)**

[d] The HAI value of a material is to be determined by test in accordance with UL 746A and CAN/CSA C22.2 No. 0.17. This material characteristic is dependent upon the minimum thickness at which the material is being used. When the thickness of an insulating material is less than the minimum specified thickness corresponding to a HAI value, the material is evaluated as in footnote e.

[e] A material without an HAI PLC value or with an HAI PLC value greater (worse) than the value required by Table 8.1 shall be subjected to the end-product Arc Resistance Test specified in UL 746C and CAN/CSA C22.2 No. 0.17.

**Comparative Tracking Index (CTI)**

[f] The Comparative Tracking Index (CTI) PLC value of a material is to be determined by test in accordance with UL 746A and CAN/CSA C22.2 No. 0.17. This material characteristic is not dependent upon the minimum thickness at which the material is being used. When the thickness of an insulating material is less than the minimum specified thickness corresponding to a CTI value, the material is evaluated as having the same CTI value found for the greater thickness.

[g] A material without a CTI PLC value or with a CTI PLC value greater (worse) than the value required by Table 8.1 shall have a proof tracking index of 175 as determined by the end-product Proof Tracking Test specified in UL 746C and CAN/CSA C22.2 No. 0.17.

**Basic Insulated sensors**

[h] Current sensors marked in accordance with 21.6 do not require molded case materials with HAI or HWI ratings, and the case shall have a CTI rating of 0, 1, 2, 3 or 4.



8.2 One side of the case may consist of a potting material complying with 8.4 or Table 8.1, if it can be demonstrated that a minimum of 0.8 mm (0.031 in) of void and bubble free potting material is provided between the external surface and all internal metal parts.

8.3 The whole case may consist of a potting material complying with Table 8.1, if it can be demonstrated that a minimum of 0.8 mm (0.031 in) of void and bubble free potting material is provided between the external surface and all internal metal parts. In addition, a molding procedure shall be provided to

demonstrate the reliability and repeatability. This construction shall be subjected to the Outdoor Use Cold Impact Test, Section 20, but at 5°C (41°F) ambient, then followed by the Dielectric Voltage-Withstand Test, Section 14. The Outdoor Use Cold Impact Test may be conducted at a lower temperature if requested by the manufacturer.

8.4 Potting material shall be at least 0.8 mm (0.031 in) thick and void and bubble free. Any generic potting material may be used whose Electrical RTI is a minimum 105°C (221°F), as determined by UL 746B and CAN/CSA C22.2 No. 0.17. Examples of suitable generic material include: Epoxy, Melamine-Phenolic, Phenolic, Unfilled Nylon and Unfilled Polycarbonate.

8.5 Potting materials that are entirely encased shall comply with the requirements in Table 8.1, the generic material requirements in 8.4, or Table 8.2.

**Table 8.2**
**Additional material characteristics allowed for internal potting**

| Flame class | RTI elec | Performance level category (PLC) | | |
|---|---|---|---|---|
| | | HWI[a] | HAI[a] | CTI[a] |
| HB | Min 90°C (194°F) | 0, 1 or 2 | 0 or 1 | 0, 1, 2 or 3 |

[a] See Table 8.1.



8.6 If provided in multiple pieces, except where it would interfere with the intended motion of a split-core bobbin, the case parts shall be reliably secured together by ultrasonic welding, solvent welding, snap-fit, glue, or other suitable means. If glue is used, it shall be rated minimum 105°C (221°F) and evaluated for adhesion with the case material.

8.7 When mounted as intended, there shall be no ventilation or other openings in the case that would allow contaminants into areas with live parts.

8.8 Flexible case materials, such as a Rogowski Coil, shall meet the insulation requirements for field wiring leads described in 10.1 and 10.3, except the exterior-most insulating material shall be rated at least 105°C (221°F).

8.9 Enclosed-type current sensors for indoor use shall meet the requirements for UL 50, Type 1.

8.10 For enclosed-type current sensors intended for outdoor use, the case shall be constructed of materials suitable for outdoor use (f1) with respect to exposure to Ultraviolet Light, Water Exposure and Immersion in accordance with UL 746C and CAN/CSA C22.2 No. 0.17. Potting material shall also be evaluated for exposure to Ultraviolet Light, Water Exposure and Immersion in accordance with UL 746C and CAN/CSA C22.2 No. 0.17. Gasket materials shall comply with the Tensile Strength and Elongation Tests, and Compression Tests of UL 50E and CSA C22.2 No. 94.2. The case shall restrict water access to interior parts. Exposed metal parts shall meet the outdoor and additional corrosion requirements for Type 6P of UL 50E and CSA C22.2 No. 94.2.

## 9 Spacings

9.1 Electrical spacings for an uncontrolled environment from any external surface to any internal live part shall comply with Table 9.1. Over-surface distances depend on the Comparative Tracking Index (CTI) of the insulation material. If the CTI value is not known, a CTI PLC rating of 4 is assumed.

**Table 9.1**
**"Uncontrolled environment" spacings to coil**

| From any external surface to coil, exposed conductor ends inside case or any other live part[a,b,c,d] | | | | |
|---|---|---|---|---|
| Marked primary voltage | Through-air mm (in) | Over-surface[e] mm (in) | | |
| | | Comparative Tracking Index (CTI) | | |
| | | PLC 0 | PLC 1 | PLC 2 or 3[f] |
| **Non-service entrance** | | | | |
| 250 V | 5.9 (0.232) | 6.4 (0.252) | 7.2 (0.283) | 8.0 (0.315) |
| 600 V | 10.5 (0.413) | 15.2 (0.598) | 17.1 (0.673) | 19.0 (0.748) |
| 1000 V | 14.3 (0.562) | 25.0 (0.984) | 28.0 (1.10) | 32.0 (1.26) |
| 1500 Vdc | 19.4 (0.763) | 37.8 (1.49) | 41.7 (1.64) | 47.2 (1.86) |
| **Service entrance** | | | | |
| 250 V | 10.5 (0.413) | 10.5 (0.413) | 10.5 (0.413) | 10.5 (0.413) |
| 600 V | 14.3 (0.562) | 15.2 (0.598) | 17.1 (0.673) | 19.0 (0.748) |
| 1000 V | 24.3 (0.957) | 25.0 (0.984) | 28.0 (1.10) | 32.0 (1.26) |
| 1500 Vdc | 31.4 (1.24) | 37.8 (1.49) | 41.7 (1.64) | 47.2 (1.86) |

[a] See 9.4 for possible increased spacings requirements due to potential tracking along dead metal parts or transformer core.

[b] For current sensors intended for altitudes above 2000 m (6562 ft) see 9.10.

[c] For indoor-use current sensors marked in accordance with 21.6, above spacings may be reduced by 50 percent. Not applicable for outdoor-use.

[d] See 9.12 and Table 9.6 for alternative method to demonstrate spacings.

[e] If the distance across a groove is less than 1.5 mm (0.059 in), the over-surface distance is measured across the groove as if the groove did not exist.

[f] Current sensors marked in accordance with 21.5 that have a case material with a CTI rating of 4 use the CTI 2 or 3 column for over-surface spacings requirements.

9.2 Ultrasonic or solvent welding shall be considered a cemented joint, thus no measurements through an ultrasonic or solvent weld need to be made. Potting material that is at least 0.8 mm (0.031 in) thick which is void and bubble free is also considered a cemented joint where it bonds to the case material or conductor insulation. A glued seam of the case material is not considered a cemented joint for purposes of spacings. Measurements shall be made through any glued seam, as if the glue were not provided.

9.3 Electrical spacings for an uncontrolled environment from any external surface to any dead metal part within or recessed within the case or to sensor core shall comply with Table 9.2.



**Table 9.2**
**"Uncontrolled environment" spacings to core**

| From any external surface to transformer core or any other dead metal part[a,b,c] | | | | |
|---|---|---|---|---|
| Marked primary voltage | Through-air mm (in) | Over-surface[d] mm (in) | | |
| | | Comparative Tracking Index (CTI) | | |
| | | PLC 0 | PLC 1 | PLC 2 or 3[e] |
| **Non-service entrance** | | | | |
| 250 V | 3.0 (0.118) | 3.2 (0.126) | 3.6 (0.142) | 4.0 (0.157) |
| 600 V | 5.5 (0.217) | 7.6 (0.299) | 8.6 (0.339) | 9.5 (0.374) |
| 1000 V | 8.0 (0.315) | 12.5 (0.492) | 14.0 (0.551) | 16.0 (0.630) |

**Table 9.2 Continued on Next Page**

**Table 9.2 Continued**

| From any external surface to transformer core or any other dead metal part[a,b,c] | | | | |
|---|---|---|---|---|
| Marked primary voltage | Through-air mm (in) | Over-surface[d] mm (in) | | |
| | | Comparative Tracking Index (CTI) | | |
| | | PLC 0 | PLC 1 | PLC 2 or 3[e] |
| 1500 Vdc | 11.0 (0.433) | 18.9 (0.744) | 20.9 (0.823) | 23.6 (0.929) |
| **Service entrance** | | | | |
| 250 V | 5.5 (0.217) | 5.5 (0.217) | 5.5 (0.217) | 5.5 (0.217) |
| 600 V | 8.0 (0.315) | 8.0 (0.315) | 8.6 (0.339) | 9.5 (0.374) |
| 1000 V | 14.0 (0.551) | 14.0 (0.551) | 14.0 (0.551) | 16.0 (0.630) |
| 1500 Vdc | 18.0 (0.709) | 18.9 (0.744) | 20.9 (0.823) | 23.6 (0.929) |

[a] See 9.4 for possible increased spacings requirements due to potential tracking along dead metal parts or transformer core.

[b] For current sensors intended for altitudes above 2000 m (6562 ft) see 9.10.

[c] For indoor-use current sensors marked in accordance with 21.6, above spacings may be reduced by 50 percent. Not applicable for outdoor-use.

[d] If the distance across a groove is less than 1.5 mm (0.059 in), the over-surface distance is measured across the groove as if the groove did not exist.

[e] Current sensors marked in accordance with 21.5 that have a case material with a CTI rating of 4 use the CTI 2 or 3 column for over-surface spacings requirements.

9.4 When measuring from the coil or other live parts to the external surfaces of the current sensor, consideration shall be given to tracking along the surface of the core or other un-insulated dead metal, to any other point along the surface of the metal piece. Thus, compliance shall be determined by measuring from the live part to the metal part, and then adding the shortest distance from any point along the metal part to the external surface.

9.5 Measurements from an external surface include any exposed surface that could come into contact with live parts within the end-use installation, including where the primary conductor or busbar passes through the current sensor.

9.6 Electrical sleeving or tubing provided on the core or other metal part used to comply with spacings requirements shall be rated minimum 105°C (221°F) and minimum 300 V for current sensors marked “250 V”, minimum 600 V for current sensors marked "600 V" or minimum 1000 V for current sensors marked "1000 V". Additionally, the sleeving shall comply with 14.4 for reduced dielectric strength values.

9.7 Tape used on the core or other metal part to comply with spacing requirements shall:

a) Be applied in two or more layers;

b) Not be wrapped over a sharp edge;

c) Have a temperature rating no less than 105°C (221°F) minimum; and

d) Be such that each layer complies with 14.4 for reduced dielectric strength values.

9.8 Insulating barriers used to comply with spacing requirements shall comply with the requirements shown for case materials, Table 8.1 or with 8.4.

9.9 Electrical spacings for a controlled environment shall comply with Table 9.3 and Table 9.4.

## Table 9.3
## "Controlled environment" spacings to coil

| From any external surface to coil, exposed conductor ends inside case or any other live part[a,b,c,d] | | | | |
|---|---|---|---|---|
| Marked primary voltage | Through-air mm (in) | Over-surface[e] mm (in) | | |
| | | Comparative Tracking Index (CTI) | | |
| | | PLC 0 | PLC 1 | PLC 2 or 3[f] |
| **Non-service entrance** | | | | |
| 250 V | 5.9 (0.232) | 5.9 (0.232) | 5.9 (0.232) | 5.9 (0.232) |
| 600 V | 10.5 (0.413) | 10.5 (0.413) | 10.5 (0.413) | 12.0 (0.472) |
| 1000 V | 14.3 (0.562) | 14.3 (0.562) | 14.3 (0.562) | 20.0 (0.787) |
| 1500 Vdc | 19.4 (0.763) | 19.4 (0.763) | 20.8 (0.819) | 30.0 (1.18) |
| **Service entrance** | | | | |
| 250 V | 10.5 (0.413) | 10.5 (0.413) | 10.5 (0.413) | 10.5 (0.413) |
| 600 V | 14.3 (0.562) | 14.3 (0.562) | 14.3 (0.562) | 14.3 (0.562) |
| 1000 V | 24.3 (0.957) | 24.3 (0.957) | 24.3 (0.957) | 24.3 (0.957) |
| 1500 Vdc | 31.4 (1.24) | 31.4 (1.24) | 31.4 (1.24) | 31.4 (1.24) |

[a] See 9.4 for possible increased spacings requirements due to potential tracking along dead metal parts or transformer core.

[b] For current sensors intended for altitudes above 2000 m (6562 ft) see 9.10.

[c] For indoor-use current sensors marked in accordance with 21.6, above spacings may be reduced by 50 percent. Not applicable for outdoor-use.

[d] See 9.12 and Table 9.6 or alternative method to demonstrate spacings.

[e] If the distance across a groove is less than 1.5 mm (0.059 in), the over-surface distance is measured across the groove as if the groove did not exist.

[f] Current sensors marked in accordance with 21.5 that have a case material with a CTI rating of 4 use the CTI 2 or 3 column for over-surface spacings requirements.



## Table 9.4
## "Controlled environment" spacings to core

| From any external surface to sensor core or any other dead metal part[a,b,c] | | | | |
|---|---|---|---|---|
| Marked primary voltage | Through-air mm (in) | Over-surface[d] mm (in) | | |
| | | Comparative Tracking Index (CTI) | | |
| | | PLC 0 | PLC 1 | PLC 2 or 3[e] |
| **Non-service entrance** | | | | |
| 250 V | 3.0 (0.118) | 3.0 (0.118) | 3.0 (0.118) | 3.0 (0.118) |
| 600 V | 5.5 (0.217) | 5.5 (0.217) | 5.5 (0.217) | 6.0 (0.236) |
| 1000 V | 8.0 (0.315) | 8.0 (0.315) | 8.0 (0.315) | 10.0 (0.394) |
| 1500 Vdc | 11.0 (0.433) | 11.0 (0.433) | 11.0 (0.433) | 15.0 (0.591) |
| **Service entrance** | | | | |
| 250 V | 5.5 (0.217) | 5.5 (0.217) | 5.5 (0.217) | 5.5 (0.217) |
| 600 V | 8.0 (0.315) | 8.0 (0.315) | 8.0 (0.315) | 8.0 (0.315) |
| 1000 V | 14.0 (0.551) | 14.0 (0.551) | 14.0 (0.551) | 14.0 (0.551) |
| 1500 Vdc | 18.0 (0.709) | 18.0 (0.709) | 18.0 (0.709) | 18.0 (0.709) |

[a] See 8.4 for possible increased spacings requirements due to potential tracking along dead metal parts or transformer core.

[b] For current sensors intended for altitudes above 2000 m (6562 ft) see 9.10.

Table 9.4 Continued on Next Page

**Table 9.4 Continued**

| From any external surface to sensor core or any other dead metal part[a,b,c] | | | | |
|---|---|---|---|---|
| Marked primary voltage | Through-air mm (in) | Over-surface[d] mm (in) | | |
| | | Comparative Tracking Index (CTI) | | |
| | | PLC 0 | PLC 1 | PLC 2 or 3[e] |

[c] For indoor-use current sensors marked in accordance with 21.6, above spacings may be reduced by 50 percent. Not applicable for outdoor-use.

[d] If the distance across a groove is less than 1.5 mm (0.059 in), the over-surface distance is measured across the groove as if the groove did not exist.

[e] Current sensors marked in accordance with 21.5 that have a case material with a CTI rating of 4 use the CTI 2 or 3 column for over-surface spacings requirements.

9.10 Electrical spacings for current sensors intended for altitudes above 2000 m (6562 ft) are determined by multiplying the spacings shown in Table 9.1 through Table 9.4 by the values shown in Table 9.5.

**Table 9.5**
**Increased spacings for high altitude current sensors**

| Intended installation altitude | Multiplication factor |
|---|---|
| 2001 – 3000 m (6,565 – 9,843 ft) | 1.14 |
| 3001 – 4000 m (9,846 – 13,123 ft) | 1.29 |
| 4001 – 5000 m (13,127 – 16,404 ft) | 1.48 |

9.11 A printed wiringboard shall be encased so that the traces to the case exterior complies with Table 9.1 or Table 9.3 and the board shall be rated minimum V-2, with an Electrical Relative Thermal Index (RTI Elec) of 105°C (221°F) , minimum.

9.12 Sensors that have been shown to comply with:

a) UL 61010-1;

b) CSA C22.2 No. 61010-1;

c) UL 61010-2-030; and

d) CSA C22.2 No. 61010-2-030, Annex K, including the use of solid insulation and material tracking characteristics, along with using the parameters outlined in Table 9.6,

are considered to comply with the spacing requirements in this standard.

**Table 9.6**
**Alternative spacings**

| Parameters from this standard | UL 61010-1 terminology |
|---|---|
| Controlled Environment | Pollution Degree 2 |
| Uncontrolled Environment | Pollution Degree 3 |
| Non-service entrance | Overvoltage Category III |
| Service entrance | Overvoltage Category IV |

**Table 9.6 Continued on Next Page**

**Table 9.6 Continued**

| Parameters from this standard | UL 61010-1 terminology |
|---|---|
| 250 V Marked Primary Voltage | >150 ≤ 300 L-N column |
| 600 V Marked Primary Voltage | >301 ≤ 600 L-N column |
| 1000 V Marked Primary Voltage | >601 ≤ 1000 L-N column |

9.13 The insulation of internal wiring is considered to be a suitable insulating barrier if it complies with 10.1, and all temperatures measured within the current sensor, when adjusted for maximum rated ambient, do not exceed the temperature rating of the conductor insulation.

## 10 Field Wiring

10.1 Current sensors field wiring leads and electrical sleeving shall be rated minimum 300 V for current sensors marked "250 V", minimum 600 V for current sensors marked "600 V", minimum 1000 V for current sensors marked "1000 V", and "1500 Vdc" for all others. All conductor insulation and conductor sleeving shall be rated minimum 90°C (194°F).

10.2 Each field-wiring lead shall be copper. Conductors smaller than 0.75 $mm^2$ (18 AWG), but not smaller than 0.32 $mm^2$ (22 AWG) for a single conductor and 0.21 $mm^2$ (26 AWG) for a multi-conductor cable, shall be permitted to be used.

10.3 Field wiring leads of indoor-use current sensors shall be suitable for contact with exposed live parts of a Class 1 circuit and/or routing through the same conduit with other Class 1 circuit conductors. The conductors shall consist of Class 1 wiring or appliance wiring material with insulation that meets the following:

a) At least 0.75 mm (30 mils) “Minimum Average” thickness with at least 0.68 mm (27 mils) thickness “Minimum-At-Any-Point”; or

b) At least 0.4 mm thick (16 mils) thickness “Minimum-At-Any-Point” and additional electrical sleeving that is also minimum 0.4 mm thick. Sleeving shall also be rated in accordance with 10.1, above.

10.4 Heat shrink tubing shall meet the above thickness requirements “After Heating”.

10.5 The insulation thickness requirements of field wirings leads shall be met for each conductor individually or by a jacket or sleeve around a group of conductors.

*Exception: Internal wiring and the portion of any field wiring lead that is located within the current sensor case may have insulation of any thickness, so long as the insulation is rated in accordance with 10.1.*

10.6 Field wiring leads of an enclosed-type current sensor shall comply with 10.1 and 10.2. Additionally, field wiring leads shall be hard-service or junior hard-service flexible cord, rated for outdoor use and water resistant (such as type SOOW or SJOW).

10.7 In lieu of field wiring leads, a current sensor may use a connector and cable set if it meets all of the following parameters:

a) Cable/Connector assembly is rated in accordance with 10.1.

b) No minimum wire size for conductors within the multiconductor cable, but the cable jacket thickness complies with 10.3 (a) or (b).

c) Spacings from external surfaces to conductive parts with the cable, as measured with the mating connectors connected, comply with Table 9.1 or Table 9.3, or comply with 9.12 and Table 9.6.

d) In addition, the cable and connector assembly shall comply with UL 2238 and CSA C22.2 No. 182.3. For enclosed-type sensors, the cable assembly is rated outdoor use in accordance with UL 2238 and CSA C22.2 No. 182.3 and "Type 6P" in accordance with the following:

1) UL 50 and CSA C22.2 No. 94.1; and

2) UL 50E and CSA C22.2 No. 94.2.

e) Connector and mating cable assembly are supplied with the current sensor.

10.8 Terminal blocks may also be used for wiring indoor-use current sensors in the field if all of the following parameters are met:

a) The terminal block complies with UL 1059 and CSA C22.2 No. 158 with a wire range that includes 0.75 $mm^2$ (18 AWG) copper and has a field wiring code of “FW2”.

b) All metallic parts of the terminal are recessed so that spacings from external surfaces of the current transformer to conductive terminal parts, with a representative minimum 0.75 $mm^2$ (18 AWG) conductor installed, comply with Table 9.1 or Table 9.3, or comply with 9.12 and Table 9.6.

c) Terminals do not need to have a voltage or current rating that correlates to the marked primary voltage rating of the current sensors.

## 11 Open Circuit Secondary Voltage

11.1 Each current sensor shall be provided with installation instructions or a statement identifying how open circuit secondary voltage is limited to no greater than 30 Vrms, 42.4 Vpeak or 60 Vdc at its output. Where internal burden components are used, see Section 18. In Canada, the dc limits are 42.4 Vdc as defined CAN/CSA C22.2 No. 0.

# CURRENT SENSORS PERFORMANCE

## 12 General

12.1 Only one representative sample of a design type need be subjected to performance testing.

## 13 Mold Stress Relief Test

13.1 One representative of each size of current sensor for each series is to be placed for 7 hours in an air-circulating oven maintained at a uniform temperature of at least 10°C (18°F) higher than the maximum temperature of the material measured under normal operating conditions, but not less than 115°C (239°F). After removal from the oven, a Dielectric Voltage-Withstand Test shall be performed while still in a well-heated state, see Section 14. Additionally, after the devices return to room temperature, each device is to be visually inspected to determine if any of the following occurred:

a) Reduced spacings below the values specified in this standard;

b) Make any bare live parts or internal wiring accessible to contact, or defeating the integrity of the case so that acceptable mechanical protection is not afforded to internal parts; or

c) Produce any other condition that might increase the risk of fire, electric shock, or injury to persons.

## 14 Dielectric Voltage-Withstand Test

14.1 While still in a well-heated state from the Mold Stress Relief Test, Section 13, a Dielectric Voltage-Withstand Test using either the AC or the DC values in Table 14.1, shall be performed from the conductors to foil wrapped around case, including all seams and conductor insulation at the lead entrance. There shall be no dielectric breakdown.

14.2 The test potential is to be supplied from a 500 volt ampere or larger capacity testing transformer, the output voltage of which can be varied. The applied potential is to be increased from zero at an essentially uniform rate and as rapidly as is consistent with its value being correctly indicated by the voltmeter until the required test value is reached; it is to be held at that level for the test duration. The voltage is then to be reduced to zero at the same uniform rate.

14.3 The test voltage test of Table 14.1 shall be applied for 1 minute. The test voltage of Table 14.2 shall be applied for 5 seconds. Alternately, the test voltage of Table 14.2 can be applied for 1 minute and the test voltages of Table 14.1 need not be tested.

**Table 14.1**
**Dielectric values, 1 minute test**

| Primary Voltage Vac | Test voltage, Vac | |
|---|---|---|
| | Reinforced Insulation | Basic Insulation |
| 0 – 250 V | 3000 | 1500 |
| 251 – 600 V | 3600 | 1800 |
| 601 – 1000 V | 4400 | 2200 |
| 1001 – 1500 Vdc | 4540 | 2270 |

**Table 14.2**
**Dielectric values, 5 second test**

| Primary Voltage Vac | Test voltage, Vac | | | |
|---|---|---|---|---|
| | Non service entrance | | Service entrance | |
| | Reinforced insulation | Basic insulation | Reinforced insulation | Basic insulation |
| 0 – 250 V | 3510 | 2210 | 5400 | 3310 |
| 251 – 600 V | 5400 | 3310 | 7400 | 4260 |
| 601 – 1000 V | 7400 | 4260 | 11940 | 6600 |
| 1001 – 1500 Vdc | 11940 | 6600 | 14930 | 8250 |



14.4 Basic Insulation may be used for reduced spacings for indoor-use sensors, see footnote (c) of Table 9.1, Table 9.2, Table 9.3, or Table 9.4, if the transformer is also marked in accordance with 21.6. Not applicable for outdoor-use.

*Exception: A 500 volt ampere or larger capacity transformer need not be used if the transformer is provided with a voltmeter to measure directly the applied output potential.*

## 15 Lead Securement Test

15.1 Following the Mold Stress Relief Test, Section 13, and Dielectric Voltage-Withstand Test, Section 14, one representative sample of each size of current transformer for each series that is provided with field wiring leads shall be subject to the Lead Securement Test. An 80 N (18 pound) force for an open-type

current transformer or 156 N (35 pound) force for an enclosed-type current transformer shall be gradually applied to each lead wire individually and maintained for 60 seconds.

15.2 After the test, each device shall be visually inspected. There shall be no damage to the conductors or displacement of the conductors.

## 16 Permanence of Marking Test

16.1 An adhesive label shall be suitable for the applied surface and comply with UL 969 and C22.2 No. 0.15. Such labels are considered to comply with these requirements without further evaluation. Labels applied on enclosed-type current sensors shall be additionally rated for outdoor use.

16.2 Markings molded into the case material are also considered to comply without further evaluation.

16.3 Stenciled, die-stamped or other unevaluated markings shall be rubbed by hand, without undue pressure, for 30 seconds with a cloth soaked with a 70 percent isopropyl alcohol solution. After the test, each representative device shall be visually inspected to determine if markings remain legible and marking securement is unaffected.

## 17 Temperature Test

17.1 The current transformer is to be tested in an ambient temperature within the range of 10 – 40°C (50 – 104° F). The current sensor shall have a primary conductor, energized at rated current and frequency, passing through the window. If the current sensor has multiple frequency ratings, the lowest frequency shall be used. The current sensor shall be operated continuously with secondary conductors short-circuited until constant temperatures are reached.

*Exception: Because there is negligible self-heating in Rogowski coils, they are exempt from the Temperature Test.*

17.2 For current sensor specified for use above 40° C (104° F) ambient, allowable temperature rise values are to be calculated in accordance with the following formula:

$$T_R = T_T - [T_M - 40° C\ (104° F)]$$

in which:

$T_R$ is the allowable temperature rise;

$T_T$ is the maximum temperature rise allowed in this standard;

$T_M$ is the rated elevated ambient temperature described in the sensor's documentation.

17.3 Constant temperatures are considered to exist only if three successive readings indicate no change, when taken at the conclusion of each of three consecutive equal intervals of time, the duration of each interval being whichever of the following is longer:

a) 15 minutes, or

b) 10 percent of the total test time elapsed previous to the start of the first interval up to a maximum of 30 minutes.

17.4 Temperatures on parts, other than windings, shall be monitored by thermocouples. The winding temperature shall be measured by the change-of-resistance method. The tips of the thermocouples are

secured to the heated parts by solder, tape, or sodium silicate. Burden components may be removed from the temperature test samples, as they have been known to interfere with the accuracy of some change of resistance measurements for coil temperatures.

17.5 Thermocouples shall consist of wires not larger than 0.21 $mm^2$ (24 AWG) and not smaller than 0.05 $mm^2$ (30 AWG). Whenever referee temperature measurements by thermocouples are necessary, thermocouples consisting of 0.05 $mm^2$ (30 AWG) iron and constantan wire and a potentiometer-type instrument are to be used. The thermocouple wire shall conform with the requirements for special tolerances thermocouples as listed in the Tolerances on Initial Values of EMF Versus Temperature tables in ASTM E230/E230M.

17.6 The temperature rise shall be determined by the change-of-resistance method using the following formula (windings are to be at room temperature at the start of the test):

$$\Delta t = \frac{R_2}{R_1}(k + t_1) - (k + t_2)$$

in which:

$\Delta t$ in °C is the temperature rise;

$R_2$ is the resistance of the coil at the end of test;

$R_1$ is the resistance of the coil at the beginning of the test;

$k$ is 234.5 for copper;

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

$t_2$ is the room temperature in °C at the end of the test.

17.7 The primary conductor used in the test shall have an ampacity equal to the test current. For test currents that are between ampacity values, the next larger conductor size may be used. Ampacity values provided in Table 17.1 or Table 17.2 shall be used to determine the size of the primary conductor.



**Table 17.1**
**Ampacities of insulated conductors**

| Primary conductor size | | Ampacity (A) |
|---|---|---|
| $mm^2$ | (AWG) | Copper |
| 2.1 | (14) | 15 |
| 3.3 | (12) | 20 |
| 5.3 | (10) | 30 |
| 8.4 | (8) | 50 |
| 13.3 | (6) | 65 |
| 21.2 | (4) | 85 |
| 26.7 | (3) | 100 |
| 33.6 | (2) | 115 |
| 42.4 | (1) | 130 |

**Table 17.1 Continued on Next Page**

**Table 17.1 Continued**

| Primary conductor size | | Ampacity (A) |
|---|---|---|
| 53.5 | (1/0) | 150 |
| 67.4 | (2/0) | 175 |
| 85.0 | (3/0) | 200 |
| 107.2 | (4/0) | 230 |
| | **(kcmil)** | |
| 127 | (250) | 255 |
| 152 | (300) | 285 |
| 177 | (350) | 310 |
| 203 | (400) | 335 |
| 253 | (500) | 380 |
| 304 | (600) | 420 |
| 355 | (700) | 460 |
| 380 | (750) | 475 |
| 405 | (800) | 490 |
| 456 | (900) | 520 |
| 633 | (1250) | 590 |
| 760 | (1500) | 625 |
| 887 | (1750) | 650 |
| 1013 | (2000) | 665 |
| 506 | (1000) | 545 |



**Table 17.2**
**Ampacity of copper bus bars**

| Ampacity | Bus bars per phase | Width of bus bars, mm (in)<br>Note: All thicknesses are 6.4 mm (1/4 in) |
|---|---|---|
| 450 – 600 | 1 | 51 (2) |
| 601 – 1000 | 1 | 76 (3) |
| 1001 – 1200 | 1 | 102 (4) |
| 1201 – 1600 | 2 | 76 (3) |
| 1601 – 2000 | 2 | 102 (4) |
| 2001 – 2500 | 2 | 127 (5) |
| | 4 | 64 (2-1/2) |
| 2501 – 3000 | 3 | 127 (5) |
| | 4 | 102 (4) |

17.8 When tested in accordance with 17.1, the temperature rise by the change-of-resistance method on the windings shall not exceed a 65°C (149°F) rise for Class A 105°C (221°F) or undefined systems, 80°C (176°F) rise for a Class E 120°C (248°F) system, 90°C (194°F) rise for a Class B 130°C (266°F) system and 115°C (239°F) rise for a Class F 155°C (311°F) or better system. If the temperature rise on the coil exceeds Class A levels, any potting compound used in a current transformer that contacts coil or insulation on coil shall be part of an insulation system evaluated in accordance with UL 1446.

17.9 When tested in accordance with 17.2, for a rated ambient greater than 40° C (104° F), the temperature rise on the windings shall not, as determined by the change of resistance method, exceed the following:

$$T_R = T_I - T_A$$

in which:

$T_R$ is the allowable temperature rise;

$T_I$ is the rating of the insulation system (Class A = 105°C (221°F), etc.);

$T_A$ is the rated ambient.

The elevated ambient calculation shown in 17.2 is incorporated into the above calculation. Additionally, if the temperature rise on the coil exceeds Class A levels, any potting compound used in a current transformer that contacts coil or insulation on coil shall be part of an insulation system evaluated in accordance with UL 1446.

17.10 The external surface of the current sensor case shall not exceed a 65° C (149° F) rise by the thermocouple method for current transformers rated at or below 40° C (104° F). Current transformers with ambient ratings above 40° C (104° F) shall not exceed a 65° C (149° F) rise when adjusted in accordance with 17.2.

17.11 The insulation of the current sensor conductors shall not exceed a temperature rise of 50° C (122°F), by the thermocouple method.

## 18 Permissible Limit Test

18.1 Where internal burden components are used or the current sensor technology does not generate high open circuit voltages, the current sensor open secondary voltage shall be verified. With a primary conductor passing through the current transformer, energized at rated current and frequency, the open circuit secondary voltage shall be measured across a 1500 Ω burden resistor. Secondary voltage on the current transformer leads shall be no greater than 30 Vrms, 42.4 Vpeak or 60 Vdc. In Canada, the dc limits are 42.4 Vdc as defined in CAN/CSA C22.2 No. 0.

18.2 Additionally, when internal burden components are used, the CT shall be at 100% continuous current with the secondary open circuited. The limits of Section 17 shall be met.

18.3 The highest rated primary current sensor of a design type shall be tested.

## 19 Outdoor Use Submersion Test

19.1 The complete enclosed-type current sensors shall be placed in a tank filled with water so that the highest point of the current sensor case is 1.8 m (6 ft) below the surface of the water. If the test device field wiring leads are long enough to extend out of the tank, it is permitted to keep the conductor ends out of the water.

*Exception: The sensor case need not be submersed to a depth of 1.8 m (6 ft) if an equivalent pressure differential between the interior and the exterior of the enclosure is maintained for the required period of time. This differential may be achieved by pressurizing the water surrounding the sensor.*