



UL 1004-1

Underwriters Laboratories Inc.

Standard for Safety

Rotating Electrical Machines – General Requirements



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UL Standard for Safety for Rotating Electrical Machines – General Requirements, UL 1004-1

First Edition, Dated September 15, 2008

Summary of Topics

This First Edition of ANSI/UL 1004-1 applies to rotating electrical machines and linear motors, both AC and DC, rated 7,200 volts or less and is used to evaluate both motors intended to be field installed as well as those intended to be factory installed.

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

Future Effective Dates	References
September 15, 2010	Entire Standard

The new and revised requirements are substantially in accordance with UL's Proposal(s) on this subject dated November 16, 2007 and April 4, 2008.

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

The UL Foreword is no longer located within the UL Standard. For information concerning the use and application of the requirements contained in this Standard, the current version of the UL Foreword is located on ULStandardsInfoNet at: <http://ulstandardsinfo.net/ulforeword.html>

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

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UL 1004-1

Standard for Rotating Electrical Machines – General Requirements

First Edition

September 15, 2008

The most recent designation of ANSI/UL 1004-1 as an American National Standard (ANSI) occurred on August 19, 2008. The ANSI approval for this standard does not include the Cover Page, Transmittal Pages, Title Page, or effective date information.

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

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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INTRODUCTION

1 Scope

1.1 This Standard applies to rotating electrical machines and linear motors, both AC and DC, rated 7,200 volts or less.

1.1 effective September 15, 2010

1.2 This Standard is used to evaluate both motors intended to be field installed as well as those intended to be factory installed. Motors intended to be factory installed need not comply with the requirements in Section 12, Ventilation Openings; Section 13, Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts; 16.9 – 16.16, 16.28, 18.1 – 18.5, 32.1 – 32.3, 32.5 – 32.7, and 33.1.

1.2 effective September 15, 2010

1.3 For the purposes of this Standard, the term “machine” is representative of and equivalent to the terms rotating electrical machine and rotating machine, and is understood to mean all manner of electric motors and generators covered by the scope of this Standard. The term “machine” is understood to apply to both AC and DC machines.

1.3 effective September 15, 2010

1.4 These requirements do not cover machines intended for used in hazardous locations as defined in the *National Electrical Code*®, NFPA 70.

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1.4 effective September 15, 2010

1.5 These requirements do not cover sealed (hermetic type) motor-compressor parts, which are evaluated under the Standard for Hermetic Refrigerant Motor-Compressors, UL 984.

1.5 effective September 15, 2010

2 Components

2.1 Except as indicated in 2.2, 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 generally used in the products covered by this standard. In particular:

a) Positive Temperature Coefficient devices (PTCs) used in self-holding thermal motor protectors shall comply with the Standard for Thermistor-Type Devices, UL 1434.

b) Solid-state controllers shall comply with the Standard for Automatic Electrical Controls for Household and Similar Use, Part 1: General Requirements, UL 60730-1A.

c) Thermal protectors shall comply with the Standard for Automatic Electrical Controls for Household and Similar Use; Part 2 Particular Requirements for Thermal Motor Protectors, UL 60730-2-2 or with the Standard for Overheating Protection for Motors, UL 2111.

2.1 effective September 15, 2010

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.

2.2 effective September 15, 2010

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

2.3 effective September 15, 2010

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.

2.4 effective September 15, 2010

3 Units of Measurement

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

3.1 effective September 15, 2010

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.

4.1 effective September 15, 2010

5 Glossary

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

5.1 effective September 15, 2010

5.2 AIR-OVER MOTOR – A motor that relies upon a stream of air to cool the motor.

5.2 effective September 15, 2010

5.3 ARAMID PAPER – An aromatic polyamide (such as Nomex).

5.3 effective September 15, 2010

5.4 ARMATURE – The part of a machine that has windings and rotates.

5.4 effective September 15, 2010

5.5 AUXILIARY SWITCH – A switch that is actuated by motor rotation and intended to control an external load.

5.5 effective September 15, 2010

5.6 BONDED (BONDING) – The permanent joining of metallic parts to form an electrically conductive path that provides electrical continuity and the capacity to conduct any current likely to be imposed without a risk of electric shock, fire, or injury to persons.

5.6 effective September 15, 2010

5.7 BONDING CONDUCTOR – A conductor, including a strap or similar part, that is used to provide the required electrical conductivity between metal parts required to be electrically connected.

5.7 effective September 15, 2010

5.8 BRUSH – A conducting part that provides electrical connection to the armature of a machine through a commutator.

5.8 effective September 15, 2010

5.9 BRUSH HOLDER – A structure that supports the brush and provides a means to maintain contact with the commutator of the armature.

5.9 effective September 15, 2010

5.10 CAMBRIC – A varnish-impregnated white linen fabric using an electrical grade resin.

5.10 effective September 15, 2010

5.11 COMMUTATOR – An assembly of conducting members insulated from one another, against which the brushes bear, that provides electrical connection to the circuits of the armature.

5.11 effective September 15, 2010

5.12 CONTINUOUS DUTY MOTOR – A motor intended to be directly coupled to a load other than a fan or blower and that is intended to operate indefinitely.

5.12 effective September 15, 2010

5.13 DIRECTLY ACCESSIBLE MACHINE – A machine that can be physically contacted without opening or removing any part, or is located so that it is accessible to contact.

5.13 effective September 15, 2010

5.14 ELECTRICAL GRADE PAPER – Paper produced from wood pulp formed by wood chips boiled in an alkaline solution containing sodium sulfate.

5.14 effective September 15, 2010

5.15 ENCLOSED MACHINE – A machine that is totally enclosed in order to prevent the free exchange of air between the inside and outside of the enclosure for the windings. It may not be sufficiently enclosed to be airtight.

5.15 effective September 15, 2010

5.16 ENCLOSURE – That portion of a unit that:

a) Reduces the accessibility of a part that involves a risk of fire, electric shock, or injury to persons; or

b) Reduces the risk of propagation of flame, sparks, and molten metal initiated by an electrical disturbance occurring within.

5.16 effective September 15, 2010

5.17 END SHIELD – A part of the machine used to protect the windings and to support the bearing, but does not include either part. It is secured to the frame. Also called an end bell, end cap, or bracket.

5.17 effective September 15, 2010

5.18 FACTORY INSTALLATION – The act of wiring and mounting a rotating electric machine in a manufacturing environment under controlled conditions by trained personnel.

5.18 effective September 15, 2010

5.19 FIELD INSTALLATION – The act of wiring and mounting a rotating electric machine outside of a manufacturing environment where the installation is subject to the requirements of the *National Electrical Code®*, NFPA 70.

5.19 effective September 15, 2010

5.20 FIELD TERMINAL COMPARTMENT – Where the outgoing power is connected to the machine at the field installation site and the connection is a wire-to-terminal connection.

5.20 effective September 15, 2010

5.21 FIELD WIRING COMPARTMENT – Where the outgoing power is connected to the machine at the field installation site and the connection is a wire-to-wire connection.

5.21 effective September 15, 2010

5.22 FIXED – Equipment that is intended to be permanently connected electrically to the wiring system.

5.22 effective September 15, 2010

5.23 GROUND – A conducting connection, whether intentional or accidental, between an electrical circuit or equipment and the earth or to some conducting body that serves in place of the earth.

5.23 effective September 15, 2010

5.24 GROUNDING CONDUCTOR – An equipment or circuit conductor that is intentionally connected between that electrical circuit or equipment and the earth or to some conducting body that serves in place of the earth.

5.24 effective September 15, 2010

5.25 HORSEPOWER – A measure of mechanical output. In the context of this Standard, one horsepower is defined as, and shall be used interchangeably with, 0.746 kilowatts of output power.

5.25 effective September 15, 2010

5.26 IMPEDANCE PROTECTED MOTOR – A motor that relies solely upon the impedance of the windings to prevent overheating.

5.26 effective September 15, 2010

5.27 INDIRECTLY ACCESSIBLE MACHINE – A machine that is accessible only by opening or removing a part of the outer enclosure, such as a guard or panel, that can be opened or removed without the aid of a tool, or is located at such a height or is otherwise guarded or enclosed so that it is unlikely to be contacted.

5.27 effective September 15, 2010

5.28 INSULATION SYSTEM – An assembly of insulating materials used to isolate the live parts from ground and from parts of opposite polarity. All materials in contact with windings are considered part of the system.

5.28 effective September 15, 2010

5.29 INTERMITTENT DUTY MOTOR – A motor intended to be connected to a load and that is intended to operate for no longer than a specified time period or for a specified duty-cycle.

5.29 effective September 15, 2010

5.30 LINEAR MOTOR – An electric motor that produces linear (as opposed to rotary) motion when supplied by a suitable source of electric power.

5.30 effective September 15, 2010

5.31 MAJOR COMPONENTS – The components of an insulation system that are relied upon to prevent a risk of electric shock or fire. Examples of this type of insulation include ground, interwinding, turn, and encapsulant. See the Major and Minor Component Table in the Standard for Systems of Insulating Materials – General, UL 1446.

5.31 effective September 15, 2010

5.32 MICA – Small pieces of aluminum silicate materials held in place by electrical grade resin.

5.32 effective September 15, 2010

5.33 MINOR COMPONENTS – The components of an insulation system that are used typically in mechanical or thermal conduction capacities, and are not relied upon to prevent risk of fire or electric shock. Examples of minor components are balancing compound, crossover insulation, and lead wire. See the Major and Minor Component Table in the Standard for Systems of Insulating Materials – General, UL 1446.

5.33 effective September 15, 2010

5.34 MULTI-SPEED MOTOR – A motor with separate windings, reconfigured windings, or tapped windings provided for each speed.

5.34 effective September 15, 2010

5.35 NON-METALLIC FUNCTIONAL PART – A non-metallic, typically, but not necessarily, polymeric, part that is required for the safe operation of the machine (that is, not a trim part). The removal or absence of the part would either render the machine inoperative or unable to satisfy the remaining requirements of this Standard with regard to safe operation. The failure of the part (typically through deformation) would result in a risk of fire, shock, or injury.

5.35 effective September 15, 2010

5.36 OIL IMMERSED MACHINE – A machine having its windings immersed in oil and relying on the oil as a cooling medium.

5.36 effective September 15, 2010

5.37 PORTABLE – Equipment that is easily carried or conveyed by hand, and is provided with a power-supply cord for connection to the supply circuit.

5.37 effective September 15, 2010

5.38 ROTOR – A rotating part of a rotating electric machine that does not have windings.

5.38 effective September 15, 2010

5.39 SERVICE FACTOR – A multiplier that, when applied to the rated horsepower of an AC motor, the rated armature current of a DC motor, or the rated output of a generator, indicates a permissible loading that can be carried continuously at the rated voltage and frequency

5.39 effective September 15, 2010

5.40 SIZE – The outside diameter of the machine measured in the plane of the laminations, of the circle circumscribing the stator frame (or rotor frame, in the case of an outer rotor motor), excluding lugs, fins, boxes, or the like, used solely for machine mounting, cooling, assembly, or connection.

5.40 effective September 15, 2010

5.41 SHEET METAL SCREW – A screw with a thread pitch that exceeds the thickness of the sheet metal and is designed to engage an unextruded, unthreaded hole in the metal.

5.41 effective September 15, 2010

5.42 SINGLE-OPERATION DEVICE – A device that incorporates a bimetal assembly that is calibrated to open the motor circuit upon reaching a certain temperature and is resettable only by cooling to minus 35°C (minus 31°F), or lower.

5.42 effective September 15, 2010

5.43 START SWITCH – A switch used for the connection and disconnection of the start winding of a motor.

5.43 effective September 15, 2010

5.44 STATIONARY – Equipment that is intended to be fastened in place or located in a dedicated space, and is provided with a power-supply cord for connection to the supply circuit.

5.44 effective September 15, 2010

5.45 STATOR – The stationary part of a machine that includes the stationary windings about or within which a rotor or armature turns or rotates.

5.45 effective September 15, 2010

5.46 TERMINAL COMPARTMENT – An enclosure where the outgoing power is connected to the machine and the connection is a wire-to-terminal connection.

5.46 effective September 15, 2010

5.47 THERMAL CUTOFF – A device that incorporates a melting alloy or other material that is calibrated to permanently open the motor circuit upon reaching a certain temperature.

5.47 effective September 15, 2010

5.48 TREATED CLOTH – A varnish-impregnated material using an electrical grade resin.

5.48 effective September 15, 2010

5.49 VOLTAGE REGULATOR – An electrical or mechanical device that, within performance limits, maintains a constant voltage output when supplied by a varying voltage input.

5.49 effective September 15, 2010

5.50 VULCANIZED FIBER – A term used in this outline to denote a material normally used as electrical insulation. Vulcanized fiber is made by combining layers of chemically gelled paper. The zinc chloride used in gelling the paper is subsequently removed by a water leaching treatment, and the resultant product, after being dried and finished by calendaring, is a dense material of partially, regenerated cellulose where the fibrous structure is retained in varying degrees, depending upon the grade of fiber. Cellulose fiberboard, pressboard, fullerboard, or cardboard are not acceptable as the equivalent of fiber. Fishpaper is a designation commonly used in the trade to refer to thin sheets of electrical grade vulcanized fiber.

5.50 effective September 15, 2010

5.51 WIRING COMPARTMENT – Where the incoming/outgoing power is connected to the machine and the connection is a wire-to-wire connection.

5.51 effective September 15, 2010

CONSTRUCTION

6 Current and Horsepower Relation

6.1 In the application of requirements based on horsepower to a motor not rated in horsepower, use shall be made of the appropriate tables of the *National Electrical Code*®, NFPA 70, (Tables 6.1 – 6.4 of this standard) that gives the relationships between horsepower and full-load currents for motors. For a universal motor, the table applying to a single-phase, alternating-current motors, Table 6.2, shall be used when the motor is marked for use on alternating current only; otherwise, the table applying to direct-current motors, Table 6.1, shall be used.

6.1 effective September 15, 2010

Table 6.1
Full-load current in amperes, direct current motors

Table 6.1 effective September 15, 2010

HP	Armature voltage rating ^a					
	90 V	120 V	180 V	240 V	500 V	550 V
1/4	4.0	3.1	2.0	1.6		
1/3	5.2	4.1	2.6	2.0		
1/2	6.8	5.4	3.4	2.7		
3/4	9.6	7.6	4.8	3.8		
1	12.2	9.5	6.1	4.7		
1-1/2		13.2	8.3	6.6		
2		17	10.8	8.5		
3		25	16	12.2		
5		40	27	20		
7-1/2		58		29	13.6	12.2
10		76		38	18	16
15				55	27	24
20				72	34	31
25				89	43	38
30				106	51	46
40				140	67	61
50				173	83	75
60				206	99	90
75				255	123	111
100				341	164	148
125				425	205	185
150				506	246	222
200				675	330	294

^a These are average direct-current quantities.

NOTE – Linear interpolation may be used to calculate motor currents for motors whose rated voltage does not appear in this Table.

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Table 6.1 Continued on Next Page

Table 6.1 Continued

HP	Armature voltage rating ^a					
	90 V	120 V	180 V	240 V	500 V	550 V
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Table 6.2
Full-load currents in amperes single-phase alternating-current motors

Table 6.2 effective September 15, 2010

HP	115 V	200 V	208 V	230 V
1/6	4.4	2.5	2.4	2.2
1/4	5.8	3.3	3.2	2.9
1/3	7.2	4.1	4.0	3.6
1/2	9.8	5.6	5.4	4.9
3/4	13.8	7.9	7.6	6.9
1	16	9.2	8.8	8
1-1/2	20	11.5	11	10
2	24	13.8	13.2	12
3	34	19.6	18.7	17
5	56	32.2	30.8	28
7-1/2	80	46	44	40
10	100	57.5	55	50
NOTES: (1) – The values in this table are full-load currents for motors running at usual speeds and motors with normal torque characteristics. Motors built for especially low speeds or high torques may have higher full-load currents, and multispeed motors will have full-load current varying with speed, in which case the nameplate current ratings shall be used. The voltages listed are rated motor voltages. The currents listed shall be permitted for system voltage ranges of 110 – 120, and 220 – 240 volts. (2) – Linear interpolation may be used to calculate motor currents for motors whose rated voltage does not appear in this Table. Reprinted with permission from NFPA 70-2005, the <i>National Electrical Code®</i>. Copyright © 2004, National Fire Protection Association, Quincy, MA 02169 This reprinted material is not the official position of the NFPA on the referenced subject which is represented solely by the standard in its entirety. <i>National Electrical Code®</i> and <i>NEC®</i> are registered trademarks of the National Fire Protection Association, Inc., Quincy, MA 02169.				

Table 6.3
Full-load current two-phase alternating-current motors (4-wire)

Table 6.3 effective September 15, 2010

HP	Induction type squirrel-cage and wound-rotor amperes				
	115 V	230 V	460 V	575 V	2300 V
1/2	4	2	1	0.8	
3/4	4.8	2.4	1.2	1.0	
1	6.4	3.2	1.6	1.3	
1-1/2	9	4.5	2.3	1.8	
2	11.8	5.9	3	2.4	
3		8.3	4.2	3.3	
5		13.2	6.6	5.3	
7-1/2		19	9	8	
10		24	12	10	
15		36	18	14	
20		47	23	19	
25		59	29	24	
30		69	35	28	
40		90	45	36	
50		113	56	45	
60		133	67	53	14
75		166	83	66	18
100		218	109	87	23
125		270	135	108	28
150		312	156	125	32
200		416	208	167	43

NOTES:

(1) – The values in the table for full-load current are for motors running at speeds usual for belted motors and motors with normal torque characteristics. Motors built for especially low speeds or high torques may require more running current, and multispeed motors will have full-load current varying with speed, in which case the nameplate current rating shall be used. Current in the common conductor of a 2-phase, 3-wire system will be 1.41 times the values given. The voltages listed are rated motor voltages. The currents listed shall be permitted for system voltage ranges of 110 – 120, 220 – 240, 440 – 480, and 550 – 600 volts.

(2) – Linear interpolation may be used to calculate motor currents for motors whose rated voltage does not appear in this Table. Reprinted with permission from NFPA 70-2005, the *National Electrical Code*®

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Table 6.4
Full-load current three-phase alternating-current motors

Table 6.4 effective September 15, 2010

HP	Induction type squirrel-cage and wound-rotor amperes							Synchronous type unity power factor ^a amperes			
	115 V	200 V	208 V	230 V	460 V	575 V	2300 V	230 V	460 V	575 V	2300 V
1/2	4.4	2.5	2.4	2.2	1.1	0.9					
3/4	6.4	3.7	3.5	3.2	1.6	1.3					
1	8.4	4.8	4.6	4.2	2.1	1.7					
1-1/2	12.0	6.9	6.6	6.0	3.0	2.4					
2	13.6	7.8	7.5	6.8	3.4	2.7					
3		11.0	10.6	9.6	4.8	3.9					
5		17.5	16.7	15.2	7.6	6.1					
7-1/2		25.3	24.2	22	11	9					
10		32.2	30.8	28	14	11					
15		48.3	46.2	42	21	17					
20		62.1	59.4	54	27	22					
25		78.2	74.8	68	34	27		53	26	21	
30		92	88	80	40	32		63	32	26	
40		120	114	104	52	41		83	41	33	
50		150	143	130	65	52		104	52	42	
60		177	169	154	77	62	16	123	61	49	12
75		221	211	192	96	77	20	155	78	62	15
100		285	273	248	124	99	26	202	101	81	20
125		359	343	312	156	125	31	253	126	101	25
150		414	396	360	180	144	37	302	151	121	30
200		552	528	480	240	192	49	400	201	161	40
250					302	242	60				
300					361	289	72				
350					414	336	83				
400					477	382	95				
450					515	412	103				
500					590	472	118				

^a For 90 and 80 percent power factor, the above figures shall be multiplied by 1.1 and 1.25 respectively.

NOTE – Linear interpolation may be used to calculate motor currents for motors whose rated voltage does not appear in this Table.

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7 Motors Provided With Controls

7.1 When a motor is provided with a controller, or where a solid-state control provides required protection, the control shall comply with:

- a) The Standard for Automatic Electrical Controls for Household and Similar Use, Part 1: General Requirements, UL 60730-1A, when intended only for commercial or residential use; and
- b) The Standard for Automatic Electrical Controls for Household and Similar Use, Part 1: General Requirements, UL 60730-1A, the Standard for Industrial Control Equipment, UL 508, or the Standard for Power Conversion Equipment, UL 508C, when intended only for industrial applications.

7.1 effective September 15, 2010

8 Mechanical Assembly

8.1 A machine shall be assembled so that it is not adversely affected by the vibration of normal operation. Brush caps shall be tightly threaded or otherwise designed to prevent loosening.

8.1 effective September 15, 2010

8.2 An uninsulated live part shall be secured to the base or mounting surface so that it is prevented from turning or shifting in position if such motion may result in a reduction of spacings below the minimum acceptable value.

8.2 effective September 15, 2010

8.3 Friction between surfaces is not acceptable as the sole means to prevent shifting or turning of a live part; but a properly applied lock washer is acceptable for this purpose.

8.3 effective September 15, 2010

8.4 A switch, a motor-attachment plug, an attachment-plug receptacle or similar component shall be mounted securely and shall be prevented from turning. See 8.5.

Exception: A switch need not be prevented from turning if all of the following conditions are met:

- a) The switch is of a plunger or other type that does not tend to rotate when operated. A toggle switch is considered to be subject to forces that tend to turn the switch during the normal operation of the switch.*
- b) Means for mounting the switch makes it unlikely that operation of the switch will loosen it.*
- c) Spacings are not reduced below the minimum acceptable values if the switch rotates, and leads or connections are not stressed.*
- d) Operation of the switch is by mechanical means rather than by direct contact by persons.*

8.4 effective September 15, 2010

8.5 A properly applied lock washer is acceptable as a means to prevent a small stem-mounted switch or other device having a single-hole mounting means from turning.

8.5 effective September 15, 2010

8.6 Lifting lugs and their mountings shall be designed for the intended purpose. See 32.7.

8.6 effective September 15, 2010

9 Frame and Enclosure

9.1 General

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

9.1.1 effective September 15, 2010

9.1.2 Among the factors taken into consideration when the acceptability of an enclosure is being judged are its:

- a) Mechanical strength;
- b) Resistance to impact;
- c) Moisture-absorptive properties;
- d) Combustibility;
- e) Resistance to corrosion;
- f) Resistance to distortion at temperatures to which the enclosure may be subjected under conditions of normal or abnormal use; and
- g) Resistance to ignition from electrical sources.

9.1.2 effective September 15, 2010

9.1.3 Enclosures for machines that make use of oil as a cooling or insulating medium shall exhibit sufficient structural integrity to contain the pressures produced by the expanding oil during abnormal operation.

9.1.3 effective September 15, 2010

9.1.4 For a nonmetallic enclosure, 9.1.2 (a) – (g) shall be evaluated with respect to thermal aging. See 9.4 for polymeric enclosures and enclosure parts.

9.1.4 effective September 15, 2010

9.1.5 Acceptability of the size, number, and location of openings in an enclosure of a machine intended for factory installation shall depend upon requirements for the end-use equipment. Among the factors that are taken into consideration when the end-use equipment is being judged are:

- a) Environment;
- b) Degree of exposure;

- c) Protection against unintentional contact with live parts, including film-coated wire; and
- d) Prevention of expulsion of molten metal, burning insulation, flaming particles and the like onto combustible materials, if applicable.

9.1.5 effective September 15, 2010

9.2 Cast metal enclosures

9.2.1 The thickness of cast metal for an enclosure shall be as specified in Table 9.1.

Exception: Cast metal of a lesser thickness is not prohibited when upon investigation (consideration being given to the shape, size, and function of the enclosure) it is found to be mechanically equivalent for the intended use.

9.2.1 effective September 15, 2010

Table 9.1
Thickness of cast-metal enclosures

Table 9.1 effective September 15, 2010

Location or dimension of area	Minimum thickness, mm (inch)	
	Die-cast metal	Cast metal of other than the die-cast type
Area of 154.8 cm ² (24 square inches) or less and having no dimension greater than 152 mm (6 inches)	1.6 ^a (1/16)	3.2 (1/8)
Area greater than 154.8 cm ² (24 square inches) or having any dimension greater than 152 mm (6 inches)	2.4 (3/32)	3.2 (1/8)
At a threaded conduit hole	6.4 (1/4)	6.4 (1/4)
At an unthreaded conduit hole	3.2 (1/8)	3.2 (1/8)
^a The area limitation for metal 1.6 mm (1/16 inch) thick is obtained by the provision of reinforcing ribs subdividing a larger area.		

9.3 Sheet metal enclosures

9.3.1 Sheet metal enclosures shall comply with 9.3.2 or the requirements in the Standard for Enclosures for Electrical Equipment, UL 50.

9.3.1 effective September 15, 2010

9.3.2 The thickness of a sheet-metal enclosure shall not be less than that specified in Tables 9.2 and 9.3. Uncoated steel shall not be less than 0.81 mm (0.032 inch) thick, zinc-coated steel shall not be less than 0.86 mm (0.034 inch) thick, and nonferrous metal shall not be less than 1.14 mm (0.045 inch) thick for surfaces of an enclosure at which a wiring system is to be connected.

Exception: The thickness of a sheet metal enclosure may be less than specified in Tables 9.2 and 9.3 when investigated and determined to be mechanically equivalent.

9.3.2 effective September 15, 2010

9.3.3 With reference to Tables 9.2 and 9.3, a supporting frame is a structure of angle or channel or a folded rigid section of sheet metal that is rigidly attached to and has the same outside dimensions as the enclosure surface and that has the torsional rigidity to resist the bending moments that are applied via the enclosure surface. An example of a construction that has equivalent reinforcement is one that produces a structure that is as rigid as one built with a frame of angles or channels.

9.3.3 effective September 15, 2010

9.3.4 With reference to 9.3.3 and Tables 9.2 and 9.3, a construction does not have a supporting frame when it is:

- a) A single sheet with single formed flanges – formed edges;
- b) A single sheet that is corrugated or ribbed;
- c) An enclosure formed or fabricated from sheet metal; or
- d) An enclosure surface loosely attached to a frame – for example, by spring clips.

9.3.4 effective September 15, 2010

Table 9.2
Thickness of carbon steel or stainless steel enclosures

Table 9.2 effective September 15, 2010

Without supporting frame ^a		With supporting frame or equivalent reinforcing ^a		Minimum thickness, mm (inch)	
Maximum width ^b mm (inches)	Maximum length ^c mm (inches)	Maximum width ^b mm (inches)	Maximum length ^c mm (inches)	Uncoated	Metal Coated
102 (4)	Not limited	159 (6-1/4)	Not limited	0.51 ^d (0.020)	0.58 ^d (0.023)
121 (4-3/4)	146 (5-3/4)	171 (6-3/4)	210 (8-1/4)		
152 (6)	Not limited	241 (9-1/2)	Not limited	0.66 ^d (0.026)	0.74 (0.029)
178 (7)	222 (8-3/4)	254 (10)	318 (12-1/2)		
203 (8)	Not limited	305 (12)	Not limited	0.81 (0.032)	0.86 (0.034)
229 (9)	292 (11-1/2)	330 (13)	406 (16)		
318 (12-1/2)	Not limited	495 (19-1/2)	Not limited	1.07 (0.042)	1.14 (0.045)
356 (14)	457 (18)	533 (21)	635 (25)		
457 (18)	Not limited	686 (27)	Not limited	1.35 (0.053)	1.42 (0.056)
508 (20)	635 (25)	737 (29)	914 (36)		
559 (22)	Not limited	838 (33)	Not limited	1.52 (0.060)	1.60 (0.063)
635 (25)	787 (31)	889 (35)	1092 (43)		
635 (25)	Not limited	991 (39)	Not limited	1.70 (0.067)	1.78 (0.070)
737 (29)	914 (36)	1041 (41)	1295 (51)		
838 (33)	Not limited	1295 (51)	Not limited	2.03 (0.080)	2.13 (0.084)
1034 (38)	1194 (47)	1372 (54)	1676 (66)		
1067 (42)	Not limited	1626 (64)	Not limited	2.36 (0.093)	2.46 (0.097)
1194 (47)	1499 (59)	1727 (68)	2134 (84)		
1321 (52)	Not limited	2032 (80)	Not limited	2.74 (0.108)	2.82 (0.111)
1524 (60)	1880 (74)	2134 (84)	2616 (103)		
1600 (63)	Not limited	2464 (97)	Not limited	3.12 (0.123)	3.20 (0.126)
1854 (73)	2286 (90)	2616 (103)	3226 (127)		

NOTE – This table is based on a uniform deflection of the enclosure surface for any given load concentrated at the center of the surface regardless of metal thickness.

^a See 9.3.3 and 9.3.4.

^b The width is the smaller dimension of a rectangular sheet metal piece that is part of an enclosure. Adjacent surfaces of an enclosure are not prohibited from having supports in common and being made of a single sheet.

^c "Not limited" applies only where the edge of the surface is flanged at least 12.7 mm (1/2 inch) or fastened to adjacent surfaces not normally removed in use.

^d Sheet steel for an enclosure intended for outdoor use shall not be less than 0.86 mm (0.034 inch) thick when metal coated and not less than 0.81 mm (0.032 inch) thick when uncoated.

Table 9.3
Thickness of aluminum, copper, or brass enclosures

Table 9.3 effective September 15, 2010

Without supporting frame ^a		With supporting frame or equivalent reinforcing ^a		Minimum thickness	
Maximum width ^b mm (inches)	Maximum length ^c mm (inches)	Maximum width ^b mm (inches)	Maximum length ^c mm (inches)		
76 (3)	Not limited	178 (7)	Not limited	0.58 ^d	(0.023)
89 (3-1/2)	102 (4)	216 (8-1/2)	241 (9-1/2)		
102 (4)	Not limited	254 (10)	Not limited	0.74	(0.029)
127 (5)	152 (6)	267 (10-1/2)	343 (13-1/2)		
152 (6)	Not limited	356 (14)	Not limited	0.91	(0.036)
165 (6-1/2)	203 (8)	381 (15)	457 (18)		
203 (8)	Not limited	483 (19)	Not limited	1.14	(0.045)
241 (9-1/2)	292 (11-1/2)	533 (21)	635 (25)		
305 (12)	Not limited	711 (28)	Not limited	1.47	(0.058)
356 (14)	406 (16)	762 (30)	940 (37)		
457 (18)	Not limited	1067 (42)	Not limited	1.91	(0.075)
508 (20)	634 (25)	1143 (45)	1397 (55)		
634 (25)	Not limited	1524 (60)	Not limited	2.41	(0.095)
737 (29)	914 (36)	1626 (64)	1981 (78)		
940 (37)	Not limited	2210 (87)	Not limited	3.10	(0.122)
1067 (42)	1346 (53)	2362 (93)	2896 (114)		
1321 (52)	Not limited	3124 (123)	Not limited	3.89	(0.153)
1524 (60)	1880 (188)	3302 (130)	4064 (160)		

NOTE – This table is based on a uniform deflection of the enclosure surface for any given load concentrated at the center of the surface regardless of metal thickness.

^a See 9.3.3 and 9.3.4.

^b The width is the smaller dimension of a rectangular sheet metal piece that is part of an enclosure. Adjacent surfaces of an enclosure are not prohibited from having supports in common and being made of a single sheet.

^c "Not limited" applies only when the edge of the surface is flanged at least 12.7 mm (1/2 inch) or fastened to adjacent surfaces not normally removed in use.

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

9.4 Polymeric enclosures

9.4.1 A polymeric enclosure or a polymeric part of an enclosure shall comply with the applicable requirements specified in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, and with the additional requirements specified in this Standard. See Table 9.4 for an overview of the evaluation.

Exception: Thermoset materials used in a Class A machine are not required to comply with the mold stress relief test.

9.4.1 effective September 15, 2010

9.4.2 Polymeric enclosures intended for field installation shall not deform under conditions of normal use. See Section 32, Mechanical Tests.

Exception: A polymeric plug or other enclosure part less than 645 mm² (1 inch²) made of a material classified in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, and assembled to a sheet-metal or aluminum frame to form a part of an enclosure is able to be used when the material is rated minimum V-2 or VTM-2, or rated HB and complying with the 12 mm or 3/4-inch Flame Tests as specified in UL 746C.

9.4.2 effective September 15, 2010

Table 9.4
Tests required on polymeric enclosures

Table 9.4 effective September 15, 2010

Type of equipment	Machine enclosure for factory installation	Machine enclosure for field installation	Reference in UL 746C
Portable	Flame: HB	Flame: V-0, -1, -2; VTM-0, -1, -2 5000 volt dielectric Impact Severe conditioning Mold stress Volume resistivity	(Section 10) (Section 22) (Section 28) (Section 29) (Section 14)
Stationary or fixed	Flame: HB	Flame: 5VA, 5VB 5000 volt dielectric Impact Crush Severe conditioning Mold stress Conduit connections (Standard for Industrial Control Equipment, UL 508) Volume resistivity UV exposure Water exposure	(Section 10) (Section 22) (Section 21) (Section 28) (Section 29) (Section 14) (Section 25) (Section 26)
References in parentheses, unless otherwise noted, are to the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C. In addition, the material shall have the following HAI (Section 13) performance levels.			
Flame rating	HAI performance level		
HB	1		
V-2, VTM-2	2		
V-1, VTM-1	2		
V-0, VTM-0	3		
5VA, 5VB	3		

10 Grounding

10.1 Machines exhibiting the following characteristics shall have provision for grounding:

- a) A machine for use in damp or wet locations;
- b) A machine intended to be field installed and used on a circuit operating at more than 150 volts to ground – see 10.2; or
- c) An electric generator.

Exception: A machine may be provided with a double insulation system that complies with the Standard for Double Insulation Systems for Use in Electrical Equipment, UL 1097, in place of a provision for grounding.

10.1 effective September 15, 2010

10.2 With reference to 10.1(b), when the machine is marked to indicate that it is to be connected to a circuit operating at 150 volts or less to ground, it is not required to comply with this Section.

10.2 effective September 15, 2010

10.3 A machine marked as being provided with double insulation shall not be provided with a means for grounding.

10.3 effective September 15, 2010

10.4 If a grounding means is provided, whether required or not, it shall comply with this Section.

10.4 effective September 15, 2010

10.5 All exposed dead metal parts and all dead metal parts within the enclosure that are exposed to contact during any user servicing operation and likely to become energized shall be reliably connected to the means for grounding.

10.5 effective September 15, 2010

10.6 A grounding terminal or lead shall be provided for a machine intended to be permanently connected.

10.6 effective September 15, 2010

10.7 A separable connection, such as that provided by an attachment plug and a mating connector or receptacle, shall be such that the equipment-grounding connection is made before connection to and broken after disconnection from the output conductors.

Exception: Interlocked plugs, receptacles, and connectors that are not energized when the equipment-grounding connection is made or broken are acceptable.

10.7 effective September 15, 2010

10.8 A terminal solely for the connection of an equipment-grounding conductor shall be capable of securing a conductor of the size necessary for the application. A connection device that depends on solder alone shall not be provided for connecting the equipment-grounding conductor.

10.8 effective September 15, 2010

10.9 A wire-binding screw or pressure wire connector intended for the connection of an equipment-grounding conductor shall be located so that it is not removed during normal servicing of the machine.

10.9 effective September 15, 2010

11 Grounding Identification

11.1 The surface of the insulation of a grounding conductor of a flexible cord shall be green with or without one or more yellow stripes.

11.1 effective September 15, 2010

11.2 The surface of an insulated lead intended solely for the connection of an equipment-grounding conductor shall be green with or without one or more yellow stripes, and no other lead shall be so identified.

11.2 effective September 15, 2010

11.3 A wire-binding screw intended for connection of an equipment-grounding conductor shall have a green-colored head that is hexagonal, slotted, cross slotted, or both. A pressure terminal connector intended for connection of an equipment-grounding conductor shall be plainly identified by:

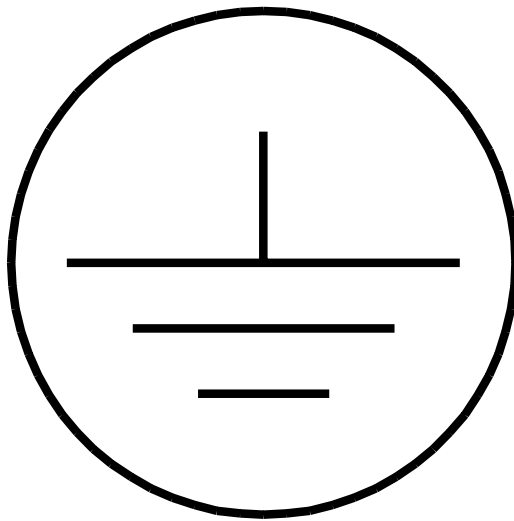
- a) A marking, such as "G", "GR", "GND", "Ground", "Grounding", or the like;
- b) A wiring diagram provided on the appliance; or
- c) The grounding symbol illustrated in Figure 11.1, on or adjacent to the terminal, or on a wiring diagram provided on the appliance.

The wire-binding screw or pressure wire connector shall be located so that it is not removed during normal servicing of the machine.

11.3 effective September 15, 2010

Figure 11.1
Grounding symbol

Figure 11.1 effective September 15, 2010



IEC417, Symbol 5019

12 Ventilation Openings

12.1 General

12.1.1 Ventilation openings for machines intended for field installation shall comply with the requirements in Section 12, Ventilation Openings.

12.1.1 effective September 15, 2010

12.1.2 A ventilation opening in the top of a Type 1 enclosure shall be covered by a hood or protective shield spaced above the opening when there are energized components below the opening.

12.1.2 effective September 15, 2010

12.1.3 Any ventilating opening in a Type 1, 2, or 3R enclosure (enclosure types per the Standard for Enclosures for Electrical Equipment, UL 50) shall comply with Section 13, Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts.

12.1.3 effective September 15, 2010

12.1.4 The area of an opening covered by a louver, a perforated or an expanded-metal mesh panel that is thinner than the enclosure shall not exceed 1290 cm² (200 square inches).

12.1.4 effective September 15, 2010

12.1.5 The diameter of the wires of a screen shall be at least 1.3 mm (0.05 inch) if the screen openings are 323 mm² (0.5 square inch) or less in area, and shall be at least 2.1 mm (0.08 inch) for larger screen openings.

12.1.5 effective September 15, 2010

12.1.6 Perforated sheet steel and sheet steel employed for expanded-metal mesh shall be at least 1.1 mm (0.04 inch) thick uncoated steel for mesh openings or perforations 323 mm² (0.5 square inch) or less in area. For larger openings, at least 2 mm (0.08 inch) thick uncoated steel shall be used.

Exception: In a small device where the indentation of a guard or enclosure does not adversely affect the performance or reduce the spacings below the minimum value specified in Section 18, Spacings, expanded-metal mesh of uncoated steel not less than 0.51 mm (0.02 inch) thick may be employed when:

a) The exposed mesh on any one side or surface of the device so protected has an area not more than 464 cm² (72 square inches) and has no dimension greater than 304.8 mm (12 inches); or

b) The width of the opening so protected is not greater than 88.9 mm (3.50 inches).

12.1.6 effective September 15, 2010

12.2 Barriers used with ventilation openings

12.2.1 A barrier interposed between ventilation openings and live parts to prevent the emission of flames or molten metal from an enclosure shall comply with 12.2.

12.2.1 effective September 15, 2010

12.2.2 The barrier shall be of such dimensions and so located that any straight line drawn from any arcing part past the edge of the barrier intersects a point in the ventilating opening plane that is at least 6.4 mm (1/4 inch) outside of the edge of the ventilation opening. See Figure 12.1.

12.2.2 effective September 15, 2010