UL 1004-1

STANDARD FOR SAFETY

Rotating Electrical Machines – General Requirements

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

Second Edition, Dated September 19, 2012

Summary of Topics

This revision of ANSI/UL 1004-1 dated November 5, 2020 includes the following changes in requirements:

Replaced Reference to UL 508C with UL 61800-5-1; 7.1

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

The revised requirements are substantially in accordance with Proposal(s) on this subject dated May 29, 2020 and August 28, 2020.

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UL 1004-1

Standard for Rotating Electrical Machines – General Requirements

First Edition – September, 2008

Second Edition

September 19, 2012

This ANSI/UL Standard for Safety consists of the Second Edition including revisions through November 5, 2020.

The most recent designation of ANSI/UL 1004-1 as an American National Standard (ANSI) occurred on October 22, 2020. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

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

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INTRODUCTION

1 Scope

1.1 This Standard applies to form wound rotating electrical machines rated less than 460 volts and all other rotating electrical machines and linear motors, both AC and DC, rated 1,000 volts or less.

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, 33.1 – 33.3, 33.5 – 33.7, and 34.1.

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.

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

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1.5 These requirements do not cover sealed (hermetic type) motor-compressor parts, which are evaluated under the Standard for Household and Similar Electrical Appliances – Safety – Part 2-34: Particular Requirements for Motor-Compressors, UL 60335-2-34.

1.6 If the risk of fire does not exist at a machine, part, or circuit, then the requirements of this Standard and associated parts of this Standard, intended to address the risk of fire shall not apply to that machine, part, or circuit.

1.7 If the risk of electric shock does not exist at a machine, part, or circuit, then the requirements of this Standard and associated parts of this Standard, intended to address the risk of electric shock shall not apply to that machine, part, or circuit.

1.8 The requirements of this Standard and associated parts of this Standard, intended to address the risk of fire do not apply to a motor provided with a metal enclosure in which there are no openings in the enclosure through which molten metal, burning insulation, flaming particles, or other ignited material could fall onto flammable material, or through which a flame could be projected.

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. 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 60730-1.

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.

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.

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 Glossary

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

5.2 AIR-OVER MOTOR – A motor that relies upon a stream of air to cool the motor and is marked in accordance with 44.8.

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

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

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

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.

5.7 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.

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

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

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

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.

5.12 CONTINUOUS DUTY MOTOR – A motor intended to operate indefinitely at rated load.

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.

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

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.

5.16 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.

5.17 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.

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

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.

5.20 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.

5.21 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.

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

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.

5.24 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.

5.25 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.

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

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.

5.28 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.

5.29 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.

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

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.

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

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.

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

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. Polymeric impellers as part of a motor intended to move air for the purposes of cooling are not considered non-metallic functional parts if they do not contact bare live parts.

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

5.37 OPERATING CONTROL – A device or circuit the operation of which starts or regulates the rotating machine during normal operation.

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

5.39 PROTECTIVE CONTROL – A device or circuit the operation of which is intended to prevent a hazardous situation during abnormal operation of the machine or equipment. In the context of this Standard, a protective control is one that is relied upon to provide overtemperature protection for a rotating machine.

5.40 RISK OF ELECTRIC SHOCK – A risk of electric shock is considered to exist at any part if:

a) The potential between the part and earth ground or any other simultaneously accessible part is more than 42.4 V peak for alternating current potentials or 60 volts for direct current potentials; and

b) The continuous current flow through a 1500-ohm resistor connected across the potential exceeds 0.5 mA.

5.41 RISK OF FIRE – A risk of fire is considered to exist if the open-circuit voltage between any two points is equal to or greater than 2500 volts peak, or if power of more than 15 watts can be delivered into an external resistor connected between the two points.

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

5.43 SERVICE FACTOR – A multiplier that, when applied to the rated output of a machine, indicates a permissible loading that can be carried continuously at the rated voltage and frequency.

5.44 SIMULTANEOUSLY ACCESSIBLE – Parts are considered to be simultaneously accessible when they are no further than 2 m apart.

5.45 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.

5.46 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.

5.47 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.

5.48 SMALL PARTS – Materials that do not exceed 2 cm^3 (0.12 in^3) in volume and 3 cm (1.18 in) in maximum dimension, and are located such that they cannot propagate flame from one area to another or act as a bridge between a possible source of ignition and other ignitable parts.

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

5.50 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.

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

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

5.53 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.

5.53.1 THERMAL STABILIZATION – Thermal stabilization is considered to have been attained when the temperature does not vary by more than 2°C (3.6°F) in 30 minutes.

5.54 TRACTION MOTOR – An electric motor used for propulsion that exerts a tractive force through a vehicle's wheels.

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

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

5.57 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.

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

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, (Table 6.1 – Table 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.

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

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

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Table 6.1 Continued

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

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.

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

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.

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

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					

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Table 6.4 Continued

	Induction type squirrel-cage and wound-rotor amperes							Synchronous type unity power factor[a] amperes			
HP	115 V	200 V	208 V	230 V	460 V	575 V	2300 V	230 V	460 V	575 V	2300 V
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 60730-1, 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 60730-1, the Standard for Industrial Control Equipment, UL 508, the Standard for Controllers for Use in Power Production, UL/ULC 6200, or the Standard for Adjustable Speed Electrical Power Drive Systems – Part 5-1: Safety Requirements – Electrical, Thermal, and Energy, UL 61800-5-1, when intended only for industrial applications.

7.2 Operating controls shall be evaluated to the applicable Standard noted in 7.1 for resistance to fire, electric shock, or other risk of injury posed by the control.

7.3 Compliance of controls to the requirements of the Standard for Automatic Electrical Controls for Household and Similar Use, Part 1: General Requirements, UL 60730-1, shall be achieved through declarations by the control manufacturer. The information required is specified in Table 7.2DV of UL 60730-1. Table 7.1 specifies the declarations necessary for a motor operating control evaluated to the requirements of this Standard.

Table 7.1
Motor control correlation table

UL 60730-1 Table 7.2DV item number	Information	Motor control requirement
6	Purpose of control	Operating control
7	Type of load controlled	Motor load
39	Type 1 or Type 2 action	Type 1
49	Pollution degree	Pollution degree to be determined by reference to 18.8.
52	The minimum parameters of any heat dissipater (heat sink) not provided with an electronic control but essential to its correct operation	Must be specified
53	Output waveform if other than sinusoidal	Must be specified
69	Software Class	Software Class A
74	External load and emission control measures to be used for test purposes	Intended motor

7.4 Protective controls shall be evaluated, to the applicable Standard noted in 7.1, for their ability to provide required overtemperature protection for the rotating machine as well as their resistance to fire, electric shock, or other risk of injury posed by the control.

Exception: If a rotating machine complies with the requirements of the Standard for Impedance Protected Motors, UL 1004-2, or the Standard for Thermally Protected Motors, UL 1004-3, independent of the protective control, then the control is only to be evaluated as an operating control as described in 7.2.

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.

8.2 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.

8.3 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.

8.4 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.

8.5 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.

8.6 Lifting lugs and their mountings shall be designed for the intended purpose. See 33.7.

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.

9.1.2 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.

9.1.3 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.

9.1.4 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.

9.1.5 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.

9.2 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.

Table 9.1
Thickness of cast-metal enclosures

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, Non-Environmental Considerations, UL 50.

9.3.2 The thickness of a sheet-metal enclosure shall not be less than that specified in Table 9.2 and Table 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 Table 9.2 and Table 9.3 when investigated and determined to be mechanically equivalent.

9.3.3 With reference to Table 9.2 and Table 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.

9.3.4 With reference to 9.3.3 and Table 9.2 and Table 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.

Table 9.2
Thickness of carbon steel or stainless steel enclosures

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]				Minimum thickness, mm (inch)			
Maximum width[b]		Maximum length[c]		Maximum width[b]		Maximum length		Uncoated		Metal Coated	
mm	(inches)	mm	(inches)	mm	(inches)	mm	(inches)				
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

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]				Minimum thickness	
Maximum width[b]		Maximum length[c]		Maximum width[b]		Maximum length			
mm	(inches)	mm	(inches)	mm	(inches)	mm	(inches)	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	(0029)
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.

9.4.2 Polymeric enclosures intended for field installation shall not deform under conditions of normal use. See Section 33, Mechanical Tests.

Exception: A polymeric plug or other enclosure part less than 645 mm^2 (1 inch^2) 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.

Table 9.4
Tests required on polymeric enclosures

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	(Section 10)
		Impact	(Section 22)
		Severe conditioning	(Section 28)
		Mold stress	(Section 29)
		Volume resistivity	(Section 14)
Stationary or fixed	Flame: HB	Flame: 5VA, 5VB	
		5000 volt dielectric	(Section 10)
		Impact	(Section 22)
		Crush	(Section 21)
		Severe conditioning	(Section 28)
		Mold stress	(Section 29)
		Conduit connections (Standard for Industrial Control Equipment, UL 508)	
		Volume resistivity	(Section 14)
		UV exposure	(Section 25)
		Water exposure	(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 11) 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.

10.2 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.

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

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

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. Compliance shall be checked by the Grounding Test, Section 39.

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

10.6.1 A generator shall provide in a location inaccessible from outside the assembly in its end use application:

a) A flat, unpainted, corrosion protected, surface integral with or irreversibly connected to the generator barrel that is properly sized for the generator's fault current capability; and

b) Tapped with a hole or holes for machine thread fasteners or other approved method for securing any grounding conductor(s) for equipment provided with the generator and grounding conductor terminals properly sized for the generator's fault current capability.

Exception: The generator foot or mounting location shall not be prohibited as a secondary location when all criteria in (a) are satisfied elsewhere on the generator.

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.

10.8 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.

10.9 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.

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.

11.2 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.

11.3 A terminal connector intended for connection of an equipment-grounding conductor shall be plainly identified by:

a) Use of a wire binding screw with a green-colored head that is hexagonal, slotted, cross-slotted, or both;

b) Use of a threaded stud with a green colored hexagonal nut;

c) Use of a green colored pressure terminal connector;

d) Being marked "G", "GR", "'GND", "Ground", "Grounding", or the like;

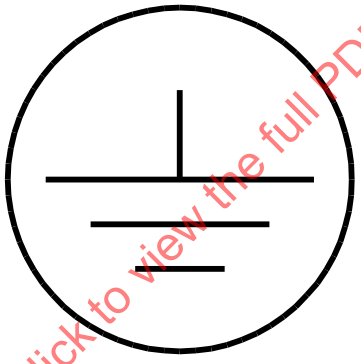
e) A marking on a wiring diagram provided on the product; or

f) The grounding symbol illustrated in Figure 11.1, on or adjacent to the terminal, or on a wiring diagram provided on the product.

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

Figure 11.1

Grounding symbol



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.

12.1.2 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.

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

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 cm^2 (200 square inches).

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 mm^2 (0.5 square inch) or less in area, and shall be at least 2.1 mm (0.08 inch) for larger screen openings.

12.1.6 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 mm^2 (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 cm^2 (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).

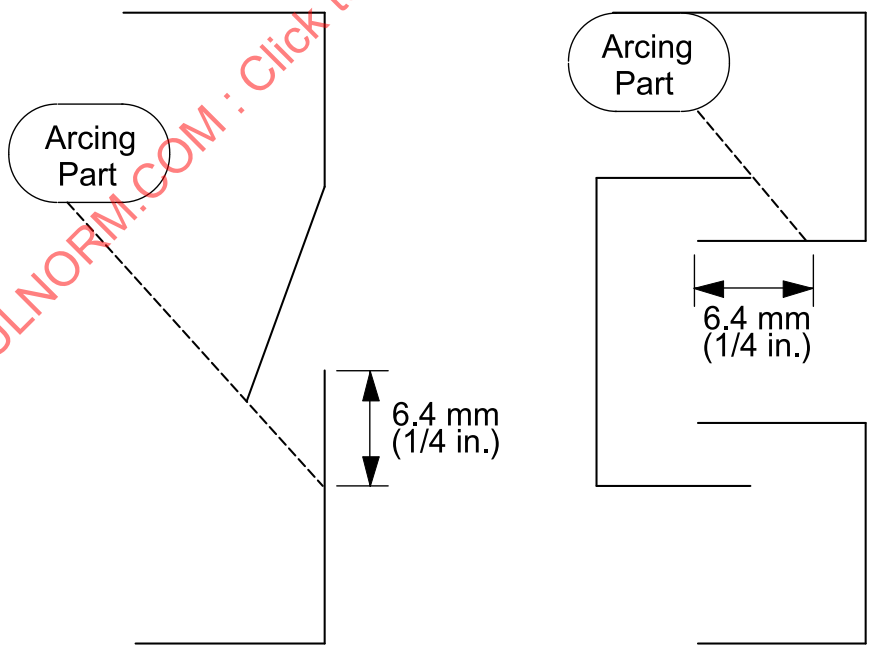
12.2 Barriers used with ventilation openings

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.

12.2.2 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.

Figure 12.1

Barriers for ventilation openings



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12.2.3 A sheet-metal barrier shall be at least 1.35 mm (0.053 inch) thick uncoated steel, or 1.91 mm (0.075 inch) thick aluminum.

Exception: A metal barrier may be of thinner metal provided its strength and rigidity are not less than that of a flat sheet of steel having the same dimensions as the barrier and of the specified thickness.

12.2.4 A nonmetallic barrier shall be at least 6.4 mm (1/4 inch) thick and shall be supported to provide mechanical strength and rigidity.

Exception: A nonmetallic material may be less than 6.4 mm (1/4 inch) thick if it is:

a) Located so that it is not subjected to mechanical damage during installation; and

b) Supported to provide mechanical strength and rigidity.

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

13.1 To reduce unintentional contact that involves a risk of electric shock from an uninsulated live part or film-coated wire, or injury to persons from a moving part, an opening in an enclosure shall comply with either of the following:

a) For a directly accessible machine:

1) An opening that has a minor dimension (see 13.9) less than 25.4 mm (1 inch), such a part or wire shall not be contacted by the probe illustrated in Figure 13.1; or

2) An opening that has a minor dimension of 25.4 mm (1 inch) or more, such a part or wire shall be spaced from the opening as specified in Table 13.1.

b) For an indirectly accessible machine:

1) The probe illustrated in Figure 13.2, shall not contact an uninsulated live part; or

2) An opening that has a minor dimension of 19.1 mm (3/4 inch) or more is acceptable if a part or wire is spaced from the opening as specified in Table 13.1.

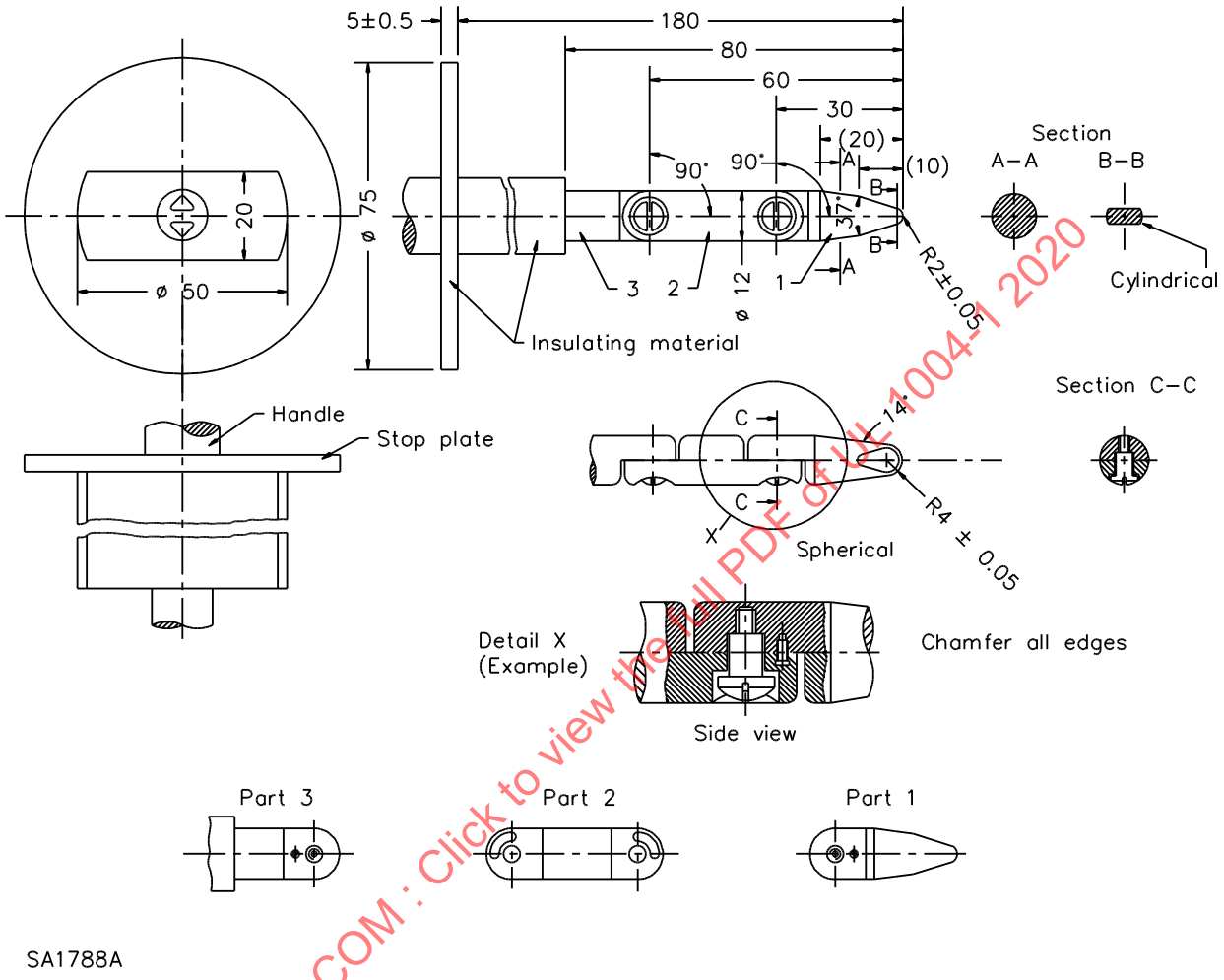
Exception No. 1: An opening in an integral enclosure of a machine is not required to comply with these requirements if it complies with the requirements of 13.2.

Exception No. 2: Machines are not required to comply with the requirements of this Section if the machine is only intended for factory installation.

Figure 13.1

Articulate probe with web stop

(Dimensions in mm)



Dimensions and the equivalent unit conversions for Figure 13.1:

mm	(Inch)
0.05	(0.002)
1	(0.039)
2	(0.079)
3	(0.118)
5	(0.197)
10	(0.394)
20	(0.787)
30	(1.181)
50	(1.968)
60	(2.362)
80	(3.150)
180	(7.087)

Figure 13.2

Straight probe

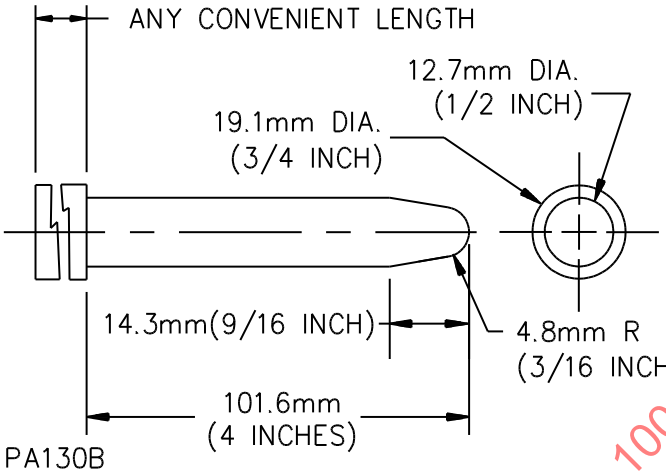


Figure 13.3

Pin probe

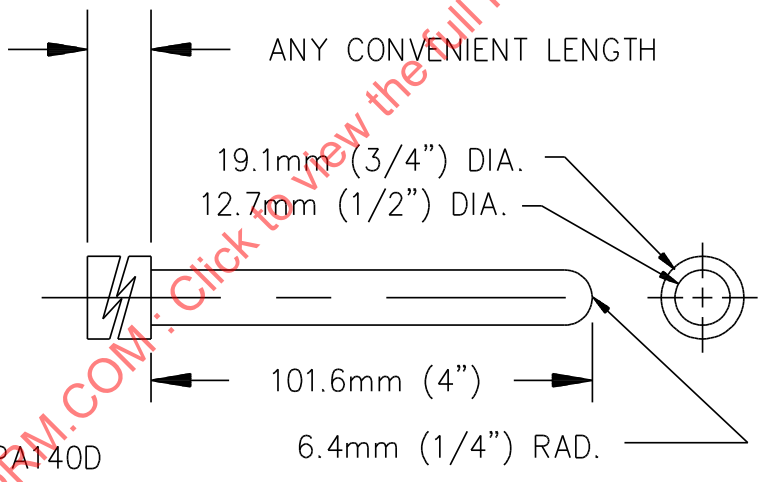


Table 13.1
Minimum distance from an opening to a part involving a risk of electric shock or injury to persons

Minor dimension [a] of opening		Minimum distance from opening to part	
mm	(inches)	mm	(inches)
19.1	(3/4)	114	(4-1/2)
25.4	(1)	165	(6-1/2)
31.8	(1-1/4)	190	(7-1/2)
38.1	(1-1/2)	318	(12-1/2)
47.6	(1-7/8)	394	(15-1/2)
54.0	(2-1/2)	444	(17-1/2)

Table 13.1 Continued on Next Page

Table 13.1 Continued

Minor dimension [a] of opening		Minimum distance from opening to part	
mm	(inches)	mm	(inches)
More than 54 mm, but not more than 152 mm	(More than 2-1/8 inches, but not more than 6 inches.)	762	(30)
NOTE – Between 19.1 mm (3/4 inch) and 54 mm (2-1/8 inch), interpolation is to be used to determine a value between values specified in this Table. [a] See 13.9.			

13.2 With respect to a part or wire as specified in 13.1, in an integral enclosure of a machine as specified in Exception No. 1 to 13.1:

a) An opening that has a minor dimension (see 13.9) less than 19.1 mm (3/4 inch) complies when:

1) A moving part is not contacted by the probe illustrated in Figure 13.2;

2) Film-coated wire is not contacted by the probe illustrated in Figure 13.3;

3) In a directly accessible machine, an uninsulated live part is not contacted by the probe illustrated in Figure 13.1; and

4) In an indirectly accessible machine, the probe illustrated in Figure 13.2 does not contact an uninsulated live part.

b) An opening that has a minor dimension of 19.1 mm (3/4 inch) or more complies when a part or wire is spaced from the opening as specified in Table 13.1.

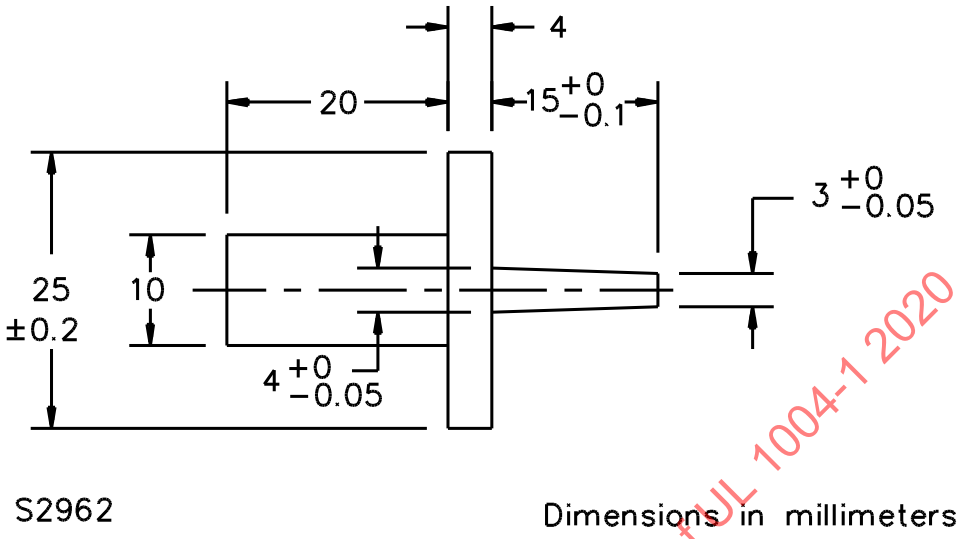
13.3 The probe shown in Figure 13.1 and the test pin shown in Figure 13.4 are to be inserted as specified in 13.6 – 13.8 into all openings, including those in the bottom of the unit. The probe and test pin are to be inserted into all openings in the bottom that are accessible without tipping, turning over, or otherwise moving the unit from its intended installed position.

13.4 During the examination of a unit to determine whether it complies with the requirements in 13.1 or 13.2, a part of the enclosure that is opened or removed by the user without using a tool (to attach an accessory, to make an operating adjustment, to give access to a fuse or other overload protective device or for other reasons) is to be opened or removed. A fastener, such as a slotted-head thumbscrew, that is turned by hand, does not require the use of a tool.

13.5 With reference to the requirements in 13.1 and 13.2, insulated brush caps are not required to be additionally enclosed.

Figure 13.4

Test pin



Dimensions and the equivalent unit conversions for Figure 13.4:

mm	(Inch)
0.05	(0.002)
0.1	(0.004)
0.2	(0.008)
3	(0.118)
4	(0.157)
10	(0.394)
15	(0.591)
20	(0.787)
25	(0.964)

13.6 The test pin illustrated in Figure 13.4, when inserted as specified in 13.4 through an opening in an enclosure, shall not touch any uninsulated live part that involves a risk of electric shock.

13.7 The probes shall be applied to any depth that the opening permits; and shall be rotated or angled before, during, and after insertion through the opening to any position that is necessary to examine the enclosure. If necessary, the probe illustrated in Figure 13.1 shall have the configuration changed after insertion through the opening.

13.8 The probes shall be applied with a force not to exceed 10 N (2.2 pounds). The probe is to be used to determine the accessibility provided by an opening, and not as an instrument to determine the strength of a material.

13.9 With reference to the requirements in 13.1, the minor dimension of an opening is the diameter of the largest cylindrical probe having a hemispherical tip that can be inserted through the opening.

14 Protection Against Corrosion

14.1 Metal shall be used in combinations that are galvanically compatible and shall not be subject to significant corrosion due to electrochemical action in any working, storage, or transport environmental conditions. Compliance is checked by inspection and by reference to Figure 14.1. Combinations above the line in the table shown in Figure 14.1 shall be avoided. Corrosion resistance may be achieved by a suitable plating or coating process.

Figure 14.1

Table of electrochemical potentials

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

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

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

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14.2 Iron and steel parts shall be protected against corrosion by enameling, galvanizing, plating, or other means if the corrosion of such parts results in a risk of fire, electric shock, or injury to persons.

Exception No. 1: This requirement does not apply to surfaces of sheet steel and cast-iron parts within an enclosure if oxidation of the part due to exposure of the metal to air and moisture is not likely to be appreciable – thickness of metal and temperature also being factors.

Exception No. 2: Bearings, laminations, or minor parts of iron or steel, such as washers, screws, and the like need not be protected from corrosion.

14.3 Copper, bronze, brass containing not less than 80 percent copper, or stainless steel may be used without additional protection against corrosion.

14.4 Sheet, extruded, or cast aluminum, die-cast zinc, and other metals shall either be of a grade or alloy known to be resistant to atmospheric corrosion, shall be subjected to the Corrosion Resistance Test in the Standard for Enclosures for Electrical Equipment, Environmental Considerations, UL 50E, or shall be additionally protected against corrosion.

15 Cord-Connected Motors

15.1 The requirements in this Section apply to a motor that is intended to be connected to a source of supply in the field by means of a flexible cord and an attachment plug that are both provided with the motor.

15.2 A flexible cord shall be acceptable for the intended use. It shall be rated for a voltage not less than maximum rated voltage of the motor, and shall have an ampacity not less than the marked or assigned current rating of the motor.

15.3 A general-use attachment plug shall be rated for a current not less than 125 percent of the rated current, and a voltage equal to the rated voltage of the motor.

Exception: A general-use attachment plug on a motor not intended for continuous operation may have a current rating not less than the rated current of the motor.

15.4 The attachment plug provided with a motor designed so that it can be adapted for use on two or more different values of voltage by field alteration of internal connections shall be rated for the voltage for which the motor is connected when shipped from the factory.

15.5 Unless it is to be provided in the end-use equipment, strain relief shall be provided to prevent a mechanical stress on the flexible cord from being transmitted to terminals, splices, or interior wiring. See Section 34, Strain Relief Test.

15.6 Unless investigated for the purpose, a clamp of any material – metal or otherwise – is not acceptable on Types SPT-1, SPT-2, SVT, and SVTO cords, except that a cord protected by varnished-cloth tubing or the equivalent under the clamp may be accepted subject to the investigation described in 34.3. For heavier types of thermoplastic-insulated cord, clamps may be employed; in such cases, the auxiliary insulation is not required unless it is judged that the clamp may damage the insulation of the cord.

15.7 Unless it is to be provided in the end-use equipment, means shall be provided to prevent the cord from being pushed into the enclosure of the machine through the cord entry hole when such displacement results in:

a) Subjecting the cord to mechanical damage;

b) Exposing the cord to a temperature higher than that for which it is rated;

c) Reducing spacings (such as from a live part to a metal strain-relief clamp) below the minimum required values; or

d) Damaging internal connections or components.

To determine compliance, the cord shall be tested in accordance with Section 35, Push-Back Relief Test.

15.8 If a knot in a flexible cord serves as strain relief, a surface with which the knot may contact shall be free from projections, sharp edges, burrs, fins, and the like, that may cause abrasion of the cord jacket or the insulation on the conductors.

15.9 At a point where a flexible cord passes through an opening in a wall, barrier, or enclosing case, there shall be a bushing or the equivalent that shall be substantial, and reliably secured in place, or the opening shall have a smooth, rounded surface against which the cord may bear. If Type SP-1, SPT-1, SP-2, SPT-2, or other cord lighter than Type SV is employed, and if the wall or barrier is of metal, an electrical insulating bushing shall be provided.

15.10 If the cord-entry hole is in porcelain, phenolic composition, or other nonconducting material, a smooth, rounded surface is considered to be equivalent to a bushing.

15.11 Ceramic materials and some molded compositions are generally acceptable for an insulating bushing, but separate bushings of wood or of so-called hot-molded shellac and tar compositions are not acceptable.

15.12 Vulcanized fiber or fiber treated to resist moisture absorption may be employed as a bushing if it is not less than 1.2 mm (3/64 inch) thick and if the bushing is formed so that it is reliably secured in place.

15.13 A bushing of any insulating material that has not been found to afford sufficient protection to the cord may be employed at any point in a motor if used with a type of cord for which an insulating bushing is not required. The edges of the hole in which such a bushing is mounted are to be smooth and free of burrs, fins, and the like.

15.14 At any point in a motor, a bushing of the same material as, and molded integrally with, the supply cord is acceptable on a Type SP-1 or heavier cord if the built-up section of the bushing is not less than 1.6 mm (1/16 inch) thick at the point where the cord passes through the enclosure.

15.15 An insulated metal grommet may be used in place of an insulating bushing if the insulating material is not less than 0.8 mm (1/32 inch) thick and completely fills the space between the grommet and the metal in which it is mounted.

16 Input and Output Connections

16.1 The requirements in this Section apply to a machine having input, output, control, or equipment-grounding connections that are intended to be made to the machine in the field.

16.2 A machine intended for permanent connection shall have provision for connection of a wiring system.

16.3 In a general use enclosure, an opening for connection of a wiring system that may not be used shall be closed by a knockout, cover, or plug. The closure shall be formed of metal not less than 1.35 mm (0.053 inch) thick or of a nonmetallic material acceptable for the purpose. The closure shall be such that it may be readily removed, but will not drop out in ordinary handling.

16.4 Type 3, 3R, 3S, 4, 4X, 6, or 6P enclosures shall have a conduit hub or equivalent mounted in place to provide a watertight connection at conduit entrances in order to comply with the appropriate tests (refer to the Standard for Enclosures for Electrical Equipment, Environmental Considerations, UL 50E). The conduit hub does not need to be provided if the marking or instructions in 46.4 are provided.

16.5 An environmental type connection, such as provided for conduit entrance on a Type 2, 3, 3R, 3S, 4, 4X, 5, 6, or 6P enclosure, shall be a conduit hub, a knockout, a fitting, a threaded hole, or the equivalent. On a Type 12, 12K or 13 enclosure, it shall be a conduit hub, a fitting, a threaded hole or the equivalent. This connection shall be located so that when conduit is connected and the enclosure is mounted in the intended manner, the enclosure is found to be acceptable when subjected to the tests specified in the Standard for Enclosures for Electrical Equipment, Environmental Considerations, UL 50E.

Exception No. 1: For Type 2 and 3R enclosures, a hole for conduit is not required to be threaded if it is wholly below the lowest terminal lug or other live part intended for use within the enclosure.

Exception No. 2: Enclosures intended for use with conduit hubs or closure plates, but shipped from the factory without them, shall be marked or provided with instructions in accordance with 46.4.

16.6 A hole for open wiring in an enclosure marked Type 2, 3, 3R, or 3S shall be provided with a bushing and shall not be located either in the top or back of the enclosure unless a hood fitting is provided. If located in the side, the hole and hood shall be formed to provide a downward direction for wires leaving the enclosure.

16.7 A Type 12 enclosure shall have no conduit knockout or conduit opening and no hole through the enclosure other than a hole for a Type 12 mechanism, or the equivalent. A gasket, if provided, shall be oil resistant.

Exception: A Type 12 enclosure may employ a conduit opening if the instructions specified in 46.5 are included.

16.8 A Type 13 enclosure shall have no conduit knockouts, but may have other conduit openings if these openings have provisions for oil tight connections.

16.9 A field terminal compartment shall be located so that the connections can be readily inspected after the machine is installed as intended.

16.10 A field terminal compartment intended for the connection of a raceway shall be attached to the machine so as to preclude turning.

16.11 A field terminal or splice compartment attached to the case, end-bell, or frame of a machine shall be complete and shall enclose all field-wiring terminals and all splices to be made in the field.

16.12 An enclosure of cast metal to which a wiring system is to be connected in the field shall have a wall thickness not less than 3.2 mm (1/8 inch) at the point of a conduit opening or knockout, and 6.4 mm (1/4 inch) at a tapped hole for conduit.

16.13 The minimum dimension of cover opening and usable volume of a field compartment intended to enclose wire-to-wire connections to be made in the field to an input or output circuit shall be in accordance with Table 16.1, Table 16.2, or Table 16.3 as applicable.

16.14 The usable volume of a field compartment intended to enclose wire-to-wire connections to be made in the field to an input or output circuit shall be verified by any convenient means. When required, the volume of a test sample shall be verified as described in (a) – (d):

a) All cable clamps, fixture studs, grounding pigtails, internal screws, and other internal accessories are to be removed. Any projections that extend outside the plane of the open face of a box, such as ears for mounting a cover or a flush device, are to be ground flush with the face of the box.

b) All large openings are to be closed by flat, rigid plates clamped in place across the openings. One of the plates is to contain two small holes, one for the entrance of a measuring fluid, the other for venting air.

c) Using modeling clay, putty, glazing compound, or similar material:

1) A hole through the side or bottom of the sample and a hole between the sample and the plate mentioned in (b) are to be filled flush with the inside surface.

2) An internal hub, when tapped through, is to be filled flush with the end of the hub.

3) A bushed opening is to be filled flush with the conduit stop.

d) A clean, graduated vessel (pipette or the equivalent) having a volume equal to or greater than the volume specified for the machine rating in Table 16.1, Table 16.2, or Table 16.3, as applicable, is to be filled with water at room temperature. The water is then to be transferred from the vessel to the test sample through the hole in the plate specified in (b). The results are acceptable when the test sample holds a volume of water equal to or greater than the required volume specified in Table 16.1, Table 16.2, or Table 16.3.

Table 16.1
Field wiring compartment for machines 279 mm (11 inches) or less in diameter

Rated horsepower (kW)	Field wiring compartment			
	Minimum dimension of field wiring compartment opening		Minimum usable volume	
	mm	(inches)	cm^3	($inches^3$)
1 and smaller[a] (0.75)	41	(1-5/8)	170	(10.5)
1-1/2, 2, and 3[a] (1.1, 1.5, and 2.2)	45	(1-3/4)	275	(16.8)
5 and 7-1/2 (3.7 and 5.6)	50	(2)	365	(22.4)
10 and 15 (7.5 and 11.2)	65	(2-1/2)	595	(36.4)

[a] For a field wiring compartment partially or wholly integral with the frame or end shield, the minimum dimension of cover opening is not specified and the volume of the field wiring compartment per wire-to-wire connection may be not less than 18 cm^3 (1.1 cubic inch) for a machine rated 1 horsepower or less, or 23 cm^3 (1.4 cubic inch) for a machine rated 1-1/2, 2, and 3 horsepower.

Table 16.2
Field wiring compartment for a machine over 279 mm (11 inches) in diameter

Maximum full-load current for 3-phase machines with maximum of 12 leads[a], amps	Minimum dimension of field wiring compartment opening		Minimum usable volume	
	mm	(inches)	cm^3	($inches^3$)
0 – 45	65	(2.5)	595	(36.4)
46 – 70	84	(3.3)	1265	(77)
71 – 110	100	(4.0)	2295	(140)
111 – 160	125	(5.0)	4135	(252)
161 – 250	150	(6.0)	7380	(450)

Table 16.2 Continued on Next Page

Table 16.2 Continued

Maximum full-load current for 3-phase machines with maximum of 12 leads[a], amps	Minimum dimension of field wiring compartment opening		Minimum usable volume	
	mm	(inches)	cm^3	($inches^3$)
251 – 400	175	(7.0)	13775	(840)
401 – 600	200	(8.0)	25255	(1540)

[a] Auxiliary leads for such items as brakes, thermostats, space heaters, or exciting fields are not required to be evaluated when their current-carrying area does not exceed 25 percent of the current-carrying area of the generator power leads.

Table 16.3
Field wiring compartment for direct-current machines

Maximum full-load current for D-C machines with maximum of 6 leads[a], amps	Minimum dimension of field wiring compartment opening		Minimum usable volume	
	mm	(inches)	cm^3	($inches^3$)
0 – 68	65	(2.5)	425	(26)
69 – 105	84	(3.3)	900	(55)
106 – 165	100	(4.0)	1640	(100)
166 – 240	125	(5.0)	2950	(180)
241 – 375	150	(6.0)	5410	(330)
376 – 600	175	(7.0)	9840	(600)
601 – 900	200	(8.0)	18040	(1100)

[a] Auxiliary leads for such items as brakes, thermostats, space heaters, or exciting fields are not required to be evaluated when their current-carrying area does not exceed 25 percent of the current-carrying area of the machine power leads.

16.15 A field terminal compartment that encloses rigidly mounted machine terminals for field connection to an input or output circuit shall provide room for spacings in accordance with Table 18.1 or Table 18.2, as appropriate, and usable volume not less than that specified in Table 16.4.

16.16 A knockout in a sheet-metal enclosure for connection of a wiring system in the field shall be reliably secured but shall be capable of being removed without undue deformation of the enclosure.

16.17 A knockout as specified in 16.15 shall be surrounded by a flat surface that permits proper seating of a conduit bushing, and shall be located so that installation of a bushing at any knockout likely to be used during installation will not result in spacings less than the minimum acceptable values between uninsulated live parts and the bushing.

16.18 An integral conduit stop shall be provided at the inner end of a threaded conduit opening, or sufficient room shall be provided inside of the enclosure for attachment of a conduit bushing to the protruding end of the threaded conduit.

16.19 An integral conduit stop shall be smooth and rounded and shall have a throat or inner diameter as specified in Table 16.5.

Table 16.4
Field wiring compartments for rigidly mounted machine terminals

Power output conductor size[a]		Minimum usable volume per power supply conductor[b]	
AWG	(mm^2)	cm^3	(cubic inches)
14 and smaller	(2.1 and smaller)	16	(1)
12 and 10	(3.3 and 5.3)	20	(1-1/4)
8 and 6	(8.4 and 13.3)	37	(2-1/4)

[a] Based on copper supply conductors having a temperature rating of 60°C (140°F), except that connection of aluminum supply conductors will be assumed if terminals are acceptable for use with aluminum conductors.

[b] The specified volume is not applicable to machines with higher ratings, greater number of leads, or larger wire sizes, or for machines intended to be installed as a part of factory-wired equipment, without additional connection being required at the machine terminal housing during equipment installation, but the terminal housing shall be of ample size to make connections.

Table 16.5
Throat diameter of conduit stop

Trade size of conduit, inches	Throat diameter of conduit stop, mm (inches)			
	Minimum		Maximum	
1/2	14.1	(0.56)	15.8	(0.62)
3/4	18.8	(0.74)	20.9	(0.82)
1	24.0	(0.94)	26.6	(1.05)
1-1/4	31.5	(1.24)	35.0	(1.38)
1-1/2	36.8	(1.45)	40.9	(1.61)
2	47.2	(1.86)	52.5	(2.07)
2-1/2	56.4	(2.22)	62.7	(2.47)
3	70.1	(2.76)	77.9	(3.07)
3-1/2	81.1	(3.19)	90.1	(3.55)
4	92.0	(3.62)	102.3	(4.03)

16.20 In a threaded conduit opening not provided with an integral conduit stop, the threads shall be tapered 1 mm per 16 mm (3/4 inch per foot).

16.21 Threads in a conduit opening provided with an integral conduit stop may be straight or tapered.

16.22 A threaded conduit opening shall be provided with at least 3-1/2 full threads.

16.23 If threads for the connection of conduit are tapped all the way through a hole in an enclosure wall there shall not be less than 3-1/2 full threads and not more than the number specified in Table 16.6.

Table 16.6
Maximum number of threads in a conduit opening

Conduit size, inch	Number of threads per inch	Maximum number of threads
1/2, 3/4	14	7
1, 1-1/4, 1-1/2, 2	11-1/2	8
2-1/2, 3, 3-1/2, 4	8	9

16.24 A conduit hub not integrally cast with an enclosure shall:

a) Have a wall thickness before threading not less than that of the corresponding trade-size conduit;

b) Not depend upon friction alone to prevent it from turning; and

c) Withstand the torque specified in 33.5.

16.25 A conduit nipple used to enclose wiring leads shall fully engage at least 3-1/2 threads in the machine enclosure and be secured against turning, or be secured to the machine enclosure by a solid and continuous weld. The outer end of the nipple shall have at least 3-1/2 full threads.

16.26 A field-wiring terminal is considered to be a terminal to which a wire may be connected in the field; however, if the wire and a means of making the connection (a pressure terminal connector, a soldering lug, a solder loop, a crimped eyelet, or the like) is factory assembled to the wire and provided as part of the machine, the terminal is considered to be a factory-wired terminal.

16.27 A permanently connected machine shall be provided with field-wiring terminals for the connection of conductors having an ampacity acceptable for the machine; or the machine shall be provided with leads for such connection.

16.28 A machine provided with a terminal housing intended to be used for field wiring shall be provided with an equipment-grounding terminal at the machine housing. The terminal shall be provided on housings for wire-to-wire or fixed terminal connections, and may be located either inside or outside the machine terminal housing.

Exception: A means for attaching a terminal for a grounding conductor, such as a screw, a tapped hole, a nut and bolt combination, or the like, may be used provided:

a) The means is not likely to be removed during servicing; and

b) The means is located so that the addition of a terminal will not reduce electrical spacings in the terminal housing to a value less than the applicable value in Table 18.1 or Table 18.2, as appropriate.

16.29 A terminal solely for the connection of an equipment-grounding conductor shall be capable of securing a conductor of a size required for the application. The terminal shall be a pressure connector, clamp, or the equivalent. A connection device or fitting that depends solely on solder shall not be used. A sheet-metal screw shall not be provided for connection of the grounding conductor to enclosures.

Exception No. 1: A No. 10 or larger, wire-binding screw or stud-and-nut combination may be employed at a wiring terminal intended to accommodate a 10 AWG (5.3 mm^2) or smaller conductor when upturned lugs or the equivalent are provided to hold the wire in position. See 16.36.

Exception No. 2: A No. 8 or larger screw or stud-and-nut combination may be used at a terminal intended only for the connection of a 14 AWG (2.1 mm^2) or 12 AWG (3.3 mm^2) conductor.

Exception No. 3: A No. 6 or larger screw or stud-and-nut combination is able to be used at a terminal intended only for the connection of a 14 AWG (2.1 mm^2) conductor.

16.30 A wiring terminal shall be provided with a soldering lug or pressure terminal connector securely fastened in place – for example, firmly bolted or held by a screw.

Exception No. 1: A No. 10 or larger, wire-binding screw or stud-and-nut combination may be employed at a wiring terminal intended to accommodate a 10 AWG (5.3 mm^2) or smaller conductor if upturned lugs or the equivalent are provided to hold the wire in position. See 16.35.

Exception No. 2: A No. 8 screw or stud-and-nut combination may be used at a terminal intended only for the connection of a 14 AWG (2.1 mm^2) conductor.

16.31 A wiring terminal shall be prevented from turning.

16.32 A terminal plate tapped for a wire-binding screw shall be of metal not less than 1.27 mm (0.050 inch) thick, and there shall be two or more full threads in the metal.

Exception: A plate not less than 0.76 mm (0.030 inch) thick is acceptable provided that the tapped threads have equivalent mechanical strength.

16.33 The metal of a terminal plate may be extruded at the tapped hole to provide at least two full threads if the thickness of the unextruded metal is not less than the pitch of the thread.

16.34 Upturned lugs or a cupped washer shall be capable of retaining a conductor of the size specified in 16.28, but not smaller than 14 AWG (2.1 mm^2), under the head of the screw or within the cupped washer.

16.35 The free length of a field-connection lead inside a splice box or wiring compartment shall be 152 mm (6 inches) or more.

Exception No. 1: The lead may be less than 152 mm (6 inches) long if it is evident that the use of a longer lead may result in a risk of fire or electric shock.

Exception No. 2: For a machine more than 279 mm (11 inches) in diameter or rated more than 15 horsepower (11 kW), the leads shall be long enough to facilitate proper connections.

16.36 A terminal intended for the connection of a grounded output conductor shall be of, or plated with, metal that is substantially white in color and shall be readily distinguishable from the other terminals; or proper identification of that terminal shall be clearly shown in some other manner, such as on an attached wiring diagram. A lead intended for the connection of a grounded conductor shall be finished to show a white or gray color and no other lead for field connection shall be so identified.

16.37 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.

Exception: A lead larger than 6 AWG (13.3 mm^2) may have the insulation stripped completely from the exposed length, and be painted or otherwise colored green, or be marked with green tape or green colored adhesive.

16.38 Each lead or flexible cord provided for wiring to or for interconnection between parts of a machine, for example, machine windings to capacitor, shall be provided with a means to prevent stress from being transmitted to internal connections.

17 Factory Wiring Terminals and Leads

17.1 Among the factors to be considered in judging factory-wiring terminals and leads are the type and size of wire to be connected, ampacity of the terminals, and mechanical protection.

17.2 A factory-provided pigtail lead for equipment grounding connections shall be connected to the machine housing by a fastener that complies with Section 16, Input and Output Connections, and which is not intended to be removed during servicing, or by means of a rivet. Sheet metal screws shall not be used.

17.3 Terminals shall be secured to their supporting surfaces by means other than friction between surfaces so that they are prevented from turning or shifting in position if such motion may result in reduction of spacings to less than the minimum acceptable values.

17.4 A receptacle, attachment plug, or connector body intended to facilitate interconnection to an appliance, shall be acceptable for a current not less than the marked or assigned current rating of the machine and for the rated voltage of the machine.

17.5 Machines with multiple circuits of different voltages shall have suitable separation between circuits in accordance with 20.21.

18 Spacings

18.1 The requirements in 18.2 – 18.5 apply to a machine having input, output, control, or equipment-grounding connections that are intended to be made to the machine in the field.

18.2 The spacing between field-wiring terminals of opposite polarity, and a spacing between a field-wiring terminal and any other uninsulated metal part – dead or live – not always of the same polarity, shall not be less than that specified in Table 18.1 or Table 18.2, as appropriate.

Table 18.1
Minimum acceptable spacings at field wiring terminals for voltages up to 750

Potential involved, Volts	Minimum spacings through air or over surface[a]	
	mm	(inch)
250 or less	6.4	(1/4)
251 – 750	9.5	(3/8)

[a] Applies to the sum of the spacings involved where an isolated dead metal part is interposed.

Table 18.2
Minimum acceptable spacings at field wiring terminals for voltages over 750 V

Voltage range, Volts	Minimum spacings			
	Through air		Over surface	
	mm	(inches)	mm	(inches)
751 – 1000	9.5	(3/8)	12.7	(1/2)

18.3 The spacing at a field-wiring terminal is to be measured with wire of the appropriate size for the rating connected to the terminal as in actual service. The connected wire is to be the next larger size than would normally be required if the terminal will accommodate it properly or the device is not marked to restrict its use.

18.4 For an enclosure provided with conduit openings or knockouts, spacings not less than the minimum specified in Table 18.1 or Table 18.2, as appropriate shall be provided between uninsulated live parts and a conduit bushing used during installation.

18.5 When measuring a spacing between an uninsulated live part and a bushing installed in a knockout, it is to be assumed that a bushing having the dimensions specified in Table 18.3 is in place, and that a single locknut is installed on the outside of the enclosure.

Table 18.3
Dimensions of bushings

Trade size of conduit, inches	Bushing dimensions			
	Overall diameter		Height	
	mm	(inches)	mm	(inches)
1/2	25.4	(1)	9.5	(3/8)
3/4	31.4	(1-15/64)	10.7	(27/64)
1	40.5	(1-19/32)	13.1	(33/64)
1-1/4	49.2	(1-15/16)	14.3	(9/16)
1-1/2	56.0	(2-13/64)	15.1	(19/32)
2	68.7	(2-45/64)	15.9	(5/8)
2-1/2	51.8	(3-7/32)	19.0	(3/4)
3	98.4	(3-7/8)	20.6	(13/16)
3-1/2	112.7	(4-7/16)	23.8	(15/16)
4	126.2	(4-31/32)	25.4	(1)
4-1/2	140.9	(5-35/64)	27.0	(1-1/16)
5	158.0	(6-7/32)	30.2	(1-3/16)
6	183.4	(7-7/32)	31.8	(1-1/4)

18.6 Other than at field-wiring terminals, the spacing between uninsulated live parts of opposite polarity and between an uninsulated live part and a dead metal part that is exposed to contact by persons or that may be grounded shall either not be less than the appropriate value specified in Table 18.4, or alternatively be evidenced through compliance with the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840.

Exception: The spacing requirements do not apply to the inherent spacings of a component of the machine, such as a snap switch. Such spacings are judged on the basis of the requirements for the component in question.

Table 18.4
Minimum acceptable spacings at other than field-wiring terminals

Voltage range, volts	Parts involved	Over surface		Through air	
		mm	(inches)	mm	(inches)
0 – 125	Commutator or collector rings	1.6	(1/16)	1.6	(1/16)
	Elsewhere in the motor	1.6	(1/16)	1.6	(1/16)
126 – 250	Commutator or collector rings	1.6	(1/16)	1.6	(1/16)
	Elsewhere in the motor	2.4	(3/32)	2.4	(3/32)
251 – 750	Commutator or collector rings and live parts of the brush rigging	6.4	(1/4)	6.4[b]	(1/4)
	Elsewhere in the motor	6.4[a]	(1/4)	6.4[a]	(1/4)
751 – 1000	Elsewhere in the motor	12.7	(1/2)	9.5	(3/8)

[a] Film-coated wire is considered to be an uninsulated live part. However, a spacing of not less than 2.4 mm (3/32 inch), over surface and through air between film-coated wire, rigidly supported and held in place on a coil, and a dead metal part is acceptable.

[b] Through-air spacings involving a collector ring may be not less than 3.2 mm (1/8 inch).

18.7 If an uninsulated live part is not rigidly fixed in position by means other than friction between surfaces or if a movable dead metal part is in proximity to an uninsulated live part, the construction shall be such that the minimum acceptable spacing is maintained.

18.8 The applicable pollution degree and overvoltage category, as defined in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, shall be that of the microenvironment of the spacing(s) being evaluated, which may or may not be the same as the pollution degree and overvoltage category of the entire product.

18.9 An insulating liner or barrier of vulcanized fiber or similar material used where a spacing is otherwise less than the minimum required value shall be no less than 0.8 mm (1/32 inch) thick, and shall be so located or of such material that it is not adversely affected by arcing.

Exception No. 1: Vulcanized fiber no less than 0.4 mm (1/64 inch) thick may be used with an air spacing of no less than 50 percent of the minimum required through-air spacing.

Exception No. 2: Other insulating material or insulating material having a thickness less than that specified may be used when, upon investigation, it is evaluated for the particular application, in accordance with the requirements for Internal Barriers in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

18.10 A capacitor, as described in Section 26, Capacitors, that employs an internal interrupter to protect against expulsion of a flammable dielectric in the event of rupture of the enclosure shall have additional through-air expansion spacings in the axial direction to allow for movement of the terminals. The additional expansion spacing shall be at least 12.7 mm (1/2 inch) through air in addition to the applicable electrical spacings. See Table 18.5.

Table 18.5
Examples of minimum acceptable spacings at capacitor terminals

Motor rating, volts	Expansion spacing		Electrical spacing[a]		Total spacing[a]	
	mm	(inch)	mm	(inch)	mm	(inch)
0 – 300	12.7	(1/2)	1.6	(1/16)	14.3	(9/16)
301 – 600	12.7	(1/2)	3.2	(1/8)	15.9	(5/8)

[a] An insulating liner or barrier as mentioned in 18.9 may be used in lieu of the required electrical spacing; however, at least 12.7 mm (1/2 inch) expansion spacing shall be provided.

19 Current-Carrying Parts

19.1 A current-carrying part shall be of silver, copper, a copper-alloy, aluminum, or other material acceptable for the particular application.

19.2 Plated iron or steel may be used for a current-carrying part within a machine if acceptable in accordance with Section 2, Components, but unplated iron or steel is not acceptable. The foregoing restriction does not apply to stainless steel or to other corrosion-resistant alloys.

20 Internal Wiring

20.1 Unless it is to be judged as an uninsulated live part, each insulated internal conductor, including an equipment-grounding conductor, shall consist of wire of a type that is acceptable for the particular application when considered with respect to:

a) Exposure to oil, grease, cleaning fluid, or other substances likely to have a deleterious effect on the insulation;

b) Exposure to moisture; and

c) The temperature, voltage, and other conditions of service to which the wiring is likely to be subjected.

20.2 Insulated wire shall be standard building wire or appliance wiring material that is acceptable for the purpose.

20.3 Building wire used as internal wiring shall comply with the *National Electrical Code*®, NFPA 70, with regard to voltage, current, temperature, and minimum insulation thickness for the insulation material type.

20.4 Appliance wiring material used as internal wiring shall comply with the Standard for Appliance Wiring Material, UL 758, and shall have a minimum insulation thickness as specified in UL 758, as appropriate for the insulation material type [see the table for Thickness Requirements For Extruded, Non-Fluoropolymer Insulation Materials, the table for Thickness Requirements For Extruded, Fluoropolymer Insulation Materials (ECTFE, ETFE, FEP, MFA, PFA, PTFE, and PVDF), and the table for Thickness Requirements For PVC Insulation With A Nylon Jacket, in UL 758].

20.5 Wiring shall be protected from sharp edges – including screw threads – burrs, fins, moving parts, and other features that might abrade the insulation on conductors.

20.6 A hole in a metal wall through which insulated wires pass shall be provided with a smoothly rounded bushing or shall have smooth surfaces, free of burrs, fins, sharp edges, and the like, upon which the wires may bear, to prevent abrasion of the insulation.

20.7 All splices and connections shall be mechanically secure and shall provide adequate and reliable electrical contact.

20.8 A soldered connection shall be made mechanically secure before being soldered.

20.9 A wire inserted into a hole in a terminal is considered to be mechanically secure whether or not it is bent before soldering.

20.10 An internal connection shall be provided with acceptable means to prevent it from becoming loosened due to vibration if such loosening might result in a risk of fire, electric shock, or injury to persons.

20.11 An internal connection terminating in an open-end spade lug is not acceptable unless additional means, such as upturned lugs or the like, are provided to hold the lug in place should the wire-binding screw or nut become slightly loosened. In any case, an open-end lug with a lock washer alone is not acceptable.

20.12 A splice shall be provided with insulation equivalent to that of the wires involved if permanence of spacing between the splice and other metal parts cannot be established.

Exception: A splice within a machine winding is not required to have insulation equivalent to that of the wires involved.

20.13 A splicing device such as a pressure wire connector that provides adequate mechanical security and insulation acceptable for the voltage to which it is subjected may be employed.

20.14 In evaluating splice insulation consisting of coated fabric, thermoplastic, or other tubing, such factors as its electrical and mechanical properties and its flammability in accordance with the requirements in Section 22, Electrical Insulation, are to be evaluated. Thermoplastic tape wrapped over a sharp edge is not acceptable.

20.15 On a splice where the voltage involved is less than 250 volts, insulation evaluated to the requirements in Section 22, Electrical Insulation, and consisting of two layers of thermoplastic tape is acceptable.

20.16 Stranded internal wiring shall be connected at a wire-binding screw so that loose strands of wire will be prevented from contacting other uninsulated live parts not always of the same polarity as the wire, and from contacting dead metal parts. This may be accomplished by use of a pressure terminal connector, a soldering lug, a crimped eyelet, soldering all strands of the wire together, or other reliable means.

20.17 Splices between machine leads and windings may:

a) Employ insulating tubing found suitable for the voltage, current, temperature, and other pertinent conditions through evaluation to the Standard for Extruded Insulating Tubing, UL 224;

b) Employ coated electrical sleeving found suitable for the voltage, current, temperature, and other pertinent conditions through evaluation to the Standard for Coated Electrical Sleeving, UL 1441;

c) Employ insulation found suitable for the voltage, current, temperature, and other pertinent conditions through compliance with Section 22, Electrical Insulation;

d) Employ insulation suitable for the voltage, current, temperature, and other pertinent conditions through compliance with the protector insulation test described in the Standard for Automatic Electrical Controls for Household and Similar Use; Part 2 Particular Requirements for Thermal Motor Protectors, UL 60730-2-2; or

Exception: Alternatively, the temperatures used for the oven temperature cycling conditioning of the Protector Insulation Test may be derived from the Figure for "Conditioning time versus oven temperature for temperature index of adhesives" in the Standard for Polymeric Materials - Use in Electrical Equipment Evaluations, UL 746C, where the temperature index T is the average locked rotor temperature limit for the insulation system Class and the spread between the higher and lower of the oven cycling temperatures is no less than 50°C. A shorter or longer time at a higher or lower temperature respectively may be employed if agreeable to all concerned, but a period no less than 300 hours is to be used.

e) Employ material from a system which has been evaluated in accordance with the Standard for Systems of Insulating Materials – General, UL 1446. Materials which have additionally been evaluated as ground or interwinding insulation need no further evaluation. Other materials within a system used to insulate a splice shall be subjected to a minimum of 18 days of locked-rotor conditioning, followed by the Dielectric Voltage-Withstand Test in Section 37.

20.18 Electrical quick connect tabs and connectors, used either for internal wiring or for factory terminals, shall comply with the Standard for Electrical Quick-Connect Terminals, UL 310.

20.19 Ring terminals, spade terminals, and the like shall comply with the requirements of the Standard for Wire Connectors, UL 486A-486B.

20.20 Terminal blocks, where the efficacy of the connection relies upon the integrity of a polymeric part of the terminal block, whether used for internal wiring or for factory or field connection terminals shall comply with the Standard for Terminal Blocks, UL 1059.

20.21 Insulated conductors of circuits having different voltages within a machine, including wires within a terminal box and/or wiring compartment, shall be separated. The separation shall be accomplished by one of the following means:

a) A physical barrier;

b) Clamping, routing, or an equivalent means that maintains permanent separation from other circuits; or

c) Providing all conductors within the same space (such as a wiring cabinet and/or junction box) with insulation suitable for the maximum voltage present.

21 Bonding for Grounding

21.1 Bonding conductor

21.1.1 A bonding conductor shall consist of a material acceptable for use as an electrical conductor.

21.1.2 A bonding conductor of ferrous metal shall be protected against corrosion by painting, plating, or the equivalent.

21.1.3 The size of the conductor or strap employed to bond an electrical enclosure or machine frame shall be based on the rating of the branch-circuit overcurrent-protective device by which the equipment is intended to be protected. Other than as noted in 21.1.7, the size of the conductor or strap shall be in accordance with Table 21.1.

Table 21.1
Minimum size of bonding wire conductor

Rating of overcurrent-protective device, amperes	Size of bonding conductor	
	Copper wire, AWG	Aluminum or copper-clad aluminum wire, AWG
15	14	12
20	12	10
30	10	8
40	10	8
60	10	8
100	8	6
200	6	4
400	3	1
600	1	2/0

21.1.4 A bonding conductor may be bare.

21.1.5 The surface of the insulation (if provided) on a bonding conductor shall be green with or without one or more yellow stripes.

21.1.6 A conductor, such as a clamp or strap, used in place of a separate wire conductor shall have a minimum cross-sectional conducting area equivalent to the wire size specified in Table 21.1.

21.1.7 A bonding conductor is not required to be larger than the machine-circuit conductors. A smaller conductor than required by 21.1.3 may be used if, using a separate sample for each test, neither the bonding conductor nor the connection opens under either of the following conditions:

a) When carrying an overload current equal to 1.35 or 2 times the rating or setting of the intended branch-circuit overcurrent-protective device for the time specified in Table 21.2; or

b) When subjected to the Limited Short Circuit Test, Section 38, in the as-received condition only.

Table 21.2
Duration of overcurrent test

Rating or setting of branch-circuit overcurrent-protective device, amperes	Test time, minutes	
	At 135 percent current	At 200 percent current
0 – 30	60	2
31 – 60	60	4
61 – 100	120	6
101 – 200	120	8
201 – 400	120	10
401 – 600	120	12

21.2 Bonding and grounding connections

21.2.1 Bonding shall be by a positive means, such as by clamping, riveting, bolted or screwed connection, brazing, or welding. Connection devices or fittings that depend solely on solder shall not be used. The bonding connection shall reliably penetrate nonconductive coatings such as paint. Compliance shall be checked by the Grounding Test, Section 39.

21.2.2 A bolted or screwed connection that incorporates a star-washer under the screw head, a serrated screw head, or equivalent, is acceptable for penetrating nonconductive coatings if required for compliance with 21.2.1.

21.2.3 If the bonding means depends upon screw threads, two or more screws, or two full threads of a single screw engaging metal, is considered to comply with 21.2.1.

21.2.4 A sheet metal screw is unacceptable for use as a bonding connection.

21.2.5 A splice shall not be employed in wire conductors used to bond an electrical enclosure, a machine frame, or other electrical components.

21.3 Resilient elastomeric mountings

21.3.1 The requirements in 21.3 apply only to resilient elastomeric mountings that are depended upon for bonding.

21.3.2 An electrical bonding member across a resilient mounting shall be metal. Conductive elastomeric compounds – loaded rubber – are not acceptable for bonding.

21.3.3 Electrical bonding shall be such that a path for electric current exists regardless of the manner in which the machine is rotated with respect to the base.

21.3.4 A bonding member shall be secured by a means that provides retention if the machine is removed from its base. A connection that it is necessary to remove intentionally, such as a screw or a bolt, at one or both ends of a bonding member is considered to comply with this requirement.

21.3.5 A bonding member shall be enclosed, located, or otherwise protected so that it is unlikely to be damaged during handling or installation.

21.3.6 A metal part of a resilient mounting that also serves as a bonding path shall be inherently resistant to corrosion or shall be plated or finished as protection against corrosion (see Section 14, Protection Against Corrosion).

21.3.7 Metal parts in a bonding path shall be galvanically compatible so that there is little or no electrolytic action between dissimilar metals (see 14.1).

21.3.8 A bonding member shall have the flexibility necessary to withstand normal mechanical stress due to vibration.

21.3.9 A resilient elastomeric mounting shall comply with the performance requirements specified in Section 36, Resilient Elastomer Mounting Tests.

22 Electrical Insulation

22.1 Material in direct contact with uninsulated live parts other than magnet wire shall be porcelain or another material investigated and found acceptable in accordance with the requirements covering mechanical/electrical property considerations of the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C. These materials shall withstand the most severe conditions likely to be met in service.

Exception: Small parts and adhesives need not be investigated if they are:

a) Not relied upon to maintain the proper functioning of the device with regard to the likelihood of electric shock, fire, and injury to persons; and/or

b) Not relied upon to maintain separation between uninsulated live parts of opposite polarity, live parts, and accessible metal parts and/or uninsulated live parts and earth ground.

22.2 The material of any part of a base or body shall not introduce a risk of fire or shock by warping, creeping, or distorting under conditions of arcing, temperature, and mechanical stress that are likely to occur in service.

22.3 Material in contact with live parts other than magnet wire shall comply with Table 22.1 with respect to resistance to flame propagation, resistance to arc tracking, resistance to ignition from electrical sources, resistance to moisture absorption, dielectric strength, and mechanical strength. A material shall not display a loss of these properties beyond the minimum required level as a result of aging.

Exception No. 1: The minimum required CTI (PLC) for rotating machinery that successfully passes the Dust Test – Outdoor Method as specified in the Standard for Enclosures for Electrical Equipment, Environmental Considerations, UL 50E, is 4.

Exception No. 2: Small parts and adhesives need not be investigated if they are:

a) Not relied upon to maintain the proper functioning of the device with regard to the likelihood of electric shock, fire, and injury to persons; and/or

b) Not relied upon to maintain separation between uninsulated live parts of opposite polarity, live parts, and accessible metal parts and/or uninsulated live parts and earth ground.

Exception No. 3: The application of the provisions of Section 9, Creepage Distances, of the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, may be used as an alternative to a material having the CTI (PLC) required by Table 22.1.

Exception No. 4: Commutator insulation material made of phenolic is acceptable with no further testing.

Exception No. 5: Commutator insulation material other than phenolic and having a CTI (PLC) less than specified in Table 22.1 may be used provided it complies with 37A.1.

Table 22.1
Performance levels

Flame rating	Volume resistivity (ohm-cm) (dry/wet)	Dielectric strength (volts)	CTI (PLC)	HAI (PLC)	HWI (PLC)
HB	$50/10 \times 10^6$	5000	2	1	2
V-2, VTM-2	$50/10 \times 10^6$	5000	2	2	2
V-1, VTM-1	$50/10 \times 10^6$	5000	2	2	3
V-0, VTM-0	$50/10 \times 10^6$	5000	2	3	4

22.4 Material used to support live parts or an insulating barrier shall be acceptable for continuous operation at the maximum temperature measured on the material during the Temperature Test, Section 32.

22.5 A small molded part such as a terminal block shall have mechanical strength and rigidity that withstands the stresses of actual service.

22.6 A molded part shall not exhibit softening of the material determined by handling immediately after the condition specified in 33.4, nor shall there be shrinkage, warpage, or other distortions as determined after cooling to room temperature that results in any of the following:

a) Reduction of spacings between uninsulated live parts of opposite polarity, uninsulated live parts and accessible dead or grounded metal, and uninsulated live parts and the enclosure below the minimum acceptable values;

b) Uninsulated live parts or internal wiring accessible to contact, or defeating the integrity of the enclosure so that acceptable mechanical protection is not afforded to internal parts of the equipment;

c) Interference with the intended operation or servicing of the equipment.

23 Insulation Systems

23.1 The insulation system of a machine shall be rated for a temperature not less than that at which the machine windings are intended to operate in the end-use application under normal conditions. See Figure 23.1 for details on investigations of machine insulation systems or alternate major components and materials.

23.2 Cemented joints used to join two parts of an insulation system so as to provide a contiguous barrier in lieu of spacings shall comply with the requirements for Adhesives – Specialized Applications, in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

23.3 The acceptance criteria following the tests specified in 23.2 are:

a) There shall be no obvious separation of the joined parts; and

b) The motor shall successfully complete the Dielectric Voltage-Withstand Test specified in Section 36.

23.4 The test program specified in this Section for a Class A insulation system shall consider the end-use of the machine. For instance, a machine for use in attended equipment, products in operation while the user is present, then the 15-Day Abnormal Operation Test specified in the Standard for Polymeric Materials – Coil Forms, UL 1692, may not be required. The end product Standard shall be reviewed before developing a test program for the insulation system.

23.5 Materials in direct contact with uninsulated live parts other than magnet wire shall be a material specified in 22.1 or comply with the Mechanical/Electrical Property Considerations table in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C. Table 22.1 provides the specific performance levels required.

23.6 All materials used in the insulation system of a machine rated above Class A shall comply with the requirements specified in the Standard for Systems of Insulating Materials – General, UL 1446, or in accordance with Annex A.

Exception: Polymeric enclosures of thermal motor protectors and/or insulating tubing or sleeving used to insulate thermal motor protectors which are in contact with motor windings are not required to be part of the motor insulating system.

23.7 *Deleted*

23.8 *Deleted*

23.9 If materials comprising components of two different insulation systems are to be used within the same machine, they shall be physically separated by at least 3.18 mm (0.125 inch) of air space.

Exception No. 1: Two different insulation systems may be used, one for the stator and one for the rotor, of a universal motor and they need not be separated by the minimum distance of 3.18 mm (0.125 inch).

Exception No. 2: This requirement does not apply to motors rated Class A.

23.10 All insulation systems employing integral ground insulation shall comply with the requirements specified in the Standard for Systems of Insulating Materials – General, UL 1446.

23.11 Class A insulation systems shall consist of a combination of magnet wire and major component insulation materials evaluated and found to operate as intended for this use. Thermoset materials and materials in Table 23.1 at the thicknesses specified are permitted to be used without further evaluation. Wood is permitted to be used for wedges. Other materials shall comply with 23.12.

Table 23.1
Primary Class A insulating materials and minimum thicknesses

Material	Minimum thickness	
	mm	(inches)
Vulcanized fiber	0.71	(0.028)
Polyethylene terephthalate film	0.18	(0.007)
Cambric	0.71	(0.028)
Treated cloth	0.71	(0.028)
Electrical grade paper	0.71	(0.028)
Mica	0.15	(0.006)
Aramid paper	0.25	(0.010)

23.12 For Class A insulation systems employing other materials or thinner materials than those indicated in Table 23.1 or a combination of materials, the materials, whether polymeric or not polymeric (treated cloth, for example), shall comply with the requirements specified in the Standard for Polymeric Materials – Coil Forms, UL 1692. When reviewing Figure 23.1 for tests related to the use of insulating materials in insulating systems of UL 1692, the end-use of the machine shall be considered as indicated in 23.4. Any of the possible tests in UL 1692 may be eliminated or adapted to meet a specific end-use application. The Locked Rotor Cycling Test described in 42.2.2 may be performed in lieu of the Abnormal Conditioning Test of 7.4, Severe Conditioning Test of 7.5, Overload Burnout Conditioning Test of 7.6, and the 15-Day Abnormal Operation Test of 7.7, in UL 1692.

Exception: The combination of the Locked Rotor Temperature Test and Locked Rotor Endurance Tests described in Section 3, Locked-Rotor or No-Load Temperature Test, and Section 4, Endurance Test, of the Standard for Impedance Protected Motors, UL 1004-2, and Section 8, Locked Rotor Temperature Test, and Section 9, Locked Rotor Endurance Test, of the Standard for Thermally Protected Motors, UL 1004-3, may be substituted for the Locked Rotor Cycling Test.

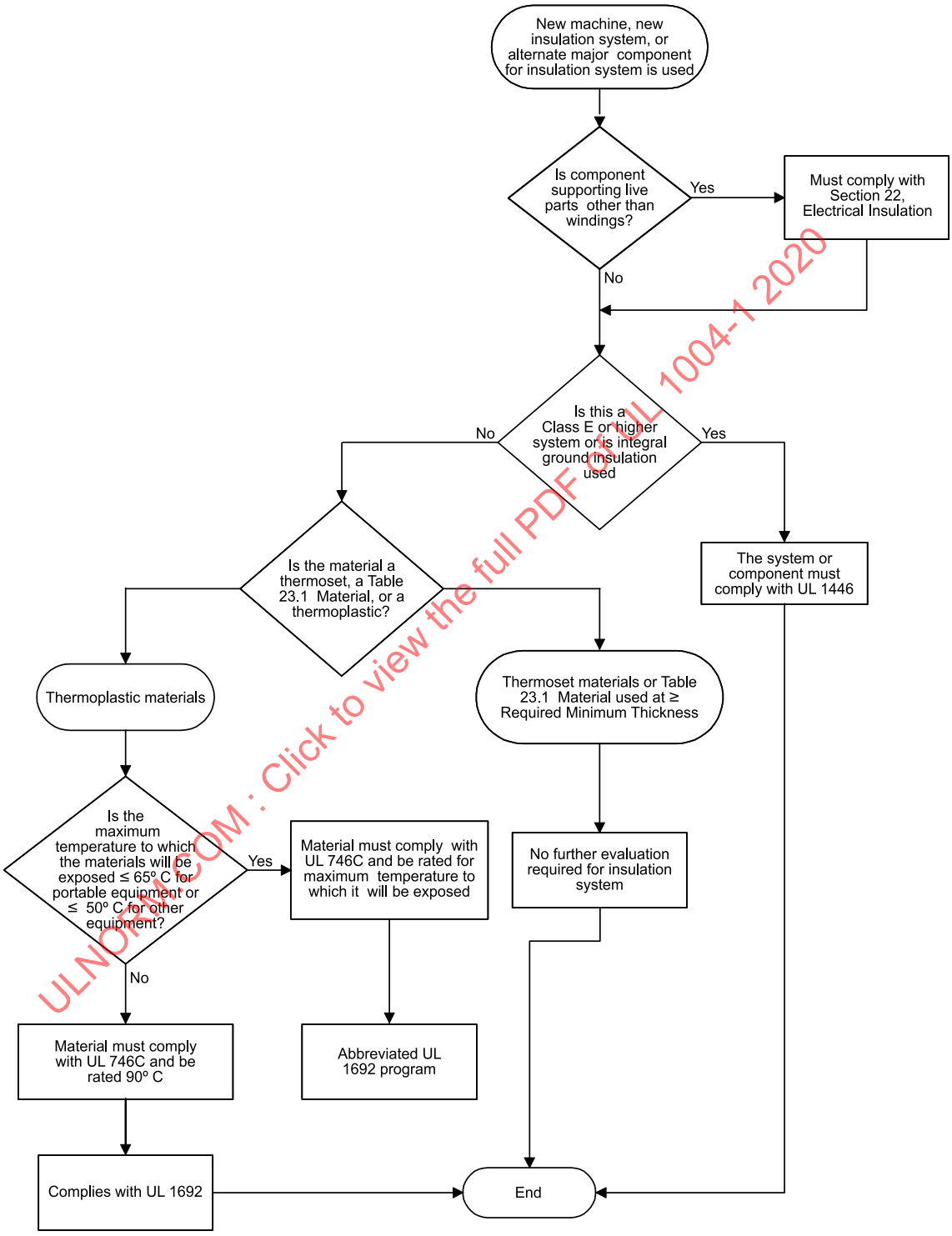
23.13 Machines provided with oil as a cooling or insulating medium shall be subjected to the Oil Compatibility Test, Section 40, to ensure that incompatibility of the oil with the remaining insulation system materials does not result in unacceptable deterioration of insulating properties.

23.14 The oil used in machines that make use of oil as a cooling or insulating medium shall have a flash point no lower than 95°C (203°F) higher than the temperature rating of the insulation class, (for example, 200°C for a Class A motor).

Exception: A thermally protected motor evaluated to the requirements of the Standard for Impedance Protected Motors, UL 1004-2, or the Standard for Thermally Protected Motors, UL 1004-3, may use an oil with a flash point no lower than 20° C (36° F) higher than the highest temperature recorded during the Locked Rotor Tests.

Figure 23.1

Investigation of machine insulation system or alternate major insulation system component



NOTE - Classification of an insulation component as major or minor shall be determined per the requirements in the Major and Minor Components section of UL 1446, Standard for Systems of Insulating Materials - General.

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24 Windings

24.1 A machine winding shall resist the absorption of moisture and shall be formed and assembled in a uniform manner.

24.2 With reference to the requirement in 24.1, film-coated wire is not required to be additionally treated to retard absorption of moisture, but fiber slot liners, cloth coil wrap, and similar moisture-absorptive materials shall be provided with impregnation or otherwise treated to retard the absorption of moisture.

24.3 A primary crossover lead for a bobbin wound machine shall be suitably and reliably spaced (see Section 18, Spacings) from adjacent windings or suitable insulation (crossover insulation) shall be provided (See Section 22, Electrical Insulation, and Section 23, Insulation systems).

Exception No. 1: Crossover insulation (aside from the film integral to the magnet wire) or reliable spacing of the crossover lead is not required if the maximum power available at the crossover point is less than 15 watts.

Exception No. 2: Crossover insulation (aside from the film integral to the magnet wire) or reliable spacing of the crossover lead is not required for a motor evaluated for use as a component of a specific product and intended for air movement only, provided that it meets the following criteria:

a) The free end of a cut crossover lead shall not be capable of contacting accessible dead metal parts of the motor. The cut can be made at any point where the crossover lead is not captivated by the winding coil or other constraining part. If this criterion is not met, the entire motor shall be considered an uninsulated live part in the end application and shall be so marked (e.g. "live part").

b) The motor shall be marked in accordance with 44.12.

25 Brush Holders

25.1 A brush-holder assembly shall be constructed so that when a brush is worn out – no longer capable of performing its function – the brush, spring, and other parts of the assembly are retained to the degree necessary to prevent accessible dead metal parts from becoming energized, and to prevent live parts from becoming accessible.

26 Capacitors

26.1 All motor starting or running capacitors shall comply with the construction requirements in the Standard for Capacitors, UL 810.

26.2 All non-electrolytic motor starting or running capacitors shall comply with the testing requirements of the Standard for Capacitors, UL 810.

26.3 A motor starting or running capacitor, mounted on a motor in end-use applications not intended to be totally enclosed, shall be housed within an enclosure that protects the capacitor against mechanical damage and prevents the emission of flame or molten material resulting from malfunction or breakdown of the capacitor. The enclosure shall comply with the requirements in Section 8, Frame and Enclosure.

26.4 The individual enclosure of an electrolytic capacitor used for motor starting or running that is not provided with a means for venting and with an opening more than 1.6 mm (1/16 inch) wide in the capacitor enclosure or between the capacitor enclosure and the motor housing shall be subjected to the Electrolytic Capacitor Overvoltage Test, Section 41.

26.5 All motor starting or running capacitors shall protect against expulsion of the dielectric medium under both normal and abnormal conditions of use.

26.6 A motor starting or running capacitor shall be rated for the appropriate voltage, and with the exception of electrolytic type, the maximum available fault current (AFC) to which it can be subjected, in accordance with the following:

a) A value of 5,000 A minimum when connected directly across the line;

b) For capacitors connected in series with a motor coil, the maximum current available to a short-circuited capacitor, when connected in series with the motor coil energized under locked rotor conditions; and

c) A dry metallized-polypropylene film capacitor operating at a maximum of 330 VRMS shall not be required to have a maximum AFC rating.

27 Switches

27.1 A start switch or auxiliary switch integral to or provided with a motor shall operate as required for the intended application, shall have a rating suitable for the load to be controlled, shall comply with the requirements of the Standard for Automatic Electrical Controls for Household and Similar Use, Part 1: General Requirements, UL 60730-1, as an operating control, and shall successfully complete 100,000 cycles of endurance as part of the UL 60730-1 test program.

Exception No. 1: This requirement does not apply to a start switch used in a thermally protected motor.

Exception No. 2: If there is no potential risk of fire or electric shock caused by a start switch that experiences a single-fault failure in either the open or shorted condition, then this requirement does not apply to that switch.

Exception No. 3: Switches where the switching function is accomplished by means of a semiconductor junction and does not involve any mechanical or eletromechanical action are required to undergo 100 cycles of endurance instead of 100,000 cycles.

28 Non-metallic Functional Parts

28.1 A non-metallic functional part, the breakdown of which creates a risk of fire, electric shock or injury to persons, shall be evaluated as described in this Section and as illustrated in Figure 28.1.

Exception No. 1: A non-metallic part outside the enclosure of a totally-enclosed motor is not required to be investigated with respect to resistance to ignition from electrical sources.

Exception No. 2: A non-metallic functional part which forms a part of a motor which complies with the Locked-Rotor Endurance Test of the Standard for Impedance Protected Motors, UL 1004-2, or the Standard for Thermally Protected Motors, UL 1004-3, is not required to be further evaluated.

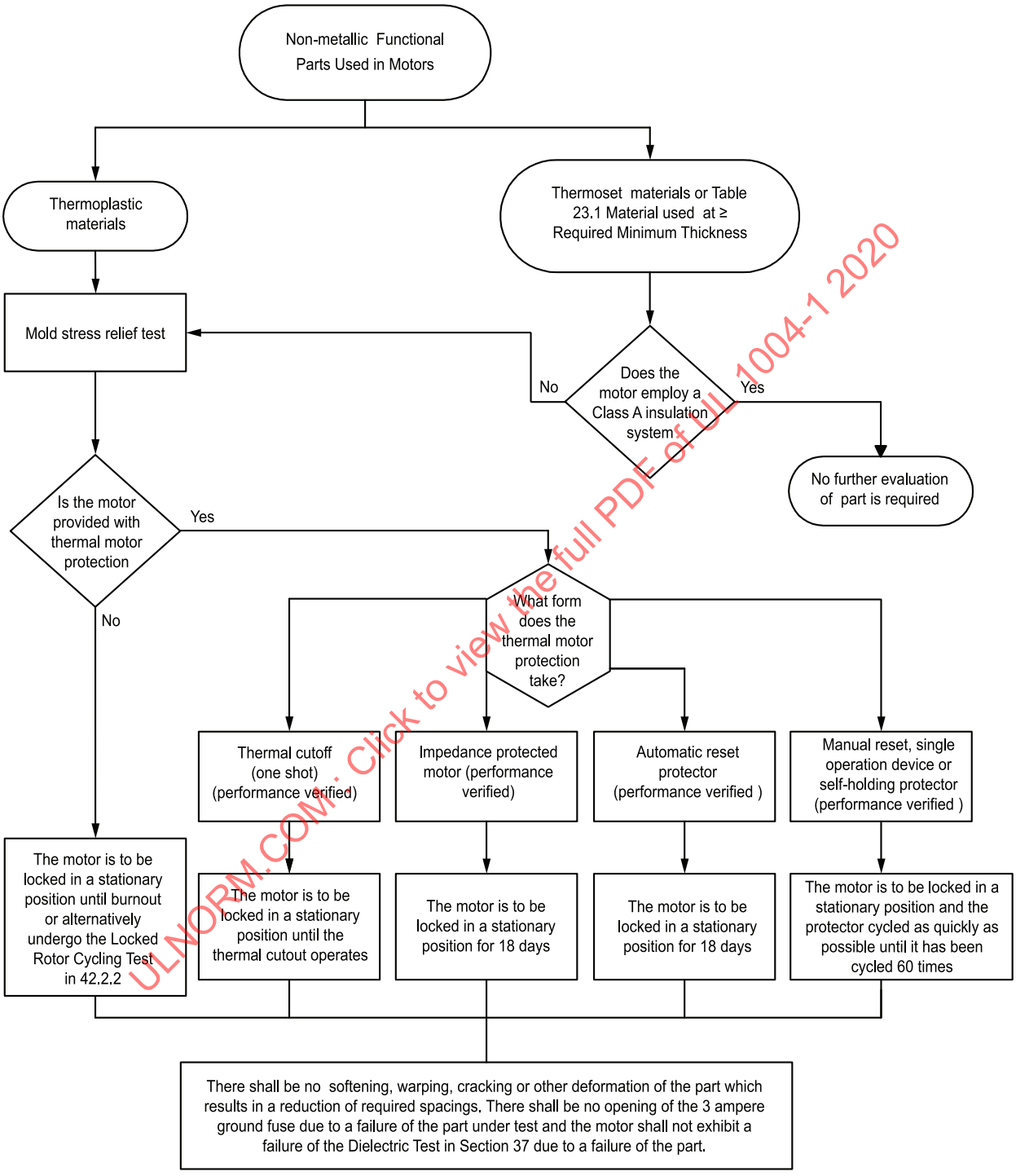
Exception No. 3: This requirement does not apply to a non-metallic functional part that is either:

a) Made of a thermoset material; or

b) Has an established RTI which is higher than the required values of the Temperature Test of Section 32.

Figure 28.1

Non-metallic functional parts



28.2 If the non-metallic functional part is fabricated of a thermoset material or a material described in Table 23.1, and used at the required minimum thickness, and be used in a machine employing a Class A insulation system, then no further evaluation is required.

28.3 All non-metallic functional parts except those described in 28.2 shall undergo the mold stress relief test described in 33.4, the Locked Rotor Test for Non-Metallic Functional Parts, Section 42, and the Dielectric Voltage-Withstand Test, Section 37.

Exception: The combination of Locked Rotor Temperature Test and Locked Rotor Endurance Test required for impedance protected and thermal device protected motors may be substituted for the Locked Rotor Test for Non-Metallic Functional Parts, Section 42. At the conclusion of the Locked Rotor Temperature Test and the Locked Rotor Endurance Test (if it is conducted), there shall be no softening, warping, cracking or other deformation of the part.

29 Traction Motors

29.1 Traction motors shall be evaluated, as specified in 33.8, for tolerance to the vibration encountered in their intended use.

PERFORMANCE

30 General

30.1 Machines shall comply with the applicable requirements when tested as described herein. A machine of a type not specifically described herein shall be tested in accordance with the intent of these requirements.

30.2 The performance tests are to be conducted on representative samples of the machine.

30.3 All locked rotor tests are to be conducted with the frame of the motor grounded through a 3-A non-time delay fuse.

30.4 For each test, the machine is to be mounted to wood or other material of low thermal conductivity.

30.5 Blades or other load attachments are to be removed from the machine. Integral mounting brackets are to be left in place.

30.6 A machine is to be mounted accordingly when the machine has:

a) A permanently attached, fixed, or rigid base;

b) Instructions for mounting marked on the machine; or

c) A construction feature, such as an oil hole, indicating a mounting position.

A motor without one of these features shall be tested with the protector in the maximum possible down position. A motor with one of these features may be tested with the protector in the maximum possible down position when agreeable to those concerned.

30.7 The voltage of the supply circuit shall be as specified in Table 30.1. For motors intended for use over a range of voltages, all applicable nominal voltages shall be tested. For example, a motor rated 200 – 230 V shall be tested at 208 V and at 240 V.

Exception: A motor having a voltage rating outside the ranges specified in Table 30.1 shall be tested at 100 – 105 percent of the rated voltage, but not less than 100 percent.

Table 30.1
Test voltages

Motor nameplate rating, volts	Nominal test voltage
110 – 120	120
200 – 208	208
220 – 240	240
254 – 277	277
440 – 480	480
550 – 600	600

30.8 A motor shall be tested under each intended operating condition with respect to each rated voltage, frequency, speed, and rotation direction. When rated for two frequencies, the motor shall be tested at both frequencies. When rated for a frequency range, the motor shall be tested at the minimum rating and the maximum rating.

Exception: Motors, such as split-phase motors, that are reversed by interchanging one winding with respect to another, are not required to be tested in both rotation directions.

30.9 Testing is to be conducted at any ambient temperature between 10°C (50°F) and 40°C (104°F) unless a motor is marked with an ambient temperature that does not fall within this range, in which case the motor is to be tested at the marked ambient.

31 Ratings Tests

31.1 Generator output test

31.1.1 When tested as described in 31.1.2, the generator output voltage and output power shall be within 5 percent of the nominal output rating. In addition, the generator output voltage shall be within 5 percent of the nominal output rating in the range from no-load to rated full-load during any steady-state condition.

31.1.2 The generator is to be connected to a linear load having adjustable impedance. The generator is to be run at rated RPM and is to be increasingly loaded until one of the following occurs:

a) The generator produces full rated output power multiplied by any service factor if provided;

b) The output voltage drops by 5 percent; or

c) The output power drops by 5 percent before the output voltage has dropped by 5 percent.

31.2 Motor rating test

31.2.1 When a motor is operated from a supply of rated voltage and rated frequency and loaded to deliver rated output, the input current shall not vary from the marked rating by more than 10 percent.

Exception No. 1: Motors having greater than 74.6 kW (100 horsepower) output are not required to undergo the motor rating test provided that their rated (marked) voltage and current is within 10% of the values shown in the appropriate table in Section 6, Current and Horsepower Relation.

Exception No. 2: Motors having greater than 373 kW (500 horsepower) output are not required to undergo the motor rating test.

31.2.2 When a motor rated in speed and amperes only is delivering rated speed from a supply of rated voltage and frequency, the input current shall not vary from the marked rating by more than 10 percent.

31.2.3 Motors capable and rated for operation at multiple speeds are to be tested and shall comply with 31.2.1 and 31.2.2 at the lowest speed, at an intermediate speed, and at the highest speed if so marked.

Exception: Motors marked only with voltage and frequency are not required to undergo the rating test. See 44.1.

31.3 Air-over motor rating test

31.3.1 The air-over motor rating test is to be conducted as specified in 31.2. However, consideration needs to be given to the unique characteristics of the air-over motor, which may cause operation of a thermal protector or undue heating of the motor if the motor is operated without being supplied by a sufficient stream of cooling air. The test is to either be conducted quickly to obtain the necessary measurements before this occurs or, alternatively, the motor may be artificially fan cooled to allow acquisition of the required measurements.

32 Temperature Test

32.1 The temperature test is to be conducted with the machine under test delivering full rated operating power multiplied by any service factor. For motors without marked rated output, the motor is to be loaded, or if necessary the voltage raised, until the motor consumes rated current.

Exception No. 1: The temperature test for air-over motors is to be conducted in the end product.

Exception No. 2: Motors marked only with voltage and frequency are not required to undergo the temperature test. See 44.1.

Exception No. 3: Motors having greater than 74.6 kW (100 horsepower) output may alternatively use any of the methods described in Section 5, Superposition method, of IEC 60034-29, Rotating electrical machines – Part 29: Equivalent loading and superposition techniques – Indirect testing to determine temperature rise.

32.2 The temperature test is to be conducted until thermal stabilization is attained.

32.3 The temperature test for an intermittent duty motor is to be conducted at the manufacturers rated duty cycle.

32.4 With the exception of coils and windings, all temperatures are to be measured by a thermocouple. Thermocouples are to consist of wires not larger than 30 AWG (0.05 mm^2). The thermocouple wire shall conform to the requirements specified in the "Tolerances on Initial Values of EMF versus Temperature" tables in the Standard Specification and Temperature-Electromotive Force (EMF) Tables for Standardized Thermocouples, ANSI/ASTM E230.

32.5 The thermocouple is to be attached so that the welded bead is in direct contact with the component whose temperature is being measured. The contact point is to be held in place by a solution of Fuller's earth and sodium silicate (water glass) or other means that provides good thermal conductivity.

32.6 Temperatures on materials or components shall not exceed the values specified in Table 32.1.

Table 32.1
Maximum temperatures

Materials and components		°C	(°F)
1.	Capacitors[a]		
	Electrolytic[b]	65	(149)
	Other types	90	(194)
2.	Fuses[c]		
	Body	125	(257)
	Ferrule or blade	110	(230)
3.	Fiber employed as electrical insulation	90	(194)
4.	At any point within a terminal box or wiring compartment of a permanently connected appliance in which power-supply conductors are to be connected in the field, including such conductors themselves[i].	60	(140)
5.	Class A (105)[m]		
	Thermocouple method	105	(221)
	Resistance method	115	(239)
6.	Class E (120)[m]		
	Thermocouple method	115	(239)
	Resistance method	125	(257)
7.	Class B (130)[m]		
	Thermocouple method	125	(257)
	Resistance method	135	(275)
8.	Class F (155)[m]		
	Thermocouple method	150	(302)
	Resistance method	160	(320)
9.	Class H (180)[m]		
	Thermocouple method	165	(329)
	Resistance method	175	(347)
10.	Class N (200)[m]		
	Thermocouple method	180	(356)
	Resistance method	190	(374)
11.	Class R (220)[m]		
	Thermocouple method	195	(383)
	Resistance method	205	(401)
12.	Phenolic composition employed as electrical insulation or as a part the deterioration of which would result in a risk of fire or electric shock[d].	150	(302)
13.	Rubber- or thermoplastic-insulated wire and cord[e,f].	60	(140)
14.	Sealing compound	40°C (104°F) less than melting point	
15.	Thermoplastic sealing compound	j	j
16.	Varnished-cloth insulation	85	(185)
17.	Wood and other combustible material	90	(194)
18.	Bus bar	g	g
19.	Power semiconductor	k	k

Table 32.1 Continued on Next Page

Table 32.1 Continued

Materials and components	°C	(°F)
20. Printed-wiring board	l	l
21. Other components	h	h

[a] A capacitor that is designed and marked to operate at a temperature of more than 90°C (117°F) may be judged on the basis of its marked temperature limit. In no case shall a capacitor temperature exceed its marked temperature limit.

[b] The temperature on insulating material integral with the enclosure of an electrolytic capacitor that is physically integral with or attached to a machine shall not be more than 90°C (117°F).

[c] A fuse that has been investigated and found usable at a higher temperature may be used at that temperature.

[d] The limitations on phenolic composition and on rubber and thermoplastic insulation do not apply to compounds that have been investigated and found usable at higher temperatures.

[e] Rubber-insulated conductors within a Class A insulated machine, rubber-insulated machine leads, and a rubber-insulated flexible cord entering a machine may be subjected to a temperature of more than 60°C (63°F), when a braid is employed on the conductor of other than a flexible cord. However, this does not apply to thermoplastic-insulated wires or cords.

[f] A short length of rubber- or thermoplastic-insulated flexible cord exposed to a temperature of more than 60°C (140°F), such as at terminals, is acceptable if supplementary heat-resistant insulation of adequate dielectric strength is employed on the individual conductors of the cord to protect the conductor insulation against deterioration.

[g] The maximum temperatures for this type of construction are determined by the temperature limitations on the support material, adjacent part material, or 100°C (212°F) temperature rise on the copper material, whichever is lower. There shall be no structural deterioration of the assembly, loosening of parts, cracking or flaking of material, loss of temper of spring, annealing of parts, or other visible damage.

[h] The temperature on other components shall not exceed the temperature rating of the component.

[i] A limit of 75°C (167°F) is acceptable provided that the product has been found acceptable for the higher limit and is marked in accordance with 44.5 to require the use of 75°C field-installed conductors.

[j] The temperature limit for thermoplastic sealing compounds is 15°C (27°F) less than the softening point of the compound as determined by the test method for Vicat Softening Temperature of Plastics, ASTM D1525.

[k] The case temperature limit for a power semiconductor is the maximum case temperature specified by the device manufacturer.

[l] The temperature limit is the temperature rating of the printed-wiring board.

[m] A machine with a Service Factor (SF) equal to or greater than 1.15 or a totally enclosed machine is permitted to have a winding temperature 5°C (9°F) higher than those stated.

32.7 The temperatures specified in Table 32.1 are based upon an ambient of 40°C (104°F).

32.8 The observed test temperature shall be corrected to rated ambient. When the stabilized test ambient is lower than the rated ambient, the observed test temperature is to be increased by the difference between stabilized test ambient and rated ambient. When the test ambient is higher than the rated ambient, the observed test temperature is to be reduced by the difference.

32.9 *Deleted*

32.10 Coil and winding temperatures are to be measured either by thermocouples or by the change of resistance method, which compares the heated coil resistance to the resistance at a known (ambient) temperature. This method uses the following equation to determine the heated coil temperature:

$$T = \left[\left(\frac{R_2}{R_1}\right)\left(K + T_1\right)\right] - K + \left(T_1 - T_2\right)$$

Where:

R_2 = *the coil resistance at the conclusion of the test*

R_1 = *the coil resistance under ambient conditions at the beginning of the test*

K = is a constant equal to 234.5 for copper, 225.0 for electrical conductor grade (EC) aluminum. The value of K for other conductor materials is to be determined.

T = the coil temperature at the conclusion of the test

T_1 = the room ambient at the beginning of the test

T_2 = the room ambient at the conclusion of the test.

32.11 If the change of resistance method is used:

a) The product under test is to be permitted to soak or condition at the test ambient temperature sufficiently long for the entire coil mass to stabilize at that temperature before the initial resistance measurement is made. Consideration is to be given to the mass of the product under test but a conditioning period of 24 hours may not be unusual.

b) The winding resistance is to be measured after shutdown and this is to be used to determine the final temperature of the machine and its temperature rise. This measurement requires a quick shutdown of the machine at the end of the temperature test and quick application of the leads from the resistance-measuring device. A carefully planned procedure and an adequate number of people are required to obtain readings soon enough to give reliable data.

c) For all motors less than 50 horsepower and for those motors where the resistance reading after shutdown cannot be made within the time allowed by Table 32.2, it is to be made as soon as possible, and additional resistance readings are to be taken at intervals of 5 – 60 seconds for a minimum of 10 readings. A curve of these readings is to be plotted as a function of time and is to be extrapolated back to time zero for motors less than 50 horsepower or back to the time delay given by Table 32.2 for the rating of the machine. A semi-logarithmic plot is recommended, in which resistance is plotted on the logarithmic scale. The value of resistance thus obtained is to be considered as the resistance at shutdown.

d) The total time for the ten measurements in (c) shall be approximately the same as the thermal time constant of the windings being measured. Note: the observed constant is exponential and is approximately the time it takes for the temperature to drop by around 63 percent of its initial value, but may be approximated using somewhat lesser drops.

Table 32.2
Time Delay

Machine rating			Time delay after switching off power
KVA	KW	Hp	Seconds
50 – 200	38 – 150	50 – 200	90
Above 200	Above 150	Above 200	120

33 Mechanical Tests

33.1 General

33.1.1 With the exception of 33.4 which applies to all machines, the requirements of this Section apply only to machines intended for field installation.

33.1.2 A machine shall withstand the mechanical tests described in 33.2 – 33.6 without resulting in any of the following:

a) Damage that results in the risk of fire, electric shock, or personal injury;

b) Permanent distortion that results a reduction of required spacings to levels less than those permitted by Section 18, Spacings;

c) Permanent distortion that results in openings larger than those that are acceptable according to Section 12, Ventilation Openings, and Section 13, Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts; or

d) Transient distortion that produces contact of the enclosure with uninsulated live parts other than those connected in an isolated low-voltage circuit.

33.2 Pressure test

33.2.1 Any point on the overall enclosure of a machine shall withstand, for 1 minute, the application of a 111 N (25 lb.) force as described in 33.2.2.

33.2.2 The 111 N force is to be applied by means of a 12.5 ±0.5 mm diameter rod, the end of which is rounded to a 12.5 ±0.5 mm diameter hemisphere.

33.3 Impact test

33.3.1 Any point on the overall enclosure of a machine shall withstand an impact of 6.8 J (5 foot-pounds).

33.3.2 The impact is to be applied by means of a smooth, solid, steel sphere 50.8 mm (2 inches) in diameter and having 535 g (1.18 pounds) mass. The sphere is to fall freely through a vertical distance of 1.29 m (51 inches) then striking the enclosure with the required energy.

33.4 Mold stress relief

33.4.1 The overall enclosure shall withstand either of the conditions described in 33.4.3 (a) or (b) without any shrinkage, warpage, or any other distortion that results in any of the following conditions:

a) Interference with the operation or user-servicing of the product;

b) Noncompliance with the criteria specified in Section 9, Frame and Enclosure; or

c) Risk of fire, electric shock, or personal injury.

33.4.2 Component parts such as knobs, windows, and inserts that are distorted as a result of the temperature-stability test may be removed in order to eliminate interference with the operation or user-servicing of the product provided that removal of the parts does not result in a risk of fire, shock, or personal injury.

33.4.3 The mold stress relief test can, at the manufacturer's option, be conducted as described in either (a) or (b):

a) A sample of the complete product is to be placed in an unvented test cell and arranged so that the circulation of air within the cell simulates normal room conditions. The air temperature within the cell, measured at the base of the product, is to be maintained at 60°C (140°F). The product is to be operated continuously for 7 hours while resting on a supporting surface having an area approximately equal to that of the product base and centrally located in the test cell.

b) The complete product is to be placed in a circulating-air oven for 7 hours. The oven is to be maintained at a temperature of 10°C (18°F) higher than the maximum operating temperature of the enclosure, measured at the hottest spot on the inside of the enclosure, under operating conditions, but not less than 70°C (158°F). The product is not to be operated during the test.

33.5 Conduit hubs

33.5.1 A conduit hub not integrally cast with an enclosure shall not turn in the enclosure and shall not strip any threads when the torque specified in 33.5.2 is applied.

33.5.2 To determine whether a conduit hub complies with the requirement in 33.5.1, the torque is to be applied to a short length of rigid-metal conduit that has been threaded into the hub of the enclosure in the intended manner. The applied torque is to be as described in Table 33.1.

Table 33.1
Tightening torque

Trade size of conduit hub, inches	Tightening torque	
	N·m	(pound-inches)
3/4 and smaller	90.5	(800)
1, 1-1/4, and 1-1/2	113	(1000)
2 and larger	181	(1600)

33.6 Rain test

33.6.1 At the manufacturer's option, a machine intended for outdoor use is to be subjected to a rain test as described in 33.6.2 – 33.6.5. At the conclusion of the test:

a) For a machine having a rainproof enclosure, there shall be no wetting of a live part nor entrance of water above the lowest live part; and

b) For a machine having a raintight enclosure, there shall be no entrance of water into the enclosure.

33.6.2 A product intended for multiple mounting orientations shall be tested in all intended orientations.

33.6.3 After being subjected to the rain test, an outdoor-use machine shall:

a) Have an insulation resistance of not less than 50 K-ohms between live parts and interconnected dead metal; and

b) Shall comply with the requirements in Dielectric Voltage-Withstand Test, Section 37, in a repeated dielectric voltage-withstand test.

33.6.4 The complete enclosure with conduit connected – without pipe thread compound – is to be mounted as intended. The tightening torque for rigid conduit threaded into an opening in the enclosure is to be as specified in Table 33.1.

33.6.5 The water spray apparatus is to consist of three spray heads mounted in a pipe rack as illustrated in Figure 33.1. Spray heads are to be constructed in accordance with the details shown in Figure 33.2. The water pressure for all tests is to be maintained at 34 kPa (5 psi) at each spray head. The distance between the center nozzle and the equipment is to be 1.5 m (5 feet). The spray is to be directed at an angle of 45

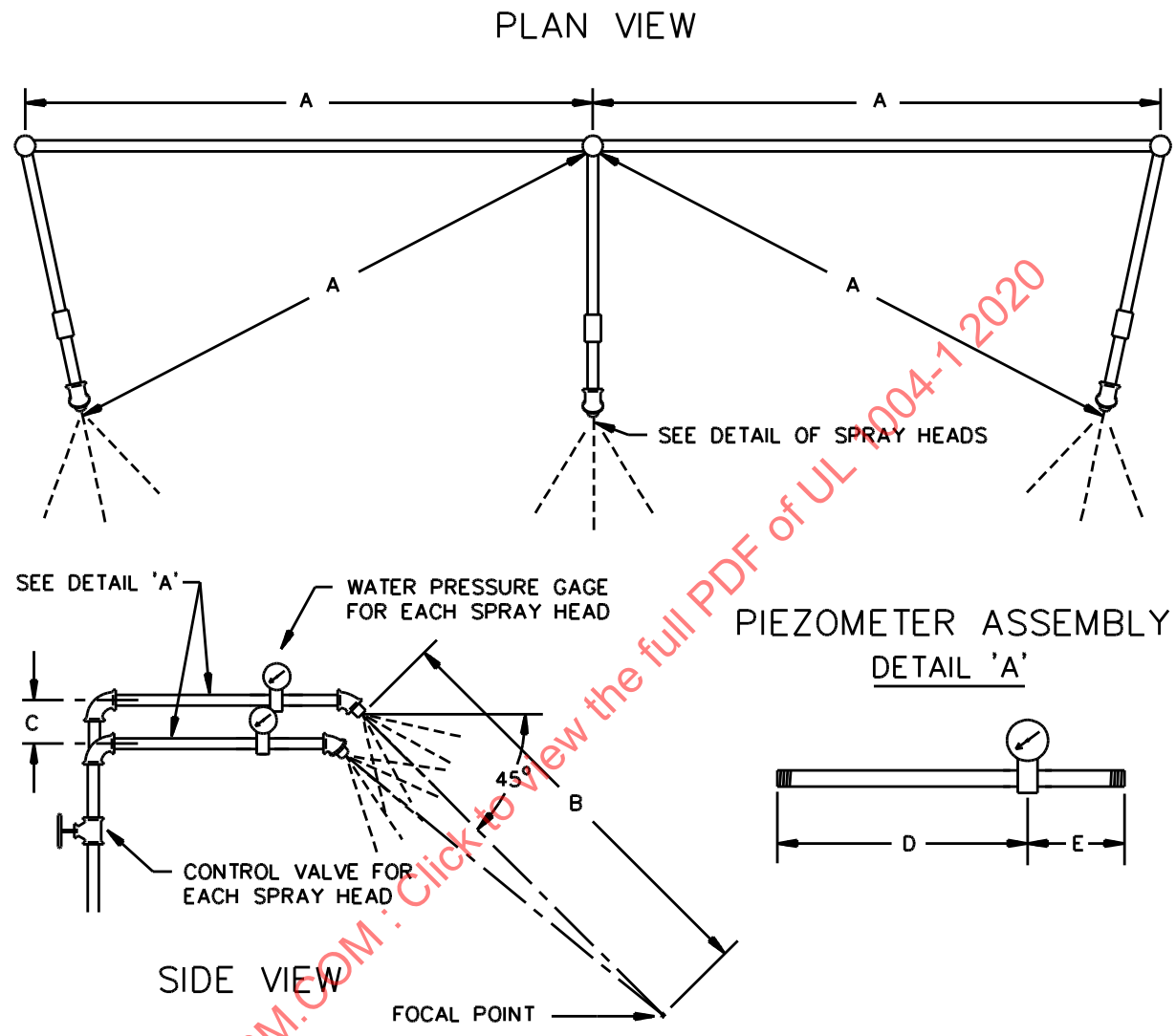
degrees from vertical toward the louvers or other openings nearest current-carrying parts. A water spray is then to be applied to the enclosure from the top and sides for 3 hours as described in Table 33.2.

Table 33.2
Operating sequence for rain test

Duration in hours	Product	Water
1	On	Off
1/2	Off	On
1	On	On
1/2	Off	On

Figure 33.1

Water spray test apparatus



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

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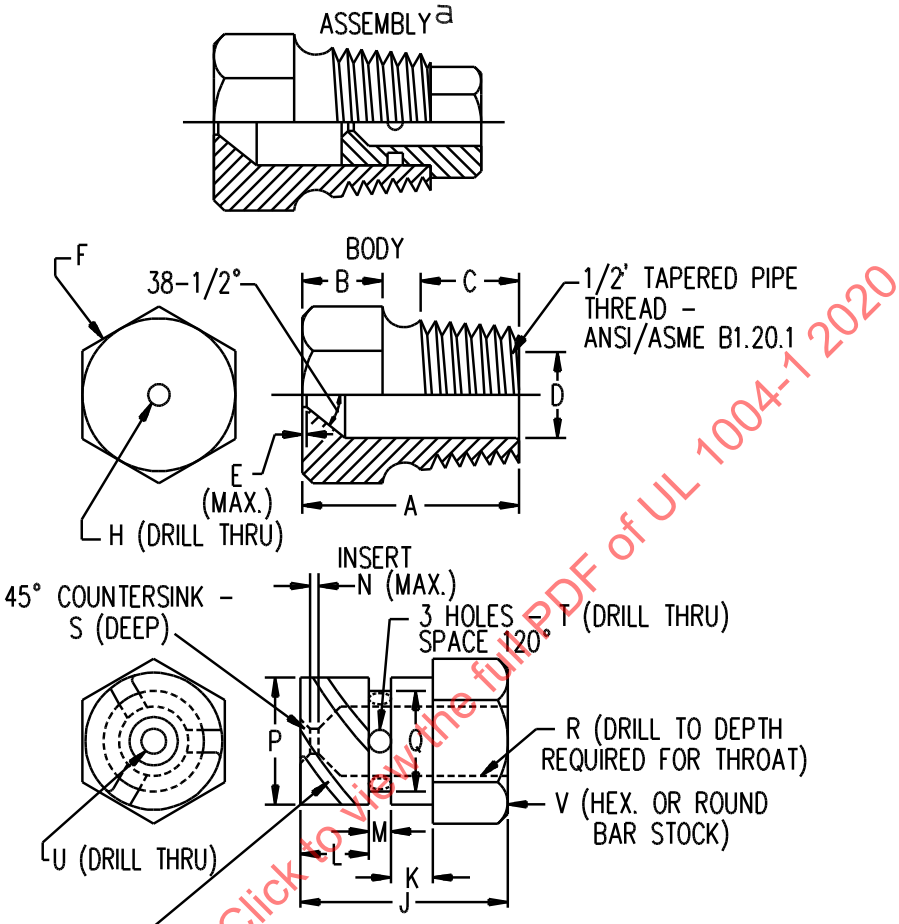
Figure 33.2

Water spray head piping



Item	mm	inch	Item	mm	inch
A	31.0	1-7/32	N	0.80	1/32
B	11.0	7/16	P	14.61	.575
C	14.0	9/16		14.63	.576
D	14.68	.578	Q	11.51	.453
	14.73	.580		11.53	.454
E	0.40	1/64	R	6.35	1/4
F	c	c	S	0.80	1/32
G	1.52	.06	T	2.80	(No. 35) [b]
H	5.0	(No.9) [b]	U	2.50	(No. 40) [b]
J	18.3	23/32	V	16.0	5/8
K	3.97	5/32	W	1.52	0.06
L	6.35	1/4			
M	2.38	3/32			

[a] Nylon Rain-Test Spray Heads are available from Underwriters Laboratories

[b] ANSI B94.11M Drill Size

[c] Optional - To serve as a wrench grip.

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