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Subject 2202

333 Pfingsten Road
 Northbrook, IL 60062
 October 4, 1996

TO: Electrical Council of Underwriters Laboratories Inc.,
 Subscribers to UL's Standards Service for
 Electric Vehicle (EV) Charging System Equipment,
 Electric-Battery-Powered Industrial Trucks,
 Power Units Other Than Class 2,
 Battery Chargers for Charging Engine-Starter Batteries,
 Industrial Battery Chargers, and
 Uninterruptible Power Supply Equipment,
 Subscribers to UL's Listing Service for
 Electric Vehicle (EV) Charging System Equipment

SUBJECT: Request for Comments on the Proposed First Edition of the Standard for Electric Vehicle (EV) Charging System Equipment, UL 2202; PROPOSED EFFECTIVE DATE

SUMMARY OF TOPICS

This bulletin proposes the First Edition of the Standard for Electric Vehicle (EV) Charging System Equipment, UL 2202.

COMMENTS DUE: January 3, 1997

Attached as Appendix A for your review and comment are proposed requirements for UL 2202. Questions regarding interpretation of requirements should be directed to the responsible UL Staff. Please see Appendix B of this bulletin regarding designated responsibility for the subject product category.

Please note that proposed requirements are of a tentative and early nature and are for review and comment only. Current requirements are to be used to judge a product until these requirements are published in final form.

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PROPOSED EFFECTIVE DATES

The proposed requirements specified in 6.1.1 will necessitate a review and possible retest of currently Listed products. Therefore, UL proposes that the new requirements become effective 12 months after publication. This is intended to provide manufacturers with sufficient time to submit modified products for investigation and to implement the necessary changes in production. Please note that this also includes the time that will be needed by UL to conduct a review of the modified product.

The remainder of the requirements will not necessitate a review or additional testing of currently Listed products. Therefore, UL proposes that these requirements become effective upon publication.

RATIONALE

The proposed Standard for Electric Vehicle (EV) Charging System Equipment, UL 2202, is needed to provide written requirements for product submittals under the subject category. Presently, there is no standard to cover the subject category. A standard will provide published requirements that will facilitate uniform interpretation of the requirements.

The proposed first edition of UL 2202 has been derived from the requirements applied to equipment presently Listed under the Electric Vehicle (EV) Charging System Equipment Product Category.

IMPACT

The proposed requirements specified in 6.1.1, if adopted, will require a review and possible retest of currently Listed products.

Until UL 2202 becomes effective, manufacturers may continue to submit their electric vehicle charging system equipment products for investigation in accordance with the requirements specified in the Outline of Investigation for Electric Vehicle (EV) Charging System Equipment, Subject 2202.

REQUEST FOR COMMENTS ON PROPOSALS

Please provide the following:

1. Your comments concerning the proposed requirements; and
2. Your comments concerning the proposed effective date, should the proposals be adopted.

Written comments should be sent to the attention of Steve Chiu at UL's Northbrook office, 333 Pfingsten Road, Northbrook, IL 60062-2096. Please reference all correspondence to Subject 2202.

All comments should be sent by January 3, 1997.

Unless specifically requested to do so, UL will not acknowledge comments indicating concurrence with these proposals.

Subject 2202

-3-

October 4, 1996

UNDERWRITERS LABORATORIES INC.

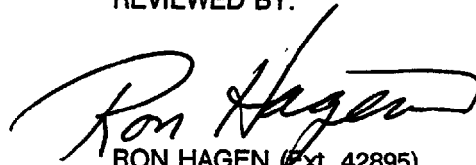
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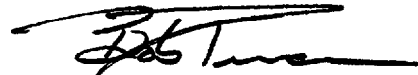
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PROPOSED REQUIREMENTS ARE OF A TENTATIVE AND EARLY NATURE AND ARE FOR REVIEW AND COMMENT ONLY. CURRENT REQUIREMENTS ARE TO BE USED TO JUDGE A PRODUCT UNTIL THESE REQUIREMENTS ARE PUBLISHED IN FINAL FORM.

APPENDIX A

PROPOSED FIRST EDITION OF THE STANDARD FOR
ELECTRIC VEHICLE (EV) CHARGING SYSTEM EQUIPMENT,
UL 2202

OCTOBER, 1996 DRAFT

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FOREWORD

A. This Standard contains basic requirements for products covered by Underwriters Laboratories Inc. (UL) under its Follow-Up Service for this category within the limitations given below and in the Scope section of this Standard. These requirements are based upon sound engineering principles, research, records of tests and field experience, and an appreciation of the problems of manufacture, installation, and use derived from consultation with and information obtained from manufacturers, users, inspection authorities, and others having specialized experience. They are subject to revision as further experience and investigation may show is necessary or desirable.

B. The observance of the requirements of this Standard by a manufacturer is one of the conditions of the continued coverage of the manufacturer's product.

C. A product which complies with the text of this Standard will not necessarily be judged to comply with the Standard if, when examined and tested, it is found to have other features which impair the level of safety contemplated by these requirements.

D. A product employing materials or having forms of construction differing from those detailed in the requirements of this Standard may be examined and tested according to the intent of the requirements and, if found to be substantially equivalent, may be judged to comply with the Standard.

E. UL, in performing its functions in accordance with its objectives, does not assume or undertake to discharge any responsibility of the manufacturer or any other party. The opinions and findings of UL represent its professional judgment given with due consideration to the necessary limitations of practical operation and state of the art at the time the Standard is processed. UL shall not be responsible to anyone for the use of or reliance upon this Standard by anyone. UL shall not incur any obligation or liability for damages, including consequential damages, arising out of or in connection with the use, interpretation of or reliance upon this Standard.

F. Many tests required by the Standards of UL are inherently hazardous and adequate safeguards for personnel and property shall be employed in conducting such tests.

INTRODUCTION

1 Scope

1.1 These requirements cover conductive and inductive charging system equipment intended to be supplied by a branch circuit of 600 volts or less for recharging the storage batteries in over-the-road electric vehicles (EVs). This equipment is connected to the vehicle by means of a flexible cord and an electric vehicle connector. The equipment can be located on- or off-board the vehicle. Off-board equipment can be for indoor or outdoor use.

1.2 Electric vehicle charging system equipment that is not a complete assembly and depends upon installation in an end product for compliance with the requirements in this standard is investigated under the requirements of this standard and the standard for the end product.

1.3 These requirements do not cover battery chargers covered by the Standard for Battery Chargers for Charging Engine-Starter Batteries, UL 1236, or the Standard for Industrial Battery Chargers, UL 1564.

1.4 The requirements for devices or systems intended to reduce the risk of electric shock to the user in grounded or isolated circuits for charging electric vehicles are covered in the Outline of Investigation for Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits; Part 1: General Requirements, Subject 2231-1, and the Outline of Investigation for Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits; Part 2: Particular Requirements for Protective Devices for Use in Charging Systems, Subject 2231-2.

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

2 Glossary

2.1 In the text of this standard, the term "unit" refers to any product covered by this standard. The letters "EV" refers to an electric vehicle. For the purpose of this standard, the definitions in 2.2 – 2.38 apply.

2.2 ACCESSIBLE – Able to be contacted by an accessibility probe.

2.3 BARRIER – A part inside an enclosure that reduces access to a part that involves a risk of fire, electric shock, injury to persons, or electrical energy – high current levels.

2.4 BATTERY, VALVE-REGULATED – A battery in which the venting of the products of electrolysis is controlled by a reclosing pressure-sensitive valve. These batteries have commonly been referred to as "maintenance-free, starved electrolyte."

2.5 BATTERY, VENTED – A battery in which the products of electrolysis and evaporation are allowed to escape freely to the atmosphere. These batteries have commonly been referred as "flooded" or "wet."

2.6 BRANCH CIRCUIT – The portion of the building wiring system beyond the final overcurrent protective device on the power-distribution panel that protects the circuit to the field-wiring terminals in a permanently connected unit or to the receptacle outlet for a cord-connected unit.

2.7 CELL – Two electrodes of dissimilar material separated from one another by a common ionically conductive electrolyte, that are intended to convert chemical energy directly into electrical energy.

2.8 CLASS 2 TRANSFORMER – A step-down transformer complying with the applicable requirements in the Standard for Class 2 and Class 3 Transformers, UL 1585, or the Standard for Class 2 Power Units, UL 1310.

2.9 CONTROL CIRCUIT – A circuit that carries electric signals but not main power current.

2.10 DOUBLE INSULATION – An insulation system comprised of both basic insulation and supplementary insulation.

2.11 ELECTRIC VEHICLE (EV) - An over-the-road automotive-type vehicle for highway use, such as a passenger automobile, bus, truck, van, or the like, primarily powered by an electric motor that draws current from a rechargeable storage battery.

2.12 ELECTROLYTE – A semisolid, liquid, or aqueous salt solution that permits ionic conduction between positive and negative electrodes of a cell.

2.13 ENCLOSURE – That portion of a unit that reduces the accessibility of a part that may involve a risk of fire, electric shock or injury to persons, or reduces the risk of propagation of flame, sparks, and molten metal initiated by an electrical disturbance occurring within.

2.14 EXPOSED – Visible but not necessarily able to be contacted by an accessibility probe.

2.15 FIELD-WIRING LEAD – Any lead to which a supply, load, or other wire is intended to be connected by an installer.

2.16 FIELD-WIRING TERMINAL – A terminal to which a supply, load, or other wire is intended to be connected by an installer.

2.17 FIXED UNIT – A unit that is intended to be permanently connected electrically.

2.18 GUARD – A part outside of the enclosure that reduces access to a component that may result in a risk of injury to persons. See Enclosures and Guards, Section 40.

2.19 LEAKAGE CURRENT – Electric current which flows through a person upon contact, between accessible parts of a unit and:

- a) Ground, or
- b) Other accessible parts of the unit.

2.20 LIMITED-ENERGY CIRCUIT – An ac or dc circuit having a voltage not exceeding 1000 volts and the energy limited to 100 volt-amperes by either a secondary winding of a transformer, one or more resistors complying with 24.10, or a regulating network complying with 24.11.

2.21 LIVE PART – A conductive part, such as metal, within the unit that during intended use has a potential difference with respect to earth ground or any other conductive part.

2.22 LOW-VOLTAGE, LIMITED-ENERGY (LVLE) CIRCUIT – A circuit involving an alternating current voltage of not more than 30 volts, rms (42.4 volts peak) or a direct current voltage of not more than 60 volts and supplied by:

a) An inherently limited Class 2 transformer or power unit or a not inherently limited Class 2 transformer or power unit and an overcurrent protective device that is:

- 1) Not of the automatic reclosing type,
- 2) Trip-free from the reclosing mechanism, and
- 3) Either not readily interchangeable with a device of a different rating or a marking in accordance with 69.3.8 is provided; or

b) A combination of an isolated transformer secondary winding and one or more resistors or a regulating network complying with 24.11 that complies with all the performance requirements for an inherently limited Class 2 transformer or power source.

2.23 MEASUREMENT INDICATION UNIT (MIU) – The output voltage across the meter, in millivolts rms, in the measurement instrument in Figure 48.2, divided by 500 ohms. (The instrument indication is equal to the rms value in milliamperes when the frequency is 60 Hz (sinusoidal current). The reading may not be a direct indication of the rms or other common amplitude quantifier of leakage current when the leakage current is of complex waveform or frequency other than 50 or 60 Hz.)

2.24 MULTI-CELL BATTERY – A battery consisting, internally, of a series or parallel array of two or more cells.

2.25 PORTABLE UNIT – A unit that has no provisions for permanent mounting or wiring, and can be easily carried or conveyed by hand.

2.26 PRESSURE TERMINAL CONNECTOR – A field wiring terminal that accomplishes the connection of one or more conductors by means of pressure without the use of solder. A pressure terminal connector may be the barrel and setscrew type, crimp-type barrel, or clamping plate and screw type.

2.27 PRIMARY CIRCUIT – Wiring and components that are conductively connected to a branch circuit.

2.28 PRIMARY SOURCE – The branch circuit to which the power conversion portion of the unit is connected.

2.29 REINFORCED INSULATION – A single insulation system with such mechanical and electrical qualities that it, in itself, provides the same degree of protection against the risk of electric shock as does double insulation. The term "single insulation system" does not necessitate that the insulation must be in one homogeneous piece. The insulation system may comprise two or more layers that cannot be tested as supplementary or basic insulation.

2.30 RISK OF ELECTRICAL ENERGY – HIGH CURRENT LEVELS – The capability for damage to property or injury to persons, other than by electric shock, from available electrical energy is considered to exist, if between a live part and an adjacent dead metal part or between live parts of different polarity, there exists a potential of 2 volts or more and either an available continuous power level of 240 volt-amperes or more, or a reactive energy level of 20 joules or more. For example, a tool, or other metal short-circuiting a component may cause a burn or a fire if enough energy is available at the component to vaporize, melt, or more than warm the metal.

2.31 RISK OF ELECTRIC SHOCK – As defined in the Outline of Investigation for Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits; Part I: General Requirements, Subject 2231.

2.32 RISK OF FIRE – A risk of fire is considered to exist at any component unless an investigation of the supply delivering power to that component complies with the criteria in 24.4 – 24.12.

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

2.34 SAFETY INTERLOCK – A means relied upon to reduce the accessibility to an area that may result in a risk of electric shock, electrical energy – high current levels, or injury to persons until the risk has been removed, or to automatically remove the risk when access is gained.

2.35 SECONDARY CIRCUIT – A circuit supplied from a secondary winding of an isolating transformer. See 26.1.3.

2.36 SERVICE PERSONNEL – Trained persons having familiarity with the construction and operation of the equipment and the risks involved.

2.37 STATIONARY UNIT – A cord and plug connected unit that is intended to be fastened in place or located in a dedicated place.

2.38 TOOL – A screwdriver, coin, key, or any other object that may be used to operate a screw, latch, or similar fastening means.

3 General

3.1 Components

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

3.1.2 A component need not comply with a specific requirement that:

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

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

3.1.4 Specific components are recognized as being 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 for which they have been recognized.

3.2 Units of measurement

3.2.1 If a value for measurement is followed by a value in other units in parentheses, the second value may be only approximate. The first stated value is the requirement.

3.3 References

3.3.1 Any undated reference to a code or standard appearing in the requirements of this standard shall be interpreted as referring to the latest edition of that code or standard.

CONSTRUCTION

4 Frame and Enclosure

4.1 General

4.1.1 A unit shall be provided with one or more enclosures that house all live parts. The enclosure shall protect the various parts of the unit against mechanical damage from forces external to the unit. The parts of the enclosure that are required to be in place to comply with the requirements for risk of fire, electric shock, injury to persons, and electrical energy – high current levels shall comply with the applicable enclosure requirements specified in this standard.

Exception: Live parts, including terminals, which do not present a risk of electric shock or a risk of electrical energy – high current levels, need not be enclosed.

4.1.2 The frame or chassis of a unit shall not be used to carry current during intended operation.

Exception: As provided in the Exception to 16.1.12.

4.1.3 A part, such as a dial, display face, or nameplate, that serves as a functional part of the enclosure shall comply with the enclosure requirements.

4.1.4 If an electrical instrument, such as a meter, forms part of the enclosure, the face or the back of the instrument housing, or both together, shall comply with the requirements for an enclosure.

Exception: A meter complying with the requirements in the Standard for Electrical Analog Instruments – Panelboard Types, UL 1437, need not comply.

4.1.5 A component of a unit rated greater than 12 amperes, 12 volts, that may produce arcing, such as a snap switch, a relay, or a receptacle, shall be located at least 18 inches (457 mm) above the floor and the unit shall be marked in accordance with 69.3.12.

4.2 Access covers

4.2.1 An access cover shall be hinged if it gives access to a fuse or other overload-protective device, the functioning of which requires renewal or resetting, or if it is necessary to open the cover in connection with intended operation of the unit. A means shall be provided to hold the cover positively closed.

Exception No. 1: A hinged cover is not required if the only overload-protective device enclosed is:

- a) Connected in a control circuit, provided the protective device and the circuit loads are within the same enclosure,
- b) Rated 2 amperes or less for loads not exceeding 100 volt-amperes,
- c) An extractor fuse having an integral enclosure, or
- d) Connected in a low-voltage, limited-energy circuit.

Exception No. 2: A hinged cover is not required for an enclosure that (1) contains no user-serviceable or -operable parts and (2) is marked in accordance with 69.3.7.

4.2.2 A door or cover giving access to a fuse shall be tight-fitting.

4.3 Cast metal enclosures

4.3.1 The thickness of cast metal for an enclosure shall be as specified in Table 4.1.

Exception: Die-cast metal and cast metal of a lesser thickness may be employed if upon investigation (consideration being given to the shape, size, and function of the enclosure) it is found to have equivalent mechanical strength for the intended use.

Table 4.1
Thickness of cast-metal enclosures

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

4.4 Sheet metal enclosures

4.4.1 Sheet metal enclosures shall comply with the requirements in the Standard for Enclosures for Electrical Equipment, UL 50, or mentioned in 4.4.2.

4.4.2 With reference to 4.4.1, the thickness of a sheet-metal enclosure shall not be less than that specified in Tables 4.2 and 4.3. Uncoated steel shall not be less than 0.032 inch (0.81 mm) thick, zinc-coated steel shall not be less than 0.034 inch (0.86 mm) thick, and nonferrous metal shall not be less than 0.045 inch (1.14 mm) thick for surfaces of an enclosure at which a wiring system is to be connected.

Exception: A part of the enclosure that complies with the Mechanical Strength Tests for Metal Enclosures as specified in the Standard for Power Units Other Than Class 2, UL 1012, need not comply with the thickness specified in Tables 4.2 and 4.3

Table 4.2
Thickness of carbon steel or stainless steel enclosures

Without supporting frame ^a		With supporting frame ^a or equivalent reinforcing ^a		Minimum thickness inch (mm)	
Maximum width, inches (cm)	Maximum length, inches (cm)	Maximum width, inches (cm)	Maximum length, inches (cm)	Uncoated	Metal coated
4.0 (10.2)	Not limited	6.25 (15.9)	Not limited	0.020 ^d (0.51)	0.023 ^d (0.58)
4.75 (12.1)	5.75 (14.6)	6.75 (17.1)	8.25 (21.0)		
6.0 (15.2)	Not limited	9.5 (24.1)	Not limited	0.026 ^d (0.66)	0.029 ^d (0.74)
7.0 (17.8)	8.75 (22.2)	10.0 (25.4)	12.5 (31.8)		
8.0 (20.3)	Not limited	12.0 (30.5)	Not limited	0.032 (0.81)	0.034 (0.86)
9.0 (22.9)	11.5 (29.2)	13.0 (33.0)	16.0 (40.6)		
12.5 (31.8)	Not limited	19.5 (49.5)	Not limited	0.042 (1.07)	0.045 (1.14)
14.0 (35.6)	18.0 (45.7)	21.0 (53.3)	25.0 (63.5)		
18.0 (45.7)	Not limited	27.0 (68.6)	Not limited	0.053 (1.35)	0.056 (1.42)
20.0 (50.8)	25.0 (63.5)	29.0 (73.7)	36.0 (91.4)		
22.0 (55.9)	Not limited	33.0 (83.8)	Not limited	0.060 (1.52)	0.063 (1.60)
25.0 (63.5)	31.0 (78.7)	35.0 (88.9)	43.0 (109.2)		
25.0 (63.5)	Not limited	39.0 (99.1)	Not limited	0.067 (1.70)	0.070 (1.78)
29.0 (73.7)	36.0 (91.4)	41.0 (104.1)	51.0 (129.5)		
33.0 (83.8)	Not limited	51.0 (129.5)	Not limited	0.080 (2.03)	0.084 (2.13)
38.0 (103.4)	47.0 (119.4)	54.0 (137.2)	66.0 (167.6)		
42.0 (106.7)	Not limited	64.0 (162.6)	Not limited	0.093 (2.36)	0.097 (2.46)
47.0 (119.4)	59.0 (149.9)	68.0 (172.7)	84.0 (213.4)		
52.0 (132.1)	Not limited	80.0 (203.2)	Not limited	0.108 (2.74)	0.111 (2.82)
60.0 (152.4)	74.0 (188.0)	84.0 (213.4)	103.0 (261.6)		
63.0 (160.0)	Not limited	97.0 (246.4)	Not limited	0.123 (3.12)	0.126 (3.20)
73.0 (185.4)	90.0 (228.6)	103.0 (261.6)	127.0 (322.6)		

^a See 4.4.4 and 4.4.5.

^b The width is the smaller dimension of a rectangular sheet metal piece that is part of an enclosure. Adjacent surfaces of an enclosure may have supports in common and be made of a single sheet.

^c "Not limited" applies only if the edge of the surface is flanged at least 1/2 inch (12.7 mm) 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 0.034 inch (0.86 mm) thick if metal coated and not less than 0.032 inch (0.81 mm) thick if uncoated.

Table 4.3
Thickness of aluminum, copper, or brass enclosures

Without supporting frame ^a		With supporting frame ^a or equivalent reinforcing		Minimum thickness inches (mm)
Maximum width ^b	Maximum length ^c	Maximum width ^b	Maximum length ^c	
inches (cm)	inches (cm)	inches (cm)	inches (cm)	
3.0 (7.6)	Not limited	7.0 (17.8)	Not limited	0.023 ^d
3.5 (8.9)	4.0 (10.2)	8.5 (21.6)	9.5 (24.1)	(0.58)
4.0 (10.2)	Not limited	10.0 (25.4)	Not limited	0.029
5.0 (12.7)	6.0 (15.2)	10.5 (26.7)	13.5 (34.3)	(0.74)
6.0 (15.2)	Not limited	14.0 (35.6)	Not limited	0.036
6.5 (16.5)	8.0 (20.3)	15.0 (38.1)	18.0 (45.7)	(0.91)
8.0 (20.3)	Not limited	19.0 (48.3)	Not limited	0.045
9.5 (24.1)	11.5 (29.2)	21.0 (53.3)	25.0 (63.5)	(1.14)
12.0 (30.5)	Not limited	28.0 (71.1)	Not limited	0.058
14.0 (35.6)	16.0 (40.6)	30.0 (76.2)	37.0 (94.0)	(1.47)
18.0 (45.7)	Not limited	42.0 (106.7)	Not limited	0.075
20.0 (50.8)	25.0 (63.4)	45.0 (114.3)	55.0 (139.7)	(1.91)
25.0 (63.4)	Not limited	60.0 (152.4)	Not limited	0.095
29.0 (73.7)	36.0 (91.4)	64.0 (162.6)	78.0 (198.1)	(2.41)
37.0 (94.0)	Not limited	87.0 (221.0)	Not limited	0.122
42.0 (106.7)	53.0 (134.6)	93.0 (236.2)	114.0 (289.6)	(3.10)
52.0 (132.1)	Not limited	123.0 (312.4)	Not limited	0.153
60.0 (152.4)	74.0 (188.0)	130.0 (330.2)	160.0 (406.4)	(3.89)

^a See 4.4.4 and 4.4.5.

^b The width is the smaller dimension of a rectangular sheet metal piece that is part of an enclosure. Adjacent surfaces of an enclosure may have supports in common and be made of a single sheet.

^c "Not limited" applies only if the edge of the surface is flanged at least 1/2 inch (12.7 mm) 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 0.029 inch (0.74 mm) thick.

4.4.3 Tables 4.2 and 4.3 are based on a uniform deflection of the enclosure surface for any given load concentrated at the center of the surface regardless of metal thickness.

4.4.4 With reference to Tables 4.2 and 4.3, 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 essentially the same outside dimensions as the enclosure surface and that has the torsional rigidity to resist the bending moments that may be applied via the enclosure surface. A construction that is considered to have equivalent reinforcement may be accomplished by designs that will produce a structure that is as rigid as one built with a frame of angles or channels.

4.4.5 With reference to 4.4.4 and Tables 4.2 and 4.3, a construction is not considered to have a supporting frame if 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.

4.5 Nonmetallic enclosures

4.5.1 A polymeric enclosure or polymeric part of an enclosure shall comply with the requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C. See 4.5.2.

Exception: See 4.5.3.

4.5.2 With reference to 4.5.1, for a cord-connected unit that is intended to be supported on a bench, desk, table, or the like, the flammability requirements for portable equipment specified in UL 746C are to be applied.

4.5.3 A nonmetallic part that forms part of the enclosure need not comply with the requirement in 4.5.1 under any one of the following conditions:

- a) The part covers an opening that has no dimension greater than 1 inch (25.4 mm) and the part is made of a material classed as 94V-0, 94V-1, 94V-2, or 94HB,
- b) The part is made of a material classed 94V-0, 94V-1, 94V-2, or 94HB and covers an opening which does not allow access to live parts involving a risk of fire, electric shock, or electric energy – high current levels – or moving parts to the user when the part is removed.
- c) The part covers an opening that has no dimension greater than 4 inches (101.6 mm) and the part is made of a material classed as 94V-0, 94V-1, 94V-2, or 94HB, and there is no source of a risk of fire closer than 4 inches from the surface of the enclosure, or
- d) The part is made of a material classed 94V-0, 94V-1, 94V-2, or 94HB and there is a barrier or a device that forms a barrier made of a material classed 94V-0 between the part and a source of a risk of fire.

Exception: A part of a component need not be classed 94V-0, 94V-1, 94V-2, or 94HB if it complies with the flammability class applicable to the component.

4.5.4 A polymeric material enclosure having in any single unbroken section, a projected surface area greater than 10 square feet (0.93 m²) or a single linear dimension greater than 6 feet (1.83 m) shall have a flame-spread rating of 200 or less when tested in accordance with the:

- a) Standard for Test for Surface Burning Characteristics of Building Materials, UL 723; or
- b) Radiant-panel furnace method in the Test Method for Surface Flammability of Materials Using a Radiant Heat Energy Source, ASTM E162-1987.

4.5.5 A material with a flame-spread rating higher than specified in 4.5.4 can be used as the exterior finish or covering on any portion of the enclosure if the flame-spread rating of the combination of the base material and finish or covering complies with 4.5.4.

4.5.6 A conductive coating applied to a nonmetallic surface (such as the inside surface of a cover or an enclosure) shall comply with the appropriate requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

Exception: If flaking or peeling of the coating will not result in a risk of fire or electric shock as a result of a reduction of spacings or the bridging of live parts, then the coating need not comply with UL 746C.

4.6 Glass covered openings

4.6.1 Glass covering an opening shall be secured in place so that it cannot be readily displaced in service, and shall provide mechanical protection for the enclosed parts. Glass for an opening not more than 4 inches (102 mm) in any dimension shall not be less than 1/16 inch (1.6 mm) thick, and glass for an opening not more than 144 square inches (929 cm²) in area and having no dimension greater than 12 inches (305 mm) shall not be less than 1/8 inch (3.2 mm) thick. Glass used to cover an area larger than noted in item 2 shall not be less than 1/8 inch thick and shall:

a) Be of a nonshattering or tempered type that, when broken, complies with the Safety Performance Specifications and Methods of Test for Glazing Materials Used in Buildings, ANSI Z97.1-1984 (R1944); or

b) Be subjected to the test described in 60.1.

4.7 Openings for wiring

4.7.1 The requirements described in 4.7.2 – 4.7.9 apply to fixed units.

4.7.2 If threads for the connection of conduit are tapped all the way through a hole in an enclosure wall or if an equivalent construction is employed, there shall not be less than three nor more than five threads in the metal, and the construction of the enclosure shall be such that a conduit bushing can be attached as intended. If threads for the connection of conduit are not tapped all the way through a hole in an enclosure wall, conduit hub, or the like, there shall not be less than 3-1/2 threads in the metal and there shall be a smooth, rounded inlet hole for the conductors equivalent to that provided by a standard conduit bushing with an internal diameter approximately the same as that of the corresponding trade size of rigid conduit.

4.7.3 Clamps and fasteners for the attachment of conduit, electrical metallic tubing, armored cable, nonmetallic flexible tubing, nonmetallic-sheathed cable, service cable, and the like that are supplied as a part of an enclosure shall comply with the Standard for Metallic Outlet Boxes, UL 514A, and the Standard for Fittings for Conduit and Outlet Boxes, UL 514B.

4.7.4 A knockout in a sheet-metal enclosure shall be secured but shall be removable without undue deformation of the enclosure.

4.7.5 A knockout shall be provided with a flat surrounding surface so that the conduit bushing can be seated as intended, and shall be located so that installation of a bushing at any knockout likely to be used during installation will not result in spacing between an uninsulated live part and the bushing to be less than that specified in Spacings, Section 22.

4.7.6 In measuring a spacing between an uninsulated live part and a bushing installed in a knockout as mentioned in 4.7.5, it is to be assumed that a bushing having the dimensions specified in Table 4.4 is in place, in conjunction with a single locknut installed on the outside of the enclosure.

Table 4.4
Knockout or hole sizes and dimensions of bushings

Trade size of conduit	Knockout or hole diameter		Bushing dimensions			
			Overall diameter		Height	
Inches	Inches	mm	Inches	mm	Inches	mm
1/2	7/8	22.2	1	25.4	3/8	9.5
3/4	1-3/32	27.8	1-15/64	31.4	27/64	10.7
1	1-23/64	34.5	1-19/32	40.5	33/64	13.1
1-1/4	1-23/32	43.7	1-15/16	49.2	9/16	14.3
1-1/2	1-31/32	50.0	2-13/64	56.0	19/32	15.1
2	2-15/32	62.7	2-45/64	68.7	5/8	15.9
2-1/2	3	76.2	3-7/32	81.8	3/4	19.1
3	3-5/8	92.1	3-7/8	98.4	13/16	20.6
3-1/2	4-1/8	104.8	4-7/16	112.7	15/16	23.8
4	4-5/8	117.5	4-31/32	126.2	1	25.4
4-1/2	5-1/8	130.2	5-35/64	140.9	1-1/16	27.0
5	5-5/8	142.9	6-7/32	158.0	1-3/16	30.2
6	6-3/4	171.5	7-7/32	183.4	1-1/4	31.8

4.7.7 For an enclosure not provided with conduit openings or knockouts, spacings not less than the minimum specified in Spacings, Section 22 shall be provided between uninsulated live parts and a conduit bushing installed at any location likely to be used during installation. Permanent marking on the enclosure, a template, or a drawing furnished with the unit may be used to specify such a location. The specified location of the openings shall be such that damage to internal parts shall not result when openings are made.

4.7.8 With respect to the requirement in 4.7.7, means shall be provided so that an opening for conduit can be made without subjecting internal parts to contamination resulting from the presence of metallic particles. Compliance with this requirement may be accomplished by the use of a removable, bolted plate.

4.7.9 A polymeric- or metal-closure plug for an unused conduit opening shall comply with the requirements in the Standard for Outlet Boxes, UL 514A.

4.8 Openings in an enclosure

4.8.1 The enclosure of a unit shall be designed and constructed to reduce the risk of emission of flame, molten metal, flaming or glowing particles, or flaming drops.

4.9 Enclosure bottom openings

4.9.1 The requirement in 4.8.1 necessitates a complete noncombustible bottom or a construction employing individual noncombustible barriers under components, groups of components, or assemblies, as specified in Figure 4.1.

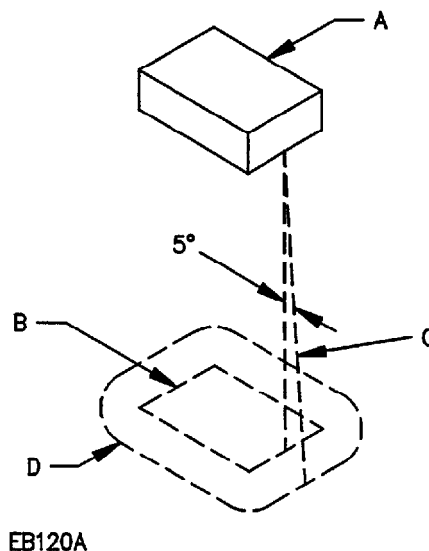
Exception No. 1: Ventilating openings may be provided in the bottom panel if noncombustible baffle plates are provided to reduce the risk of materials from falling directly from the interior of the unit onto the supporting surface or any other location under the unit. An example of an acceptable baffle is illustrated in Figure 4.2.

Exception No. 2: Ventilation openings may be provided in the bottom of an enclosure if the openings incorporate a perforated metal plate as described in Table 4.5, or a galvanized or stainless steel screen having a 14- by 14-mesh per inch (25.4-mm) constructed of wire with a diameter of 0.018 inch (0.5 mm) minimum.

Exception No. 3: The bottom of the enclosure under areas containing only materials classed 94V-1 or better in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, may have openings no larger than 1/4 inch (6.4 mm) square. Openings that are not square can be provided if they do not have an area greater than 1/16 square inch (40 mm²).

Exception No. 4: Ventilating openings without limitation on their size and number but complying with 5.1.10 may be provided in the bottom panel in areas (1) that contain only wires, cables, plugs, receptacles, transformers, and impedance protected or thermally protected motors, and (2) in areas that contain only capacitors that are described in 30.4.

Figure 4.1
Enclosure bottom



A – Region to be shielded by barrier. This will consist of the entire component if it is not otherwise shielded, and will consist of the unshielded portion of a component which is partially shielded by the component enclosure or equivalent.

B – Projection of outline of component on horizontal plane.

C – Inclined line which traces out minimum area of barrier. When moving, the line is always (1) tangent to the component, (2) five degrees from the vertical, and (3) so oriented that the area traced out on a horizontal plane is maximum.

D – Location (horizontal) and minimum area for barrier. The area is that included inside the line of intersection traced out by the inclined line C and the horizontal plane of the barrier.

Figure 4.2
Example of acceptable bottom-enclosure baffle

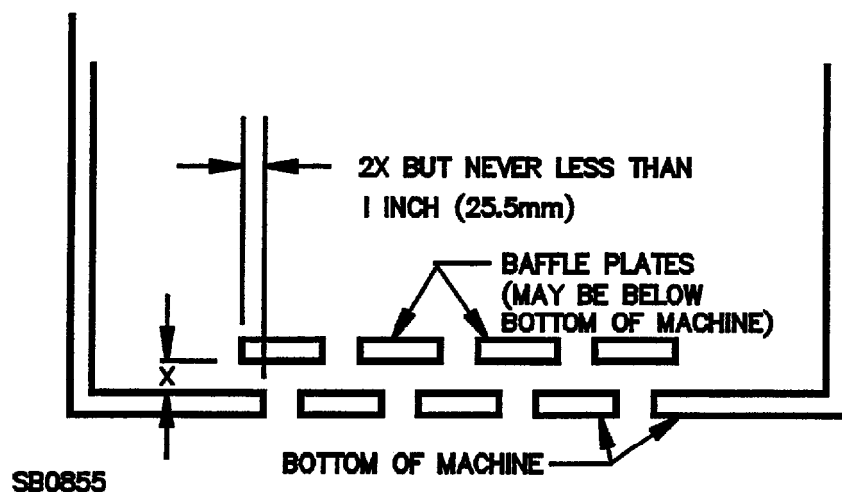


Table 4.5
Perforated metal plates for enclosure bottom^a

Minimum thickness, inch (mm)	Maximum diameter of holes, inch (mm)	Minimum spacings of holes center to center, inch (mm)
0.026 (0.66)	0.045 (1.14)	0.067 (1.70) 233 holes per inch ² (645 mm ²)
0.026 (0.66)	0.047 (1.19)	0.093 (2.36)
0.030 (0.76)	0.045 (1.14)	0.067 (1.70)
0.030 (0.76)	0.047 (1.19)	0.093 (2.36)
0.032 (0.81)	0.075 (1.91)	0.125 (3.18) 72 holes per inch ² (645 mm ²)
0.035 (0.89)	0.075 (1.90)	0.125 (3.18)
0.036 (0.91)	0.063 (1.60)	0.109 (2.77)
0.036 (0.91)	0.078 (1.98)	0.125 (3.18)
0.039 (0.99)	0.063 (1.60)	0.109 (2.77)
0.039 (0.99)	0.079 (2.00)	0.118 (3.00)

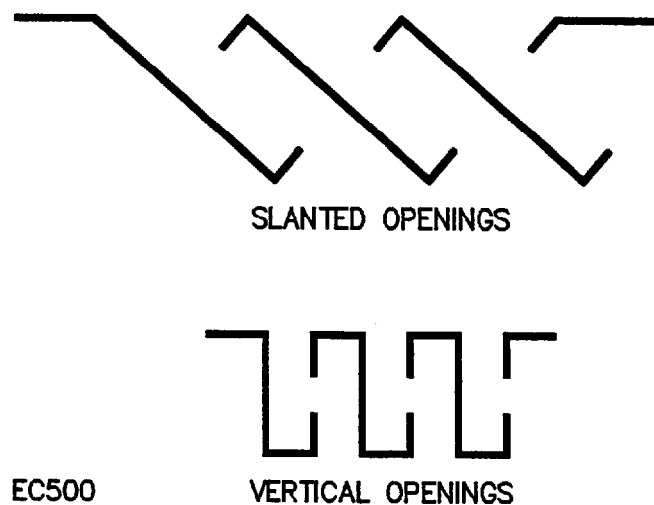
^a In accordance with Exception No. 2 to 4.9.1.

4.10 Enclosure top openings

4.10.1 The minor dimension – see 5.1.6 – of any opening in the top of an enclosure directly over an uninsulated live part involving a risk of electric shock or electrical energy – high current levels – shall not exceed 3/16 inch (4.8 mm) unless the configuration is such that the likelihood of direct vertical entry of a falling object to uninsulated live parts is reduced by means of a trap or restriction. See Figure 4.3 for examples of top surface openings that reduce the likelihood of direct entry.

Exception: Openings located 6 feet or higher from the floor, when the unit is installed in accordance with the manufacturer's instructions, may have a minor dimension greater than 3/16 inch. Such openings shall comply with the accessibility requirements in Protection of Users – Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts- and User Servicing, Section 5.

Figure 4.3
Cross sections of top-enclosure designs



5 Protection of Users – Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts – and User Servicing

5.1 General

5.1.1 The requirements in this section apply to parts that are accessible to the user. For protection of service personnel requirements, refer to Protection of Service Personnel, Section 36.

5.1.2 To reduce the likelihood of unintentional contact that may involve a risk of electric shock from an uninsulated live part or film-coated wire, electrical energy – high current levels, or injury to persons from a moving part, an opening in an enclosure shall comply with either (a) or (b).

- a) For an opening that has a minor dimension (see 5.1.6) less than 1 inch (25.4 mm), such a part or wire shall not be contacted by the probe illustrated in Figure 5.1.
- b) For an opening that has a minor dimension of 1 inch or more, such a part or wire shall be spaced from the opening as specified in Table 5.1.

Exception: An opening in an integral enclosure of a motor – a motor housing itself – need not comply with these requirements if it complies with the requirements in 5.1.3.

Table 5.1
Minimum acceptable distance from an
opening to a part that may involve
a risk of electric shock, electrical
energy-high current level,
or injury to persons

Minor dimension of opening ^{a,b}		Minimum distance from opening to part ^b	
Inches	(mm)	Inches	(mm)
3/4 ^c	(19.1)	4-1/2	(114.0)
1 ^c	(25.4)	6-1/2	(165.0)
1-1/4	(31.8)	7-1/2	(190.0)
1-1/2	(38.1)	12-1/2	(318.0)
1-7/8	(47.6)	15-1/2	(394.0)
2-1/8	(54.0)	17-1/2	(444.0)
d		30	(762.0)

^a See 5.1.6.
^b Between 3/4 and 2-1/8 inches, interpolation is to be used to determine a value between values specified in the table.
^c Any dimension less than 1 inch applies to a motor only.
^d More than 2-1/8 inches, but not more than 6 inches (152.0 mm).

5.1.3 With respect to a part or wire as mentioned in 5.1.2, in an integral enclosure of a motor as mentioned in the exception to 5.1.2:

a) An opening that has a minor dimension (see 5.1.6) less than 3/4 inch (19.1 mm) is acceptable if:

- 1) A moving part cannot be contacted by the probe illustrated in Figure 5.2;
- 2) Film-coated wire cannot be contacted by the probe illustrated in Figure 5.3;
- 3) In a directly accessible motor (see 5.1.7), an uninsulated live part cannot be contacted by the probe illustrated in Figure 5.1; or
- 4) In an indirectly accessible motor (see 5.1.7), an uninsulated live part cannot be contacted by the probe illustrated in Figure 5.2.

b) An opening that has a minor dimension of 3/4 inch or more is acceptable if a part or wire is spaced from the opening as specified in Table 5.1.

Figure 5.2
Probe for moving parts and uninsulated live parts in motors

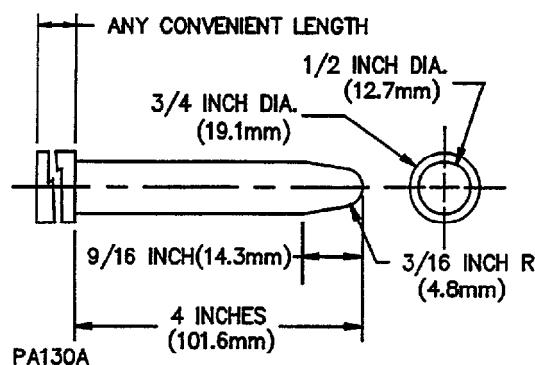
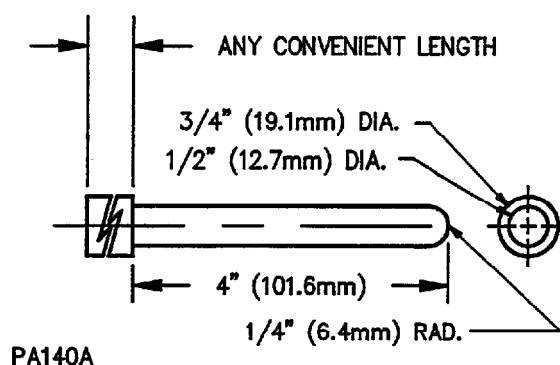


Figure 5.3
Probe for film-coated wire in motors



5.1.4 The probes mentioned in 5.1.2 and 5.1.3 and illustrated in Figures 5.1 – 5.3 shall be applied to any depth that the opening will permit; and shall be rotated or angled before, during, and after insertion through the opening to any position that is necessary to examine the enclosure. The probe illustrated in Figure 5.1 shall be applied in any possible configuration; and, if necessary, the configuration shall be changed after insertion through the opening.

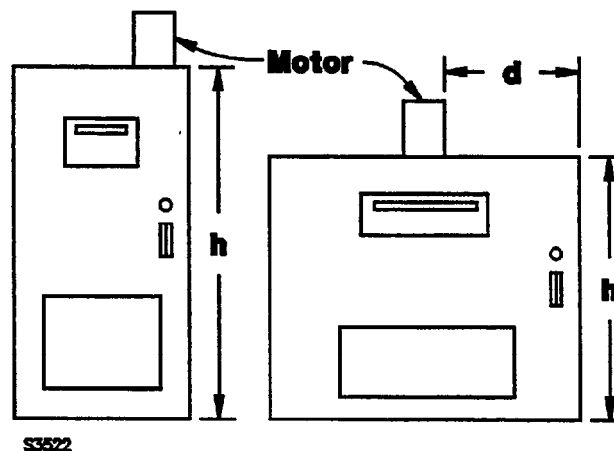
5.1.5 The probes mentioned in 5.1.4 shall be used as measuring instruments to judge the accessibility provided by an opening, and not as instruments to judge the strength of a material; they shall be applied with a maximum force of 1 pound (4.4 N).

5.1.6 With reference to the requirements in 5.1.2 and 5.1.3, the minor dimension of an opening is the diameter of the largest cylindrical probe that can be inserted through the opening.

5.1.7 With reference to the requirements in 5.1.3, an indirectly accessible motor is a motor 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 using a tool – see 2.31, that is guarded or enclosed so that it is unlikely to be contacted, or by its location it is considered unlikely to be contacted – see 5.1.8. A directly accessible motor is a motor that can be contacted without opening or removing any part and that is located so as to be accessible to contact.

5.1.8 With reference to 5.1.7, a motor is considered indirectly accessible by location if it is located at either a minimum height of 6 feet (1.8 m) from the floor level or the total distance from the floor level plus the distance along a horizontal surface of the unit from any side of the unit is not less than 7-1/2 feet (2.3 m) – see Figure 5.4.

Figure 5.4
Indirectly accessible motor by location^a



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$$h \geq 6 \text{ feet}$$

$$h + d = 7\text{-}1/2 \text{ feet minimum}$$

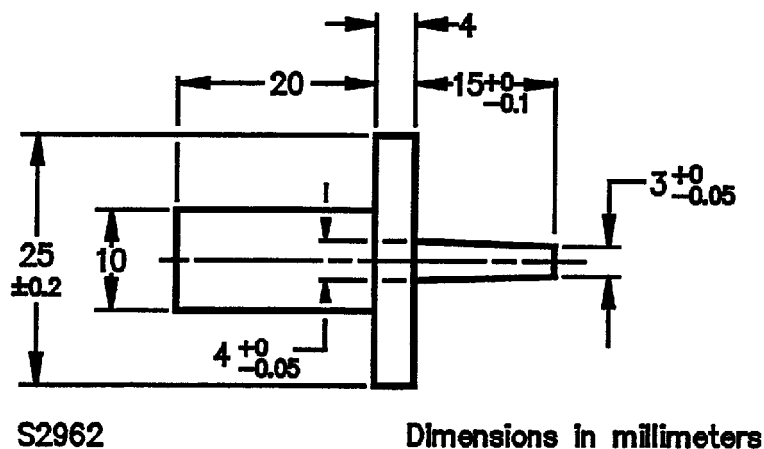
^aSee 5.1.8.

5.1.9 The test pin illustrated in Figure 5.5, when inserted as specified in 5.1.4 through an opening in an enclosure, shall not touch any uninsulated live part that involves a risk of electric shock.

5.1.10 The probe shown in Figure 5.1 and the test pin shown in Figure 5.4 are to be inserted as specified in 5.1.4 into all openings, including those in the bottom of the unit. The unit is to be moved in whatever way necessary to make the entire bottom accessible for insertion of the probe.

Exception: For a floor-standing 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.

Figure 5.5
Test pin



1 mm = 0.039 inch

5.1.11 During the examination of a unit to determine whether it complies with the requirements in 5.1.2 or 5.1.3, a part of the enclosure that may be 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 as described in 4.2.1, or for other reasons) is to be opened or removed. A fastener, such as a slotted-head thumb screw, that can be turned by hand, is not considered to require the use of a tool.

5.1.12 With reference to the requirements in 5.1.2 and 5.1.3, insulated brush caps are not required to be additionally enclosed.

5.2 User servicing

5.2.1 The maximum voltage of a battery supply of a unit employing batteries intended for user replacement shall not exceed 60 volts.

5.2.2 Uninsulated live parts at a potential involving a risk of electric shock that are located in the area containing batteries intended for replacement by the user shall be insulated or enclosed to reduce the likelihood of contact with such parts, regardless of their location.

5.2.3 The instruction manual for a unit containing batteries intended for user installation or replacement shall include instructions for battery replacement.

6 Electric Shock

6.1 Personnel protection systems

6.1.1 Electric vehicle charging system equipment shall comply with the requirements in the Outline of Investigation for Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits; Part 1: General Requirements, Subject 2231-1, and the Outline of Investigation for Personnel Protection Systems for Electric Vehicle (EV) Supply Circuits; Part 2: Particular Requirements for Protective Devices for Use in Charging Systems, Subject 2231-2.

6.1.1 effective (12 months after date of publication)

6.2 Stored energy

6.2.1 The allowable capacitance between capacitor terminals that are accessible as determined by the requirements in Protection of Users – Accessibility of Uninsulated Live Parts, Film-Coated Wire, and Moving Parts – and User Servicing, Section 5, and Protection of Service Personnel, Section 36, shall satisfy the following expressions:

$V < 40,000$	where $C < 0.00328$
$V < 729 C^{-0.7}$	where $0.00328 \leq C < 2.67$
$V < 367$	where $2.67 \leq C < 13.9$
$V < 2314 C^{-0.7}$	where $13.9 \leq C < 184.5$ in a DRY environment
$V < 60$	where $C \geq 184.5$ in a DRY environment
$V < 2314 C^{-0.7}$	where $13.9 \leq C < 497$ in a WET environment
$V < 30$	where $C \geq 497$ in a WET environment

in which:

C is the capacitance of the capacitor in microfarads; and

V is the voltage across the capacitor in volts. V is to be measured 5 seconds after the capacitor terminals are accessible by the removal or opening of an interlocked cover, or the like. Typical calculated values appear in Table 6.1, and the equation is shown graphically in Figure 6.1.

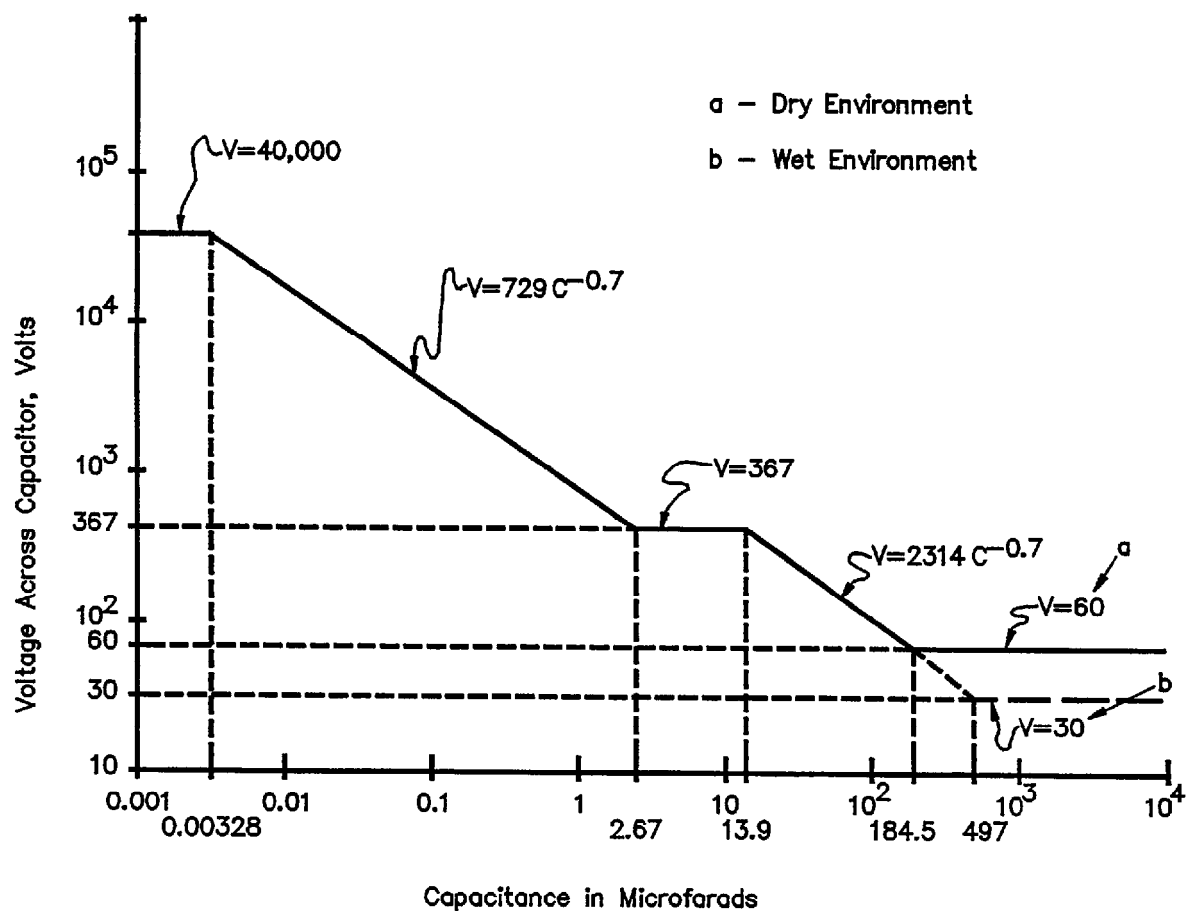
6.2.2 With reference to 6.2.1, a part involving a potential of more than 40 kilovolts peak is to be investigated to determine whether or not it involves a risk of electric shock.

Table 6.1
Risk of electric shock – stored energy current

Environment	Capacitance in microfarads ^a	Maximum allowable voltage across the capacitor, in volts
Wet or Dry	0.00328 or less	40,000
	0.005	29,749
	0.01	18,313
	0.02	11,273
	0.05	5,936
	0.1	3,654
	0.2	2,249
	0.5	1,184
	1.0	729
	2.0	449
	2.0	449
	2.67 to 13.9	367
	20.0	284
	50.0	150
	100.0	92.1
	184.5	60.0
Dry only	184.5 or more	60.0
Wet	200	56.7
	497 or more	30.0

^a See Figure 6.1.

Figure 6.1
Limits for voltage across capacitance



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7 Mounting

7.1 A unit that is intended to be fastened in place shall have provision for mounting it securely in position. Bolts, screws, or other parts used for mounting the unit shall be independent of those used to secure components of the unit to the frame, base, or panel.

7.2 Keyhole slots for mounting screws may be provided if they are arranged so that wall-mounting screws will not project into a compartment containing electrical parts and reduce spacings to less than those specified in Spacings, Section 22.

7.3 For a unit having bottom ventilation openings, if the supporting feet are made of rubber or neoprene material, then the aging and physical properties of the material shall be investigated in accordance with the requirements specified in 80.2.1.

Exception: As specified in 51.7 and 54.1.5 for a unit subjected to the temperature and abnormal tests with the supporting means removed.

7.6 A fixed unit shall not be provided with casters.

Exception: A unit may have casters if they are used solely for transporting the unit and provided with leveling feet that are intended to be lowered after the unit is installed.

8 Corrosion Protection

8.1 Iron and steel parts shall be protected against corrosion by painting, galvanizing, sherardizing, plating, or other equivalent means. This requirement applies to all enclosure parts, whether of sheet steel or cast iron, and to all springs and other parts upon which intended mechanical operation may depend. Bearing surfaces shall be of such materials and constructed so that binding due to corrosion is inhibited.

Exception: The parts specified in (a) – (d) need not be protected against corrosion:

- a) Bearings, or the like, where such protection is impracticable,
- b) A minor part, such as a washer, screw, bolt, and the like, if the failure of such unprotected parts would not be likely to result in a risk of fire, electric shock, electrical energy-high current levels, or injury to persons, or the operation of the unit being affected adversely,
- c) A decorative grille that is not required to form a part of the enclosure, and
- d) A part made of stainless steel.

9 Mechanical Assembly

9.1 Loosening of parts in a unit as a result of vibration due to handling and operation of the unit shall not result in a risk of fire, electric shock, injury to persons, or electrical energy – high current levels.

9.2 Screws with lock washers applied as intended, screws tightened by means of a power tool, rivets, and staked and upset screws are considered not subject to loosening. See 9.3.

9.3 The construction of staked and upset screws is to consist of an interference fit between the nut and bolt resulting in uneasy turning of the screw. This may be accomplished by the use of a center punch applied to the end of a bolt after assembly, mismatching of the nut and bolt threads, or the equivalent.

9.4 A rotating part that, when loosened, results in a risk of fire, electric shock, electrical energy – high current levels, or injury to persons shall be assembled so that the direction of rotation tends to tighten the means that hold the rotating part in place.

Exception: A keyed part, a press fit, a part locked in place with a pin, or equivalent means can be used to hold a rotating part in place.

9.5 A switch, fuseholder, lampholder, attachment-plug receptacle, motor-attachment plug, or other component that is handled by the operator shall be mounted securely, not turn, and comply with the requirements specified in 9.6.

Exception: The requirement that a switch shall not turn may be waived if all the following conditions are met:

- a) The switch is of a plunger, slide, or other type that does not tend to rotate during intended operation (a toggle switch is considered to be subjected to forces that tend to turn the switch);
- b) The means of mounting the switch make it unlikely that operation will loosen the switch;
- c) Spacings are not reduced below the minimum required value if the switch rotates; and
- d) Intended operation of the switch is by mechanical means rather than by direct contact by persons.

9.6 The means of securing components mentioned in 9.5 shall include more than friction between surfaces. A lock washer can be used as a means to secure a device having a single-hole mounting means.

9.7 A blower or fan motor including the blower or fan blade itself shall be secured by bolts and nuts complying with 9.3, bolts and nuts having holes or slots with cotter pins applied as intended, bolts having a compression type lock nut, rivets, or the equivalent means to reduce the likelihood of the motor, blower, or fan blade from vibrating loose and falling from its mounting support.

Exception No. 1: A blower or fan motor, including the blower or fan blade itself, secured by means described in 9.2 and oriented, positioned, or located above a barrier such that either the motor, blower, or fan blade is not likely to contact other components resulting in a risk of fire, electric shock, or electrical energy – high current levels in the event that such parts vibrated loose from their support.

Exception No. 2: Blowers and fans rated 200 cubic feet per minute or less.

10 Switches and Controls

10.1 A switch or other control device shall have current and voltage ratings not less than those of the circuit that it controls when the unit is operated in its intended manner.

10.2 A primary-circuit switch that controls an inductive load having a power factor less than 75 percent, such as a transformer or some ballasts and that does not have an inductive rating, shall be either rated not less than twice the maximum load current under normal operating conditions, or be investigated for the application.

10.3 A switch used to connect a load to various sources or potentials shall be a type that has been investigated and rated for such use. This would include a switch used for switching a voltmeter, frequency meter, and power factor meter between various phases.

10.4 A switch or other device controlling a relay, solenoid coil, or the like shall have a pilot duty rating intended for the application.

Exception: A device as described in 10.5 need not comply.

10.5 A device that is rated for across-the-line motor starting of an alternating current motor is acceptable for alternating current pilot duty without further tests provided the power factor for the motor test was 0.5 or less and the overload test current was at least 150 percent of the pilot duty inrush current at the same voltage. Switching devices rated in accordance with Table 10.1 are considered to comply with this requirement.

Table 10.1
Horsepower rating versus pilot duty rating

Horsepower rating 1 phase (120 – 600 Volts)	Alternating current pilot duty rating
1/10	125 VA (light duty)
1/2	360 VA (standard duty)
1	720 VA (heavy duty)

10.6 Each pole of a snap switch rated as a 2-circuit, 3-circuit, or multicircuit switch may control a separate load at the full voltage rating of the switch. Each pole of a snap switch rated as a 240-volt, 2-pole switch may control a separate 120-volt load, or both poles may be used to control both legs of a single 240-volt load. Each pole of a snap switch rated as a 240-volt, 3-pole switch may control a separate load not exceeding 139 volts or the three poles may be used to control the three legs of a 3-phase, 240-volt load.

10.7 A 240-volt or 250-volt snap switch used in a circuit involving more than 120 volts to ground shall be rated for such use as indicated by a double underlining under the voltage rating.

10.8 A switch shall not disconnect the grounded conductor of a circuit.

Exception No. 1: The grounded conductor may be disconnected by a switch that simultaneously disconnects all conductors of the circuit.

Exception No. 2: The grounded conductor may be disconnected by a switch that is so arranged that the grounded conductor may not be disconnected until the ungrounded conductors of the circuit have been disconnected.

10.9 Solid state switches shall comply with the requirements in this standard. Mechanical and electromechanical switches shall comply with the appropriate requirements for switches such as in the Standard for General-Use Snap Switches, UL 20, the Standard for Industrial Control Equipment, UL 508, or other appropriate standards.

10.10 If a unit switch or circuit breaker is mounted such that movement of the operating handle between the on position and off position results in one position being above the other position, the upper position shall be the on position. This requirement does not apply to a switching device having more than one on position, a double throw switch, a rotationally-operated switch, or a rocker switch.

11 Supply Connections

11.1 Fixed units

11.1.1 General

11.1.1.1 A fixed unit shall have provision for connection of a wiring system. This provision shall consist of either wiring terminals as specified in 11.1.1.3 – 11.1.2.10 or wiring leads as specified in 11.1.1.3 and 11.1.2.10 – 11.1.2.16 and a means for connection of cable or conduit as specified in 11.1.3.3.

Exception: The requirements described in 11.1.1.3 – 11.1.3.3 do not apply to the means for connection to accessible signal circuits complying with the requirements specified in Section 26.

11.1.1.2 The requirement in 11.1.1.1 applies to the wiring connection means for the alternating current and direct current input and output power circuits of a unit. These connections are intended to be made in the field when the unit is installed.

11.1.1.3 A wiring terminal or lead shall be acceptable for the connection of a conductor having an ampacity based on Table 310-16 of the National Electrical Code, ANSI/NFPA 70-1996 of no less than 125 percent of the maximum current that the circuit will carry during rated conditions described in 50.1. For determining the appropriate column in Table 310-16, see 71.2(o) and 71.2(p).

11.1.2 Wiring terminals

11.1.2.1 A wiring terminal shall comply with the requirement in 11.1.1.3 for a wire of each metal for which it is marked. See 69.2.9.

11.1.2.2 A wiring terminal shall be provided with a pressure terminal connector of other than the crimping type that is securely fastened in place – for example, firmly bolted or held by a screw.

Exception No. 1: A pressure terminal connector, including a crimping type, may be field-installed in accordance with 11.1.2.4.

Exception No. 2: A wire-binding screw may be employed at a wiring terminal intended for connection of a No. 10 AWG (5.3 mm²) or smaller conductor if upturned lugs, a cupped washer, or the equivalent is provided to hold the wire in position.

11.1.2.3 A wiring terminal shall be prevented from turning or shifting in position by a means other than friction between surfaces. This may be accomplished by two screws or rivets; by square shoulders or mortises; by a dowel pin, lug, or offset; by a connecting strap or clip fitted into an adjacent part; or by an equivalent method.

Exception: A pressure terminal connector of the type that secures the wire by crimping and used in accordance with the requirements in 11.1.2.4 need not be prevented from turning provided that when the connectors are oriented in the position resulting in the least spacing between adjacent terminals and also between terminals and dead metal parts, the spacing complies with Spacings, Section 22.

11.1.2.4 In accordance with the Exception to 11.1.2.2, a pressure terminal connector need not be provided if the conditions in (a) – (e) are complied with:

- a) One or more component terminal assemblies shall be available from the unit manufacturer or others, and they shall be specified in the instruction manual. See 71.2(b) and (c).

- b) The fastening hardware such as a stud, nut, bolt, spring or flat washer, and the like, as mounted on or separately packaged with the unit, or specified in the instruction manual.
- c) The installation of the terminal assembly shall not involve the loosening or disassembly of parts other than a cover or other part giving access to the terminal location. The means for securing the terminal connector shall be readily accessible for tightening before and after installation of conductors.
- d) If the pressure terminal connector provided in a terminal assembly requires the use of other than an ordinary tool for securing the conductor, identification of the tool and any necessary instructions shall be included in the assembly package or with the unit. See 71.2(d).
- e) Installation of the pressure terminal connector in the intended manner shall result in a unit complying with the requirements of this standard.

11.1.2.5 An insulating base for support of a pressure terminal connector shall be subjected to the Strength of Terminal Insulating Base and Support Test, Section 59.

11.1.2.6 A wire-binding screw at a field-wiring terminal shall not be smaller than No. 10 (4.8 mm diameter).

Exception No. 1: A No. 8 (4.2 mm diameter) screw may be used at a terminal intended only for the connection of a No. 14 AWG (2.1 mm²) conductor or a No. 16 or 18 AWG (1.3 or 0.82 mm²) control-circuit conductor.

Exception No. 2: A No. 6 (3.5 mm diameter) screw may be used for the connection of a No. 16 or 18 AWG (1.3 or 0.82 mm²) control-circuit conductor.

11.1.2.7 A wire-binding screw shall thread into metal.

11.1.2.8 A terminal plate tapped for a wire-binding screw shall be of metal not less than 0.050 inch (1.27 mm) thick.

Exception: A terminal plate less than 0.050 inch (1.27 mm) thick is acceptable in a LVLE circuit or limited energy circuit (see 2.20 and 2.23) if the tapped threads can withstand the tightening torque specified in Table 11.1 without stripping.

Table 11.1
Tightening torque for wire-binding screws

Size of terminal screw, number	Wire sizes to be tested, AWG ^a	Tightening torque	
		Pound-inches	Newton meters
6	16 – 18 (ST)	12	1.4
8	14 (S) and 16 – 18 (ST)	16	1.8
10	10 – 14 (S) and 16 – 18 (ST)	20	2.3

^a ST – stranded wire; S – solid wire.

11.1.2.9 There shall be two or more full threads in the metal of a terminal plate. The metal may be extruded at the tapped hole to provide at least two full threads.

Exception: Two full threads are not required for a terminal in a LVLE or limited-energy circuit – see 2.20 and 2.23 – if a lesser number of threads results in a secure connection in which the threads will not strip when subjected to the tightening torque specified in Table 11.1.

11.1.2.10 A terminal for connection of a grounded conductor of an alternating current power circuit shall be identified as described in 69.2.11.

11.1.2.11 A field-wiring lead shall not be more than two wire sizes smaller than the copper conductor to which it will be connected, and shall not be smaller than No. 18 AWG (0.82 mm^2), for example, a No. 10 AWG (5.3 mm^2) or larger field-wiring lead is required for connection to a No. 6 AWG (13.3 mm^2) field-provided conductor. A field-wiring lead shall not be less than 6 inches (152.4 mm) long.

Exception No. 1: A No. 18 AWG size field-wiring lead may be provided for connection to a No. 12 AWG (3.3 mm^2) size branch circuit conductor.

Exception No. 2: A lead may be more than two wire sizes smaller than the field-provided copper conductor to which it will be connected, but not smaller than No. 18 AWG (0.82 mm^2), if more than one factory-provided copper lead is intended for connection to the same field-provided lead, and the construction complies with the conditions in (a) – (c):

- a) A wire connector for connection of the field-provided wire is provided as part of the unit or remote-control assembly, and the wire connector is acceptable for the combination of wires that will be spliced;*
- b) The factory-provided leads are bunched or otherwise arranged so that stress does not result on an individual lead; and*
- c) Instructions are provided in accordance with 71.2(e).*

11.1.2.12 A field-wiring lead shall consist of general building wire, or other wiring if it has an insulation of:

- a) At least 1/32-inch (0.8-mm) thick thermoplastic material;
- b) At least 1/64-inch (0.4-mm) thick rubber plus a braid cover for applications of 300 volts or less;
- c) At least 1/32-inch thick rubber plus a braid cover for applications between 301 and 600 volts.

11.1.2.13 A field-wiring lead shall be subjected to the test specified in 56.1.4.

11.1.2.14 A field-wiring lead provided for connection to an external line-voltage circuit shall not be connected to a wire-binding screw or pressure terminal connector located in the same compartment as the free end of the wiring lead unless the screw or connector is rendered unusable for field-wiring connection or the lead is insulated at the unconnected end, and a marking is provided on the unit in accordance with 69.2.16.

11.1.2.15 The free end of a field-wiring lead that will not be used in every installation, such as a tap for a multivoltage transformer, shall be insulated. For a grounding lead, see 16.1.8.

11.1.2.16 A field-wiring lead for connection of a grounded conductor shall be identified as described in 69.2.11.

11.1.3 Wiring compartments

11.1.3.1 A wiring compartment on a fixed unit shall be located so that wire connections therein will be accessible for inspection, without disturbing either factory or field connected wiring, after the unit is installed in the intended manner.

11.1.3.2 Wiring compartments, raceways, and the like, for routing and stowage of conductors connected in the field shall not contain rough, sharp, or moving parts that may damage conductor insulation.

11.2 Openings for conduit or cable connection

11.2.1 For a fixed unit, an opening or knockout complying with the requirements specified in 4.7.1 – 4.7.8 shall be provided for connection of conduit or cable wiring system.

Exception: A unit complying with the requirements specified in 4.7.6 and 4.7.7 need not be provided with an opening or a knockout.

11.3 Openings for Class 2 circuit conductors

11.3.1 An opening for the entry of a conductor or conductors of a Class 2 circuit shall be provided with an insulating bushing. The bushing may be mounted in place in the opening or may be within the enclosure so that it may be mounted as intended when the unit is installed.

Exception: The bushing may be omitted if the opening is acceptable for accommodating armored cable or conduit and the installation instructions indicate that Class 1 wiring methods are to be used as indicated in 71.2(p).

11.3.2 A bushing of rubber or rubber-like material provided in accordance with 11.3.1 shall be at least 1/8 inch (3.2 mm) thick, except that it may be not less than 3/64 inch (1.2 mm) thick if the metal around the hole is eyeletted or similarly treated to provide smooth edges. A bushing shall be located so that it will not be exposed to oil, grease, oily vapors, or other substances having a deleterious effect on the material of the bushing. A hole in which such a bushing is mounted shall be free from sharp edges, burrs, projections, or the like, that may damage the bushing.

11.4 Cord-connected units

11.4.1 General

11.4.1.1 For a stationary unit, flexible cords and attachment plugs and receptacles shall be used for connection to the alternating current and direct current input and output power circuits. The requirements described in 11.4.2.1 – 11.4.2.9 do not apply to a Class 2 circuit or to an accessible signal circuit complying with the requirements in Accessible Signal Circuits, Section 25.

11.4.2 Cords and plugs

11.4.2.1 The cord shall be Type G, SJTW-A, SJEOW-A, S, ST, SE, SO, SOO, STO, STOO, or W. The length of the cord used for the alternating current input circuit as measured from the face of the attachment plug to the point where the cord emerges from the unit shall be not less than 6 feet (1.8 m).

11.4.2.2 The voltage rating of a flexible cord shall be at least the rated voltage of the unit, and its ampacity shall be at least the current rating of the unit.

11.4.2.3 The attachment plug of a supply cord shall have a current rating in accordance with 11.4.2.4 and have a voltage rating corresponding to the rated voltage of the unit.

11.4.2.4 With reference to 11.4.2.3, the current rating of an attachment plug for the alternating current input circuit shall not be less than 125 percent of the rated input alternating current.

11.4.2.5 The attachment plug shall be of the polarized type if the unit is not provided with a grounding type attachment plug – see 13.5.

11.5 Strain relief

11.5.1 Strain relief shall be provided to reduce the risk of mechanical twisting or stress on a flexible cord or welding cable from being transmitted to terminals, splices, or interior wiring. See 56.1.1 and 55.1.3. The means for preventing twisting is to be evaluated by inspection. The tests described in 56.1.1 and 55.1.3 are to be conducted to evaluate the means for preventing stress.

11.5.2 If a knot in a flexible cord serves as strain relief, the surfaces that the knot may contact shall be free from burrs, fins, sharp edges, and projections that may damage the cord.

11.5.3 Means shall be provided to reduce the risk of the flexible cord from being pushed into the unit enclosure through the cord-entry hole if such displacement may result in mechanical damage to the cord, expose the cord to a temperature higher than that for which it is rated, or reduce spacings, such as to a metal strain-relief clamp, below the minimum acceptable values.

11.6 Bushings

11.6.1 At the point at which a supply cord passes through an opening in a wall, barrier, or the overall enclosure, there shall be a bushing or the equivalent that is secured in place and that has a smooth, well-rounded surface against which the cord can bear.

11.6.2 Ceramic materials and some molded compositions are acceptable for insulating bushings, but bushings of wood or hot-molded shellac and tar compositions are not acceptable.

11.6.3 A bushing of the same material as is molded integrally with the supply cord is acceptable if the built-up section is not less than 1/16 inch (1.6 mm) thick at the point at which the cord passes through the enclosure.

11.7 Identification

11.7.1 A unit rated:

- a) 120 volts, 2-wire;
- b) 120/240 volts, single-phase, 3-wire;
- c) 208Y/120 volts, two-phase, 3-wire;
- d) 208Y/120 volts, three-phase, 4-wire;
- e) 480Y/277 volts, three-phase, 4-wire in which the neutral is used as a circuit conductor;
- f) 240/120 volts, three-phase, 4-wire in which the midpoint on one phase is used as a circuit conductor; or
- g) 240 or 480 volts, three-phase, 3-wire, corner-grounded delta;

shall have the grounded conductor connected to the following items, if provided the screw shell of an Edison-base lampholder and the screw shell of an Edison-base fuseholder. The grounded conductor of a fixed unit shall be connected to the field-wiring terminal intended for the connection of a grounded conductor – see 11.1.2.10 – or shall be connected to the field-wiring lead intended for the connection of a grounded conductor – see 11.1.2.16. The grounded conductor of a stationary or portable unit shall be connected to the blade of the attachment plug intended for connection to the grounded supply conductor. A single-pole switch or single-pole overcurrent protective device, other than an automatic control without a marked off position shall be connected to the ungrounded conductor. See also 10.8.

12 Wire Bending Space

12.1 A permanently connected unit employing pressure terminal connectors for field connection of circuits described in 11.1.1.2 shall be provided with space within the enclosure as specified in 12.3 – 12.7 for the installation of conductors including grounding conductors likely to be employed in the installation.

12.2 The conductor size used in judging the wiring space is to be based on the use of a conductor sized in accordance with 11.1.1.3.

12.3 Wire bending space for field installed conductors shall be provided opposite any pressure wire connector as specified in 12.4 or 12.5 and opening or knockout for a conduit or wireway in a gutter as specified in 12.9.

12.4 If a conductor is likely to enter or leave the enclosure surface opposite its wire connector, the wire bending space shall be as specified in Table 12.1. A wire is considered likely to enter or leave a top, back, bottom, or side surface if there is an opening or knockout for a wireway or conduit.

12.5 If a conductor is not likely to enter or leave the enclosure surface opposite its wire connector, the wire bending space shall be as specified in Table 12.2. The wire bending space may be in accordance with Table 12.2 if a barrier is provided between the connector and the opening, or drawings are provided specifying that the conductors are not to enter or leave the enclosure directly opposite the wire connector. See Illustrations A, B, and C of Figure 12.1.

12.6 If a conductor is restricted by a barrier or other means from being bent where it leaves the connector, the distance is to be measured from the end of the barrier. See illustration D of Figure 12.1.

12.7 For a unit not provided with a conduit opening or knockout – see 4.7.6 – the minimum wiring bending space mentioned in 12.4 – 12.6 shall be based on any enclosure wall likely to be used for installation of the conduit or only specific walls that are to be used as determined by a marking, drawing, or template furnished with the unit.

12.8 The distance mentioned in 12.3 – 12.5 is to be measured in a straight line from the edge of the wire terminal closest to the wall in a direction perpendicular to the box wall or barrier. See illustrations A – C of Figure 12.1. The wire terminal is to be turned so that the axis of the wire opening in the connector is as close to perpendicular to the wall of the enclosure as it can assume without defeating any means provided to prevent turning, such as a boss, shoulder, walls of a recess, multiple bolts securing the connector, or the like. A barrier, shoulder, or the like is to be disregarded when the measurement is being made if it does not reduce the radius to which the wire must be bent. If a terminal is provided with one or more connectors for the connection of conductors in multiple, the distance is to be measured from the wire opening closest to the wall of the enclosure.

Exception: See 12.6.

Table 12.1
Minimum wire-bending space for conductors through a wall
opposite terminals in inches (mm)

Wire size, AWG or kcmil (mm ²)		Wires per terminal (pole) ^a			
		1	2	3	4 or More
14 – 10 AWG	(2.1 – 5.3)	Not Specified		–	–
8	(8.4)	1-1/2 (38.1)	–	–	–
6	(13.3)	2 (50.8)	–	–	–
4	(21.1)	3 (76.2)	–	–	–
3	(26.7)	3 (76.2)	–	–	–
2	(33.6)	3-1/2 (88.9)	–	–	–
1	(42.4)	4-1/2 (114)	–	–	–
0	(53.5)	5-1/2 (140)	5-1/2	7 (179)	–
2/0	(67.4)	6 (152)	6	7-1/2 (191)	–
3/0	(85.0)	6-1/2 [1/2] (165)	6-1/2 [1/2] (165)	8 (203)	–
4/0	(107)	7 [1] (179)	7-1/2 [1-1/2] (191)	8-1/2 [1/2] (216)	–
250 kcmil	(127)	8-1/2 [2] (216)	8-1/2 [2] (216)	9 [1] (229)	10 (254)
300	(152)	10 [3] (254)	10 [2] (254)	11 [1] (279)	12 (305)
350	(177)	12 [3] (305)	12 [3] (305)	13 [3] (330)	14 [2] (355)
400	(203)	13 [3] (330)	13 [3] (330)	14 [3] (355)	15 [3] (381)
500	(253)	14 [3] (355)	14 [3] (355)	15 [3] (381)	16 [3] (406)
600	(304)	15 [3] (381)	16 [3] (406)	18 [3] (457)	19 [3] (483)
700	(355)	16 [3] (406)	18 [3] (457)	20 [3] (508)	22 [3] (559)
750	(380)	17 [3] (432)	19 [3] (483)	22 [3] (559)	24 [3] (610)
800	(405)	18 (457)	20 (508)	22 (559)	24 (610)
900	(456)	19 (483)	22 (559)	24 (610)	24 (610)
1000	(507)	20 (508)	–	–	–
1250	(633)	22 (559)	–	–	–
1500	(760)	24 (610)	–	–	–
1750	(886)	24 (610)	–	–	–
2000	(1013)	24 (610)	–	–	–

Note – The table includes only those multiple-conductor combinations that are likely to be used. Combinations not mentioned may be given further consideration.

^a Wire bending space shall be permitted to be reduced by the number of inches shown in brackets under the following conditions:

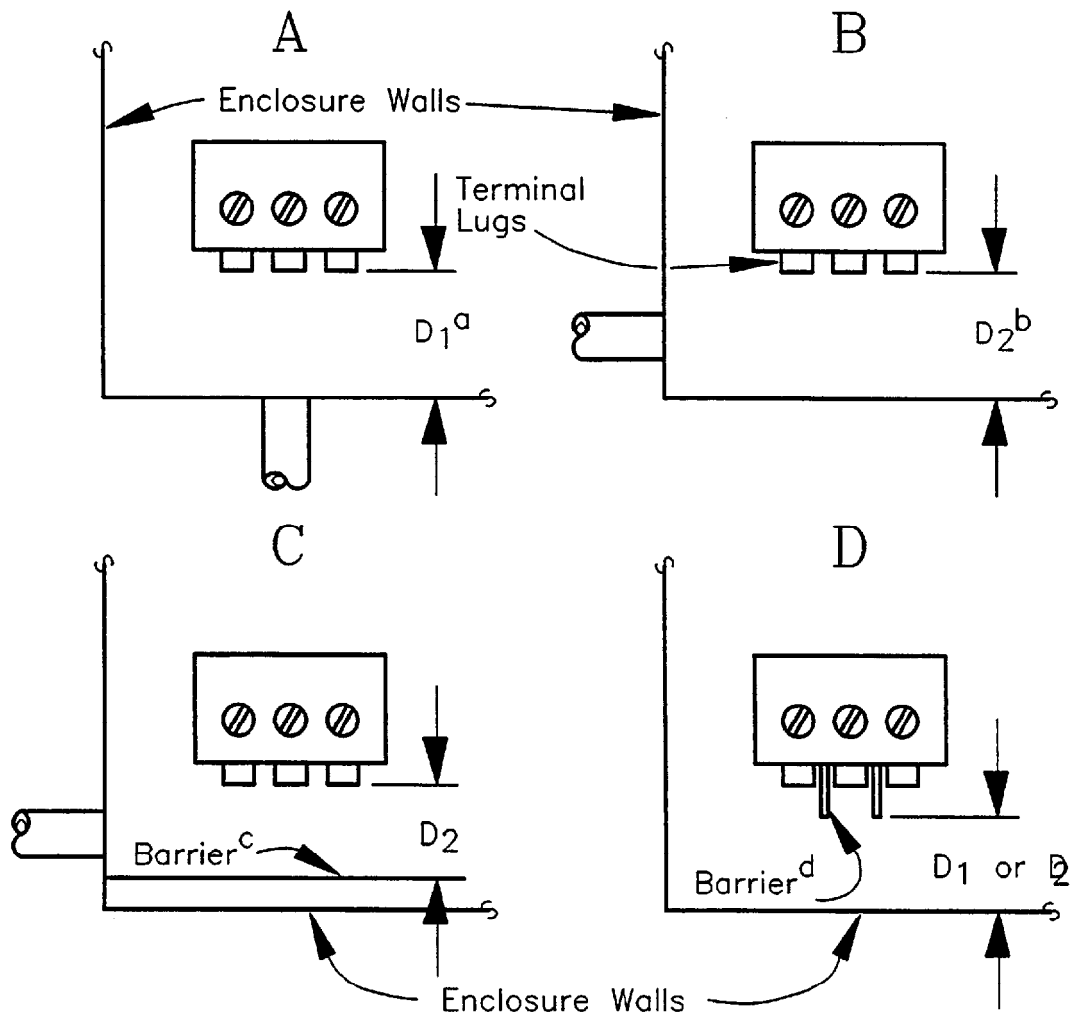
- 1) Only removable or lay-in wire connectors receiving one wire each are used (there may be more than one removable wire connector per terminal) and
- 2) The removable wire connectors can be removed from their intended location without disturbing structural or electrical parts other than a cover, and can be installed with the conductor in place.

Table 12.2
Minimum width of gutter and wire-bending space for conductors
through a wall not opposite terminals in inches (mm)

Size of wire, AWG or kcmil (mm ²)	Wires per terminal (pole)				
	1	2	3	4	5
14 – 10 AWG (2.1 – 5.3)	Not Specified	–	–	–	–
8 – 6 (8.4 – 13.3)	1-1/2 (38.1)	–	–	–	–
4 – 3 (21.1 – 26.7)	2 (50.8)	–	–	–	–
2 (33.6)	2-1/2 (63.5)	–	–	–	–
1 (42.4)	3 (76.2)	–	–	–	–
1/0 – 2/0 (53.5 – 7.4)	3-1/2 (88.9)	5 (127)	7 (178)	–	–
3/0 – 4/0 (85.0 – 107)	4 (102)	6 (152)	8 (203)	–	–
250 kcmil (127)	4-1/2 (114)	6 (152)	8 (203)	10 (254)	–
300 – 350 (152 – 177)	5 (127)	8 (203)	10 (254)	12 (305)	–
400 – 500 (203 – 253)	6 (152)	8 (203)	10 (254)	12 (305)	14 (356)
600 – 700 (304 – 355)	8 (203)	10 (254)	12 (305)	14 (356)	16 (406)
750 – 900 (380 – 456)	8 (203)	12 (305)	14 (356)	16 (406)	18 (457)
1000 – 1250 (507 – 633)	10 (254)	–	–	–	–
1500 – 2000 (760 – 1010)	12 (305)	–	–	–	–

NOTE – The table includes only those multiple-conductor combinations that are likely to be used. Combinations not mentioned may be given further consideration.

Figure 12.1
Wire bending space



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(Continued)