UL 1741

STANDARD FOR SAFETY

Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources

UL Standard for Safety for Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources, UL 1741

Third Edition, Dated September 28, 2021

Summary of Topics:

This revision of UL 1741 dated May 19, 2023 includes the addition of requirements Arc-Fault Circuit Protection: Section 34A, 93.18, 94.1 and Appendix A.

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

The new and revised requirements are substantially in accordance with Proposal(s) on this subject dated October 19, 2022 and April 12, 2023.

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SEPTEMBER 28, 2021
(Title Page Reprinted: May 19, 2023)

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UL 1741

Standard for Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources

Before November 7, 2005, the title for UL 1741 was Standard for Inverters, Converters, and Controllers for Use in Independent Power Systems.

First Edition – May, 1999
Second Edition – January, 2010

Third Edition

September 28, 2021

This UL Standard for Safety consists of the Third edition including revisions through May 19, 2023.

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

NOTE – The user's attention is called to the possibility that compliance with this standard may require use of an invention covered by patent rights.

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INTRODUCTION

1 Scope

1.1 These requirements cover inverters, converters, charge controllers, and interconnection system equipment (ISE) intended for use in stand-alone (not grid-connected) or interactive (grid-connected) power systems. Interactive inverters, converters, and ISE are intended to be operated in parallel with an electric power system (EPS) to supply power to common loads.

1.2 For interactive equipment, these requirements are intended to supplement and be used in conjunction with the Standard for Interconnecting Distributed Resources With Electric Power Systems, IEEE 1547, and the Standard for Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems, IEEE 1547.1.

1.3 These requirements cover AC modules that combine flat-plate photovoltaic modules and inverters to provide AC output power for stand-alone use or interaction with the electric power system (EPS), commonly the electric utility grid, and power systems that combine other alternative energy sources with inverters, converters, charge controllers, and interconnection system equipment (ISE), in system specific combinations.

1.4 These requirements also cover power systems that combine independent power sources with inverters, converters, charge controllers, and interconnection system equipment (ISE) in system specific combinations.

1.5 The products covered by these requirements are intended to be installed in accordance with the National Electrical Code, NFPA 70.

1.6 These requirements also cover rapid shutdown equipment and systems.

2 Glossary

2.1 General

2.1.1 In the text of this standard, the term "unit" refers to any product covered by this Standard. For the purpose of this Standard, the definitions in 2.1.2 – 2.1.54 apply.

2.1.2 AC MODULE – The smallest complete unit that includes solar cells, optics, inverters, and other components, excluding tracking devices, intended to generate ac power from sunlight.

2.1.3 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.

2.1.4 BRANCH CIRCUIT – The portion of the building wiring system beyond the final overcurrent protective device in the power-distribution panel that protects the ac output of the field-wiring terminals in a permanently connected unit.

2.1.5 BYPASS SOURCE – A branch circuit or generator to which the load is connected when the power conversion portion of the inverter is not supplying power to the load.

2.1.6 CHARGE CONTROLLER – A device intended to control the charging process of storage batteries used in photovoltaic power systems.

2.1.7 CLASS 2 TRANSFORMER – A step-down transformer complying with the applicable requirements in the Standard for Low Voltage Transformers – Part 1: General Requirements, UL 5085-1, and the Standard for Low Voltage Transformers – Part 3: Class 2 and Class 3 Transformers, UL 5085-3.

2.1.8 CONTROL CIRCUIT – A circuit that carries low-voltage, limited-energy (LVLE) electric signals and not main power, voltage or current.

2.1.9 CONVERTER – A device that accepts ac or dc power input and converts it to another form of ac or dc power. For the purposes of this standard and unless otherwise specified, ac output converters intended to directly supply power to loads are to be subjected to all of the requirements for inverters.

2.1.10 DC GROUND FAULT DETECTOR/INTERRUPTER – A device that provides protection for photovoltaic arrays by detecting a ground fault and interrupting the fault path in the dc circuit.

2.1.11 DEGREE OF PROTECTION – The extent of protection provided by an enclosure against access to parts which involve a risk of injury to persons, ingress of foreign solid objects, and/or ingress of water as verified by standardized test methods.

2.1.12 DISCONNECT DEVICE – A device that disconnects the conductors of a circuit from a supply, source, utility, or load.

2.1.12A DOOR – A cover provided with a hinge and a hand-operable latch.

2.1.13 ELECTRIC POWER SYSTEM (EPS) – Equipment or facilities that deliver electric power to a load. The most common example of an EPS is an electric utility.

2.1.14 ENCLOSURE – A surrounding case constructed to provide a degree of protection against:

a) The accessibility of a part that potentially involves a risk of fire, electric shock or injury to persons, or

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

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

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

2.1.17 FIXED UNIT – A unit that is intended to be permanently connected mechanically and electrically and only able to be detached by the use of a tool.

2.1.18 GRID SUPPORT UTILITY-INTERACTIVE INVERTER / GRID SUPPORT UTILITY-INTERACTIVE ISE – An inverter or ISE intended for use in parallel with an electric utility that complies with the advanced interconnection requirements in Supplement SA for Grid Support Utility-Interactive Equipment, and/or Supplement SB for Grid Support Utility-Interactive Inverters and Converters Based upon IEEE 1547-2018 and IEEE 1547.1-2020.

2.1.19 GROUNDED CONDUCTOR – A system or circuit conductor that is intentionally grounded.

2.1.20 GUARD – A part outside of the enclosure that reduces access to a component involving a risk of injury to persons. See Enclosures and Guards, Section 38.

2.1.21 INTERACTIVE EQUIPMENT – Generic reference for equipment that operates in parallel with an EPS. Some examples are; utility interactive, grid support utility-interactive or special purpose utility-interactive equipment including generation sources such as inverters, converters, or rotating generators. Another example is ISE that performs interconnection monitoring, protection and control that may be used in conjunction with DERs to address the requirements for interactive equipment.

2.1.22 INTERCONNECTION SYSTEM EQUIPMENT (ISE) – A component or system of components that performs protective and control functions used to interconnect a distributed resource to an EPS. ISE may be a control subassembly(s) of an inverter or non-inverter distributed energy resource (DER).

2.1.23 INVERTER – An electronic device that changes dc power to ac power.

2.1.24 ISLANDING PROTECTION – Protection against the continuous operation of the inverter and part of the utility load while isolated from the remainder of the electric utility system.

2.1.25 ISOLATED CIRCUIT – A circuit having an isolation transformer or isolating components such as optically or magnetically coupled devices.

2.1.26 ISOLATION TRANSFORMER – A transformer having its primary winding electrically isolated from its secondary winding and constructed so that there is no electrical connection – under normal and overload conditions – between the primary and secondary windings, between the primary winding and the core, or between separate adjacent secondary windings, where such connection results in a risk of fire or electric shock.

2.1.27 KNOCKOUT – A portion of the wall of an enclosure so fashioned that it is capable of being readily removed by a hammer, screwdriver, and pliers at the time of installation in order to provide an opening or hole for the attachment of an auxiliary device, raceway, cable, or fitting.

2.1.28 LIMITED-ENERGY (LE) CIRCUIT – An ac or dc circuit having a voltage not exceeding 1000 volts and the energy limited to 100 volt-amperes by:

a) The secondary winding of a transformer,

b) One or more resistors complying with 31.10, or

c) A regulating network complying with 31.11.

2.1.29 LIVE PART – An electrically conductive part within a unit that during intended use has a potential difference with respect to earth ground.

2.1.29A LOW-VOLTAGE COMPARTMENT – A portion of an enclosure that does not contain wiring or components operating above 1000 Vac or above 1500 Vdc and that is completely separated from any medium-voltage compartment by grounded metal barriers.

Note: It is acknowledged that other standards and codes may have different definitions and voltage limits for medium voltage.

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

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

1) Not of the automatic reclosing type,

2) Trip-free from the reclosing mechanism, and

3) Not readily interchangeable with a device of a different rating or the device is marked in accordance with 67.7.

b) A combination of an isolated transformer secondary winding and one or more resistors or a regulating network complying with 31.11 that complies with all the performance requirements for an inherently limited Class 2 transformer or power source; or

c) A battery that is isolated from the primary circuit or a combination of a battery, including the battery charging circuit of a unit that is isolated from the primary circuit, and one or more resistors or a regulating network complying with 31.11.

2.1.31 MANUFACTURER-SPECIFIED EXTERNAL ISOLATION TRANSFORMER – A manufacturer-specified isolation transformer that is external to the product, but which is always required for proper operation of the product. For example, when an isolation transformer is required to prevent circulating ground current in installations that have a grounded conductor in the ac or dc input power circuit.

2.1.32 MAXIMUM INPUT SHORT-CIRCUIT CURRENT (I_{sc} MAX) – Absolute maximum prospective short circuit current that a DC port of the DUT is rated to have connected to it.

Note: This could be the short circuit from a PV array, battery or, energy storage device. For a PV source it would account for worst-case conditions of ambient temperature, irradiance, etc. For NEC compliant installation, this Maximum Input Short Circuit Current rating equates to 1.25 × I_{sc} of the PV array.

2.1.33 MAXIMUM SYSTEM VOLTAGE – The open-circuit voltage (Voc) of the photovoltaic module or panel multiplied by the temperature correction factor specified in Article 690.7 of the National Electrical Code, ANSI/NFPA 70, for crystalline and multi-crystalline silicon photovoltaic modules and panels. The maximum system voltage is equal to the Voc for amorphous silicate and thin film photovoltaic modules and panels.

2.1.33A MEDIUM VOLTAGE – Voltage above 1000 Vac or above 1500Vdc.

Note: It is acknowledged that other standards and codes may have different definitions and voltage limits for medium voltage.

2.1.33B MEDIUM VOLTAGE COMPARTMENT – A portion of an enclosure that contains any wiring or component operating at medium voltage.

2.1.33C MEDIUM VOLTAGE DOOR – A door that provides access to insulated or uninsulated medium voltage components, equipment or wiring, other than those in individual grounded metal enclosures.

2.1.34 OPEN-CIRCUIT VOLTAGE (Voc) – The maximum no load output voltage of a photovoltaic module or panel at standard test conditions (STC). See 2.1.49.

2.1.35 PERMANENTLY CONNECTED UNIT – A unit connected to the electrical supply by means other than a supply cord and an attachment plug.

2.1.36 POWER CONNECTOR – A single conductor or multiple conductor, cable mounted or chassis (bulkhead) mounted connector that carries the main input or output power of the device under test. Connectors used for control, communication or data signals or cables carrying limited power for these devices are not considered power connectors.

2.1.37 PRESSURE TERMINAL CONNECTOR – A terminal that accomplishes the connection of one or more conductors by means of pressure without the use of solder. Examples of pressure terminal connectors are:

a) Barrel and setscrew type,

b) Crimp-type barrel, or

c) Clamping plate and screw type.

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

2.1.39 PULSE-WIDTH MODULATED (PWM) CHARGING – A charge control method that enables the photovoltaic current to bring the battery voltage to constant voltage type regulation using pulse width modulated control by setting the voltage regulation reconnect (V_{rr}) setpoint photovoltaic array closer to the disconnect (V_r) using pulse-width-modulated control circuitry. Based on the rate of switching, the overall current is able to taper similar to the constant voltage type regulation.

2.1.40 PV MODULES WITH INTEGRATED ELECTRONICS (PVIE) – A PV module with electronics physically connected.

2.1.41 RISK OF ELECTRICAL ENERGY- HIGH CURRENT LEVEL – The capability for damage to property or injury to persons, other than by electric shock, from available electrical energy existing between a live part and an adjacent dead metal part or between live parts of different polarity, where there is a potential of 2 volts or more and:

a) An available continuous power level of 240 volt-amperes or more, or

b) A reactive energy level of 20 joules or more.

For example, a tool, or other metal, short-circuiting a component that is able to result in a burn or a fire when enough energy is available at the component to vaporize, melt, or more than warm the metal.

2.1.42 SAFETY CIRCUIT – Any primary or secondary circuit that is used to reduce the risk of fire, electric shock, injury to persons, or electrical energy – high current levels. A safety interlock circuit, for example, is a safety circuit.

2.1.43 SAFETY INTERLOCK – A means relied upon to reduce the accessibility to an area that involves 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.

2.1.44 SECONDARY CIRCUIT – A circuit supplied from a secondary winding of an isolation transformer.

2.1.45 SERIES CHARGE CONTROLLER – A control element for battery charging that is in series with a photovoltaic array and a battery. The control element usually operates in an on/off mode, a pulse-width modulated (PWM) mode, or a linear control mode. The control element is usually a solid state switching device or a mechanical relay.

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

2.1.47 SPECIAL PURPOSE INTERACTIVE INVERTER / CONVERTER / PRODUCT – An interactive inverter / converter / product evaluated for specific applications different from those where utility-interactive and grid support inverters are generally used. These units may have specific utility interconnection protection settings that allow them to provide specific interactive functions for a special application. These products may rely upon internal or external utility interconnection protection functions or devices, as identified for the particular product. External utility interconnection protection may be provided by means of utility protection relays as required by the local electric utility. IEEE 1547-2018 refers to this type of product as a Partially Compliant Product.

Note: Special purpose interactive products are intended for use in specific power production applications that export power to the electric utility. These units are often installed in power farm applications. These units may be evaluated for compliance to a subset of the published grid interconnection requirements and they may also include additional special purpose interactive features addressed through other documents, standards, and other functions that may be enabled in accordance with local utility interconnection protection requirements.

2.1.48 STAND-ALONE INVERTER – An inverter intended to supply a load and does not provide power back to the electric utility.

2.1.49 STANDARD TEST CONDITIONS (STC) – Test conditions consisting of:

a) 100 mW/cm^2 irradiance,

b) AM 1.5 spectrum, and

c) 25 °C (77 °F) cell temperature.

2.1.50 TOOL – A screwdriver, coin, key, or any other object that is usable to operate a screw, latch, or similar fastening means.

2.1.51 TOTAL HARMONIC DISTORTION (THD) – The ratio of the root-mean-square (rms) of the harmonic content to the root-mean-square value of the fundamental quantity, expressed as a percentage.

THD = [(sum of squares of amplitudes of all harmonics)/(square of amplitude of fundamental)]$^{1/2}$ × 100

2.1.52 UTILITY-INTERACTIVE INVERTER – An inverter intended for use in parallel with an electric utility to supply common loads and sometimes deliver power to the utility.

Note: This term is traditionally associated with products compliant with IEEE 1547-2003 and IEEE1547.1-2005.

2.1.53 VOLTAGE REGULATION (V_r) SETPOINT – The maximum battery voltage that a charge controller enables the battery to reach under charging conditioners. At this voltage the charge controller discontinues charging or begins to minimize the charging current to the battery.

2.1.54 VOLTAGE REGULATION RECONNECT (V_{rr}) SETPOINT – The battery voltage at which the charge controller reconnects the array to the battery when it has been disconnected at the V_r setpoint.

2.2 PV rapid shutdown equipment and systems

2.2.1 ATTENUATE OR ATTENUATED – To reduce either the voltage or current, or both, in controlled conductors resulting in a reduction of the respective magnitudes and a reduction in available energy to levels as specified in sections of this standard where the function is required. The attenuation or attenuation equipment as specified in this standard may use active electronic circuits or dissipative methods that are switched or permanently connected.

2.2.2 CONTROLLED CONDUCTOR(S) – PV system conductors that are subject to the Rapid Shutdown System requirements in Section 690.12 of the NEC (NFPA 70). Controlled conductors may include PV source and PV output conductors, PV input conductors to an inverter, ac output conductors of an inverter, input and output conductors of a charge controller (CC) and conductors connected to an energy storage system that is directly connected to a PV dc source.

2.2.3 CONTROLLED STATE – A condition related to Controlled Conductors under which the voltage, volt-amperes, and currents on the conductors adhere to the rapid shutdown safety specifications of this standard when the rapid shutdown is activated.

2.2.4 INITIATION DEVICE(S) or INITIATOR(S) – One or more manual or automatic switching device(s), input port(s) or signal(s) that will result in the activation of the rapid shutdown system function(s).

2.2.5 NOMINAL OPERATING CELL TEMPERATURE (NOCT) – The equilibrium cell junction temperature corresponding to nominal module service operating conditions in a reference environment of 80 mW/cm^2 irradiance, 20 °C (68 °F) ambient air temperature, 1 m/s wind across the module from side to side, an electrically open circuit, and a mounting method in accordance with the Standard for Flat-Plate Photovoltaic Modules and Panels, UL 1703.

2.2.6 PV RAPID SHUTDOWN EQUIPMENT (PVRSE) – Equipment intended to be used in a PVRSS to initiate, disconnect, isolate or attenuate the controlled conductors of a PV system.

2.2.7 PV RAPID SHUTDOWN SYSTEM (PVRSS) – System consisting of PVRSE intended to initiate, in addition to disconnect, isolate or attenuate the controlled conductors of a PV system.

2.2.8 RAPID SHUTDOWN TIME LIMIT – The rated time limit that a PVRSE or PVRSS takes to achieve the required level in Section 98.1. The rated time limit of a PVRSS shall not exceed the limit defined in Section 690.12 of the NEC (NFPA 70).

Note: NEC 690.12 specifies the response time as no greater than 30 seconds in the 2017 NEC and 2014 NEC as amended by TIA 14-10 log number 1223 dated August 13, 2016.

2.2.9 RESET DEVICE – A device used to return the PVRSS to its normal state.

2.2.10 SIMULTANEOUSLY – For the purpose of testing within this standard, the term simultaneously indicates that multiple switching events will all occur with no intentional delay. Test circuits shall be designed to minimize temporal switching event differences.

2.2.11 STATUS INDICATOR – Visual indicator located at an initiation device or other location showing a visual confirmation to the operator that the rapid shutdown command has been effectively implemented.

3 Components

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

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

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

b) Is superseded by a requirement in this standard.

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

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

4 Units of measurement

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

5 References

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

CONSTRUCTION

6 General

6.1 A unit intended to operate at rated voltages of 50 volts or less shall operate as intended in both grounded and ungrounded circuits.

6.2 Converters shall be subjected to all of the requirements for inverters.

7 Frame and Enclosure

7.1 General

7.1.1 A unit shall be provided with an enclosure that houses all current-carrying 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 to reduce the risk of fire, electric shock, injury to persons shall comply with the applicable enclosure requirements specified in this Standard.

7.1.2 The frame or chassis of a unit shall not be relied upon to carry current during normal operation.

Exception: As provided in the Exception to 22.12.

7.1.3 A part, such as a dial or nameplate that is a part of the enclosure shall comply with the enclosure requirements.

7.1.4 An enclosure other than a Type 1 (indoor use only) shall comply with Environmental Rated Enclosures, Section 7.9, or the requirements for the respective Type in the Standard for Enclosures for Electrical Equipment, UL 50.

7.1.5 Sheet-metal screws threading directly into metal shall not be used to attach a cover, door, or other part that is to be removed to install field wiring or for operation of the equipment. Machine screws, self-tapping machine screws, and thread forming screws are able to thread directly into sheet-metal when they allow for at least two full threads of screw engagement.

7.1.6 Sheet-metal screws mounting internal components that are not removed for installation or operation are able to thread directly into metal.

7.1.7 All medium voltage wiring and components shall be completely enclosed by grounded metal enclosures or metallic raceway, with the exception of viewing panes and ventilation openings. Polymeric enclosures shall not be used for enclosing medium voltage wiring or components.

Exception: Shielded medium voltage wiring may be exposed in units rated only for installation in restricted areas which are not in general access areas.

7.2 Access covers

7.2.1 For a unit used as a load center, a cover that gives access to a fuse or other overload-protective device, the functioning of which requires renewal shall be hinged. A hinged cover is also required for a unit when it is required to open the cover in connection with normal operation of the unit. The cover shall not depend solely upon screws or other similar means requiring the use of a tool to hold it closed; however, it shall be provided with a spring latch or catch, or a hand operable captive fastener. Live parts shall not be accessible when the cover is open.

Exception No. 1: A cover is not required to be provided with a hinge when the only overload-protective devices enclosed are:

a) Supplementary types in control circuits and the protective device and the circuit loads are within the same enclosure,

b) Supplementary types rated 2 amperes or less for loads not exceeding 100 volt-amperes,

c) Extractor fuses having an integral enclosure, or

d) Protective devices connected in a low-voltage, limited-energy (LVLE) circuit.

Exception No. 2: A cover is not required to be provided with a hinge for an enclosure that contains no user-serviceable or -operable parts and which is provided with a marking in accordance with 67.6.

7.2.2 With reference to 7.2.1, a door or cover giving access to a fuse shall comply with the requirements for doors and covers, in the Standard for Industrial Control Equipment, UL 508.

7.2A Doors for medium voltage equipment

7.2A.1 Doors providing access to live medium voltage components, equipment or wiring shall be interlocked to prevent opening the door when medium voltage parts are energized. This interlocking shall comply with Interlocking of Medium Voltage Equipment, Section 15A.

7.3 Cast metal enclosures

7.3.1 The thickness of cast metal for an enclosure shall not be less than indicated in Table 7.1.

Exception: Cast metal of lesser thickness is usable where the enclosure complies with Compression Test, Section 63.

Table 7.1
Thickness of Cast-Metal Enclosures

Use, or dimension of area involved	Minimum thickness, mm (inch)			
	Die-cast metal		Cast metal other than die-cast type	
Area of 154.8 cm^2 (24 in^2) 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 in^2) 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 limitations for metal 1.6 mm (1/16 inch) thick are attainable by the provision of reinforcing ribs subdividing a larger area.

7.4 Sheet metal enclosures

7.4.1 The thickness of a sheet-metal enclosure shall not be less than that specified in Table 7.2 and Table 7.3; however, 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 at points at which a wiring system is to be connected.

Exception: Sheet metal of lesser thickness is usable where the enclosure complies with Compression Test, Section 63.

7.4.2 With reference to Table 7.2 and Table 7.3, a supporting frame is a structure consisting of angles, channels, or folded rigid sections of sheet metal that is rigidly attached to and has similar outside dimensions as the enclosure surface and that has the torsional rigidity to resist the bending moments that result when the enclosure surface is deflected. A construction that has equivalent reinforcing is one that is as rigid as one built with a frame of angles or channels.

Table 7.2
Thickness of Sheet Metal for Enclosures, Carbon Steel or Stainless Steel

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,[c]					
cm	(inch)	cm	(inch)	cm	(inch)	cm	(inch)	Uncoated		Coated	
10.2	(4.0)	Not limited		15.9	(6.25)	Not limited		0.51[d]	(0.020)	0.58[d]	(0.023)
12.1	(4.75)	14.6	(5.75)	17.1	(6.75)	21.0	(8.25)				
15.2	(6.0)	Not limited		24.1	(9.5)	Not limited		0.66[d]	(0.026)	0.74[d]	(0.029)
17.8	(7.0)	22.2	(8.75)	25.4	(10.0)	31.8	(12.5				
20.3	(8.0)	Not limited		30.5	(12.0)	Not limited		0.81	(0.032)	0.86	(0.034)
22.9	(9.0)	29.2	(11.5)	33.0	(13.0)	40.6	(16.0)				
31.8	(12.5	Not limited		49.5	(19.5)	Not limited		1.07	(0.042)	1.14	(0.045)
35.6	(14.0	45.7	(18.0)	53.3	(21.0)	63.5	(25.0)				
45.7	(18.0)	Not limited		68.6	(27.0)	Not limited		1.35	(0.053)	1.42	(0.056)
50.8	(20.0)	63.5	(25.0)	73.7	(29.0)	91.4	(36.0)				
55.9	(22.0)	Not limited		83.8	(33.0)	Not limited		1.52	(0.060)	1.60	(0.063)

Table 7.2 Continued on Next Page

Table 7.2 Continued

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,[c]					
cm	(inch)	cm	(inch)	cm	(inch)	cm	(inch)	Uncoated		Coated	
63.5	(25.0)	78.7	(31.0)	88.9	(35.0)	109.2	(43.0)				
63.5	(25.0)	Not limited		99.1	(39.0)	Not limited		1.70	(0.067)	1.78	(0.070)
73.7	(29.0)	91.4	(36.0)	104.1	(41.0)	129.5	(51.0)				
83.8	(33.0)	Not limited		129.5	(51.0)	Not limited		2.03	(0.080)	2.13	(0.084)
103.4	(38.00	119.4	(47.0)	137.2	(54.0)	167.6	(66.0)				
106.7	(42.0)	Not limited		162.6	(64.0)	Not limited		2.36	(0.093)	2.46	(0.097)
119.4	(47.0)	149.9	(59.0)	172.7	(68.0)	213.4	(84.0)				
132.1	(52.0)	Not limited		203.2	(80.0)	Not limited		2.74	(0.108)	2.82	(0.111)
152.4	(60.0)	188.0	(74.0)	213.4	(84.0)	261.6	(103.0)				
160.0	(63.0)	Not limited		246.4	(97.0)	Not limited		3.12	(0.123)	3.20	(0.126)
185.4	(73.0)	228.6	(90.0)	261.6	(103.0)	322.6	(127.0)				

[a] See 7.4.2 and 7.4.3.

[b] The width is the smaller dimension of a rectangular sheet metal piece that is part of an enclosure. In some cases, adjacent surfaces of an enclosure have supports in common and are 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 for coated metal and not less than 0.81 mm (0.032 inch) thick for uncoated metal.

Table 7.3
Thickness of Sheet Metal for Enclosures, Aluminum, Copper, or Brass

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]				Minimum thickness,	
Maximum width[b],		Maximum length[c],		Maximum width[b],		Maximum length[c],			
cm	(inch)	cm	(inch)	cm	(inch)	cm	(inch)	mm	(inch)
7.6	(3.0)	Not limited		17.8	(7.0)	Not limited		0.58[d]	(0.023)
8.9	(3.5)	10.2	(4.0)	21.6	(8.5)	24.1	(9.5)		
10.2	(4.0)	Not limited		25.4	(10.0)	Not limited		0.74	(0.029)
12.7	(5.0)	15.2	(6.0)	26.7	(10.5)	34.3	(13.5)		
15.2	(6.0)	Not limited		35.6	(14.0)	Not limited		0.91	(0.036)
16.5	(6.5)	20.3	(8.0)	38.1	(15.0)	45.7	(18.0)		
20.3	(8.0)	Not limited		48.3	(19.0)	Not limited		1.14	(0.045)
24.1	(9.5)	29.2	(11.5)	53.3	(21.0)	63.5	(25.0)		
30.5	(12.0)	Not limited		71.1	(28.0)	Not limited		1.47	(0.058)
35.6	(14.0)	40.6	(16.0)	76.2	(30.0)	94.0	(37.0)		
45.7	(18.0)	Not limited		106.7	(42.0)	Not limited		1.91	(0.075)
50.8	(20.0)	63.5	(25.0)	114.3	(45.0)	139.7	(55.0)		
63.5	(25.0)	Not limited		152.4	(60.0)	Not limited		2.41	(0.095)
73.7	(29.0)	91.4	(36.0)	162.6	(64.0)	198.1	(78.0)		

Table 7.3 Continued on Next Page

Table 7.3 Continued

Without supporting frame[a]				With supporting frame or equivalent reinforcing[a]				Minimum thickness,	
Maximum width[b],		Maximum length[c],		Maximum width[b],		Maximum length[c],			
cm	(inch)	cm	(inch)	cm	(inch)	cm	(inch)	mm	(inch)
94.0	(37.0)	Not limited		221.0	(87.0)	Not limited		3.10	(0.122)
106.7	(42.0)	134.6	(53.0)	236.2	(93.0)	289.6	(114.0)		
132.1	(52.0)	Not limited		312.4	(123.0)	Not limited		3.89	(0.152)
152.4	(60.0)	188.0	(74.0)	330.2	(130.0)	406.4	(160.0)		

[a] See 7.4.2 and 7.4.3.

[b] The width is the smaller dimension of a rectangular sheet metal piece that is part of an enclosure. In some cases, adjacent surfaces of an enclosure have supports in common and are 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 copper, brass, or aluminum for an enclosure intended for outdoor use shall not be less than 0.74 mm (0.029 inch) thick.

7.4.3 With reference to 7.4.2 and Table 7.2 and Table 7.3, a construction does not have a supporting frame when it is:

a) An enclosure formed or fabricated from sheet metal,

b) A single sheet with single formed flanges or formed edges,

c) A single sheet that is corrugated or ribbed, or

d) An enclosure surface loosely attached to a frame, for example, by spring clips.

7.5 Nonmetallic enclosures

7.5.1 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 7.5.3.

Exception: A polymeric enclosure which complies with the Standard for Enclosures for Electrical Equipment, UL 50, is not required to be investigated for compliance with UL 746C.

7.5.2 Where 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 Standard for Electrical Analog Instruments – Panelboard Type, UL 1437, complies with this requirement.

7.5.3 The requirement in 7.5.1 does not apply to a nonmetallic part that forms part of the enclosure under any one of the following conditions:

a) The part covers an opening that has no dimension greater than 25.4 mm (1 inch) and the part is made of a material Classed as V-0, V-1, V-2, or HB, in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94,

b) The part is made of a material Classed V-0, V-1, V-2, or HB and covers an opening which does not give access to the user, when the part is removed, to live parts involving a risk of fire, electric shock, or electric energy-high current levels or moving parts.

c) The part covers an opening that has no dimension greater than 101.6 mm (4 inches) and the part is made of a material Classed as V-0, V-1, V-2, or HB, 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 V-0, V-1, V-2, or HB and there is a barrier or a device that forms a barrier made of a material Classed V-0 between the part and a source of a risk of fire.

Exception: A part of a component is not required to be Classed V-0, V-1, V-2, or HB when it complies with the flammability requirements applicable to the component. See Components, Section 3.

7.5.4 A nonmetallic enclosure intended for connection to a rigid conduit system shall comply with the Polymeric Enclosure Rigid Metallic Conduit Connection Tests in the Standard for Enclosures for Electrical Equipment, UL 50.

7.6 Openings covered by glass

7.6.1 Glass covering an opening shall comply with 7.6.2, shall be secured in place so that it is not readily displaced in service, and shall provide mechanical protection for the enclosed parts.

7.6.2 Glass for an opening:

a) Not more than 102 mm (4 inches) in any dimension shall not be less than 1.6 mm (1/16 inch) thick,

b) Glass for an opening other than described in (a) and not more than 929 cm^2 (144 square inches) in area and having no dimension greater than 305 mm (12 inches), shall not be less than 3.2 mm (1/8 inch) thick, and

c) Glass used to cover an area greater than described in (b) shall not be less than 3.2 mm thick and:

1) Shall be of a nonshattering or tempered type that, when broken, complies with the Performance Specifications and Methods of Test for Safety Glazing Material Used in Buildings, ANSI Z97.1-1984 (R1994), or

2) Shall withstand a 3.38 joules (2-1/2 ft-lbf) impact from a 50.8-mm (2-inch) diameter, 535 gram (1.18 pound) steel sphere without cracking or breaking to the extent that a piece is dislodged from its normal position.

7.6.3 Infrared viewports shall comply with the Outline of Investigation for Infrared Viewports, UL 50V.

7.7 Openings for wiring system connections

7.7.1 Where threads for the connection of conduit are tapped all the way through a hole in an enclosure wall, or where an equivalent construction is employed, there shall not be less than three, or more than five threads in the metal; and the construction of the enclosure shall be such that a conduit bushing is attachable as intended. Where threads for the connection of conduit are not tapped all the way through a hole in an enclosure wall, conduit hub, or a similar component; 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 and the hole shall have an internal diameter that corresponds with the applicable trade size of rigid conduit.

7.7.2 Clamps and fasteners for the attachment of conduit, electrical metallic tubing, armored cable, nonmetallic flexible tubing, nonmetallic-sheathed cable, service cable, or equivalent, that are supplied as a part of an enclosure shall comply with the Standard for Conduit, Tubing, and Cable Fittings, UL 514B.

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

7.7.4 A knockout shall be provided with a flat surrounding surface so a conduit bushing of the corresponding size seats as intended. A knockout intended to be used for installation purposes, shall be located so that installation of a bushing does not result in spacings between uninsulated live parts and the bushing of less than required in Spacings, Section 26.

7.7.5 In measuring a spacing between an uninsulated live part and a bushing installed in a knockout as specified in 7.7.4, it is to be assumed that a bushing having the dimensions specified in Table 5.4 is in place, in conjunction with a single locknut installed on the outside of the enclosure.

Table 5.4
Knockout or Hole Sizes and Dimensions of Bushings

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

7.7.6 For an enclosure not provided from the factory with conduit openings or knockouts, spacings not less than the minimum required in this Standard shall be provided between uninsulated live parts and a conduit bushing installed at any location on the enclosure. Permanent marking on the enclosure, a template, or a full-scale drawing furnished with the unit is usable to limit such a location.

7.7.7 A plate or plug for an unused conduit opening or other hole in the enclosure shall have a thickness not less than:

a) 0.36 mm (0.014 inch) for steel or 0.48 mm (0.019 inch) for nonferrous metal for a hole having a 6.4-mm (1/4-inch) maximum dimension, and

b) 0.69-mm (0.027-inch) steel or 0.81-mm (0.032-inch) nonferrous metal for a hole having a 34.9-mm (1-3/8-inch) maximum dimension.

A closure for a larger hole shall have a thickness equal to that required for the enclosure of the unit or a standard knockout seal shall be used. Such plates or plugs shall be securely mounted.

7.7.8 An opening in an environmental rated enclosure shall be closed with components having the applicable environmental ratings as specified in Table 5.5.

Table 5.5
Openings in Environmental Rated Enclosures

Enclosure type	Openings shall be closed by components rated for enclosure types
2	2, 3, 3R, 3S, 4, 4X, 6, 6P, 12, 12K, 13
3	3S, 4, 4X, 6, 6P
3R	3, 3S, 4, 4X, 6, 6P
3S	3, 4, 4X, 6, 6P
4	4, 4X, 6, 6P
4X	4X
6	6, 6P
6P	6P
12, 12K	12, 12K, 13
13	13

7.8 Openings for ventilation

7.8.1 General

7.8.1.1 The enclosure of a unit shall be constructed to protect the unit against the emission of flame, molten metal, flaming or glowing particles, or flaming drops from the enclosure.

7.8.1.2 Barriers shall be provided behind all ventilating openings into medium-voltage compartments. The barrier shall be effectively secured in place and shall be positioned such that a straight line (of zero diameter) may not be drawn from any point outside of the equipment, through the ventilation opening, to any insulated or uninsulated live part. Removable ventilation filters shall not be considered as barriers to meet this requirement.

7.8.2 Ventilation openings in enclosure bottoms

7.8.2.1 The requirement in 7.8.1.1 necessitates a complete noncombustible bottom or a construction employing individual noncombustible barriers as specified in Figure 5.1, under components, groups of components, or assemblies.

Exception No. 1: Ventilation openings provided in the bottom of an enclosure meet the intent of the requirement where noncombustible baffle plates are provided to obstruct or deflect materials from falling directly from the interior of the unit onto the supporting surface or other locations under the unit. An example of a baffle that meets the intent of this requirement is illustrated in Figure 5.2.

Exception No. 2: Ventilation openings provided in the bottom of an enclosure meet the intent of the requirement where the openings are covered by a perforated metal plate as described in Table 5.6, or where a galvanized or stainless steel screen having a 14- by 14-mesh per 25.4 mm (1 inch) constructed of wire with a diameter of 0.5 mm (0.018 inch) minimum is used.

Exception No. 3: The bottom of the enclosure under areas containing only materials Classed V-1 or better in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94, are able to have openings no larger than 6.4 mm (1/4 inch) square. Openings that are not square shall not have an area greater than 40 mm^2 (1/16 square inch).

Exception No. 4: Ventilation openings without limitation on their size and number that comply with 11.7 meet the intent of the requirement where the openings are only in the bottom panel in areas:

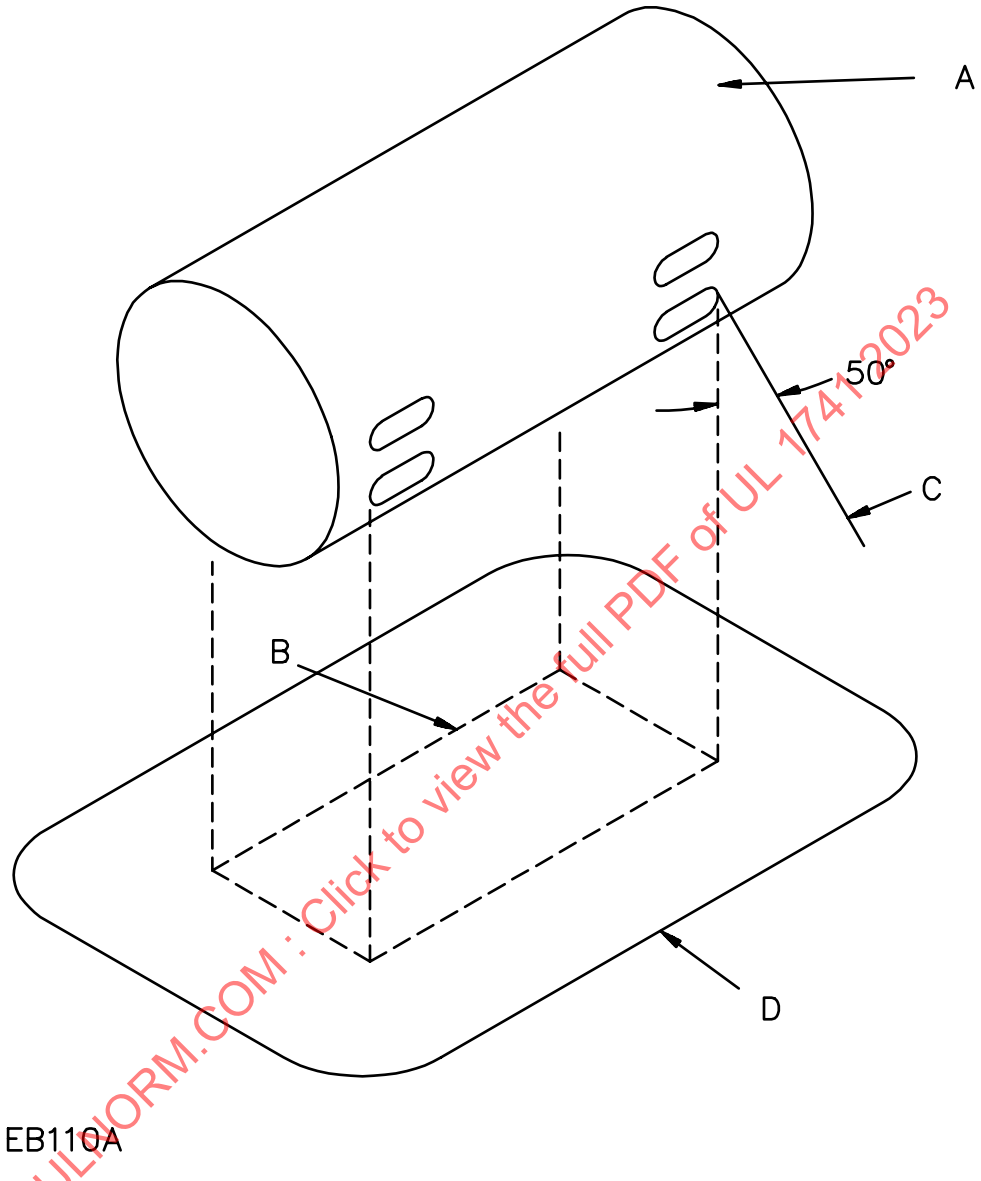
a) That contain only wires, cables, plugs, receptacles, and transformers, and

b) In areas that contain low-voltage, limited-energy (LVLE) circuits.

Exception No. 5: Ventilation openings are provided in the bottom of an enclosure meet the intent of the requirement where the openings incorporate an expanded metal mesh as described in 7.8.5.

Figure 5.1

Baffle Plates



NOTES –

A. The entire component under which a barrier (flat or dished with or without a lip or other raised edge) of noncombustible material is to be provided. The sketch (Figure 5.1) is of an enclosed component with ventilation openings showing that the protective barrier is required only for those openings through which flaming parts are able to be emitted. When the component or assembly does not have its own noncombustible enclosure, the area to be protected is the entire area occupied by the component or assembly.

B. Projection of the outline of the area of A that requires a bottom barrier vertically downward onto the horizontal plane of the lowest point on the outer edge D of the barrier.

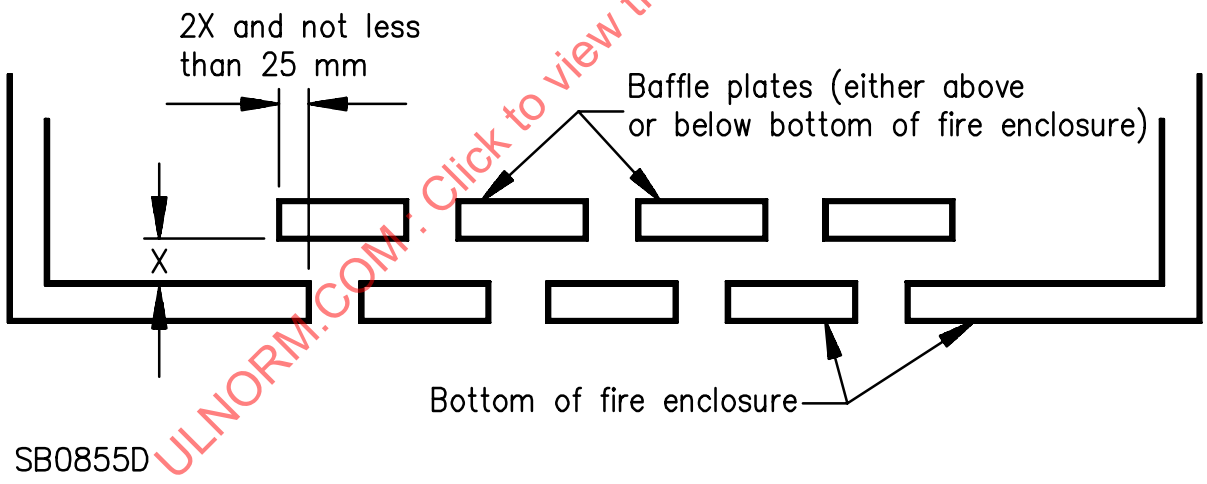
C. Inclined line that traces out an area D on the horizontal plane of the barrier. Moving around the perimeter of the area B that requires a bottom barrier, this line projects at a 50-degree angle from the line extending vertically at every point around the perimeter of A and is oriented to trace out the largest area; however, an angle less than 50 degrees complies where the barrier or portion of the bottom cover contacts a vertical barrier or side panel of noncombustible material, or where the horizontal extension of the barrier B to D exceeds 152 mm (6 inches).

D. Minimum outline of the barrier; however, the extension B to D is not required to exceed 152 mm (6 inches) (flat or dished with or without a lip or other raised edge). The bottom of the barrier is able to be flat or formed in any manner where every point of area D is at or below the lowest point on the outer edge of the barrier.

Table 5.6
Perforated Metal Plates for Enclosure Bottom

Minimum thickness,		Maximum diameter of holes,		Minimum spacings of holes center to center,	
mm	(inch)	mm	(inch)	mm	(inch)
0.66	(0.026)	1.14	(0.045)	1.70	(0.067), or 233 holes per 645 mm^2 (1 $inch^2$)
0.66	(0.026)	1.19	(0.047)	2.36	(0.093)
0.76	(0.030)	1.14	(0.045)	1.70	(0.067)
0.76	(0.030)	1.19	(0.047)	2.36	(0.093)
0.81	(0.032)	1.91	(0.075)	3.18	(0.125), or 72 holes per 645 mm^2 (1 $inch^2$)
0.89	(0.035)	1.90	(0.075)	3.18	(0.125)
0.91	(0.036)	1.60	(0.063)	2.77	(0.109)
0.91	(0.036)	1.98	(0.078)	3.18	(0.125)
0.99	(0.039)	1.60	(0.063)	2.77	(0.109)
0.99	(0.039)	2.00	(0.079)	3.00	(0.118)

Figure 5.2
Example of Baffle Overlap



7.8.3 Openings in enclosure tops

7.8.3.1 Openings in the top of an enclosure shall be located and sized to protect against the entry of foreign objects. Openings directly over uninsulated live parts:

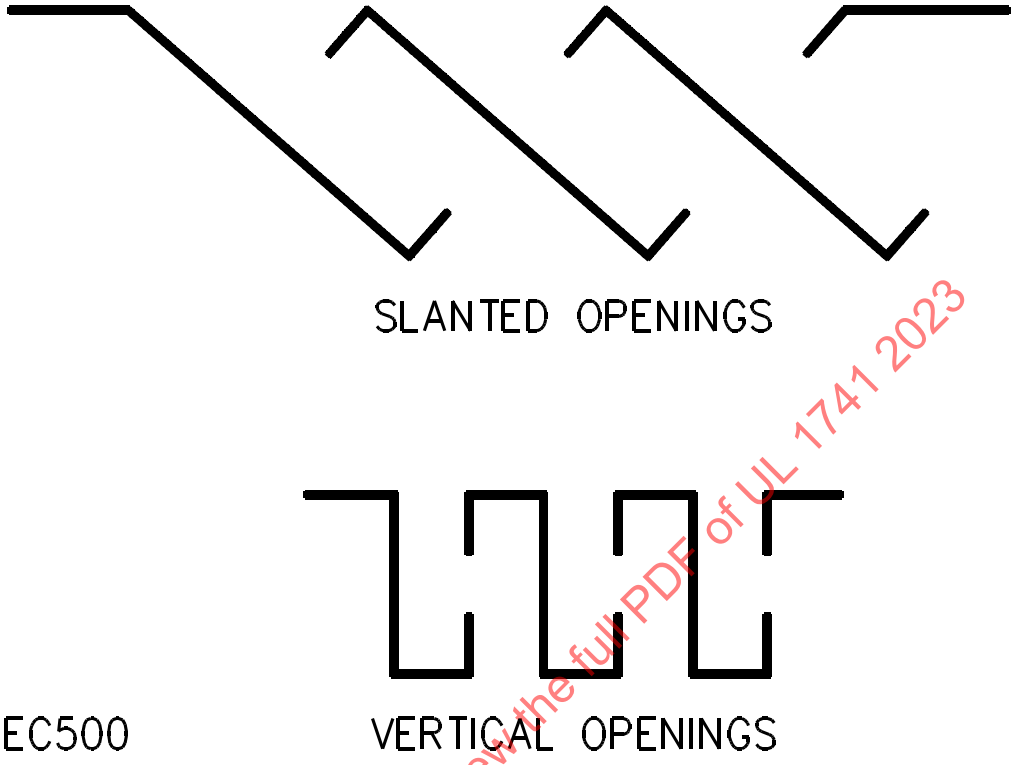
a) Shall not exceed 4.7 mm (0.187 inch) in any dimension,

b) Be configured as illustrated in Figure 5.3, or

c) Be constructed to provide equivalent protection against the entry of foreign objects.

Figure 5.3

Cross Sections of Top-Cover Design



7.8.4 Openings in enclosure sides

7.8.4.1 A louver shall not be more than 305 mm (12 inches) long.

7.8.4.2 The area of an opening covered by louvers, perforated sheet steel, or by expanded-metal mesh that is thinner than the enclosure shall not exceed 0.129 m^2 (200 square inches).

7.8.5 Expanded metal mesh and screens

7.8.5.1 The thickness of perforated sheet steel and sheet steel employed for expanded-metal mesh used to cover an opening in the enclosure shall comply with of Table 5.7.

Exception: Thicknesses less than specified in Table 5.7, and not less than specified in Table 5.8 meet the intent of the requirement where:

a) The indentation of the material does not adversely affect performance or reduce spacings to live parts below the minimum values specified in Spacings, Section 26, or Alternate Spacings-Clearances and Creepage Distances, Section 27, and

b) The opening has an area of not more than 464.5 cm^2 (72 in^2) and no dimension greater than 304.8 mm (12 inches), or

c) The width of the opening is not greater than 88.9 mm (3-1/2 inches).

Table 5.7
Minimum Thickness of Expanded Metal Mesh

Opening area	Uncoated,		Zinc coated, mm (inch)	
	mm	(inch)	mm	(inch)
Maximum 323 mm^2 (0.5 in^2) or less	1.07	(0.042)	1.14	(0.045)
More than 323 mm^2 (0.5 in^2)	2.03	(0.080)	2.13	(0.084)

Table 5.8
Minimum Thickness of Expanded Metal Mesh

Uncoated,		Zinc coated,	
mm	(inch)	mm	(inch)
0.51	(0.020)	0.61	(0.024)

7.8.5.2 The diameter of the wires of a screen shall not be less than 1.30 mm (0.051 inch) where the screen openings are 323 mm^2 (0.5 in^2) or less in area, and not less than 2.06 mm (0.081 inch) for larger screen openings.

7.8.6 Barriers used with ventilation openings in low voltage compartments

7.8.6.1 Unless a ventilation opening is located at least 305 mm (12 inches) from an arcing part, such as a switch, fuse, circuit breaker or a similar source, a barrier shall be placed between the ventilation opening and the source of arcing.

7.8.6.2 The barrier shall be of such dimensions and so located that any straight line drawn from an arcing part past the edge of the barrier intersects a point in the ventilation opening plane that is at least 6.4 mm (0.25 inch) outside of the edge of the ventilation opening.

7.8.6.3 A sheet-metal barrier shall not be less than 1.35 mm (0.053 inch) thick when uncoated steel, 1.42 mm (0.056 inch) thick when zinc-coated, or 1.19 mm (0.075 inch) thick when aluminum.

Exception: A metal barrier of thinner material meets the intent of the requirement when its strength and rigidity are not less than that of flat sheet steel having the same dimensions of the barrier and having the specified thickness.

7.9 Environmental rated enclosures

7.9.1 An enclosure shall comply with the construction requirements applicable to an enclosure of the Type number or numbers with which it is marked.

7.9.2 An environmental type connection, such as a watertight connection at a conduit entrance, shall be a conduit hub or the equivalent, such as a knockout or fitting, located so that when conduit is connected and the enclosure is mounted in the intended manner, the enclosure complies with the tests specified in the Enclosure Types Table, in the Standard for Enclosures for Electrical Equipment, UL 50.

7.9.3 Type 3, 3R, and 3S enclosures shall comply with the Rain and Sprinkler Tests, Section 64.

7.9.4 A Type 2 enclosure shall have provision for drainage of water and shall have a threaded conduit hub or the equivalent for the connection of conduit in the top or sidewalls.

Exception No. 1: A threaded conduit hub or the equivalent is not required where the conduit connection opening is wholly below the lowest terminal lug or other live part within the enclosure. See 66.33.

Exception No. 2: A conduit hub or fitting is not required when information is provided in accordance with 66.31.

7.9.5 A Type 3 enclosure shall have:

a) A threaded conduit hub or the equivalent for a watertight connection at conduit entrances – see 7.9.2,

b) A mounting means external to the equipment cavity, and

c) Provision for locking a door, when a door is provided.

Exception: A conduit hub or fitting is not required when information is provided in accordance with 66.31.

7.9.6 A Type 3R enclosure shall have:

a) A threaded conduit hub or the equivalent for a watertight connection at conduit entrances – see 7.9.2,

b) Provision for drainage of water, and

c) Provision for locking a door, when a door is provided.

Exception No. 1: A threaded conduit hub or the equivalent is not required where the conduit connection opening is wholly below the lowest terminal lug or other live part intended for use within the enclosure. See 66.33.

Exception No. 2: A conduit hub or fitting is not required when information is provided in accordance with 66.31.

7.9.7 A Type 3S enclosure shall have:

a) A threaded conduit hub or the equivalent for a watertight connection at conduit entrances – see 7.9.2,

b) A mounting means external to the equipment cavity,

c) Provision for locking a door, when a door is provided, and

d) Operating mechanisms that support the additional weight of ice and that withstand the removal of ice by means of a hand tool used to gain access to the interior of the enclosure when ice is present. Auxiliary means are able to be provided to break the ice and to enable operation of external mechanisms.

Exception: A conduit hub or fitting is not required when information is provided in accordance with 66.31.

7.9.8 A Type 4, 4X, 6, 6P, or 11 enclosure shall have a conduit hub or the equivalent mounted in place to provide a watertight connection at conduit entrances and shall have mounting means external to the equipment cavity – see 7.9.2.

Exception No. 1: The watertight conduit connection is not required to be mounted in place when information is provided in accordance with 68.2.4.

Exception No. 2: A hub or a fitting is not required to be provided or installed on a Type 4 or 4X enclosure when instructions are provided as specified in 68.2.6.

7.9.9 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, when provided, shall be oil resistant.

Exception: A Type 12 enclosure is able to employ a conduit opening when the enclosure is marked in accordance with 66.35.

7.9.10 A Type 12K enclosure is to be as specified in 7.9.9, unless it has knockouts located in the top or bottom walls, or both.

7.9.11 A Type 13 enclosure shall have oil-resistant gaskets and, when intended for wall or machine mounting, shall have a mounting means external to the equipment cavity. There shall be no conduit knockout or unsealed opening providing access to the equipment cavity. All conduit openings shall have provisions for oiltight connections.

7.9.12 A gasket of an elastomeric or thermoplastic material or a composition gasket utilizing an elastomeric material employed to comply with the requirements for a Type 2, 3, 3R, 3S, 4, 4X, 6, 6P, 11, 12, 12K, or 13 enclosure shall comply with the Gasket Tests, Section 43, in the Standard for Enclosures for Electrical Equipment, UL 50.

7.9.13 When a component, such as a pilot light, a disconnect, a pushbutton, or similar component, intended for use with a Type designated environmental enclosure is used with a specific Type enclosure, it shall meet the following:

a) The component has been evaluated for its intended use installed on a representative enclosure.

b) All hardware, gaskets, or other parts required to complete the installation are provided with the component.

Exception: Hardware, gaskets, or other parts are not required to be provided with the component when they are available from the component manufacturer in the form of a kit and are marked or rated for the application.

c) Installation instructions including such information as mounting hole location, opening configuration, and similar information, are provided on the component, in the component package, or on a stuffer sheet.

d) The component, its carton, or accompanying instruction sheet shall be marked or rated for use on a flat surface of the specific type enclosure in the construction.

7.9.14 A drain hole shall be provided on all units to prevent the accumulation of water above a level that results in the wetting of an electrical part or opening for the connection of conduit or for an auxiliary part under all mounting orientations specified by the installation instructions. The hole shall be as specified in Table 5.9.

Exception: A unit that has been subjected to the Rain and Sprinkler Tests, Section 64, is not required to be provided with a drain hole where no water enters the fixture.

Table 5.9
Size of Drain Holes

Opening shape	Minimum dimension		Minimum area		Maximum dimension		Maximum area	
	mm	(inch)	mm^2	($inch^2$)	mm	(inch)	cm^2	($inches^2$)
Slot	3.2 (width)	(1/8)	7.74	(0.012)	9.6 (width)	(3/8)	9.68	(1-1/2)
Square	3.2 (side)	(1/8)	–		12.7 (side)	(1/2)	–	
Round	3.2 (diameter)	(1/8)	–		12.7 (diameter)	(1/2)	–	
Irregular	–		7.74	(0.012)	–		9.68	(1-1/2)

8 Protection Against Corrosion

8.1 Iron and steel parts shall be protected against corrosion by enameling, galvanizing, plating, or other equivalent means. This applies to all springs and other parts which are relied upon for the intended mechanical operation.

Exception No. 1: Parts such as bearings and thermal elements for which such protection is impracticable.

Exception No. 2: Small minor parts of iron or steel such as washers, screws, or bolts that are not current-carrying and are not in the equipment grounding conductor path, when corrosion of such unprotected parts does not result in a risk of fire, electric shock, or injury to persons.

Exception No. 3: Parts made of stainless steel.

9 Mechanical Assembly

9.1 A unit shall be assembled so that it is not adversely affected by the vibration of normal operation.

9.2 A switch, a fuseholder, or a lampholder shall be securely mounted and shall be prevented from turning or shifting in its mounting panel.

Exception: The requirement that a switch be prevented from turning or shifting does not apply where:

a) The switch is a plunger, slide, or other type that does not rotate when operated. A toggle switch is subjected to forces that tend to turn the switch during normal operation of the switch,

b) Means for mounting the switch prevents the switch from loosening during operation,

c) Spacings are not reduced below the minimum specified in Spacings, Section 26, or Alternate Spacings-Clearances and Creepage Distances, Section 27, when the switch rotates, and

d) Normal operation of the switch is by mechanical means rather than by direct contact by persons.

9.3 With reference to 9.2, friction between surfaces shall not be the sole means to prevent shifting or turning of live parts for a device having a single-hole mounting means. An additional means such as a lock washer applied as intended shall be used.

10 Mounting

10.1 Provision shall be made for securely mounting a unit in position. Bolts, screws, or other parts used for mounting a unit shall be independent of those used for securing components to the frame, base, or panel.

Exception: A provision for mounting is not required for a floor supported or freestanding unit. See Stability, Section 61.

10.2 A keyhole slot for a mounting screw shall be provided with at least one round hole for accommodation of a permanent mounting screw. A keyhole slot shall be arranged so that a wall-mounting screw does not project into a compartment containing electrical parts and reduce spacings to less than those specified in Spacings, Section 26, or Alternate Spacings – Clearances and Creepage Distances, Section 27.

10.3 A unit shall not be provided with casters unless the casters are used solely for transporting the unit and the unit is provided with four leveling feet that are intended to be lowered after the unit is installed or the unit is provided with an equivalent means for securing the unit in position.

11 Protection of Users – Accessibility of Uninsulated Live Parts

11.1 The requirements in this Section apply to a part that is accessible to the user. For protection of service personnel, see Protection of Service Personnel, Section 12.

11.2 To reduce the potential for unintentional contact that involves 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 (a) or (b):

a) For an opening that has a minor dimension (see 11.5) less than 25.4 mm (1 inch), the part or wire shall not be contacted by the probe illustrated in Figure 11.1.

b) For an opening that has a minor dimension of 25.4 mm (1 inch) or more, the part or wire shall be spaced from the opening as specified in Table 11.1.

Figure 11.1

Accessibility Probe

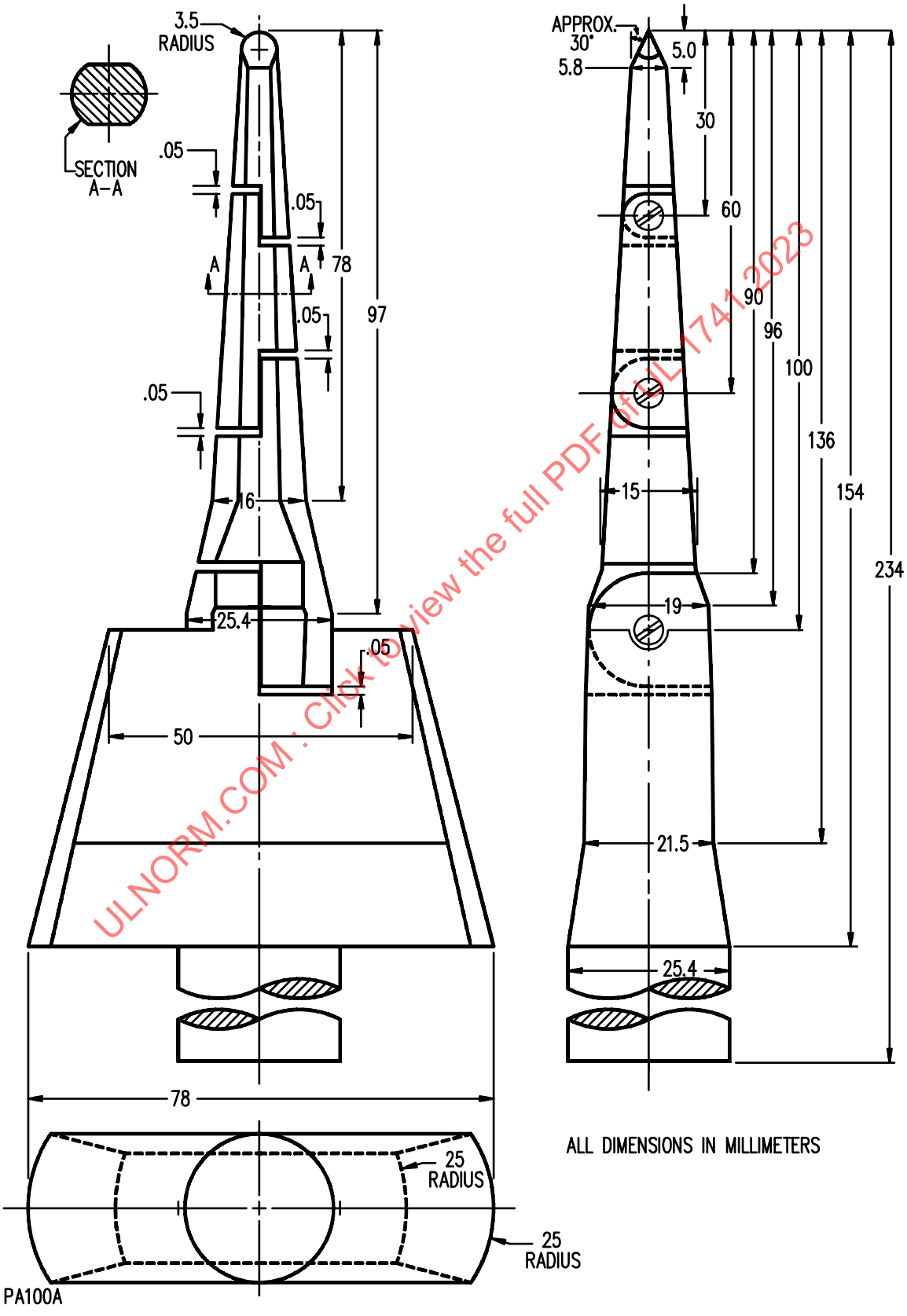


Table 11.1
Minimum Distance from an Opening to a Part That Involves a Risk of Electric Shock, Electrical Energy-High Current Levels, or Injury to Persons

Minor dimension of opening[a,b]		Minimum Distance from opening to part[b]	
mm	(inch)	mm	(inch)
25.4	(1)	165.0	(6-1/2)
31.8	(1-1/4)	190.0	(7-1/2)
38.1	(1-1/2)	318.0	(12-1/2)
47.6	(1-7/8)	394.0	(15-1/2)
54.0	(2-1/2)	444.0	(17-1/2)
(c)		762.0	(30)

[a] See 11.5.

[b] Between 25.4 and 54.0 mm, interpolation is to be used to determine a value between values specified in the table.

[c] More than 54.0 mm, and not more than 152.0 mm (5.98 in).

11.3 The probe illustrated in Figure 11.1 shall be applied to any depth that the opening accommodates; and shall be rotated or angled before, during, and after insertion through the opening to any position that is required to examine the enclosure. The probe shall be applied in any possible configuration; and, when required, the configuration shall be changed after insertion through the opening.

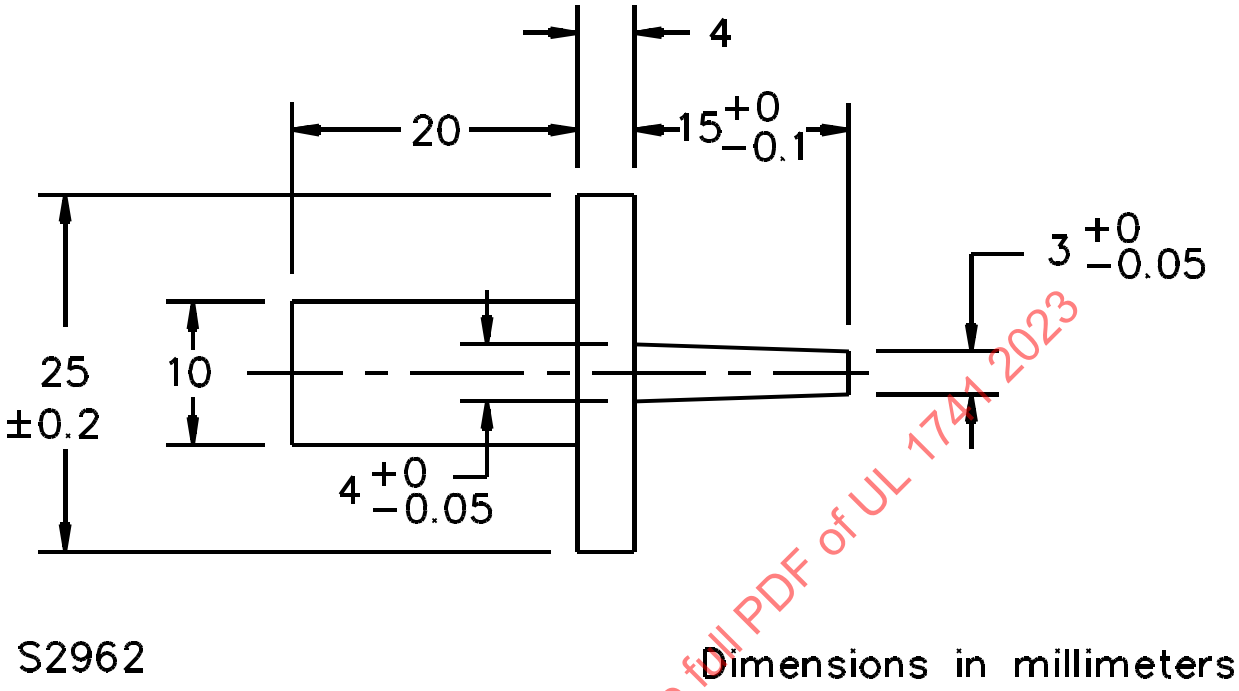
11.4 The probe specified in 11.3 shall be used as a measuring instrument to investigate the accessibility provided by an opening, and not as an instrument to investigate the strength of a material; it shall be applied with a maximum force of 4.4 N (1 pound).

11.5 With reference to 11.2, the minor dimension of an opening is equal to the diameter of the largest cylindrical probe that is able to be inserted through the opening.

11.6 The test pin illustrated in Figure 11.2, when inserted as specified in 11.3 through an opening in an enclosure, shall not touch any uninsulated live part that involves a risk of electric shock.

Figure 11.2

Test Pin



11.7 The probe shown in Figure 11.1 and the test pin shown in Figure 11.2 are to be inserted as specified in 11.3 into all openings, including those in the bottom of the unit. The unit is to be positioned so that the entire bottom is accessible for insertion of the probe.

Exception: For openings in the bottom of a floor-standing unit, the probe and test pin are only to be inserted into openings that are accessible without tipping, turning over, or otherwise moving the unit from its intended installed position.

11.8 During the examination of a unit to determine compliance with 11.2 through 11.7, a part of the enclosure that is able to 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 7.2.1, or for other reasons) is to be opened or removed. A fastener, such as a slotted-head thumb screw, that is able to be turned by hand, does not require the use of a tool.

11.9 For medium voltage applications, interlocking is required by Interlocking of Medium Voltage Equipment, Section 15A, and barriers are required in accordance with 7.8.1.2 to be placed behind ventilation openings to prevent user access to medium voltage components, equipment and circuits.

12 Protection of Service Personnel

12.1 The requirements in this Section apply to the protection of service personnel who reach over, under, across, or around uninsulated electrical parts or moving parts to make adjustments or measurements while the unit is energized. For requirements covering protection of users, see Protection of Users – Accessibility of Uninsulated Live Parts, Section 11.

Exception: Performing service in medium voltage compartments when the equipment is energized is not possible based on the interlocking requirements of Interlocking of Medium Voltage Equipment, Section 15A.

12.2 Live parts shall be arranged and covers located to reduce the risk of electric shock or electrical energy-high current levels while covers are being removed and replaced.

12.3 An uninsulated live part involving a risk of electric shock or electrical energy-high current levels and a moving part that involves a risk of injury to persons shall be located, guarded, or enclosed to protect against unintentional contact by service personnel adjusting or resetting controls, or similar actions, or performing mechanical service functions that are performed with the equipment energized, such as lubricating a motor, adjusting the setting of a control with or without marked dial settings, resetting a trip mechanism, or operating a manual switch.

12.4 Live parts involving a risk of electric shock or electrical energy-high current levels and located on the back side of a door shall be guarded or insulated to protect against unintentional contact with live parts by service personnel.

12.5 A component that requires examination, resetting, adjustment, servicing, or maintenance while energized shall be located and mounted with respect to other components and with respect to grounded metal parts so that it is accessible for electrical service functions without subjecting service personnel to a risk of electric shock, electrical energy-high current levels, or injury to persons by adjacent moving parts. Access to a component shall not be impeded by other components or by wiring.

12.6 For an adjustment that is to be made with a screwdriver or similar tool when the unit is energized, protection shall be provided against inadvertent contact with adjacent uninsulated live parts involving a risk of electric shock. Misalignment of the tool with the adjustment means when an adjustment is attempted is to be taken into account. This protection is able to be provided by:

a) Location of the adjustment means away from uninsulated live parts involving a risk of electric shock, or

b) A guard to reduce the potential for the tool contacting uninsulated live parts.

12.7 A live heat sink for a solid-state component, a live relay frame, and similar components, involving a risk of electrical shock or electrical energy-high current levels, which is mistakable for dead metal, shall be guarded to protect against unintentional contact by service personnel or shall be marked in accordance with 67.4.

Exception: This requirement does not apply to a heat sink mounted on a printed wiring board.

12.8 A moving part that involves a risk of injury to persons and that must be in motion during service operations not involving the moving part shall be located or protected against unintentional contact with the moving parts.

12.9 Reduction of the risk of electric shock and injury to persons is able to be accomplished by mounting control components so that unimpeded access to each component is provided by an access cover or panel in the outer cabinet.

13 Electric Shock

13.1 Voltage

13.1.1 The requirements described in 13.1.2 – 13.2.2 are to be used to determine whether or not the voltage of an accessible live part involves a risk of electric shock.

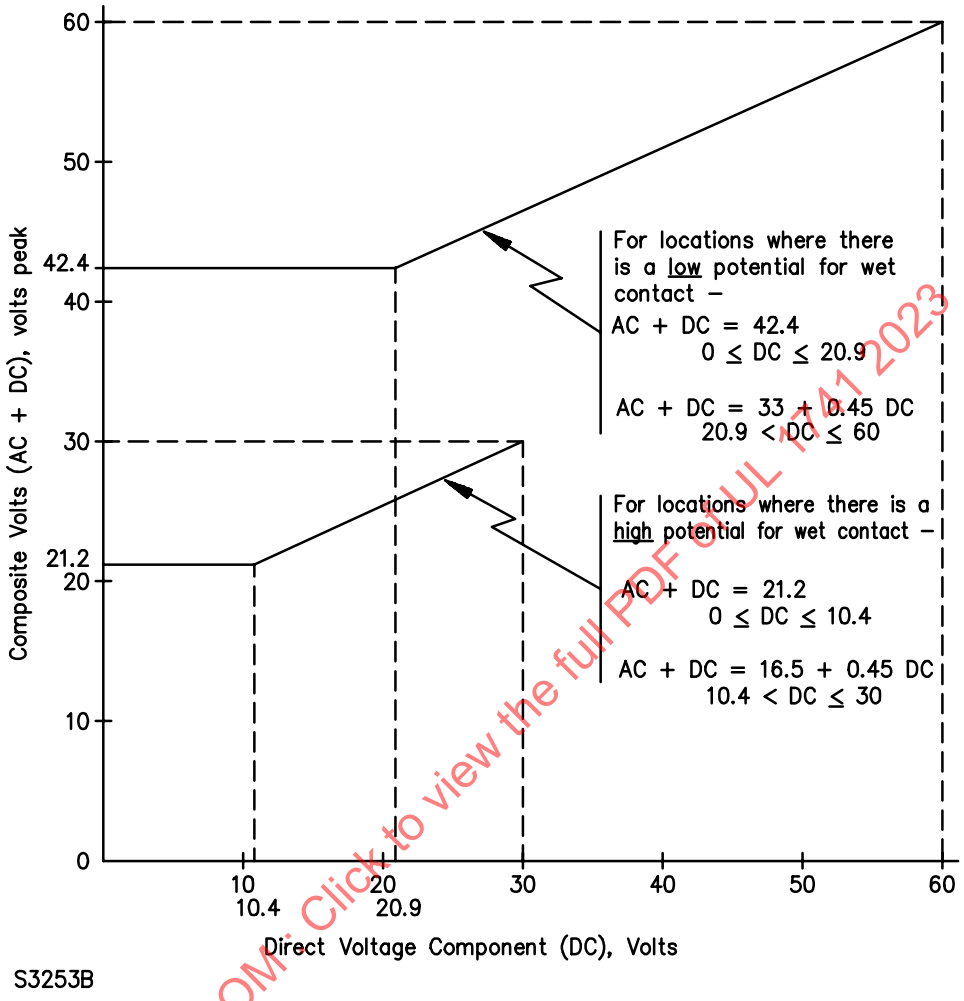
13.1.2 A live part does not involve a risk of electric shock where the voltage of the part does not exceed the values specified in Table 13.1.

Table 13.1
Risk of Electric Shock – Maximum Voltage

Voltage type		Indoor-use units (low potential for wet contact)	Outdoor-use units (high potential for wet contact – immersion not included)
1.	Sinusoidal ac	30 V rms	15 V rms
2.	Nonsinusoidal ac	42.4 V peak	21.2 V peak
3.	Pure dc	60 V	30 V
4.	DC interrupted at a rate of 10 to 200 Hz	24.8 V peak	12.4 V peak
5.	Combinations of dc and sinusoidal ac at frequencies not greater than 100 Hz	See Figure 13.1	See Figure 13.1

Figure 13.1

Maximum Voltage



13.2 Stored energy

13.2.1 The capacitance between capacitor terminals that are accessible as determined in accordance with Protection of Users – Accessibility of Uninsulated Live Parts, Section 11, and Protection of Service Personnel, Section 12, shall satisfy the following expressions:

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

in which:

C is the capacitance of the capacitor in microfarads, and

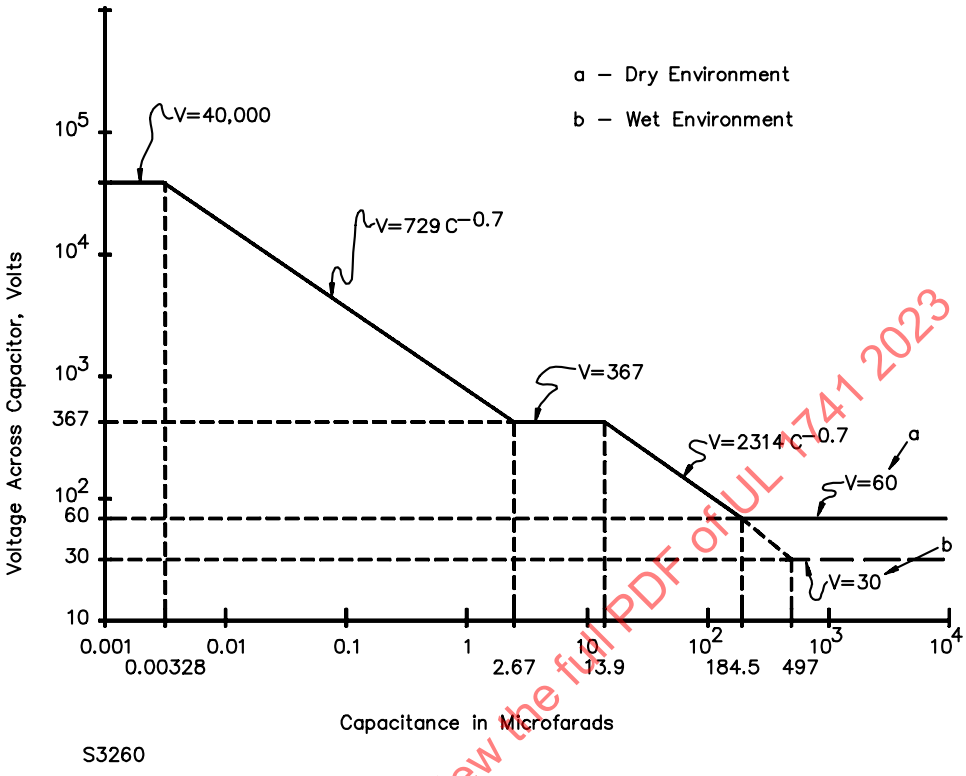
V is the voltage across the capacitor. The voltage is to be measured in accordance with 60.1. Typical calculated values are specified in Table 13.2, and the equation is shown graphically in Figure 13.2.

Table 13.2
Risk of Electric Shock – Stored Energy Current

Environment	Capacitance in microfarads	Maximum voltage across the capacitor, in volts peak
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

Figure 13.2

Voltage Limits Across Capacitors



13.2.2 With reference to 13.2.1, a part involving a potential of more than 40 kilovolts peak shall be investigated to determine whether or not it involves a risk of electric shock.

13.2.3 A means such as a bleeder resistor shall be provided to drain the charge stored in a capacitor so that it does not provide a risk of electric shock or a risk of electrical energy-high current level. A risk of electric shock exists when the voltage across the capacitor, determined in accordance with Capacitor Voltage Determination Test, Section 60, exceeds the limits specified in 13.1.2. A risk of electrical energy-high current level exists when the stored energy exceeds 20 joules as determined by the following equation:

$$J = 5 \times 10^{-7} \ CV^2$$

in which:

J is the stored energy in Joules,

C is the capacitance in microfarads, and

V is the voltage determined in accordance with Capacitor Voltage Determination Test, Section 60.

Exception No. 1: The requirement does not apply where:

a) A tool is required to remove a panel to reach the capacitor or accessible uninsulated portions of the associated circuit,

b) The time required to discharge the capacitor is within the limitations specified in 13.2.1 and is less than 5 minutes, and

c) The unit is marked as specified in 67.11.

Exception No. 2: The requirement does not apply where:

a) The unit is marked in accordance with 67.12, and

b) The unit is provided with a built-in, insulated circuit that discharges the capacitor or capacitor bank by the actuation of a switch or by plugging in a connector. When a connector or a non-momentary type switch is used, the circuit assembly shall be constructed and evaluated for continuous operation. When a momentary type switch is used, the capacitor or capacitor bank shall be discharged to levels in accordance with Table 13.2 within 1 minute.

Exception No. 3: The requirement does not apply where:

a) The capacitor terminals and all parts connected to these terminals are insulated to protect against contact with these terminals and parts by the serviceman, and

b) A cautionary marking in accordance with 67.13 is provided.

13.2.4 Any equipment connecting to a controlled conductor of PV source or output circuits and has devices that may store energy (e.g. batteries, capacitors, etc.) shall comply with 97.1.10 and provide the markings and instructions in accordance with 101.3 and 102.4.

14 Switches and Controls

14.1 An ac or dc switch or similar 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.

14.2 A primary-circuit switch that controls an inductive load having a power factor less than 75 percent, and that does not have an inductive rating, shall:

a) Be rated not less than twice the maximum load current under normal operating conditions, or

b) Be investigated for the application.

14.3 A switch used to connect a load to various sources or potentials shall be rated for such use. This includes a switch used for switching a voltmeter, frequency meter, or power factor meter between various phases.

14.4 A switch or other device controlling a relay coil, solenoid coil, or similar coil load shall have a pilot-duty rating.

Exception: A device as described in 14.5 is not required to have a pilot duty-rating.

14.5 A device that is rated for across-the-line motor starting of an alternating current motor is usable for alternating current pilot-duty without further tests when the power factor is 0.5 or less and the overload current is at least 150 percent of the pilot-duty inrush current at the same voltage. Switching devices rated in accordance with Table 14.1 are in compliance with this requirement.

Table 14.1
Horsepower Rating Versus Pilot Duty Rating

Horsepower rating 1-phase (120 – 600 volts)	AC pilot-duty rating
1/10	125 VA (light duty)
1/2	360 VA (standard duty)
1	720 VA (heavy duty)

14.6 Each pole of a snap switch rated as a 2-circuit, 3-circuit, or multi-circuit switch is not prohibited from controlling 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 is not prohibited from controlling a separate 120-volt load, and both poles are not prohibited from controlling both legs of a single 240-volt load. Each pole of a snap switch rated as a 240-volt, 3-pole switch is not prohibited from controlling a separate load not exceeding 139 volts and the three poles are not prohibited from controlling the three legs of a 3-phase, 240-volt load.

14.7 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.

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

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

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

14.9 A bypass switch or maintenance bypass used to connect the load directly to the bypass source shall comply with the Standard for Transfer Switch Equipment, UL 1008.

Exception: A bypass switch or maintenance bypass complying with Load Transfer Test, Section 50.7, is not required to comply with UL 1008. See 14.10.

14.10 With reference to the Exception to 14.9, a solid-state switch shall comply with the requirements in this Standard. A mechanical or electromechanical switch shall comply with the applicable requirements for switches in the Standard for General-Use Snap Switches, UL 20, and the Standard for Industrial Control Equipment, UL 508.

14.11 Where 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.

Exception: This requirement does not apply to:

a) A switching device having more than one on position (such as a bypass switch),

b) A double throw switch,

c) A rotationally-operated switch, or

d) A rocker switch.

15 Disconnect Devices

15.1 General

15.1.1 A disconnect device serving as an isolating device, equipment disconnect or system disconnect means required by the NEC shall be evaluated to the requirements in this section.

15.1.2 A disconnect device shall open all conductors of the circuit to which it is connected that are not solidly grounded.

Note: "Grounded" PV systems with overcurrent devices, resistors, etc. in the connection between the PV system and ground are "functional grounded" systems, and the "functional grounded" conductors are not solidly grounded.

15.1.3 System Disconnecting Means: A device serving the function of the NEC-required system disconnecting means shall:

a) Consist of a manually operated switch or a circuit breaker,

b) Employ an actuating mechanism that is accessible from outside of the enclosure or located behind a hinged cover not requiring a tool (other than a key) for opening, and

c) Be marked in accordance with 66.21 and 66.27.

Disconnect actuating mechanisms shall clearly indicate the operational status of the disconnect with the following text “ON (CLOSED)” and “OFF (OPEN)” or symbols in accordance with 66.21.

15.1.4 Equipment Disconnecting Means: A device serving the function of the NEC-required equipment disconnecting means shall:

a) Consist of a manually operated switch or a circuit breaker,

b) Employ an actuating mechanism that is capable of being operated without exposing the operator to inadvertent contact with live parts, and

c) Be marked in accordance with 66.21 and 66.27 to indicate its function.

Disconnect actuating mechanisms shall clearly indicate the operational status of the disconnect with the following text “ON (CLOSED)” and “OFF (OPEN)” or symbols in accordance with 66.21.

15.2 Provision for locking

15.2.1 Isolating and disconnecting devices serving as the means of de-energization of external sources of supply to the equipment, to facilitate safe servicing, shall have provision for being locked in the "off" (open or de-energized) position.

15.3 Medium voltage disconnect devices (isolating means)

15.3.1 Medium voltage isolating means may be any one of the following:

a) A three-pole switch complying with IEEE C37.20.4;

b) A three-pole switch complying with IEEE C37.20.4; in mechanical combination with medium-voltage fuses;

c) Metal-enclosed switchgear complying with IEEE C37.20.2, IEEE C37.20.3, or IEEE C37.20.9; or

c) A drawout assembly, complying with UL 347 or NEMA C37.54.

15.3.2 The medium voltage isolating means shall be:

a) Arranged to be operated from a location where the operator is not exposed to energized parts;

b) Arranged to open all ungrounded conductors of the main circuit simultaneously with one operation (gang operated); and

c) Interlocked with the medium voltage door in accordance with Interlocking of Medium Voltage Equipment, Section 15A.

15.3.3 Where an enclosed isolating switch is located inside another outer enclosure, and no medium voltage components or wiring are accessible when accessing the isolating switch, the door for the outer enclosure is not considered a medium voltage door.

15.3.4 Any doors of the inner enclosure that give access to medium voltage components or wiring shall be interlocked with the switch in accordance with Section 15A.

15.3.5 All switch blades shall be de-energized when the switch is in the open position, unless a switch is required to be energized from both sides (e.g., bus-tie and loop-sectionalizing), in which case:

a) Barriers or enclosures shall be installed over the switches for protection against contact with the energized switch blades; and

b) The switch is marked in accordance with 67.8.

15.3.6 Medium voltage isolating means shall:

a) Be gang-operated so all poles are operated in a single operation;

b) Provide the isolating distance of the controller complying with the requirements of the impulse and power frequency dielectric test requirements of this standard;

c) Include position indication in accordance with 15.3.7 that verifies that the isolating distance has been established;

d) Be capable of interrupting the no-load current of all transformers connected to the load side of the disconnecting means;

e) Be capable of interrupting the full-load current of any transformers connected to the load side of the disconnecting means, unless interlocking with the secondary load circuits is provided to prevent opening the switch with a transformer delivering second current;

f) Have provision for being padlocked in the open position;

g) Be interlocked in accordance with Section 15A; and

h) Be arranged so that gravity will not cause movement towards the closed position.

15.3.7 Medium voltage isolating means shall provide visible evidence of an isolating distance in the circuit adequate for the rated voltage complying with all of the following:

a) Isolating and load-break switches or drawout assemblies shall be provided with position indicators indicating the fully closed and fully open positions.

b) For drawout type isolating means, the isolation gap or a mechanically operated indicator shall be visible through a viewing pane. The mechanical operator shall be actuated by the movement of the actual isolating switch assembly, the shutter of a drawout assembly, or the like. The action of the mechanical indicator shall not be dependent on the movement of the operating handle or mechanism alone.

c) Non-drawout type isolating and load-break switches shall have an observation window (or windows) through which the isolating distance is visible. Alternatively, a camera system may be provided that complies with the requirements for Alternate Viewing Systems in IEEE C37.20.9.

d) The isolating means operating system shall provide indication of “Open” and “Closed” position via one or more of the following means; color coding (red – closed, black or green – open), words (“OPEN,” ”ON,” “CLOSED,” “OFF”) or symbols in accordance with 66.21.

15A Interlocking of Medium Voltage Equipment

15A.1 If an isolating means is not rated for making and breaking the required current, the isolating means shall be mechanically interlocked with a device capable of interrupting the current to prevent opening or closing the isolating means unless the load interrupting device is in the open position. The interlocking shall also prevent energizing the isolating means unless it is in the closed position or the drawout isolating means is separated by the isolating distance.

15A.2 When the sum of the full load ratings of any connected transformers exceeds the interrupting capacity of the isolating means, electrical interlocks shall be provided to disconnect secondary loads of transformers before the isolating means can be opened.

15A.3 In addition to the requirements of 15A.1 and 15A.2, equipment using a drawout element shall be provided with mechanical interlocks that will:

a) Positively lock the drawout element in the housing when the primary disconnecting devices are in their fully closed or fully connected position;

b) Discharge or block stored-energy devices prior to complete removal of the drawout element; and

c) Prevent contact with medium-voltage live parts as determined by the rod entry test in Section 64A with the drawout element in the test position and with the drawout element removed from the cubicle, when the medium voltage compartment door is open.

Note: Means to padlock a shutter assembly in a closed position may be used to meet this requirement when the drawout element is removed from the cubicle.

15A.4 In addition to the requirements of 15A.3, equipment using a drawout element that is used as the isolating means shall be provided with an automatic shutter assembly or the equivalent that:

a) Is maintained in the closed position in a manner that prevents inadvertent opening. Opening of the shutter shall require a degree of difficulty involving a minimum of two separate and distinct operations. Turning a knob, or moving a lever, or removing a single bolt, or the like, shall not be considered to provide the required degree of difficulty; and

b) Complies with the shutter integrity test described in Section 64B.

15A.5 Mechanical door interlocks shall be provided to meet these requirements:

a) Interlocks shall prevent the opening of a door to a medium-voltage compartment when the isolating means is closed.