UL 3703

STANDARD FOR SAFETY

Solar Trackers

UL Standard for Safety for Solar Trackers, UL 3703

First Edition, Dated October 8, 2015

SUMMARY OF TOPICS

This revision of ANSI/UL 3703 dated April 22, 2025 includes the addition of references to UL 61010-1 for Controllers and Control Systems: Section 11A 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 requirements are substantially in accordance with Proposal(s) on this subject dated January 17, 2025 and March 14, 2025.

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1

UL 3703

Standard for Solar Trackers

First Edition

October 8, 2015

This ANSI/UL Standard for Safety consists of the First Edition including revisions through April 22, 2025.

The most recent designation of ANSI/UL 3703 as an American National Standard (ANSI) occurred on April 22, 2025. ANSI approval for a standard does not include the Cover Page, Transmittal Pages, and Title Page.

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

No Text on This Page

CONTENTS

INTRODUCTION

CONSTRUCTION

PROTECTION AGAINST RISKS OF INJURY TO PERSONS

PERFORMANCE

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INTRODUCTION

1 Scope

1.1 These requirements cover solar trackers intended for installation as fixed trackers which are not attached to buildings, in accordance with the National Electrical Code, NFPA 70. Trackers intended to be installed in an area where public access is anticipated shall be evaluated for all mechanical hazards as defined in this standard. Trackers intended to be installed in an area where public access is restricted by a fence, secured location, etc. should be evaluated with consideration given to the mechanical hazard requirements of this standard. These requirements also cover freestanding trackers, which are by design not required to be mechanically secured in position.

1.2 These requirements cover the attachment means of solar devices to the tracker platform, in both mechanical and electrical aspects, but do not cover the solar devices themselves. The solar devices shall have all suitable electrical and mechanical characteristics in order to be attached to the tracker evaluated in accordance with this standard. Any solar devices attached to the tracker shall be compliant with the solar devices standard for safety, and the specific mounting, bonding, and grounding means described in the tracker's installation manual. Alternatively, the combination of tracker and solar device can be evaluated in accordance with this standard and relevant solar device standards, such as, but not limited to, the Standard for Flat-Plate Photovoltaic Modules and Panels, UL 1703 for flat plate PV modules, and the Outline for Concentrator Photovoltaic Modules and Assemblies, UL 8703, for CPV modules.

1.3 The tracker and its functions are to be evaluated with respect to risk of electric shock, mechanical and fire hazards. Any part of the tracker that is utilized for mechanical support, bonding or grounding of the solar devices shall comply with the Standard for Mounting Systems, Mounting Devices, Clamping/Retention Devices, and Ground Lugs for Use With Flat-Plate Photovoltaic Modules and Panels, UL 2703, or as referenced to UL 2703 within the requirements of this standard.

1.4 These requirements cover solar trackers intended for use with solar devices with a maximum system voltage of 1500 V.

1.5 These requirements do not cover:

a) Equipment intended to accept the electrical or thermal output from the solar devices, such as inverters, converters, charge controllers, and batteries;

b) Trackers installed in hazardous locations;

c) Mechanical or structural integrity of the tracker under wind conditions, seismic conditions, and uplift conditions of the tracker base and base to platform connection;

d) Trackers installed in marine, offshore, and/or locations above standing water; and

e) Lightning striking the tracker.

2 Glossary

2.1 For the purpose of this standard, the definitions in 2.2 – 2.48 apply.

2.2 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.

2.3 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 tracker.

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

2.5 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.

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

2.7 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.

2.8 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.

2.9 DEAD METAL – An electrically conductive metal part of the tracker which is not electrically connected to, or is, a source of voltage, and has no electric potential difference with respect to earth ground during the intended operation.

2.10 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.

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

2.12 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.

2.13 EMERGENCY STOP – A safety mechanism used to shut off the tracker in an emergency situation, which overrides all automatic controls and stops the moving of the tracker as quickly as possible, and the tracker needs a manual reset to return to an automatic control and moving.

2.14 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.

2.15 FIELD-WIRING LEAD – A 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 TRACKER – A tracker that is intended to be permanently connected mechanically and electrically and only able to be detached by the use of a tool.

2.18 FREESTANDING TRACKER – A tracker that is not intended to be permanently connected mechanically and electrically, such as, but not limited to portable (not fixed) floor units.

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

2.20 GUARD – A part outside of the enclosure that reduces access to a component involving a risk of injury to persons.

2.21 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.

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

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

2.24 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.

2.25 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.

2.26 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 25.10, or

c) A regulating network complying with 25.11.

2.27 LIVE PART – An electrically conductive tracker part which is electrically connected to, or is, a source of voltage, and/or during intended use has an electric potential difference with respect to earth ground.

2.28 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 65.6.

b) A combination of an isolated transformer secondary winding and one or more resistors or a regulating network complying with 25.11 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 tracker that is isolated from the primary circuit, and one or more resistors or a regulating network complying with 25.11.

2.29 MACHINE SCREW – A threaded fastener which is utilized with a threaded nut or internal threads in a material, to provide a clamp load on the mechanical joint being fastened. See ANSI/ASME B18.6.3 for illustrations of the various types of machine screws.

2.30 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.

2.31 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.

2.32 OPEN-CIRCUIT VOLTAGE (Voc) – The maximum no load output voltage of a photovoltaic module or panel at standard test conditions (STC). See 2.45.

2.33 PERMANENTLY CONNECTED TRACKER – A tracker connected to the electrical supply by means other than a supply cord and an attachment plug.

2.34 PLATFORM – The portion of the tracker to which the solar devices are directly attached.

2.35 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.

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

2.37 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.

2.38 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.

2.39 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.

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

2.41 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.

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

2.43 SOLAR TRACKER – A controlled moveable supporting system for solar devices, single or dual axis, which follows the sunlight to increase power output from solar devices mounted to the tracker's platform. For the purposes of this standard the solar tracker is an assembly, and will be referred to throughout this document as a "tracker".

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

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

a) 1000 W/m^2 irradiance,

b) AM 1.5 solar spectrum, and

c) 25°C (77°F) cell temperature.

2.46 STOW – A position the tracker moves to when adverse weather conditions (e.g., high wind, heavy snow or hail) are present or expected so that the excessive loads that might damage the tracker or solar devices can be reduced. Not all trackers have a stow function, and the exact position may vary depending on the tracker design. It is possible that one tracker have multiple stow positions. For example, the front surface of the tracker could face up horizontally for high wind, or as vertical as possible for snow or hail.

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

2.48 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.

3 General

3.1 Components

3.1.1 Except as indicated in 3.1.2, a component of a tracker or product covered by this standard shall comply with the requirements for that component. See Appendix A for a list of standards covering components commonly used in the trackers or products covered by this standard.

3.1.2 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 tracker or product 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 rating established for the intended conditions of use.

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

3.2 Units of measurement

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

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 Electrical Enclosure

4.1 General

4.1.1 System components shall be provided within an enclosure that houses all current-carrying parts. The enclosure shall protect the enclosure's internal electrical components against mechanical damage from forces external to the enclosure. 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.

4.1.2 The chassis and/or supporting frame inside an enclosure shall not be relied upon to carry current during normal operation.

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

4.1.4 An enclosure shall comply with Environmental Rated Enclosures, Section 4.9, or the requirements for the respective Type in the Standard for Enclosures for Electrical Equipment, UL 50.

4.1.5 Sheet-metal screw thread form shall not be used. Machine screws, self-tapping machine screws, and thread forming machine screws are to be utilized in sheet-metal when there are at least two full threads of screw engagement.

4.2 Access covers

4.2.1 For an enclosure 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 an enclosure when it is required to open the cover in connection with normal operation of the tracker. 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 65.5.

4.2.2 With reference to 4.2.1, 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.

4.3 Cast metal enclosures

4.3.1 The thickness of cast metal for an enclosure shall not be less than indicated in Table 4.1.

Exception: Cast metal of lesser thickness is usable where the enclosure complies with Compression Test, Section 48.

Table 4.1
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.

4.4 Sheet metal enclosures

4.4.1 The thickness of a sheet-metal enclosure shall not be less than that specified in Table 4.2 and Table 4.3; 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 48.

4.4.2 With reference to Table 4.2 and Table 4.3, 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. Compliance of this requirement is to be determined by Compression Test, Section 48.

Table 4.2
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)
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 4.4.2 and 4.4.3.

[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 4.3
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)		
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 4.4.2 and 4.4.3.

[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.

4.4.3 With reference to 4.4.2 and Table 4.2 and Table 4.3, 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.

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 4.5.3.

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.

4.5.2 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 – Panel Board Types, UL 1437, complies with this requirement.

4.5.3 The requirement in 4.5.1 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 3.1.

4.5.4 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.

4.6 Openings covered by glass

4.6.1 Glass covering an opening shall comply with 4.6.2, shall be secured in place so that it is not readily displaced in service, and shall provide mechanical protection for the enclosed parts.

4.6.2 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.

4.7 Openings for wiring system connections

4.7.1 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.

4.7.2 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.

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

4.7.4 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 20.

4.7.5 In measuring a spacing between an uninsulated live part and a bushing installed in a knockout as specified in 4.7.4, 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	
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)

4.7.6 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 enclosure is usable to limit such a location.

4.7.7 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 or a standard knockout seal shall be used. Such plates or plugs shall be securely mounted.

4.7.8 An opening in an environmental rated enclosure shall be closed with components having the applicable environmental ratings as specified in Table 4.5.

Table 4.5
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

4.8 Openings for ventilation

4.8.1 General

4.8.1.1 Enclosures shall be constructed to protect against the emission of flame, molten metal, flaming or glowing particles, or flaming drops from the enclosure.

4.8.2 Ventilation openings in enclosure bottoms

4.8.2.1 The requirement in 4.8.1.1 necessitates a complete noncombustible bottom or a construction employing individual noncombustible barriers as specified in Figure 4.1, 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 enclosure onto the supporting surface or other locations under the enclosure. An example of a baffle that meets the intent of this requirement is illustrated in Figure 4.2.

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 4.6, 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 8.7 meet the intent of the requirement where the openings are only in the bottom panel in areas:

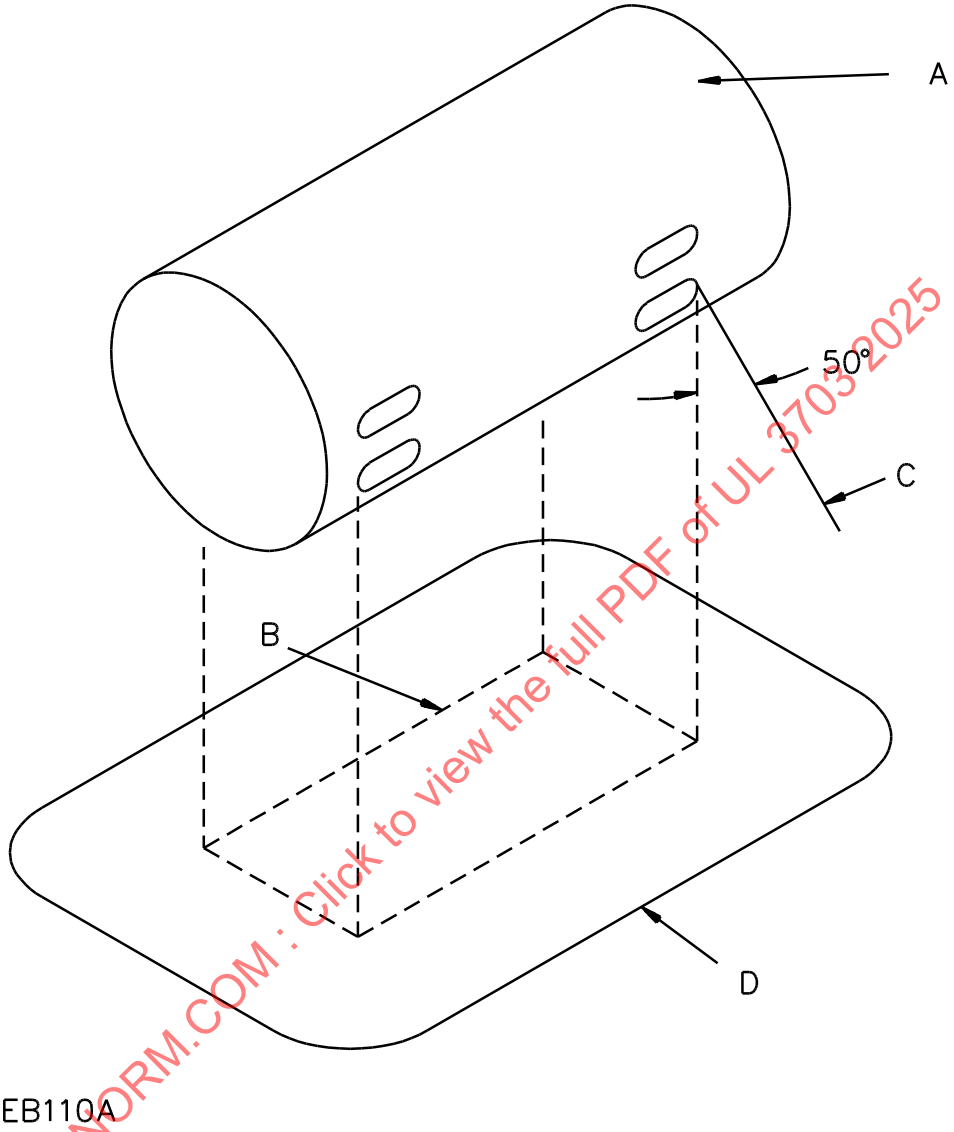
a) That contain only wires, cables, plugs, receptacles, and transformers, and

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 4.8.5.

Figure 4.1

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 4.1) 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.

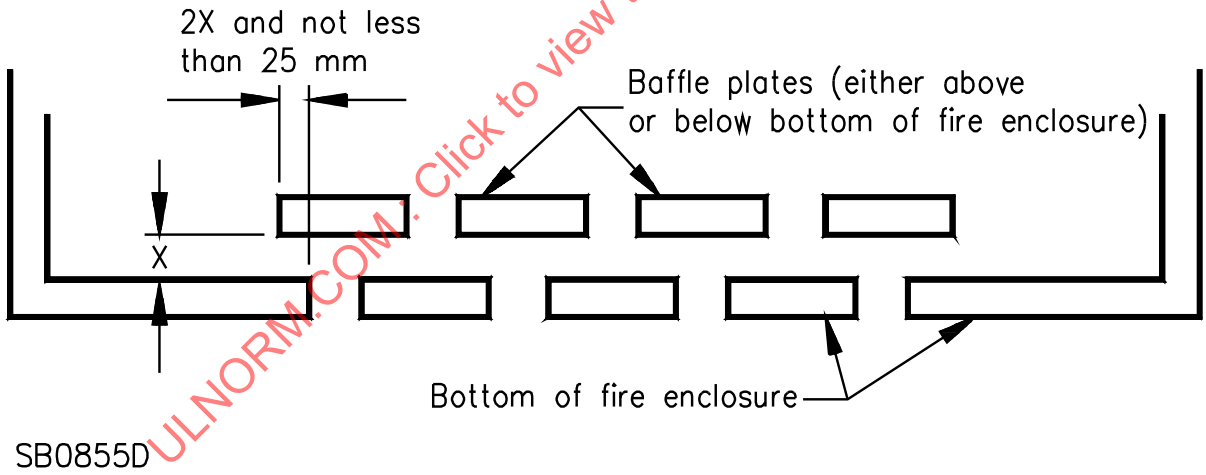
C. Inclined line that traces out an area D on the horizontal plane of the barrier. Moving around the perimeter of the area B that requires a bottom barrier, this line projects at a 50-degree angle from the line extending vertically at every point around the perimeter of A and is oriented to trace out 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 4.6
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 4.2
Example of baffle overlap



4.8.3 Openings in enclosure tops

4.8.3.1 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:

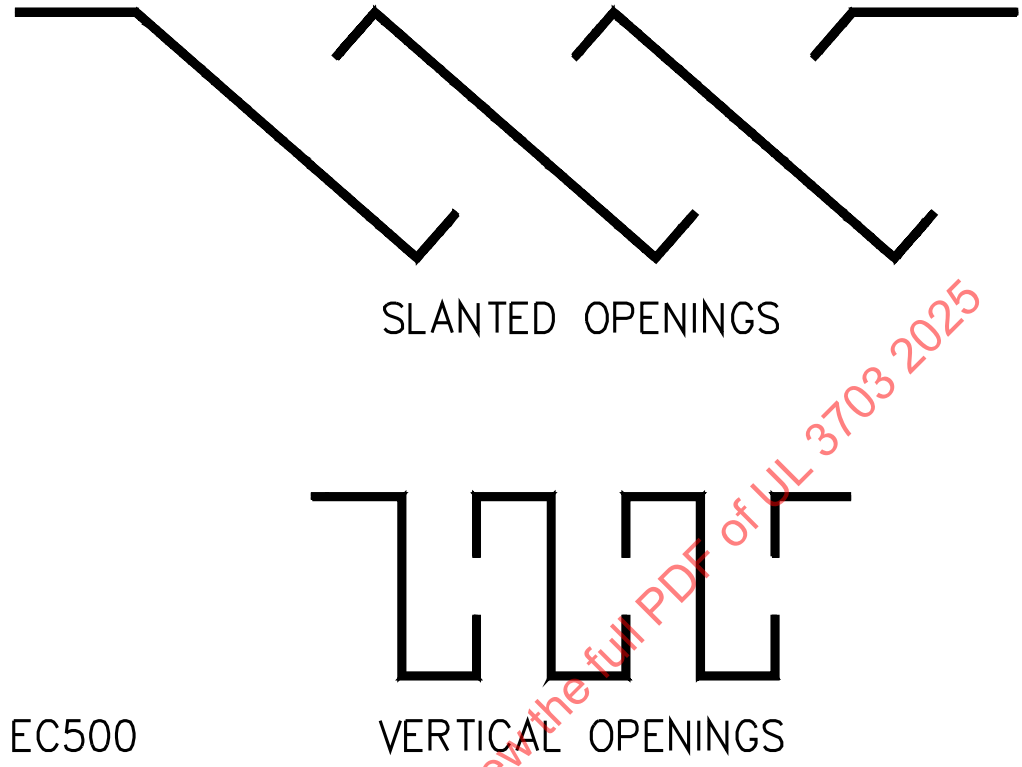
a) Shall not exceed 4.7 mm (0.187 inch) in any dimension,

b) Be configured as illustrated in Figure 4.3, or

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

Figure 4.3

Cross sections of top-cover design



4.8.4 Openings in enclosure sides

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

4.8.4.2 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).

4.8.5 Expanded metal mesh and screens

4.8.5.1 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 4.7.

Exception: Thicknesses less than specified in Table 4.7, and not less than specified in Table 4.8 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 20, or Alternate Spacings-Clearances and Creepage Distances, Section 21, 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 4.7
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 4.8
Minimum thickness of expanded metal mesh

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

4.8.5.2 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.

4.8.6 Barriers used with ventilation openings

4.8.6.1 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.

4.8.6.2 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.

4.8.6.3 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.

4.9 Environmental rated enclosures

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

4.9.2 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.

4.9.3 Type 3, 3R, and 3S enclosures shall comply with the Rain and Sprinkler Tests, Section 49.

4.9.4 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 64.27.

Exception No. 2: A conduit hub or fitting is not required when information is provided in accordance with 64.25.

4.9.5 A Type 3 enclosure shall have:

a) A threaded conduit hub or the equivalent for a watertight connection at conduit entrances – see 4.9.2,

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 64.25.

4.9.6 A Type 3R enclosure shall have:

a) A threaded conduit hub or the equivalent for a watertight connection at conduit entrances – see 4.9.2,

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 64.27.

Exception No. 2: A conduit hub or fitting is not required when information is provided in accordance with 64.25.

4.9.7 A Type 3S enclosure shall have:

a) A threaded conduit hub or the equivalent for a watertight connection at conduit entrances – see 4.9.2,

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 64.25.

4.9.8 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 4.9.2.

Exception No. 1: The watertight conduit connection is not required to be mounted in place when information is provided in accordance with 66.2.4.

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 66.2.6.

4.9.9 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 64.28.

4.9.10 A Type 12K enclosure is to be as specified in 4.9.9, unless it has knockouts located in the top or bottom walls, or both.

4.9.11 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 oil-tight connections.

4.9.12 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.

4.9.13 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.

4.9.14 A drain hole shall be provided on all enclosures 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 4.9.

Exception: An enclosure that has been subjected to the Rain and Sprinkler Tests, Section 49, is not required to be provided with a drain hole where no water enters the fixture.

Table 4.9
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)

5 Protection Against Corrosion

5.1 The protection against corrosion requirements in this Section apply to components within electrical enclosures. For other parts of the tracker, the requirements from Sections 10 and 19 of the Standard for Mounting Systems, Mounting Devices, Clamping/Retention Devices, and Ground Lugs for Use With Flat-Plate Photovoltaic Modules and Panels, UL 2703, and the applicable UL 2703 tests shall be applied.

5.2 Iron and steel parts shall be protected against corrosion by enameling, galvanizing, plating, or other equivalent means. This applies to all framing, fasteners, 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 300-series stainless steel.

6 Mechanical Assembly

6.1 The mechanical assembly requirements in this Section are for electrical enclosures. For other parts of the tracker, the requirements from Section 6 of the Standard for Mounting Systems, Mounting Devices, Clamping/Retention Devices, and Ground Lugs for Use With Flat-Plate Photovoltaic Modules and Panels, UL 2703, and the applicable UL 2703 tests shall be applied.

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

6.3 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 20, or Alternate Spacings-Clearances and Creepage Distances, Section 21, when the switch rotates, and

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

6.4 With reference to 6.3, 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.

7 Mounting

7.1 Provision shall be made for securely mounting a tracker in position. Bolts, screws, or other parts used for mounting a tracker 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 freestanding tracker. See Stability Test, Section 46.

7.2 When the tracker mounting instructions specify mounting hardware that is not readily available commercially, the manufacturer shall provide the hardware with the tracker.

7.3 For enclosures, 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 20, or Alternate Spacings – Clearances and Creepage Distances, Section 21.

8 Protection of Users – Accessibility of Uninsulated Live Parts

8.1 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 9.

8.2 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 8.5) less than 25.4 mm (1 inch), the part or wire shall not be contacted by the probe illustrated in Figure 8.1.

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 8.1.

Figure 8.1

Accessibility probe

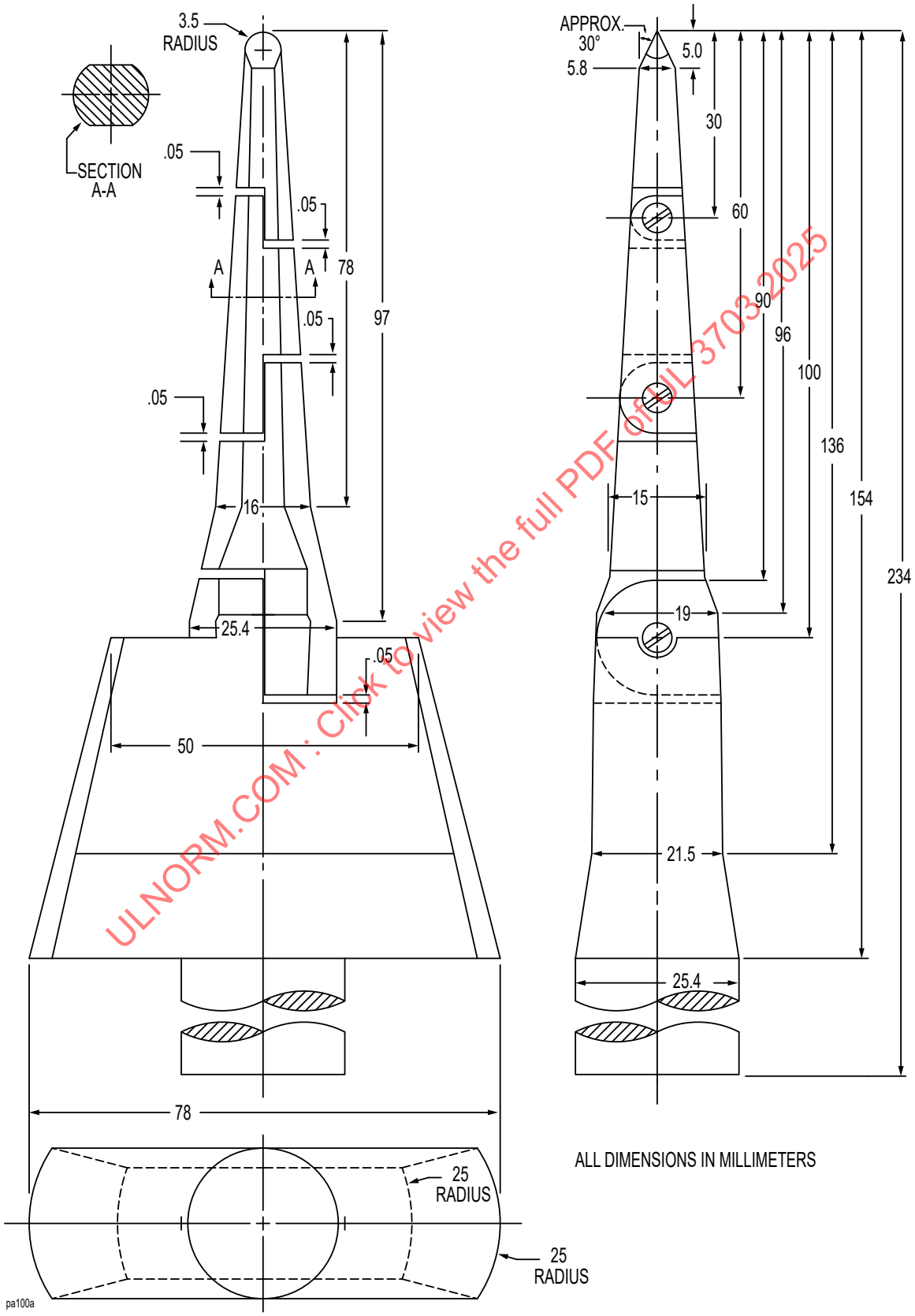


Table 8.1
Minimum distance from an opening to a part that involves a risk of electric shock, electrical energy-high current levels, or injury to persons

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 8.5.

[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).

8.3 The probe illustrated in Figure 8.1 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.

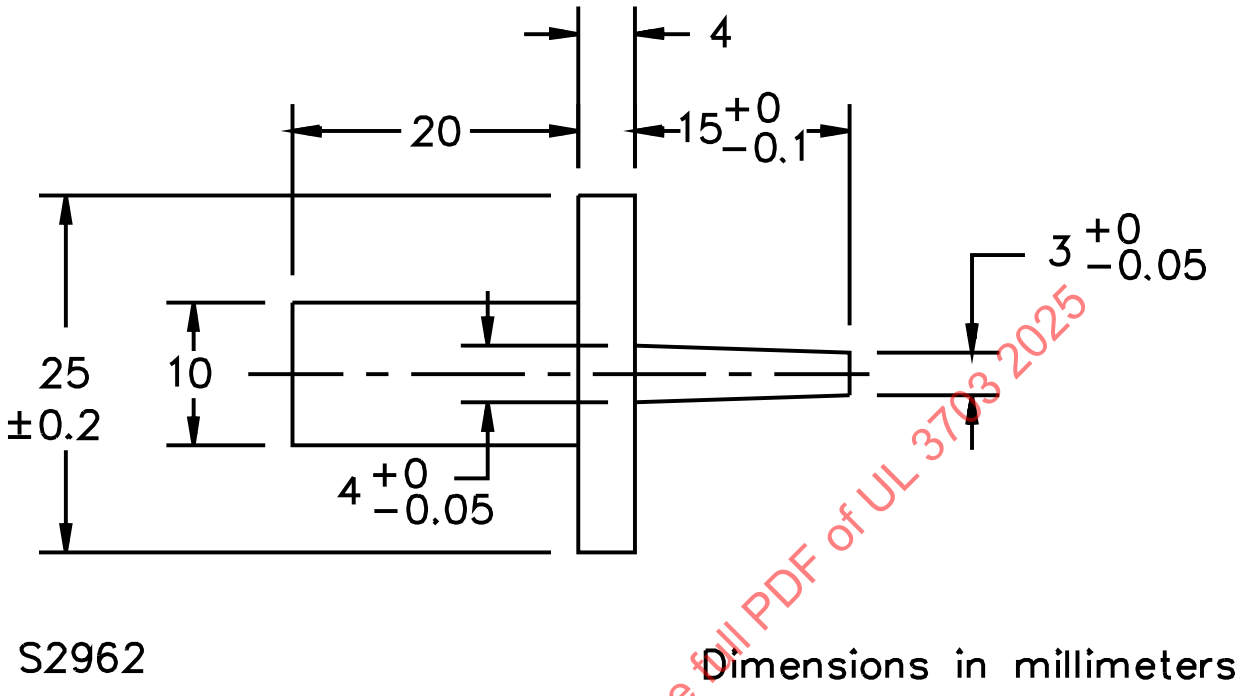
8.4 The probe specified in 8.3 shall be used as a measuring instrument to investigate the accessibility provided by an opening, and not as an instrument to investigate the strength of a material; it shall be applied with a maximum force of 4.4 N (1 pound).

8.5 With reference to 8.2, 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.

8.6 The test pin illustrated in Figure 8.2, when inserted as specified in 8.3 through an opening in an enclosure, shall not touch any uninsulated live part that involves a risk of electric shock.

Figure 8.2

Test pin



8.7 The probe shown in Figure 8.1 and the test pin shown in Figure 8.2 are to be inserted as specified in 8.3 into all openings, including those in the bottom of the enclosures. The enclosure is to be positioned so that the entire bottom is accessible for insertion of the probe.

8.8 During the examination of a tracker to determine compliance with 8.2 through 8.7, 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 4.2.1, 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.

9 Protection of Service Personnel

9.1 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 tracker is energized. For requirements covering protection of users, see Protection of Users – Accessibility of Uninsulated Live Parts, Section 9.

9.2 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.

9.3 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.

9.4 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.

9.5 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.

9.6 For an adjustment that is to be made with a screwdriver or similar tool when the tracker 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.

9.7 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 65.4.

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

9.8 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.

9.9 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.

10 Electric Shock

10.1 Voltage

10.1.1 The requirements described in 10.1.2 – 10.2.2 are to be used to determine whether or not the voltage of an accessible live part involves a risk of electric shock.

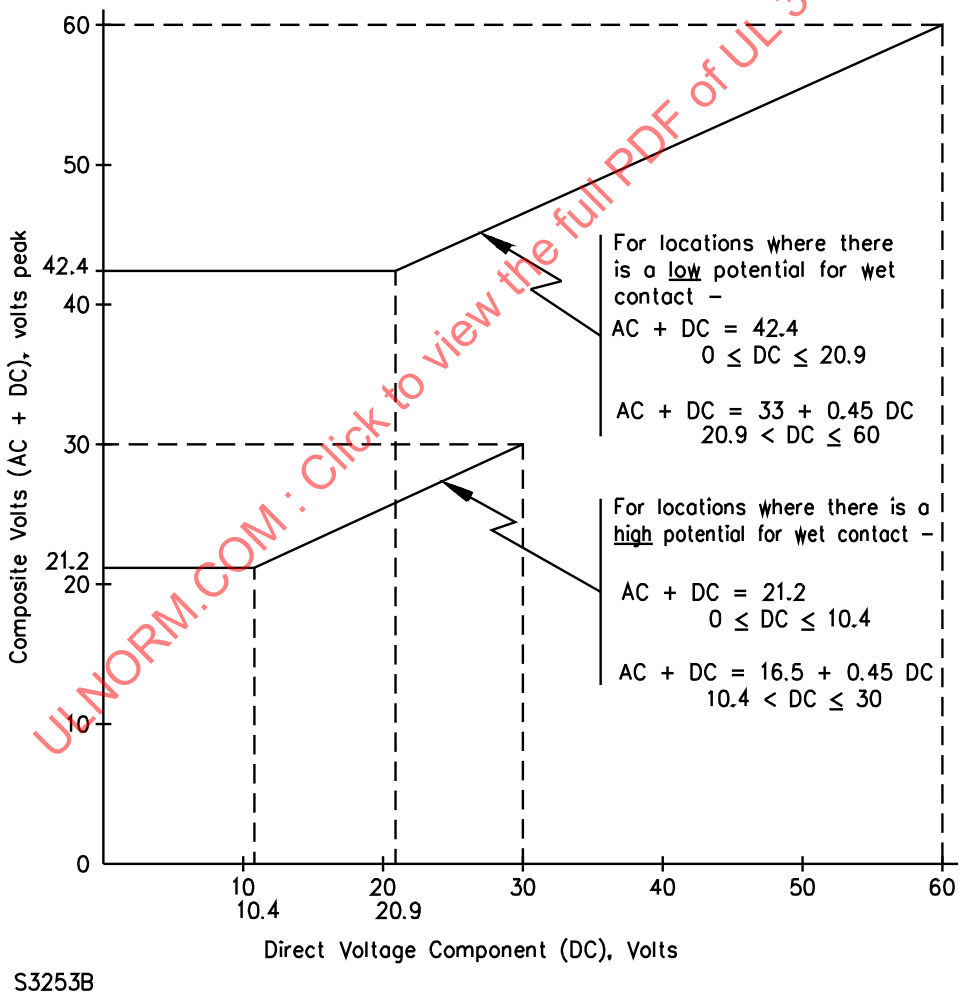
10.1.2 A live part does not involve a risk of electric shock where the voltage of the part does not exceed the values specified in Table 10.1.

Table 10.1
Risk of electric shock – maximum voltage

Voltage type		Outdoor-use trackers (high potential for wet contact – immersion not included)
1.	Sinusoidal ac	15 V rms
2.	Nonsinusoidal ac	21.2 V peak
3.	Pure dc	30 V
4.	DC interrupted at a rate of 10 to 200 Hz	12.4 V peak
5.	Combinations of dc and sinusoidal ac at frequencies not greater than 100 Hz	See Figure 10.1

Figure 10.1

Maximum voltage



10.2 Stored energy

10.2.1 The capacitance between capacitor terminals that are accessible as determined in accordance with Protection of Users – Accessibility of Uninsulated Live Parts, Section 8, and Protection of Service Personnel, Section 9, 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

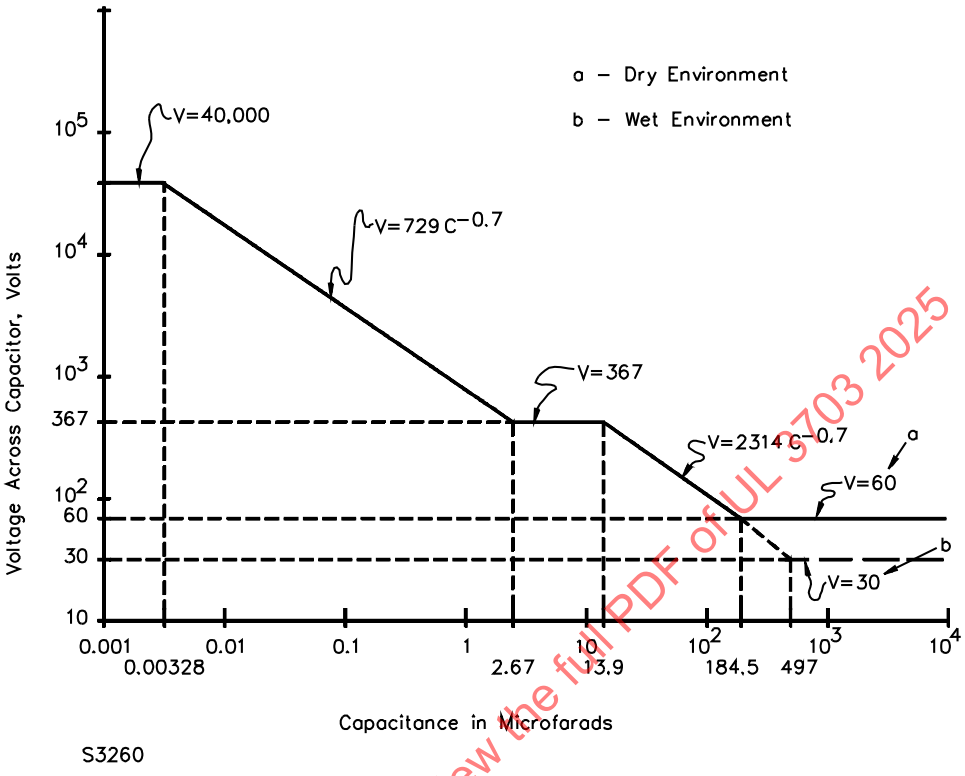
V is the voltage across the capacitor. The voltage is to be measured in accordance with 51.1. Typical calculated values are specified in Table 10.2, and the equation is shown graphically in Figure 10.2.

Table 10.2
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 10.2

Voltage limits across capacitors



10.2.2 With reference to 10.2.1, 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.

10.2.3 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 51, exceeds the limits specified in 10.1.2. 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 51.

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 10.2.1 and is less than 5 minutes, and

c) The tracker is marked as specified in 65.10.

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

a) The tracker is marked in accordance with 65.11, and

b) The tracker 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 10.2 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 65.12 is provided.

11 Switches and Controls

11.1 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 tracker is operated in its intended manner.

11.2 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.

11.3 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.

11.4 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 11.5 is not required to have a pilot duty-rating.

11.5 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 11.1 are in compliance with this requirement.

Table 11.1
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)

11.6 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.

11.7 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.

11.8 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.

11.9 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.

11.10 With reference to the Exception to 11.9, 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.

11.11 Where a tracker 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.

11A Controllers and Control Systems

11A.1 Controllers and control systems for solar tracker applications shall comply with either the:

a) Requirements in Sections 4 – 29 and Section 36 in this standard; or

b) Standard for Electrical Equipment for Measurement, Control, and Laboratory Use – Part 1: General Requirements, UL 61010-1, in addition to Section 36 of this standard; or

c) Standard for Industrial Control Equipment, UL 508, in addition to Section 36 of this standard.

11A.1 For controller enclosures used in outdoor applications, enclosure type rating (see 4.9, Environmental Rated Enclosures) and material requirements with respect to exposure to Ultraviolet Light, Water Exposure and Immersion (see 4.5, Nonmetallic Enclosures) shall apply.

12 Disconnect Devices

12.1 A disconnect device shall:

a) Open all ungrounded conductors of the circuit to which it is connected,

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

c) Employ an operating handle that is accessible from outside of the enclosure or located behind a hinged cover not requiring a tool for opening, and

d) Be marked in accordance with 64.22.

12.2 Where the operating handle of a disconnect device is operated vertically rather than rotationally or horizontally, the up position of the handle shall be the on position.

12.3 For a tracker investigated in combination with a remote battery supply intended to be used with the tracker, only one disconnect device is required to be provided for the battery supply circuit.

13 Supply Connections

13.1 General

13.1.1 A tracker shall have provision for connection of a wiring system consisting of:

a) Wiring terminals as specified in 13.1.3 – 13.2.10 or wiring leads as specified in 13.1.3 and 13.3.1 – 13.3.6, and

b) A means for connection of cable or conduit as specified in 13.5.1.

Exception: The requirements described in 13.1.3 – 13.4.3 do not apply to the means for connection to isolated accessible signal circuits complying with the requirements specified in Isolated Accessible Signal Circuits, Section 24.

13.1.2 The requirement in 13.1.1 applies to the wiring connection means for ac and dc input and output power circuits of a tracker intended to be made in the field when the tracker is installed.

13.1.3 A wiring terminal or lead shall be rated and sized for connection to a field wiring conductor having an ampacity based on Table 310.16 of the National Electrical Code, ANSI/NFPA 70, of no less than 125 percent of the RMS or dc current that the circuit carries during rated conditions. For determining the appropriate column in Table 310.16, see 67.4 (J) and (K).

13.2 Wiring terminals

13.2.1 A wiring terminal shall comply with the requirement in 13.1.3 for a wire of each metal for which it is marked. See 64.8.

13.2.2 A wiring terminal shall be provided with a factory-installed pressure terminal connector that is securely fastened in place – for example, firmly bolted or held by a screw.

Exception No. 1: A field-installed pressure terminal connector in accordance with 13.2.4 meets the intent of this requirement.

Exception No. 2: A wire-binding screw employed at a wiring terminal intended for connection of a 10 AWG (5.3 mm^2) or smaller conductor and having upturned lugs, a cupped washer, or the equivalent to hold the wire in position meets the intent of this requirement.

13.2.3 A wiring terminal shall be secured in position, by a means other than friction between surfaces, so that it does not turn or shift. This is able to 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 used in accordance with 13.2.4 is able to turn when the spacing complies with Spacings, Section 20, when the connector is oriented in the position resulting in the least spacing between adjacent terminals and also between terminals and dead metal parts.

13.2.4 With reference to Exception No. 1 to 13.2.2, a pressure terminal connector is not required to be factory installed when the conditions in (a) – (e) are met:

a) One or more component terminal assemblies shall be available from the component manufacturer or others and specified in the instruction manual. See 67.4(B) and (C).

b) The fastening hardware such as a stud, nut, bolt, spring, or flat washer, and similar hardware, as required for an effective installation, shall be:

1) Provided as part of the terminal assembly,

2) Mounted on or separately packaged with the tracker, or

3) 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) When the pressure terminal connector provided in a terminal assembly requires the use of other than a common tool for securing the conductor, identification of the tool and any additional instructions shall be included in the assembly package or with the tracker. See 67.4(D).

e) Installation of the pressure terminal connector in the intended manner shall result in a tracker complying with the requirements of this standard.

13.2.5 A terminal block or insulating base for support of a pressure terminal connector shall comply with the Standard for Terminal Blocks, UL 1059.

13.2.6 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 is usable at a terminal intended only for the connection of:

a) 14 AWG (2.1 mm^2) conductor, or

b) 16 or 18 AWG (1.3 or 0.82 mm^2) control-circuit conductor.

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

13.2.7 A wire-binding screw shall thread into metal.

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

Exception: A terminal plate of metal less than 1.27 mm (0.050 inch) thick complies where used in a low-voltage, limited-energy (LVLE) circuit or limited energy (LE) circuit (see 2.26 and 2.28) and the tapped threads are capable of withstanding the tightening torque specified in Table 13.1 without stripping.

Table 13.1
Tightening torque for wire-binding screws

Size of terminal screw,		Wire sizes to be tested,	Tightening torque	
No.	(diameter, mm)	AWG (mm^2)	Newton meters	(Pound-inch)
6	(3.5)	Stranded 16 – 18 (1.3 – 0.82)	1.4	(12)
8	(4.2)	Solid 14 (2.1) and Stranded 16 – 18	1.8	(16)
10	(4.8)	Solid 10 – 14 (4.8 – 2.1) and Stranded 16 – 18	2.3	(20)

13.2.9 There shall be two or more full threads in the metal of a terminal plate. The metal is to 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 low-voltage, limited-energy (LVLE) circuit or limited-energy (LE) circuit, see 2.26 and 2.28, when a lesser number of threads results in a secure connection in which the threads do not strip when subjected to the tightening torque specified in Table 13.1.

13.2.10 A terminal for connection of a grounded conductor of an ac circuit shall be identified as described in 64.12.

13.3 Wiring leads

13.3.1 A field-wiring lead shall not be more than two wire sizes smaller than the copper conductor to which it is to be connected, and shall not be smaller than 18 AWG (0.82 mm^2). For example, a 10 AWG (5.3 mm^2) or larger field-wiring lead is required for connection to a 6 AWG (13.3 mm^2) field-provided conductor. A field-wiring lead shall not be less than 152.4 mm (6 inches) long.

Exception: A lead is able to be more than two wire sizes smaller than the field-provided copper conductor to which it is to be connected, and be not smaller than 18 AWG (0.82 mm^2), when more than one factory-provided copper lead is intended for connection to the same field-provided lead, and the construction complies with the following:

a) A wire connector for connection of the field-provided wire is factory-installed as part of the tracker, and the wire connector is rated for the combination of wires that are to 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 67.4(E).

13.3.2 A field-wiring lead shall consist of general building wire, or of other wiring having an insulation of:

a) At least 0.8-mm (1/32-inch) thick thermoplastic material,

b) At least 0.4-mm (1/64-inch) thick rubber plus a braid cover for applications of 300 volts or less, or

c) At least 0.8-mm thick rubber plus a braid cover for applications between 301 and 600 volts.

13.3.3 A field-wiring lead shall comply with Strain Relief Test, Section 43.

13.3.4 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:

a) The lead is insulated at the unconnected end, and

b) A marking is provided on the tracker in accordance with 64.20.

13.3.5 The free end of a field-wiring lead that is not used in every installation, such as a lead for a tap of a multivoltage transformer, shall be insulated. For an equipment-grounding lead, see 15.1.7.

13.3.6 A field-wiring lead for connection of a grounded conductor of an ac circuit shall be identified as described in 64.12.

13.4 Wiring compartments

13.4.1 A wiring compartment for a tracker shall be located so that wire connections therein are accessible for inspection, without disturbing factory or field connected wiring, after the tracker is installed in the intended manner.

13.4.2 A wiring compartment, raceway, or similar device, for routing and stowage of conductors connected in the field shall not contain rough, sharp, or moving parts that are capable of damaging conductor insulation.

13.4.3 A wiring compartment shall not have a volume less than specified in Table 13.2. The volume is to be determined in accordance with the Standard for Metallic Outlet Boxes, UL 514A, or the Standard for Nonmetallic Outlet Boxes, Flush-Device Boxes and Covers, UL 514C, as applicable. No compartment enclosure dimension shall be less than 19.1 mm (3/4 inch).

Table 13.2
Wiring compartment volume

Size of conductor,		Free space for each conductor	
AWG	(mm^2)	Cubic centimeter	(Cubic inches)
18	(0.82)	24.60	(1.50)
16	(1.3)	28.70	(1.75)
14	(2.1)	32.80	(2.00)

Table 13.2 Continued on Next Page

Table 13.2 Continued

Size of conductor,		Free space for each conductor	
AWG	(mm^2)	Cubic centimeter	(Cubic inches)
12	(3.3)	36.90	(2.25)
10	(5.3)	40.00	(2.50)
8	(8.4)	49.20	(3.00)
6	(13.3)	82.00	(5.00)

13.5 Openings for conduit or cable connection

13.5.1 For a fixed tracker, an opening or knockout complying with the requirements specified in 4.7.1 – 4.7.7 shall be provided for connection of conduit or a cable wiring system.

Exception: A tracker complying with 4.7.6 is not required to be provided with an opening or a knockout.

13.6 Openings for class 2 circuit conductors

13.6.1 An opening for the entry of a conductor or conductors of a Class 2 circuit, such as a control or sensor circuit, shall be supplied with an insulating bushing. The bushing shall be factory-installed in the opening or shall be supplied within the enclosure so that it is available for installation when the tracker is installed.

Exception: A bushing is not required where:

a) The opening is sized and intended for armored cable or conduit, and

b) The installation instructions indicate that Class 1 wiring methods are to be used as indicated in 67.4(L).

13.6.2 For Type 1 enclosures only, a bushing of rubber or rubber type material provided in accordance with 13.6.1 shall not be less than 3.2 mm (1/8 inch) thick; however, it shall not be less than 1.2 mm (3/64 inch) thick when the metal around the hole is eyeletted or similarly treated to provide smooth edges. A bushing shall be located so that it is not 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 hinge is mounted shall be free from sharp edges, burrs, or projections capable of damaging the bushing.

14 Wire-Bending Space

14.1 A permanently connected tracker employing pressure terminal connectors for field connection of circuits described in 13.1.2 shall be provided with wire-bending space within the enclosure for the installation of conductors (including grounding conductors) that are to be employed in the installation as specified in 13.1.2 – 13.2.4.

14.2 The conductor size used to determine compliance with 14.1 is to be based on the use of a conductor sized in accordance with 13.1.3.

Exception No. 1: Where a tracker is marked with a maximum wire size for a field-installed conductor in accordance with 64.23, the marked maximum size is to be used.

Exception No. 2: The requirements in 13.4.3 are to be used to investigate the wire-bending space in a wiring compartment.

14.3 Wire-bending space for field installed conductors shall be provided opposite any:

a) Pressure wire connector as specified in 14.4 or 14.5, and

b) Opening or knockout for a conduit or wireway in a gutter as specified in 14.9.

14.4 Where a conductor is able to be installed such that it enters or leaves the enclosure surface opposite its wire-terminal, the wire-bending space shall be as specified in Table 14.1. A wire is able to enter or leave a top, back, bottom, or side surface when there is an opening or knockout for a wireway or conduit.

Table 14.1
Minimum wire-bending space for conductors through a wall opposite terminals in mm (inch)

Wire size, AWG or		Wires per terminal (pole)[a]											
		1			2			3			4 or More		
kcmil	(mm^2)	mm		(inch)	mm		(inch)	mm		(inch)	mm		(inch)
14 – 10	(2.1 – 5.3)	Not specified			–			–			–		
8	(8.4)	38.1		(1-1/2)	–			–			–		
6	(13.3)	50.8		(2)	–			–			–		
4	(21.1)	76.2		(3)	–			–			–		
3	(26.7)	76.2		(3)	–			–			–		
2	(33.6)	88.9		(3-1/2)	–			–			–		
1	(42.4)	114		(4-1/2)	–			–			–		
0	(53.5)	140		(5-1/2)	140		(5-1/2)	179		(7)	–		
2/0	(67.4)	152		(6)	152		(6)	191		(7-1/2)	–		
3/0	(85.0)	165	[12.7]	(6-1/2)	165	[12.7]	(6-1/2)	203		(8)	–		
4/0	(107)	179	[25.4]	(7)	191	[38.1]	(7-1/2)	216	[12.7]	(8-1/2)	–		
250	(127)	216	[50.8]	(8-1/2)	216	[50.8]	(8-1/2)	229	[25.4]	(9)	254		(10)
300	(152)	254	[76.2]	(10)	254	[50.8]	(10)	279	[25.4]	(11)	305		(12)
350	(177)	305	[76.2]	(12)	305	[76.2]	(12)	330	[76.2]	(13)	355	[50.8]	(14)
400	(203)	330	[76.2]	(13)	330	[76.2]	(13)	355	[76.2]	(14)	381	[76.2]	(15)
500	(253)	355	[76.2]	(14)	355	[76.2]	(14)	381	[76.2]	(15)	406	[76.2]	(16)
600	(304)	381	[76.2]	(15)	406	[76.2]	(16)	457	[76.2]	(18)	483	[76.2]	(19)
700	(355)	40	[76.2]	(16)	457	[76.2]	(18)	508	[76.2]	(20)	559	[76.2]	(22)
750	(380)	432	[76.2]	(17)	483	[76.2]	(19)	559	[76.2]	(22)	610	[76.2]	(24)
800	(405)	457		(18)	508		(20)	559		(22)	610		(24)
900	(456)	483		(19)	559		(22)	610		(24)	610		(24)
1000	(507)	508		(20)	–			–			–		
1250	(633)	559		(22)	–			–			–		
1500	(760)	610		(24)	–			–			–		
1750	(886)	610		(24)	–			–			–		
2000	1013	610		(24)	–			–			–		

Note – This table includes only those multiple-conductor combinations that are commonly used. Combinations not specified shall be further investigated.

Table 14.1 Continued on Next Page

Table 14.1 Continued

Wire size, AWG or kcmil (mm²)	Wires per terminal (pole)[a]							
	1		2		3		4 or More	
	mm	(inch)	mm	(inch)	mm	(inch)	mm	(inch)

[a] Compliance with the following conditions reduces the wire-bending space by the number of mm's shown in brackets:

1) Only removable or lay-in wire connectors receiving one wire each are used (sometimes there is more than one removable wire connector per terminal) and

2) A removable wire connector is able to be removed from its intended location and reinstalled with the conductor in place without disturbing structural or electrical parts other than a cover.

14.5 Where a conductor is intended to enter or leave the enclosure surface adjacent (not opposite) to its wire terminal, the wire-bending space shall be as specified in Table 14.2 where:

a) A barrier is provided between the connector and the opening, or

b) Drawings are provided specifying that the conductor is not to enter or leave the enclosure directly opposite the wire connector. See Illustrations A, B, and C of Figure 14.1.

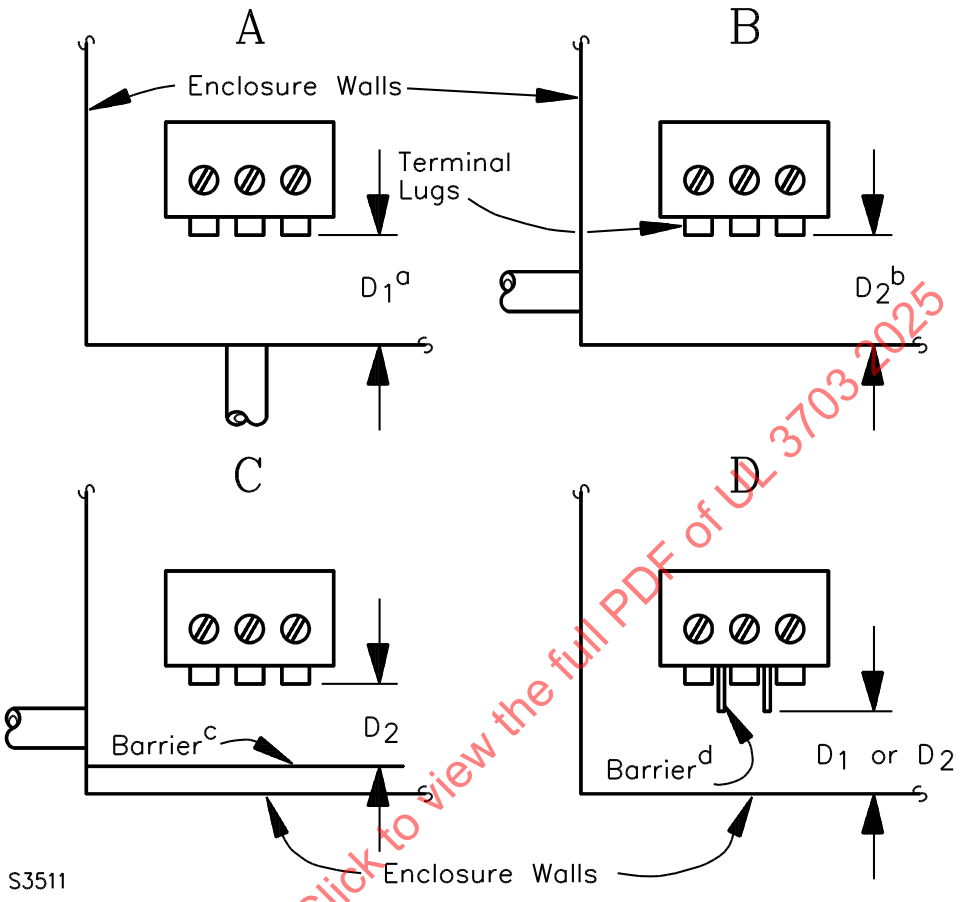
Table 14.2
Minimum wire-bending space and width of gutter for conductors through a wall not opposite terminals in mm (inches)

Size of wire, AWG or kcmil (mm²)		Wires per terminal (pole)									
		1		2		3		4		5	
		mm	(inch)	mm	(inch)	mm	(inch)	mm	(inch)	mm	(inch)
14 – 10	(2.1 – 5.3)	Not specified	–	–		–		–		–	
8 – 6	(8.4 – 13.3)	38.1	(1-1/2)	–		–		–		–	
4 – 3	(21.1 – 26.7)	50.8	(2)	–		–		–		–	
2	(33.6)	63.5	(2-1/2)	–		–		–		–	
1	(42.4)	76.2	(3)	–		–		–		–	
1/0 – 2/0	(53.5 – 7.4)	88.9	(3-1/2)	127	(5)	178	(7)	–		–	
3/0 – 4/0	(85.0 – 107)	102	(4)	152	(6)	203	(8)	–		–	
250	(127)	114	(4-1/2)	152	(6)	203	(8)	254	(10)	–	
300 – 350	(152 – 177)	127	(5)	203	(8)	254	(10)	305	(12)	–	
400 – 500	(203 – 253)	152	(6)	203	(8)	254	(10)	305	(12)	356	(14)
600 – 700	(304 – 355)	203	(8)	254	(10)	305	(12)	356	(14)	406	(16)
750 – 900	(380 – 456)	8	(203)	305	(12)	356	(14)	406	(14)	457	(18)
1000 – 1250	(507 – 633)	254	(10)	–		–		–		–	
1500 – 2000	(760 – 1010)	305	(12)	–		–		–		–	

Note – This table includes only those multiple-conductor combinations that are commonly used. Combinations not specified shall be further investigated.

Figure 14.1

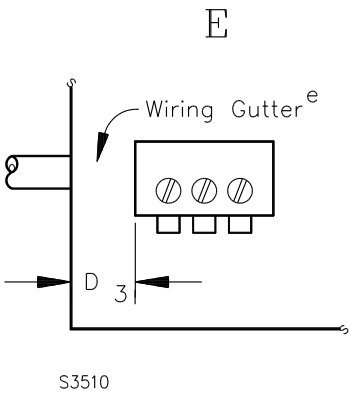
Wire-bending space



(Continued)

Figure 14.1 (cont'd)

Wire-bending space



NOTES –

D_1 is the distance between a wire connector or an adjacent barrier and the opposite wall that conductors pass through.

D_2 is the distance between a wire connector or an adjacent barrier and the opposite wall or barrier that conductors do not pass through.

D_3 is the width of a wiring gutter having a side through which conductors pass through.

[a] A conduit opening or knockout is provided in the wall opposite the terminal lugs.

D_1 shall not be less than the minimum wire-bending space specified in Table 14.1. [b] A conduit opening or knockout is provided in the wall at a right angle to the wall opposite the terminal lugs. The wall opposite the terminal lugs:

1) Is not provided with a knockout or conduit opening, or

2) A marking is provided indicating that the conduit opening or knockout is not to be used. D_2 shall not be less than the minimum wire-bending space specified in Table 14.2.

[c] A conduit opening or knockout is provided in the wall at a right angle to the wall opposite the terminal lugs. In addition, a conduit opening or knockout is provided in the wall opposite the terminal lugs; however, a barrier preventing the use of the opening is provided. D_2 shall not be less than the minimum wire-bending space specified in Table 14.2.

[d] Where a barrier or other means restricts bending of the conductor, the distance D_1 or D_2, as appropriate – see notes D_1 – D_3 – is to be measured from the end of the barrier.

[e] A conduit opening or knockout is provided in a wiring gutter. The width of the gutter, D_3, shall not be less than the minimum wire-bending space specified in Table 14.2.

14.6 Where 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 14.1.

14.7 For a tracker not provided from the factory with a conduit opening or knockout, see 4.7.6, the minimum wiring-bending space specified in 14.4 – 14.6 shall be based on:

a) Any enclosure wall used for installation of the conduit, or

b) Only specific walls that are to be used as specified by a marking, drawing, or template furnished with the tracker.

14.8 The distance specified in 14.3 – 14.5 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 14.1. 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 possible without defeating any means provided to prevent turning, such as a boss, shoulder, walls of a recess, multiple bolts securing the connector, or a similar means. A barrier, shoulder, or similar component is to be disregarded when the measurement is being made where it does not reduce the radius to which the wire must be bent. Where 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 14.6.

14.9 The width of a wiring gutter in which one or more knockouts are provided shall be large enough to accommodate (with respect to wire-bending space) conductors of the maximum size usable at that knockout. The width of a wiring gutter is given in Table 14.2. See illustration E of Figure 14.1.

Exception: The wiring space is able to be narrower when:

a) Knockouts are provided elsewhere that are in compliance with these requirements,

b) The wire-bending space at such other point or points is of a width that accommodates the conductors in question, and

c) The knockout or knockouts at such other points are able to be conveniently used in the intended wiring of the tracker.

15 Equipment Grounding

15.1 General

15.1.1 There shall be means for grounding all dead metal parts of a tracker.

15.1.2 The means for equipment grounding specified in 15.1.1 shall be provided for each wiring system to be connected to the tracker for the following circuits:

a) Each dc input or output circuit,

b) Each ac input circuit,

c) Each ac output circuit, and

d) Each battery circuit.

Exception: An isolated accessible signal circuit complying with Isolated Accessible Signal Circuits, Section 24, is not required to have means for equipment grounding.

15.1.3 The equipment-grounding means for a fixed tracker shall consist of an equipment-grounding terminal or lead.

15.1.4 An equipment-grounding terminal or lead shall be connected to the frame or enclosure by a positive means, such as by a bolted or screwed connection. The head of a screw or bolt, other than a double-nut secured bolt or screw, used to secure a terminal or lead, shall not be accessible from outside of the enclosure.

15.1.5 An equipment-grounding connection shall penetrate a nonconductive coating, such as anodization, paint or vitreous enamel.

15.1.6 An equipment-grounding means shall be located so that the means is not subject to inadvertent removal during servicing.

15.1.7 A free end of an equipment-grounding lead shall be insulated (for example, the end is to be folded back and taped to the lead) unless the lead is located so that the lead is not capable of contacting live parts in the event that the lead is not used in the field.

15.1.8 Equipment grounding leads or equipment grounding terminals shall be provided for each input and each output circuit. Any supplied lead shall have a free length of not less than 152 mm (6 inches) and the surface of the insulation shall be green with or without one or more yellow stripes. Where equipment ground leads are used, no other lead in a field-wiring compartment or that is visible to the installer shall be so identified. Equipment-grounding terminals shall be marked as described in 64.9. An equipment-grounding lead or equipment-grounding terminal shall have a minimum size or be rated to carry the required current in accordance with the following:

a) For a dc input from a photovoltaic source or output circuit, 1.25 times the rated short-circuit input current for that input, see Table 63.1.

b) For any ac input or output circuit or dc (non-PV) input or output circuit, Column 2 of Table 15.1 based on the size of the overcurrent device protecting that circuit.

Exception: The color coding requirement does not apply to Class 2 circuits where the leads are:

a) Located remote from the line-voltage connections and the segregation complies with the requirements in Separation of Circuits, Section 19, or

b) Marked in accordance with 64.21.

Table 15.1
Size of equipment-grounding and grounding electrode conductors

Column 1	Column 2				Column 3			
	Minimum size of equipment-grounding or bonding conductor AWG or kcmil (mm^2)				Minimum size of grounding electrode conductor, AWG or kcmil (mm^2)			
Maximum current rating, amperes	Copper		Aluminum or copper-clad aluminum		Copper		Aluminum or copper-clad aluminum	
15	14	(2.1)	12	(3.3)	8	(8.4)	6	(13.3)
20	12	(3.3)	10	(5.3)	8	(8.4)	6	(13.3)
30	10	(5.3)	8	(8.4)	8	(8.4)	6	(13.3)

Table 15.1 Continued on Next Page

Table 15.1 Continued

Column 1	Column 2				Column 3			
	Minimum size of equipment-grounding or bonding conductor AWG or kcmil (mm^2)				Minimum size of grounding electrode conductor, AWG or kcmil (mm^2)			
Maximum current rating, amperes	Copper		Aluminum or copper-clad aluminum		Copper		Aluminum or copper-clad aluminum	
40	10	(5.3)	8	(8.4)	8	(8.4)	6	(13.3)
60	10	(5.3)	8	(8.4)	8	(8.4)	6	(13.3)
90	8	(8.4)	6	(13.3)	8	(8.4)	6	(13.3)
100	8	(8.4)	6	(13.3)	6	(13.3)	6	(13.3)
150	6	(13.3)	4	(21.2)	6	(13.3)	4	(21.2)
200	6	(13.3)	4	(21.2)	4	(21.2)	2	(33.6)
300	4	(21.2)	2	(33.6)	2	(33.6)	1/0	(53.5)
400	3	(26.7)	1	(42.4)	1/0	(53.5)	3/0	(85.0)
500	2	(33.6)	1/0	(53.5)	2/0	(67.4)	4/0	(107.2)
600	1	(42.4)	2/0	(67.4)	2/0	(67.4)	4/0	(107.2)
800	1/0	(53.5)	3/0	(85.0)	3/0	(85.0)	250	(127)
1000	2/0	(67.4)	4/0	(107.2)	3/0	(85.0)	250	(127)
1200	3/0	(85.0)	250	(127)	3/0	(85.0)	250	(127)
1600	4/0	(107.2)	350	(177)	3/0	(85.0)	250	(127)
2000	250	(127)	400	(203)	3/0	(85.0)	250	(127)
2500	350	(177)	600	(304)	3/0	(85.0)	250	(127)
3000	400	(203)	600	(304)	3/0	(85.0)	250	(127)
4000	500	(253)	800	(405)	3/0	(85.0)	250	(127)
5000	700	(355)	1200	(608)	3/0	(85.0)	250	(127)
6000	800	(405)	1200	(608)	3/0	(85.0)	250	(127)

15.1.9 An equipment-grounding conductor shall not be spliced internal to the equipment.

15.1.10 An equipment-grounding connection, equipment-grounding conductor, enclosure, frame, component mounting panel, or other part connected to earth ground shall not carry current unless an electrical malfunction occurs. See 16.13.

Exception: This requirement does not apply to a line bypass capacitive impedance circuit for a radio frequency signal circuit or a transient voltage surge suppressor.

15.1.11 A soldering lug, a connection means that depends on solder, a screwless (push-in) connector, a quick-connect connector, or other friction-fit connector shall not be used as an equipment-grounding means.

15.1.12 An equipment-grounding terminal shall be rated for securing a conductor of a size based on the size of the overcurrent protection device to be employed in accordance with Columns 1 and 2 of Table 15.1 and shall be constructed in accordance with 13.2.1 – 13.2.9.

15.1.13 A wire-binding screw intended for the connection of a field-installed equipment-grounding conductor shall have a green colored head that is hexagonal, slotted, or both. A pressure wire connector

or a stud-and-nut type terminal intended for connection of such a conductor shall be marked as described in 64.9.

15.2 Grounding electrode terminal

15.2.1 Equipment intended to be installed as service entrance equipment or equipment containing the main dc or ac bonding connection shall be provided with a grounding electrode terminal. The terminal shall:

a) Be capable of securing a conductor size based on the maximum current rating of the highest current circuit connected to the tracker, as specified in Column 3 of Table 15.1,

b) Comply with 13.2.1 – 13.2.10 for construction, and

c) Be marked as described in 64.13.

15.2.2 A grounding-electrode terminal shall be connected to the main bonding point (ac or dc) in the equipment by a positive means, such as by a bolted or screwed connection. For grounding electrode connections that are internal to a product, the head of a screw or bolt, other than a double-nut secured bolt or screw, used to secure a terminal shall not be accessible from outside of the enclosure.

15.2.3 For any ground terminal or lug outside an enclosure, the requirements from Sections 8 and 9 of the Standard for Mounting Systems, Mounting Devices, Clamping/Retention Devices, and Ground Lugs for Use With Flat-Plate Photovoltaic Modules and Panels, UL 2703, and the applicable UL 2703 tests shall be applied.

16 Bonding for Grounding

16.1 Trackers shall have a means for bonding all accessible dead metal parts, which in the event of an electrical malfunction, involve a risk of electric shock or electrical energy-high current levels, shall be conductively connected to the equipment-grounding means specified in Equipment Grounding, Section 15.

16.2 All uninsulated metal parts of the enclosure, motor frames and mounting brackets, component mounting brackets, capacitors, and other electrical components that involve a risk of electric shock or electrical energy-high current levels shall be bonded for grounding where they are accessible for contact by the user or inadvertent contact by a serviceman. The tracker is to be evaluated for bonding using the Standard for Mounting Systems, Mounting Devices, Clamping/Retention Devices, and Ground Lugs for Use With Flat-Plate Photovoltaic Modules and Panels, UL 2703.

Exception: A metal part as described in (a) – (f) is not required to be bonded for grounding:

a) An adhesive-attached metal foil marking that is located on the outside of an enclosure or cabinet and isolated from electrical components or wiring by grounded metal parts so that they do not become energized.

b) An isolated metal part, such as a magnet frame and an armature.

c) Within an enclosure, a panel or cover that does not enclose uninsulated live parts; and wiring is positively separated from the panel or cover so that it is unable to become energized.

d) Within an enclosure, a panel or cover that is secured in place and that is insulated from electrical components and wiring by an insulating barrier of vulcanized fiber, varnished cloth, phenolic composition, or similar material not less than 0.8 mm (1/32 inch) thick.

e) Within an enclosure, an isolated metal part that is mounted on a printed wiring board – such as transformer and choke cores and heat sinks.

f) Within an enclosure, a capacitor sleeved with insulating tubing complying with 20.2.2.

16.3 A metal-to-metal piano-type hinge is usable as a means for bonding a door for grounding.

16.4 Where the continuity of the bonding to grounding system relies on the dimensional integrity of a nonmetallic material, the material shall be in accordance with the requirements for creep in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A. See also 16.9.

16.5 A conductor or strap used for bonding shall be of copper, a copper alloy, or an equivalent material. A conductor or strap:

a) Shall be located within an enclosure, or if outside an enclosure, shall comply with Section 9 of the Standard for Mounting Systems, Mounting Devices, Clamping/Retention Devices, and Ground Lugs for Use With Flat-Plate Photovoltaic Modules and Panels, UL 2703, and the applicable UL 2703 tests,

b) Shall not be secured by a removable fastener used for any purpose other than bonding for grounding, unless there is a low risk of the bonding conductor being omitted after removal and replacement of the fastener, and

c) Shall not be spliced.

16.6 A connection in the bonding path shall be by a positive means, such as by a clamp, a rivet, a bolted or screwed connection, or by welding, soldering, or brazing with materials having a softening or melting point greater than 455°C (850°F). The bonding connection shall penetrate nonconductive coatings, such as paint or vitreous enamel. Ferrous metal parts shall comply with Protection Against Corrosion, Section 6.

16.7 A bolted or screwed connection that incorporates a star washer or other nonconductive material piercing device shall penetrate nonconductive coatings.

16.8 Where the bonding connection depends on machine screw threads in metal, two or more screws or two full threads of a single screw engaging two full threads in the metal shall be used.

16.9 A connection that depends on the clamping action exerted by rubber or similar material shall comply with 16.4. The material shall be rated for the condition of use, such as UV, oil, grease, water, and thermal degradation that potentially occur in service.

16.10 A bonding conductor or strap utilized within an enclosure:

a) Shall not be smaller than the size specified in Column 2 of Table 15.1, see 16.12, or

b) Shall not be smaller than the conductor supplying the component.

16.11 A bonding conductor or strap utilized outside of an enclosure shall comply with Section 9 of the Standard for Mounting Systems, Mounting Devices, Clamping/Retention Devices, and Ground Lugs for Use With Flat-Plate Photovoltaic Modules and Panels, UL 2703, and the applicable UL 2703 tests.

16.12 With reference to Column 2 of Table 15.1, where more than one size branch-circuit overcurrent device is involved, the size of the bonding conductor or strap is to be based on the rating of the overcurrent device intended to provide ground-fault protection for the component bonded by the conductor.

16.13 For all dead metal on the tracker, the bonding components shall not carry current other than current resulting from an electrical malfunction.

17 Internal Wiring

17.1 General

17.1.1 The internal wiring of a tracker shall consist of general-use building wire or appliance wiring material rated for the temperature, voltage, and conditions of service to which the wiring is subjected. The insulation of appliance wiring material shall comply with Table 17.1.

Exception: Appliance wiring material having an insulation thickness other than specified in Table 17.1 complies when the insulation ratings are equivalent to that specified with respect to temperature, voltage, and conditions of service.

Table 17.1
Appliance-wiring material

Type of insulation	Thickness of insulation, mm (inch)[a]	
	600-volt applications	300-volt applications
Thermoplastic	0.8 (1/32)	0.8 (1/32)[b,c]
Rubber	0.8 (1/32) plus an impregnated braid cover	0.4 (1/64) plus impregnated braid cover
		0.8 (1/32) without a braid cover
Neoprene	0.2 (3/64)	0.4 (1/64) plus an impregnated braid cover
		0.8 (1/32) without a braid cover
Silicone rubber	0.8 (1/32) plus an impregnated braid cover	0.4 (1/64) plus an impregnated braid cover
	0.8 (1/32) without a braid cover[d]	0.8 (1/32) without a braid cover[d]
Cross-linked synthetic polymer	0.4 (1/64)	0.4 (1/64)

[a] The minimum thickness is 0.71 mm (0.028 inch) for 0.8 mm-thick insulation; the minimum thickness is 0.33 mm (0.013 inch) for 0.4 mm-thick insulation

[b] Shall not be less than 0.33 mm (0.013 inch) for short, moving pigtails or coil leads in a small device, where such leads make no more than casual contact with parts of opposite polarity or ungrounded parts.

[c] Shall not be less than 0.18 mm (0.007 inch) where routed away from live parts of opposite polarity and protected from mechanical damage during installation of field wiring and while the equipment is in operation.

[d] Applies only when routed away from live parts of opposite polarity and protected from mechanical damage during installation of field wiring and while the equipment is in operation.

17.1.2 Insulating tubing or sleeving shall not be used as insulation other than for a short length of insulated conductor, for example, a short coil lead, or similar component. Where so used:

a) The tubing or sleeving shall not be subjected to compression, repeated flexure, or sharp bends,

b) The conductor covered with the tubing or sleeving shall be well rounded and free from sharp edges,

c) A shrinkable tubing shall be used in accordance with the tubing manufacturer's instructions, and

d) The tubing or sleeving shall not be subjected to a temperature or voltage higher than that for which the tubing or sleeving is rated.

17.1.3 Where wiring extends to a hinged door or other part that is subject to movement in use, stranded conductors shall be employed, and the arrangement shall preclude twisting or stressing of conductors as a

result of the movement. The wiring shall be routed or protected against damage to the insulation. The conductors shall be secured so that stress is not transmitted to terminals or splices.

17.2 Protection of wiring

17.2.1 Internal wiring shall not be accessible from outside the enclosure in accordance with 8.1.

17.2.2 Wires within an enclosure, compartment, raceway, or similar housing, shall be located or protected against contact with any sharp edge, burr, fin, moving part, or similar part that is able to damage the conductor insulation.

17.2.3 Mounting screws and nuts shall be constructed or located so that sharp edges do not damage wiring. A screw shall have a flat or blunt end. The end of the screw shall not have burrs, fins, or sharp edges that are able to abrade wire insulation, and the end shall not project more than 4.8 mm (3/16 inch) into a wireway.

17.2.4 A hole through which insulated wires pass in a sheet metal wall internal to the overall enclosure of a tracker shall be provided with smooth, rounded surfaces upon which the wires bear, to protect against abrasion of the insulation.

17.3 Electrical connections

17.3.1 A splice or connection shall be mechanically secure and shall make reliable electrical contact.

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

Exception: A connection is not required to be mechanically secured before soldering when:

a) A soldering or brazing material having a softening or melting point greater than 454°C (849°F) is used,

b) A hand-soldered lead is passed through a hole in a printed wiring board and bent 90 degrees to the board to make contact with the conductor before soldering,

c) Soldering on a printed wiring board is done by a machine process in which the soldering time and solder temperature are automatically controlled – bending over of leads is not required, or

d) The lead wire is strapped in place, or the equivalent, adjacent to the soldered connection to hold the lead end in place.

17.3.3 A stranded internal wiring connection shall be such that it reduces the potential for loose strands of wire contacting dead metal parts or other live parts not always of the same potential. This is able to be accomplished by the use of a pressure terminal connector, a soldering lug, a crimped eyelet, soldering of all strands together, or an equivalent means.

17.3.4 An open-end spade lug secured by a screw or nut shall be secured by additional means, such as upturned ends on the lug, or bosses or shoulders on the terminal, to hold the lug in place in the event the screw or nut loosens.

17.3.5 A nominal 0.110-, 0.125-, 0.187-, 0.205-, or 0.250-inch wide quick-connect terminal shall comply with the Standard for Electrical Quick-Connect Terminals, UL 310. Other sizes of quick-connect terminals shall be investigated with respect to crimp pull-out, engagement-disengagement forces of the connector and tab, and temperature rises in accordance with UL 310.

17.3.6 Aluminum conductors, insulated or uninsulated, used as internal wiring, such as for interconnection between current-carrying parts or in a component winding, shall be terminated at each end by a terminal that is rated for the combination of metals involved at the connection points. A wire-binding screw or a pressure wire connector used as a terminating device shall be rated for use with aluminum under the conditions involved – for example, temperature, heat cycling, vibration, and other similar conditions.

17.3.7 A splice shall be provided with insulation equivalent to that of the wires involved unless permanent spacings are maintained between the splice and other metal parts.

a) Splicing devices such as pressure wire connectors insulated for the voltage and temperature to which they are subjected are in compliance with this requirement.

b) Insulating tubing or sleeving used to cover a splice shall comply with 17.1.2.

c) Two layers of thermoplastic tape, or two layers of friction tape, or one layer of friction tape and one layer of rubber tape, are able to be used on a splice when the voltage involved is less than 250 volts. The use of thermoplastic tape wrapped over a sharp edge is not in compliance with the requirement.

18 Live Parts

18.1 A current-carrying part shall be of silver, copper, copper alloy, aluminum, or the equivalent.

18.2 Uninsulated live parts and components that have uninsulated live parts shall be secured so they do not turn or shift in position where such displacement results in a reduction of spacings below the minimum values specified in Spacings, Section 20, or Alternate Spacings – Clearances and Creepage Distances, Section 21.

19 Separation of Circuits

19.1 Factory wiring

19.1.1 Insulated conductors of different circuits – see 19.1.2 – within a tracker, including wires in a terminal box or compartment, shall be separated by barriers or segregated and shall also be so separated or segregated from uninsulated live parts connected to different circuits.

Exception: For insulated conductors of different circuits, where each conductor is provided with insulation rated for the highest of the circuit voltages, no barriers or segregation are required.

19.1.2 For the purpose of determining compliance with 19.1.1, different circuits include:

a) Circuits connected to the primary and secondary windings of an isolation transformer,

b) Circuits connected to different isolated secondary windings of a multi-secondary transformer,

c) Circuits connected to secondary windings of different transformers,

d) Input and output circuits of an optical isolator,

e) Isolated circuits, and

f) AC power and dc power circuits.

Exception: Power circuits that are derived from the taps of an autotransformer or similar component – that does not provide isolation – are not different circuits.

19.1.3 Segregation of insulated conductors shall be by means of clamping, routing, or an equivalent means that maintains permanent separation from insulated and uninsulated live parts and from conductors of a different circuit.

19.2 Field wiring

19.2.1 A tracker shall be constructed so that a field-installed conductor of a circuit is separated as specified in 19.2.2 or separated by barriers as specified in 19.3.1 and 19.3.2 from:

a) Factory-installed conductors connected to any other circuit, unless the conductors of both circuits are insulated for the maximum voltage of one of the circuits.

b) An uninsulated live part of another circuit or from an uninsulated live part where a short circuit between the conductors involves a risk of fire, electric shock, electrical energy-high current levels, or injury to persons.

c) Field-installed conductors connected to any other circuit unless:

1) Both circuits are Class 2 or Class 3 or both circuits are other than Class 2 or Class 3, and

2) Both circuits are insulated for the maximum voltage of one of the circuits.

Exception: A field-installed conductor is not required to be separated from a field wiring terminal of a different circuit where the field wiring is intended to be insulated for the maximum voltage of one of the circuits, and both circuits are Class 2 or Class 3 or both circuits are other than Class 2 or Class 3.

19.2.2 Separation of a field-installed conductor from another field-installed conductor and from an uninsulated live part connected to another circuit is able to be accomplished by locating an opening in the enclosure for the conductor opposite to the conductor terminal so that, when the installation is complete, the conductors and parts of different circuits are separated by a minimum of 6.4 mm (1/4 inch). In determining whether a tracker having such openings complies with this requirement, it is to be wired as in service including 152.4 mm (6 inches) of slack in each conductor within the enclosure. No more than average care is to be exercised in routing the wiring and stowing the conductor slack into the wiring compartment.

19.2.3 With reference to 19.2.2, when the number of openings in the enclosure does not exceed the minimum required for the intended wiring of the tracker, and where each opening is located opposite a set of terminals, it is to be assumed that a conductor entering an opening is to be connected to the terminal opposite that opening. When more than the minimum number of openings are provided, the possibility of a conductor entering an opening other than the one opposite the terminal to which it is intended to be connected and the potential for it to contact insulated conductors or uninsulated current-carrying parts connected to a different circuit is to be investigated.

19.3 Separation barriers

19.3.1 A barrier used for separation between the wiring of different circuits shall be:

a) Grounded metal or 0.71 mm (0.028 inch) minimum thick insulating material, and

b) Supported so that it is unable to be readily deformed or displaced to defeat its purpose.

19.3.2 A barrier used for separation between field wiring of one circuit and field or factory wiring or uninsulated live parts of another circuit shall not be spaced more than 1.6 mm (1/16 inch) from the surface that serves to provide separated compartments.

20 Spacings

20.1 General

20.1.1 The spacings in a tracker shall not be less than specified in Table 20.1.

Exception No. 1: Where liners and barriers are employed, 20.2.1 shall be used to determine the spacings.

Exception No. 2: As an alternative to Table 20.1, the spacings are able to be investigated in accordance with Alternate Spacings – Clearances and Creepage Distances, Section 21.

Exception No. 3: The inherent spacings of a component shall comply with the spacing requirements for the component.

Exception No. 4: The spacings specified in Table 20.1 do not apply within a circuit that complies with Isolated Accessible Signal Circuits, Section 24, or Control Circuits, Section 25. The spacing between these circuits and other circuits shall comply with Table 20.1.

Exception No. 5: Spacings between adjacent foils on a printed wiring board with a conformal coating complying with the requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluation, UL 746C, are not required to comply with Table 20.1.

Exception No. 6: On printed wiring boards having a flammability classification of V-0 and constructed from a base material having a minimum Comparative Tracking Index (CTI) rating of 175 volts, spacings (other than spacings to ground, between primary and secondary circuits, between the battery supply circuit and other circuits and at field wiring terminal) are not specified between traces of different potential connected in the same circuit where:

a) The spacing complies with Reduced Spacings on Printed Wiring Boards Tests, Section 44, or

b) An analysis of the circuit indicates that no more than 12.5 milliamperes of current is able to flow between short-circuited traces having reduced spacings.

Exception No. 7: For multilayer printed wiring boards, the minimum spacing between adjacent internal foils of opposite polarity and between an internal foil and a plated through-hole shall not be less than 0.8 mm (1/32 inch).

Exception No. 8: Spacing requirements do not apply between adjacent terminals of a power switching semiconductor device, including the connection points of the terminals of the device.

Table 20.1
Spacings

Potential involved, volts rms (peak)	Minimum spacings, mm (inch)					
	Between an uninsulated live part and an uninsulated live part of opposite polarity, uninsulated grounded part other than the enclosure, or exposed metal part[a]				Between an uninsulated live part and the walls of a metal enclosure including a fitting for conduit or armored cable[b]	
	Through air		Over surface		Shortest distance	
0 – 50 (0 – 70.7)	1,6[c,d]	(1/16)	1.6[c,d]	(1/16)	1.6[c]	(1/16)
Greater than 50 to 150 (70.7 to 212.1)	3.2[c,d]	(1/8)	6.4[d]	(1/4)	6.4	(1/4)
Greater than 150 to 300 (212.1 to 424.2)	6.4	(1/4)	9.5	(3/8)	12.7	(1/2)
Greater than 300 to 600 (424.2 to 848.4)	9.5	(3/8)	12.7	(1/2)	12.7	(1/2)

[a] For printed wiring boards, see Exceptions Nos. 2 – 7 to 20.1.1.

[b] A metal piece attached to the enclosure shall be investigated as a part of the enclosure where deformation of the enclosure reduces spacings between the metal piece and uninsulated live parts.

[c] The spacing between field-wiring terminals of opposite polarity and the spacing between a field-wiring terminal and a grounded dead metal part shall not be less than 6.4 mm (1/4 inch).

[d] At closed-in points only, such as a screw and washer construction of an insulated stud mounted in metal, the spacing shall not be less than 1.2 mm (3/64 inch).

20.1.2 Uninsulated live parts connected to different circuits shall be investigated as though they are parts of opposite polarity and on the basis of the highest voltage involved. See Maximum-Voltage Measurements, Section 38.

20.1.3 The spacing at a field wiring terminal is to be measured with wires representative of field wiring in place and connected to the terminals as in actual service.

20.1.4 In a multi-component tracker, the spacings from one component to another, from any component to the enclosure, and to another uninsulated dead metal part (excluding the component mounting surface), are to be based on the maximum voltage rating of the complete tracker and not on the individual component ratings. The inherent spacings of an individual component is to be investigated on the basis of the voltage used and controlled by the individual component. Spacings between metal oxide varistors, capacitors, and other components shall comply with Table 20.1.

Exception: Components that comply with the requirements in the Standard for Fixed Capacitors for Use in Electronic Equipment – Part 14: Sectional Specification: Fixed Capacitors for Electromagnetic Interference Suppression and Connection to the Supply Mains, UL 60384-14, are not required to comply with Table 20.1.

20.1.5 Spacings for a fuse and fuseholder are to be measured with a fuse in place that has the maximum standard dimension for the rating, and such spacings shall not to be less than those specified in Table 20.1.

20.1.6 Where an uninsulated live part is not rigidly secured in position by means other than friction between surfaces, or where a movable dead metal part is in proximity to an uninsulated live part, the construction shall be such that for any position resulting from turning or other movement of the parts in question, at least the minimum required spacings shall be maintained.

20.1.7 With reference to 20.1.6, a lock washer is one means of rigidly securing a part.

20.1.8 Spacings to film coated wire are to be investigated as though the wire is an uninsulated live part.

20.1.9 Spacings within the circuits described in (a), (b), or (c) that are not safety circuits shall be such that the circuit complies with Dielectric Voltage-Withstand, Section 40. Spacings between these circuits and the enclosure, grounded dead metal, and other circuits shall comply with the applicable spacing requirements of this standard.

a) Secondary circuits supplied by a transformer winding rated less than 200 volt-amperes or at a potential of 100 volts or less,

b) Battery circuits at a potential of 100 volts or less, or

c) A circuit derived from a battery rated over 100 volts in which the voltage within the circuit is limited to 100 volts or less by a regulating network complying with the requirement in 25.11.

20.2 Insulating liners and barriers

20.2.1 With reference to Exception No. 1 to 20.1.1, an insulating liner or barrier of material such as vulcanized fiber is able to be used when it is:

a) Not the sole support for uninsulated live parts involving a risk of fire, electric shock, or electrical energy-high current levels,

b) Not less than 0.71 mm (0.028 inch) thick, and

c) Located so that it is not adversely affected by arcing.

Other insulating materials used as a barrier or as direct or indirect support of uninsulated live parts involving a risk of fire, electric shock, or electrical energy-high current levels shall comply with the requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

Exception No. 1: Vulcanized fiber not less than 0.33 mm (0.013 inch) thick is usable when:

a) In conjunction with an air spacing of not less than 50 percent of the minimum through air spacing as specified in Table 20.1, and

b) Between a heat sink and a metal mounting surface, including the enclosure, of an isolated secondary circuit rated 50 volts rms or less.

Exception No. 2: Mica shall be not less than 0.165 mm (0.006 inch) thick when used as insulation between a heat sink and a live case of a semiconductor device.

20.2.2 Insulating tubing complying with the requirements in the Standard for Extruded Insulating Tubing, UL 224, is usable for insulating a conductor including a bus bar in lieu of the minimum specified spacings and insulating a capacitor case in lieu of bonding the case for grounding, when the following conditions are met:

a) The conductor is not subjected to compression, repeated flexing, or sharp bends,

b) The conductor or case covered with the tubing is well rounded and free from sharp edges,

c) The tubing is used in accordance with the manufacturer's instructions, and

d) The conductor or case is not subjected to a temperature or voltage higher than that for which the tubing is rated.

20.2.3 A wrap of thermoplastic tape, complying with the requirements in the Standard for Polyvinyl Chloride, Polyethylene, and Rubber Insulating Tape, UL 510, is usable when all of the following conditions are met:

a) The wrap is no less than 0.33 mm (0.013 inch) thick, is applied in two or more layers, and is used in conjunction with not less than one-half the required through-air spacing.

b) The wrap is not less than 0.72 mm (0.028 inch) thick where used in conjunction with less than one-half the required through-air spacing.

c) The temperature rating of the tape is not less than the maximum temperature observed during the temperature test.

d) The tape is not subject to compression.

e) The tape is not wrapped over a sharp edge.

21 Alternate Spacings – Clearances and Creepage Distances

21.1 Other than specified in 21.2 and 21.3, as an alternative approach to the spacing requirements specified in Spacings, Section 20, clearances and creepage distances are able to be investigated in accordance with the requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, as described in 21.4. See Maximum-Voltage Measurements, Section 38.

21.2 The clearances between an uninsulated live part and the walls of a metal enclosure, including fittings for conduit or armored cable, shall be as specified in Table 20.1. The clearances are to be determined by physical measurement.

21.3 The clearances and creepage distances at field wiring terminals shall comply with Spacings, Section 20.

21.4 In conducting investigations in accordance with the requirements in the Standard for Insulation Coordination Including Clearances and Creepage Distances for Electrical Equipment, UL 840, the following shall be used:

a) Unless specified elsewhere in this standard, the pollution degree 3 applies,

b) Pollution degree 2 applies on a printed wiring board between adjacent conductive material which is covered by any coating which provides an uninterrupted covering over at least one side and the complete distance up to the other side of conductive material,

c) All printed wiring boards shall be identified as having a minimum Comparative Tracking Index (CTI) of 100 without further investigation.

d) The use of a coating which complies with the requirements for conformal coatings in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C is in compliance with the requirements of UL 840 to achieve pollution degree 1,

e) Pollution degree 1 is achievable at a specific printed wiring board location by application of at least a 0.79 mm (1/32 inch) thick layer of silicone rubber or for a group of printed wiring boards through potting, without air bubbles, in epoxy or potting material,

f) The Phase-to-Ground Rated System Voltage used in the determination of Clearances shall be the equipment rated supply voltage rounded to the next higher value (in the table for determining clearances for equipment) for all points on the supply side of an isolating transformer or the entire product when no isolating transformer is provided. The System Voltage used in the evaluation of

secondary circuitry is able to be interpolated across the table for the Rated Impulse Withstand Voltage Peak and Clearance, and

g) Determination of the dimensions of clearance and creepage distances shall be conducted in accordance with the requirements for Measurement of Clearance and Creepage Distances of UL 840.

22 Insulating Materials

22.1 General

22.1.1 A polymeric material on which uninsulated live parts is mounted shall be Classed V-0, V-1, or V-2 in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94. The use of a material Classed V-2 requires the use of an enclosure without ventilation openings. Drain holes are not prohibited regardless of the material Class.

Exception: This requirement does not apply to a material supporting only live parts connected in low-voltage, limited-energy (LVLE) circuits where deterioration of the material does not involve a risk of fire or electric shock.

22.1.2 Vulcanized fiber shall not be used as the sole support of an uninsulated live part where shrinkage, current leakage, or warpage introduces a risk of fire or electric shock. Electrical grade vulcanized fiber is able to be used for an insulating bushing, a washer, a separator, or a barrier.

22.1.3 A polymeric material used to support an uninsulated live part or parts, shall comply with the requirements for mechanical strength and rigidity, resistance to heat, resistance to flame propagation, and dielectric strength in the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A; Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B; and the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C.

22.2 Barriers

22.2.1 An insulating barrier of vulcanized fiber, thermoplastic, or other material used in lieu of required spacings shall not be less than 0.71 mm (0.028 inch) thick and shall be so located or of such material that it is not adversely affected by arcing.

Exception: Vulcanized fiber not less than 0.33 mm (0.013 inch) thick is usable:

a) In conjunction with an air spacing of not less than 50 percent of the minimum through-air spacing as specified in Table 20.1, and

b) Between a heat sink and a metal mounting surface, including the enclosure, or an isolated secondary circuit rated 50 volts rms or less.

22.2.2 Insulation used in lieu of required spacings between a magnet-coil winding and other uninsulated live parts or grounded dead metal parts, shall comply with 22.2.1.

23 Capacitors

23.1 A capacitor used for electromagnetic interference elimination or power-factor correction that is oil filled shall comply with the Standard for Capacitors, UL 810.

Exception: The container of the capacitor is able to be of thinner sheet metal or be of material other than metal, where the capacitor is mounted inside a tracker having an enclosure that complies with the requirements in 4.1.1 – 4.5.1 without Exceptions.

23.2 A capacitor connected across an input/output ac circuit that is connected to a utility shall comply with the requirements for across-the-line capacitors in the Standard for Fixed Capacitors for Use in Electronic Equipment – Part 14: Sectional Specification: Fixed Capacitors for Electromagnetic Interference Suppression and Connection to the Supply Mains, UL 60384-14.

24 Isolated Accessible Signal Circuits

24.1 An isolated accessible signal circuit having means for external connections, such as a RS232 communication port and similar connections, shall comply with 24.2 and 24.3.

24.2 A signal circuit that extends outside of an enclosure shall be an isolated circuit and shall be isolated from internal circuits having a voltage involving a risk of electric shock, as determined in accordance with Electric Shock, Section 10, by one of the following:

a) An optical isolator, complying with the Standard for Optical Isolators, UL 1577, having an isolation voltage rating of not less than the test potential required in 40.1,

b) An isolation transformer complying with 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, or an isolation transformer as defined in 2.24 – autotransformers are excluded,

c) A capacitor complying with the Standard for Fixed Capacitors for Use in Electronic Equipment – Part 14: Sectional Specification: Fixed Capacitors for Electromagnetic Interference Suppression and Connection to the Supply Mains, UL 60384-14,

d) An electro-mechanical relay complying with the requirements in the Standard for Industrial Control Equipment, UL 508, or

e) A voltage regulating network where:

1) The voltage being isolated is not directly derived from the ac circuit, and

2) The network does not involve a risk of electric shock at the external connection as determined in accordance with Electric Shock, Section 10, or as indicated by a failure mode and effect analysis in accordance with the method described in the Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991.

24.3 The maximum power voltage and current available from an isolated accessible signal circuit shall comply with 25.4 – 25.11.

24.4 The maximum power available from an isolated accessible signal circuit that employs an overcurrent protection device to limit the current as described in the Exception to 25.4 shall not exceed the values specified in Table 24.1.

Table 24.1
Maximum power of isolated accessible signal circuits

Circuit voltage, volts rms	Maximum power, volt-amperes
15 or less	350
More than 15 and not greater than 60	250

25 Control Circuits

25.1 A control circuit that is a low-voltage, limited-energy (LVLE) circuit or a limited-energy (LE) circuit is able to be connected to a single-point reference ground.

25.2 Other than for safety circuits, as indicated in 25.3, a low-voltage, limited-energy (LVLE) circuit is not required to be investigated. Printed-wiring boards and insulated wire used in such circuits shall comply with 17.1.1 and 27.1.

25.3 A control circuit that is a safety circuit shall be investigated in accordance with the requirements for primary circuits.

25.4 A control circuit, including associated electronic components on printed wiring boards, that does not extend out of an enclosure is not required to be investigated where the maximum voltage and current are limited as specified in (a) and (b). Printed wiring boards and insulated wires used in such circuits shall comply with 17.1.1 and 27.1.

a) The voltage shall not exceed the limits specified in Table 10.1, and

b) The current shall not exceed:

1) Eight amperes for 0 – 42.4 volts peak ac, or 0 – 30 volts dc, or

2) Amperes equal to 150 divided by the maximum voltage for 30 – 60 volts dc. See 25.5.

Exception: The maximum current specified is able to be exceeded where the circuit includes an overcurrent protective device as described in 25.8 and 25.9.

25.5 With reference to 25.4(b), the maximum current is to be measured under any condition of loading including short circuit using a resistor that is to be continuously readjusted during the 1-minute period to maintain maximum load current; however, the value indicated in (b) is not to be exceeded.

25.6 With reference to 25.4(a), measurement is to be made with the tracker connected to the voltage specified in Section 40 and with all loading circuits disconnected. When a tapped transformer winding is used to supply a full-wave rectifier, voltage measurement is to be made from either end of the winding to the tap.

25.7 When the control circuit specified in 25.4 is not limited as to available short-circuit current by the construction of a transformer, and the circuit includes one or more resistors, a fuse, a nonadjustable manual-reset protective device, or a regulating network – see 25.11 – the circuits in which the current is limited in accordance with 25.8, 25.9, or 25.10 are not required to be investigated.

25.8 A fuse or circuit-protective device used to limit the current in accordance with 25.7 shall be rated or set at not more than the values specified in Table 25.1.

Table 25.1
Rating for secondary fuse or circuit protector

Circuit voltage, V rms	Maximum overcurrent protection, amperes
20 or less	5
More than 20 and not greater than 60	100/V[a]
[a] V is the maximum output voltage, regardless of load, with the primary energized in accordance with Section 40.	

25.9 A fuse or circuit-protective device connected to the primary of a transformer to limit the current in accordance with 25.7 shall be equivalent to that specified in 25.8 as determined by conducting the Overcurrent Protection Calibration Test, Section 50.

Exception: The Overcurrent Protection Calibration Test, Section 50, does not apply when the combination of a fuse or overcurrent protective device and a transformer complies with 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.

25.10 A regulating network or one or more resistors used to limit the current in accordance with 25.7 shall be such that the current under any condition of load, including short circuit, does not exceed the values indicated in 25.4(b).

25.11 Where a regulating network is used to limit the voltage or current in accordance with 25.4 – 25.10, and the performance is affected by malfunction (short circuit or open circuit) of any single component – excluding short-circuiting a resistor – the network:

a) Shall comply with the tests specified in 25.13, and

b) Critical components identified by the failure mode and effect analysis in accordance with the Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991, shall be derated in accordance with the Electronic Reliability Design Handbook, Military Handbook Number 338-1988.

25.12 In a circuit of the type described in 25.7, the secondary winding of the transformer, the fuse or circuit protective device, or the regulating network, and all wiring up to the point at which the current and voltage are limited shall be investigated in accordance with the applicable requirements in this standard.

25.13 With reference to 25.11(a), the regulating network shall comply with the following tests in accordance with the method described in the Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991. See 25.14.

a) Transient Overvoltage Test,

b) Ramp Voltage Test,

c) Electromagnetic Susceptibility Tests,

d) Electrostatic Discharge Test,

e) Thermal Cycling Test,

f) Humidity Test, and

g) Effects of Shipping and Storage Test.

25.14 The following test parameters are to be used in the investigation of a regulating network covered by 25.13.

a) Electrical supervision of critical components applies,

b) Audibility is usable as a trouble indicator for an electrical supervision circuit,

c) A field strength of 3 volts per meter is to be used for the Radiated EMI Test, and

d) Exposure Class H5 is to be used for the Humidity Test.

26 Overcurrent Protection

26.1 General

26.1.1 An overcurrent protective device, the intended functioning of which requires renewal, replacement, or resetting, shall be accessible:

a) From outside of the enclosure, or

b) Behind a hinged cover – see 4.2.1.

Exception No. 1: A protective device that is normally unknown to the user because of its location and omission of reference to the device in the operating instructions provided with the tracker is not required to be accessible.

Exception No. 2: A control-circuit fuse does not require renewal as an intended function when the fuse and the load are contained within the same enclosure.

26.1.2 The screw shell of a plug-type fuseholder and the contacts, including associated live parts that are able to be contacted by the probe illustrated in Figure 8.1, of an extractor-type fuseholder shall be connected toward the load.

26.1.3 A fuse and a fuseholder shall have voltage and current ratings not less than the circuit in which they are connected. A plug fuse shall not be used in a circuit exceeding 125 volts or in a 125/250 volts, 3-wire, circuit.

26.1.4 A fuseholder shall be of the cartridge, plug, or extractor type.

Exception: A fuse intended to be replaced only by service personnel – see Protection of Service Personnel, Section 9 – that is bolted in place meets the intent of this requirement.

26.1.5 A circuit breaker in the input or output circuit shall open all ungrounded conductors of the circuit. A multipole circuit breaker shall be a common trip type.

Exception: Single-pole circuit breakers with handle ties, the combination of which complies with the applicable requirements in the Standard for Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures, UL 489, are usable as the protection for each ungrounded conductor supplying line-to-line connected loads of equipment rated for connection to one of the following circuits of a grounded system, where no conductor involves a potential to ground in excess of 150 volts (see 65.8):

a) In a single-phase circuit,

b) In a 3-wire dc circuit, or

c) In a circuit that is connected to a 4-wire, 3-phase; or 5-wire, 2-phase, system with a grounded neutral.

26.1.6 A tracker shall be marked in accordance with 65.5 when it is provided with overcurrent protection consisting of an interchangeable fuse and when the fuse is:

a) Accessible to the user, or

b) Used to comply with the requirements in this standard.

26.1.7 An overcurrent protective device shall not be connected in the grounded (neutral, in an ac circuit) side of the supply circuit unless the protective device simultaneously disconnects the grounded and ungrounded conductors of the supply circuit.

26.1.8 Temperature or current-sensitive devices such as temperature limiting thermostats, thermal cutoffs, appliance protectors, fuses, circuit breakers, or similar devices shall comply with the requirements applicable to the particular component. See Components, Section 3.1.

26.1.9 Overcurrent protection employing solid-state component circuitry used for protection of control circuits in accordance with 26.2.1 – 26.2.5 shall comply with the calibration and interrupt requirements in the Standard for Molded-Case Circuit Breakers, Molded-Case Switches, and Circuit-Breaker Enclosures, UL 489.

Exception: These requirements do not apply to overcurrent protection whose performance is not affected by malfunction of any single component that is short-circuited or open-circuited.

26.1.10 Trackers having overcurrent protective devices connected directly to input or output terminals or having overcurrent device terminals serving as inputs or outputs shall have labels or markings near those input or output terminals showing conductor temperature limitations for field installed conductors in accordance with Section 110.14 of the National Electrical Code, ANSI/NFPA 70.

26.2 Control circuit overcurrent protection

26.2.1 A control circuit that extends from the tracker to a remote control panel, status panel, or a similar component shall be protected in accordance with 26.2.2 – 26.3.2.

Exception: An external control circuit derived from a Class 2 transformer is not required to be provided with overcurrent protection.

26.2.2 The overcurrent protective device specified in 26.2.1 shall be a circuit breaker or fuse that is rated for branch-circuit overcurrent protection. When the protective device is a fuse, the tracker shall be marked in accordance with 65.5.

26.2.3 A Class 1 power-limited circuit, in accordance with the National Electrical Code, ANSI/NFPA 70, used to supply an external control circuit shall be supplied from a source having a rated output of no more than 30 volts and 1000 volt-amperes. When the source is other than a transformer, the circuit shall be protected by an overcurrent protection device rated no more than 167 percent of the volt-ampere rating divided by the rated voltage. The overcurrent device shall not be interchangeable with overcurrent devices of higher ratings.

26.2.4 An external control circuit derived from the secondary of a transformer other than that described in 26.2.3 and the Exception to 26.2.1 shall be provided with overcurrent protection in accordance with 26.2.5. For a transformer not having a rating, the rated primary or secondary current specified in 26.2.5 is to consist of the maximum current during normal operation of the tracker.

26.2.5 A transformer used to supply a control circuit shall be provided with overcurrent protection in the primary circuit rated as indicated in Table 26.1.

Exception No. 1: Where the rated primary current of the transformer is 9 amperes or more and 125 percent of this current does not correspond to a Standard rating of fuse or circuit breaker, the next higher Standard rating of protective device shall be used. Standard ratings of protective devices are specified in Section 240.6 of the National Electrical Code, ANSI/NFPA 70.

Exception No. 2: Where the rated secondary current of the transformer is less than 9 amperes, the overcurrent protection in the secondary circuit is able to be rated or set at no more than 167 percent of the rated secondary current.

Exception No. 3: Where a control circuit is derived from the secondary of a transformer that is provided with primary circuit overcurrent protection rated at no more than 250 percent of the rated primary current of the transformer, additional overcurrent protection is not required in the primary circuit where the secondary circuit is protected at no more than 125 percent of the rated secondary current of the transformer.

Table 26.1
Primary overcurrent protection for control circuit transformers

Rated primary current, amperes	Maximum rating of overcurrent device, percent of transformer primary current rating
Less than 2	300
2 or more and less than 9	167
9 or more	125

26.3 Output ac power circuit overcurrent protection

26.3.1 An ac output power circuit shall be provided with overcurrent protection for all ungrounded conductors as described in 26.3.2 and 26.3.3. The voltage rating of the overcurrent protection shall not be less than the rating of the circuit with which it is used. The voltage rating for a 3-phase circuit shall be based on the phase-to-phase voltage. The overcurrent protection device shall be a circuit breaker or a fuse rated for use as branch circuit protection.

Exception: Overcurrent protection is not required to be provided with a tracker having provision for permanent wiring connection of the output circuit and the instruction manual indicates that the overcurrent protection is to be provided by others. See 67.4(N).

26.3.2 For a tracker having provision for permanent wiring connection of the ac output power circuit, the rating of the overcurrent protection shall not exceed the ampacity of the conductors intended to be connected to the tracker as determined in accordance with 13.1.3.

26.3.3 Where a tracker includes one or more attachment-plug receptacles for connections to the ac output circuit, overcurrent protection shall be provided for each receptacle. A single overcurrent protection device, whose rating does not exceed the ampere rating of any receptacle connected to it, is usable when all receptacles are connected in parallel.

Exception: Two or more 15 ampere rated receptacles in a tracker with 12 AWG (3.3 mm^2) minimum internal wiring are able to be protected by a 20 ampere overcurrent protection device.

26.4 Battery circuits

26.4.1 A tracker intended for connection to a battery circuit shall be provided with overcurrent protection complying with the requirements described in 26.4.2 and 26.4.3.

Exception: Overcurrent protection is not required to be provided when the instruction manual contains the statement indicated in 67.4(N).

26.4.2 The overcurrent protective device shall be dc rated and shall be for branch-circuit protection in accordance with the National Electrical Code, NFPA 70.

26.4.3 The protective device shall be located adjacent to the battery connecting means ahead of any component which is able to malfunction under short-circuit conditions such as capacitors, solid-state devices, or similar components.

27 Printed-Wiring Boards

27.1 A printed-wiring board in an enclosure shall comply with the Standard for Printed-Wiring Boards, UL 796. For a tracker with miscellaneous or ventilation openings in the enclosure, the board shall be classed V-0 or V-1 in accordance with the Standard for Tests for Flammability of Plastic Materials for Parts in Devices and Appliances, UL 94. The use of a material Classed V-2 requires the use of an enclosure without openings. Drain holes are not prohibited regardless of the material Class.

Exception: This requirement does not apply to a printed wiring board connected only in low-voltage, limited-energy (LVLE) circuits and where deterioration or breakage of the bond between a conductor and the base material does not result in a risk of fire or electric shock.

28 Polymeric Materials Used as Mechanical Parts

28.1 Polymeric Materials, Section 7, of the Standard for Mounting Systems, Mounting Devices, Clamping/Retention Devices, and Ground Lugs for Use With Flat-Plate Photovoltaic Modules and Panels, UL 2703, shall be applied.

29 Conductors

29.1 Wiring that extends between non-moving and moving parts of a tracker that is subject to movement in use other than installation and servicing, shall be stranded and the arrangement shall preclude twisting or stressing of terminations as a result of the movement. The wiring shall be routed or protected to reduce the likelihood of damage to the insulation. The conductors shall be of a jacketed type – such as Type SJ, SJO, SJT or other conductors suitable for the purpose – and shall be provided with strain relief so that stress will not be transmitted to terminals or splices.

Exception: Wiring in Class 2 circuitry – where damage of the wire does not result in a risk of injury to persons, an uncontrolled motion, dropping payload or the like – need not be jacketed.

29.2 Wiring that is subject to motion, and any supplementary insulation provided on the wire, may be subjected to a flexing test to determine the acceptability for the application. See 52.1.

29.3 Impregnated or unimpregnated cotton- or asbestos-insulated wire shall not be employed.

29.4 Metal clamps and guides used for routing stationary internal wiring shall be smooth or provided with rounded edges.

29.5 Auxiliary mechanical protection that is not electrically conductive shall be provided:

a) Under a clamp at which pressure is exerted on a conductor having thermoplastic insulation less than 0.76 mm (0.030 inch) thick and no overall braid; and

b) On any wire or wires that are subject to motion, as defined in 29.1.

29.6 Tubing shall not be subjected to sharp bends, tension, compression, or repeated flexing, and shall not contact sharp edges, projections, or corners. Tubing may be used in dry or damp locations but is not acceptable in wet locations.

29.7 Rubber-insulated conductors shall not be exposed to oil, grease, oily vapor, or other substance having a deleterious effect on rubber, unless the insulation has been investigated and found to be acceptable for the application.

PROTECTION AGAINST RISKS OF INJURY TO PERSONS

30 General

30.1 The requirements in Sections 31 – 36 apply to the normal operation of tracker equipment which may involve a risk of injury to persons.

30.2 There are risks of injury to persons inherent in some tracker equipment that, if completely eliminated, would defeat the utility of the equipment. The requirements in this Section are intended to reduce such risks, while retaining the intended function of the equipment.

31 Moving Parts

31.1 The rotor of a motor, a pulley, a belt, gears, a chain, a fan, or other moving part shall be enclosed or guarded so as to reduce the risk of injury to persons.

31.2 The effects of the following factors shall be determined for compliance of an exposed moving part:

a) The degree of exposure,

b) The sharpness of the moving part,

c) The risk of unintentional contact therewith,

d) The speed of the moving part, and

e) The risk of fingers, arms, feet, or clothing becoming endangered by the moving parts.

These factors shall be evaluated with respect to both normal and abnormal operation.

31.3 A belt or a chain 6 ft (1.83 m) or more above the base need not be guarded over its entire length, but is to be guarded where it enters a pulley or engages a sprocket. A moving nut or shaft end that is not sufficiently sharp to present a risk of a cut need not be guarded.

31.4 An opening in a guard or enclosure around a moving part capable of causing injury – a gear, a pulley, a fan, a chain, or the like:

a) Shall be provided with a baffle to prevent contact with the moving part – see 31.5, or

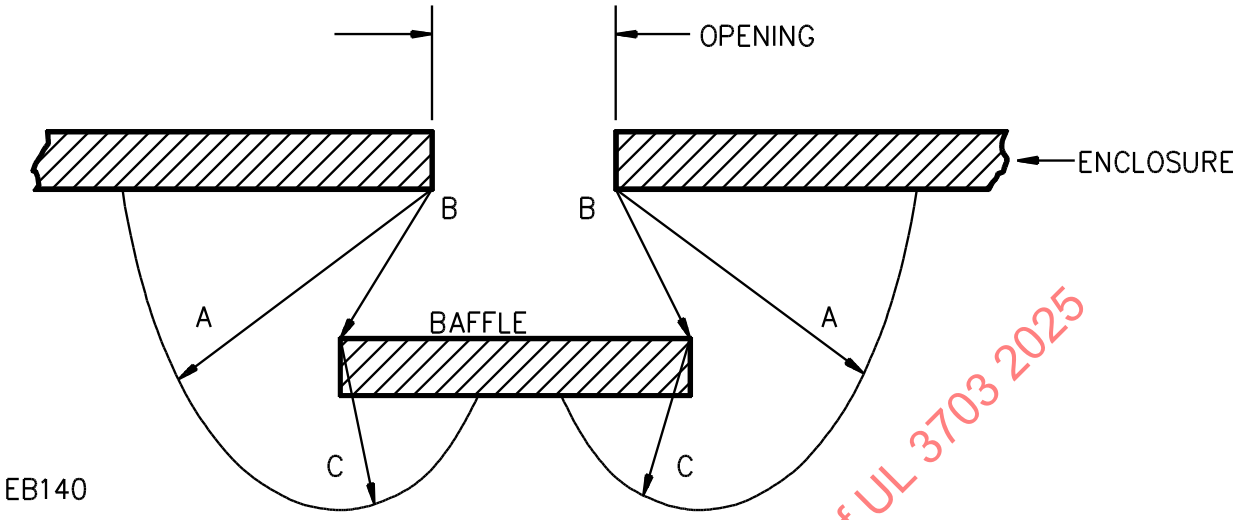
b) Shall not permit passage of a 1-in (25.4-mm) diameter probe having a hemispherical tip applied with a force of 3 lbf (13.34 N) and shall be spaced from the moving part as indicated in 31.5.

Exception: A fan blade is considered to be acceptably guarded or enclosed if it cannot be contacted by the probe illustrated in Figure 8.1.

31.5 A baffle as mentioned in 31.4(a), is considered to prevent contact with a moving part if the distance from the opening in the guard or enclosure to the moving part, measured around the baffle as illustrated in Figure 31.1, is not less than 8D minus 1/2 in (12.7 mm), where D is the minor dimension of the opening in inches but not less than 1/4 in (6.4 mm). No distance is specified between a moving part and an opening having a minor dimension less than 1/4 in.

Figure 31.1

Measurement around a baffle



A – Minimum distance from opening to moving part as specified in 31.5.

B – Distance from opening to edge of baffle.

C – A minus B.

32 Interruption of Power

32.1 Interruption of power shall not cause the relocation of any parts that would result in a hazard.

33 Clearance

33.1 Where the conditions of maintenance and supervision assure that only qualified persons will service the installation, the dimensions of the working space in the direction of access to live parts operating at not over 150 volts – or areas of high temperature, high pressure, or moving parts which could result in the risk of injury to persons – that are likely to require examination, adjustment, servicing, or maintenance while energized shall be a minimum of 915 mm (3.0 ft). Where controls are enclosed in cabinets, the door(s) shall open at least 90 degrees or be removable.

34 Moving Parts – Other Than the Tracker Platform

34.1 A hinged or pivoted panel or cover shall be positioned or arranged such that it is not subject to falling or swinging due to gravity or normal vibration that can cause injury to persons by the panel or cover, by other moving parts capable of causing injury to persons, or by uninsulated live parts.

34.2 The rotor of a motor, a pulley, a belt, gears, a chain, a fan, or other moving part that could cause injury to persons shall be enclosed or guarded to reduce the risk of unintentional contact with the moving part.

34.3 A moving part within an integral enclosure that may involve a risk of injury to persons shall comply with the requirements specified in Table 8.1, and shall be considered with respect to the:

a) Degree of exposure;

b) Sharpness of the moving part;

c) Likelihood of unintentional contact with it;

d) Speed of the moving part; and

e) Likelihood that fingers, arms, or clothing would be endangered by the moving part.

35 Moving Parts – Tracker Platform

35.1 When drive power is available to the platform, an indicator shall be provided to let others know that the tracker is operating and that platform motion is possible.

35.2 The tracker shall be provided with a reliable means to prevent hazards associated with uncontrolled movement, and the like, caused by:

a) Activation of the emergency stop;

b) Loss of drive power (hydraulic, electrical, pneumatic, and the like). Unless it can be demonstrated that a risk of fire, electric shock and injury to persons is unlikely, the control system shall also be provided with a means not to restart (automatically) the tracker when power is restored; or

c) Failure to complete an intended motion.

36 Emergency Stop

36.1 An emergency stop button shall be provided on the control panel and shall be readily visible. Proper space shall be provided around the control panel so that the operator can easily activate the emergency stop button.

36.2 The emergency stop button shall be red in color with a yellow background; palm or mushroom head type; unguarded; and of the latched type or equivalent so that it is not possible to restart the tracker until the emergency stop button is manually reset. Restarting of the tracker shall only be possible by operating the start control after the emergency stop switch has been reset.

36.3 If there is more than one normal working or control location, each location shall be provided with an emergency stop button.

36.4 The tracker shall have an emergency stop circuit using hardware-based components. The emergency stop shall override all other controls, remove drive power from the tracker actuators, and cause all moving parts to stop.

PERFORMANCE

37 General

37.1 Unless otherwise specified, the tracker is to be energized from a supply that simulates the current-voltage characteristics and time response of the input source. The tests are to be performed at the maximum and minimum rated input voltages.

37.2 Overcurrent protection is to be installed in accordance with the manufacturer's instructions.

37.3 The equipment under test provided with, or intended for use with, specific defined input sources that cannot provide the input power range described in the test shall be tested within the limitations of the specified or supplied input source. Under these circumstances, the test may be performed with the actual

source or a simulated source. Test results shall only be applicable to the combination of the equipment under test and the specified source, and this limitation is to be noted.

38 Maximum-Voltage Measurements

38.1 The maximum voltage determined in accordance with 38.2 and 38.3 is to be used as a basis for the:

a) Calculation of the dielectric voltage-withstand test potentials specified in 40.1, and

b) Determination of the minimum spacings specified in Spacings, Section 20, or Alternate Spacings – Clearances and Creepage Distances, Section 21.

38.2 A connector or comparable part that is expected to be disconnected during intended operation is to be both connected and disconnected during the test to obtain maximum voltage.

38.3 When a complex voltage is present, the peak value of the voltage is to be measured and this value is to be used for calculation of the dielectric voltage-withstand potential and determination of the minimum spacings. For a sinusoidal or a direct current voltage, the rms or average values respectively is to be measured.

39 Temperature Test

39.1 A tracker shall not attain a temperature at any point so as to result in a risk of fire, to damage any material used, to result in the operation of a protective device, or to exceed the maximum temperatures specified in 39.2 and Table 39.1 and Table 39.2:

a) When the tracker is delivering maximum rated output power in an ambient temperature as specified in 39.3, and

b) For a tracker marked for operation at a higher ambient at reduced output power, the test is to also be performed at the specified higher ambient and the associated reduced output power.

Table 39.1
Maximum temperature

Materials and Components			Degrees °C	Degrees °F
1.	Capacitors:			
	a.	Electrolytic types	65[b]	149[b]
	b.	Other than electrolytic	90[b]	194[b]
2.	Field wiring terminals		75[c]	167[c]
3.	Vulcanized fiber employed as electric insulation		90	194
4.	Relays, solenoids, and similar components			
	a.	Class 105 (Class A) coil insulation systems:		
		Thermocouple method	90[a]	194[a]
		Resistance method	110	230
	b.	Class 130 (Class B) coil insulation systems:		
		Thermocouple method	110[a]	230[a]
		Resistance method	120	248

Table 39.1 Continued on Next Page

Table 39.1 Continued

Materials and Components	Degrees °C	Degrees °F
5. Transformer insulation systems:		
a. Class 105 (Class A):		
Thermocouple method	90[a]	194[a]
Resistance method	95	203
b. Class 130 (Class B):		
Thermocouple method	110[a]	230[a]
Resistance method	120	248
c. Class 155 (Class F):		
Thermocouple method	135[a]	275[a]
Resistance method	140	284
d. Class 180 (Class H):		
Thermocouple method	150[a]	302[a]
Resistance method	160	320
e. Class 200 (Class N):		
Thermocouple method	165[a]	329[a]
Resistance method	175	347
f. Class 220 (Class R):		
Thermocouple method	180[a]	356[a]
Resistance method	190	374
6. Phenolic composition employed as electrical insulation or as a part the deterioration of which results in a risk of fire or electric shock	150[d]	302[d]
7. Wood and other combustible material	90	194
8. Rubber- or thermoplastic-insulated wire and cord	60[d,e]	140[d,e]
9. Other types of insulated wire	f	f
10. A surface upon which a stationary tracker is mounted and surfaces that are adjacent to the tracker when so mounted	90	194
11. Any point on or within a terminal box or wiring compartment of a fixed tracker which field-installed conductors are able to contact	60[c]	140[c]
12. Thermoplastic sealing compound	g	g
13. Selenium rectifier	75[h,d]	167[h,d]
14. Power semiconductor	i	i
15. Printed-wiring board	j	j

[a] At a point on the surface of a coil where the temperature is affected by an external source of heat, the temperature measured by a thermocouple is able to be 5°C (9°F) higher than that specified when the temperature of the coil as measured by the resistance method is not more than that specified.

[b] A capacitor that operates at a temperature of more than 65°C (149°F) for electrolytic or more than 90°C (194°F) for other types that are rated for a higher temperature shall not exceed its marked temperature limit.

[c] The temperature observed on the terminals and at points within a terminal box or wiring component of a tracker is able to exceed the values specified and shall not attain a temperature higher than the temperature marking required 64.8 and 67.4 (J) and (K).

[d] The temperature limitation on phenolic composition and on rubber and thermoplastic insulation do not apply to a compound that has heat-resistant properties in accordance with the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B.

[e] For a short length of rubber- or thermoplastic-insulated cord inside the tracker, a temperature greater than 60° C (140°F) where each individual conductor has supplementary insulation rated for the measured temperature and has dielectric properties in

Table 39.1 Continued on Next Page

Table 39.1 Continued

Materials and Components	Degrees °C	°F
accordance with the Standard for Polymeric Materials – Short Term Property Evaluations, UL 746A, and the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B.		
[f] Other than specified in (e), the maximum temperature shall not to exceed the temperature rating of the wire.		
[g] The sealing compound temperature limit is 15°C (27°F) less than the softening point of the compound as determined in accordance with the test method for Vicat Softening Temperature of Plastics, ASTM D1525-91.		
[h] A maximum temperature of 85°C (185°F) applies where the stack assembly is insulated with phenolic composition or other insulating material rated for a temperature of 150°C (302°F) or more.		
[i] For a power-switching semiconductor and similar devices, the maximum temperature limit on the case shall not exceed the maximum case temperature specified by the semiconductor manufacturer.		
[j] For a printed-wiring board, the maximum temperature shall not exceed the temperature rating of the board.		

39.2 The temperature of a surface that is subject to contact shall not be more than specified in Table 39.2.

Exception: The temperature maximums specified for casual contact in Table 39.2 do not apply when:

a) The tracker is a fixed tracker that is typically not subject to contact by persons;

b) The tracker is marked as required by 65.7; and

c) The tracker is provided with instructions as specified in 67.4(H).

Table 39.2
Maximum surface temperatures

Location	Composition of surface[a]			
	Metal		Nonmetallic	
Handles or knobs that are grasped for lifting, carrying, or holding	50°C	(122°F)	60°C	(140°F)
Handles or knobs that are contacted that do not involve lifting, carrying, or holding; and other surfaces subject to contact and user maintenance	60°C	(140°F)	85°C	(185°F)
Surfaces subject to casual contact[b]	70°C	(158°F)	95°C	(203°F)
[a] A handle, knob, or similar component made of a material other than metal that is plated or clad with metal having a thickness of 0.127 mm (0.005 inch) or less is to be judged as a nonmetallic part.				
[b] See Exception to 39.2.				

39.3 The temperature maximums in Table 39.1 and Table 39.2 are based on an ambient temperature of 25°C (77°F). Tests are to be performed in the ambient temperature specified in Table 39.3 and corrected in accordance with Table 39.3.

Table 39.3
Temperature measurement correction

Ambient temperature rating of tracker	Test ambient temperature	Correction of observed temperature
Above 40°C (104°F)	Rated ambient [a]	b

[a] Tolerances are:

Minus – not less than 5°C (9°F) below rated ambient.

Plus – not specified.

[b] When the test ambient temperature equals rated ambient, no correction is to be made, and the measured temperature shall not exceed the maximum temperature limit specified in Table 39.1. When the test ambient temperature is other than rated ambient, correction is to be made as described in b.

39.4 Temperatures used to determine compliance are to be stable. A temperature is stable when three successive readings taken at intervals of 10 percent of the previously elapsed duration of the test, and not less than 15 minutes apart, indicate no further increase in temperature.

39.5 During the temperature test, the tracker is to be connected as specified in 37.1 and mounted as in normal service to provide for normal convection cooling.

39.6 A tracker intended for mounting or support in more than one position or in a confined location is to be tested in a manner representing the most severe conditions. An adjacent mounting or supporting surface shall consist of 25.4-mm (1-inch) thick soft-pine boards.

39.7 Thermocouples are to consist of wires not larger than 24 AWG and not smaller than 30 AWG. When thermocouples are used in determining temperatures, it is common practice to employ thermocouples consisting of 30 AWG iron and constantan wire and a potentiometer type instrument. Such equipment is to be used whenever referee temperature measurements by thermocouples are required. The thermocouples and related instruments are to be accurate and calibrated in accordance with laboratory practice. The thermocouple wire is to conform with the requirements specified in the Tolerances on Initial Values of EMF versus Temperature tables in the Standard Specification and Temperature-Electromotive Force (emf) Tables for Standardized Thermocouples, ANSI/ASTM E230/E230M.

39.8 A thermocouple junction is to be held securely in intimate thermal contact with the surface of the material being tested. Thermocouples are to be secured to surfaces by welding, brazing, soldering, fuller's earth and sodium silicate (waterglass), adhesive rated for the surface and temperatures involved, or an equivalent method. Tape is not to be used as a means of securing the thermocouple junction. The thermocouple lead is to be secured so that strain on the lead does not affect the adhered thermocouple junction. Tape is usable as a means of strain relief for the thermocouple junction.

39.9 Coil and winding temperatures are to be measured by thermocouples located on exposed surfaces.

Exception: The change-of-resistance method is to be used for a coil that is inaccessible for attachment of thermocouples, such as a coil:

a) Immersed in sealing compound,

b) Wrapped with thermal insulation, or

c) Wrapped with more than two layers of material, such as cotton, paper, or rayon, more than 0.8 mm (1/32 inch) thick.

39.10 The temperature of a winding by the change-of-resistance method is to be determined using the following formula:

$$T = \frac{R}{r}(k + t) - k$$

in which:

T is the temperature of the winding in degrees C;

R is the resistance of the winding at the end of the test in ohms;

r is the resistance of the winding at the beginning of the test in ohms;

t is the ambient temperature in degrees C at the beginning of the test; and

k is 234.5 for copper, 225.0 for electrical conductor grade (EC) aluminum. Values of the constant for other conductor materials are to be determined.

39.11 Localized component heating is able to occur in products that reduce their output power with an increase in temperature. For example, heat generating components, such as Transformers, Inductors, Capacitors, Semiconductors and other similar components, which quickly increase in temperature, independent of the temperature sensing device, are able to attain thermal peaks prior to the first or subsequent power reductions. This is more prevalent in a lower ambient. In such instances, the measured peak temperature results is to be taken as the component operating temperature and shall comply with 39.1, or the results shall be investigated to the requirements for Temperature Excursions Beyond the Maximum Use Temperature in the Standard for Polymeric Material – Electrical Equipment Evaluations, UL 746C.

40 Dielectric Voltage-Withstand Test

40.1 Immediately following the temperature test or with the tracker at normal operating temperature, it shall withstand for 1 minute without breakdown the application of an ac rms test potential of:

a) One thousand volts plus twice the maximum voltage (see 38.1) between:

1) The input circuit and dead metal parts,

2) The output circuit and dead metal parts, and

3) The input and output circuits.

b) Five hundred volts between a secondary circuit operating at 50 volts or less and dead metal parts; 1000 volts plus twice the maximum secondary circuit voltage between a secondary circuit operating at more than 50 volts and dead metal parts.

c) One thousand volts plus twice the voltage between the terminals of a capacitor used across the ac or dc power circuit for electromagnetic interference elimination or power factor correction; and between the terminals of a capacitor connected between an ac or dc power circuit and the enclosure.

Exception: This test potential does not apply to capacitors that comply with either the Standard for Capacitors, UL 810, the Standard for Fixed Capacitors for Use in Electronic Equipment – Part 14: Sectional Specification: Fixed Capacitors for Electromagnetic Interference Suppression and Connection to the Supply Mains, UL 60384-14, or the Standard for Electromagnetic Interference Filters, UL 1283 or the Standard for Electrochemical Capacitors, UL 810A.

Exception: As an alternative to the ac rms test potential specified, use of a dc test potential of 1.414 times the ac rms value is not prohibited.

40.2 To determine whether a tracker complies with the requirements in 40.1, the it is to be tested using a 500 volt-ampere or larger capacity transformer, the output voltage of which is variable. The applied potential is to be increased from zero until the required test level is reached, and is to be held at that level for 1 minute. The increase in applied potential is to be at a substantially uniform rate as rapid as is consistent with correct indication of its value by a voltmeter.

Exception: When a voltmeter is connected across the output circuit to directly indicate the test potential, the transformer is not required to be rated 500 or more volt-amperes.

40.3 A low-voltage control circuit or a sensor circuit is not required to be connected during the test. Any circuit which is connected from input to output circuit shall remain connected during the test and provide proper isolation in accordance with 2.23.

41 Overload Test

41.1 The tracker shall operate without a risk of fire, electric shock or injury to persons when the platform is loaded to 125 percent of its rated weight load capacity and operated for at maximum speed for 3 hours, or until thermal equilibrium is reached or is prevented from operation by overload protection means at any time during the test period. See 41.2 for definition of thermal equilibrium.

41.2 Thermal equilibrium is considered attained when three successive readings taken at 15 minute intervals indicate that there is no temperature increase of the part(s).

42 Bonding Path Resistance Test

42.1 The resistance between grounding or bonding junctions shall not be more than 0.1 Ω when measured in accordance with 12.2.

42.2 Direct current equal to twice the fuse ampere rating specified for the PV module is to be passed between the grounding/bonding connection points (for example; the PV module frame to the rack mounting system frame, which may be through the bonding clamp device, if applicable, and also through the rack mounting system frame connection points, where applicable). The resistance is to be calculated using the voltage drop measured between the grounding terminal or lead and a point within 1/2 in (12.7 mm) of the point of current injection.

Exception: A direct current of 25 amperes may be substituted for twice the fuse ampere rating.

42.3 If more than one test is needed to evaluate all the paths of conduction between accessible metal parts, there is to be a cooling time of at least 15 min between tests.

43 Strain Relief Test

43.1 A wiring lead intended for field-wiring connection – see 13.3.1 and 13.3.3 – shall withstand without damage or displacement a direct pull of:

a) 89 N (20 lbf) for 1 minute applied to a lead extending from the enclosure (such as through a knockout), and

b) 44.5 N (10 lbf) for 1 minute applied to a lead within a wiring compartment.

43.2 An input or output cord shall withstand a 155.7 N (35 lbf) pull for one minute in the most severe direction without damage or displacement. All internal connections are to be severed during the test.

44 Reduced Spacings on Printed Wiring Boards Tests

44.1 General

44.1.1 With reference to Exception No. 6(a) to 20.1.1, printed wiring board traces of different potential having reduced spacings shall comply with the Dielectric Voltage-Withstand Test, Section 44.2.

44.2 Dielectric voltage-withstand test

44.2.1 A printed wiring board as specified in 44.1.1 shall withstand for 1 minute without breakdown the application of a potential between the traces having reduced spacings in accordance with 40.1, as appropriate.

44.2.2 Power-dissipating component parts, electronic devices, and capacitors connected between traces having reduced spacings are to be removed or disconnected so that the spacings and insulations, rather than these component parts, are subjected to the full test potential.

45 Bonding Conductor Test

45.1 The Bonding Conductor Test in Section 22 of the Standard for Mounting Systems, Mounting Devices, Clamping/Retention Devices, and Ground Lugs for Use With Flat-Plate Photovoltaic Modules and Panels, UL 2703, shall be applied.

46 Stability Test

46.1 A freestanding tracker shall be positioned in the least stable normal operating position and shall return to its normal at-rest position and not tip over when:

a) Canted through an angle of 10 degrees in the direction of least stability from an at-rest position on a horizontal surface,

b) Placed on a plane inclined at an angle of 10 degrees from the horizontal, or

c) Positioned in accordance with the manufacturer's instructions, and subjected to an externally-applied horizontal force of 20 percent of the weight of the tracker or 22.7 kg (50 pounds), whichever is less. See 46.3.

Exception: A fixed tracker is not required to be tested for stability.

46.2 When a part or surface of the tracker that is not normally in contact with the horizontal supporting surface touches the supporting surface before the tracker has been tipped to an angle of 10 degrees, the tipping is to be continued until the surface or plane of the surface of the tracker originally in contact with the horizontal supporting surface is at an angle of 10 degrees from the horizontal supporting surface.

46.3 The force specified in 46.1(c) is to be applied in a horizontal direction at that point on the tracker that is expected to overturn the tracker structure. The force is not to be applied more than 1.5 m (5 feet) above floor level. The legs or points of support are to be blocked to prevent the tracker from sliding during the application of the force.

47 Enclosure Mounting Static Load Test

47.1 When mounted as specified by the manufacturer, any enclosure that is intended to be fastened to a supporting base of the tracker shall be loaded as described in 47.2 with a force equal to three times the weight of the enclosure and not less than 89 N (20 lbf). As a result of the loading, there shall not be permanent deformation, breakage, dislocation, cracking, or other damage to the enclosure or the tracker or its mounting hardware.

Exception: An enclosure intended for floor mounting securement is not required to be subjected to this test.

47.2 The force is to be applied through the center of gravity of the enclosure, is to be increased gradually so as to reach the required value in 5 to 10 seconds, and is to be maintained at that value for 1 minute.

48 Compression Test

48.1 An enclosure that is thinner than that specified in Table 4.1, Table 4.2, or Table 4.3 shall be constructed so that during the test described in 48.2, the resulting deflection does not result in spacings less than specified in Spacings, Section 20, or Alternate Spacings – Clearances and Creepage Distances, Section 21.

48.2 A force of 445 N (100 pounds) is to be applied to the end, side, and walls of the enclosure. The enclosure is to rest on a smooth solid, horizontal surface. A vertical force is to be applied at any point through a rod having a 12.7 mm (1/2 inch) square flat steel face.

49 Rain and Sprinkler Tests

49.1 General

49.1.1 Before a rain or sprinkler test is performed, the tracker is to be fitted with the intended supply connection means as described in the tracker's installation instructions.

49.1.2 A tracker intended for multiple mounting orientations shall be tested in all the intended orientations.

49.1.3 The rain and sprinkler tests are to be performed in the operating sequence specified in Table 49.1.

Table 49.1
Operating sequence for rain and sprinkler tests

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

49.1.4 As a result of the rain and sprinkler tests, no water shall enter the tracker.

Exception: When water enters ground-mounted or surface-mounted trackers and the water does not wet any wiring or other electrical parts that are not inherently waterproof, and when the tracker is provided with drain holes in accordance with 4.9.14, the tracker is in compliance with the rain and sprinkler tests.

49.2 Rain test

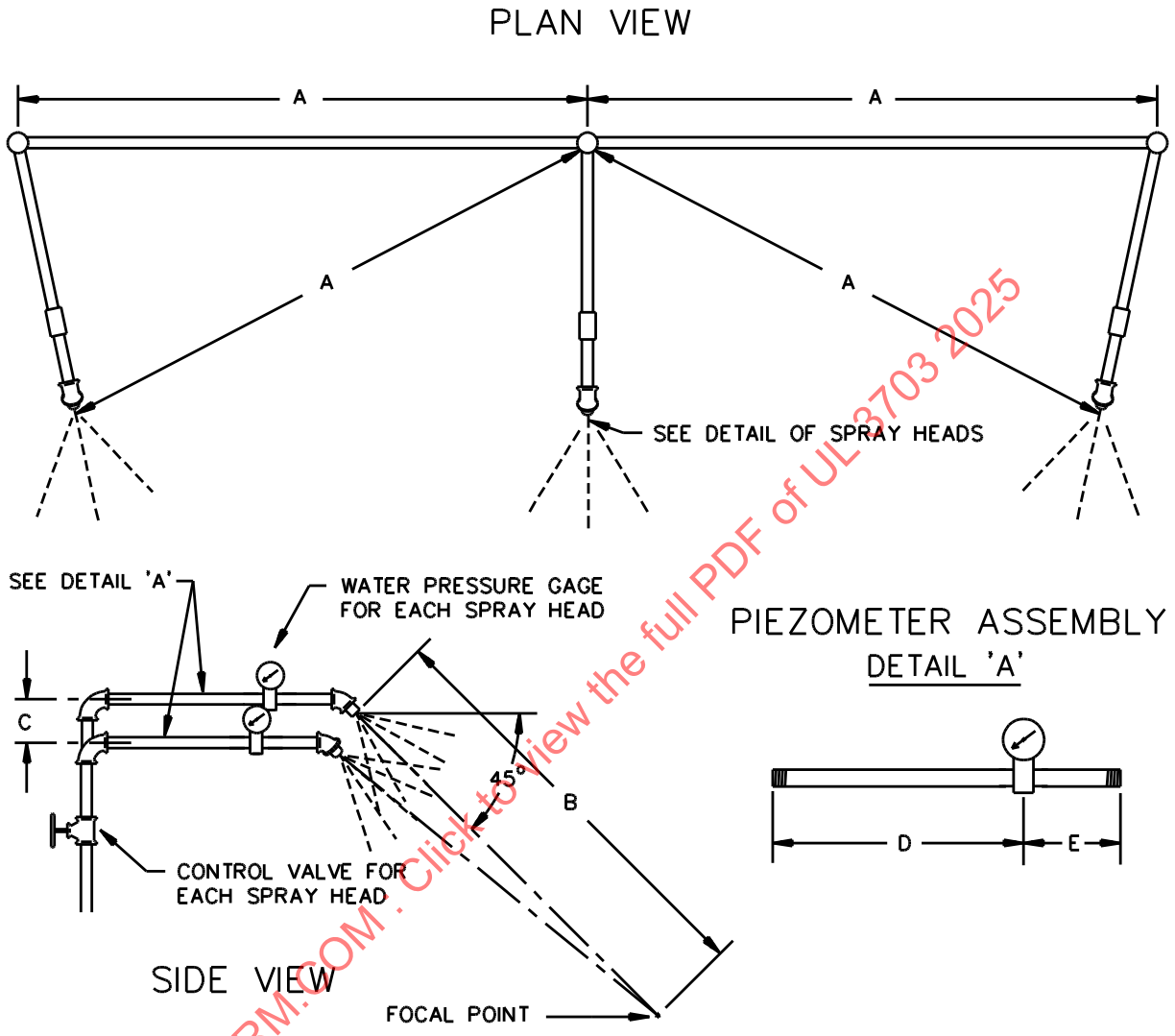
49.2.1 A tracker required to be subjected to a rain test is to be tested as described in 49.2.2 and 49.2.3.

49.2.2 The water spray test apparatus is to consist of three spray heads mounted in a water supply pipe rack as shown in Figure 49.1. Spray heads are to be constructed in accordance with the details shown in Figure 49.2. The tracker is to be set up as in a normal installation with conduit connections. Each electrical enclosure is to be positioned in the focal area of the spray heads so that the greatest possible quantity of water enters the enclosure. The water pressure is to be maintained at 34.5 kPa (5 psi) at each spray head.

49.2.3 Where gaskets are utilized, the tracker shall be tested after the temperature test or after operation for 1/2 hour, followed by removal and reinstallation of doors, access panels, frames, covers, or other removable parts serving to compress the gasket.

Figure 49.1

Spray head piping



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

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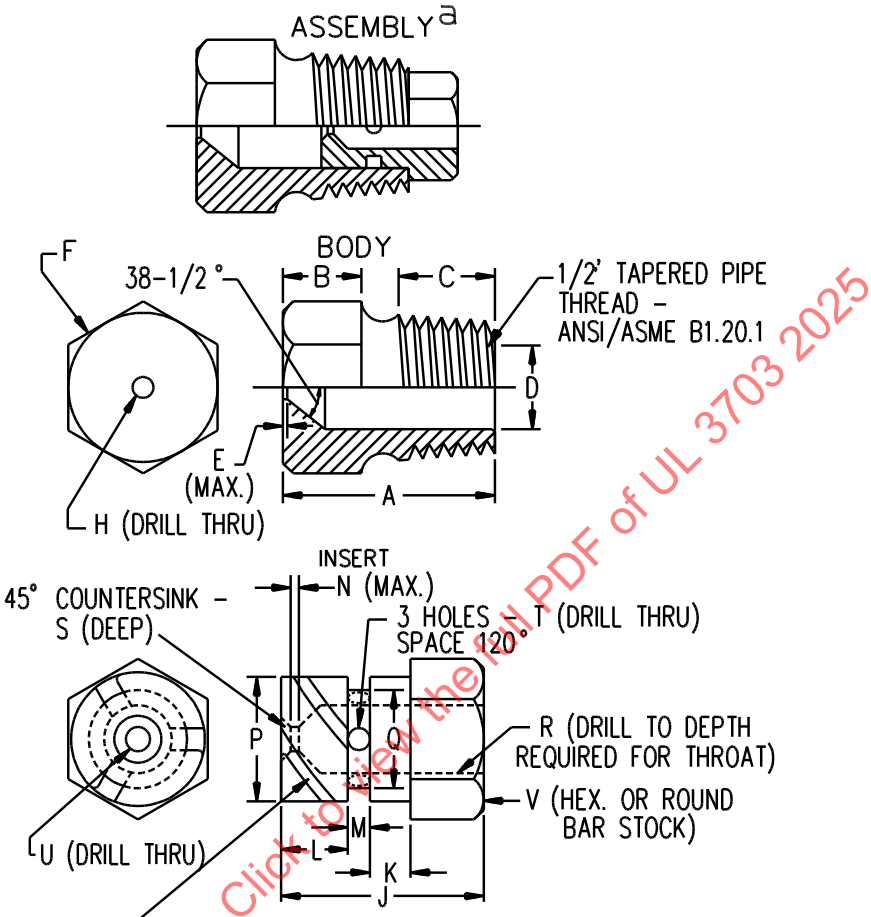
Figure 49.2

Spray head



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

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

[b] ANSI B94.11M Drill Size

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

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