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UL 3730

OUTLINE OF INVESTIGATION
FOR
PHOTOVOLTAIC JUNCTION BOXES

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Summary of Topics

This is the second issue of the Outline of Investigation for Photovoltaic Junction Boxes. It includes revisions to the gasket test requirements in accordance with recent UL 1703 revisions, and the addition of compliance criteria for the impact test.

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INTRODUCTION

1 Scope

1.1 These requirements cover photovoltaic junction boxes intended to be attached to photovoltaic modules and panels.

1.2 These requirements cover photovoltaic junction boxes intended for factory and field wiring and may include conduit openings, wiring leads, and/or photovoltaic connectors intended for interconnection of PV modules.

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

2 General

2.1 Components

2.1.1 Except as indicated in 2.1.2, a component of a product covered by this Outline of Investigation shall comply with the requirements for that component. See Appendix A for a list of standards covering components generally used in the products covered by this Outline of Investigation.

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

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- b) Is superseded by a requirement in this Outline of Investigation.

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

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

2.2 Units of measurement

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

2.3 References

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

3 Glossary

3.1 In the text of this outline, the term "unit" refers to any product covered by this outline. For the purpose of this outline, the definitions in 3.2 – 3.17 apply.

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

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

3.4 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.

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

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

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

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

3.9 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.

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

3.11 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.

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

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

3.14 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.

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

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

- a) 100 mW/cm² irradiance,
- b) AM 1.5 spectrum, and
- c) 25°C (77°F) cell temperature.

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

CONSTRUCTION

4 Enclosure and Materials

4.1 General

4.1.1 Photovoltaic junction boxes shall be considered an enclosure or be provided with an enclosure that houses all current-carrying parts. The enclosure shall protect the various parts of the unit against mechanical damage from forces external to the unit. The parts of the enclosure that are required to be in place to comply with the requirements to reduce the risk of fire, electric shock, injury to persons shall comply with the applicable enclosure requirements specified in this Outline.

4.1.2 The frame or chassis of a junction box shall not be relied upon to carry current during normal operation.

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

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

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

4.2 Cast metal enclosures

4.2.1 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 33.

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.		

4.3 Sheet metal enclosures

4.3.1 The thickness of a sheet-metal enclosure shall not be less than that specified in Tables 4.2 and 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 33.

4.3.2 With reference to Tables 4.2 and 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.

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	Uncoated	Coated
cm (inch)	cm (inch)	cm (inch)	cm (inch)		
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 4.3.2 and 4.3.3.

^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.

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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, mm (inch)	
Maximum width ^b , cm (inch)	Maximum length ^c , cm (inch)	Maximum width ^b , cm (inch)	Maximum length ^c , cm (inch)		
7.6 (3.0) 8.9 (3.5)	Not limited 10.2 (4.0)	17.8 (7.0) 21.6 (8.5)	Not limited 24.1 (9.5)	0.58 ^d	(0.023)
10.2 (4.0) 12.7 (5.0)	Not limited 15.2 (6.0)	25.4 (10.0) 26.7 (10.5)	Not limited 34.3 (13.5)	0.74	(0.029)
15.2 (6.0) 16.5 (6.5)	Not limited 20.3 (8.0)	35.6 (14.0) 38.1 (15.0)	Not limited 45.7 (18.0)	0.91	(0.036)
20.3 (8.0) 24.1 (9.5)	Not limited 29.2 (11.5)	48.3 (19.0) 53.3 (21.0)	Not limited 63.5 (25.0)	1.14	(0.045)
30.5 (12.0) 35.6 (14.0)	Not limited 40.6 (16.0)	71.1 (28.0) 76.2 (30.0)	Not limited 94.0 (37.0)	1.47	(0.058)
45.7 (18.0) 50.8 (20.0)	Not limited 63.5 (25.0)	106.7 (42.0) 114.3 (45.0)	Not limited 139.7 (55.0)	1.91	(0.075)
63.5 (25.0) 73.7 (29.0)	Not limited 91.4 (36.0)	152.4 (60.0) 162.6 (64.0)	Not limited 198.1 (78.0)	2.41	(0.095)
94.0 (37.0) 106.7 (42.0)	Not limited 134.6 (53.0)	221.0 (87.0) 236.2 (93.0)	Not limited 289.6 (114.0)	3.10	(0.122)
132.1 (52.0) 152.4 (60.0)	Not limited 188.0 (74.0)	312.4 (123.0) 330.2 (130.0)	Not limited 406.4 (160.0)	3.89	(0.152)
^a See 4.3.2 and 4.3.3. ^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.					

4.3.3 With reference to 4.3.2 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.

4.4 Nonmetallic enclosures and polymeric materials

4.4.1 A polymeric enclosure or polymeric part of an enclosure shall comply with Sections 7 and 34 in the Standard for Flat-Plate Photovoltaic Modules and Panes, UL 1703, except as noted by the following.

4.4.2 With reference to paragraph 7.2 (c) of the Standard for Flat-Plate Photovoltaic Modules and Panes, UL 1703, a polymeric material serving as the support or insulation of a live part as defined in Table 6.1 of the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, shall have a Comparative Tracking Index performance level category (PLC) as determined in accordance with the Standard for Polymeric Materials - Short Term Property Evaluations, UL 746A, and as defined in Table 4.4, when the system voltage rating is 600 V or less.

Exception No. 1: The CTI rating is not required for a polymeric material serving as the support or insulation of a live part as defined in UL 746C, Table 6.1, when both the material and live part are completely encapsulated by the potting material such that there is no surface upon which tracking may occur, and the potting material has been evaluated according to UL 746C, Table 6.1, for Electric Strength, Resistance to Electrical Ignition Sources (HAI and HWI), and Thermal Endurance.

Exception No. 2: The CTI rating is not required for a polymeric material serving as the support or insulation of a live part as defined in UL 746C, Table 6.1, when both the material and live part are completely coated by a conformal coating that has been evaluated to the requirements of UL 746C, Section 43, at the rated thickness such that there is no surface upon which tracking may occur.

Exception No. 3: Silicon based RTV when applied in accordance with Exception No. 2 is considered a suitable conformal coating without further evaluation.

Table 4.4
Determination of comparative tracking index performance level category (PLC)

Voltage	Creepage distance	IPT 1 hr rating required	CTI PLC of 2 or better required
0 – 30	Any	No	No
> 30 – 600	< 12.7 mm	No	Yes
> 30 – 601	≥ 12.7 mm	No	No
> 600 – 1000	< 16.0 mm	Yes	No
> 600 – 1000	≥ 16.0 mm	No	No
Note - Voltage is determined as follows: Between live parts: the maximum potential difference during normal use Between live parts and dead metal parts that may be grounded in service: maximum system voltage Between live parts and any surface exposed to contact: maximum system voltage			

4.4.3 With reference to paragraph 7.2 (d) of the Standard for Flat-Plate Photovoltaic Modules and Panes, UL 1703, a polymeric material serving as the support or insulation of a live part as defined in Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C, Table 6.1, shall have an Inclined Plane Tracking (ASTM D2303) rating of 1 hour using the time to track method at the higher of system voltage or 1000 V when the system voltage is in the range of 601 – 1000 V as specified in Table 4.4.

Exception No. 1: The 1 hr rating is not required for a polymeric material serving as the support or insulation of a live part as defined in UL 746C, Table 6.1, when both the material and live part are completely encapsulated by a potting material such there is no surface upon which tracking may occur, and the potting material has been evaluated according to UL 746C, Table 6.1, for Electric Strength, Resistance to Electrical Ignition Sources (HAI and HWI), and Thermal Endurance.

Exception No. 2: The 1 hr rating is not required for a polymeric material serving as the support or insulation of a live part as defined in UL 746C, Table 6.1, when both the material and live part are completely coated by a conformal coating that has been evaluated to the requirements of UL 746C, Section 43, at the rated thickness such that there is no surface upon which tracking may occur.

Exception No. 3: Silicon based RTV when applied in accordance with Exception No. 2 is considered a suitable potting material without further evaluation.

4.4.4 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.

4.4.5 Relative thermal indexes for polymeric materials are required according to 7.3 of the Standard for Flat-Plate Photovoltaic Modules and Panes, UL 1703, and shall be considered applicable for junction boxes as follows:

- a) RTI Electrical – applies to all polymeric materials in contact with live parts as defined in UL 746C, Table 6.1, and to all polymeric materials protecting, insulating, or encapsulating live parts.
- b) RTI Mechanical Strength – applies to all polymeric materials that form an enclosure and all polymeric materials that make up a part of a junction box that is relied upon to meet spacing requirements, Section 17, Strain Relief Test compliance, Section 26, Mold Stress-Relief Test compliance, Section 25, Crush Test compliance, Section 27, or polymeric materials that otherwise protect or insulate live parts.
- c) RTI Mechanical Impact – applies to all polymeric materials that are subject to impact from hail or other impact sources during normal operation when installed per the manufacturer's instructions.

4.4.6 Gasket materials shall comply with Section 34.1.

4.5 Openings for wiring system connections

4.5.1 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.

4.5.2 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.

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

4.5.4 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 17.

4.5.5 In measuring a spacing between an uninsulated live part and a bushing installed in a knockout as specified in 4.5.4, it is to be assumed that a bushing having the dimensions specified in Table 4.5 is in place, in conjunction with a single locknut installed on the outside of the enclosure.

Table 4.5
Knockout or hole sizes and dimensions of bushings

Trade size of conduit, Inch	Knockout or hole diameter mm (inch)		Bushing dimensions			
			Overall diameter		Height	
	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)

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

- a) 0.36 mm (0.014 inch) for steel or 0.48 mm (0.019 inch) for nonferrous metal for a hole having a 6.4-mm (1/4-inch) maximum dimension, and
- b) 0.69-mm (0.027-inch) steel or 0.81-mm (0.032-inch) nonferrous metal for a hole having a 34.9-mm (1-3/8-inch) maximum dimension.

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

5 Protection Against Corrosion

5.1 Junction boxes shall comply with the Corrosion Resistance requirements of Section 14 in the Standard for Flat-Plate Photovoltaic Modules and Panels, UL 1703.

6 Protection of Users - Accessibility of Uninsulated Live Parts

6.1 Junction boxes shall comply with the Accessibility requirements of Section 15 in the Standard for Flat-Plate Photovoltaic Modules and Panels, UL 1703.

7 Electric Shock - Voltage

7.1 A live part does not involve a risk of electric shock when the maximum voltage of the part to ground does not exceed 30 Vdc.

8 Wiring Terminals

8.1 A wiring terminal shall comply with the requirement in 8.3 for a wire of each metal for which it is marked.

8.2 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 8.4 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 mm²) 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.

8.3 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 8.4 is able to turn when the spacing complies with Spacings, Section 17, when the connector is oriented in the position resulting in the least spacing between adjacent terminals and also between terminals and dead metal parts.

8.4 With reference to Exception No. 1 to 8.2, 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 unit manufacturer or others and specified in the instruction manual.
- 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 unit, or
 - 3) Specified in the instruction manual.

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