# TEST REPORT

## UL 1741

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

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| **Report Number .....:** | LCSA04115089S |
| **Date of issue .....:** | 2025-04-25 |
| **Total number of pages.....:** | 131 |
| **Applicant's name .....:** | KTECH ESS CO.,LTD |
| **Address .....:** | Room 1201, Building 1, Taihu Bay Information Technology Industrial Park, No. 688 Zhenze Road, Taihu Street, Wuxi Economic Development Zone |
| **Test specification:** | |
| **Standard.....:** | UL 1741: 2021 (Third Edition) |
| **Test procedure .....:** | Type Tested |
| **Non-standard test method .....:** | N/A |
| **Test Report Form No. .....:** | TRF-4-S-117 A/0 |
| **Test Report Form(s) Originator ....:** | Shenzhen LCS Compliance Testing Laboratory Ltd |
| **Master TRF.....:** | Dated 2023-09 |
| **General disclaimer:** | |
| The test results presented in this report relate only to the object tested. | |

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| **Test item description :** | American standard split-phase hybrid inverter |
| **Trade Mark(s) :** | KTECH |
| **Manufacturer :** | Same as the applicant |
| **Model/Type reference :** | KE-10KLSUF, KE-8KLSUF, KE-12KLSUF, KE-5KC5LSUF, KE-5K6C5LSUF, KE-6KC5LSUF, KE-5KC5L1UF, KE-5K6C5L1UF, KE-6KC5L1UF, GV-5KC5L1UF,GV-5K6C5L1UF, GV-6KC5L1UF, GV-5KC5LSUF,GV-5K6C5LSUF, GV-6KC5LSUF |
| **Ratings :** | **Input rating:**<br>See model list for details. |

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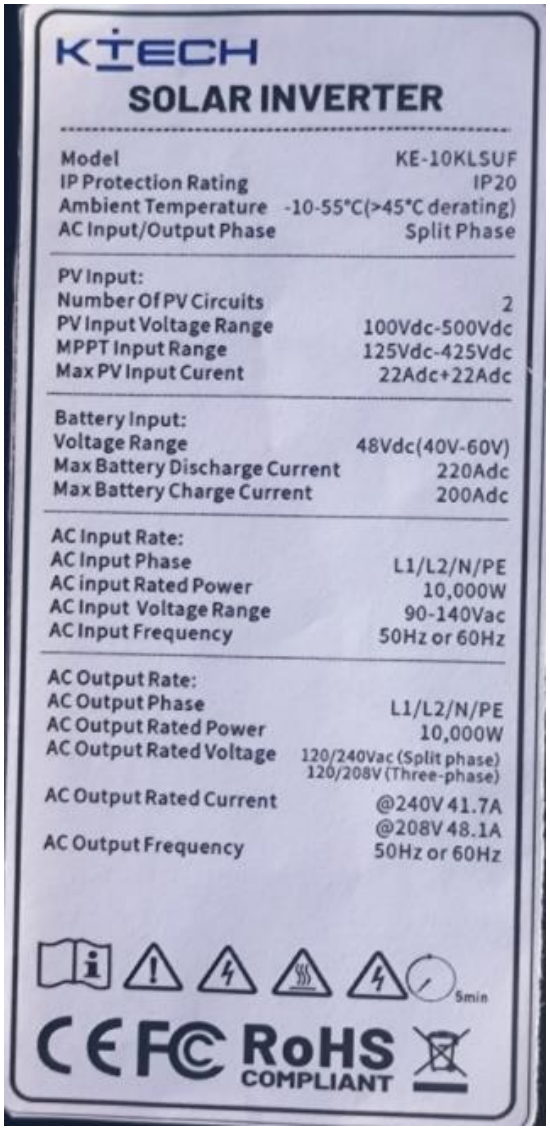
| **Responsible Testing Laboratory (as applicable), testing procedure and testing location(s):** | | |
| Testing Laboratory: | Shenzhen LCS Compliance Testing Laboratory Ltd. | |
| **Testing location/ address** | Room 101, 201, Building A and Room 301, Building C, Juji Industrial Park, Yabianxueziwei, Shajing Street, Bao'an District, Shenzhen, Guangdong, China | |
| **Prepared by.....:** | Terry Zhu<br>Project Handler | |
| **Checked by.....:** | Benson Kuai<br>Reviewer | LCS TESTING LABORATORY APPROVED |
| **Approved by.....:** | Hart Qiu<br>Technical Director | |

**Copy of marking plate:**

The artwork below may be only a draft.




Note:

1. The above markings are the minimum requirements required by the safety standard. For the final production samples, the additional markings which do not give rise to misunderstanding may be added.
2. Since similar label used, only label for models above listed to represent other similar ones.

**Test item particulars:**

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| Equipment mobility..... : | ☐ movable ☐ hand-held ☐ transportable<br>☒ stationary ☐ for building-in ☐ direct plug-in |
| Supply connection ..... : | ☐ pluggable equipment ☐ type A ☐ type B<br>☒ permanent connection<br>☐ detachable power supply cord<br>☐ non-detachable power supply cord<br>☐ not directly connected to the mains |
| Operating condition ..... : | ☒ continuous<br>☐ rated operating / resting time: ____ |
| Installation / Over Voltage Category (OVC) . : | ☐ OVC I ☒ OVC II ☐ OVC III ☐ OVC IV<br>☐ other: |
| Mains supply tolerance (%) or absolute mains supply values ..... : | 10% |
| Protection Class of Equipment..... : | ☒ Class I ☐ Class II ☐ Class III<br>☐ Not classified |
| Classification of installation and use..... : | |
| Mfr.'s Declared Temperature, Ambient ..... : | 0 to 55°C |
| Ingress protection..... : | Enclosure Type __ / IPx0__ |
| Overall size of the equipment (L x W x H) .. : | |
| Mass of the equipment (kg)..... : | __23.4_ kg |

**Possible test case verdicts:**

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| **- test case does not apply to the test object** | **:** | N/A |
| **- test object does meet the requirement** | **:** | P (Pass) |
| **- test object does not meet the requirement** | **:** | F (Fail) |

**Testing:**

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| **Date of receipt of test item** | **:** | 2025-04-11 |
| **Date (s) of performance of tests** | **:** | From 2025-04-11 to 2025-04-25 |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |

**INTRODUCTION**

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| **1** | **Scope** | — |

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| **2** | **Glossary** | — |

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| **3** | **Components** | | P |
| 3.1 | Except as indicated in 3.2, a component of a product covered by this standard shall comply with the requirements for that component. See Annex A for a list of standards covering components commonly used in the products covered by this Standard. | | P |
| 3.2 | A component is not required to comply with a specific requirement that: | | N/A |
| | a) Involves a feature or characteristic not required in the application of the component in the product covered by this standard, or | | N/A |
| | b) Is superseded by a requirement in this standard. | | N/A |
| 3.3 | A component shall be used in accordance with its rating established for the intended conditions of use. | | P |
| 3.4 | Specific components are incomplete in construction features or restricted in performance capabilities. Such components are intended for use only under limited conditions, such as certain temperatures not exceeding specified limits, and shall be used only under those specific conditions | | N/A |

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| **6** | **General** | | P |
| 6.1 | A unit intended to operate at rated voltages of 50 volts or less shall operate as intended in both grounded and ungrounded circuits. | | P |
| 6.2 | Converters shall be subjected to all of the requirements for inverters. | | P |

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| **7** | **Frame and Enclosure** | | P |
| 7.1 | **General** | | P |
| 7.1.1 | A unit shall be provided with an enclosure that houses all current-carrying parts. The enclosure shall protect the various parts of the unit against mechanical damage from forces external to the unit. The parts of the enclosure that are required | | P |

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| | to be in place to comply with the requirements to reduce the risk of fire, electric shock, injury to persons shall comply with the applicable enclosure requirements specified in this Standard. | | |
| 7.1.2 | The frame or chassis of a unit shall not be relied upon to carry current during normal operation. | | N/A |
| | *Exception: As provided in the Exception to 22.12* | | -- |
| 7.1.3 | A part, such as a dial or nameplate that is a part of the enclosure shall comply with the enclosure requirements. | | P |
| 7.1.4 | An enclosure other than a Type 1 (indoor use only) shall comply with Environmental Rated Enclosures, Section 7.9, or the requirements for the respective Type in the Standard for Enclosures for Electrical Equipment, UL 50. | | N/A |
| 7.1.5 | Sheet-metal screws threading directly into metal shall not be used to attach a cover, door, or other part that is to be removed to install field wiring or for operation of the equipment. Sheet-metal screws that are threaded into sheet-metal nuts that are permanently mounted and protected against corrosion. Machine screws and self-tapping machine screws are able to thread directly into sheet-metal walls. | | N/A |
| 7.1.6 | Sheet-metal screws mounting internal components that are not removed for installation or operation are able to thread directly into metal. | | N/A |
| 7.2 | **Access covers** | | N/A |
| 7.2.1 | For a unit used as a load center, a cover that gives access to a fuse or other overload-protective device, the functioning of which requires renewal shall be hinged. A hinged cover is also required for a unit when it is required to open the cover in connection with normal operation of the unit. The cover shall not depend solely upon screws or other similar means requiring the use of a tool to hold it closed; however, it shall be provided with a spring latch or catch, or a hand operable captive fastener. Live parts shall not be accessible when the cover is open. | | N/A |
| | *Exception No. 1: A cover is not required to be provided with a hinge when the only overload-protective devices enclosed are:*<br>*a) Supplementary types in control circuits and the protective device and the circuit loads are within the same enclosure,*<br>*b) Supplementary types rated 2 amperes or less for loads not exceeding 100 volt-amperes,* | | -- |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| | *c) Extractor fuses having an integral enclosure, or*<br>*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 64.6.* | | -- |
| 7.2.2 | With reference to 7.2.1, a door or cover giving access to a fuse shall comply with the requirements for doors and covers, in the Standard for Industrial Control Equipment, UL 508. | | N/A |
| 7.3 | **Cast metal enclosures** | | N/A |
| 7.3.1 | The thickness of cast metal for an enclosure shall not be less than indicated in Table 7.1. | | N/A |
| | *Exception: Cast metal of lesser thickness is usable where the enclosure complies with Compression Test, Section 63.* | | -- |
| 7.4 | **Sheet metal enclosures** | | N/A |
| 7.4.1 | The thickness of a sheet-metal enclosure shall not be less than that specified in Tables 7.2 and 7.3; however, uncoated steel shall not be less than 0.81 mm (0.032 inch) thick, zinc-coated steel shall not be less than 0.86 mm (0.034 inch) thick, and nonferrous metal shall not be less than 1.14 mm (0.045 inch) thick at points at which a wiring system is to be connected. | | N/A |
| | *Exception: Sheet metal of lesser thickness is usable where the enclosure complies with Compression Test, Section 63.* | | -- |
| 7.4.2 | With reference to Tables 7.2 and 7.3, a supporting frame is a structure consisting of angles, channels, or folded rigid sections of sheet metal that is rigidly attached to and has similar outside dimensions as the enclosure surface and that has the torsional rigidity to resist the bending moments that result when the enclosure surface is deflected. A construction that has equivalent reinforcing is one that is as rigid as one built with a frame of angles or channels. | | N/A |
| 7.4.3 | With reference to 7.4.2 and Tables 7.2 and 7.3, a construction does not have a supporting frame when it is: | | N/A |
| | a) An enclosure formed or fabricated from sheet metal, | | N/A |
| | b) A single sheet with single formed flanges or formed edges, | | N/A |
| | c) A single sheet that is corrugated or ribbed, or | | N/A |

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| | d) An enclosure surface loosely attached to a frame, for example, by spring clips. | | N/A |
| 7.5 | **Non-metallic enclosures** | | P |
| 7.5.1 | A polymeric enclosure or polymeric part of an enclosure shall comply with the requirements in the Standard for Polymeric Materials – Use in Electrical Equipment Evaluations, UL 746C. See 7.5.3. | | P |
| | *Exception: A polymeric enclosure which complies with the Standard for Enclosures for Electrical Equipment, UL 50, is not required to be investigated for compliance with UL 746C.* | | -- |
| 7.5.2 | Where an electrical instrument, such as a meter, forms part of the enclosure, the face or the back of the instrument housing, or both together, shall comply with the requirements for an enclosure. | | N/A |
| | *Exception: A meter complying with the Standard for Electrical Analog Instruments – Panelboard Type, UL 1437, complies with this requirement.* | | -- |
| 7.5.3 | The requirement in 7.5.1 does not apply to a non-metallic part that forms part of the enclosure under any one of the following conditions: | | P |
| | 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 | | P |
| | 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. | | P |
| | 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 | | N/A |
| | 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. | | N/A |
| | *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* | | -- |

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| | *the component. See Components, Section 3.* | | |
| 7.5.4 | A non-metallic 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. | | N/A |
| 7.6 | **Openings covered by glass** | | N/A |
| 7.6.1 | Glass covering an opening shall comply with 7.6.2, shall be secured in place so that it is not readily displaced in service, and shall provide mechanical protection for the enclosed parts. | | N/A |
| 7.6.2 | Glass for an opening: | | N/A |
| | a) Not more than 102 mm (4 inches) in any dimension shall not be less than 1.6 mm (1/16 inch) thick, | | N/A |
| | 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 | | N/A |
| | c) Glass used to cover an area greater than described in (b) shall not be less than 3.2 mm thick and:<br>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 (R1 994), or<br>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. | | N/A<br>N/A |
| 7.7 | **Openings for wiring system connections** | | N/A |
| 7.7.1 | Where threads for the connection of conduit are tapped all the way through a hole in an enclosure wall, or where an equivalent construction is employed, there shall not be less than three, or more than five threads in the metal; and the construction of the enclosure shall be such that a conduit bushing is attachable as intended. Where threads for the connection of conduit are not tapped all the way through a hole in an enclosure wall, conduit hub, or a similar component; there shall not be less than 3-1/2 threads in the metal, and there shall be a smooth, rounded inlet hole for the | | N/A |

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| | conductors equivalent to that provided by a standard conduit bushing and the hole shall have an internal diameter that corresponds with the applicable trade size of rigid conduit. | | |
| 7.7.2 | Clamps and fasteners for the attachment of conduit, electrical metallic tubing, armored cable, non-metallic flexible tubing, non-metallic-sheathed cable, service cable, or equivalent, that are supplied as a part of an enclosure shall comply with the Standard for Fittings for Conduit and Outlet Boxes, UL 514B. | | N/A |
| 7.7.3 | A knockout in a sheet metal enclosure shall be secured and shall be removable without undue deformation of the enclosure. | | N/A |
| 7.7.4 | A knockout shall be provided with a flat surrounding surface so a conduit bushing of the corresponding size seats as intended. A knockout intended to be used for installation purposes, shall be located so that installation of a bushing does not result in spacings between uninsulated live parts and the bushing of less than required in Spacings, Section 24. | | N/A |
| 7.7.5 | In measuring a spacing between an uninsulated live part and a bushing installed in a knockout as specified in 7.7.4, it is to be assumed that a bushing having the dimensions specified in Table 5.4 is in place, in conjunction with a single locknut installed on the outside of the enclosure. | | N/A |
| 7.7.6 | For an enclosure not provided from the factory with conduit openings or knockouts, spacings not less than the minimum required in this Standard shall be provided between uninsulated live parts and a conduit bushing installed at any location on the enclosure. Permanent marking on the enclosure, a template, or a full-scale drawing furnished with the unit is usable to limit such a location. | | N/A |
| 7.7.7 | A plate or plug for an unused conduit opening or other hole in the enclosure shall have a thickness not less than:<br>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<br>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. | | N/A |
| | A closure for a larger hole shall have a thickness | | N/A |

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| | equal to that required for the enclosure of the unit or a standard knockout seal shall be used. Such plates or plugs shall be securely mounted. | | |
| 7.7.8 | An opening in an environmental rated enclosure shall be closed with components having the applicable environmental ratings as specified in Table 5.5 | | N/A |
| 7.8 | **Openings for ventilation** | | P |
| 7.8.1 | General | | P |
| 7.8.1.1 | The enclosure of a unit shall be constructed to protect the unit against the emission of flame, molten metal, flaming or glowing particles, or flaming drops from the enclosure. | | P |
| 7.8.2 | Ventilation openings in enclosure bottoms | | N/A |
| 7.8.2.1 | The requirement in 7.8.1.1 necessitates a complete non-combustible bottom or a construction employing individual non-combustible barriers as specified in Figure 5.1, under components, groups of components, or assemblies. | | N/A |
| | *Exception No. 1: Ventilation openings provided in the bottom of an enclosure meet the intent of the requirement where noncombustible baffle plates are provided to obstruct or deflect materials from falling directly from the interior of the unit onto the supporting surface or other locations under the unit. An example of a baffle that meets the intent of this requirement is illustrated in Figure 5.2.* | | -- |
| | *Exception No. 2: Ventilation openings provided in the bottom of an enclosure meet the intent of the requirement where the openings are covered by a perforated metal plate as described in Table 5.6, or where a galvanized or stainless steel screen having a 14- by 14-mesh per 27.4 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 mm2 (1/16 square inch).* | | -- |
| | *Exception No. 4: Ventilation openings without limitation on their size and number that comply with 11.7 meet the intent of the requirement where the openings are only in the bottom panel in areas:*<br>*a) That contain only wires, cables, plugs, receptacles, and transformers, and*<br>*b) In areas that contain low-voltage, limited-energy (LVLE) circuits.* | | -- |
| | *Exception No. 5: Ventilation openings are provided in the bottom of an enclosure meet the intent of the requirement where the openings incorporate an expanded metal mesh as described in 7.8.5.* | | -- |

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| 7.8.3 | **Openings in enclosure tops** | | N/A |
| 7.8.3.1 | Openings in the top of an enclosure shall be located and sized to protect against the entry of foreign objects. Openings directly over uninsulated live parts: | | N/A |
| | a) Shall not exceed 4.7 mm (0.187 inch) in any dimension, | | N/A |
| | b) Be configured as illustrated in Figure 5.3, or | | N/A |
| | c) Be constructed to provide equivalent protection against the entry of foreign objects. | | N/A |
| 7.8.4 | **Openings in enclosure sides** | | P |
| 7.8.4.1 | A louver shall not be more than 305 mm (12 inches) long. | | P |
| 7.8.4.2 | The area of an opening covered by louvers, perforated sheet steel, or by expanded-metal mesh that is thinner than the enclosure shall not exceed 0.129 $m^2$ (200 square inches). | | P |
| 7.8.5 | **Expanded metal mesh and screens** | | N/A |
| 7.8.7.1 | The thickness of perforated sheet steel and sheet steel employed for expanded-metal mesh used to cover an opening in the enclosure shall comply with of Table 5.7. | | N/A |
| | *Exception: Thicknesses less than specified in Table 5.7, and not less than specified in Table 5.8 meet the intent of the requirement where:*<br>*a) The indentation of the material does not adversely affect performance or reduce spacings to live parts below the minimum values specified in Spacings, Section 26, or Alternate Spacings-Clearances and Creepage Distances, Section 27, and*<br>*b) The opening has an area of not more than 464.5 cm2 (72 in2) and no dimension greater than 304.8 mm (12 inches), or*<br>*c) The width of the opening is not greater than 88.9 mm (3-1/2 inches).* | | -- |
| 7.8.7.2 | 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. | | N/A |
| 7.8.6 | **Barriers used with ventilation openings** | | N/A |
| 7.8.6.1 | Unless a ventilation opening is located at least 305 mm (12 inches) from an arcing part, such as a switch, fuse, circuit breaker or a similar source, a barrier shall be placed between the ventilation opening and the source of arcing. | | N/A |
| 7.8.6.2 | The barrier shall be of such dimensions and so located that any straight line drawn from an | | N/A |

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| | arcing part past the edge of the barrier intersects a point in the ventilation opening plane that is at least 6.4 mm (0.25 inch) outside of the edge of the ventilation opening. | | |
| 7.8.6.3 | A sheet-metal barrier shall not be less than 1.35 mm (0.053 inch) thick when uncoated steel, 1.42 mm (0.056 inch) thick when zinc-coated, or 1.19 mm (0.075 inch) thick when aluminum. | | N/A |
| | *Exception: A metal barrier of thinner material meets the intent of the requirement when its strength and rigidity are not less than that of flat sheet steel having the same dimensions of the barrier and having the specified thickness.* | | -- |
| 7.9 | **Environmental rated enclosures** | | P |
| 7.9.1 | An enclosure shall comply with the construction requirements applicable to an enclosure of the Type number or numbers with which it is marked. | | P |
| 7.9.2 | An environmental type connection, such as a watertight connection at a conduit entrance, shall be a conduit hub or the equivalent, such as a knockout or fitting, located so that when conduit is connected and the enclosure is mounted in the intended manner, the enclosure complies with the tests specified in the Enclosure Types Table, in the Standard for Enclosures for Electrical Equipment, UL 50. | | P |
| 7.9.3 | Type 3, 3R, and 3S enclosures shall comply with the Rain and Sprinkler Tests, Section 64. | | N/A |
| 7.9.4 | A Type 2 enclosure shall have provision for drainage of water and shall have a threaded conduit hub or the equivalent for the connection of conduit in the top or sidewalls. | | P |
| | *Exception No. 1: A threaded conduit hub or the equivalent is not required where the conduit connection opening is wholly below the lowest terminal lug or other live part within the enclosure. See 66.33.* | | -- |
| | *Exception No. 2: A conduit hub or fitting is not required when information is provided in accordance with 66.31.* | | -- |
| 7.9.5 | A Type 3 enclosure shall have:<br>a) A threaded conduit hub or the equivalent for a watertight connection at conduit entrances – see 7.9.2,<br>b) A mounting means external to the equipment cavity, and<br>c) Provision for locking a door, when a door is provided. | | N/A |

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| | *Exception: A conduit hub or fitting is not required when information is provided in accordance with 66.31.* | | -- |
| 7.9.6 | A Type 3R enclosure shall have:<br>a) A threaded conduit hub or the equivalent for a watertight connection at conduit entrances – see 7.9.2,<br>b) Provision for drainage of water, and<br>c) Provision for locking a door, when a door is provided. | | N/A |
| | *Exception No. 1: A threaded conduit hub or the equivalent is not required where the conduit connection opening is wholly below the lowest terminal lug or other live part intended for use within the enclosure. See 66.33.* | | -- |
| | *Exception No. 2: A conduit hub or fitting is not required when information is provided in accordance with 66.31.* | | -- |
| 7.9.7 | A Type 3S enclosure shall have:<br>a) A threaded conduit hub or the equivalent for a watertight connection at conduit entrances – see 7.9.2,<br>b) A mounting means external to the equipment cavity,<br>c) Provision for locking a door, when a door is provided, and<br>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. | | N/A |
| | *Exception: A conduit hub or fitting is not required when information is provided in accordance with 66.31.* | | -- |
| 7.9.8 | A Type 4, 4X, 6, 6P, or 11 enclosures shall have a conduit hub or the equivalent mounted in place to provide a watertight connection at conduit entrances and shall have mounting means external to the equipment cavity – see 7.9.2. | | N/A |
| | *Exception No. 1: The watertight conduit connection is not required to be mounted in place when information is provided in accordance with 68.2.4.* | | -- |
| | *Exception No. 2: A hub or a fitting is not required to be provided or installed on a Type 4 or 4X enclosure when instructions are provided as specified in 68.2.6.* | | -- |
| 7.9.9 | A Type 12 enclosure shall have no conduit knockout or conduit opening and no hole through the enclosure other than a hole for a Type 12 mechanism, or the equivalent. A | | N/A |

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| | gasket, when provided, shall be oil resistant. | | |
| | *Exception: A Type 12 enclosure is able to employ a conduit opening when the enclosure is marked in accordance with 66.35.* | | N/A |
| 7.9.10 | A Type 12K enclosure is to be as specified in 7.9.9, unless it has knockouts located in the top or bottom walls, or both. | | N/A |
| 7.9.11 | A Type 13 enclosure shall have oil-resistant gaskets and, when intended for wall or machine mounting, shall have a mounting means external to the equipment cavity. There shall be no conduit knockout or unsealed opening providing access to the equipment cavity. All conduit openings shall have provisions for oil tight connections. | | N/A |
| 7.9.12 | A gasket of an elastomeric or thermoplastic material or a composition gasket utilizing an elastomeric material employed to comply with the requirements for a Type 2, 3, 3R, 3S, 4, 4X, 6, 6P, 11, 12, 12K, or 13 enclosure shall comply with the Gasket Tests, Section 43, in the Standard for Enclosures for Electrical Equipment, UL 50. | | N/A |
| 7.9.13 | When a component, such as a pilot light, a disconnect, a pushbutton, or similar component, intended for use with a Type designated environmental enclosure is used with a specific Type enclosure, it shall meet the following: | | N/A |
| | a) The component has been evaluated for its intended use installed on a representative enclosure. | | N/A |
| | b) All hardware, gaskets, or other parts required to complete the installation are provided with the component. | | N/A |
| | *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. | | N/A |
| | 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. | | N/A |
| 7.9.14 | A drain hole shall be provided on all units to | | N/A |

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| | prevent the accumulation of water above a level that results in the wetting of an electrical part or opening for the connection of conduit or for an auxiliary part under all mounting orientations specified by the installation instructions. The hole shall be as specified in Table 5.9. | | |
| | *Exception: A unit that has been subjected to the Rain and Sprinkler Tests, Section 64, is not required to be provided with a drain hole where no water enters the fixture.* | | -- |
| **8** | **Protection Against Corrosion** | | N/A |
| 8.1 | Iron and steel parts shall be protected against corrosion by enameling, galvanizing, plating, or other equivalent means. This applies to all springs and other parts which are relied upon for the intended mechanical operation. | | N/A |
| | *Exception No. 1: Parts such as bearings and thermal elements for which such protection is impracticable.* | | -- |
| | *Exception No. 2: Small minor parts of iron or steel such as washers, screws, or bolts that are not current-carrying and are not in the equipment grounding conductor path, when corrosion of such unprotected parts does not result in a risk of fire, electric shock, or injury to persons.* | | -- |
| | *Exception No. 3: Parts made of stainless steel.* | | -- |
| **9** | **Mechanical Assembly** | | N/A |
| 9.1 | A unit shall be assembled so that it is not adversely affected by the vibration of normal operation. | | N/A |
| 9.2 | A switch, a fuseholder, or a lampholder shall be securely mounted and shall be prevented from turning or shifting in its mounting panel. | | N/A |
| | *Exception: The requirement that a switch be prevented from turning or shifting does not apply where:*<br>*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,*<br>*b) Means for mounting the switch prevents the switch from loosening during operation,*<br>*c) Spacings are not reduced below the minimum specified in Spacings, Section 26, or Alternate Spacings-Clearances and Creepage Distances, Section 27, when the switch rotates, and*<br>*d) Normal operation of the switch is by mechanical means rather than by direct contact by persons.* | | -- |

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

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| **10** | **Mounting** | | P |
| 10.1 | Provision shall be made for securely mounting a unit in position. Bolts, screws, or other parts used for mounting a unit shall be independent of those used for securing components to the frame, base, or panel. | | P |
| | *Exception: A provision for mounting is not required for a floor supported or freestanding unit. See Stability, Section 61.* | | -- |
| 10.2 | A keyhole slot for a mounting screw shall be provided with at least one round hole for accommodation of a permanent mounting screw. A keyhole slot shall be arranged so that a wall-mounting screw does not project into a compartment containing electrical parts and reduce spacings to less than those specified in Spacings, Section 26, or Alternate Spacings – Clearances and Creepage Distances, Section 27. | | N/A |
| 10.3 | A unit shall not be provided with casters unless the casters are used solely for transporting the unit and the unit is provided with four leveling feet that are intended to be lowered after the unit is installed or the unit is provided with an equivalent means for securing the unit in position. | | P |

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| **11** | **Protection of Users – Accessibility of Uninsulated Live Parts** | | P |
| 11.1 | The requirements in this Section apply to a part that is accessible to the user. For protection of service personnel, see Protection of Service Personnel, Section 12. | | P |
| 11.2 | To reduce the potential for unintentional contact that involves a risk of electric shock from an uninsulated live part or film-coated wire; electrical energy - high current levels; or injury to persons from a moving part; an opening in an enclosure shall comply with (a) or (b): | | P |
| | a) For an opening that has a minor dimension (see 11.5) less than 25.4 mm (1 inch), the part or wire shall not be contacted by the | | P |

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| | probe illustrated in Figure 11.1. | | |
| | b) For an opening that has a minor dimension of 25.4 mm (1 inch) or more, the part or wire shall be spaced from the opening as specified in Table 11.1. | | N/A |
| 11.3 | The probe illustrated in Figure 11.1 shall be applied to any depth that the opening accommodates; and shall be rotated or angled before, during, and after insertion through the opening to any position that is required to examine the enclosure. The probe shall be applied in any possible configuration; and, when required, the configuration shall be changed after insertion through the opening. | | P |
| 11.4 | The probe specified in 11.3 shall be used as a measuring instrument to investigate the accessibility provided by an opening, and not as an instrument to investigate the strength of a material; it shall be applied with a maximum force of 4.4 N (1 pound). | | P |
| 11.5 | With reference to 11.2, the minor dimension of an opening is equal to the diameter of the largest cylindrical probe that is able to be inserted through the opening. | | P |
| 11.6 | The test pin illustrated in Figure 11.2, when inserted as specified in 11.3 through an opening in an enclosure, shall not touch any uninsulated live part that involves a risk of electric shock. | | P |
| 11.7 | The probe shown in Figure 11.1 and the test pin shown in Figure 11.2 are to be inserted as specified in 11.3 into all openings, including those in the bottom of the unit. The unit is to be positioned so that the entire bottom is accessible for insertion of the probe. | | P |
| | *Exception: For openings in the bottom of a floor-standing unit, the probe and test pin are only to be inserted into openings that are accessible without tipping, turning over, or otherwise moving the unit from its intended installed position.* | | -- |
| 11.8 | During the examination of a unit to determine compliance with 11.2 through 11.7, a part of the enclosure that is able to be opened or removed by the user without using a tool (to attach an accessory, to make an operating adjustment, to give access to a fuse or other overload protective device as described in 7.2.1, or for other reasons) is to be opened or removed. A fastener, such as a slotted-head thumb screw, that is able to be turned by hand, does not require the use of a tool. | | P |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| **12** | **Protection of Service Personnel** | | P |
| 12.1 | The requirements in this Section apply to the protection of service personnel who reach over, under, across, or around uninsulated electrical parts or moving parts to make adjustments or measurements while the unit is energized. For requirements covering protection of users, see Protection of Users – Accessibility of Uninsulated Live Parts, Section 11. | | P |
| 12.2 | Live parts shall be arranged and covers located to reduce the risk of electric shock or electrical energy-high current levels while covers are being removed and replaced. | | P |
| 12.3 | An uninsulated live part involving a risk of electric shock or electrical energy-high current levels and a moving part that involves a risk of injury to persons shall be located, guarded, or enclosed to protect against unintentional contact by service personnel adjusting or resetting controls, or similar actions, or performing mechanical service functions that are performed with the equipment energized, such as lubricating a motor, adjusting the setting of a control with or without marked dial settings, resetting a trip mechanism, or operating a manual switch. | | P |
| 12.4 | Live parts involving a risk of electric shock or electrical energy-high current levels and located on the back side of a door shall be guarded or insulated to protect against unintentional contact with live parts by service personnel. | | N/A |
| 12.5 | A component that requires examination, resetting, adjustment, servicing, or maintenance while energized shall be located and mounted with respect to other components and with respect to grounded metal parts so that it is accessible for electrical service functions without subjecting service personnel to a risk of electric shock, electrical energy-high current levels, or injury to persons by adjacent moving parts. Access to a component shall not be impeded by other components or by wiring. | | N/A |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| 12.6 | For an adjustment that is to be made with a screwdriver or similar tool when the unit is energized, protection shall be provided against inadvertent contact with adjacent uninsulated live parts involving a risk of electric shock. Misalignment of the tool with the adjustment means when an adjustment is attempted is to be taken into account. This protection is able to be provided by: | | N/A |
| | a) Location of the adjustment means away from uninsulated live parts involving a risk of electric shock, or | | N/A |
| | b) A guard to reduce the potential for the tool contacting uninsulated live parts. | | N/A |
| 12.7 | A live heat sink for a solid-state component, a live relay frame, and similar components, involving a risk of electrical shock or electrical energy-high current levels, which is mistakable for dead metal, shall be guarded to protect against unintentional contact by service personnel or shall be marked in accordance with 67.4. | | N/A |
| | *Exception: This requirement does not apply to a heat sink mounted on a printed wiring board.* | | N/A |
| 12.8 | A moving part that involves a risk of injury to persons and that must be in motion during service operations not involving the moving part shall be located or protected against unintentional contact with the moving parts. | | N/A |
| 12.9 | Reduction of the risk of electric shock and injury to persons is able to be accomplished by mounting control components so that unimpeded access to each component is provided by an access cover or panel in the outer cabinet. | | N/A |

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| **13** | **Electric Shock** | | P |
| 13.1 | **Voltage** | | P |
| 13.1.1 | The requirements described in 13.1.2 – 13.2.2 are to be used to determine whether or not the voltage of an accessible live part involves a risk of electric shock. | | P |
| 13.1.2 | A live part does not involve a risk of electric shock where the voltage of the part does not exceed the values specified in Table 13.1. | | P |
| 13.2 | Stored energy | | N/A |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| 13.2.1 | The capacitance between capacitor terminals that are accessible as determined in accordance with Protection of Users – Accessibility of Uninsulated Live Parts, Section 9, and Protection of Service Personnel, Section 10, shall satisfy the following expressions: | | N/A |
| | $V < 40{,}000$ where $C < 0.00328$<br>$V < 729\ C^{-0.7}$ where $0.00328 < C < 2.67$<br>$V < 367$ where $2.67 < C < 13.9$<br>$V < 2314\ C^{-0.7}$ where $13.9 < C < 184.5$ in a DRY environment<br>$V < 60$ where $C > 184.5$ in a DRY environment<br>$V < 2314\ C^{-0.7}$ where $13.9 < C < 497$ in a WET environment<br>$V < 30$ where $C > 497$ in a WET environment<br>*in which:*<br>*C is the capacitance of the capacitor in microfarads, and*<br>*V is the voltage across the capacitor. The voltage is to be measured in accordance with 60.1. Typical calculated values are specified in Table 13.2, and the equation is shown graphically in Figure 13.2.* | | — |
| 13.2.2 | With reference to 13.2.1, a part involving a potential of more than 40 kilovolts peak shall be investigated to determine whether or not it involves a risk of electric shock. | | N/A |
| 13.2.3 | A means such as a bleeder resistor shall be provided to drain the charge stored in a capacitor so that it does not provide a risk of electric shock or a risk of electrical energy-high current level. A risk of electric shock exists when the voltage across the capacitor, determined in accordance with Capacitor Voltage Determination Test, Section 60, exceeds the limits specified in 13.1.2. A risk of electrical energy-high current level exists when the stored energy exceeds 20 joules as determined by the following equation: | | N/A |
| | $J = 5 \times 10^{-7}\ CV^2$<br>*in which:*<br>*J is the stored energy in Joules,*<br>*C is the capacitance in microfarads, and*<br>*V is the voltage determined in accordance with Capacitor Voltage Determination Test, Section 60.* | | — |
| | *Exception No. 1: The requirement does not apply where:*<br>*a) A tool is required to remove a panel to reach the capacitor or accessible uninsulated portions of the associated circuit,*<br>*b) The time required to discharge the capacitor is within the limitations specified in 13.2.1 and is less than 5 minutes, and*<br>*c) The unit is marked as specified in 67.11.* | | N/A |

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| | *Exception No. 2: The requirement does not apply where:*<br>*a) The unit is marked in accordance with 67.12, and*<br>*b) The unit is provided with a built-in, insulated circuit that discharges the capacitor or capacitor bank by the actuation of a switch or by plugging in a connector. When a connector or a nonmomentary type switch is used, the circuit assembly shall be constructed and evaluated for continuous operation. When a momentary type switch is used, the capacitor or capacitor bank shall be discharged to levels in accordance with Table 13.2 within 1 minute.* | | N/A |
| | *Exception No. 3: The requirement does not apply where:*<br>*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*<br>*b) A cautionary marking in accordance with 67.13 is provided.* | | N/A |
| 13.24 | Any equipment connecting to a controlled conductor of PV source or output circuits and has<br>devices that may store energy (e.g. batteries, capacitors, etc.) shall comply with 97.1.10 and provide the<br>markings and instructions in accordance with 101.3 and 102.4. | | N/A |
| **14** | **Switches and Controls** | | P |
| 14.1 | An ac or dc switch or similar control device shall have current and voltage ratings not less than those of the circuit that it controls when the unit is operated in its intended manner. | Approved power switch used. | P |
| 14.2 | A primary-circuit switch that controls an inductive load having a power factor less than 75 percent, and that does not have an inductive rating, shall: | | N/A |
| | a) Be rated not less than twice the maximum load current under normal operating conditions, or | | N/A |
| | b) Be investigated for the application. | | N/A |
| 14.3 | A switch used to connect a load to various sources or potentials shall be rated for such use. This includes a switch used for switching a voltmeter, frequency meter, or power factor meter between various phases. | | N/A |
| 14.4 | A switch or other device controlling a relay coil, solenoid coil, or similar coil load shall have a pilot-duty rating. | | N/A |
| | *Exception: A device as described in 14.5 is not required to have a pilot duty-rating.* | | N/A |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| 14.5 | A device that is rated for across-the-line motor starting of an alternating current motor is usable for alternating current pilot-duty without further tests when the power factor is 0.5 or less and the overload current is at least 150 percent of the pilot-duty inrush current at the same voltage. Switching devices rated in accordance with Table 14.1 are in compliance with this requirement. | | N/A |
| 14.6 | Each pole of a snap switch rated as a 2-circuit, 3-circuit, or multi-circuit switch is not prohibited from controlling a separate load at the full voltage rating of the switch. Each pole of a snap switch rated as a 240-volt, 2-pole switch is not prohibited from controlling a separate 120-volt load, and both poles are not prohibited from controlling both legs of a single 240-volt load. Each pole of a snap switch rated as a 240-volt, 3-pole switch is not prohibited from controlling a separate load not exceeding 139 volts and the three poles are not prohibited from controlling the three legs of a 3-phase, 240-volt load. | | N/A |
| 14.7 | A 240-volt or 250-volt snap switch used in a circuit involving more than 120 volts to ground shall be rated for such use. | | N/A |
| 14.8 | A switch shall not disconnect the grounded conductor of a circuit. | | N/A |
| | *Exception No. 1: The grounded conductor is able to be disconnected by a switch that simultaneously disconnects all conductors of the circuit.* | | N/A |
| | *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.* | | N/A |
| 14.9 | A bypass switch or maintenance bypass used to connect the load directly to the bypass source shall comply with the Standard for Automatic Transfer Switches, UL 1008. | | N/A |
| | *Exception: A bypass switch or maintenance bypass complying with Load Transfer Test, Section 50.7, is not required to comply with UL 1008. See 14.10.* | | |
| 14.10 | With reference to the Exception to 14.9, a solid-state switch shall comply with the requirements in this Standard. A mechanical or electromechanical switch shall comply with the applicable requirements for switches in the Standard for General-Use Snap Switches, UL 20, and the Standard for Industrial Control Equipment, UL 508. | | N/A |
| 14.11 | Where a unit switch or circuit breaker is | | N/A |

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| | 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:*<br>*a) A switching device having more than one on position (such as a bypass switch),*<br>*b) A double throw switch,*<br>*c) A rotationally-operated switch, or*<br>*d) A rocker switch.* | | N/A |
| **15** | **Disconnect Devices** | | N/A |
| 15.1.3 | System Disconnecting Means: A device serving the function of the NEC-required system disconnecting means shall::<br>a) Consist of a manually operated switch or a circuit breaker,<br>b) Employ an actuating mechanism that is accessible from outside of the enclosure or located behind a hinged cover not requiring a tool (other than a key) for opening, and<br>c) Be marked in accordance with 6.21 and 66.27 | Permanent connection equipment. | N/A |
| 15.1.4 | Equipment Disconnecting Means: A device serving the function of the NEC-required equipment disconnecting means shall:<br>a) Consist of a manually operated switch or a circuit breaker,<br>b) Employ an actuating mechanism that is capable of being operated without exposing the operator to inadvertent contact with live parts, and<br>c) Be marked in accordance with 66.21 and 66.27 to indicate its function.<br>Disconnect actuating mechanisms shall clearly indicate the operational status of the disconnect with the following text “ON (CLOSED)” and “OFF (OPEN)” or symbols in accordance with 66.21. | | N/A |
| 15.2 | **Provision for locking** | | N/A |
| 15.2.1 | Isolating and disconnecting devices serving as the means of de-energization of external sources of supply to the equipment, to facilitate safe servicing, shall have provision for being locked in the "off" (open or de-energized) position. | | N/A |
| **16** | **AC Output Connections** | | P |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| 16.1 | **Stand-alone inverters** | | P |
| 16.1.1 | The ac output of a stand-alone inverter shall be provided with (a) or (b), or both: | | P |
| | a) Receptacles which comply with 16.1.2. | | P |
| | b) Provision for connection of a fixed wiring system in accordance with Supply Connections, Section 18. | | N/A |
| 16.1.2 | An inverter provided with an ac output receptacle shall comply with the following:<br>a) The receptacle shall be of the grounding type,<br>b) The ac output conductor that is connected to the white or silver terminal of the receptacle shall be bonded to ground in accordance with 21.1, 21.3, and 21.5,<br>c) An equipment-grounding connection as described in Equipment Grounding, Section 18, shall be provided. Grounding of the receptacle shall not rely on mounting means only. The ground terminal provided as part of the receptacle shall be employed, and<br>d) Receptacles installed in raised covers shall not be secured solely by a single screw. | | P |
| 16.1.3 | A ground-fault circuit-interrupter shall comply with the Standard for Ground-Fault Circuit-Interrupters, UL 943. | | N/A |
| **16.2** | **Utility-interactive inverters** | | N/A |
| 16.2.1 | A utility-interactive inverter shall have provision for connection of a wiring system complying with Supply Connections, Section 18. | | N/A |
| 16.2.2 | A general-use ac output receptacle shall not be provided on a utility-interactive inverter unless it is internal to the unit and accessible for service personnel use only. | | N/A |
| 16.2.3 | An inverter with an ac output shall comply with the following:<br>a) The installation instructions shall comply with 68.2, and<br>b) The output circuit shall not be bonded to the enclosure. See also 21.2. | | N/A |
| **17** | **Receptacles** | | N/A |
| 17.1 | A general-use receptacle in an inverter shall be of the grounding type. | | N/A |
| 17.2 | A receptacle supplied from the output ac circuit | | N/A |

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| | of an inverter shall comply with the following:<br>a) The white or silver terminal of the receptacle shall be grounded, see AC Output Circuit Grounded Conductor, Section 19,<br>b) The equipment-grounding terminal of the receptacle shall be conductively connected to the equipment-grounding means in accordance with Internal Bonding for Grounding, Section 21, and<br>c) A receptacle installed in a raised cover shall be in accordance with Section 410.56(i) of the National Electrical Code, ANSI/NFPA 70. | | |

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| **18** | **Supply Connections** | | P |
| 18.1 | **General** | | P |
| 18.1.1 | A unit shall have provision for connection of a wiring system consisting of:<br>a) Wiring terminals as specified in 18.1.3 – 18.2.10 or wiring leads as specified in 18.1.3 and 18.3.1 – 18.3.6, and<br>b) A means for connection of cable or conduit as specified in 18.5.1. | | P |
| | *Exception No. 1: The requirements described in 18.1.3 – 18.4.3 do not apply to the means for connection to isolated accessible signal circuits complying with the requirements specified in Isolated Accessible Signal Circuits, Section 30.* | | N/A |
| | *Exception No. 2: This requirement does not apply to ac output power circuit of an inverter consisting of receptacles complying with the requirements specified in Receptacles, Section 17.* | | N/A |
| 18.1.2 | The requirement in 18.1.1 applies to the wiring connection means for ac and dc input and output power circuits of a unit intended to be made in the field when the unit is installed. | | N/A |
| 18.1.3 | A wiring terminal or lead shall be rated and sized for connection to a field wiring conductor having an ampacity based on Table 310.15(B)(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 310.15(B)(16), see 69.4 (L) and (M). | | N/A |
| 18.2 | **Wiring Terminals** | | N/A |
| 18.2.1 | A wiring terminal shall comply with the requirement in 18.1.3 for a wire of each metal for which it is marked. See 66.12. | | N/A |
| 18.2.2 | A wiring terminal shall be provided with a | | N/A |

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| | 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 18.2.4 meets the intent of this requirement.* | | N/A |
| | *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.* | | N/A |
| 18.2.3 | 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. | | N/A |
| | *Exception: A pressure terminal connector used in accordance with 18.2.4 is able to turn when the spacing complies with Spacings, Section 26, when the connector is oriented in the position resulting in the least spacing between adjacent terminals and also between terminals and dead metal parts.* | | N/A |
| 18.2.4 | With reference to Exception No. 1 to 18.2.2, a pressure terminal connector is not required to be factory installed when the conditions in (a) – (e) are met: | | N/A |
| | a) One or more component terminal assemblies shall be available from the unit manufacturer or others and specified in the instruction manual. See 69.4(B) and (C). | | N/A |
| | 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:<br>1) Provided as part of the terminal assembly,<br>2) Mounted on or separately packaged with the unit, or<br>3) Specified in the instruction manual. | | N/A |
| | 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. | | N/A |

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| | 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 unit. See 69.4(D). | | N/A |
| | e) Installation of the pressure terminal connector in the intended manner shall result in a unit complying with the requirements of this Standard. | | N/A |
| 18.2.5 | A terminal block or insulating base for support of a pressure terminal connector shall comply with the Standard for Terminal Blocks, UL 1059. | | N/A |
| 18.2.6 | A wire-binding screw at a field-wiring terminal shall not be smaller than No. 10 (4.8 mm diameter). | | N/A |
| | *Exception No. 1: A No. 8 (4.2 mm diameter) screw is usable at a terminal intended only for the connection of:*<br>*a) 14 AWG (2.1 mm2) conductor, or*<br>*b) 16 or 18 AWG (1.3 or 0.82 mm2) control-circuit conductor* | | N/A |
| | *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 mm2) control-circuit conductor.* | | N/A |
| 18.2.7 | A wire-binding screw shall thread into metal. | | N/A |
| 18.2.8 | A terminal plate tapped for a wire-binding screw shall be of metal not less than 1.27 mm (0.050 inch) thick. | | N/A |
| | *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 2.1.28 and 2.1.30 and the tapped threads are capable of withstanding the tightening torque specified in Table 18.1 without stripping.* | | N/A |
| 18.2.9 | 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. | | N/A |
| | *Exception: Two full threads are not required for a terminal in a low-voltage, limited-energy (LVLE) circuit or limited-energy (LE) circuit, see 2.1.28 and 2.1.30, 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 18.1.* | | N/A |
| 18.2.10 | A terminal for connection of a grounded conductor of an ac circuit shall be identified as described in 66.16. | | N/A |
| 18.3 | **Wiring leads** | | P |
| 18.3.1 | A field-wiring lead shall not be more than two | | P |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| | wire sizes smaller than the copper conductor to which it is to be connected, and shall not be smaller than No. 18 AWG (0.82 mm2). For example, a No. 10 AWG (5.3 mm2) or larger field-wiring lead is required for connection to a No. 6 AWG (13.3 mm2) 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 mm2), 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:*<br>*a) A wire connector for connection of the field-provided wire is factory-installed as part of the unit or remote-control assembly, and the wire connector is rated for the combination of wires that are to be spliced,*<br>*b) The factory-provided leads are bunched or otherwise arranged so that stress does not result on an individual lead, and*<br>*c) Instructions are provided in accordance with 69.4(E).* | | N/A |
| 18.3.2 | A field-wiring lead shall consist of general building wire, or of other wiring having an insulation of: | | P |
| | a) At least 0.8-mm (1/32-inch) thick thermoplastic material, | | N/A |
| | b) At least 0.4-mm (1/64-inch) thick rubber plus a braid cover for applications of 300 volts or less, or | | P |
| | c) At least 0.8-mm thick rubber plus a braid cover for applications between 301 and 600 volts. | | N/A |
| 18.3.3 | A field-wiring lead shall comply with Strain Relief Test, Section 53. | | N/A |
| 18.3.4 | 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: | | N/A |
| | a) The lead is insulated at the unconnected end, and<br>b) A marking is provided on the unit in accordance with 66.24. | | N/A |
| 18.3.5 | 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 20.1.7. | | N/A |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| 18.3.6 | A field-wiring lead for connection of a grounded conductor of an ac circuit shall be identified as described in 66.16. | | N/A |
| 18.4 | **Wiring Compartments** | | N/A |
| 18.4.1 | A wiring compartment for a unit shall be located so that wire connections therein are accessible for inspection, without disturbing factory or field connected wiring, after the unit is installed in the intended manner. | | N/A |
| 18.4.2 | 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. | | N/A |
| 18.4.3 | A wiring compartment shall not have a volume less than specified in Table 18.2. The volume is to be determined in accordance with the Standard for Metallic Outlet Boxes, UL 514A, or the Standard for Non-metallic 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). | | N/A |
| 18.5 | **Openings for Conduit or Cable Connection** | | N/A |
| 18.5.1 | For a fixed unit, an opening or knockout complying with the requirements specified in 7.7.1 – 7.7.7 shall be provided for connection of conduit or a cable wiring system. | | N/A |
| | *Exception: A unit complying with 7.7.6 is not required to be provided with an opening or a knockout.* | | N/A |
| 18.6 | **Openings for Class 2 Circuit Conductors** | | N/A |
| 18.6.1 | 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 unit is installed. | | N/A |
| | *Exception: A bushing is not required where:*<br>*a) The opening is sized and intended for armored cable or conduit, and*<br>*b) The installation instructions indicate that Class 1 wiring methods are to be used as indicated in 69.4(N).* | | N/A |
| 18.6.2 | For Type 1 enclosures only, a bushing of rubber or rubber type material provided in accordance with 18.6.1 shall not be less than 3.2 mm (1/8 inch) thick; however, it shall not be less | | N/A |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| | than 1.2 mm (3/64 inch) thick when the metal around the hole is eyeleted 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. | | |
| **19** | **Wire-Bending Space** | | N/A |
| 19.1 | A permanently connected unit employing pressure terminal connectors for field connection of circuits described in 18.1.2 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 18.1.2 – 18.2.4. | | N/A |
| 19.2 | The conductor size used to determine compliance with 19.1 is to be based on the use of a conductor sized in accordance with 18.1.3. | | N/A |
| | *Exception No. 1: Where a unit is marked with a maximum wire size for a field-installed conductor in accordance with 66.28, the marked maximum size is to be used.* | | N/A |
| | *Exception No. 2: The requirements in 18.4.3 are to be used to investigate the wire-bending space in a wiring compartment.* | | N/A |
| 19.3 | Wire-bending space for field installed conductors shall be provided opposite any: | | N/A |
| | a) Pressure wire connector as specified in 19.4 or 19.5, and | | N/A |
| | b) Opening or knockout for a conduit or wireway in a gutter as specified in 19.9. | | N/A |
| 19.4 | 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 19.1. 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. | | N/A |
| 19.5 | 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 19.2 where: | | N/A |
| | a) A barrier is provided between the connector and the opening, or | | N/A |
| | b) Drawings are provided specifying that the | | N/A |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| | conductor is not to enter or leave the enclosure directly opposite the wire connector. See Illustrations A, B, and C of Figure 19.1. | | |
| 19.6 | 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 19.1. | | N/A |
| 19.7 | For a unit not provided from the factory with a conduit opening or knockout, see 7.7.6, the minimum wiring-bending space specified in 19.4 – 19.6 shall be based on: | | N/A |
| | a) Any enclosure wall used for installation of the conduit, or | | N/A |
| | b) Only specific walls that are to be used as specified by a marking, drawing, or template furnished with the unit. | | N/A |
| 19.8 | The distance specified in 19.3 – 19.5 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 19.1. 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. | | N/A |
| | *Exception: See 19.6.* | | N/A |
| 19.9 | 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 19.2. See illustration E of Figure 19.1. | | N/A |
| | *Exception: The wiring space is able to be narrower when:*<br>*a) Knockouts are provided elsewhere that are in compliance with these requirements,* | | N/A |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| | *b) The wire-bending space at such other point or points is of a width that accommodates the conductors in question, and*<br>*c) The knockout or knockouts at such other points are able to be conveniently used in the intended wiring of the unit.* | | |

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| **20** | **Equipment Grounding** | | P |
| 20.1 | **General** | | P |
| 20.1.1 | There shall be means for grounding all dead metal parts of a unit. | | P |
| 20.1.2 | The means for equipment grounding specified in 20.1.1 shall be provided for each wiring system to be connected to the unit for the following circuits:<br>a) Each dc input circuit,<br>b) Each ac input circuit,<br>c) Each ac output circuit, and<br>d) Each battery circuit. | | N/A |
| | *Exception: An isolated accessible signal circuit complying with Isolated Accessible Signal Circuits, Section 30, is not required to have means for equipment grounding.* | | N/A |
| 20.1.3 | The equipment-grounding means for a fixed unit shall consist of an equipment-grounding terminal or lead. | | N/A |
| 20.1.4 | 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. | | N/A |
| 20.1.5 | An equipment-grounding connection shall penetrate a nonconductive coating, such as paint or vitreous enamel. | | N/A |
| 20.1.6 | An equipment-grounding means shall be located so that the means is not subject to inadvertent removal during servicing. | | N/A |
| 20.1.7 | 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. | | N/A |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| 20.1.8 | 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 66.13. 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: | | N/A |
| | 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 65.1. | | N/A |
| | b) For any ac input or output circuit or dc (non-PV) input or output circuit, Column 2 of Table 20.1 based on the size of the overcurrent device protecting that circuit. | | N/A |
| | *Exception: The color coding requirement does not apply to Class 2 circuits where the leads are:*<br>*a) Located remote from the line-voltage connections and the segregation complies with the requirements in Separation of Circuits, Section 25, or*<br>*b) Marked in accordance with 66.25.* | | N/A |
| 20.1.9 | An equipment-grounding conductor shall not be spliced internal to the equipment. | | N/A |
| 20.1.10 | 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 22.12. | | N/A |
| | *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.* | | N/A |
| 20.1.11 | 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. | | N/A |
| 20.1.12 | 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 20.1 and shall be constructed in | | N/A |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| | accordance with 18.2.1 – 18.2.9. | | |
| 20.1.13 | 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 66.13. | | N/A |
| 20.2 | **Grounding electrode terminal** | | N/A |
| 20.2.1 | 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:<br>a) Be capable of securing a conductor size based on the maximum current rating of the highest current circuit connected to the unit, as specified in Column 3 of Table 20.1,<br>b) Comply with 18.2.1 – 18.2.10 for construction, and<br>c) Be marked as described in 66.17. | | N/A |
| 20.2.2 | 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. | | N/A |

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| **21** | **AC Output Circuit Grounded Conductor** | | N/A |
| 21.1 | The requirements for circuit grounding specified in 21.3 – 21.5 apply to the ac output circuit of a stand-alone inverter. | | N/A |
| 21.2 | An inverter intended to be utility-interactive shall not have a direct/solid electrical connection between any output ac conductor and the enclosure. | | N/A |
| 21.3 | Other than as specified in 21.2, each ac output circuit shall have a grounded conductor. The ac output circuit conductor to be grounded shall be as follows: | | N/A |
| | a) Single-phase, 2-wire – one conductor. | | N/A |
| | b) Single-phase, 3-wire – the neutral conductor. | | N/A |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| | c) Multiphase system having one wire common to all phases – the common conductor. | | N/A |
| | d) Multiphase system in which one phase is used as in item (b) – the neutral conductor. | | N/A |
| 21.4 | The conductor specified in 21.3 is to be connected by a bonding jumper connected between the grounded conductor and: | | N/A |
| | a) The enclosure of a metal-enclosed unit, or | | N/A |
| | b) For a non-metallic enclosed unit, the metal chassis that is bonded to the equipment-grounding conductor or terminal. See 20.2.1. | | N/A |
| 21.5 | The size of the bonding jumper specified in 21.4 shall not be less than specified in Table 21.1. | | N/A |

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| **22** | **Internal Bonding for Grounding** | | N/A |
| 22.1 | All exposed 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 20. | | N/A |
| 22.2 | In a unit having means for grounding, 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. | | N/A |
| | *Exception: A metal part as described in (a) – (g) is not required to be bonded for grounding:*<br>*a) An adhesive-attached metal foil marking, a screw, a handle, or similar metal part, 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.*<br>*b) An isolated metal part, such as a magnet frame and an armature, a small assembly screw, or similar part, that is positively separated from wiring and uninsulated live parts.*<br>*c) 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.*<br>*d) 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.*<br>*e) An isolated metal part that is mounted on a printed wiring board – such as* | | N/A |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| | *transformer and choke cores and heat sinks.*<br>*f) An isolated metal part that is marked in accordance with 67.12.*<br>*g) A capacitor sleeved with insulating tubing complying with 26.2.2.* | | |
| 22.3 | A metal-to-metal piano-type hinge is usable as a means for bonding a door for grounding. | | N/A |
| 22.4 | Where the continuity of the grounding system relies on the dimensional integrity of a non-metallic 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 22.9. | | N/A |
| 22.5 | A conductor or strap used for bonding shall be of copper, a copper alloy, or an equivalent material. A conductor or strap:<br>a) Shall be protected from mechanical damage or be located within the outer enclosure or frame,<br>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<br>c) Shall not be spliced. | | N/A |
| 22.6 | 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 in the grounding path shall be protected against corrosion by painting, galvanizing, plating, or equivalent means. Bonding around a resilient mount shall not depend on the clamping action of rubber or similar material. | | N/A |
| 22.7 | A bolted or screwed connection that incorporates a star washer under the screwhead shall penetrate nonconductive coatings and shall comply with Grounding Impedance Test, Section 51. | | N/A |
| 22.8 | Where the bonding connection depends on 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. | | N/A |
| 22.9 | A connection that depends on the clamping action exerted by rubber or similar material shall | | N/A |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| | comply with Bonding Conductor Test, Section 55, when installed as intended. The material shall be rated for the condition of use, such as oil, grease, moisture, and thermal degradation that potentially occur in service. Before testing, the clamping device is to be disassembled as it is for maintenance purposes and then reassembled. | | |
| 22.10 | A bonding conductor or strap: | | N/A |
| | a) Shall not be smaller than the size specified in Column 2 of Table 20.1, see 22.11, | | N/A |
| | b) Shall not be smaller than the conductor supplying the component, or | | N/A |
| | c) Shall comply with Grounding Impedance Test, Section 51. | | N/A |
| | *Exception: A smaller conductor or strap is usable when it complies with Bonding Conductor Test, Section 55.* | | N/A |
| 22.11 | With reference to Column 2 of Table 20.1, 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. | | N/A |
| 22.12 | The bonding connection, the enclosure, the frame, or a component mounting panel shall not carry current other than current resulting from an electrical malfunction. | | N/A |
| | *Exception: An enclosure, frame, chassis, or panel, having bolted joints, is not restricted from carrying the current of a low-voltage, limited-energy (LVLE) circuit. Current shall not normally be carried through the field-equipment grounding means, the metallic raceway or other inverter grounding means, or the earth ground.* | | N/A |

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| **23** | **Internal Wiring** | | P |
| 23.1 | **General** | | P |
| 23.1.1 | The internal wiring of a unit 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 23.1. | | P |
| | *Exception: Appliance wiring material having an insulation thickness other than specified in Table 23.1 complies when the insulation ratings are equivalent to that specified with respect to temperature, voltage, and conditions of service.* | | -- |

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| 23.1.2 | 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:<br>a) The tubing or sleeving shall not be subjected to compression, repeated flexure, or sharp bends,<br>b) The conductor covered with the tubing or sleeving shall be well rounded and free from sharp edges,<br>c) A shrinkable tubing shall be used in accordance with the tubing manufacturer's instructions, and<br>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. | | P |
| 23.1.3 | 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. | | N/A |
| 23.2 | **Protection of wiring** | | P |
| 23.2.1 | Internal wiring shall not be accessible from outside the enclosure in accordance with 11.1. | | P |
| 23.2.2 | 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. | | N/A |
| 23.2.3 | 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. | | N/A |
| 23.2.4 | A hole through which insulated wires pass in a sheet metal wall internal to the overall enclosure of a unit shall be provided with smooth, rounded surfaces upon which the wires bear, to protect against abrasion of the insulation. | | N/A |
| 23.3 | **Electrical connections** | | P |
| 23.3.1 | A splice or connection shall be mechanically secure and shall make reliable electrical | | P |

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| | contact. | | |
| 23.3.2 | A soldered connection shall be made mechanically secure before being soldered. | | P |
| | *Exception: A connection is not required to be mechanically secured before soldering when:*<br>*a) A soldering or brazing material having a softening or melting point greater than 454°C (849°F) is used,*<br>*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,*<br>*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*<br>*d) The lead wire is strapped in place, or the equivalent, adjacent to the soldered connection to hold the lead end in place.* | | P |
| 23.3.3 | 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. | | P |
| 23.3.4 | 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. | | N/A |
| 23.3.5 | 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. | | N/A |
| 23.3.6 | 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. | | N/A |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| 23.3.7 | 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. | | P |
| | 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. | | N/A |
| | b) Insulating tubing or sleeving used to cover a splice shall comply with 23.1.2. | | P |
| | 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. | | P |

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| **24** | **Live Parts** | | P |
| 24.1 | A current-carrying part shall be of silver, copper, copper alloy, aluminum, or the equivalent. | | P |
| 24.2 | 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 26, or Alternate Spacings – Clearances and Creepage Distances, Section 27. | | P |

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| **25** | **Separation of Circuits** | | P |
| **25.1** | **Factory wiring** | | P |
| 25.1.1 | Insulated conductors of different circuits– see 25.1.2 – within a unit, 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. | | P |
| | *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.* | | P |
| 25.1.2 | For the purpose of determining compliance with 25.1.1, different circuits include: | | P |
| | a) Circuits connected to the primary and | | P |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| | secondary windings of an isolation transformer, | | |
| | b) Circuits connected to different isolated secondary windings of a multi-secondary transformer, | | N/A |
| | c) Circuits connected to secondary windings of different transformers, | | P |
| | d) Input and output circuits of an optical isolator, | | P |
| | e) Isolated circuits, and | | P |
| | f) AC power and dc power circuits. | | P |
| | *Exception: Power circuits that are derived from the taps of an autotransformer or similar component – that does not provide isolation – are not different circuits.* | | P |
| 25.1.3 | 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. | | P |
| **25.2** | **Field wiring** | | N/A |
| 25.2.1 | A unit shall be constructed so that a field-installed conductor of a circuit is separated as specified in 25.2.2 or separated by barriers as specified in 25.3.1 and 25.3.2 from: | | N/A |
| | 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. | | N/A |
| | 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. | | N/A |
| | c) Field-installed conductors connected to any other circuit unless:<br>1) Both circuits are Class 2 or Class 3 or both circuits are other than Class 2 or Class 3, and<br>2) Both circuits are insulated for the maximum voltage of one of the circuits. | | N/A |
| | *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.* | | N/A |
| 25.2.2 | Separation of a field-installed conductor from another field-installed conductor and from an | | N/A |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| | 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 unit 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. | | |
| 25.2.3 | With reference to 25.2.2, when the number of openings in the enclosure does not exceed the minimum required for the intended wiring of the unit, 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. | | N/A |
| 25.3 | **Separation barriers** | | N/A |
| 25.3.1 | A barrier used for separation between the wiring of different circuits shall be:<br>a) Grounded metal or 0.71 mm (0.028 inch) minimum thick insulating material, and<br>b) Supported so that it is unable to be readily deformed or displaced to defeat its purpose. | | N/A |
| 25.3.2 | 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. | | N/A |

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| **26** | **Spacings** | | P |
| 26.1 | **General** | | P |
| 26.1.1 | The spacings in a unit shall not be less than specified in Table 26.1. | | P |
| | *Exception No. 1: Where liners and barriers are employed, 26.2.1 shall be used* | | P |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| | *to determine the spacings.* | | |
| | *Exception No. 2: As an alternative to Table 26.1, the spacings are able to be investigated in accordance with Alternate Spacings – Clearances and Creepage Distances, Section 27* | | P |
| | *Exception No. 3: The inherent spacings of a component shall comply with the spacing requirements for the component.* | | P |
| | *Exception No. 4: The spacings specified in Table 26.1 do not apply within a circuit that complies with Isolated Accessible Signal Circuits, Section 30, or Control Circuits, Section 31. The spacing between these circuits and other circuits shall comply with Table 26.1.* | | N/A |
| | *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 26.1.* | | P |
| | *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:*<br>*a) The spacing complies with Reduced Spacings on Printed Wiring Boards Tests, Section 54, or*<br>*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.* | | N/A |
| | *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).* | | N/A |
| | *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.* | | P |
| 26.1.2 | 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 45. | | N/A |
| 26.1.3 | 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. | | N/A |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| 26.1.4 | In a multi-component unit, 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 unit 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 26.1. | | N/A |
| | *Exception: Components that comply with the requirements in the Standard for Capacitors and Suppressors for Radio- and Television-Type Appliances, UL 1414, are not required to comply with Table 26.1.* | | N/A |
| 26.1.5 | 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 26.1. | | P |
| 26.1.6 | 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. | | N/A |
| 26.1.7 | With reference to 26.1.6, a lock washer is one means of rigidly securing a part. | | N/A |
| 26.1.8 | Spacings to film coated wire are to be investigated as though the wire is an uninsulated live part. | | N/A |
| 26.1.9 | 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 44. Spacings between these circuits and the enclosure, grounded dead metal, and other circuits shall comply with the applicable spacing requirements of this Standard. | | P |
| | a) Secondary circuits supplied by a transformer winding rated less than 200 volt-amperes or at a potential of 100 volts or less, | | P |
| | b) Battery circuits at a potential of 100 volts or less, or | | P |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| | 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 31.11. | | P |
| 26.2 | **Insulating liners and barriers** | | N/A |
| 26.2.1 | With reference to Exception No. 1 to 26.1.1, an insulating liner or barrier of material such as vulcanized fiber is able to be used when it is:<br>a) Not the sole support for uninsulated live parts involving a risk of fire, electric shock, or electrical energy-high current levels,<br>b) Not less than 0.71 mm (0.028 inch) thick, and<br>c) Located so that it is not adversely affected by arcing. | | N/A |
| | 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. | | N/A |
| | *Exception No. 1: Vulcanized fiber not less than 0.33 mm (0.013 inch) thick is usable when:*<br>*a) In conjunction with an air spacing of not less than 50 percent of the minimum through air spacing as specified in Table 26.1, and*<br>*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.* | | -- |
| 26.2.2 | 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:<br>a) The conductor is not subjected to compression, repeated flexing, or sharp bends,<br>b) The conductor or case covered with the tubing is well rounded and free from sharp edges,<br>c) The tubing is used in accordance with the manufacturer's instructions, and | | N/A |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| | d) The conductor or case is not subjected to a temperature or voltage higher than that for which the tubing is rated. | | |
| 26.2.3 | 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:<br>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.<br>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.<br>c) The temperature rating of the tape is not less than the maximum temperature observed during the temperature test.<br>d) The tape is not subject to compression.<br>e) The tape is not wrapped over a sharp edge. | | N/A |

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| **27** | **Alternate Spacings – Clearances and Creepage Distances** | | N/A |
| 27.1 | Other than specified in 27.2 and 27.3, as an alternative approach to the spacing requirements specified in Spacings, Section 26, 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 27.4. See Maximum-Voltage Measurements, Section 45. | | N/A |
| 27.2 | 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 26.1. The clearances are to be determined by physical measurement. | | N/A |
| 27.3 | The clearances and creepage distances at field wiring terminals shall comply with Spacings, Section 26. | | N/A |
| 27.4 | 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: | | N/A |
| | a) Unless specified elsewhere in this Standard, | | N/A |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| | the pollution degree 3 applies, | | |
| | b) An inverter shall comply with the requirements for Overvoltage Category IV, | | N/A |
| | c) 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, | | N/A |
| | d) All printed wiring boards shall be identified as having a minimum Comparative Tracking Index (CTI) of 100 without further investigation. | | N/A |
| | e) 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, | | N/A |
| | f) 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, | | N/A |
| | g) 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 | | N/A |
| | h) 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. | | N/A |
| **28** | **Insulating Materials** | | P |
| 28.1 | **General** | | P |
| 28.1.1 | A polymeric material on which uninsulated live | | P |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| | 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.* | | N/A |
| 28.1.2 | 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. | | N/A |
| 28.1.3 | 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. | | N/A |
| 28.2 | **Barriers** | | N/A |
| 28.2.1 | 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. | | N/A |
| | *Exception: Vulcanized fiber not less than 0.33 mm (0.013 inch) thick is usable:*<br>*a) In conjunction with an air spacing of not less than 50 percent of the minimum through-air spacing as specified in Table 26.1, and*<br>*b) Between a heat sink and a metal mounting surface, including the enclosure, or an isolated secondary circuit rated 50 volts rms or less.* | | N/A |
| 28.2.2 | 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 28.2.1. | | N/A |

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| **29** | **Capacitors** | | P |
| 29.1 | A capacitor used for electromagnetic | | N/A |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| | 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 unit having an enclosure that complies with the requirements in 7.1.1 – 7.5.1 without Exceptions.* | | N/A |
| 29.2 | 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. | | P |
| **30** | **Isolated Accessible Signal Circuits** | | N/A |
| 30.1 | An isolated accessible signal circuit having means for external connections, such as a RS232 communication port and similar connections, shall comply with 30.2 and 30.3. | | N/A |
| 30.2 | A signal circuit that extends outside of a unit 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 13, by one of the following: | | N/A |
| | 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 47.1, | | N/A |
| | b) An isolation transformer complying with the Standard for Class 2 and Class 3 Transformers, UL 1585, or an isolation transformer as defined in 2.1.26 – autotransformers are excluded, | | N/A |
| | 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, | | N/A |
| | d) An electro-mechanical relay complying with the requirements in the Standard for Industrial Control Equipment, UL 508, or | | N/A |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| | e) A voltage regulating network where:<br>1) The voltage being isolated is not directly derived from the ac circuit, and<br>2) The network does not involve a risk of electric shock at the external connection as determined in accordance with Electric Shock, Section 13, 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. | | N/A |
| 30.3 | The maximum power voltage and current available from an isolated accessible signal circuit shall comply with 31.4 – 31.11. | | N/A |
| 30.4 | 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 30.4 shall not exceed the values specified in Table 30.1. | | N/A |

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| **31** | **Control Circuits** | | N/A |
| 31.1 | 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. | | N/A |
| 31.2 | Other than for safety circuits, as indicated in 31.3, 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 23.1.1 and 35.1. | | N/A |
| 31.3 | A control circuit that is a safety circuit shall be investigated in accordance with the requirements for primary circuits. | | N/A |
| 31.4 | A control circuit, including associated electronic components on printed wiring boards, that does not extend out of the unit 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 23.1.1 and 35.1. | | N/A |
| | a) The voltage shall not exceed the limits specified in Table 13.1, and | | N/A |
| | b) The current shall not exceed: | | N/A |
| | 1) Eight amperes for 0 – 42.4 volts peak ac, or 0–30 volts dc, or | | N/A |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| | 2) Amperes equal to 150 divided by the maximum voltage for 30 – 60 volts dc. See 31.5. | | N/A |
| | *Exception: The maximum current specified is able to be exceeded where the circuit includes an overcurrent protective device as described in 31.8 and 31.9.* | | N/A |
| 31.5 | With reference to 31.4(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. | | N/A |
| 31.6 | With reference to 31.4(a), measurement is to be made with the unit connected to the voltage specified in 47.1 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. | | N/A |
| 31.7 | When the control circuit specified in 31.4 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 31.11 – the circuits in which the current is limited in accordance with 31.8, 31.9, or 31.10 are not required to be investigated. | | N/A |
| 31.8 | A fuse or circuit-protective device used to limit the current in accordance with 31.7 shall be rated or set at not more than the values specified in Table 31.1. | | N/A |
| 31.9 | A fuse or circuit-protective device connected to the primary of a transformer to limit the current in accordance with 31.7 shall be equivalent to that specified in 31.8 as determined by conducting the Overcurrent Protection Calibration Test, Section 52. | | N/A |
| | *Exception: The Overcurrent Protection Calibration Test, Section 49, 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.* | | N/A |
| 31.10 | A regulating network or one or more resistors used to limit the current in accordance with 31.7 shall be such that the current under any condition of load, including short circuit, does not exceed the values indicated in 31.4(b). | | N/A |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| 31.11 | Where a regulating network is used to limit the voltage or current in accordance with 31.4 – 31.10, and the performance is affected by malfunction (short circuit or open circuit) of any single component – excluding short-circuiting a resistor – the network: | | N/A |
| | a) Shall comply with the tests specified in 31.13, and | | N/A |
| | 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. | | N/A |
| 31.12 | In a circuit of the type described in 31.7, 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. | | N/A |
| 31.13 | With reference to 31.11 (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 31.14.<br>a) Transient Overvoltage Test,<br>b) Ramp Voltage Test,<br>c) Electromagnetic Susceptibility Tests,<br>d) Electrostatic Discharge Test,<br>e) Thermal Cycling Test,<br>f) Humidity Test, and<br>g) Effects of Shipping and Storage Test. | | N/A |
| 31.14 | The following test parameters are to be used in the investigation of a regulating network covered by 31.13.<br>a) Electrical supervision of critical components applies,<br>b) Audibility is usable as a trouble indicator for an electrical supervision circuit,<br>c) A field strength of 3 volts per meter is to be used for the Radiated EMI Test, and<br>d) Exposure Class H5 is to be used for the Humidity Test. | | N/A |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| **32** | **Overcurrent Protection** | | P |
| 32.1 | **General** | | P |
| 32.1.1 | An overcurrent protective device, the intended functioning of which requires renewal, replacement, or resetting, shall be accessible: | | P |
| | a) From outside of the enclosure, or | | N/A |
| | b) Behind a hinged cover – see 7.2.1. | | N/A |
| | *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 unit is not required to be accessible.* | | P |
| | *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.* | | N/A |
| 32.1.2 | 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 11.1, of an extractor-type fuseholder shall be connected toward the load. | | N/A |
| 32.1.3 | The type of fuseholder described in 32.1.2 shall not be used in circuits where both ends of the fuse are live, such as between an inverter and the utility or between a charge controller and a battery. | | N/A |
| 32.1.4 | 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. | | P |
| 32.1.5 | A fuseholder shall be of the cartridge, plug, or extractor type. | | N/A |
| | *Exception: A fuse intended to be replaced only by service personnel – see Protection of Service Personnel, Section 12 – that is bolted in place meets the intent of this requirement.* | | P |
| 32.1.6 | A plug-type fuseholder shall be of the Type S construction. | | N/A |
| 32.1.7 | An appliance protector used in the output circuit of an inverter in lieu of a branch-circuit rated fuse or circuit breaker shall have a short-circuit interrupting rating not less than the maximum fault current available from the inverter and shall comply with the requirements in the Standard for Supplementary Protectors for Use in Electrical Equipment, UL 1077. | | N/A |
| 32.1.8 | A circuit breaker in the input or output circuit shall open all ungrounded conductors of the circuit. A multipole circuit breaker shall be a | | N/A |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| | 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 67.9):*<br>*a) In a single-phase circuit,*<br>*b) In a 3-wire dc circuit, or*<br>*c) In a circuit that is connected to a 4-wire, 3 phase; or 5-wire, 2-phase, system with a grounded neutral.* | | N/A |
| 32.1.9 | A unit shall be marked in accordance with 67.6 when it is provided with overcurrent protection consisting of an interchangeable fuse and when the fuse is: | | N/A |
| | a) Accessible to the user, or | | N/A |
| | b) Used to comply with the requirements in this Standard. | | N/A |
| 32.1.10 | 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. | | N/A |
| 32.1.12 | Overcurrent protection employing solid-state component circuitry used for protection of control circuits in accordance with 32.2.1 – 32.2.5 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. The interrupt test is to be based on the maximum rated short circuit current available from the inverter. | | N/A |
| | *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.* | | N/A |
| 32.1.13 | Units 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. | | N/A |
| 32.2 | **Control circuit overcurrent protection** | | N/A |

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|---|---|---|---|
| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| 32.2.1 | A control circuit that extends from the unit to a remote control panel, status panel, or a similar component shall be protected in accordance with 32.2.2– 32.3.2. | | N/A |
| | *Exception: An external control circuit derived from a Class 2 transformer is not required to be provided with overcurrent protection.* | | N/A |
| 32.2.2 | The overcurrent protective device specified in 32.2.1 shall be a circuit breaker or fuse that is: | | N/A |
| | a) Rated for branch-circuit overcurrent protection, or | | N/A |
| | b) In compliance with 32.1.6. | | N/A |
| | When the protective device is a fuse, the unit shall be marked in accordance with 67.6. | | N/A |
| 32.2.3 | 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 32 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. | | N/A |
| 32.2.4 | An external control circuit derived from the secondary of a transformer other than that described in 32.2.3 and the Exception to 32.2.1 shall be provided with overcurrent protection in accordance with 32.2.5. For a transformer not having a rating, the rated primary or secondary current specified in 32.2.5 is to consist of the maximum current during normal operation of the unit. | | N/A |
| 32.2.5 | A transformer used to supply a control circuit shall be provided with overcurrent protection in the primary circuit rated as indicated in Table 32.1. | | N/A |
| | *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.* | | N/A |
| | *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.* | | N/A |
| | *Exception No. 3: Where a control circuit is derived from the secondary of a transformer that is provided with primary circuit overcurrent protection rated* | | N/A |

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|---|---|---|---|
| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| | *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.* | | |
| **32.3** | **Output ac power circuit overcurrent protection** | | P |
| 32.3.1 | An ac output power circuit shall be provided with overcurrent protection for all ungrounded conductors as described in 32.3.2 and 32.3.3. 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. | | P |
| | *Exception: Overcurrent protection is not required to be provided with a unit 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 69.4(Q).* | | N/A |
| 32.3.2 | For a unit 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 unit as determined in accordance with 18.1.3. | | N/A |
| 32.3.3 | Where a unit 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. | | P |
| | *Exception: Two or more 15 ampere rated receptacles in a unit with 12 AWG (3.3 $mm^2$) minimum internal wiring are able to be protected by a 20 ampere overcurrent protection device.* | | N/A |
| **32.4** | **Battery circuits** | | P |
| 32.4.1 | A unit intended for connection to a battery circuit shall be provided with overcurrent protection complying with the requirements described in 32.4.2– 32.4.4. | | P |
| | *Exception: Overcurrent protection is not required to be provided when the instruction manual contains the statement indicated in 69.4(Q).* | | P |
| 32.4.2 | The overcurrent protective device shall be dc rated and shall be for branch-circuit protection in accordance with the National Electrical Code, NFPA 70. | | P |
| 32.4.3 | The protective device shall be located adjacent | | P |

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|---|---|---|---|
| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| | 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. | | |
| 32.4.4 | The rating of the overcurrent protective device shall be based on the ampacity of the conductors intended to be connected between the unit and battery as determined from the requirement described in 18.1.3 under inverter mode operating conditions. | | P |

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| **34** | **DC Ground Fault Detector/Interrupter** | | N/A |
| 34.1 | Inverters or charge controllers with direct photovoltaic inputs from a grounded photovoltaic array or arrays shall be provided with a ground-fault detector/interrupter (GFDI). The GFDI shall be capable of detecting a ground fault, providing an indication of the fault, interrupting the flow of fault current, and either isolating the faulted array section or disabling the inverter to cease the export of power. The GFDI shall comply with 34.2 – 34.6 and Sections 56 – 59. | | N/A |
| | *Exception No. 1: AC modules are not required to be provided with a GFDI.* | | N/A |
| | *Exception No. 2: Inverters or charge controllers without GFDI devices may be used when the unit includes markings in accordance with 69.4(S).* | | N/A |
| 34.2 | The ground-fault detector/interrupter (GFDI) shall sense a ground fault, interrupt the ground-fault current path and provide an indication of the fault when the ground-fault currents exceed the limits shown in Table 34.1. | | N/A |
| 34.3 | A ground fault detector/interrupter that has tripped in accordance with 34.2 shall not be capable of automatic reclosure. | | N/A |
| 34.4 | When a ground fault detector/interrupter trips as a result of utility loss of power in accordance with Utility Disconnect, Section 43, it shall be capable of automatic reclosure when power is restored. | | N/A |
| 34.5 | When the ground fault detector/interrupter incorporates solid-state components, the ground fault detector/interrupter circuit shall be analyzed to determine the effect of malfunction of any component excluding the short circuiting of a resistor. Critical components identified by the failure mode and effect analysis in accordance with the Standard for Tests for Safety-Related Controls Employing Solid-State | | N/A |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| | Devices, UL 991, shall be derated in accordance with the Electronic Reliability Design Handbook, Military Hand Book Number 338-1988. | | |
| 34.6 | When the analysis specified in 34.5 indicates that the malfunction of one or more components renders the ground fault detector/interrupter inoperative, the components shall comply with the Standard for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991. See 34.7 and 34.8. | | N/A |
| 34.7 | With reference to 34.6, the components are to be subjected to the following test in accordance with the methods described in the Standard for Test for Safety-Related Controls Employing Solid-State Devices, UL 991:<br>a) Transient Overvoltage Test,<br>b) Ramp Voltage Test,<br>c) Electromagnetic Susceptibility Tests,<br>d) Electrostatic Discharge Test,<br>e) Thermally Cycling Tests,<br>f) Humidity Test, and<br>g) Effects of Shipping and Storage Test. | | N/A |
| 34.8 | For the tests specified in 34.7:<br>a) Electrical supervision of critical components applies,<br>b) Audibility is usable as a trouble indicator for an electrical supervision circuit,<br>c) A field strength of 3 volts per meter is to be used for the Radiated EMI Test, and<br>d) Exposure class H5 is to be used for the Humidity Test. | | N/A |
| 34.9 | An integral ground-fault detector/interrupter (GFDI) or a separate device shall not be linked to any main photovoltaic disconnect (internal or external to the unit) and operation of the main photovoltaic disconnect shall not affect the normal grounding of the system. | | N/A |
| 34.10 | An integral ground-fault detector/interrupter (GFDI) or a photovoltaic inverter intended for operation with a separate GFDI shall be marked in accordance with 67.15. | | N/A |

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| **35** | **Printed-Wiring Boards** | | P |
| 35.1 | A printed-wiring board in a unit shall comply with the Standard for Printed-Wiring Boards, UL 796. For a unit with miscellaneous or ventilation | | P |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| | 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.* | | N/A |

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| **36** | **External Transformers** | | N/A |
| 36.1 | A manufacturer-specified external isolation transformer, see 2.25A, shall comply with the Standard for Dry-Type General Purpose and Power Transformers, UL 1561, or the Standard for Transformers, Distribution, Dry-Type B Over 600 Volts, UL 1562, whichever applies. | | N/A |
| 36.2 | A product that measures the utility voltage and frequency through a manufacturer-specified external isolation transformer that is also used to export power to the EPS shall be provided with that manufacturer-specified external isolation transformer. | | N/A |
| 36.3 | A product, not covered by 36.2, that uses a manufacturer-specified external isolation transformer shall be provided with instructions in accordance with 68.2.8. | | N/A |
| | | | |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |

**PROTECTION AGAINST RISKS OF INJURY TO PERSONS**

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|---|---|---|---|
| **37** | **General** | | P |
| 37.1 | When operation, maintenance, or foreseeable misuse of a unit involves a risk of injury to persons, protection shall be provided to reduce the risk. | | P |
| 37.2 | Among the factors to be regarded in judging exposed moving parts are:<br>a) Degree of exposure required to perform its intended function,<br>b) Sharpness of the moving part,<br>c) Potential for unintentional contact,<br>d) Speed of the moving part, and<br>e) Potential for a part of the body to be endangered or for clothing to be entangled by the moving part. | | N/A |
| | These factors are to be regarded with respect to both intended operation of the unit and foreseeable misuse. | | N/A |
| 37.3 | Whether a guard, a release, an interlock, or similar device is required and whether such a device functions as intended shall be determined from a study of the complete unit, its operating characteristics, and the potential for a risk of injury to persons. The investigation is to include evaluation of the results of a breakdown or malfunction of any one component; however, not more than one component is to be investigated at a time, unless one event contributes to another. When the study shows that malfunction of a component is able to result in a risk of injury to persons, that component is to be investigated for reliability. | | N/A |

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| **38** | **Enclosures and Guards** | | P |
| 38.1 | A part capable of resulting in a risk of injury to persons shall be enclosed. | | P |
| 38.2 | An opening in a guard or enclosure around a moving part that is able to involve a risk of injury to persons shall have a minor dimension less than 25.4 mm (1 inch), and shall not accommodate the probe illustrated in Figure 11.1 to contact the part when the probe is inserted through the opening to its maximum depth in a straight or articulated position. | The opening is less than 25.4mm | P |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |

**PROTECTION AGAINST RISKS OF INJURY TO PERSONS**

| | | | |
|---|---|---|---|
| 38.3 | An enclosure, an opening, a frame, a guard, a knob, a handle, or similar component, shall not be sharp enough to constitute a risk of injury to persons in normal maintenance or use. | | P |
| 38.4 | A guard or portion of an enclosure acting as a guard for a part that involves a risk of injury to persons shall be: | | P |
| | a) Mounted to the assembly so that the part is unable to be operated with the guard or portion of the enclosure removed, | | P |
| | b) Secured to the assembly using fasteners requiring a tool for removal, or | | N/A |
| | c) Provided with an interlock to reduce the risk of contacting the part. | | N/A |

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| **39** | **Moving Parts** | | P |
| 39.1 | A rotating member, such as a fan blade, breakage of which results in a risk of injury to persons, shall be enclosed or guarded to reduce the risk of injury to persons. | | P |
| 39.2 | A rotating or moving part that involves a risk of injury to persons when it becomes disengaged shall be provided with a positive means to retain it in place under conditions of use. | | N/A |

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| **40** | **Switches and Controls** | | P |
| 40.1 | When unintentional operation of a switch involves a risk of injury to persons, the actuator of the switch shall be located or guarded so that such operation is unforeseeable. | | P |
| 40.2 | When required in accordance with 40.1, the actuator of a switch shall be guarded by recessing ribs, barriers, or similar component. | | P |

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| **41** | **Mounting** | | N/A |
| 41.1 | When mounting instructions furnished with a unit specify mounting hardware that is not readily available commercially, the manufacturer shall provide the hardware with the unit. | | N/A |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |

**OUTPUT POWER CHARACTERISTICS AND UTILITY COMPATIBILITY**

| | | | |
|---|---|---|---|
| **42** | **General** | | N/A |
| 42.1 | A stand-alone inverter shall comply with 48.2.1 and with the harmonic voltage distortion requirements in 48.4.1. | | N/A |
| 42.2 | A utility-interactive inverter shall comply with the applicable tests in Utility Interaction, Section 43. | | N/A |
| **43** | **Utility Interaction** | | N/A |
| 43.1 | A utility-interactive inverter or interconnection system equipment (ISE) shall comply with the Standard for Interconnecting Distributed Resources With Electric Power Systems, IEEE 1547, and the Standard for Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems, IEEE 1547.1, excluding the requirements for Interconnection Installation Evaluation, Commissioning Tests, and Periodic Interconnection Tests. | | N/A |
| 43.2 | Interactive equipment and interconnection system equipment (ISE) shall be provided with adjustable functions, parameters, limits and response times as defined by product ratings, including referenced interconnection requirements. | | N/A |
| 43.3 | For interactive inverter or interconnection system equipment (ISE) with adjustable parameters, the controls (locally or accessible through communication) shall only be accessible to authorized personnel. | | N/A |
| 43.4 | For units with field adjustable trip points, the installation manual shall describe the trip limit and time adjustment ranges in addition to the default factory settings, see 68.2.1(g). | | N/A |
| 43.5 | Units with field adjustable trip points shall be provided with a means to display or indicate the programmed trip limits, trip times and reconnect time delay. | | N/A |
| | *Exception: ISE with provisions for signal injection testing of trip limits, trip times and reconnect time delay complies with this requirement.* | | N/A |
| 43.6 | Each combination of microprocessor model, manufacturer and firmware/software version used in the production of a utility-interactive inverter or interconnection system equipment (ISE) shall be evaluated in accordance with 43.1. | | N/A |
| | *Exception: For units with firmware/software that is in compliance with the Standard for Software in Programmable Components, UL 1998, subsequent* | | N/A |

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|---|---|---|---|
| Clause | Requirement – Test | Measuring result – Remark | Verdict |

**OUTPUT POWER CHARACTERISTICS AND UTILITY COMPATIBILITY**

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| | *firmware/software revisions may be entitled to a limited revaluation in accordance with 43.1 as determined by the subsequent UL 1998 evaluation of the revised firmware or software. The scope of the 43.1 re-evaluation shall be defined by the potential impact of the firmware or software revisions.* | |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |

**PERFORMANCE**

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| **44** | **General** | | P |
| 44.1 | Inverters and converters shall be subjected to the tests described in Sections 46 – 60. | | P |
| 44.2 | Unless otherwise specified, the unit 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. The output of a utility-interactive inverter or converter is to be connected to a supply voltage as specified in 44.3 and Table 44.1. | | P |
| 44.3 | When a simulated utility source is required for a test, the impedance of the simulated utility source for a utility-interactive inverter shall be less than 5 percent of the inverter output impedance where the inverter output impedance is equal to the inverter rated output voltage divided by the inverter rated output current. | | N/A |
| 44.4 | When a simulated utility source is required for a test, the actual utility is able to be used for the simulated utility. | | N/A |
| 44.5 | Input and output overcurrent protection is to be installed in accordance with the manufacturer's instructions. | | N/A |
| 44.6 | 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 utility 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. | | P |

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| **45** | **Maximum-Voltage Measurements** | | P |

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| **46** | **Temperature** | | P |
| 46.2 | *Exception: The temperature maximums specified for casual contact in Table 46.2 do not apply when:*<br>*a) The unit is a fixed unit that is typically not subject to contact by persons;*<br>*b) The unit is marked as required by 67.8; and*<br>*c) The unit is provided with instructions as specified in 69.4(H).* | | N/A |

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|---|---|---|---|
| Clause | Requirement – Test | Measuring result – Remark | Verdict |

**PERFORMANCE**

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|---|---|---|
| 46.9 | *Exception: The change-of-resistance method is to be used for a coil that is inaccessible for attachment of thermocouples, such as a coil:*<br>*a) Immersed in sealing compound,*<br>*b) Wrapped with thermal insulation, or*<br>*c) Wrapped with more than two layers of material, such as cotton, paper, or rayon, more than 0.8 mm (1/32 inch) thick.* | N/A |

| | | | |
|---|---|---|---|
| **47** | **Dielectric Voltage-Withstand Test** | | P |
| 47.1.a) (3) | *Exception: A test between input and output circuits is not required for an inverter not provided with a transformer or capacitor network isolating the input from the output circuit.* | | N/A |
| 47.1.c) | *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.* | | P |
| 47.1 | *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.* | | P |
| 47.2 | *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.* | | N/A |

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|---|---|---|---|
| **48** | **Output Power Characteristics** | | P |
| 48.1 | When a utility-interactive inverter or ac module is required to be connected to a simulated utility source by Sections 48.2 – 48.4, the simulated utility source shall be in accordance with 44.3. | | P |
| 48.2 | **Output ratings** | | P |
| 48.3 | **Input range** | | P |
| | *Exception: This test does not apply to an ac module inverter that is provided integral to a photovoltaic panel.* | | N/A |
| 48.4 | **Harmonic distortion** | | N/A |
| | *Exception: A unit having total rms harmonic voltages exceeding 30 percent of the fundamental rms output voltage rating meets the intent of the requirement when the inverter is marked in accordance with 66.29.* | | P |

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| **49** | **Utility Compatibility**<br>…comply with IEEE 1547, and IEEE 1547.1… | | N/A |

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|---|---|---|---|
| **50** | **Abnormal Tests** | | P |

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|---|---|---|---|
| Clause | Requirement – Test | Measuring result – Remark | Verdict |

**PERFORMANCE**

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|---|---|---|---|
| 50.1 | **General** | | P |
| 50.1.2 | *Exception No. 1: More than one abnormal test is able to be conducted on a unit, and the dielectric voltage-withstand test is able to be conducted after completion of all abnormal tests.* | | P |
| | *Exception No. 2: This test is not required following the DC Input Miswiring Test, Section 50.4.* | | N/A |
| 50.1.4 | *Exception No. 1: A unit not having bottom openings is not required to be placed on a softwood surface covered with tissue paper.* | | N/A |
| | *Exception No. 2: When it is inappropriate to drape the entire unit, cheesecloth is able to be placed only over all ventilation openings.* | | P |
| 50.1.3 | *Exception No. 1: When the manually reset protector is a circuit breaker that complies with the Standard for Molded-Case Circuit Breakers, Molded-Case Switches and Circuit-Breaker Enclosures, UL 489, it is to be operated for 3 cycles using the minimum resetting time not exceeding 10 cycles of operation per minute.* | | N/A |
| | *Exception No. 2: A manual reset protector that becomes inoperative in the open condition is able to be operated fewer than 10 cycles, and not less than 3 cycles.* | | N/A |
| 50.2 | **Output overload test** | | P |
| 50.2.3 | *Exception: Thermal stabilization is obtainable with a load adjusted to result in maximum obtainable output power without resulting in operation of overcurrent protective devices, followed by increased incremental loading as described in 50.2.3.* | | P |
| 50.3 | **Short-circuit test** | | P |
| 50.4 | **DC input miswiring test** | | P |
| 50.5 | **Ventilation test** | | P |
| 50.5.2 | *Exception: Simultaneously locking all fan motors in a unit having more than one fan motor is not prohibited.* | | N/A |
| 50.6 | **Component short- and open-circuit** | | P |
| 50.6.1 | *Exception: This test is not required:*<br>*a) Where circuit analysis indicates that no other component or portion of the circuit is able to be overloaded.*<br>*b) For components in low-voltage, limited-energy (LVLE) circuits, or other circuits that are not required to be investigated in accordance with this Standard.* | | N/A |
| 50.7 | **Load transfer test** | | N/A |
| 50.8 | **Loss of Control Circuit** | | N/A |
| | *Exception No. 1: When the control circuit is unable to be disabled under any single fault condition, this test is not required to be performed.* | | N/A |
| | *Exception No. 2: The unit may continue to export power if it continues to meet 43.1 with the single fault specified in 50.8.2 in place.* | | N/A |

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|---|---|---|---|
| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| **PERFORMANCE** | | | |
| **51** | **Grounding Impedance Test** | | N/A |
| **52** | **Overcurrent Protection Calibration Test** | | N/A |
| **53** | **Strain Relief Test** | | N/A |
| **54** | **Reduced Spacings on Printed Wiring Boards Tests** | | N/A |
| 54.1 | **General** | | N/A |
| 54.2 | **Dielectric voltage-withstand test** | | N/A |
| 54.3 | **Shorted trace test** | | N/A |
| **55** | **Bonding Conductor Test** | | N/A |
| 55.1 | *Exception: When a fuse smaller than that indicated in (a) and (b) is employed in the unit for protection of the circuit to which the bonding conductor is connected, the magnitude of the test current and size of fuse used during the test is to be based on the rating of the smaller fuse.* | | N/A |
| **56** | **Voltage Surge Test** | | N/A |
| **57** | **Calibration Test** | | N/A |
| **58** | **Overvoltage Test** | | N/A |
| **59** | **Current Withstand Test** | | N/A |
| **60** | **Capacitor Voltage Determination Test** | | P |
| **61** | **Stability** | | P |
| 61.1 | *Exception: A unit provided with instructions indicating that it is to be fastened to the supporting structure is not required to be tested for stability.* | | N/A |
| **62** | **Static Load** | | P |
| 62.1 | *Exception: A unit intended for floor mounting or an ac module is not required to be subjected to this test.* | | N/A |
| **63** | **Compression Test** | | N/A |

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|---|---|---|---|
| Clause | Requirement – Test | Measuring result – Remark | Verdict |

**PERFORMANCE**

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|---|---|---|---|
| **64** | **Rain and Sprinkler Tests** | | N/A |
| 64.1 | **General** | | N/A |
| 64.1.4 | *Exception: When water enters ground-mounted or surface-mounted units and the water does not wet any wiring or other electrical parts that are not inherently waterproof, and when the unit is provided with drain holes in accordance with 7.9.14, the unit is in compliance with the rain and sprinkler tests.* | | N/A |
| 64.2 | **Rain test** | | N/A |
| 64.3 | **Sprinkler test** | | N/A |
| | | | |

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|---|---|---|---|
| Clause | Requirement – Test | Measuring result – Remark | Verdict |

**RATING**

| **65** | **Details** | | P |
|---|---|---|---|
| 65.1 | A unit shall be rated as shown in Table 65.1. | | P |

Table 65.1 Unit ratings

| **Rating type** | **Utility-interactive** | **Stand-alone** | **Utility-interactive with charge control[d]** | **Stand-alone with charge control[d]** | **ISE** | **Charge controllers[d]** |
|---|---|---|---|---|---|---|
| a) Maximum input voltage [a] | X[b] | X | X | X | X | X |
| b) Range of input operating voltage | X[b] | X | X | X | X | X |
| c) Maximum input current (ac or dc) | X[b] | X | X | X | | X |
| d) Maximum input short circuit current | X[b] | X | X | X | X | X |
| e) Maximum input source backfeed current to input source [see 50.6.2] | X | | X | | | |
| f) Output power factor rating | X | X | X | X | | |
| g) Operating voltage range (ac) | X | X | X | X | X | X |
| h) Operating frequency range or single frequency | X | X | X | X | | X |
| i) Nominal output voltage (ac) | X | X | X | X | | |
| j) Normal output frequency | X | X | X | X | | |
| k) Maximum continuous output current (ac) | X | X | X | X | | |
| l) Maximum continuous output power (ac) | X | X | X | X | | |
| m) Maximum output fault current (ac) and duration | X | X | X | X | | |
| n) Maximum output overcurrent protection [c] | X | X | X | X | | |
| o) Nominal output voltage (dc) | | | X | X | | |
| p) Charging output voltage operation range (dc) | | | X | X | | X |
| q) Utility interconnection voltage and frequency trip limits and trip times | X | | | | X | |
| r) Synchronization in-rush current | X | | | | | |
| s) Trip limit and trip time accuracy | X | | X | | X | |
| t) Normal operation temperature range | X | X | X | X | X | X |
| u) Output power temperature derating and maximum full power operating ambient [e] | X | X | X | X | | X |

Note – A nationally accepted conventional abbreviation may be used for the rating type.
[a] The maximum input voltage determined in accordance with Section 690.7(a) of the National Electrical Code, NFPA 70, may be used for photovoltaic inverters and charge controllers.
[b] Not required for ac modules.
[c] Normally the branch-circuit overcurrent protection.

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[d] Charging of batteries is able to originate from dc or ac sources. The rating types for either ac or dc are to be applied accordingly.
[e] Only for units that derate with output temperature.

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**MARKING**

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| **66** | **Details** | | P |
| 66.1 | Unless otherwise stated, all markings shall be permanent. The following types of markings or the equivalent meet this requirement: | | P |
| | a) Molded, | | N/A |
| | b) Die-stamped, | | P |
| | c) Paint-stenciled, | | N/A |
| | d) Stamped or etched metal that is permanently secured, or | | P |
| | e) Indelibly stamped on a pressure-sensitive label complying with the Standard for Marking and Labeling Systems, UL 969. | | N/A |
| 66.2 | A unit shall be plainly and permanently marked where it is readily visible after installation with: | | P |
| | a) The manufacturer's name, trademark, or other descriptive marking by which the organization responsible for the product is able to be identified – hereinafter referred to as the manufacturer's name, | | P |
| | b) A distinctive catalog number or the equivalent, | | P |
| | c) The electrical ratings other than items a, d, e, m, n, q, r, s, t, and u specified in Table 65.1, and | | P |
| | d) The date or other dating period of manufacture not exceeding any three consecutive months. The repetition time cycle of a date code shall not be less than 20 years. | | P |
| | The date code shall not require reference to the manufacturer's records to determine when the unit was manufactured. | | P |
| | *Exception No. 1: The manufacturer's identification is able to be in a traceable code when the unit is identified by the brand or trademark of a private labeler.* | | N/A |
| | *Exception No. 2: The date of manufacture is able to be abbreviated in a nationally accepted conventional code, or in a code affirmed by the manufacturer.* | | P |
| 66.3 | When an inverter, converter, or interconnection system equipment (ISE) is intended for connection with an EPS and complies with Utility Compatibility, Section 49, it shall be marked "Utility-Interactive", "Interconnection System Equipment", or the equivalent. | | N/A |
| 66.4 | When an inverter, converter, or interconnection system equipment (ISE) is intended for | | N/A |

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| | connection with an EPS, complies with Utility Compatibility, Section 49, and with IEEE 1547-2003, it shall be marked“Utility Interactive Inverter” or equivalent to indicate the specific document and version of the interconnect requirements to which it complies. Example “Compliant with IEEE 1547a-2014 (Amd. 1)” or equivalent.<br>Inverters that comply with the requirements of UL 1741 Supplement SA, as well as the equirements for a utility interactive inverters shall be marked “Grid Support Interactive Inverter“ or “Grid Support Utility Interactive Inverter“. A reference to the specific standard(s) and version(s) complied with may optionally be added to the marking and shall be included in the installation instructions. | | |
| 66.5 | With reference to the Exception to 43.2, the inverter or interconnection system equipment (ISE) manual shall be marked with the following:<br>“This unit or system is provided with fixed trip limits and shall not be aggregated above 30 kW on a single Point of Common Connection.” | | N/A |
| 66.6 | A unit or separate device provided with integral dc ground-fault detector/interrupter protection in accordance with DC Ground-Fault Detector/Interrupter, Section 34, shall be marked to indicate its presence. If the separate device is not self-contained and is intended for installation in another enclosure, the device shall be provided with a label for fixing to the outside of the enclosure to indicate its presence. | | N/A |
| 66.7 | When a unit is produced or assembled at more than one factory, each unit shall have a distinctive marking – which is able to be in code – to identify the product of a particular factory. | | N/A |
| 66.8 | The symbols described in items (a) – (c) are usable for markings to comply with the requirement in Table 65.1: | | P |
| | a) A circuit intended to be connected to a dc circuit shall be identified by markings indicating that the circuit shall be dc. The symbol illustrated in Figure 66.1 meets the requirement for this marking. See 66.9. | | P |
| | b) A circuit intended to be connected to an ac circuit shall be identified by markings indicating that the circuit shall be ac. The markings shall include the supply-circuit frequency or supply- circuit frequency-range | | P |

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| | rating (cycles per second, cycles/second, hertz, c/s, cps, or Hz). The symbol illustrated in Figure 66.2 meets the requirement for this marking. See 66.9. | | |
| | c) The number of phases shall be indicated when the unit is designed for use on a polyphase circuit. The symbol illustrated in Figure 66.3 is equivalent to the word “phase”. See 66.9. | | N/A |
| 66.9 | When a symbol referenced in 66.8(a), (b), and (c) is used, the information described in 69.4(G) shall be provided as part of the Important Safety Instructions. | | P |
| 66.10 | The operating positions of a handle, knob, or other means intended for manual operation by the user shall be marked. | | N/A |
| 66.11 | Wiring terminals shall be marked to indicate the intended connections for the unit, or a wiring diagram coded to the terminal marking shall be securely attached to the unit. | | N/A |
| | *Exception: The terminal markings are not required when the wire connections are evident.* | | N/A |
| 66.12 | Field-wiring terminals shall be marked in accordance with 69.4 (L) and (M), Table 69.3, and the following: | | N/A |
| | a) “Use Copper Conductors Only” when the terminal is rated only for connections to copper wire, | | N/A |
| | b) “Use Aluminum Conductors Only” or “Use Aluminum Or Copper-Clad Aluminum Conductors Only” when the terminal is rated only for connection to aluminum wire, or | | N/A |
| | c) “Use Copper Or Aluminum Conductors” or “Use Copper, Copper-Clad Aluminum, or Aluminum Conductors” when the terminal is rated for connection to copper or aluminum wire. | | N/A |
| 66.13 | With reference to 20.1.13 a pressure wire connector or stud-and-nut type terminal intended for connection of an equipment-grounding conductor shall be identified by: | | N/A |
| | a) Being marked “G,” “GR,” “GND,” “Ground,” “Grounding,” or equivalent, | | N/A |
| | b) A marking on a wiring diagram attached to the unit, or | | N/A |

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| | c) The symbol illustrated in Figure 66.4 on or adjacent to the connector or on a wiring diagram provided on the unit. See 65.15. | | N/A |
| 66.14 | In accordance with 46.3, a unit having an ambient temperature rating higher than 25°C (77°F) shall be marked to indicate the maximum ambient temperature rating. When tested in accordance with 46.1(c) and 48.2.4, this rating shall include the reduced output power rating. | | P |
| 66.15 | With reference to 66.13(c), the following requirements apply when the symbol illustrated in Figure 66.4 is used: | | N/A |
| | a) The information described in 69.4(G) shall be provided in the Important Safety Instructions. | | N/A |
| | b) The symbol is usable for identifying only the field wiring equipment-grounding terminal. However, a symbol as shown in Figure 66.4 is usable with the circle omitted for identifying various points within the unit that are bonded to ground. | | N/A |
| | *Exception: Where the symbol illustrated in Figure 66.4 is used with one of the alternate means of identification specified in 66.13(a) and (b), the information is not required to be provided in the Important Safety Instructions.* | | N/A |
| 66.16 | A terminal for the connection of a grounded conductor shall be identified by means of a metallic plated coating substantially white in color, and shall be readily distinguishable from the other terminals; or identification of the terminal for the connection of the grounded conductor shall be clearly shown in some other manner, such as: | | N/A |
| | a) A marking on the unit, | | N/A |
| | b) An indication on a wiring diagram attached to the unit, or | | N/A |
| | c) Information provided in the instruction manual. | | N/A |
| | A field wiring lead intended to be grounded shall have a white or gray color and shall be readily distinguishable from other leads. | | N/A |
| 66.17 | A terminal, as described in 20.2.1, intended for connection of the grounding electrode conductor shall be marked “Grounding Electrode Terminal”. | | N/A |
| 66.18 | A unit employing pressure terminal connectors for field wiring connections shall be provided with a marking making reference to the instruction manual for the tightening torque to be applied to | | N/A |

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| | the wiring terminals. See 69.4(F). | | |
| 66.19 | A unit intended to be used with a remote battery supply shall be plainly marked indicating the polarity of the connections between the battery supply and the unit with: | | N/A |
| | a) The words ″positive″ and ″negative,″ | | N/A |
| | b) The signs ″+″ for positive and ″-″ for negative, or | | N/A |
| | c) A pictorial representation illustrating the proper polarity, orientation, and similar properties of the battery connections, as applicable for the type of battery supply involved. | | N/A |
| 66.20 | A multiple-voltage output unit for permanent connection to the branch circuit shall be marked to indicate the particular voltage for which it is set when shipped from the factory. The marking is able to be in the form of a paper tag or any other nonpermanent material. | | P |
| 66.21 | Both the on and off positions of the disconnect control devices specified in Switches and Controls, Section 14, or in Disconnect Devices, Section 15, shall be identified. The symbols illustrated in Figure 66.5 are usable for this purpose. The identification shall not be by illumination only. See 66.22. | | P |
| 66.22 | When the symbol illustrated in Figure 66.5 is used in accordance with 66.21, the information described in 69.2(G) shall be provided. | | P |
| 66.23 | A clock, timing device, or alarm circuit– on or remote from a unit – that is not a low-voltage, limited-energy (LVLE) circuit and that remains energized during servicing functions shall be marked to indicate that the circuit remains energized while the unit is off. | | N/A |
| 66.24 | With reference to 18.3.4(b), a unit containing a field-wiring lead that is intended to be connected to a wire binding screw located in the field-wiring compartment shall be marked with information clearly indicating the intended use of the lead. | | N/A |
| 66.25 | With reference to the Exception to 20.1.8, low-voltage Class 2 field-wiring leads that are not color coded shall be identified. The identification shall not require the use of a separate wiring diagram to make proper connections. | | P |
| 66.26 | A stand-alone unit having grounding type receptacles for the output ac current connections | | P |

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| | shall be marked: "One side of the output circuit is bonded to the inverter frame. Connect the grounding electrode terminal to a grounding electrode in accordance with the local codes." | | |
| 66.27 | With reference to 15.1(d), a marking shall be provided identifying the disconnect device, switch, or breaker for the output ac and dc power circuits. | | N/A |
| 66.28 | With reference to the Exception to 19.2, a unit intended for use with a field installed conductor that is of a size smaller than maximum rated conductor size yet rated for use with the field connection pressure terminal shall be marked: "Use ____ maximum AWG wire only for field connector" or the equivalent. | | P |
| 66.29 | In accordance with the Exception to 48.4.1, an inverter with a total harmonic distortion rms that exceeds 30 percent of the fundamental rms output voltage rating shall be marked to indicate the percentage that the total rms harmonic distortion exceeds the fundamental rms output voltage rating. | | N/A |
| 66.30 | An enclosure other than Type 1 shall be permanently marked with the Type designation indicating the external conditions for which it is intended as specified in the Standard for Enclosures for Electrical Equipment, UL 50. An enclosure that complies with the requirements for more than one Type of enclosure is able to be marked with multiple designations. The marking shall be on the inside or outside surface and shall be visible after installation during inspection of the field wiring connections. In addition to the Type designation marking, the optional markings specified in Table 66.1 are able to be used. | | N/A |
| 66.31 | When conduit hubs are not provided for a Type 2, 3, 3R, or 3S enclosure, the enclosure, the instruction sheet provided with the enclosure, or the packaging carton shall be marked to indicate that raintight or wet location hubs that comply with the requirements in the Standard for Fittings for Conduit and Outlet Boxes, UL 514B, are to be used. | | N/A |
| 66.32 | A separable conduit hub and a closure fitting shall be marked with the manufacturer's name or trademark and the catalog number or equivalent. Such a hub or fitting is able to be shipped separately, and any gasket, hardware, and instructions, required for installation shall be | | N/A |

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| | shipped with the fitting or packaged with the enclosure. | | |
| 66.33 | A Type 2 or 3R enclosure that has knockouts for conduit in the sides or back of the enclosure and in which the equipment to be installed is not known shall be marked to indicate the area in which live parts are to be installed. See Exception No. 1 to 7.9.4 and Exception No. 1 to 7.9.6. | | N/A |
| 66.34 | A Type 4X enclosure intended for indoor use only shall be marked “4X Indoor Use Only” in letters not less than 4.0 mm (5/32 inch) high. | | N/A |
| 66.35 | When required by the Exception to 7.9.9, a marking shall be provided to instruct the installer to fill the opening with a Type 12 conduit fitting. | | N/A |

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| **67** | **Cautionary Markings** | | P |
| 67.1 | There shall be no substitute for the words “CAUTION”, “WARNING″ or ″DANGER″ in the text of a marking. | | P |
| | *Exception: The words “WARNING” or “DANGER” are usable in lieu of the word “CAUTION.”* | | P |
| 67.2 | A cautionary marking shall be prefixed by the word “CAUTION”, “WARNING″ or ″DANGER″ ” in letters not less than 3.2 mm (1/8 inch) high. The remaining letters shall not be less than 1.6 mm (1/16 inch) high. | | P |
| 67.3 | A cautionary marking shall be:<br>a) Located on a part that is not removable without impairing the operation of the unit, and<br>b) Visible and legible to the operator during the normal operation of the unit. | | P |
| | *Exception: Cautionary markings pertaining to internal parts that are applicable only to service personnel are to be located internally in an appropriate location with respect to the parts of concern.* | | N/A |
| 67.4 | A live heat sink or other part that:<br>a) Is mistakable for dead metal,<br>b) Involves a risk of electric shock in accordance with Electric Shock, Section 13, and<br>c) Is not guarded as specified in 12.7<br>shall be marked “CAUTION – Risk of Electric Shock– Plates (or other word describing the type of part) are live. Disconnect unit before servicing”. The marking shall be located on or | | N/A |

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| | near the live part so as to make the risk known before the part is touched. A single marking for multiple parts is usable. | | |
| 67.5 | An inverter intended to be used with an isolation transformer that is not supplied with the inverter shall be marked "CAUTION – For Proper Circuit Isolation" and the following words or the equivalent "Connect a minimum ___ kVA rated isolating transformer between the output of the unit and the utility power line connections. The transformer is to be an isolation type having separate primary and secondary windings." | | N/A |
| 67.6 | For compliance with Exception No. 2 to 7.2.1, a unit shall be marked with the word "CAUTION_" and the following or equivalent: "Risk of Electric Shock, Do Not Remove Cover. No User Serviceable Parts Inside. Refer Servicing To Qualified Service Personnel." | | P |
| 67.7 | For each fuse that is used to comply with the requirements in this Standard, there shall be a legible and durable marking indicating the ampere, voltage and "ac" or "dc" rating of the fuse to be used for replacement. The marking shall be located so that it is obvious as to which fuse or fuseholder the marking applies. This marking is able to consist of a pictorial identifying the rating of one or more fuses. In addition, the following prominent marking shall be provided – a single marking is usable for a group of fuses:<br>"WARNING – For Continued Protection Against Risk Of Fire, Replace Only With Same Type And Ratings Of Fuse." | | P |
| | *Exception: The requirement does not apply to a fuse that is secured by solder.* | | P |
| 67.8 | An inverter shall be marked with the word" CAUTION" and the following words "Risk Of Electric Shock –" and the following or the equivalent. The marking shall be located on the outside of the unit or shall be prominently visible with any cover or panel opened or removed: | | P |
| | a) "Both ac and dc voltage sources are terminated inside this equipment. Each circuit must be individually disconnected before servicing" and | | N/A |
| | b) "When the photovoltaic array is exposed to light, it supplies a dc voltage to this equipment." | | N/A |

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| 67.9 | A unit that exceeds the temperature limits specified in Table 46.2 – see the Exception to 46.2 – shall be legibly marked externally where readily visible after installation with the word. "CAUTION" and the following or the equivalent:<br>"Hot surfaces – To reduce the risk of burns – Do not touch." | | N/A |
| 67.10 | A unit provided with single-pole circuit breakers in the input or output circuit in accordance with the Exception to 32.1.8 shall be marked internally with the word "CAUTION" and the following or the equivalent:<br>"To reduce the risk of electric shock and fire – Do not connect to a circuit operating at more than 150 volts to ground." | | N/A |
| 67.11 | A removable panel covering a capacitor in accordance with Exception No. 1 to 13.2.3 shall be marked "CAUTION – Risk of electric shock from energy stored in capacitor" and the following or equivalent wording:<br>"Do not remove cover until ___ minutes after disconnecting all sources of supply."<br>The time indicated in the marking is to be the time required to discharge the capacitor to within the limitations specified in 13.2.1, and shall be less than 5 minutes. | | N/A |
| 67.12 | With reference to Exception No. 2 to 13.2.3, a unit shall be marked "CAUTION – Risk of electric shock and/or electric energy-high current levels" and the following or equivalent wording:<br>"Disconnect and discharge (identify capacitor) before removing panel as follows."<br>Appropriate instructions shall follow indicating how to discharge the capacitor. The procedure indicated shall be limited to functions such as operating a switch, unplugging a connector, or the equivalent. When the time to discharge the capacitor or capacitor bank is longer than 1 second, the unit shall be additionally marked to indicate the minimum discharge time with the following or the equivalent:<br>"Do not remove cover until ___ minutes after connecting the discharge circuit."<br>The time indicated in this marking shall not exceed 1 minute for momentary type switches and 5 minutes for other means that actuate the discharge circuit. | | N/A |

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| 67.13 | An ungrounded dead metal part specified in the Exception to 20.2, item (f), shall be marked with the word “CAUTION” and the following or the equivalent:<br>“(Identify part or parts not earth grounded) (is) (are) not grounded – (it) (they) involve a risk of electric shock. Test before touching.”<br>The marking shall be provided on or adjacent to the ungrounded dead metal part and shall be visible so that each part or group of parts is positively identified. | | N/A |
| 67.14 | With reference to Exception No. 3 to 13.2.3, a marking shall be provided indicating “CAUTION – Risk of electric shock or electrical energy-high current levels” and the following or the equivalent:<br>“High-energy electric charge is stored in (identify capacitor) and associated circuitry. Test before touching.”<br>The marking shall be located internally adjacent to the capacitor. | | N/A |
| 67.15 | With reference to 34.10, units with integral ground-fault detector/interrupter or separate devices having the same function shall be marked with the word “CAUTION” and the following or equivalent:<br>“Risk of Electric Shock. Normally Grounded Conductors May Be Ungrounded and Energized When a Ground-Fault is Indicated”<br>If the separate device is not self-contained and is intended for installation in another enclosure, the device shall be provided with a label for fixing to the outside of the enclosure to indicate the caution statement. | | N/A |

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| **68** | **Equipment Information and Instructions** | | P |
| 68.1 | **Separation of information** | | P |
| 68.1.1 | Operating and operator-servicing instructions shall be separated from servicing instructions. | | P |

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| 68.1.2 | Where servicing requires access to parts that involve a risk of electric shock, servicing instructions shall be preceded by a warning. The warning shall be worded as follows or the equivalent "Warning – These servicing instructions are for use by qualified personnel only. To reduce the risk of electric shock, do not perform any servicing other than that specified in the operating instructions unless you are qualified to do so."<br>The letter height shall be in accordance with 67.2. | | P |
| 68.2 | **Operating and installation instructions** | | P |
| 68.2.1 | The operating and installation instructions shall: | | P |
| | a) Describe the equipment installation, including specifically:<br>1) Assembly, and mounting, where required,<br>2) Grounding means, and<br>3) Ventilation consideration; | | N/A |
| | b) Explain equipment markings, including specifically:<br>1) Symbols,<br>2) Controls, and<br>3) All applicable ratings in Table 65.1; | | P |
| | c) Identify and describe interconnections with:<br>1) The input source,<br>2) The utility, and<br>3) Auxiliary and accessory equipment; | | P |
| | d) Explain the operation of the equipment; | | P |
| | e) Indicate that the ac output (neutral) is (is not) bonded to ground; | | P |
| | f) In accordance with 16.2.3(a), an inverter provided with a fixed ac output shall inform the installer that the input and output circuits are isolated from the enclosure and that system grounding, when required by Sections 690.41, 690.42, and 690.43 of the National Electric Code, ANSI/NFPA 70, is the responsibility of the installer; | | N/A |
| | g) Field adjustable trip limits for voltage and frequency shall be described and include the adjustment range for voltage, frequency and trip time. The "as shipped" default settings shall be specified; and | | N/A |

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| | h) Integral dc ground-fault detector/interrupter protection shall describe the proper method for connecting and grounding the photovoltaic system. | | N/A |
| 68.2.2 | The important safety instructions shall appear before the battery installation procedures and maintenance. | | N/A |
| 68.2.3 | The installation instructions shall indicate that the wiring methods in accordance with the National Electrical Code, ANSI/NFPA 70 are to be used. | | N/A |
| 68.2.4 | An enclosure marked Type 4, 4X, 6, or 6P shall be provided with instructions for installation of a Watertight conduit connection when the connection is not mounted on the enclosure. | | N/A |
| 68.2.5 | Installation instructions shall be provided with an enclosure intended for field assembly of the bonding means that identifies the parts for bonding and specifies the method of installation. | | N/A |
| 68.2.6 | When a hub or fitting is not provided or installed on a Type 4 or 4X enclosure, instructions identifying the specific hub or fitting and installation instructions shall be provided with the enclosure. | | N/A |
| 68.2.7 | A polymeric enclosure shall have instructions stating that the hub is to be connected to the conduit before the hub is connected to the enclosure when it: | | N/A |
| | a) Is intended for connection to a rigid conduit system, | | N/A |
| | b) Has not been subjected to the torque test described in Polymeric Enclosure Rigid Metallic Conduit Connection Tests in the Standard for Enclosures for Electrical Equipment, UL 50, and | | N/A |
| | c) Is not provided with a preassembled hub. | | N/A |
| 68.2.8 | With reference to 36.3, a product, not covered by 36.2, that uses a manufacturer-specified external isolation transformer shall be provided with instructions that specify the manufacturer, model, electrical ratings, and environmental ratings for the external isolation transformer with which it is intended to be used. | | P |

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| **69** | **Important Safety Instructions** | P |

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| 69.1 | The headings “IMPORTANT SAFETY INSTRUCTIONS” and “SAVE THESE INSTRUCTIONS” for the instruction manual, and the opening statements of the instructions in the important safety instructions shall be entirely in upper case letters not less than 4.8 mm (3/16 inch) high or emphasized to distinguish them from the rest of the text. Upper case letters in the instructions shall not be less than 2.0 mm (5/64 inch) high, and lower case letters shall not be less than 1.6 mm (1/16 inch) high. | | P |
| 69.2 | There shall be no substitute for the words “CAUTION,” “WARNING,” or “DANGER” in the text of the instructions. | | P |
| | *Exception: The words “WARNING” or “DANGER” are usable in lieu of the word “CAUTION.”* | | P |
| 69.3 | The important safety instructions described in items A – S in 69.4, as appropriate, shall be provided with each unit. The information contained in items C – S is able to be marked on the unit or in the instruction manual. | | P |
| 69.4 | The important safety instructions shall include instructions for the following items A – S. The statement "IMPORTANT SAFETY INSTRUCTIONS”, and the statement “SAVE THESE INSTRUCTIONS” shall precede the list.<br>The word “WARNING”, “CAUTION”, and “DANGER” shall be entirely in upper case letters. | | P |
| | **IMPORTANT SAFETY INSTRUCTIONS**<br>A. SAVE THESE INSTRUCTIONS– This manual contains important instructions for Models _____ (blank space is to be filled in with appropriate model numbers) that shall be followed during installation and maintenance of the _____ (blank space is to indicate inverter or charge controller as appropriate). | | P |
| | *Exception: When the instructions are exactly the same for all models, specific model numbers are not required.* | | N/A |
| | B. In accordance with 18.2.4, when pressure terminal connectors or the fastening hardware are not provided on the unit as shipped, the instruction manual shall indicate which pressure terminal connector or component terminal assemblies are for use with the unit. | | N/A |
| | C. With reference to item B, the terminal assembly packages and the instruction manual shall include information identifying wire size and manufacturer’s name, trademark, or other descriptive marking by which the organization responsible for the product is identifiable. | | N/A |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |

**RATING**

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| | D. When a pressure terminal connector provided in the unit (or in a terminal assembly covered in 18.2.4(d)) for a field installed conductor requires the use of other than a common tool for securing the conductor, identification of the tool and any required instructions for using the tool shall be included in the instruction manual. | N/A |
| | E. A unit provided with a wire connector for field installed wiring as covered in Exception No. 2 to 18.3.1 shall be provided with instructions specifying that the connector provided is to be used in making the field connection. | N/A |
| | F. A unit employing pressure terminal connectors for field wiring connections shall be provided with instructions specifying a range of values or a nominal value of tightening torque to be applied to the clamping screws of the terminal connectors. The minimum specified tightening torque shall not be less than 90 percent of the value specified in Tables 69.1 or 69.2 applicable to the wire size determined in accordance with 18.1.3. | N/A |
| | *Exception: A torque less than 90 percent is usable when the connector – using the lesser assigned torque value – complies with the Standard for Wire Connectors, UL 486A-486B, or the Standard for Equipment Wiring Terminals for Use with Aluminum and/or Copper Conductors, UL 486E.* | N/A |
| | G. When a symbol is used for compliance with marking requirements specified in 66.9, 66.14, or 66.22, the instruction manual shall identify the symbol. | P |
| | H. The instruction manual for a unit that exceeds the temperature limits of Table 46.2 (see the Exception to 46.2) shall specify that the unit is to be installed so that it is not expected to be contacted by persons. | N/A |
| | I. The instruction manual for a charge controller or an inverter intended to charge batteries shall indicate the nominal voltage rating of the battery supply and a generic description of the batteries, such as lead acid, nickel cadmium, and vented or sealed. | P |
| | J. In accordance with 46.3, the instruction manual for an inverter having an ambient temperature rating higher than 25°C (77°F) shall indicate the maximum ambient temperature rating. | P |
| | K. For a unit having a single equipment field-wiring terminal that is intended for connection of more than one conductor, the instruction manual shall include information identifying the number of conductors and range of conductor sizes. | P |
| | L. For a unit provided with field-wiring terminals or leads, the instruction manual shall include the information indicated in Row 1, 2, 3, or 4 of Table 66.3 or with equivalent wording, when it is:<br>1) Intended for use on a supply circuit rated 110 amperes or less, or<br>2) Intended for field connection with 1 AWG (42.4 mm2) or smaller conductors. | P |
| | M. For a unit provided with field-wiring terminals or leads, the instruction manual shall include the information indicated in Row 3 or 4 of Table 69.3, or with equivalent wording, when it is:<br>1) Intended for use on a supply circuit rated more than 110 amperes, or<br>2) Intended for field connection with conductors larger than 1 AWG (42.4 $mm^2$). | N/A |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |

**RATING**

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| | N. When required by the Exception to 18.6.1, the instruction manual shall include a statement indicating that Class 1 wiring methods are to be used for field wiring connections to terminals of a Class 2 circuit. | N/A |
| | O. In accordance with 50.1.7, when an abnormal test is terminated by operation of the intended branch-circuit overcurrent protective device, the instruction manual for a unit shall include the word “CAUTION” and the following or the equivalent:<br>“To reduce the risk of fire, connect only to a circuit provided with _____ amperes maximum branch-circuit overcurrent protection in accordance with the National Electrical Code, ANSI/NFPA 70”.<br>The blank space is to be filled in with the ampere rating of branch-circuit overcurrent protection described in 50.1.7. | N/A |
| | P. When required by the Exception to 32.3.1, the instruction manual shall include a statement indicating that overcurrent protection for the ac output circuit is to be provided by others. | N/A |
| | Q. When required by the Exception to 32.4.1, the instruction manual shall include a statement indicating that overcurrent protection for the battery circuit is to be provided by others. | N/A |
| | R. An inverter with 120 V output shall be provided with instructions that include the word “WARNING” and the following or the equivalent:<br>“To reduce the risk of fire, do not connect to an ac load center (circuit breaker panel) having multiwire branch circuits connected.” | P |
| | S. When required by Exception No. 2 to 34.1, the manual shall include the word “WARNING” and the following or equivalent:<br>“This unit is not provided with a GFDI device. This inverter or charge controller must be used with an external GFDI device as required by the Article 690 of the National Electrical Code for the installation location.” | N/A |
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| Clause | Requirement – Test | Measuring result – Remark | Verdict |

**MANUFACTURING AND PRODUCTION TESTS**

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| **70** | **Dielectric Voltage-Withstand Test** | | P |
| 70.1 | Each unit shall withstand without breakdown, as a routine production-line test, the application of a potential: | | P |
| | a) From input and output wiring, including connected components, to accessible dead metal parts that are able to become energized, and | | P |
| | b) From input and output wiring to accessible low-voltage, limited-energy metal parts, including terminals. | | P |
| 70.2 | Other than as noted in 70.3, the potential for the production-line test shall be in accordance with Condition A or Condition B of Table 70.1 at a frequency within the range of 40 – 70 Hertz. | | N/A |
| 70.3 | A unit employing circuitry that is able to be damaged by an ac potential is able to be tested using a dc potential in accordance with Condition C or Condition D of Table 70.1. | | P |
| 70.4 | Testing of a unit in a heated or unheated condition meets the intent of the requirement for manufacturing and production tests. | | N/A |
| 70.5 | The test is to be performed on a complete, fully assembled unit. It is not intended that the unit be unwired, modified, or disassembled for the test. | | N/A |
| | *Exception No. 1: A part, such as a snap cover or a friction-fit knob, that interferes with the performance of the test is to be removed.* | | N/A |
| | *Exception No. 2: The test is able to be performed on a partial or modified unit as long as it has been evaluated to be representative of a complete unit.* | | N/A |
| | *Exception No. 3: The grounding connection of a grounded input terminal is able to be disconnected.* | | N/A |
| 70.6 | A unit employing a solid-state component that is not relied upon to reduce a risk of electric shock and that is susceptible to damage by the dielectric potential, is able to be tested before the component is electrically connected or after the component is electrically disconnected. The circuitry is able to be rearranged for the purpose of the test to minimize the potential of solid-state-component damage while retaining representative dielectric stress of the circuit. | | N/A |
| 70.7 | The test equipment for supplying an ac potential is to include a transformer having a sinusoidal output. The test equipment is to include a means of indicating the test potential, an audible or visual indicator of breakdown, and a manually | | N/A |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |

**MANUFACTURING AND PRODUCTION TESTS**

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| | reset device to restore the equipment after breakdown or a feature to automatically reject a noncomplying unit. | | |
| 70.8 | Where the output rating of the test equipment transformer is less than 500 VA, the equipment is to include a voltmeter in the output circuit to directly indicate the test potential. | | N/A |
| 70.9 | Where the output rating of the test equipment transformer is 500 VA or more, the test potential is to be indicated: | | N/A |
| | a) By a voltmeter in the primary circuit or in a tertiary-winding circuit, | | N/A |
| | b) By a selector switch marked to indicate the test potential, or | | N/A |
| | c) In the case of equipment having a single test-potential output, by a marking in a readily visible location to indicate the test potential. When marking is used without an indicating voltmeter, the equipment shall include a positive means, such as an indicator lamp, to indicate that the manually reset switch has been reset following a dielectric breakdown. | | N/A |
| 70.10 | Test equipment, other than that described in 70.7 – 70.9, is usable when found to accomplish the intended factory control. | | N/A |
| 70.11 | During the test, the unit switches are to be in the on position, both sides of the input and output circuits of the unit are to be connected together and to one terminal of the test equipment, and the second test-equipment terminal is to be connected to the accessible dead metal. | | N/A |
| | *Exception: A switch is not required to be in the on position when the testing means applies full test potential from the input and output wiring to dead metal parts with the switch not in the on position.* | | N/A |

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| **71** | **Production Tests for Interactive Equipment** | | N/A |
| 68.1 | Products rated for compliance with IEEE 1547-2003 and IEEE 1547.1-2005 shall comply with the applicable requirements in IEEE 1547.1-2005, Section 6, Production tests. Products rated for compliance with IEEE 1547-2003 and IEEE 1547.1-2005 shall comply with the applicable requirements in IEEE 1547.1-2005, Section 6, Production tests. | | N/A |
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| Clause | Requirement – Test | Measuring result – Remark | Verdict |

**INTRODUCTION**

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| **72** | **General** | | N/A |
| 72.1 | These requirements cover permanently connected charge controllers that are intended to be installed in photovoltaic panels, photovoltaic power distribution equipment, and control panels or systems. | | N/A |
| 72.2 | The requirements in Sections 72 – 83 supplement and, in some cases, amend the requirements in Sections 6 – 70. | | N/A |

**CONSTRUCTION**

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| **73** | **General** | | N/A |
| 73.1 | One of the internal current-carrying conductors (normally the negative), connecting the charge controller's input to output, shall be identified as the grounded conductor where the controller is used in grounded circuits or systems. The grounded conductor shall not contain any components, such as relays, transistors or similar devices. | | N/A |
| | *Exception: A shunt provided in the negative line is in compliance with the requirement.* | | N/A |
| 73.2 | When a shunt is provided in accordance with the Exception to 73.1, the point of connection to system ground shall be identified. The cross-sectional area of the shunt shall not be less than the minimum size conductor for the intended current and material type. See Table 21.2 for examples. | | N/A |
| | *Exception: A smaller size shunt meets the intent of the requirement when:*<br>*a) The measured temperatures do not exceed the ratings of the support materials or surrounding components under normal operation, and*<br>*b) The shunt does not open as a result of the tests in Abnormal Tests, Section 50.* | | N/A |
| 73.3 | Controls for the adjustment of the state-of-charge of a battery shall be accessible for qualified service personnel only. | | N/A |
| | *Exception: An on/off switch or disconnect device of a charge controller, power distribution panel, or inverter shall not be deemed a control for the state-of-charge of a battery.* | | N/A |
| 73.4 | When a charge controller employs temperature compensating monitoring, the monitoring means shall be remote from the charge controller, see 82.3 and 82.4. | | N/A |
| | *Exception: The monitoring means is able to be internal to a unit when the unit is* | | N/A |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| | *marked in accordance with 82.4 and, the unit is provided with instructions as described in 83.6.* | | |
| 73.5 | The polymeric material in a charge controller that is intended to be installed internally to the wiring compartment of a photovoltaic module shall have a relative thermal index of 90°C (194°F) minimum. | | N/A |

**PERFORMANCE**

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| **74** | **General** | | P |
| 74.1 | A charge controller shall be tested as described in 76.1 – 80.4. | | P |
| 74.2 | A charge controller intended for use in a photovoltaic control panel is to be installed in the smallest specified size enclosure. | | N/A |
| 74.3 | A charge controller intended for use in a photovoltaic module wiring compartment is to be installed in the smallest sized compartment in which the controller is able to be installed. Prior to testing, the charge controller is to be subjected to 20 cycles of the Temperature Cycle Test in accordance with the Standard for Flat-Plate Photovoltaic Modules and Panels, UL 1703. When performing the tests, the charge controller, without an electrical enclosure, is to be in an ambient of 60°C (140°F) minimum or as rated by the manufacturer. | | N/A |
| 74.4 | When performing tests on a charge controller, the input dc voltage is to be equal to 125 percent of the open-circuit voltage rating and is to be capable of delivering 125 percent of the rated short-circuit current of the photovoltaic source circuit intended for use with the charge controller. A battery or a simulated battery load is able to be used. A simulated battery load is to consist of one of the following loads: | | P |
| | **Table 74.1 Simulated battery loads** | | — |

| Battery current rating, amperes | Capacitance in microfarads |
|---|---|
| 0-20 | 100,000 |
| 20-40 | 185,000 |
| >40 | 300,00 |

| | | | |
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| | The capacitance is to be in parallel with a resistor and a power supply adjusted to simulate the battery voltage and adjusted to draw a specified operational battery charge current as required by the charge controller design. A series charge | | N/A |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |

**PERFORMANCE**

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| | controller is also able to be tested as shown in Figure 74.1. | | |

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| **76** | **Normal Operations** | | P |
| 76.1 | When tested as described in 76.3 – 76.5, a charge controller shall not exceed its rated input, output, or battery charge/discharge current by more than +10 percent. | | P |
| 76.2 | When tested as described in 76.3 – 76.5, a charge controller shall not exceed its rated voltages. An on/off and constant voltage charge controller shall not have an output voltage at the battery terminals or at load terminals that exceeds its rated value by more than +10 percent after the first minute of operation. | | P |
| 76.3 | The charge controller is to be connected to a photovoltaic array or simulated source adjusted as specified in Sources and Loads, Section 75. The battery interface terminals of the charge controller are to be open circuited. The output or load terminals of the charge controller are to be connected to a load. The load is to be adjusted to draw the maximum attainable output current from the charge controller and the voltage is to be measured at the load terminals and at the battery terminals. When the charge controller does not function with open-circuited battery terminals, the test method described in 76.5 is to be used. | | N/A |
| 76.4 | Once operational, the load is then to be adjusted over a range of operation, excluding short-circuit, and the voltage is to be measured at the output (load) terminals and at the battery interface for each value of load. | | N/A |
| 76.5 | For a charge controller that does not function with open-circuited battery terminals, the charge controller is to be connected to a photovoltaic source or simulated source capable of providing 125 percent of the rated current of the intended photovoltaic circuit. The output of the charge controller is to be connected to a load. The battery terminals are to be connected to a battery or battery simulator operating at the charge controller rated battery voltage. The load is to be adjusted to draw the maximum rated current of the charge controller. The test method specified in 76.4 is to be conducted while measuring output current. | | N/A |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |

**PERFORMANCE**

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| **77** | **Temperature** | | P |
| 77.1 | When tested as specified in Temperature, Section 46, the temperatures measured on polymeric materials in a charge controller intended to be installed in accordance with 73.5 shall not exceed the relative thermal index rating of the material determined in accordance with the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B. | | P |

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| **78** | **Temperature Compensation** | | N/A |
| 78.1 | While the temperature sensor input is in a short- or open-circuit condition, a charge controller provided with integral temperature compensation shall shut down or limit the output charge to the load when tested as specified in 78.2. | | N/A |
| 78.2 | The charge controller is to be connected to its rated input supply and rated load. The temperature sensor input is to be open-circuited and then short-circuited, one at a time. | | N/A |

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| **79** | **Connection Sequence** | | N/A |
| 79.1 | When tested as described in 79.2 – 79.4, the voltages and currents for a charge controller shall remain within their rated values. | | N/A |
| 79.2 | A charge controller marked with a connection sequence is to be connected in the prescribed manner and then tested in accordance with Normal Operations, Section 76. | | N/A |
| 79.3 | A charge controller not marked with a prescribed connection sequence is to be tested first, with the battery connected before the photovoltaic source, and then with the photovoltaic source connected and energized before the battery is connected. Output to the battery or load is to be measured in accordance with Normal Operations, Section 76. | | N/A |
| 79.4 | For all charge controllers, the battery voltage is to be disconnected and reconnected during normal operation. The voltages and currents are to be measured at the photovoltaic input, load output, and battery terminals. | | N/A |

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| **80** | **Abnormal Tests** | | P |
| 80.1 | **General** | | P |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| **PERFORMANCE** | | | |
| 80.1.1 | When tested as described in 50.2 – 50.6 and 80.2 – 80.4, a charge controller shall comply with 50.1.1. | | P |
| 80.1.2 | During any of the tests in 80.2 – 80.4, when shorting of the battery output terminals is required while under load, relaying shall be used to short the terminals of the unit under test while open-circuiting the battery. | | P |
| 80.2 | **Input and output faults** | | N/A |
| 80.2.1 | The photovoltaic array connections of a charge controller are to be connected to a dc simulator and the load (output) terminals are to be loaded to their rated load. While in a loaded state, the photovoltaic input to the charge controller is to be short-circuited. | | N/A |
| 80.2.2 | The photovoltaic array connections of a charge controller are to be connected to a dc supply and the rated load (output). While in a loaded state, the output of the charge controller is to be short-circuited. | | N/A |
| 80.3 | **Charge controller miswiring** | | N/A |
| 80.3.1 | A charge controller is to be connected to its rated photovoltaic source or simulated photovoltaic source and battery as noted in Table 80.1. The connection order and polarity shall be as noted in the Table. When connecting the second supply source, battery or array, it is to be connected through a relaying device, such that the first source is already energized prior to the second source. | | N/A |
| | *Exception: Those tests which limit the connection sequence do not apply to a charge controller which is marked in accordance with 81.1. For example, when a controller is marked in accordance with 81.1 indicating to connect array first, tests A, C, D, and E are not required to be performed.* | | N/A |
| 80.3.2 | When a simulated array source is used, a reverse-biased diode shall be placed across the supply to simulate the possible activation of an array bypass diode. | | N/A |
| 80.3.3 | As a result of the test for charge controllers which have load control terminals, there shall not be reverse polarity voltage present on the terminals or current unless condition A of Table 80.1 occurs. | | N/A |
| 80.3.4 | During the test, no additional external overcurrent protection is to be in the test circuit. | | N/A |
| 80.4 | **Low-voltage disconnect** | | N/A |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |

**PERFORMANCE**

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| 80.4.1 | When tested as described in 80.4.2, a charge controller shall operate in a stable, controlled manner over all ranges of charge and discharge of a battery load. | | N/A |
| 80.4.2 | A charge controller with a low-voltage disconnect is to be connected to a source providing the charge controller's rated input, a battery or simulated battery load, and a rated load. The battery source is to be adjusted to 25 percent, 50 percent, 75 percent, and 100 percent of the rated battery voltage. The load is to be adjusted so that the charge controller cycles in accordance with the charge controller design from battery charge to battery discharge state. Adjustable charge set-points are to be set to their closest tolerance so that the charge controller cycles during the battery charge. | | N/A |
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**MARKING**

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| **81** | **Cautionary Markings** | | P |
| 81.1 | A charge controller which requires a specific connection method in accordance with 80.3.1 shall be marked "CAUTION: Risk of fire and shock, connect _____ terminals prior to the connection of _____ terminals" indicating the battery or array terminals as appropriate. | | P |

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| **82** | **Details** | | P |
| 82.1 | A charge controller shall be marked in accordance with Details, Section 66, and Cautionary Markings, Section 67. | | P |
| 82.2 | A charge controller intended to be installed in the wiring compartment of a photovoltaic module shall be marked to identify the manufacturer and model number of the photovoltaic module in which the controller is intended to be installed. | | N/A |
| 82.3 | A charge controller with a temperature compensating set-point that is intended to be adjusted by service personnel shall be marked with set-point details. | | N/A |
| 82.4 | A charge controller with an internal temperature compensating means shall be marked "CAUTION: Internal Temperature Compensation. RISK OF FIRE, USE WITHIN ____ m (ft) of BATTERIES" or "RISK OF FIRE, MOUNT IN | | P |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |

**PERFORMANCE**

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| | CONTACT WITH BATTERIES." | | |
| 82.5 | A charge controller shall be marked with the minimum interrupting rating of the overcurrent protective device to be used for short-circuit protection. For example, "Minimum interrupting rating _____A dc." | | N/A |

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| **83** | **Important Safety Instructions** | | P |
| 83.1 | The installation instructions shall identify the conductor or the terminal described in 73.1 as the conductor or the terminal to be used as the grounded conductor in grounded circuits. | | N/A |
| 83.2 | The installation instructions shall specify the type and chemical composition of the battery with which the charge controller is intended to be used [see 69.4(l)]. | | N/A |
| 83.3 | A charge controller intended for field installation shall be provided with a wiring diagram or installation instructions that specify the method of installation including the connection method and wire size range in accordance with Article 690 of the National Electrical Code, NFPA 70. | | N/A |
| 83.4 | The installation instructions for a charge controller intended to be installed in the wiring compartment of a photovoltaic module shall specify the manufacturer and model of the photovoltaic module. | | N/A |
| 83.5 | The installation instructions for a charge controller shall describe the maximum overcurrent protection to be provided in accordance with Article 690 of the National Electrical Code, NFPA 70. | | N/A |
| 83.6 | The installation instructions for a charge controller with an internal temperature compensating means shall indicate where the controller is to be used with respect to the batteries (See 82.4) and the risks associated with the improper installation. | | N/A |
| 83.7 | The installation instructions for a charge controller with service personnel adjustable temperature compensating set-points shall describe the battery chemistry and types for each set point. The instructions shall detail the risks associated with improper settings. | | N/A |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |

**AC MODULES AND PV MODULES WITH INTEGRATED ELECTRONICS**

**INTRODUCTION**

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| **84** | **General** | | P |
| 84.1 | The requirements in Sections 85 – 91 supplement and, in some cases, amend the general requirements in Sections 6 – 71. | | P |

**CONSTRUCTION**

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| **85** | **General** | | P |
| 85.1 | An ac module shall be utility interactive and shall not be capable of stand alone operation. All requirements for utility-interactive inverters in Sections 6 – 71 shall apply. | | N/A |
| 85.2 | The photovoltaic panel or module of an ac module shall comply with the requirements in the Standard for Flat-Plate Photovoltaic Modules and Panels, UL 1703. | | N/A |
| 85.4 | All components across the dc input circuit of an ac module shall be rated for 125 percent of rated crystalline silicon photovoltaic module open-circuit voltage. | | P |
| 85.5 | For amorphous silicate or thin film photovoltaic modules, the components across the line shall be rated for the photovoltaic module open-circuit voltage regardless of the temperature. | | N/A |
| 85.6 | An ac disconnection means such as a terminal, connector, or similar means shall be provided. | | P |
| 85.7 | Polymeric materials shall have a relative thermal index in accordance with the Standard for Polymeric Materials – Long Term Property Evaluations, UL 746B, not less than the temperature measured during the normal temperature test and not less than 90°C (194°F). | | N/A |
| 85.8 | Connectors employed external to the module shall comply with the material and conditioning requirements in the Standard for Flat-Plate Photovoltaic Modules and Panels, UL 1703, in addition to the Standard for Attachment Plugs and Receptacles, UL 498. Connection shall not be of a NEMA configuration. | | P |
| 85.10 | Equipment grounding for a dc input circuit specified in 20.1.2 does not apply to an ac module. | | N/A |
| 85.12 | A gasket provided as part of the protective housing used on an ac module enclosure shall | | N/A |

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| Clause | Requirement – Test | Measuring result – Remark | Verdict |

**CONSTRUCTION**

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| | comply with the requirements in the Standard for Flat-Plate Photovoltaic Modules and Panels, UL 1703. | | |

**PERFORMANCE**

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| **86** | **General** | | N/A |
| 86.1 | Where electronics are mounted to the PV module with adhesive, the securement to the module shall be in accordance with PV Module Mounted Equipment Securement Test, Section 87. | | N/A |
| 86.2 | The Temperature Test, Section 46, is to be conducted as defined in either 86.3 or 86.4 based on the manufacturer's specified environmental temperature rating. The environmental temperature rating used shall be marked on the product and included in the installation instructions. | | N/A |
| 86.3 | The Temperature Test, Section 43, is to be conducted in an ambient of 35°C (95°F) or greater. | | N/A |

| | | | |
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| **87** | **PV Module Mounted Equipment Securement Test** | | N/A |
| 87.1 | Equipment secured to a PV module with adhesive shall comply with Sequence C in Figure 1 of the Standard for Photovoltaic (PV) Module Safety Qualification – Part 2: Requirements For Testing, UL 61730-2. During the MST 16 testing of Sequence C, the electronics may alternatively be tested with the Dielectric Voltage-Withstand Test, Section 47, in place of the Sequence C Insulation Test. | | N/A |
| 87.2 | In addition to the compliance criteria defined in the referenced tests for 87.1, the test shall not result in: | | N/A |
| | a) Exposure of live parts, | | N/A |
| | b) Separation of the enclosure from the substrate or superstrate, or | | N/A |
| | c) Fracturing of the enclosure, substrate, or superstrate. | | N/A |

| | | | |
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| **88** | **Module to Electronics Bonding** | | N/A |
| 88.1 | Equipment bonding between the PV modules and electronics having accessible conductive surfaces shall comply with this Section. | | N/A |
| 88.2 | Equipment bonding between the PV module equipment grounding conductor terminal or lead | | N/A |

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|---|---|---|---|
| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| | and the accessible conductive surfaces of AC modules and PVIE shall comply with the Section 13, Bonding Path Resistance Test 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, following preconditioning with the Section 18, Humidity Test. | | |
| | *Exception: The test sample from the testing in 87.1 may be used without the Section 18, Humidity Test preconditioning.* | | N/A |
| 88.3 | If multiple smaller diameter grounding conductors are used to provide the necessary crosssectional area for an equipment ground or bond for circuits or equipment with higher fault currents, the combination of smaller conductors shall be evaluated and tested using one fewer than the minimum<br>number required / rated by the manufacturer.<br>Example – If a system is rated such that at least 5 microinverters on a string harness of microinverters is suitable to provide a grounding / bonding path for a mounting rack of PV modules the wire size and test current shall be based upon the use of 4 microinverters to account for one being removed from service. | | N/A |

**RATING**

| | | | |
|---|---|---|---|
| **89** | **General** | | N/A |
| 89.1 | An ac module inverter that is provided integral to the photovoltaic module is not required to be provided with the dc input ratings specified in items (a) – (e) in Table 65.1. | | N/A |

**MARKING**

| | | | |
|---|---|---|---|
| **90** | **Details** | | N/A |
| 90.1 | The output of an ac module shall be marked with the maximum parallel combination of modules that it is intended for. | | N/A |
| 90.2 | AC modules and PVIE shall be marked with the ratings required in Section 89. | | N/A |
| 90.5 | Other markings as required by this standard shall be applied for the product and or function. See Sections 66 and 67 for additional information. | | N/A |

| | | | |
|---|---|---|---|
| **91** | **Important Safety Instructions** | | N/A |

| UL 1741 | | | |
|---|---|---|---|
| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| 91.1 | The important safety instructions shall include a statement(s) indicating the applicable information in Sections 89 and 90. | | N/A |

**RAPID SHUTDOWN EQUIPMENT AND SYSTEMS**
**INTRODUCTION**

| | | | |
|---|---|---|---|
| **92** | **General** | | N/A |
| 92.1 | The requirements in Sections 92 through 102 supplement and, in some cases, amend the general requirements in Sections 6 through 71. | | N/A |

**CONSTRUCTION**

| | | | |
|---|---|---|---|
| **93** | **Protection of Emergency Personnel** | | N/A |
| 93.2 | A PVRSS shall maintain controlled conductors at a limit of not more than 30 Vdc, 8A (for dc circuits) or 15 Vac, 8A (for ac circuits) within the time limit specified in the ratings. Both ac and dc circuits are required to not exceed 240 VA (volt-amperes) in the controlled state. PVRSE are evaluated to perform specific functions within PVRSS as defined by their specified functions and ratings. | | N/A |

| | | | |
|---|---|---|---|
| **94** | **Electrical Isolation Systems (EIS)** | | N/A |
| 94.1 | PVRSE that uses contactors or relays for isolation of controlled conductors shall contain electrical or electronic arc suppression devices on any contacts to minimize the radiated and conducted radio frequency (RF) signature of arcs created when those contacts open. | | N/A |

| | | | |
|---|---|---|---|
| **95** | **Initiators** | | N/A |
| 95.1 | An initiator for PVRSS functions shall be clearly identifiable for the function it performs. | | N/A |
| | a) The position of the initiators shall indicate the functional status of the controlled conductors, i.e. “ON” or OFF”. An “OFF” status indicates controlled conductors are in the controlled state, in accordance with 93.2. | | |
| | b) The manually operable initiator shall require manual resetting, using a reset device or manipulation of the initiator. | | N/A |
| | c) An input designed to receive an external initiation signal from emergency devices, such as fire alarm systems, shall require manual resetting. An external initiation signal, that may initiate shutdown due to other non PVRSS conditions such as inverter shutdowns due to grid fault or loss shall be permitted to automatically reset. | | N/A |

| UL 1741 | | | |
|---|---|---|---|
| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| | d) Where the PVRSS is capable of accepting initiation inputs from multiple manual or external initiation devices (e.g. fire alarm), the initiation system shall have those devices or inputs connected in such a manner that activation of any one of the devices or inputs will result in initiating the PVRSS. | | N/A |
| | e) If a status indicator light is provided, it shall indicate not later than specified response time from the initiation of the rapid shutdown and only after the PVRSS function properly occurs. | | N/A |
| **96** | **PVRSS that Includes Disconnect Functionality** | | N/A |
| 96.1 | PVRSS that includes PVRSE that will also be evaluated as a system or equipment disconnect described in 93.7 shall comply with the additional following requirements: | | N/A |
| | a) The PVRSE shall have a means for remote control by an initiator and the switching device shall comply with requirements for an electrically tripped or power operable disconnect device from one of the standards listed in 93.7. | | N/A |
| | b) The manual switching device shall allow disconnection by either manual operation or by initiator. | | N/A |
| | c) The manual switching device shall not allow manual closure (connection) while the initiator is activated (conductors placed in the controlled state). | | N/A |
| | d) The manual switching device shall be able to determine the status of the initiator at all times.<br>Failure mode analysis and functional safety evaluation shall result in the switching device being disconnected (conductors placed in the controlled state) due to loss of initiator status. | | N/A |
| | e) The combination PVRSE or PVRSS and the disconnect function shall comply with all applicable sections for PVRSE and PVRSS in this standard, including environmental stress testing applied to the mechanical devices. | | N/A |
| **97** | **PVRSS and PVRSE Functional Safety** | | N/A |
| 97.1 | General | | N/A |
| 97.1.1 | PVRSS or PVRSE that use electronic controls, communication and/or firmware shall be subjected to a risk assessment for functional safety. | | N/A |

| UL 1741 | | | |
|---|---|---|---|
| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| 97.1.2 | Standards listed in Table 97.1 shall be used along with the requirements in Section 99 to evaluate the PVRSE and if evaluating an entire PVRSS, each PVRSE of the PVRSS. | | N/A |
| 97.1.3 | All PVRSE, including mechanical devices, shall consider conditions noted in Section 97.2 and environmental stress testing in Section 99. | | N/A |
| 97.1.4 | The rapid shutdown function of the PVRSS or PVRSE shall not be affected by the appropriate environmental stresses described in Table 99.1. Verification of function may be required during and/or after the applicable environmental stress tests. | | N/A |
| 97.1.5 | An entire PVRSS can be evaluated as a combination. Each device within the PVRSS that uses electronic controls, communications and/or firmware to perform its rapid shutdown function shall be evaluated. The markings and instructions shall identify all the devices to be interconnected. | | N/A |
| 97.1.6 | PVRSE may be evaluated individually when the interaction with other devices is considered in the evaluation and explained in the manufacturer's instructions. | | N/A |
| 97.1.7 | Devices using electronic controls for the rapid shutdown function under evaluation shall have a failure mode and effect analysis (FMEA) performed as described in the standards listed in Table 97.1. | | N/A |
| 97.1.8 | Devices that also use firmware/software for the PVRSS and PVRSE function shall include a risk assessment considering the interaction of the firmware and circuit as performed in UL 1998 or other standards listed in Table 97.1. The software/firmware version shall be controlled. | | N/A |
| 97.1.9 | Any single point component failure (short or open) that causes the device not to perform its intended function or does not cause the PVRSS to lock into the controlled conductor mode shall be identified as a critical component. Critical components shall be evaluated in accordance with UL 991 or the equivalent functional safety standard listed in Table 97.1. If the PVRSS has a self-test system to identify the failure of a critical component, then the operation of a self-test system shall be verified by testing with faults implemented to simulate failure of each of the system elements covered by the self-test system. Under each fault condition 10 test cycles of operation shall be conducted. The self-test system shall recognize the fault or failure and it | | N/A |

| UL 1741 | | | |
|---|---|---|---|
| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| | shall initiate a shutdown as described in Section 98.1. | | |
| 97.1.10 | Inverters or other devices that have not been evaluated as part of a PVRSS and rely on a separate PVRSE for controlling conductors connected to input or output ports, do not require a functional safety evaluation if they are not performing PVRSS functions (such as but not limited to simple energy storage devices like capacitors, having no interactions in the PVRSS functions). Such devices shall be tested to verify that controlled input and output ports comply with 93.2 limits when the external source is removed as tested in Section 98. | | N/A |

| | | | |
|---|---|---|---|
| **97.2** | **Conditions to be addressed for a PVRSS/PVRSE** | | N/A |
| 97.1 | General | | N/A |

**PERFORMANCE**

| | | | |
|---|---|---|---|
| **98** | **General** | | N/A |
| 98.1 | Operational tests for PVRSS/PVRSE verification of levels – controlled conductors | | N/A |
| 98.2 | Verification testing of PVRSS at rated extremes | | N/A |
| 98.3 | Power supply grid support ride through | | N/A |
| 98.4 | Inverters rated as PVRSE | | N/A |
| 98.5 | Other equipment rated as PVRSE | | N/A |

| | | | |
|---|---|---|---|
| 99 | **Functional Safety Evaluation and Environmental Stress Testing For PVRSS/PVRSE** | | N/A |
| 99.1 | A Rapid Shutdown System, a Rapid Shutdown System component, or an inverter or converter intended for use as a part of a PVRSS shall comply with the limits in 93.2 on its dc or ac input or output terminals upon the loss of control circuit power when tested in accordance with 99.2. | | N/A |
| 99.2 | The DUT is to be connected to its rated input and output circuits, and its rated control circuit supply voltages if supplied separately. The circuit voltages shall be within ±2 % of rated. A single fault is to be placed in the control system such that it disables the power to the PVRSS control circuit. | | N/A |
| 99.3 | Additional fault testing shall be performed as identified in 97.1.7 through 97.1.9. | | N/A |

| UL 1741 | | | |
|---|---|---|---|
| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| 99.4 | Equipment evaluated to this section shall have the appropriate environmental stress test applied as listed in Table 99.1 and the rapid shutdown function verified. | | N/A |
| 99.5 | The method used to verify the correct function during a stress condition will depend on the PVRSS or PVRSE device being tested. It can include methods such as: verification of voltage levels, by communicating with the device or monitoring for a signal or change in state. For verification after the stress<br>condition, the methods in Section 98 can be used. | | N/A |
| 99.6 | Inverters performing a rapid shutdown function on the PV input conductors and/or ac output conductors by reacting to a loss of ac grid shall be evaluated to the appropriate environmental stress tests listed in Table 99.1. The alternate test methods listed in Table 99.1 for IEEE1547/IEEE1547.1 can be used in place of the Standard for Safety for Tests for Safety-Related Controls Employing Solid-State Devices, UL 991, and combined with any utility-interactive or grid support function testing. | | N/A |

**RATINGS**

| | | | |
|---|---|---|---|
| **100** | **General** | | N/A |
| 100.1 | A PVRSS system or component, used solely for the purpose of rapid shutdown, shall be rated in accordance with Table 65.1. | | N/A |

**MARKING**

| | | | |
|---|---|---|---|
| **101** | **Details** | | N/A |
| 101.1 | Only a complete PVRSS may be marked “photovoltaic rapid shutdown system.” Only PVRSE may be labeled “photovoltaic rapid shutdown system equipment.” The term “PHOTOVOLTAIC” may be replaced with “PV.” | | N/A |
| 101.2 | Only PV systems equipment that has been found to comply with the relevant PVRSS and or PVRSE requirements to perform rapid shutdown functions may be marked with the following wording or equivalent:<br>“All inputs and outputs of this product comply with photovoltaic rapid shutdown requirements for controlled conductors outside the array” or<br>“Only the indicated terminals of this product | | N/A |

| UL 1741 | | | |
|---|---|---|---|
| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| | comply with photovoltaic rapid shutdown requirements for controlled conductors outside the array" | | |
| 101.3 | Equipment described in 13.2.4 and 97.1.10 shall be marked on or near each port identified with the following markings: "PVRSS Controlled Conductor Connection Port – refer to instructions for conditions of use." | | N/A |
| 101.4 | Only PVRSS and PVRSE complying with Section 98.3 may be marked as follows; "grid support interactive compatible." | | N/A |
| 101.5 | Products evaluated as PVRSS or PVRSE shall include the relevant markings of Table 65.1 and Section 66, 101.1 – 101.4 in the installation instructions required in 102.14. | | N/A |
| 101.6 | For products with power supply grid support ride through, documentation shall include the minimum ride through times for each region from the testing of Sections SA9 and SA10. | | N/A |

| | | |
|---|---|---|
| **102** | **Installation Instructions** | N/A |

| | | | |
|---|---|---|---|
| **APPENDIX A –** Standards for Components | | | P |
| | Standards under which components of the products covered by this standard are evaluated… | | P |

| UL 1741 | | | |
|---|---|---|---|
| Clause | Requirement – Test | Measuring result – Remark | Verdict |

| **3.1** | **TABLE: List of critical components and circuits relied on for safety** | | | | |
|---|---|---|---|---|---|
| Object | Manufacturer | Type / model | Technical Data | Standard(s) | Remark |
| Enclosure | Interchangeable | Interchangeable | Metal, min thickness 0.8mm | EN 62109-1<br>EN 62109-2 | Tested within appliance |
| I/O terminal (SW) | ZHEN JIANG BEI ER JIA ELECTRONIC CO LTD | PS8A Series | AC 250V/125V, 6A/12A, 105°C | IEC/EN 61058-1<br>UL 61058-1 | VDE 40027141<br>UL E236875 |
| Load1 and AC grid terminal | DONGGUAN TERMINAL ELECTRONIC TECHNOLOGY CO LTD | RKM 6N-10-05 | Str8-10, Cu, FW2, 600V 40A, DA, 105°C | UL 486A | UL E346560 |
| PV and Load1 terminal | DONGGUAN TERMINAL ELECTRONIC TECHNOLOGY CO LTD | RKM 6N-10-02 | Str8-10, Cu, FW2,600V 40A,DA,105°C | UL 486A | UL E346560 |
| DC Fan | SHENZHEN HUAXIA HENGTAI ELECTRONIC CO.,LTD | DA08025B12UR | 12Vdc,0.5A, Rated 83.51CFM | EN IEC 62368-1:2020+A11 | TUVRheinland R 50473040 003 |
| PCB | Longnan Champion Asia Electronic Technology Co Ltd | F-D | V-0, 130°C | UL 796 | UL E254215 |
| (Alternate) | Interchangeable | Interchangeable | V-0, 130°C | UL 796 | UL |
| Mylar | Shenzhen Bornsun Industrial Co., Ltd. | BN-FP | V-0, 120°C | UL 94，UL746C | UL E256822 |
| LCM LCD display screen | SHEN ZHEN TIANRUIX ELECTRONIC CO.， LTD | TRB8277VW5.0-0A | Max 70°C | EN 62109-1<br>EN 62109-2 | Tested within appliance |
| (Alternate) | Interchangeable | Interchangeable | Interchangeable | EN 62109-1<br>EN 62109-2 | Tested within appliance |

| UL 1741 | | | |
|---|---|---|---|
| Clause | Requirement – Test | Measuring result – Remark | Verdict |

| | | | | | |
|---|---|---|---|---|---|
| Fuse (F2, F3, F4) | SHENZHEN LANSON ELECTRONICS CO LTD | SMT T3 | 15A 250V | UL 248-1<br>UL 248-14<br>IEC 60127-1<br>IEC 60127-3 | UL E221465<br>VDE 40012592 |
| Fuse(F6) | EUGARD CO.,LTD | MID | 150A 58V | UL 248 | UL E479415 |
| Thermistor (NTC2) | Thinking Electronic Industrial Co., Ltd. | SCK-2R55A | 5A,2.5Ω | UL1434<br>EN 60539-1<br>EN 60730-1 | UL E138827<br>TUV R 50050155 |
| Thermistor (NTC5) | Thinking Electronic Industrial Co., Ltd. | SCK-054 | 4A,5Ω | UL1434, EN60539-1, EN60730-1 | UL E138827, TUV R 50050155 |
| Thermistor (NTC3，NTC4) | Interchangeable | Interchangeable | 10Kohm,±1% | EN 62109-1<br>EN 62109-2 | Tested within appliance |
| Optocoupler (U31,U22,U57,U23,U59,U58,U28,U18,U29) | Lite-On Technology Corporation | LTV-817(VDE) LTV-817,LTV-817S(UL) | Dti≥ 0.4mm<br>Int.Dcr/cl≥ 7.0mm<br>Ext.Dcr/cl≥8.0mm<br>115°C | UL 1577<br>IEC 60747-5-5<br>DIN EN IEC 60747-5-5 | UL E113898<br>VDE 40015248 |
| VARISTOR (MOV4,MOV5,MOV1,MOV2,MOV3) | Thinking Electronic Industrial Co., Ltd. | TVR20561-D | 350Vac, V-0, 6KV/3KA, 85°C | UL 1449<br>IEC 61051-2<br>IEC 61051-1 | UL E314979<br>VDE 40021243 |
| X Capacitor (C24,C25) | CARLI ELECTRONICS CO LTD | MPX | 0.47uF,275/310 Vac, 100/110°C, X2 | UL 60384-14<br>IEC 60384-14<br>DIN EN 60384-14<br>EN 60384-14 | UL E120045<br>VDE 40008520 |
| X Capacitor (C27) | CARLI ELECTRONICS CO LTD | MPX | 2.2uF,275/310Vac, 100/110°C, X2 | UL 60384-14<br>IEC 60384-14<br>DIN EN 60384-14<br>EN 60384-14 | UL E120045<br>VDE 40008520 |
| Y1 Capacitor (C39,C19) | TDK Corporation | CD | 47pF, 400Vac 125°C, Y1 | UL 60384-14<br>IEC60384-14<br>DIN EN 60384-14<br>EN 60384-14 | UL E37861<br>VDE 40017931 |

| UL 1741 | | | | | |
|---|---|---|---|---|---|
| Clause | Requirement – Test | | Measuring result – Remark | | Verdict |
| Y1 Capacitor (C21, C2) | TDK Corporation | CD | 470pF, 250Vac, 125°C, Y1 | UL 60384-14 IEC60384-14 DIN EN 60384-14 EN 60384-14 | UL E37861 VDE 40029780 |
| Y Capacitor (C33,C17,C49,C38,C18,C70) | TDK Corporation | CD | 4700pF, 250Vac, 125°C, Y1 | UL 60384-14 IEC60384-14 DIN EN 60384-14 EN 60384-14 | UL E37861 VDE 40029780 |
| (Alternate) | Interchangeable | Interchangeable | 4700pF | UL 60384-14 IEC60384-14 DIN EN 60384-14 EN 60384-14 | UL E315719 VDE 40031733 |
| ELE Relay (RL1,RL3,RL2) | Sanyou Corporation Limited | SLA-S-112DMJ-G-F | 40A,250/277VAC | UL60947-1 | UL E190598 |
| Choke (L10) | Guangzhou Shiyuan Electronic Technology Company Limited | SYPQ3230-L007uA | 130°C | EN 62109-1 EN 62109-2 | Tested within appliance |
| PFC Choke (L1) | Guangzhou Shiyuan Electronic Technology Company Limited | SYNPF226-L839uA | 130°C | EN 62109-1 EN 62109-2 | Tested within appliance |
| Current Transformer (CT2) | Guangzhou Shiyuan Electronic Technology Company Limited | SYT18-T100A | 130°C | EN 62109-1 EN 62109-2 | Tested within appliance |
| -Wire | SHENZHEN DAYANG INDUSTRY CO LTD | xUEW-NY@/155 | 155°C | UL 1446 | UL E176101 |
| (Alternate) | Tongling Jingda Special Magnet Wire Co Ltd | xUEW N/155 | 155°C | UL 1446 | UL E223994 |
| (Alternate) | DONG GUAN YIDA INDUSTRIAL CO LTD | xUEW/155, QA-x/155 | 155°C | UL 1446 | UL E344055 |

| UL 1741 | | | | | |
|---|---|---|---|---|---|
| Clause | Requirement – Test | | Measuring result – Remark | | Verdict |
| -Bobbin | CHANG CHUN PLASTICS CO LTD | T375HF | 150°C, V-0 | UL 94, UL746 | UL E59481 |
| -Tube | CHANGYUAN ELECTRONICS GROUP CO LTD | CB-TT-L | 200°C, 150V | UL 224 | UL E180908 |
| (Alternate) | SHENGZHENG HANGXUAN S&T CO LTD | XH-TFL | 200°C, 150V | UL 224 | UL E361862 |
| PFC Choke(L2) | Guangzhou Shiyuan Electronic Technology Company Limited | SYNPF184-L626uA | 130°C | EN 62109-1 EN 62109-2 | Tested within appliance |
| Line filter(L4) | Guangzhou Shiyuan Electronic Technology Company Limited | SYT3615-L1.15mA | 130°C | EN 62109-1 EN 62109-2 | Tested within appliance |
| Line filter(L3) | Guangzhou Shiyuan Electronic Technology Company Limited | SYT38-L004mA | 130°C | EN 62109-1 EN 62109-2 | Tested within appliance |
| Current Transformer (CT1) | Guangzhou Shiyuan Electronic Technology Company Limited | SYEI28-T1000E | 130°C | EN 62109-1 EN 62109-2 | Tested within appliance |
| -Wire | DONG GUAN YIDA INDUSTRIAL CO LTD | xUEW/155, QA-x/155 | 155°C | UL 1446 | UL E344055 |
| (Alternate) | HUBEI SHOUTONG ELECTROMAGNETIC WIRE TECHNOLOGY CO LTD | xUEW/155, QA-x/155 | 155°C | UL 1446 | UL E362846 |
| (Alternate) | WUZHOU TOREAL COPPER CO LTD | xUEW/155, QA-x/155 | 155°C | UL 1446 | UL E348247 |

| UL 1741 | | | | | |
|---|---|---|---|---|---|
| Clause | Requirement – Test | | Measuring result – Remark | | Verdict |
| -Insulating Tape | JINGJIANG YAHUA PRESSURE SENSITIVE GLUE CO LTD | CT-280B | 130°C | UL 510 | UL E165111 |
| Varnish | Qingyuan Better New Materials Co Ltd | BETTER 116 (n) | 130°C | UL 1446 | UL E316816 |
| (Alternate) | SUZHOU TAIHU ELECTRIC ADVANCED MATERIAL CO LTD | ET-90(a) | 180°C | UL 1446 | UL E228349 |
| Transformer (TX1) | Guangzhou Shiyuan Electronic Technology Company Limited | SYEE65-T048B | Class B | EN 62109-1<br>EN 62109-2 | Tested within appliance |
| -Nomex | DuPont Specialty Products USA, LLC | 410 | 220°C, V-0 | UL 94, UL746 | UL E34739 |
| -Wire | Shenzhen yancheng Compound Line Co.,Ltd | xUEWF@/155, QA-x@/155，xUEW@/130 | Min. 130°C | UL 1446 | UL E360434 |
| -Tape | JINGJIANG YAHUA PRESSURE SENSITIVE GLUE CO LTD | PF* (d) (g) | 180°C | UL 510 | UL E165111 |
| -Varnish | SUZHOU TAIHU ELECTRIC ADVANCED MATERIAL CO LTD | T-4260(a) | 130°C | UL 1446 | UL E228349 |
| -Tube | CHANGYUAN ELECTRONICS GROUP CO LTD | CB-TT-L | 200°C, 150V | UL 224 | UL E180908 |
| Capacitor(C20) | YANGZHOU NISSEI ELECTRONICS CO LTD | MPY, MPYL | Max.40uF,Min.300VAC，Min.105°C | UL 810 | UL E506876 |

| UL 1741 | | | |
|---|---|---|---|
| Clause | Requirement – Test | Measuring result – Remark | Verdict |

| | | | | | |
|---|---|---|---|---|---|
| (Alternative) | Interchangeable | Interchangeable | Max.40uF,Min.300VAC，Min.105°C | UL 810 | UL |
| Capacitor(C10,C11) | Interchangeable | Interchangeable | Max.1uF,Min.630V，Min.105°C | EN 62109-1<br>EN 62109-2 | Tested within appliance |
| Capacitor(E1, E2) | Interchangeable | Interchangeable | Max.820uF,Min.500V，Min.105°C | EN 62109-1<br>EN 62109-2 | Tested within appliance |
| Capacitor(E9, E10, E11, E12) | Interchangeable | Interchangeable | Max.4700uF,Min.63V，Min.105°C | EN 62109-1<br>EN 62109-2 | Tested within appliance |
| Capacitor(E28) | Interchangeable | Interchangeable | Max.68uF,Min.450V，Min.105°C | EN 62109-1<br>EN 62109-2 | Tested within appliance |
| Capacitor(E37) | Interchangeable | Interchangeable | Max.33uF,Min.500V，Min.105°C | EN 62109-1<br>EN 62109-2 | Tested within appliance |
| Discharged resistance(R2, R8, R31) | Interchangeable | Interchangeable | 100Kohm,1/4W | EN 62109-1<br>EN 62109-2 | Tested within appliance |
| Discharged resistance(R17,R297) | Interchangeable | Interchangeable | 300Kohm,2W | EN 62109-1<br>EN 62109-2 | Tested within appliance |
| Discharged resistance(R32) | Interchangeable | Interchangeable | 100Kohm,2W | EN 62109-1<br>EN 62109-2 | Tested within appliance |
| Resistance(R247, R248, R254, R255) | Interchangeable | Interchangeable | 1Mohm,1/4W | EN 62109-1<br>EN 62109-2 | Tested within appliance |
| Resistance(R246, R253) | Interchangeable | Interchangeable | 1.5Mohm,1/4W | EN 62109-1<br>EN 62109-2 | Tested within appliance |
| Resistance(R245, R252) | Interchangeable | Interchangeable | 750Kohm,1/4W | EN 62109-1<br>EN 62109-2 | Tested within appliance |
| IGBT(Q4, Q6, Q7, Q8, Q14, Q16) | Interchangeable | Interchangeable | Min.75A,Min.650V | EN 62109-1<br>EN 62109-2 | Tested within appliance |

| UL 1741 | | | | | |
|---|---|---|---|---|---|
| Clause | Requirement – Test | | Measuring result – Remark | | Verdict |
| MOS(Q1, Q2, Q3, Q15, Q23, Q24, Q25, Q26, Q27, Q28, Q29, Q30, Q47, Q50, Q54, Q58) | Interchangeable | Interchangeable | Min.140A, Min.85V | EN 62109-1<br>EN 62109-2 | Tested within appliance |
| IGBT(Q31, Q32, Q64, Q65) | Interchangeable | Interchangeable | Min.80A, Min.650V | EN 62109-1<br>EN 62109-2 | Tested within appliance |
| Diode(D69) | Interchangeable | Interchangeable | Min.3A, Min.800V | EN 62109-1<br>EN 62109-2 | Tested within appliance |

| UL 1741 | | | |
|---|---|---|---|
| Clause | Requirement – Test | Measuring result – Remark | Verdict |
| **45** | **TABLE: Maximum-Voltage Measurements test** | | P |

| Obtain maximum voltage | test voltage (V)<br>a.c. / d.c. | breakdown<br>Yes / No |
|---|---|---|
| AC output:120/240Vac | 3000 a.c. | No |
| Supplementary information: | | |
| | | |

| UL 1741 | | | |
|---|---|---|---|
| Clause | Requirement – Test | Measuring result – Remark | Verdict |

| | | | | | |
|---|---|---|---|---|---|
| **46** | **TABLE: Temperature test** | | | | P |
| | Wind turbine RPM's | -- | -- | -- | — |
| | Supply voltage (V) ..... | A | B | C | — |
| | Ambient $T_{min}$ (°C) ..... | -- | -- | -- | — |
| | Ambient $T_{max}$ (°C) ..... | -- | -- | -- | — |

| Maximum measured temperature T of part/at:: | T (°C) ( $T_{adj} = T_m - T_{amb} + T_{mra(50°C)}$ ) | | | | | | Allowed $T_{max}$ (°C) |
|---|---|---|---|---|---|---|---|
| | $T_m$ | $T_{adj}$ | $T_m$ | $T_{adj}$ | $T_m$ | $T_{adj}$ | |
| Enclosure –Bottom | 32.9 | 62.7 | 32.1 | 61.5 | 30.7 | 60.2 | 100 |
| Enclosure –Front | 31.6 | 61.4 | 30.1 | 59.5 | 28.3 | 57.8 | 100 |
| Enclosure –Rear | 29.4 | 59.2 | 28.4 | 57.8 | 29.9 | 59.4 | 100 |
| Enclosure –Left | 28.7 | 58.5 | 29.0 | 58.4 | 29.2 | 58.7 | 100 |
| Enclosure –Right | 24.5 | 54.3 | 28.5 | 57.9 | 31.6 | 61.1 | 100 |
| Enclosure –Top | 26.4 | 56.2 | 32.7 | 62.1 | 28.3 | 57.8 | 100 |
| Fan | 34.7 | 64.5 | 36.1 | 65.5 | 31.6 | 61.1 | Ref. |
| AC Connector | 31.0 | 60.8 | 34.0 | 63.4 | 30.1 | 59.6 | 120 |
| Operation Panel | 25.9 | 55.7 | 30.5 | 59.9 | 29.2 | 58.7 | 125 |
| Internal wire | 33.6 | 63.4 | 36.0 | 65.4 | 31.7 | 61.2 | 105 |
| LF1 winding | 61.7 | 91.5 | 58.1 | 87.5 | 47.0 | 76.5 | 130 |
| LF2 winding | 63.0 | 92.8 | 62.0 | 91.4 | 55.8 | 85.3 | 130 |
| Relay1 body | 46.5 | 76.3 | 56.2 | 85.6 | 42.0 | 71.5 | 85 |
| Relay2 body | 44.6 | 74.4 | 46.9 | 76.3 | 40.3 | 69.8 | 85 |
| T1 winding | 51.8 | 81.6 | 53.1 | 82.5 | 46.9 | 76.4 | 130 |
| T2 winding | 57.4 | 87.2 | 51.7 | 81.1 | 43.0 | 72.5 | 130 |
| E. Cap (EC1) body | 38.9 | 68.7 | 41.9 | 71.3 | 39.2 | 68.7 | 105 |
| E. Cap (EC4) body | 45.6 | 75.4 | 49.1 | 78.5 | 40.3 | 69.8 | 105 |
| PCB near U15 | 46.7 | 76.5 | 47.0 | 76.4 | 41.8 | 71.3 | 130 |
| MOV1 body | 53.0 | 82.8 | 47.8 | 77.2 | 42.7 | 72.2 | 125 |
| MOV3 body | 51.8 | 81.6 | 54.9 | 84.3 | 45.3 | 74.8 | 125 |
| TX1 winding | 65.7 | 95.5 | 53.1 | 82.5 | 50.1 | 79.6 | 110 |
| TX1 core | 57.4 | 87.2 | 58.2 | 87.6 | 47.3 | 76.8 | 110 |
| L1 winding | 64.5 | 94.3 | 53.3 | 82.7 | 44.0 | 73.5 | 130 |
| L2 winding | 61.8 | 91.6 | 58.2 | 87.6 | 46.9 | 76.4 | 130 |
| E. Cap (C1) body | 57.7 | 87.5 | 48.1 | 77.5 | 45.7 | 75.2 | 105 |

| UL 1741 | | | |
|---|---|---|---|
| Clause | Requirement – Test | Measuring result – Remark | Verdict |

| Maximum measured temperature T of part/at:: | T (°C) ( $T_{adj} = T_m - T_{amb} + T_{mra(50°C)}$ ) | | | | | | Allowed $T_{max}$ (°C) |
|---|---|---|---|---|---|---|---|
| PCB near Q1&Q2 | 70.1 | 99.9 | 63.0 | 92.4 | 55.1 | 84.6 | 130 |
| PCB near Q5&Q6 | 68.9 | 98.7 | 57.9 | 87.3 | 42 | 71.5 | 130 |
| Tma | 25.2 | 55.0 | 25.6 | 55.0 | 25.5 | 55.0 | / |

Supplementary information:

A: PV input 500V，AC grid output 230V;

B: Battery input 48V，AC grid output 230V;

C: AC input 230V, battery output;

| 47 | **TABLE: electric strength tests** | P |
|---|---|---|

| test voltage applied between: | test voltage (V) a.c. / d.c. | breakdown Yes / No |
|---|---|---|
| AC output and accessible output | 1000V a.c. | No |
| AC output and accessible output | 1000V a.c. | No |
| Accessible output and AC output | 1000V a.c. | No |

Supplementary information:

| 48.2 | **TABLE: Output Power Characteristics – Output ratings** | P |
|---|---|---|

| Output voltage | Tolerance | Limit |
|---|---|---|
| 119.7Va.c. | -0.25% | <10% |
| 239.5 Va.c. | -0.21% | <10% |

Supplementary information:

| UL 1741 | | | |
|---|---|---|---|
| Clause | Requirement – Test | Measuring result – Remark | Verdict |

| | | | |
|---|---|---|---|
| **50.2** | **TABLE: Abnormal Tests – Output overload test (thermal requirements)** | | P |
| | Wind turbine RPM's | -- | |
| | Supply voltage (V) .....: | 48Vd.c. | — |
| | Ambient $T_{min}$ (°C) .....: | -- | — |
| | Ambient $T_{max}$ (°C) .....: | -- | — |

| Maximum measured temperature T of part/at: | T (°C) $T_{adj} = T_m - T_{amb} + T_{mra(50°C)}$ | | Allowed $T_{max}$ (°C) |
|---|---|---|---|
| Abnormal condition | Overload | | |
| | $T_m$ | $T_{adj}$ | |
| T1 winding | 72.3 | 107.6 | 110 |
| T1 core | 68.4 | 103.7 | 110 |
| Enclosure inside | 45.5 | 80.8 | 80 |
| Enclosure outside | 36.7 | 72.0 | 95 |
| Ambient | 24.7 | 60.0 | -- |
| Supplementary information: | | | |
| | | | |

| | | | |
|---|---|---|---|
| **50.3** | **TABLE: Abnormal Tests – Short-circuit test** | | P |
| component No. | test voltage (V) | result | |
| Charging condition: 240Vac Input | | | |
| C3 | 240V | EUT shutdown, Unrecoverable, no hazard no damage. | |
| C84 | 240V | EUT normal operation, no hazard no damage. | |
| Q24 pin1-3 | 240V | EUT normal operation, no hazard no damage. | |
| Supplementary information: | | | |
| | | | |

| | | | |
|---|---|---|---|
| **50.4** | **TABLE: Abnormal Tests – DC input miswiring test** | | P |
| Input connector | | Input voltage | Remark |
| Input connector | | -- | Not mistakenly inserted |
| Supplementary information: | | | |
| | | | |

| UL 1741 | | | |
|---|---|---|---|
| Clause | Requirement – Test | Measuring result – Remark | Verdict |

| | | | |
|---|---|---|---|
| **50.5** | **TABLE: Abnormal Test – Ventilation test (thermal requirements)** | | P |
| | Wind turbine RPM's | -- | |
| | Supply voltage (V) .....: | 48V a.c. | — |
| | Ambient $T_{min}$ (°C) .....: | -- | — |
| | Ambient $T_{max}$ (°C) .....: | -- | — |

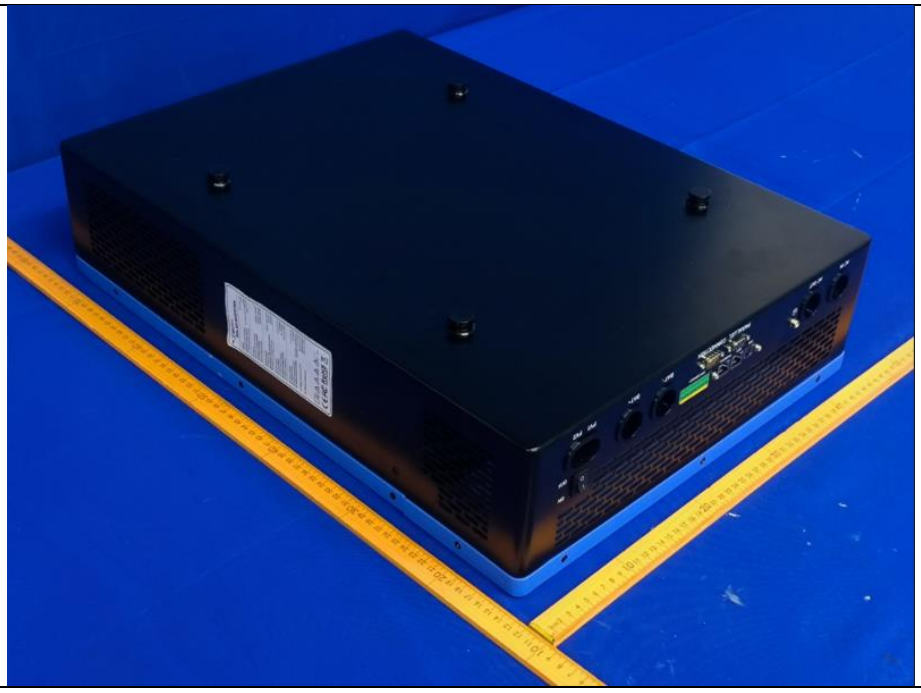
| Maximum measured temperature T of part/at: | T (°C) $T_{adj} = T_m - T_{amb} + T_{mra(50°C)}$ | | Allowed $T_{max}$ (°C) |
|---|---|---|---|
| Abnormal condition | Locked fan rotor | | |
| | $T_m$ | $T_{adj}$ | |
| T1 winding | 76.4 | 111.7 | 165 |
| T1 core | 73.2 | 108.5 | 165 |
| Enclosure inside | 56.2 | 91.5 | 95 |
| Enclosure outside | 45.9 | 81.2 | 95 |
| Ambient | 24.7 | 60.0 | -- |
| Supplementary information: | | | |
| | | | |

| **65** | **TABLE: RATINGS – Details, electrical data (in normal conditions)** | | | | | P |
|---|---|---|---|---|---|---|
| Input | | | | Output | | |
| RPM | Frequency | Voltage | I (A) | I (A) | watts | Condition/status |
| PV input, battery output. | | | | | | |
| -- | -- | 499.8Vd.c. | 21.87 | 83.22 | 9986 | -- |
| AC input, battery output. | | | | | | |
| -- | 50Hz | 117.8Va.c. | 42.67 | 47.59 | 226.5 | -- |
| -- | 60Hz | 117.2Va.c. | 42.71 | 47.59 | 226.5 | -- |
| Battery input, AC output. | | | | | | |
| -- | -- | 48.26 | 192.72 | 42.24 | 5014 | 50Hz |
| -- | -- | 48.26 | 192.72 | 43.28 | 4977 | 60Hz |
| Supplementary information: | | | | | | |
| | | | | | | |

Details of: External view


Details of: External view

Details of: External view



Details of: Terminal view

Details of: Terminal view

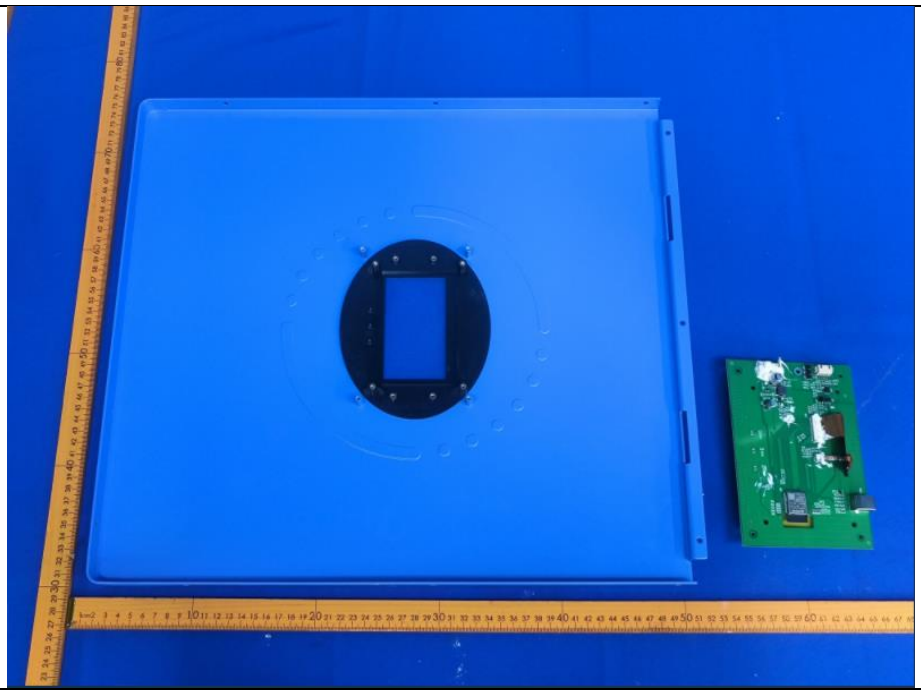

Details of: Terminal view

Details of: Terminal view

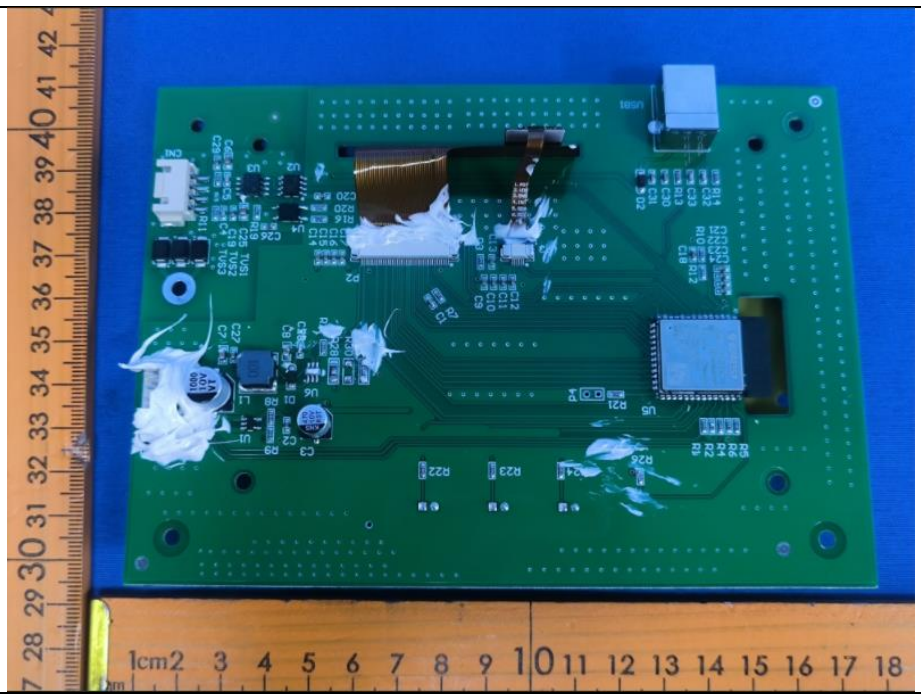

Details of: Internal view

Details of: Internal view

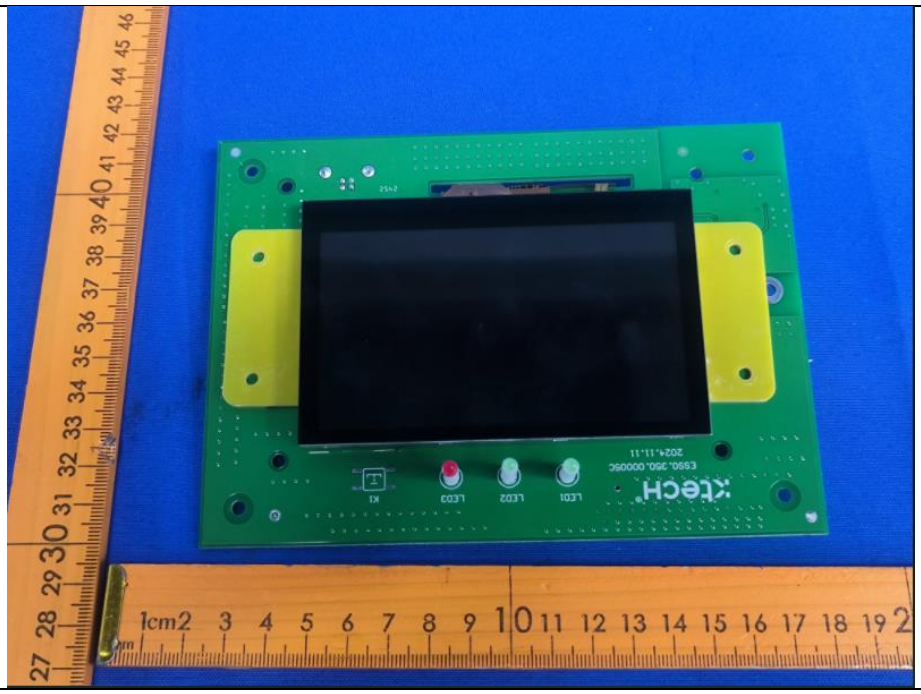
Details of: Internal view



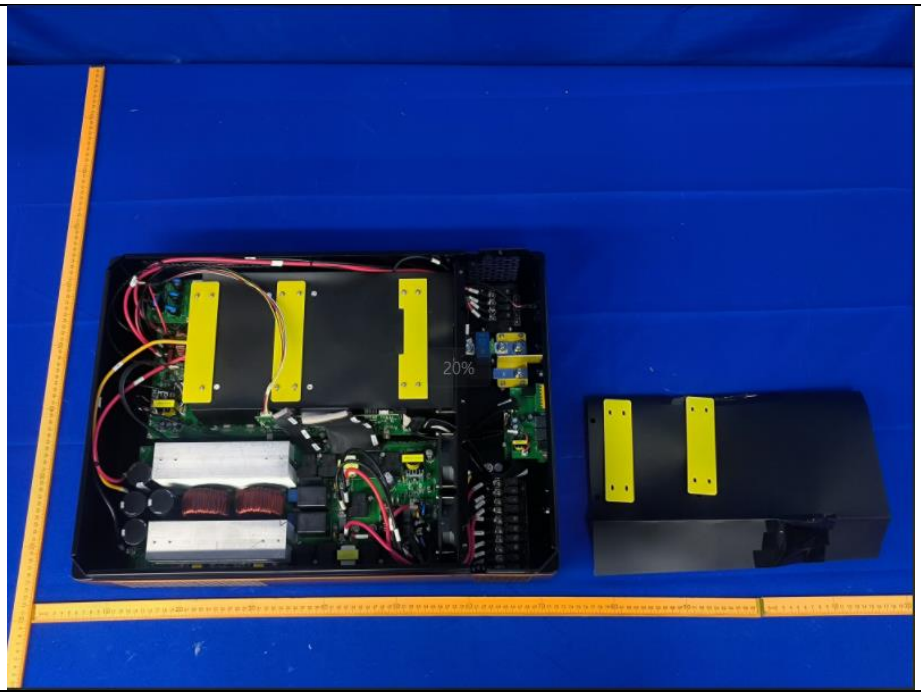
Details of: PCB view



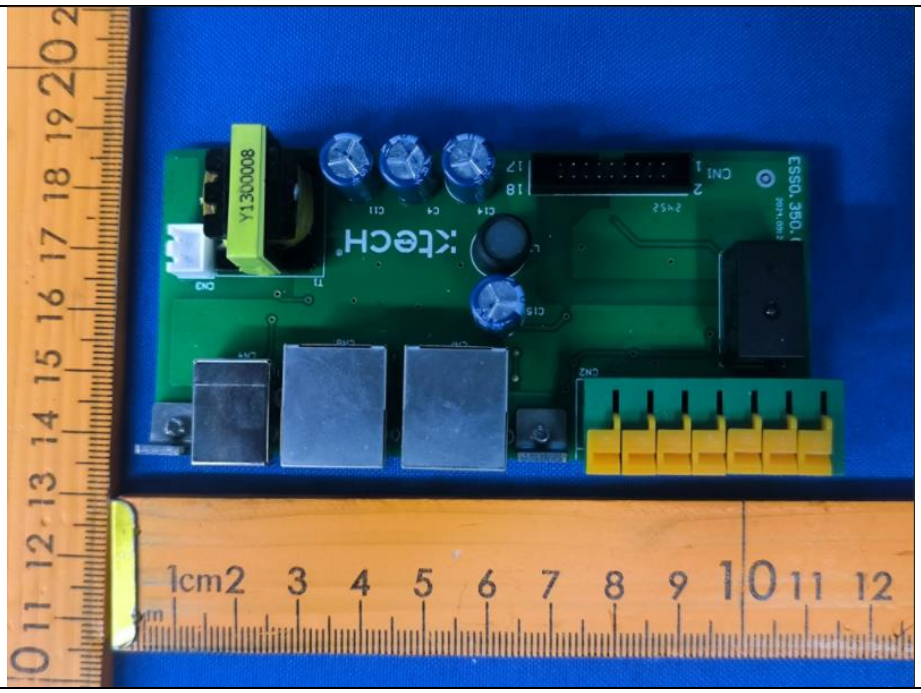
Details of: PCB view



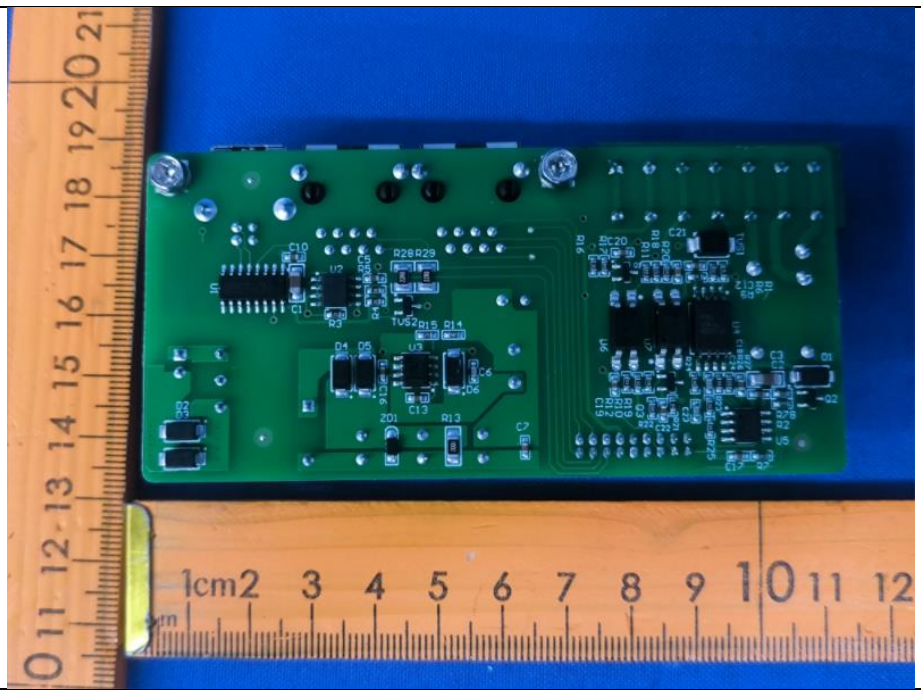
Details of: Internal view



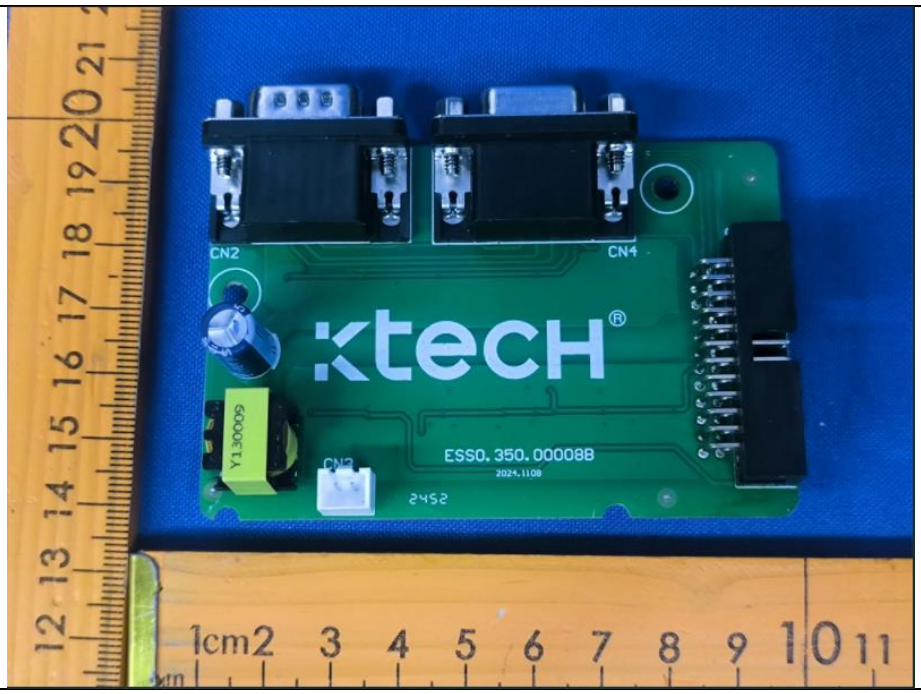
Details of: PCB view



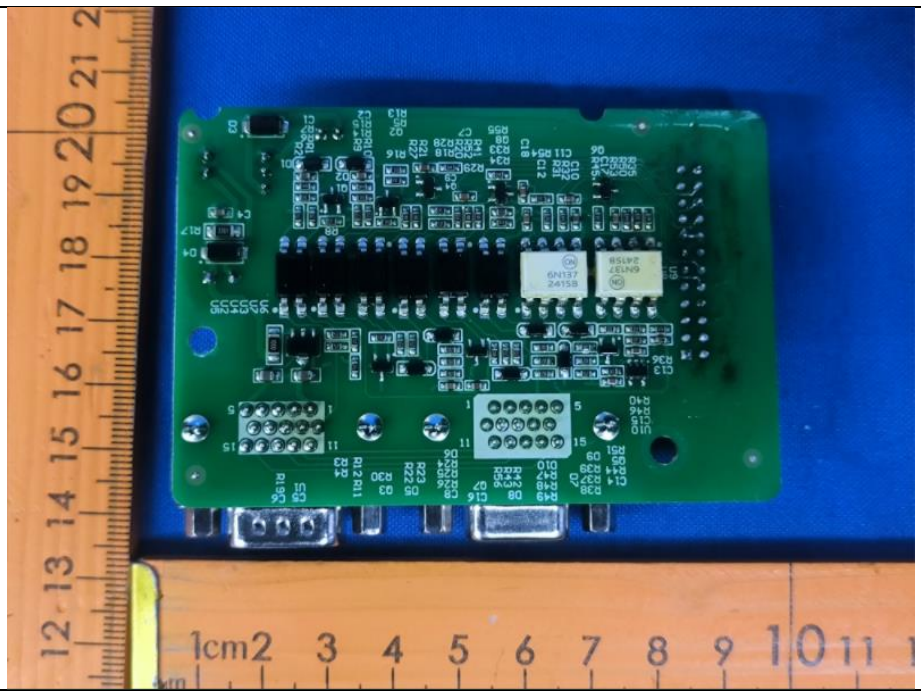
Details of: PCB view



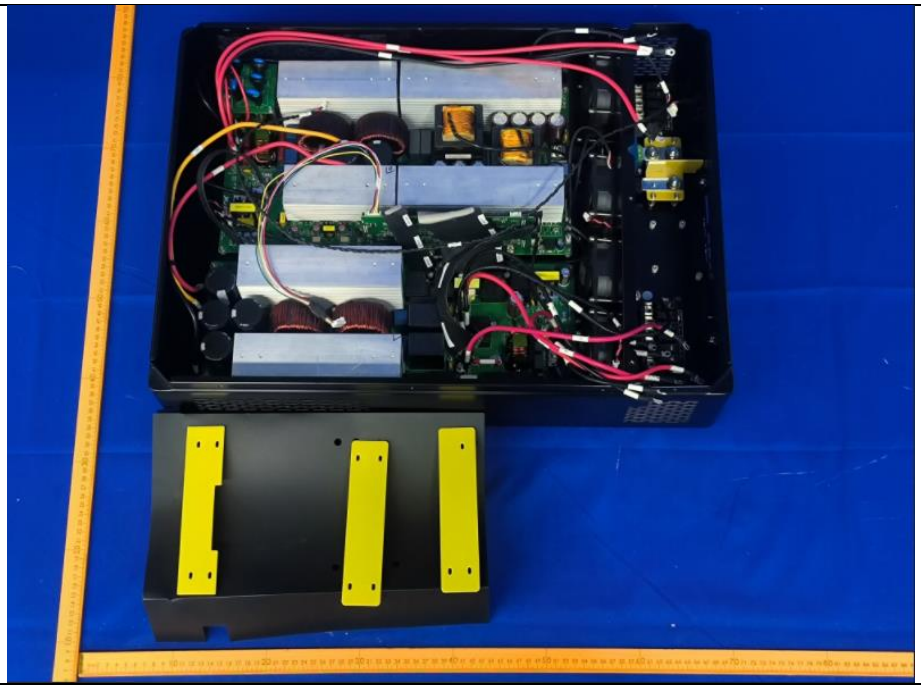
Details of: PCB view



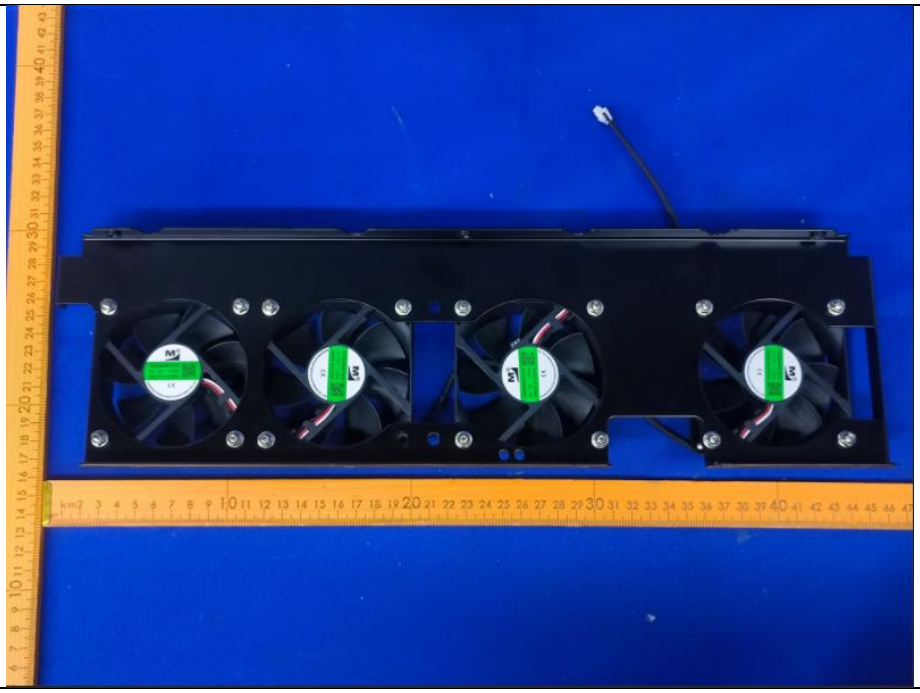
Details of: PCB view



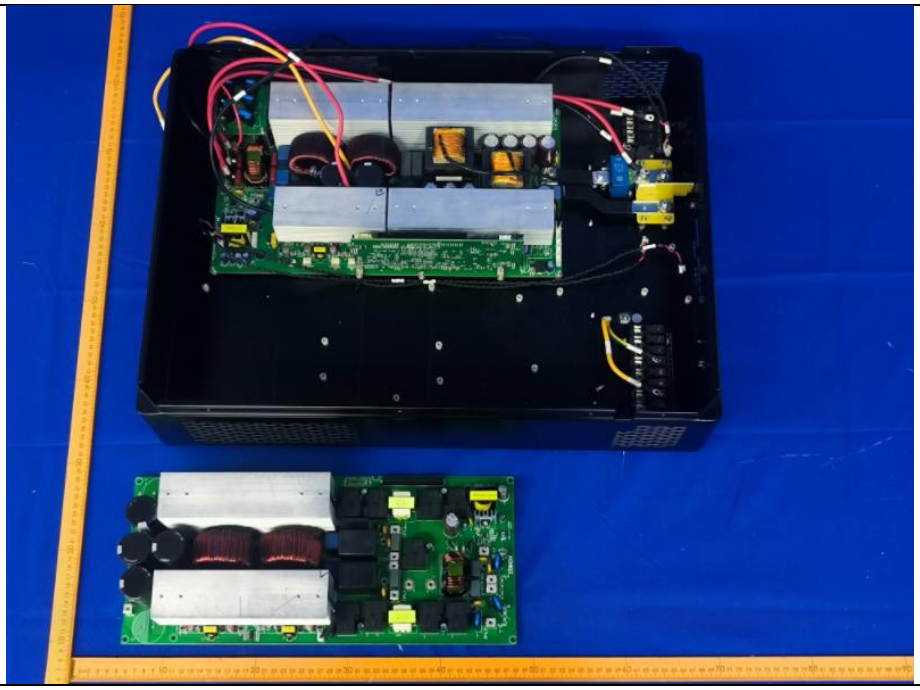
Details of: Internal view



Details of: DC fan view

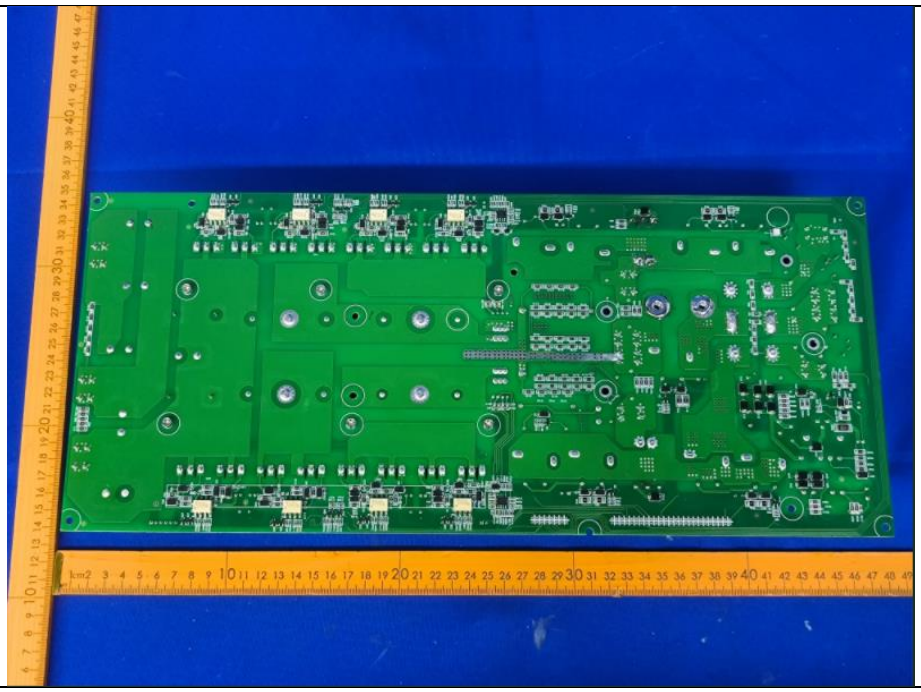


Details of: Internal view

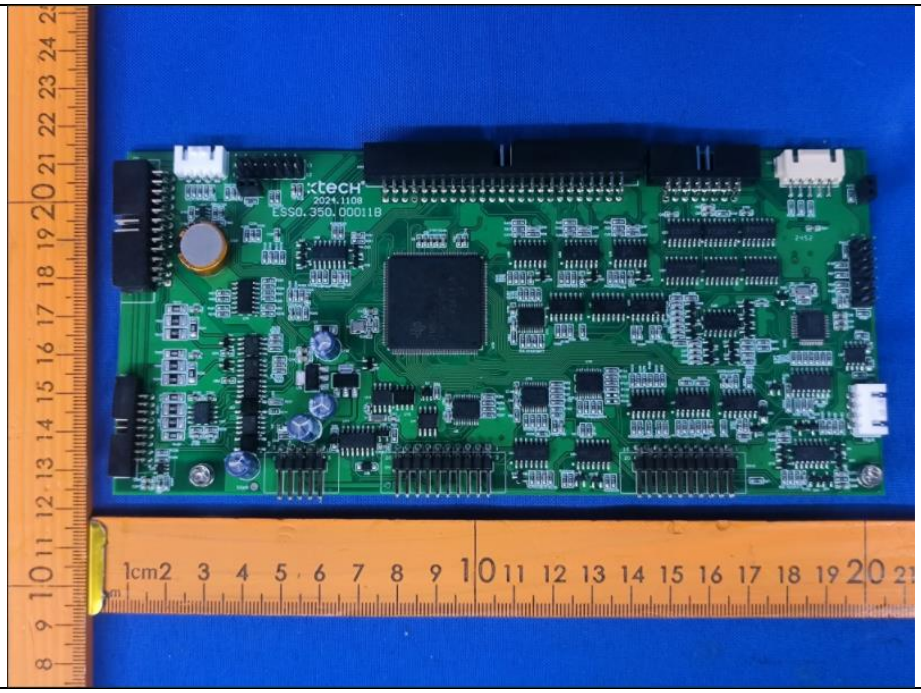


Details of: PCB view

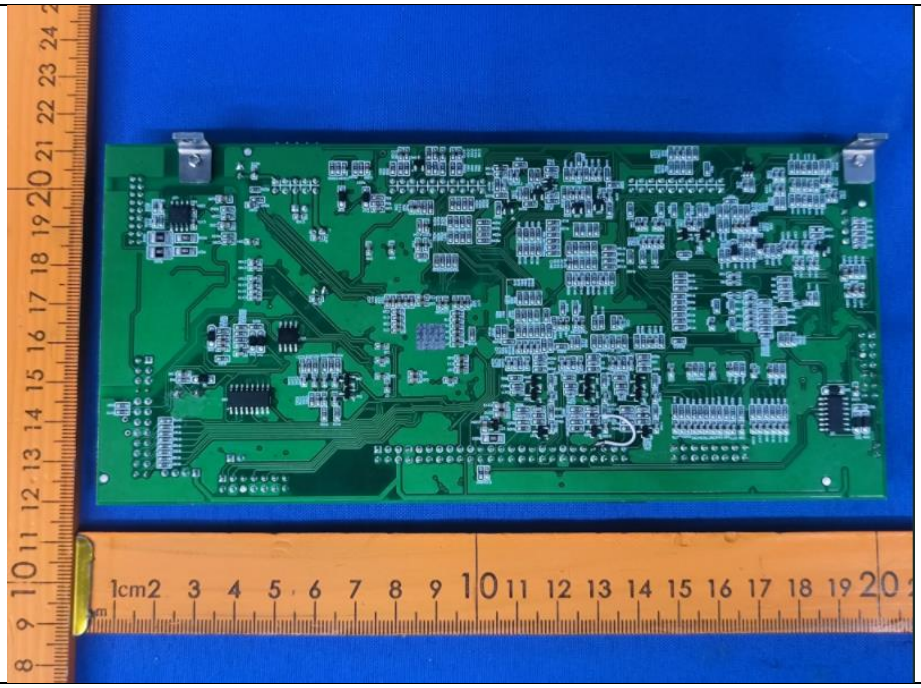
Details of: PCB view



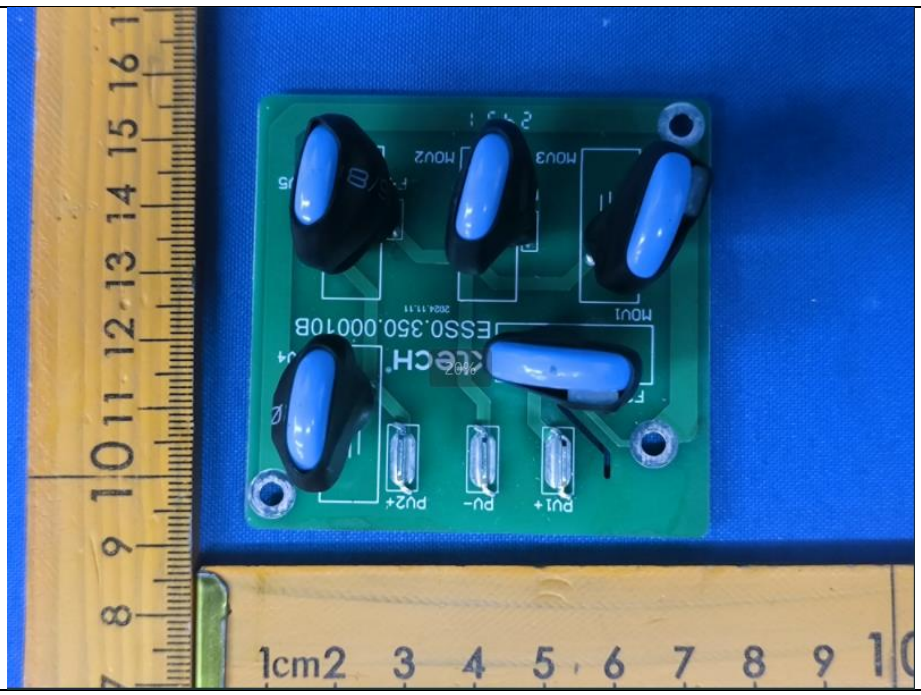
Details of: PCB view



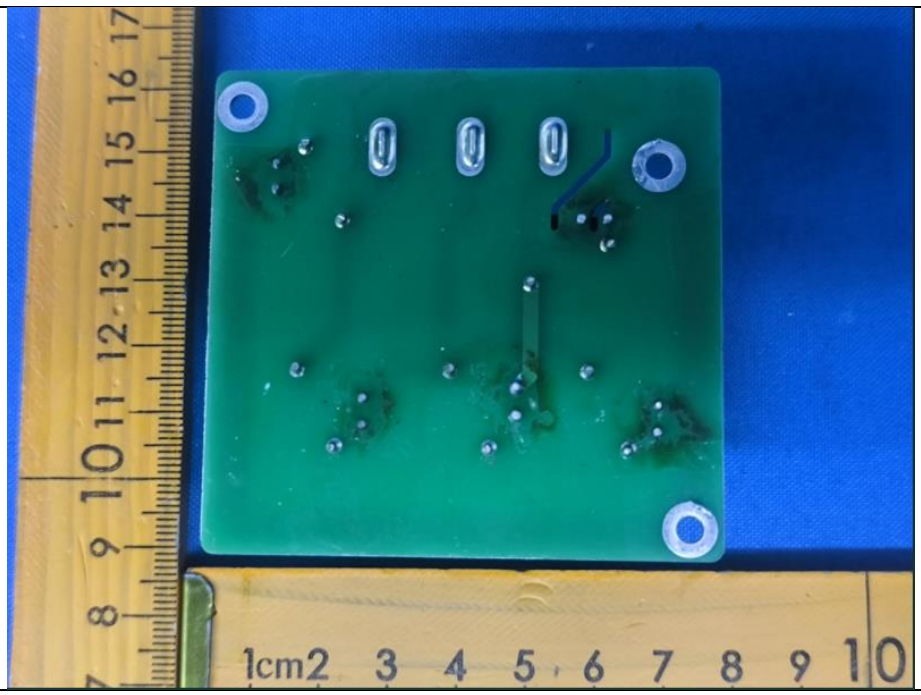
Details of: PCB view



Details of: PCB view

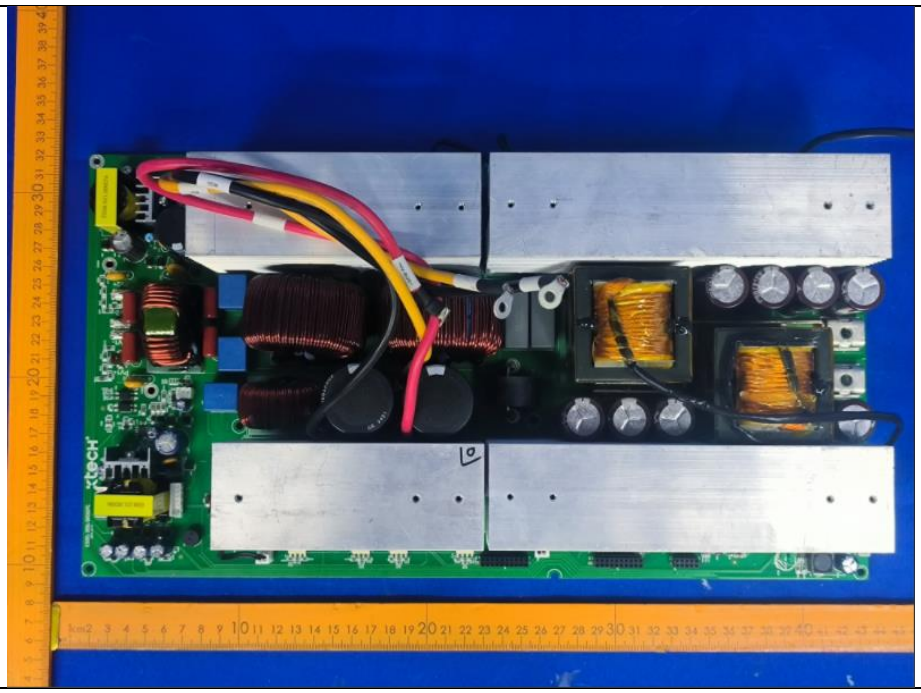



Details of: PCB view

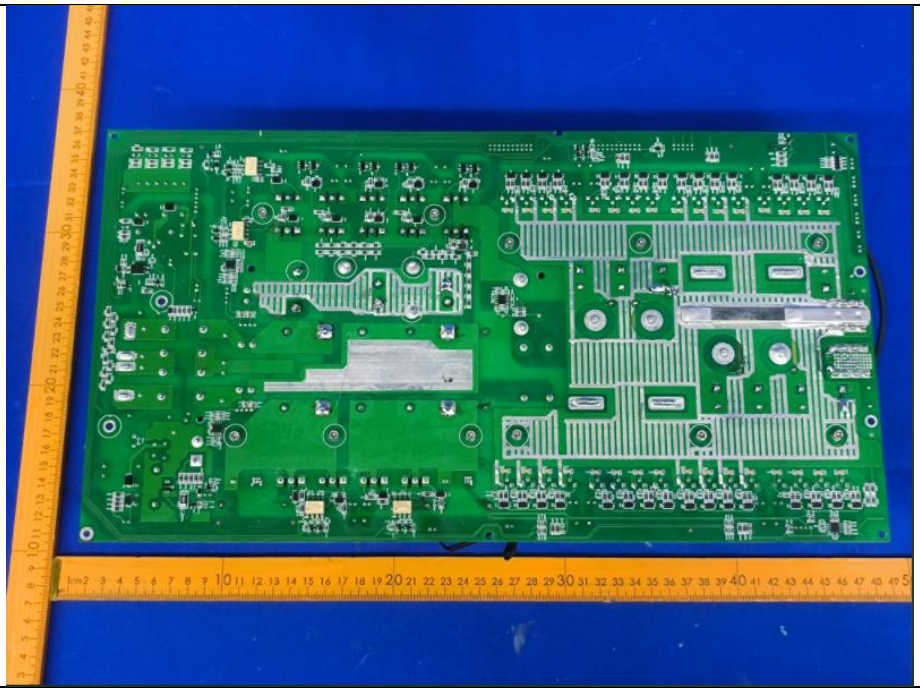


Details of: Internal view

Details of: PCB view



Details of: PCB view



***End of the report***